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October 30, 2015

Via Email: BDCPComment@icfi.com
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BDCP/WaterFix Comments
P.O. Box 1919
Sacramento, CA 95812

NOV 0 3 2015

Re: Comments on CalWater Fix RDEIR/SDEIS

Gentlepersons:

Please accept these comments concerning the Partially Recirculated Draft Environmental Impact Report (RDEIR)/Supplemental Draft Environmental Impact Statement (SDEIS) on the Bay Delta Conservation Plan/California WaterFix (referred to herein as "RDEIR").

I. Mitigation may not be limited to the footprint of the conveyance facilities.

Public Resources Code § 21002 provides that "public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects . . ." To this end, Public Resources Code § 21002.1(d) requires that "Each public agency shall mitigate or avoid the significant effects on the environment of projects that it carries out or approves whenever it is feasible to do so."

In City of Marina v. Board of Trustees of the California State University, 39 Cal.4th 341, at 360 (2006), the California Supreme Court held: "CEQA requires a public agency to mitigate or avoid its projects' significant effects not just on the agency's own property but '*on the environment*' (Pub. Resources Code § 21002.1, subd. (b), italics added), with 'environment' defined for these purposes as 'the physical conditions which exist *within the area which will be affected by a proposed project*' (id., § 21060.5, italics added)." The duty to mitigate is not defined by the geographic boundaries of an agency. (Id.) An agency may not avoid the expense of off-site mitigation of significant effects on the environment merely because the legislature has not appropriated funds for such a purpose. In City of San Diego v. Board of Trustees of California State University (2015) 61 Cal.4th 495, the court explained "unreasonable consequences would follow from a rule of fair-share payments for off-site mitigation only by earmarked appropriation." One such unreasonable consequence would be that:

> "[I]f the Legislature did not make an earmarked appropriation for mitigating the off-site effects of a particular state project but the responsible state agency nevertheless decided to proceed without mitigation, the cost of addressing that project's contribution to cumulative impacts on local infrastructure would fall upon local and regional governmental agencies." Id. at 962.

Here, the project proponents have a duty to mitigate all environmental consequences of the project. The RDEIR shirks this duty and responsibility to mitigate all environmental consequences. The full suite of conservation measurements provided in the original BDCP - designed to mitigate the impacts of the project sufficiently to enable a 50 year permit - are now being abandoned and left to the whim of a different project, Eco-Restore, which may or may not be implemented and may or may not fail. This is to say nothing of whether it would be funded.

Furthermore, the RDEIR fails to analyze and mitigate significant off-site impacts, growth impacts of various capacities, reduced levee maintenance due to potential reduced funding, and other public and private impacts of a 14 year project that would permanently modify the Delta and its environs.

II. The North Delta Diversion is in conflict with the CVPIA and not properly mitigated. CM-15 may not be relied upon because it is in conflict with the CVPIA and the best available science, and is unsupported.

In 1992 the Congress of the United States passed the Central Valley Project Improvement Act ("CVPIA"), in an effort to protect and restore anadromous fish in the Central Valley, including striped bass. Congress specified that one of its purposes in enacting the CVPIA was "to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California." CVPIA section 3402(a). Congress focused on anadromous fish, and actually defined "anadromous fish" to include striped bass. CVPIA section 3403(a).

Some provisions of the CVPIA apply specifically to striped bass, while some of the protections come from CVPIA section 3403(a) provision stating that "the term 'anadromous fish' means those stocks of . . . striped bass . . ." Thus, numerous provisions in CVPIA section 3406 for the maintenance and restoration of "anadromous fish" apply to striped bass.

In particular, section 3406(b)(1) requires the Secretary of Interior to "develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991." This is widely referred to as the "fish doubling goal" of the CVPIA. To this end, the USFWS has established the doubling goal for striped bass at 2,500,000 fish.

The CVPIA also provides protections for striped bass, as well as other anadromous fish, in section 3406(b)(1)(B), stating that "the Secretary is authorized and *directed* to modify Central Valley Project operations to provide flows of suitable quality, quantity, and timing to protect all life stages of anadromous fish . . ." (Italics added) To this end, section 3406(b)(1)(D)(2) requires that the Secretary "upon enactment of this title dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title . . ." Striped bass are intended and designated beneficiaries of these efforts.

Other CVPIA requirements for the protection and restoration of striped bass include section 3406(b)(8) requiring the implementation of "short pulses of increased water flows to increase the survival of migrating anadromous fish moving into and through the Sacramento-San Joaquin Delta and Central Valley rivers and streams." Section 3406(b)(9) provides in part that the Secretary "develop and implement a program to eliminate, to the extent possible, losses of anadromous fish due to flow fluctuations caused by the operation of any Central Valley Project storage or re-regulating facility." All of these requirements for the protection and restoration of anadromous fish are thus requirements for the restoration and maintenance of striped bass.

In addition to the requirements for anadromous fish, section 3406(b)(14) targets striped bass, requiring the Secretary to "develop and implement a program which provides for modified operations and new or improved control structures at the Delta Cross Channel and Georgiana Slough during times when significant numbers of striped bass eggs, larvae, and juveniles approach the Sacramento River intake to the Delta Cross Channel or Georgiana Slough."

Importantly, CVPIA section 3406(b)(18) requires that the Secretary "if requested by the State of California, assist in developing and implementing management measures to restore the striped bass fishery of the Bay-Delta estuary." That provision requires such measures to be "coordinated with efforts to protect and restore native fisheries."

Section 3406(b)(19) requires the Secretary to " reevaluate existing operational criteria in order to maintain minimum carryover storage at Sacramento and Trinity river reservoirs to protect and restore the anadromous fish of the Sacramento and Trinity Rivers in accordance with the mandates and requirements of this subsection . . ." Section 3406(b)(21) requires that the Secretary "assist the State of California in efforts to develop and implement measures to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions on the Sacramento and San Joaquin rivers, their tributaries, the Sacramento-San Joaquin Delta, and the Suisun Marsh."

The San Joaquin and Stanislaus Rivers provisions found in section 3406(c) of the CVPIA, to be implemented no later than September 30, 1996, specify further action by the Secretary to "[D]evelop a comprehensive plan, to reestablish where necessary and to sustain naturally reproducing anadromous fisheries from Friant Dam to its confluence with the San Francisco Bay/Sacramento-San Joaquin Delta Estuary." Subsection (c)(1).

The Secretary is also directed in section 3406(e)(1) to investigate "measures to maintain suitable temperatures for anadromous fish survival in the Sacramento and San Joaquin rivers and their tributaries, and the Sacramento-San Joaquin Delta by controlling or relocating the discharge of irrigation return flows and sewage effluent, . . .", and sub-section (e)(5) requires the investigation of "measures to provide for modified operations and new or improved control structures at the Delta Cross Channel and Georgiana Slough to assist in the successful migration of anadromous fish[.]" Sub-section 3406(f) directs further that "The Secretary, in consultation with the Secretary of Commerce, the State of California, appropriate Indian tribes, and other appropriate public and private entities, shall investigate and report on all effects of the Central Valley Project on anadromous fish populations . . .", and sub-section (g) provides for the modeling of "measures needed to restore anadromous fisheries to optimum and sustainable levels in accordance with the restored carrying capacities of Central Valley rivers . . ." and "measures designed to reach sustainable harvest levels of resident and anadromous fish . . ." Sub-sections (4) and (7).

The provisions of the CVPIA directing the protection and restoration of anadromous fish, including striped bass, are many. The intent of Congress to protect and restore striped bass is clear and consistent with the policies and existing regulations of the California Fish and Game Commission.

While the law has been in place for more than twenty (20) years, the objectives of the CVPIA have not been fully embraced by the various state and federal agencies. Further, and probably for that reason, the goals of the CVPIA have not been achieved. While the CVPIA is a federal law, the State of California also should give fair consideration to the CVPIA, and refrain from action inconsistent with the CVPIA.

Repeatedly in the RDEIR it is stated that "Near field effects" of the North Delta Diversion alternatives on winter run Chinook salmon, spring run Chinook salmon, and Sacramento river steelhead, due to "impingement and predation associated with the three new intake structures could result in negative effects on juvenile migrating fish. "(11-242, 246, 249, 289, 298, 301, 305, 352, 366, 372, and 379). Indeed, so much so that the RDEIR states: "It is expected that the level of near-field impacts would be directly correlated to the number of new intake structures. . ." Id. Moreover, the ranges of effects include "more significant effects" and the apparent response and mitigation is "CM15 would be implemented with the intent of providing localized and temporary reductions in predation pressure at the NDD." CM15 by no means contains any proven, reliable methods, and accordingly the RDEIR states that "[S]everal pre-construction studies to better understand how to minimize losses associated with the three new intake structures will be implemented as part of the final NDD screen design effort."

The approach, mitigation, and methodology is improper, speculative, and deficient on multiple counts. In the first place, CM15 targets the elimination of striped bass, a favored protected species under federal law. Essentially, the project will build a facility that will entrain striped bass eggs and larvae, attract adult striped bass, and then reduce their numbers in direct conflict with federal law.

The California Fish and Game Commission has already determined it should continue with the existing regulation of striped bass sportfishing, as wholly consistent with and in furtherance of the fishery restoration, protection, and other goals of the CVPIA. CM15 and the NDD facilities will impair and impede the mandated restoration of striped bass.

The CVPIA contains the doubling of anadromous fish requirement, and the USFWS has established target level of 2,500,000 for the doubling goal for striped bass in the Central Valley. See Final Restoration Plan for the Anadromous Fish Restoration Program, adopted January 9, 2001 ("AFRP"). That goal was never achieved, and stocks have declined precipitously due to excessive Delta diversions. Striped bass and American shad, another species protected by the CVPIA, spawn and rear in the area upstream of the NDD, as noted in the RDEIR at 11-148. It is indicated that entrainment under alternative 4A could increase on a relative basis 220%, and it is affirmatively stated that "For the alternatives proposing water conveyance with north Delta intakes, then, there is the potential for an appreciable increase in magnitude of entrainment of early life states." (Id. at 11-149) Other species will also be subject to entrainment. In other words, and more plain English, the fish will be diverted from the Delta and killed.

The RDEIR is replete with references to the adverse effects on striped bass, and the CEQA Conclusion is:

> "The impact of entrainment for striped bass and American shad therefore would be significant and unavoidable for Alternatives 1A, 1B, 1C, 2A, 2B, 2C, 3, 4, 5, 6A, 6B, 6C, 7, and 8. The impact of entrainment for striped bass and American shad would be less than significant for Alternative 9, NAA, and NAA_ELT."

In fact, the RDEIR substantially relies on CM15 to target the take of striped bass at the NDD, under the guise of predator control, to combat the optimum conditions for predation the NDD will create. The RDEIR goes on a roller-coaster ride from significant impacts of entrainment, to relying on sheer speculation, without substantiation, when it states:

> "Operation of north Delta intakes under all alternatives (except Alternative 9) would be expected to reduce overall entrainment of screenable life stages (i.e., early juveniles and older, around 20 mm long) because of the reduction in use of the south Delta facilities, which do not have the state of the art fish screens proposed for the north Delta intakes." (RDEIR 11-148)

One is further left to wonder why state of the art fish screens are not already part of the south Delta facilities. Nevertheless, the RDEIR must identify possible mitigation for striped bass, and such mitigation must be analyzed and made a part of any project. Potential mitigation would include a striped bass hatchery program, capture and salvage both inside and outside the NDD facilities, modifications to avoid attracting striped bass, operational limits during the period shad and striped bass are spawning and rearing, and elimination of the NDD. Indeed, the most feasible alternative with the least significant impacts are those with no NDD.

CM15 is in direct conflict with the very heart of the CVPIA, due to its significant, detrimental impacts on striped bass and American shad. The NDD will not only create entrainment problems for all life stages, and particularly early life stages, it will exacerbate the negative conditions for striped bass by attracting mature striped bass to feed near the rear intakes, so they will be killed by the measures embraced by CM15.

Importantly, these efforts embraced by the RDEIR to eradicate striped bass under the guise of protecting native species are not borne out by the best available service, and introduce new uncertainty, and unpredictable and potentially irretrievable consequences.

Striped bass have co-existed with many native species, including each listed species, for well over a century. Yet the project proponents appear to deem striped bass as a scourge upon the Delta and its native species. This is not borne out by the science. Further, Congress does not share the view of the project proponents, and has deemed striped bass populations to be worthy of not only protection, but also augmentation.

Whatever criticism the project proponents may have of Congress for protecting striped bass, it is the will of Congress and the law of the land. Congress provided a clear expression of its will in 1992, when enacting the CVPIA. Congress was aware when it acted more than 20 years after it enacted the Endangered Species Act of 1973, Pub.L. 107-136, 87 Stat. 884, 16 U.S.C. section 531. et seq. (1973) ("ESA"), that Sacramento River winter run chinook salmon were already listed as "threatened" under the ESA and "endangered" under state law. Central Valley Project Reform Act, House Report No. 576, Part 1, 102d Congress (June 16, 1992) ("House Report"), at 19. Congress was aware of this when Congress expressed its will in the CVPIA in no uncertain terms. Congress elected to target striped bass for special protections and restoration efforts. CVPIA sections 3402(a) and 3406(b)(1); (b)(1)(B); (b)(8); (9), (14), (18), (19), and (21); (c)(1); (e)(1) and (5); (f); and (g)(4) and (7).

In Coalition For a Sustainable Delta v. McCamman, U.S. Dist. Ct., E.D. of Cal., number 1:08-cv-00397-OWW-GSA, District Judge Oliver W. Wanger issued his Memorandum Decision Denying Plaintiffs' Motion for Partial Summary Judgment (Doc. 57) filed July 16, 2009, ("Memorandum Decision"), reviewing the numerous provisions of the CVPIA relating to striped bass and concluded on the issue:

> "Central Delta is correct that [i]t cannot be reasonably disputed that Congress intended to protect and restore striped bass."

Entrainment at NDD and CM15 would be at odds with the CVPIA and the USFWS restoration plan. While the Restoration Plan establishes a doubling goal for striped bass at 2,500,000 pursuant to CVPIA section 3406(b)(1), the goal for striped bass promulgated by USFWS has not been achieved. In fact, the striped bass population level is less than one million and since 1992 the average annual abundance of striped bass has not even been half of the target level.

USFWS's implementation of the CVPIA fully embraced California's sport-fishing regulations protecting striped bass. The provisions of the USFWS' Working Paper and its Restoration Plan relating to striped bass discuss and rely in part on the enforcement of the regulations. The Restoration Plan for the Central Valley Wide area provides a "High" priority for CDFG, USFWS, the Bureau of Reclamation, and the California Department of Water Resources to "Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish . . ." Restoration Plan, p. 77. The Working Paper of USFWS summarizes specific actions for the Sacramento-San Joaquin Delta, including action 17: "**Reduce or eliminate illegal take and poaching**: Reduce impacts of illegal fishing on striped bass populations." (Original bold.) The USFWS's review of problems facing striped bass states:

> "Illegal fishing may kill thousands of juvenile striped bass, possibly equivalent to the deaths of at least 125,000 legal-sized bass each year (Brown 1987). This level of illegal fishing could equal or exceed the annual legal sport catch of 100,000-200,000 adult striped bass (DFG 1992a). As discussed previously, healthy fish populations can sustain high levels of fishing mortality, but the precipitous decline in adult striped bass abundance over the past 20 years indicates that the population is unhealthy (Figure 2-VI-31)."
>
> "The declining status of the adult population has resulted in more stringent angling regulations, including an 18-inch minimum length and two-fish-daily bag limits (DFG 1992a). Before 1982, the minimum legal length was 16 inches and the daily bag limit was three fish. More stringent sport fishing regulations and stricter enforcement could reduce adult mortality and increase egg production." Working Paper, Vol. 2, p. 2-VIII-23.

USFWS's Restoration Plan thus identifies Restoration Actions, and Action 13 provides:

> "**Action 13**: Eliminate or reduce illegal take and poaching.
>
> Objective: Reduced impacts of illegal fishing on striped bass populations.
>
> Location: throughout the Sacramento-San Joaquin Estuary.
>
> Narrative description: Illegal take and poaching are frequent problems in bay-Delta waters. DFG wardens have cited anglers for bass overlimits and undersized fish, and have arrested people using illegal nets and set lines for striped bass. 'Stings' have uncovered marketing of illegally caught bass in the Bay-Delta area. Available levels of enforcement effort are insufficient to prevent all of the poaching.
>
> The general public and anglers should be encouraged to routinely use the Cal-Tip program to advise DFG of poachers, illegal selling of striped bass, and violations of angling regulations. DFG should continue to augment night and overtime patrols and purchase special equipment to aid striped bass enforcement, such as night-vision scopes and specialized boats. Courts and prosecutors that judge violations of striped bass laws should be fully informed of the grave plight of the bass resource so that maximum legal penalties will be

imposed to deter future violations.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: DFG enforcement personnel will carry out most of the actions necessary to reduce illegal take and poaching. Environmental and angling groups will need to share responsibility for making people aware of the problem and what they can do about it.

Potential obstacles to implementation: Limited availability of funding may greatly hinder DFG's ability to increase enforcement presence and effectiveness.

Projected benefits: Striped bass mortality associated with illegal take and poaching will likely decrease. Overall benefits in terms of increases in the striped bass population are unknown." Working Paper, Vol. 3, p. 3-Xf-19 through 20.

CDFG's striped bass sport-fishing regulations have thus been integrated into USFWS's implementation of the CVPIA, and are completely at odds with Cal Water Fix's plan to kill striped bass.

Neither the Working Paper nor the Restoration Plan call for the elimination of striped bass in order to recover any of the other species of anadromous fish, including salmon and steelhead. However, there was significant discussion of controlling predation upon salmon in relation to the Red Bluff Diversion Dam Working Paper, Vol. 3, p. 3-Xa-26-27, including predation by Sacramento squawfish, striped bass, rainbow trout, steelhead, American shad, and "numerous other fish and bird species." However, this was a structural problem arising from the dam, and now the NDD will create another structural problem. The NDD facility or "corrective measures" which would impede and impair the ability of the USFWS to meet its goal for striped bass established pursuant to the CVPIA at 2,500,000 fish, should be rejected.

III. Striped Bass have no impact on any listed species.

It has never been demonstrated that striped bass have a significant population level impact on any listed species. David J. Ostrach, Ph.D., is a Research Scientist and a member of the Pelagic Organism Decline research team, studying the collapse of the fisheries in the San Francisco Bay Estuary ecosystem using striped bass as a biological model for ecosystem health for 22 years (1987-2009) in his research at the University of California, Davis. Dr. Ostrach stated in his July 19, 2010, letter to the California Fish and Game Commission:

> "[T]here is no valid scientific evidence that striped bass predation on native endangered species has an effect on their population levels."

and

> "There is absolutely no credible scientific evidence of any kind that striped bass predation on salmon, delta smelt or any endangered species is responsible for the decline of these species. If I thought that striped bass was adversely affecting endangered fish or the ecosystem I would be the first person raising a red flag and asking for action. However this is just not the case. Striped bass, salmon, delta smelt and various other fish populations coexisted and thrived in this estuary for over a hundred years when the estuary was a healthy environment for aquatic life."

and

> "These population declines are not due to striped bass predation. Managing and maintaining a healthy striped bass population would be one of the best things for this ecosystem. If the striped bass population were healthy, it would indicate a healthy **estuarine** ecosystem for all of the local endangered endemic fish whose populations would all benefit. This is not only my opinion but one held by many other fisheries biologists including Dr. Peter Moyle the pre-eminent freshwater/estuarine fishery biologist on the West Coast of the United States." (Original bold.)

We attach Dr. Ostrach's informative letter, and incorporate his comments concerning predation. We also attach a memorandum of August 26, 2010, to the California Fish and Game Commission, from Peter B. Moyle and William A. Bennett of the University of California Davis Center for Watershed Sciences, posing the question "Striped bass predation on listed species: can a control program be justified? "In the conclusion of their discussion, the scientists stated:

> "The take home message from all this is that reducing the striped bass population may or may not have a desirable effect. In our opinion, it is most likely to have a negative effect. While the ultimate cause of death of most fish may be predation, the contribution of striped bass to fish declines is not certain. By messing with a dominant predator (if indeed it is), the agencies are inadvertently playing roulette with basic ecosystem processes that can change in unexpected ways in response to reducing striped bass numbers."

Similarly, USFWS scientist Matthew Nobriga, formerly a Senior Environmental Scientist with the California Department of Fish & Game, stated in the district court case concerning striped bass fishing regulations:

> "Food web complexity has often led to incorrect guesses about how aquatic ecosystems will respond to the addition or removal (or depletion) of important fishes (Pine et al. 2009). I think it is impossible to forecast the population responses of the Bay-Delta food web to the removal of striped bass, one of its keystone species. Further, the Pacific Ocean food web adds additional uncertainty into predictions for rebounds of salmonid fishes released from what by several accounts (DFG 1999; Lindley and Mohr 2003) appear to be a very minor constraint of striped bass predation." Declaration of Matthew L. Nobriga in Opposition to Plaintiff's Motion for Summary Adjudication of Issues filed May 9, 2009.

In addition, in Matthew L. Nobriga's A Synopsis of the State of Science Regarding the Feeding Ecology of San Francisco Estuary Striped Bass and its Effects on Listed Fishes, stated:

> "In conclusion, I found no evidence that striped bass predation has an obvious negative effect on the abundance of winter-run or spring-run Chinook salmon or delta smelt. The only potential predator that I found evidence for a statistically significant negative influence on a listed fish was for Mississippi silverside effects on delta smelt (Exhibit F; pages 16-20). It is not known whether silversides are in fact predators of early life stage delta smelt, but Bennett and Moyle (1996) and Bennett (2005) have contended that they are." p. 24

and

> "Thus, the comparison of empirical data since 1996 to Lindley and Mohr's model suggests that it overestimated the-relevance of striped bass predation to winter-run Chinook salmon viability."

> "Based on the information I have read and presented above, it is my professional opinion that the [proponents of striped bass eradication] are relying on an oversimplified conceptual model of aquatic food webs to make their case. I think it is impossible to forecast the population responses of any member of the San Francisco Estuary's food web to the removal of striped bass, one of its keystone species. Thus, it cannot be

> concluded that removal of striped bass fishing regulations will result in a substantive increase in the abundance of the listed fishes. As the examples from other systems demonstrate, partial recovery of listed fishes is only one of several possible outcomes. It is also very possible that nothing detectable would happen, or ironically, that their situation could worsen. This is particularly true for delta smelt, which spend their entire lives in the estuary. The Pacific Ocean food web, which Chinook salmon and steelhead enter once they leave the estuary, adds additional uncertainty into predictions for rebounds of salmonid fishes released from striped bass predation (Lindley et al. 2009)." (p. 30-31)

IV. Fish Screens are unproven and will impinge and entrain listed and protected species.

The three fish screened intakes of the NDD will each extend nearly a third of a mile along the river, thus encompassing nearly a mile of river frontage over a five mile length of river. The RDEIR fails to provide sufficient detail about the fish screen facility to evaluate efficacy and potential for entrainment and impingement. The flow effects on fish of having three enormous intakes over a five mile stretch of river are not evaluated or understood, and the best available science is not included. The RDEIR mentions the Contra Costa Canal Fish Screen Project (RSFS) as being completed in 2011 on Rock Slough. It is a mere 320 foot screen, with 14 feet of depth and a 350 cfs capacity. It pales in comparison to the 3 NDD intakes with more than 5,000 feet in length. The RDEIR fails to mention:

> "Since the RSFS was placed in operation in the fall of 2011, it has experienced mechanical failures, environmental releases and excessive maintenance well beyond what would be acceptable as routine. Many of these problems are likely attributable to a large amount of aquatic vegetation in the vicinity of the RSFS . . . . Among the most common issues have been . . . 4) capturing of adult salmon by the rake heads." Notice of Exemption filed July 10, 2015, by Contra Costa Water District.

The USBR issued a Rock Slough Fish Screen Assistance Agreement in February, 2013, "to facilitate identification of system defects, to design facility modifications, . . ." And in February, 2015, the USBR issued its Rock Slough Fish Screen Operations and Prototype Rake Testing Modifications noting that "[The fish screen has been only partially operational since 2009]."

The RSFS encompasses river frontage on a magnitude of less than 8% of the NDD. The adverse consequences to listed species of having ineffective, inoperable screening facilities would be devastating. Throughout the Fish and Aquatic Resources section it is stated that:

> "[S]everal pre-construction studies to better understand how to minimize losses associated with the three new intake structures will be implemented as part of the final NDD screen design effort."

In other words, there is no design for the public to evaluate, and blind faith must be placed in those who have destroyed the Delta. Reason and the law require more.

V. DWR and USBR violated CEQA and NEPA by their pre-commitment to a North Delta Diversion.

It is said of NEPA that "In summary, the comprehensive 'hard look' mandated by Congress and required by the statute must be timely, and it must be taken objectively and in good faith, not as an exercise in form over substance, and not as a subterfuge designed to rationalize a decision already made." Metcalf v. Daley, 214 F.3d 1135 (9th Cir. 2000)

Similarly, CEQA requires that "The impact report must be specially prepared in written form before the governmental entity makes its decision." Friends of Mammoth v. Bd. of Supervisors of Mono County (1972) 8 Cal. 3d 247, 264, fn. 8. And so, the California Supreme Court ruled in Laurel Heights Imp. Ass'n. v. Regents of the University of California (1988) 47 Cal. 3d 376 cautioned against a process in which "EIRs would likely become nothing more than *post hoc* rationalizations to support action already taken."

That there be no doubt about the evils of paying token lip service to the CEQA process, in Citizens for Responsible Growth v. City of Rancho Cordova (207) 40 Cal. 4th 412 the California Supreme Court explained that "[T]he later the environmental review process begins, the more bureaucratic and financial momentum there is behind a proposal project, thus providing a strong incentive to ignore environmental concerns . . ." That is precisely what occurred here, as the record overwhelmingly demonstrates. The predetermination that a NDD would be utilized is indisputable. This is impermissible, as the California Supreme Court noted in Save Tara v. City of West Hollywood, 45 Cal.4th 116 (2008), stating:

> "The full consideration of environmental effects CEQA mandates must not be reduced to a process whose result will be largely to generate paper, to

> produce an EIR that describes a journey whose destination is already predetermined. Natural Resources Defense Council, Inc. v. City of Los Angeles (2002) 103 Cal.App.4th 268, 271, 126 Cal.Rptr.2d 615.)"

The RDEIR here is exactly what is prohibited by these cases. The evidence is abundantly clear that the environmental process here has been, all along, an empty charade on a predetermined path to the NDD. This is brought by the statement of the Governor that "We are going to get s*#t done" and further verified by the DWR Director Cowin's May 6, 2014 memorandum enclosed, on the "Establishment of the DWR BDCP Office and the DHCCP Design and Construction Enterprise," and stating:

> "Second, a Delta Conveyance Facility Design and Construction Enterprise (DCE) will be established within the Department as a new program to support activities associated with design and construction of conservation measure 1, the Delta Conveyance facilities. The mission of this enterprise is intended to be limited to this singular focus, and the life span of the enterprise will be limited to the time necessary to complete construction of these facilities. As part of DWR, it will have the capacity to issue contracts for consulting services as well as construction, . . ." [I]t is anticipated that [the office] will move to another location to accommodate the growth needed to complete the design and construction of the conveyance facilities."

Additionally, we submit a report of California Governor Jerry Brown's July 25, 2013 announcement of plans to construct the twin tunnels, referencing paralysis by analysis and "I want to get s*!t done." At the announcement, DWR Director Mark Cowin stated "We will have two tunnels leading from a forebay where water from the three intakes will collect . . ." U.S. Department of Interior Secretary Kenneth Salazar stated that "We are united with the state of California to move this project forward and get it done." Also, "We are not going to back down and we intend to get something done here." https://www.youtube.com/watch?v=FTWmXQaDemA

We additionally submit a report of California Secretary for Natural Resources John Laird's May 24, 2012 briefing that the state intends to proceed with construction of the twin tunnels, Jerry Meral's statement that the "Bay Delta Conservation Plan was never about saving the Delta," and the Kern County Water Agency letter of July 27, 2012, regarding "a scientifically defensible decision-tree to operate a new conveyance facility . . ."

These all expose the lack of deference and respect for the CEQA and NEPA processes, which generated vast amounts of paper for a journey to a predetermined destination.

VI. Failure to respond to comments.

The CEQA guidelines provide in 14 C.C.R. § 15088 that a lead agency shall evaluate comments on environmental issues received "and prepare a written response." The RDEIR fails to respond at this time to the more than 12,000 comments to the draft EIR received on the BDCP, including the comments of CDWA.

To a great extent, the RDEIR appears as a subterfuge to avoid the lead agency responsibility to respond in writing to the existing comments. This is brought home by the terse statement in the RDEIR that the "Lead Agencies have substantially modified Alternative 4 to reduce its environmental impacts and have formulated new sub-alternatives . . ." REIR, ES-2. While it is further stated that at the time the Final EIR/EIS is published formal responses to comments on the draft BDCP and Draft EIR/EIS will be provided, and while subsection (d) § 15088 does allow for comments to "take the form of a revision to the draft EIR or a separate section in the final EIR", the revision here does not respond to the bulk of the comments. Accordingly, the response must be provided to those comments which were not the subject of revisions.

VII. The new RDEIR re-opens the comment period on all phases of the project, including the original draft EIR/EIS.

The RDEIR attempts to avoid re-opening the comment period on all phases of the Project. It ambiguously states that "New public comments made during the public review period for the RDEIR/SDEIS should be specific only to the newly circulated information contained in the RDEIR/SDEIS and should not address issues not directly included in the RDEIR/SDEIS." What is or is not "directly included" is ambiguous, because the RDEIR repeatedly references, and relies upon matter in the original draft BDCP EIR. Moreover, the RDEIR goes on to confusingly state "The Lead Agencies intend to only respond to comments that address analysis included within this RDEIR/SDEIS and not those related solely to the original Draft EIR/EIS." This again is ambiguous and is an impermissible attempt to limit comments. For this reason it dissuades and discourages the public from properly commenting on all phases of the project, it is improper and requires a new clear and unambiguous notice that confirms all comments on all phases of the project, including both the original draft EIR/EIS and the RDEIR, will be the subject of consideration and comment.

Section 21092.1 of the Public Resources Code provides that "When significant new information is added to an environmental impact report after notice has been given pursuant to section 21092 the public agency shall give notice again pursuant to section 21092 . . . , the public agency shall give notice again pursuant to section 21092." A new notice must be given making clear comments will be accepted on all matters within the scope of the project and all alternatives being evaluated, whether found in the RDEIR or the BDCP draft EIR, and whether directly or indirectly relating to analysis and matters included in the original BDCP draft EIR.

VIII. The DEIS is incomplete, uncertain and unintelligible.

The DEIS encompasses nearly 8,000 pages and some 1.39 gigabytes of data, added to the enormous 40,000 pages of the original draft EIR/EIS. It defies meaningful consideration and analysis, and is generally incomplete, uncertain, and unintelligible. Indeed, professionals intimately involved in the process are challenged, perplexed, and disappointed with the most current efforts. That is poignantly demonstrated by the September 30, 2015, review by the Delta Independent Science Board (DISB) stating:

> "The Current Draft contains a wealth of information but lacks completeness and clarity in applying science to far-reaching policy decisions. It defers essential material to the Final EIR/EIS and retains a number of deficiencies from the Bay Delta Conservation Plan Draft EIR/EIS. The missing content includes:
>
> 1. Details about the adaptive-management process, collaborative science, monitoring, and the resources that these efforts will require;
>
> 2. Due regard for several aspects of habitat restoration: landscape scale, timing, long-term monitoring, and the strategy of avoiding damage to existing wetlands;
>
> 3. Analyses of how levee failures would affect water operations and how the implemented project would affect the economics of levee maintenance;
>
> 4. Sufficient attention to linkages among species, landscapes, and management actions; effects of climate change on water resources; effects of the proposed project on San Joaquin Valley agriculture; and uncertainties and their consequences;

5. Informative summaries, in words, tables, and graphs, that compare the proposed alternatives and their principal environmental and economic impacts.

"The effects of California WaterFix extend beyond water conveyance to habitat restoration and levee maintenance. These interdependent issues of statewide importance warrant an environmental impact assessment that is more complete, comprehensive, and comprehensible than the Current Draft." (Cover letter)

and

"But we find the Current Draft sufficiently incomplete and opaque to deter its evaluation and use by decision-makers, resource managers, scientists, and the broader public." (p. 1, emphasis added)

and

"These and other strengths of the Current Draft are outweighed by several overarching weaknesses: overall incompleteness through deferral of content to the Final EIR/EIS (herein, "the Final report"); specific incompleteness in treatment of adaptive management, habitat restoration, levees, and long-term effects; and inadequacies in presentation." (p. 4)

and

"The Current Draft lacks key information, analyses, summaries, and comparisons. The missing content is needed for evaluation of the science that underpins the proposed project. Accordingly, the Current Draft fails to adequately inform weighty decisions about public policy. The missing content includes:

1. Details on adaptive management and collaborative science (below, p. 5).

2. Modeling how levee failures would affect operation of dual-conveyance systems (below, p. 7). Steve Centerwall told us on August 14 that modeling of the effects of levee failure would be presented in the Final Report.

3. Analysis of whether operation of the proposed conveyance would alter the economics of levee maintenance (below, p. 7).

4. Analysis of the effects of climate change on expected water exports from the Delta. '[A]n explanation and analysis describing potential scenarios for future SWP/CVP system operations and uncertainties [related to climate change] will be provided in the Final Report' (p. 1-35 of the Current Draft).

5. Potential impacts of climate change on system operations, even during the shortened time period emphasized in the Current Draft (below, p. 8 and 11).

6. Potential effects of changes in operations of the State Water Project (SWP) and Central Valley Project (CVP), or other changes in water availability, on agricultural practices in the San Joaquin Valley (p. 12).

7. Concise summaries integrated with informative graphics (below, p. 9 and 13). The Current Draft states that comparisons of alternatives will be summarized in the Final report (p. 1-35). (p. 4)

While some of the missing content has been deferred to the Final Report (examples 2, 4, and 7), other gaps have been rationalized by deeming impacts 'too speculative' for assessment. CEQA guidance directs agencies to avoid speculation in preparing an EIR/EIS [footnote omitted]. To speculate, however, is to have so little knowledge that a finding must be based on conjecture or guesswork. Ignorance to this degree does not apply to potential impacts of WaterFix on levee maintenance (example 3; see p. 7) or on San Joaquin Valley agriculture (example 6; p. 12)." (pp. 4-5)

and

"Even if content now lacking would go beyond what is legally required for an EIR/EIS, providing such content could assist scientists, decision-makers, and the public in evaluating California WaterFix and Delta problems of statewide importance (above, p. 1)." (p. 5)

and

"Yet adaptive management continues to be considered largely in terms of how it is to be organized (i.e., coordinated with other existing or proposed adaptive-management collaborations) rather than how it is to be done (i.e., the process of adaptive management). Adaptive management should be integral with planned actions and management—the Plan A rather than a Plan B to be added later if conditions warrant. The lack of a substantive treatment of adaptive management in the Current Draft indicates that it is not considered a high priority or the proposers have been unable to develop a substantive idea of how adaptive management would work for the project." (p. 5)

and

"We did not find examples of how adaptive management would be applied to assessing - and finding ways to reduce - the environmental impacts of project construction and operations." (p. 5)

and

"The Current Draft defers details on how adaptive management will be made to work: "An adaptive management and monitoring program will be implemented to develop additional scientific information during the course of project construction and operations to inform and improve conveyance facility operational limits and criteria" (p. ES-17). This is too late." (p. 6)

and

"The missing details also include commitments and funding needed for science-based adaptive management and restoration to be developed and, more importantly, to be effective."

"The Current Draft does little more than promise that collaborations will occur and that adaptive management will be implemented. This level of assurance contrasts with the central role of adaptive management in the Delta Plan and with the need to manage adaptively as climate continues to change and new contingencies arise." (p. 6)

and

"Restoration projects should not be planned and implemented as single, stand-along projects but must be considered in a broader, landscape context." (p. 6)

and

"On August 13 and 14, representatives of WaterFix and EcoRestore acknowledged the importance of the landscape scale, but the Current Draft gives it little attention. Simply because the CEQA and NEPA guidelines do not specifically call for landscape-level analyses is not a sufficient reason to ignore them." (p. 6)

and

"Sequencing apparently will be addressed as part of the permitting process with the US Army Corps of Engineers (USACE) for mitigation related to the discharge of dredged or fill material. However, it is difficult to evaluate the impacts on wetlands in advance of a clarification of sequencing and criteria for feasibility." (p. 6)

and

"When an existing wetland is restored, however, there is no net gain of area, so it is unclear whether credits for improving existing wetlands would be considered equivalent to creating wetlands where they did not recently exist." (pp. 6-7)

and

"In view of inevitable shortcomings and time delays in wetland restorations, mitigation ratios should exceed 1:1 for enhancement of existing wetlands. The ratios should be presented, rather than making vague commitments such as 'restore or create 37 acres of tidal wetland . . .' The Final Draft also needs to clarify how much of the wetland restoration is out-of-kind and how much is in-kind replacement of losses. It should examine whether enough tidal area exists of similar tidal amplitude for in-kind replacement of tidal wetlands, and whether such areas will exist with future sea-level rise." (p. 7)

and

"A Comprehensive assessment of environmental impacts should relate California WaterFix to levee failure by examining the consequences each may have for the other." (p. 7)

and

"On the one hand, the Current Draft fails to consider how levee failures would affect the short-term and long-term water operations spelled out in Table 4.1-2." (p. 7)

and

"On the other hand, the Current Draft also fails to consider how implementing the project would affect the basis for setting the State's priorities in supporting Delta levee maintenance." (p. 7)

and

"The Current Draft does not evaluate how the proposed project may affect estimates of the assets that the levees protect." (p. 8)

and

"Neither the Previous Draft nor the Current Draft, however, provides a resource chapter about Delta levees. Such a chapter would be an excellent place to examine interacting impacts of conveyance and levees." (p. 8)

and

"With the shortened time period, several potential long-term impacts of or on the proposed project no longer receive attention. While these effects may not become problematic during the initial permit period, many are likely to affect project operations and their capacity to deliver benefits over the long operational life of the proposed conveyance facilities. In our view, consideration of these long-term effects should be part of the evaluation of the science foundation of the proposed project." (p. 8)

and

"Rather than consider such effects, however, the Current Draft focuses on how the proposed project would affect 'the Delta's resilience and adaptability to expected climate change' (Current Draft section 4.3.25). Quite apart from the fact that 'resilience' and 'adaptability' are scarcely operational terms, the failure to consider how climate change and sea-level rise could affect the outcomes of the proposed project is a concern that carries over from our 2014 review and is accentuated by the current drought (below, p. 11)." (p. 8)

and

"The Current Draft states that 'Groundwater resources are not anticipated to be substantially affected in the Delta Region under the No Action Alternative (ELT) because surface water inflows to this area are sufficient to satisfy most of the agricultural, industrial, and municipal water supply needs' (p. 4.2-16). This conclusion is built on questionable assumptions: the current drought illustrates how agriculture turns to groundwater when surface-water availability diminishes. Groundwater regulation under the recently enacted Sustainable Groundwater Management Act (SGMA) can also be expected to have long-term effects on the proposed project—effects that the Current Draft does not assess. Ending of more than a million acre-feet of overdraft in the southern Central Valley under the SGMA is likely to increase demand for water exports from the Delta in the coming decades." (pp. 8-9)

and

"The Current Draft suggests that unnamed 'other programs' that are 'separate from the proposed project' will use elements of the Previous Draft to implement long-term, conservation efforts that are not part of California WaterFix (Current Draft, p. 1-3)." (p. 9)

and

"According to guidance for project proponents, 'Environmental impact statements shall be written in plain language and may use appropriate graphics so that decision-makers and the public can readily understand them' (Code of Federal Regulations, 40 CFR 1502.8). Far-reaching decisions should not hinge on environmental documents that few can grasp." (p. 9)

and

"The Current Draft is inadequate in these regards." (p. 9)

and

"These products do little to compensate for the overall paucity of readable summaries and comparisons in the Previous and Current Drafts." (p. 9)

and

"Appallingly, such summaries and comparisons remain absent in the Current Draft." (p. 9)

and

"Prescriptions in CEQA and NEPA in no way exclude cogent summaries, clear comparisons, or informative graphics. And three years is more than enough time to have developed them." (p. 9)

and

"On August 14, 2015, representatives of California WaterFix assured us that this kind of content would eventually appear, but only in the Final Report. That will be far too late in the EIR/EIS process for content so critical to comprehending what is being proposed and its potential impacts." (p. 10)

and

"Our persistent concerns include the treatment of uncertainty, the implementation of adaptive management, and the use of risk analysis. These topics receive little or no further attention in the Current Draft. We also found few revisions in response to points we raised previously about linkages among species, ecosystem components, or landscapes; the potential effects of climate change and sea-level rise; and the potential effects of changes in water availability on agricultural practices and the consequent effects on the Delta. Our previous comments about presentation also pertain." (p. 10)

and

"Nonetheless, the Current Draft retains unwarranted optimism, as on page 4.3.25-10: By reducing stressors on the Delta ecosystem through predator control at the north Delta intakes and Clifton Court Forebay and installation of a nonphysical fish barrier at Georgiana Slough, Alternative 4A will contribute to the health of the ecosystem and of individual species populations making them stronger and more resilient to the potential variability and extremes caused by climate change.' A scientific basis for this statement is lacking, and an adaptive or risk-based management framework is not offered for the likely event that such optimism is unfulfilled." (p. 10)

and

"To be effective, mitigation actions should deal with both the immediate and long-term consequences of the project. The proposed permitting should allow for monitoring long enough to assess the effectiveness of habitat restoration measures, which will need to extend beyond the initial permitting period." (p. 10)

and

"In the Current Draft, uncertainties and their consequences remain inadequately addressed, improvements notwithstanding. Uncertainties will now be dealt with by establishing 'a robust program of collaborative science, monitoring, and adaptive management' (ES 4.2). No details about this program are provided, so there is no way to assess how (or whether) uncertainties will be dealt with effectively." (p. 11)

and

"Many of our prior concerns about uncertainties pertained to impacts on fish. If those uncertainties have now been addressed in Chapter 11, they are difficult to evaluate because changes to that chapter have not been tracked in the public draft (below, p. 17)." (p. 11)

and

"There are also uncertainties with the data generated from model outputs, although values are often presented with no accompanying error estimates." (p. 11)

and

"First, the Current Draft is probably outdated in its information on climate change and sea-level rise. It relies on information used in modeling climate change and sea-level rise in the Previous Draft, in which the modeling was conducted several years before December 2013." (p. 11)

and

"Yet climate extremes, in particular, are a topic of intense scientific study, illustrated by computer simulations of ecological futures and findings about unprecedented drought." (p. 11)

and

"Thus, 'Delta exports would either remain similar or increase in wetter years and remain similar or decrease in the drier years under Alternative 4A as compared to the conditions without the project.' (p. 4.3.1-4). Such an inconclusive conclusion reinforces the need to be able to adapt to different outcomes. Simply because the Alternatives are expected to relate similarly to a No Action Alternative that includes climate change does not mean that the Alternatives will be unaffected by climate change." (pp. 11-12)

and

"The Current Draft recognizes that mitigation measures for one species or community type may have negative impacts on other species or communities, and mitigation plans may be adjusted accordingly. But the trade-offs do not seem to be analyzed or synthesized. This emphasizes the need for a broader landscape or ecosystem approach that comprehensively integrates these conflicting effects." (p. 12)

and

"In 2014 we pointed to three kinds of impacts that the Previous Draft overlooked: . . . (2) effects of levee failures on the proposed BDCP actions and effects of isolated conveyance on incentives for levee investments; and (3) effects of increased water reliability on crops planted, fertilizers and pesticides used, and the quality of agricultural runoff. The Current Draft responds in part to point 1 (in 11.3.2.7) while neglecting point 2 (above, p. 7) and point 3." (p. 12)

and

"Although the Current Draft considers how the project might affect groundwater levels south of the Delta (7.14 to 7.18), it continues to neglect the environmental effects of water use south of (or within) the Delta." (p. 12)

and

"The Current Draft does not fully consider the consequences of these assumptions, or of the projections that the project may enhance water-supply reliability but may or may not increase water deliveries to agriculture." (p. 12)

and

"The impacts of water deliveries south of the Delta extend to the question of how each intake capacity (3,000, 9,000, or 15,000 cfs) may affect population growth in Southern California." (p. 12)

and

"If the mitigation measures for terrestrial resources are implemented as described, for example, they should compensate for habitat losses and disturbance effects of the project." (p. 13)

and

"It is not apparent that the mitigation plans include these components." (p. 13)

and

"Out 2014 review advised using risk assessment and decision theory in evaluating the proposed BDCP actions and in preparing contingency plans. We noticed little improvement on this issue, just a mention that it might be considered later. This is not how the process should be used." (p. 13)

and

"The operating guidance for the new alternatives seems isolated from the many other water management and environmental activities in and upstream of the Delta likely to be important for managing environmental and water supply resources related to Delta diversions." (p. 14)

and

"The collaborative science ideas seem philosophically attractive, but are not given much substance. Monitoring is mentioned, but details of organization, intent, and resources seem lacking. Adequate funding to support monitoring, collaborative science, and adaptive management is a chronic problem. Section ES.4.2 states that 'Proponents of the collaborative science and monitoring program will agree to provide or seek additional funding when existing resources are insufficient.' This suggests that these activities are lower in priority than they should be." (p. 15)

and

"The three new alternatives, 4A, 2D, and 5A, seem to have modest changes over some previous alternatives, with the exception of not being accompanied by a more comprehensive environmental program." (p. 15)

and

"The new Sustainable Groundwater Management Act (SGMA) seems likely to increase demands for water diversions from the Delta to the south to partially compensate for the roughly 1.5-2 maf/year that is currently supplied by groundwater overdraft." (p. 15)

and

"The climate change analysis of changes in Delta inflows and outflows is useful, but isolating the graphs in a separate document disembodies the discussion. The fragmentation of the document by removing each Section 4 figure into a separate file is inconvenient for all, and makes integrated reading practically impossible for many." (p. 15)

and

"The range of impacts considered is impressive, but poorly organized and summarized." (p. 15)

and

"The effects of the likely listing of additional native fish species as threatened or endangered seems likely to have major effects on project and alternative performance. These seem prudent to discuss, and perhaps analyze." (p. 15)

and

"Have the effects of droughts or deluges been considered?" (p. 15)

and

"Text on disturbing sediments and releasing contaminants needs to add nitrogen and phosphorus to the concerns." (p. 16)

and

"The frequently repeated discussion of cyanobacteria blooms needs to be updated." (p. 16)

and

"A lot of attention is given to factors controlling *Microcystis* blooms in this chapter but little attention is given to its toxicity." (p. 17)

and

"Fish Screens

It is unclear how (and how well) the fish screens would work. The description of fish screens indicates that fish>20 mm are excluded, but what about fish and larvae that are <20 mm, as well as eggs? Table 11-21 seems out of date, because some fish screens appear to have been installed, but data on their effects are not given. Despite the lack of specific data on how well screens function, the conclusion that there will be no significant impact is stated as certain (e.g., page 1-100 line38).

Here, as in many other places, measures are assumed to function as planned, with no evidence to support the assumptions. The level of certainty seems optimistic, and it is unclear whether there are any contingency plans in case things don't work out as planned. This problem persists from the Previous Draft." (p. 17)

and

> "Weed control (fire, grazing) is suggested, but over what time frame? It may be needed in perpetuity." (p. 18)

and

> "Herbicides are prescribed to keep shorebird nesting habitat free of vegetation, but toxic effects of herbicides on amphibians etc. are not considered." (p. 18)

and

> "Impacts of invasive plants seem underestimated. Impact analysis implies that the project disturbance area is the only concern, when dispersal into all areas will also be exacerbated." (p. 18)

and

> "Is the assumption that, acre for acre, all jurisdictional waters are interchangeable, whether of different type or existing vs. created?" (p. 18)

and

> "What if this project causes the problem, e.g. via vibration?" (p. 18)

and

> "CM1 alternative 4A would fill 775 acres of WOTUS (491 wetland acres). . ." (p. 18)

and

"Only 1% of the habitat in the study area would be filled or converted" (Chapter 12, line 29, page 12-22) is how the US has lost its historical wetlands. What are the overall cumulative impacts of wetland losses in the Delta? What is the tipping point beyond which further wetland losses must be avoided? The proposed project is one part of the broader array of management actions in the Delta and should be considered in that broader context." (p. 18)

and

"How will mudflats be sustained for shorebirds? Exposed mud above half-tide can become vegetated rapidly." (p. 19)

and

"Alternative 4A would allow water diversion from the northern Delta, with fish screens, multiple intakes, and diversions limited to flows that exceed certain minima, e.g., 7000 cfs. This would reduce flood-pulse amplitudes and, presumably, downstream flooding. How does this alter opportunities for riparian restoration? Where would riparian floodplains still be restorable?" (p. 19)

and

"At some point along the pipeline-tunnel transition, wouldn't groundwater flow be affected?" (p. 19)

and

"Up to 14 years of construction activities were predicted for some areas (e.g., San Joaquin Co.); this would have cumulative impacts (e.g., dewatering would affect soil compaction, soil carbon, microbial functions, wildlife populations, and invasive species). What about impacts of noise on birds; e.g., how large an area would still be usable by greater sandhill cranes?" (p. 19)

and

> "On the need to store removed aquatic vegetation until it can be disposed: there are digesters for this purpose, and they might be efficient means of mitigation if management of harvested aquatic plants will be long-term. A waste product could be turned into a resource (methane fuel)." (p. 19)

and

> "Text says that "predator hiding spots" will be removed. What are these?" (p. 19)

> "What are the E16 nonphysical fish barriers? An electrical barrier?" (p. 19)

and

> "Boat-washing stations are mentioned; would these discharge pollutants (soap, organic debris?)" (p. 19)

In addition to pointing out the incompleteness and uncertainty of the RDEIR, the DISB comments elaborate on other, substantive deficiencies.

IX. The RDEIR fails to evaluate the risk of infrastructure and system failure due to terrorism, earthquakes or other catastrophic event.

The risk of terrorism in today's day and age is real, and the threat to an attack on infrastructure, including the electrical grid, by terrorists or foreign states should not be ignored. See Lights Out (2015), Ted Koppel. The consequences of an electrical grid failure would render the NDD unusable, as the NDD would not function and the pumps could move no water at the south Delta pumping plants, or at the Tehachapi. Similarly, the risk and effects of earthquake, design defects or other failure of the tunnels and aqueduct is not evaluated. Interestingly enough, the path of the tunnels transects a blind fault, the Thornton Arch Zone. Active Faults and Historical Seismicity, etc., Figure 9-5. Curiously, the RDEIR notes the risk of levee failure due to earthquake, but treats everything else as if it is immune. The others are not theoretical risks, but instead are part of the real world today, and as such part of the baseline. These and other risks of infrastructure failure should be evaluated, analyzed, and mitigated.

X. Denial of Equal Protection and Due Process to the residents, businesses, and property owners of the Delta.

This project is moving forward against wide-spread opposition by residents, businesses, and property owners within the Delta. There is a disproportionate effect on minority populations. Figure 28-1 and 28-2, Low Income and Minority Populations in the Plan Area. The Delta residents, businesses, and property owners were essentially excluded from the process, and no vote is being taken to obtain their consent. This is a denial of substantive Due Process of law and Equal Protection under the law.

XI. Reduced Through Delta Flows Due To The NDD Will Reduce Turbidity and Spatial Distribution of Listed Species Leaving Them Vulnerable To Increased Predation That Is Not Mitigated.

Increased turbidity and spatial distribution as a result of a higher volume of flows reduces predator exposure. Reducing flows, as will be the case under the NDD regime, will reduce turbidity and diminish the space occupied by the listed species, increasing their vulnerability to predators. See Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon, Gregory and Levings, American Fisheries Society (1998). Maintaining sufficient flows for migrating salmon, including sufficient turbidity, would contribute to necessary mitigation.

Submitted herewith on a separate CD are the following supporting documents:

1. Final Restoration Plan for the Anadromous Fish Program;

2. Working Paper on Restoration Needs, Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California;

3. Striped Bass Food Chain;

4. Striped Bass Abundance Chart;

5. Sacramento Bee report: Meral Retires But Delta Plan Endures;

6. High Country News report: Tunneling Under California's Bay Delta Water Wars;

7. Letter of David J. Ostrach, Ph.D., dated July 19, 2010;

8. Letter of NGO's dated June 12, 2012, regarding Laird comments;

9. Letter of Kern County Water Agency, dated June 27, 2012, to Ken Salazar and John Laird;

10. Mark Cowin memo dated May 6, 2014;

11. Delta Independent Science Board letter dated September 30, 2015;

12. Declaration of Matthew L. Nobriga in Opposition to Motion for Summary Adjudication of Issues, filed May 20, 2009;

13. Memorandum of Peter B. Moyle and William A. Bennett dated August 26, 2010;

14 A Synopsis of the State of Science Regarding the Feeding Ecology of San Francisco Estuary Striped Bass and its Effects on Listed Fishes, Matthew l. Nobriga, Senior Environmental Scientist, California Department of Fish and Game, Water Branch, October 1, 2009;

15. Notice of Exemption for Rock Slough Fish Screen Log Boom Relocation, filed July 10, 2015;

16. USBR's Assistance Agreement for Rock Slough Fish Screen;

17. USBR's Rock Slough Fish Screen Operations and Prototype Rake Testing Modifications; and

18. USBR's Rock Slough Fish Screen Hydraulic Evaluation.

We further to refer to the Delta Protection Commission's Economic Sustainability Plan.

In conclusion, the RDEIR and the project are defective and should be revised and the RDEIR re-released consistent with the above. Further, the NDD should be abandoned as contrary to law.

Very truly yours,

DANIEL A. McDANIEL
Attorney for
Reclamation District No. 2038

DAM:yj

Final Restoration Plan for the Anadromous Fish Restoration Program

A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California

Released as a Revised Draft on May 30, 1997
and Adopted as Final on January 9, 2001

UPDATES*

* This page is not included in the Final Restoration Plan for the AFRP. The purpose of this page is to track possible changes in the Plan as more information becomes available.

The following updates have been identified:

Appendix B-1 and Table E-1: The referred winter Chinook salmon run in the Calaveras River is not considered an authentic salmon run in this river and may have been mistaken by a late fall-run (Yoshiyama et al. 2001). Alternative production targets for other salmonids in the Calaveras River are being evaluated in the AFRP project: Lower Calaveras River salmonid life history limiting factor analysis. Updated production targets for salmonids in the Calaveras River will be reported here at the completion of that study (Last updated September 3, 2002).

References

Yoshiyama, R.M., E.R. Gertstung, F.W. Fisher and P.B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley of California. California Department of Fish and Game. Fish Bulletin 179(1): 71-176.

FINAL RESTORATION PLAN
FOR THE
ANADROMOUS FISH RESTORATION PROGRAM

A PLAN TO INCREASE NATURAL PRODUCTION OF ANADROMOUS FISH
IN THE CENTRAL VALLEY OF CALIFORNIA

Prepared for the Secretary of the Interior by the
United States Fish and Wildlife Service with assistance from
the Anadromous Fish Restoration Program Core Group
under authority of the Central Valley Project Improvement Act.

January 9, 2001

PREFACE

The Central Valley Project Improvement Act (CVPIA) directs the Secretary of the Interior to develop and implement a program that makes all reasonable efforts to double natural production of anadromous fish in Central Valley streams (Section 3406(b)(1)). The program is known as the Anadromous Fish Restoration Program (AFRP).

The document you have before you is the Restoration Plan. The Restoration Plan is a programmatic-level description of the AFRP in broad and general terms, and will be used to guide the long-term development of the AFRP. The Restoration Plan presents the goal, objectives, and strategies of the AFRP; describes how the AFRP identified and prioritized reasonable actions and evaluations; lists those actions and evaluations; and notes those actions and evaluations that are already underway or that may be implemented in the near future.

An initial draft was released for review and comment in December 1995 and a revised draft was released for review and comment in 1997. This Final Plan incorporates those 1997 comments to the extent the Department of the Interior (Interior) deemed appropriate. The Programmatic Environmental Impact Statement (PEIS) required by Section 3409 of the CVPIA has been completed.

The AFRP will use all the authority and resources provided by the CVPIA to restore anadromous fish and will rely heavily on local involvement and partnerships with property owners, watershed workgroups, public and private organizations, county and local governments, and state and federal agencies. To make restoration efforts as efficient as possible, the AFRP will coordinate restoration efforts with those by other groups, such as the California Department of Fish and Game, Category III of the Bay-Delta Agreement, the San Joaquin River Management Program, and the CALFED Bay-Delta Program. Successful implementation of the Restoration Plan will depend on the continued participation of the public and interested parties and support of involved state and federal agencies.

ACKNOWLEDGMENTS

The Restoration Plan is the responsibility of the USFWS as the lead agency for the AFRP. The USFWS thanks the AFRP=s Core Group, including Randy Brown of the California Department of Water Resources, Jim Bybee of the National Marine Fisheries Service (NMFS), Susan Hatfield and Bruce Herbold of the United States Environmental Protection Agency (USEPA), Ken Lentz of the USBR, and Terry Mills and Alan Barraco of the California Department of Fish and Game. However, this plan does not commit any Core Group members= agency to implement any of the actions noted herein. The USFWS thanks Laura King of the USBR, Gary Stern of the NMFS, Tom Hagler of the USEPA, and Dana Jacobsen of the Office of the Solicitor, and the members of Interior=s Washington Office Policy Group, including Ted Boling of the Office of the Assistant Secretary for Fish and Wildlife and Parks, Dana Cooper of the Office of the Assistant Secretary for Water and Science, Barbara Geigle of the Office of the Solicitor, Rowan Gould of the USFWS, and Steve Magnuson of the USBR; and the staffs at the Central Valley Fish and Wildlife Restoration Program, including Roger Dunn, Roger Guinee, Andy Hamilton, Jim McKevitt, and Larry Puckett; the Sacramento Field Office, including Rick Morat and Mike Thabault; the Northern Central Valley Fish and Wildlife Office, including Jim Smith; and the Sacramento-San Joaquin Estuary Fishery Resource Office, including Pat Brandes, Dan Castleberry, Kathy Corbin, John Icanberry, Marty Kjelson, Yvette Leatherman, Sam Lohr, Gary Rensink, Scott Spaulding, and John Wullschleger; for their contributions toward completion of this plan. The USFWS also thanks the many public and private organizations and individuals that took time to help prepare this plan by attending public workshops, meeting on a local watershed or interest level, or writing or calling to voice their concerns.

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[1]Appendices H and I are bound as separate documents. Appendix H presents paraphrased comments and the USFWS=s responses to each of the comments that we received during the designated comment period on the December 6, 1995 draft of the Restoration Plan. Appendix I presents the summarized oral comments and complete written comments that we paraphrased for Appendix H. Although Appendix H provides insight to help the reader further understand the Restoration Plan, it is not essential for using the Restoration Plan. Appendix I is intended to help interested parties see how their comments and the comments of others were paraphrased and represented by the USFWS in Appendix H. Appendices H and I are available upon request from the Program Manager for the AFRP at (209) 946-6400 or at the address listed in Appendix C.

INTRODUCTION

Since settlement of the Central Valley in the mid-1800s, populations of native anadromous fishes (i.e., chinook salmon, steelhead, white sturgeon, and green sturgeon) have declined dramatically. Declines have been so dramatic that several species may be in danger of extinction. At present, winter-run chinook salmon are listed as endangered under the federal and state Endangered Species acts, and all other races of chinook salmon and steelhead have been petitioned for either federal or state listing.

American shad and striped bass were introduced into the Sacramento-San Joaquin system in the 1870s. Both species supported valuable sport and commercial fisheries throughout much of this century, but California Department of Fish and Game (CDFG) data indicate that populations have declined since the mid-1960s.

Habitat degradation is the primary cause of these declines. Hydraulic mining for gold was the first human activity that resulted in large-scale habitat degradation due to sedimentation and diversion of water in many Central Valley streams. Hydraulic mining was prohibited in 1894, but habitat degradation has continued. Habitat quantity and quality have declined due to construction of barriers to migration and levees, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution. Causes of declines in habitat quality and quantity are examples of factors that may potentially reduce natural production of anadromous fish below levels that would occur in the absence of the factor, and are sometimes called limiting factors or stressors. Although the effects of habitat degradation on fish populations were evident by the 1930s, rates of decline for most anadromous fish species increased following completion of major water project facilities.

Other factors that may have adversely affected natural stocks of anadromous fish include overharvest, illegal harvest, hatchery production, and introduction of competitors, predators and diseases. Fish populations may also vary due to natural events. Droughts and poor ocean conditions, such as El Niño, may reduce populations. However, populations in healthy habitats typically recover within a few years after natural events. The decline of fish populations has continued through cycles of beneficial and adverse natural conditions, indicating the need to improve habitat.

STATUTORY SCHEME

Section 3406(b)(1) of the Central Valley Project Improvement Act (CVPIA) requires the Secretary of the Department of the Interior (Secretary) to Adevelop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967 - 1991...@ Section 3406(b)(1) also states that Athis goal shall not apply to the San Joaquin River between Friant Dam and the Mendota Pool.@ Further, Section 3406(b)(1)(A) requires that the program Agive first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations, and implementation of the supporting measures mandated by this subsection; shall be reviewed and updated every five years; and shall describe how the Secretary intends to operate the Central Valley Project to meet the fish, wildlife and habitat restoration goals and requirements set forth in this title and other project purposes.@

The Secretary directed the U.S. Fish and Wildlife Service (USFWS) and the U.S. Bureau of Reclamation (USBR) to jointly implement the CVPIA, and Section 3406(b)(1) in particular. The USFWS and USBR are approaching implementation of this directive through development of an Anadromous Fish Restoration Program (AFRP) to address those species identified for restoration in the CVPIA. Those six anadromous fish species are chinook salmon *(Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), white sturgeon (*Acipenser transmontanus*), and green sturgeon (*A. medirostris*). The term AAFRP@ is the umbrella term for all of the components of the Department of the Interior=s (Interior) and its agency and private partner=s efforts to make all reasonable efforts to at least double the natural production of anadromous fish. This Restoration Plan presents the goal, objectives, and strategies of the AFRP; describes processes the AFRP used to identify, develop, and select restoration actions; and lists actions and evaluations determined, at a programmatic level, to be reasonable to implement as part of the AFRP.

COMPLIANCE WITH RELATED STATUTES

A number of related statutes affect the development and implementation of this Restoration Plan under the CVPIA. The most important of these related statutes are the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA).

National Environmental Policy Act

This Restoration Plan was developed to comply with Section 3406(b)(1) of the CVPIA. The impacts of this programmatic-level Restoration Plan are being analyzed in the Programmatic Environmental Impact Statement (PEIS), which is being prepared pursuant to NEPA and to Section 3409 of the CVPIA. The revised Restoration Plan remains subject to change, based on the results of the PEIS, as well as through adaptive management of the actions during the life of the Restoration Plan.

While the PEIS is being finalized, Interior will continue to manage the water dedicated by Section 3406(b)(2) of the CVPIA for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes of the CVPIA, as determined by the Ninth Circuit Court of Appeals in Westlands v. United States, 43 F. 3d 457 (9th Cir. 1994). The court in that case concluded that the requirements in certain sections of the CVPIA to take action immediately upon enactment of the CVPIA created an irreconcilable conflict with the requirements of NEPA. The court concluded, therefore, that NEPA analysis of the dedication and management of the 3406(b)(2) water was not required.

The impacts of implementing individual actions identified in the Restoration Pla n pursued under authority other than Section 3406(b)(2) will be analyzed in site-specific NEPA documentation, as appropriate.

Endangered Species Act

Section 7(a) of the ESA states in part that AThe Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act.@ For example, in March 1993 the USFWS listed the delta smelt as a threatened species pursuant to the ESA. In December 1994, critical habitat was designated for the delta smelt. In November 1996, the USFWS published the Final Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes (DNFRP) (USFWS 1996). The DNFRP identifies both flow and non-flow actions. The flow actions identified in the DNFRP are classified as Apriority one actions,@ meaning that they are actions considered necessary for the recovery of the species. Many actions in this Restoration Plan are flow-related, and the life stages of many of the anadromous species overlap with critical life stages of the delta smelt and other native fishes in the Delta. The implementation schedule for actions within the DNFRP are immediate and ongoing. Therefore, many actions in the Restoration Plan will contribute towards recovery of Delta native fishes.

Actions within the Restoration Plan may have effects not foreseen at this time. All actions implemented through the AFRP will need to be reviewed for their effects on listed and proposed species. Any such actions that may affect those species will be subject to further review under the Secretary's authorities under Section 7(a)(2) of the ESA. It is Interior's intention that the USFWS, National Marine Fisheries Service (NMFS), and CDFG work closely together to coordinate actions in the implementation and recovery plans for anadromous fish and listed and proposed species.

PURPOSES

The AFRP is an opportunity for the USFWS and USBR to collaborate with other agencies, organizations and the public to increase natural production of anadromous fish in the Central Valley by augmenting and assisting restoration efforts presently conducted by local watershed workgroups, the CDFG, and others. Purposes of the CVPIA (Section 3402) relevant to the AFRP are:

- To protect, restore, and enhanc e fish, wildlife, and associated habitats in the Central Valley;
- To address impacts of the Central Valley Project (CVP) on fish, wildlife, and associated habitats;
- To improve the operational flexibility of the CVP;
- To contribute to the State of California=s interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and

- To achieve a reasonable balance among competing demands for the use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors.

GOAL AND OBJECTIVES

The goal of the AFRP, as stated in Section 3406(b)(1) of the CVPIA, is to Adevelop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991.@ Section 3406(b)(1) also states that Athis goal shall not apply to the San Joaquin River between Friant Dam and the Mendota Pool.@

Six general objectives need to be met to achieve the program goal:

- Improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat;
- Improve survival rates by reducing or eliminating entrainment of juveniles at diversions;
- Improve the opportunity for adult fish to reach their spawning habitats in a timely manner;
- Collect fish population, health, and habitat data to facilitate evaluation of restoration actions;
- Integrate habitat restoration efforts with harvest and hatchery management; and
- Involve partners in the implementation and evaluation of restoration actions.

STRATEGIES

Fishery managers must address complex biological, economic, social, and technological issues to substantially restore natural production of anadromous fish in the Central Valley. Restoration will be costly and require changing the way aquatic resources and habitats are managed. Because the challenge is great, the AFRP requires solid strategies to select and implement effective restoration actions.

The AFRP strategies consist of two components, implementation *principles* and an implementation *approach*. Implementation principles are the tenets guiding selection and prioritization of actions. The implementation approach describes key aspects of how restoration actions will be implemented.

Implementation principles

Restoration actions are being selected and prioritized based on the magnitude of the contribution to doubling natural production, the status of target species and races, and on Section 3406(b)(1)(A) of the CVPIA, which directs the AFRP to give first priority to:

- Measures which protect and restore natural channel and riparian habitat values through habitat restoration actions;
- Modifications to Central Valley Project operations; and
- Implementation of the supporting measures mandated by subsection 3406(b) of the CVPIA.

These principles are discussed below.

- Contribution to natural production

Placing priority on actions that result in large increases in natural production will most efficiently contribute to meeting target production levels.

- Species status

Placing priority on actions that benefit species and races whose abundance is precariously low will help maintain the genetic diversity of anadromous fish in the Central Valley. Maintaining genetic diversity will preserve adaptability and resilience, which are essential if natural production is to be sustainable on a long-term basis.

Winter-run chinook salmon are listed as endangered under the federal and state ESAs. Spring-run, late-fall-run, and fall-run chinook salmon have been petitioned for threatened or endangered status throughout their range in Washington, Oregon, California, and Idaho, under the federal ESA (NMFS 1995). The California Fish and Game Commission will take regulatory action concerning the candidacy of spring-run chinook salmon as an endangered species under the state ESA soon. Steelhead have been petitioned for threatened or endangered status throughout its range in Washington, Oregon, California, and Idaho, under the federal ESA (NMFS 1994). A proposed determination by NMFS identified steelhead in the Central Valley as an evolutionary significant unit, and recommended listing as an endangered species (NMFS 1996). A final determination will be made in August 1997. White sturgeon, green sturgeon, striped bass and American shad have also suffered significant, long-term declines.

- Restoring natural habitat values

Protecting and restoring natural channel and riparian habitat values promotes natural processes that regulate geomorphic characteristics, nutrient dynamics, and production capabilities of streams, rivers, and estuaries. Restoring natural processes is essential to ensure that both physical and biological ecosystem components can resist declines and recover after both natural and anthropogenic perturbations, thus contributing to long-term sustainability of natural production.

- Modifying CVP operations

Placing priority on actions that modify CVP operations will directly help minimize impacts on fish, wildlife, and associated habitats; help balance competing demands for the use of CVP water, including the requirements of fish and wildlife; and will focus restoration efforts where the Secretary has the authority to be most effective.

- Implementing supporting measures in the CVPIA

Placing priority on implementing the supporting measures mandated by subsection 3406(b) of the CVPIA focuses restoration efforts where the Secretary has the authority to be most effective.

The implementation principles can be used to compare actions that address a common limiting factor (for example, to compare two actions that address a lack of suitable spawning substrate) as well as to compare actions that address different limiting factors (for example, to compare an action that addresses lack of suitable spawning substrate with an action that addresses illegal harvest) within a watershed. In applying these principles, the AFRP will support actions that contribute to increasing the natural production of anadromous fish through restoration of natural habitat values before supporting actions that increase production by other means.

Implementation approach

The AFRP approach to making all reasonable efforts to at least double natural production of anadromous fish will include partnerships, local involvement, public support, adaptive management, and flexibility.

- Partnerships

A single entity cannot double natural production of anadromous fish throughout the Central Valley. Partnerships are needed. Voluntary collaborations to achieve mutual goals and objectives will accelerate accomplishments, increase available resources, reduce duplication of efforts, encourage innovative solutions, improve communication, and increase public involvement and support through shared authority and ownership of restoration actions. The AFRP will seek partners to facilitate restoration.

- Local involvement

The AFRP will encourage local citizens and groups to share or take the lead in implementing restoration actions. Influences on anadromous fish production in specific watersheds are often related to local water management and land use, which are typically controlled by local individuals and groups. Local people may have innovative approaches to solving problems, and may be able to implement those solutions most efficiently. This approach is consistent with ACalifornia=s Coordinated Regional Strategy to Conserve Biological Diversity@ (MOU 1991), in which 26 state and federal agencies emphasize regional solutions to regional problems.

The AFRP will encourage local involvement by joining with existing local restoration groups and supporting the formation of new groups.

- Public support

Public support is both a product and a prerequisite of partnerships and local involvement. Public sentiment is an indicator of perceived economic and social effects of restoration actions. Public support for an action will facilitate implementation and attract partners for future actions. The AFRP will seek opportunities for the public to assist in planning and implementing restoration actions.

- Adaptive management

The AFRP will employ adaptive management to increase the effectiveness of restoration actions and to address scientific uncertainty. Adaptive management is an approach that allows resource managers to learn from past experiences through formal experiment or by altering actions based on their measured effectiveness. Monitoring programs are the foundation of the adaptive management approach.

- Flexibility

Implementation of restoration actions needs to be flexible so that unforeseen opportunities can be pursued if they meet the intent of the CVPIA. Also, flexibility will help the AFRP address unforeseen factors that arise or problems that intensify in the future. For example, although there is just one evaluation in this plan that addresses the effects of nuisance, non-native aquatic organisms such as the zebra mussel, this may become a problem that will potentially intensify in unforeseen ways in the future. The AFRP has the flexibility to work with partners to develop actions consistent with the intent of the CVPIA to address specific problems as they arise or intensify. This flexibility will facilitate efforts to maximize the effects of restoration efforts and to sustain benefits to fish production that accrue from these restoration efforts and other management activities.

DEVELOPING RESTORATION PLAN ACTIONS

The AFRP is being developed in three steps: (1) attain the best available scientific and commercial data; (2) develop a long-term Restoration Plan that identifies the general approaches and actions to attain the goal; and (3) develop short-term (three-to-five years) implementation plans tiered off the Restoration Plan. One important implementation plan will be the Water Management Plan that will outline how Interior will manage CVP water resources to implement the AFRP. These implementation plans can be modified at any time in response to new information acquired through monitoring or new research; Interior presently anticipates revisions at least every three-to-five years. The long-term Restoration Plan will be reviewed and updated every five years as required by Section 3406(b)(1)(A) of the CVPIA.

IDENTIFYING THE SCIENTIFIC KNOWLEDGE BASE - THE WORKING PAPER

The first step in developing the AFRP was accomplished through development and dissemination of the "Working Paper on Restoration Needs--Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California (May 9, 1995)" (the Working Paper, USFWS 1995). The Working Paper was developed under the direction of a scientific Core Group composed of representatives of the USFWS, USBR, NMFS, U.S. Environmental Protection Agency (USEPA), CDFG, and California Department of Water Resources (CDWR). The Working Paper focused on identifying the best available science, without regard to whether CVPIA tools might reasonably be brought to bear on the identified scientific issues.

The scientific basis for the AFRP is founded in numerous pre-AFRP research, planning, management, and restoration activities, and the resulting body of information that was produced documenting these activities. In carrying out the development of the AFRP, Interior used information available from a variety of sources. These include published literature on the species, CDFG reports such as ARestoring Central Valley Streams: A Plan For Action@ (Reynolds et al. 1993) and subsequent AStatus of Implementation@ (Mills 1995), the San Joaquin River Management Program=s document title ASan Joaquin River Management Plan@ (SJRMP), Category III of the Bay-Delta Agreement=s list of actions, as well as input from stakeholders and the scientific community in general. The Core Group also sought input from individuals with expertise in the fisheries of the Delta and Central Valley to develop actions deemed necessary to at least double natural production of anadromous fish. The Working Paper listed potential factors or stressors that may limit natural production of anadromous fish and restoration actions that, if implemented, would address these factors and likely result in at least doubling natural production of anadromous fish. Reasonableness was not considered in developing the restoration actions because reasonableness would be addressed in development of this Restoration Plan.

The Working Paper actions included both non-flow actions (such as gravel restoration or use of fish screens) and flow actions. The Working Paper also included estimates of target levels of long-term, average production for four races of chinook salmon, steelhead, striped bass, American shad, and white and green sturgeon. Production was defined in Appendix A of the Restoration Plan as the number of fish recruited to the adult population, including those harvested. Estimates of target production levels are summarized in Table 1.

The Working Paper was intended to establish a list of restoration actions that, if implemented in its entirety, would likely result in at least doubling the natural production of anadromous fish. The Working Paper relied on the scientific research that was available, with acknowledgment that scientific uncertainty was a reality in many areas. As noted above, the Working Paper did not attempt any consideration of whether the actions were reasonable as required under the CVPIA. Doubling production by implementing a reasonable set of actions (that is, a subset of the Working Paper actions) is less certain than if all the actions were implemented, but it still may be possible to double production of some species and streams. For example, doubling production of fall-run chinook salmon in a small tributary of the upper Sacramento River may be relatively easy, whereas doubling production of striped bass will likely be difficult because of the potential quantity of water that could be required to provide adequate conditions for doubling.

Table 1. Target production levels for anadromous fish in Central Valley rivers and streams.

Species	Target
Chinook salmon, all races[a]	990,000
Fall run	750,000
Late-fall run	68,000
Winter run	110,000
Spring run	68,000
Steelhead[b]	13,000
Striped bass[c]	2,500,000
American shad[d]	4,300
White sturgeon	11,000
Green sturgeon	2,000

[a] Appendix B lists production targets for each race of chinook salmon for each of the streams in the Central Valley. Because of rounding errors, targets for individual races of chinook salmon do not add up to the target for all races.
[b] Production target for steelhead spawning upstream of Red Bluff Diversion Dam. Additional steelhead spawned naturally elsewhere in the Central Valley during 1967 through 1991, but no data exist from which to calculate a target production level. Absence of a production target for a species in a specific area (for example, steelhead downstream of Red Bluff Diversion Dam) does not mean that actions to benefit that species in that area will not be considered, and in fact this Restoration Plan includes several actions for species in reaches that do not have associated production targets.
[c] Production target for striped bass is expressed as the abundance of legal-sized striped bass estimated annually by the CDFG. Estimates of legal-sized fish are used as a surrogate for adult fish because these are the best available data for developing a production target. However, the estimate includes some legal-sized fish that are not sexually mature and does not include some sub-legal-sized fish that are sexually mature.
[d] Production target for American shad is expressed as the juvenile index as derived from the CDFG fall midwater trawl in the Delt a.

DEVELOPING THE DRAFT RESTORATION PLAN

The second step in developing an AFRP was the development and release of a draft Restoration Plan on December 6, 1995. The draft Restoration Plan served several functions. First, the draft Restoration Plan reflected the public comments that had been received after release of the Working Paper. In order to inform the public about the Working Paper and solicit comments, Interior held public workshops in five cities throughout northern California in June 1995. In addition, between May and November 1995, AFRP staff participated in over 30 technical workshops to discuss the Working Paper and potential provisions of the Restoration Plan. Information that was developed as a result of this outreach effort was included in the draft Restoration Plan.

The second major function of the draft Restoration Plan was to present specific target flows to be implemented in the Delta and on the CVP-controlled Central Valley streams (Sacramento River, Clear Creek, American River, and Stanislaus River). The draft Restoration Plan also included non-flow actions for all Central Valley streams (CVP-controlled and non-CVP-controlled streams).

Finally, in developing the draft Restoration Plan, Interior began its analysis of the reasonableness of AFRP actions and evaluations at the programmatic level. To assess the reasonableness of proposed AFRP actions and evaluations, Interior conducted two parallel processes. In the first process, Interior reviewed a multi-step process to evaluate each proposed action. This review, which identified reasonable actions, and which will also be used to consider proposed actions in the future, sequentially considered six steps (Figure 1) to address the following three broad categories of questions:

The first category of questions concerned the intent and technical and legal basis of an action. Specific questions Interior addressed were whether the action would benefit natural production consistent with the provisions of the CVPIA; whether key technical and scientific issues were resolved; and whether the action complied with applicable laws and regulations (steps one and two, Figure 1). If any question was not affirmed, the action was either referred to other programs, modified for reconsideration, or eliminated. Otherwise, actions were subjected to the second category of questions.

The second category of questions considered authority to implement the action. If the CVPIA specifically authorizes or directs Interior to implement the action and it does not require a partner (step three, Figure 1), it was considered reasonable for inclusion in the Restoration Plan. For example, Section 3406(b) includes a number of specific actions or programs to be implemented by the Secretary. The actions and programs determined consistent with the goal and objectives of the AFRP were considered reasonable. This same conclusion applies to certain explicit measures in the CVPIA that are also Atools@ for attaining the goal of the AFRP. That is, Interior believes that it is reasonable, at a programmatic level, to conclude that using the tools in subsections 3406 (b)(1)(B), (b)(2) and (b)(3) -- reoperation of the CVP, use of the 800,000 acre-feet of dedicated water for fish and wildlife restoration, and acquisition of additional water from willing sellers -- is reasonable for purposes of this programmatic level analysis.

If the action requires a partner with the authority to implement it, and the partners support implementation, then the action was considered reasonable (step four, Figure 1). Otherwise the action was subjected to the third category of questions.

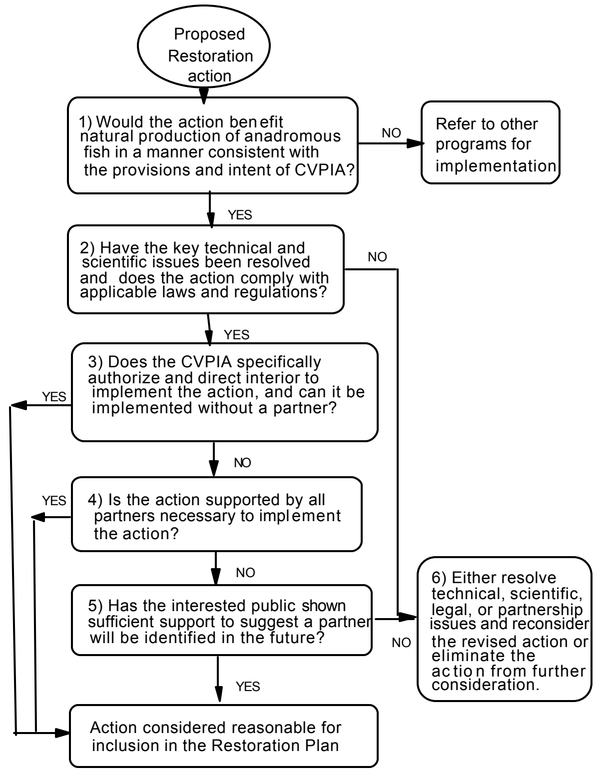

Figure 1. Process used to identify reasonable restoration actions for inclusion in the Restoration Plan (see explanation in text).

The third category of questions concerned support from the interested public for actions that would require partnerships to implement but the partnerships were not yet established. For example, some of the proposed actions require a cost-share partner as either stipulated in the CVPIA or due to the nature of the action. In these cases, Interior evaluated whether the interested public has expressed sufficient support for a particular action that it may be reasonable to assume that a cost-share partner will eventually come forward (step five, Figure 1). If partners were likely to come forward, an action was considered reasonable. Otherwise, an action was either modified for reconsideration or eliminated. Forming partnerships will be a dynamic and ongoing process continuing through the implementation phase of the AFRP, as described below.

A second reasonableness evaluation process was also being conducted during the development of the draft Restoration Plan. As noted above, the draft Restoration Plan included specific flows targets to be implemented in the Delta and on the four major CVP-controlled Central Valley streams. These flows will be addressed in the PEIS. To evaluate the reasonableness of these flows, the AFRP staff consulted with the staff developing the PEIS in an iterative process. The process resulted in modeling a range of flows, which was based on a series of assumptions considering the relative availability of water and the expected benefits to fish of flows on CVP-controlled streams and the Delta. Although the flows modeled by the PEIS may not exactly match the targets in this Restoration Plan, a range of flow regimes encompassing the targets are analyzed that more realistically portrays possible water use and acquisition scenarios than was given in the Working Paper. Differences are due primarily to the fact that the PEIS, as a NEPA document, has to take the final evaluative step of estimating how implementation of the AFRP would occur in the future.

In addition, the Restoration Plan does not contain flow targets for non-CVP-controlled streams, but the PEIS modeled stream flows that would likely result from a reasonable level of water acquisition. To model stream flows, the PEIS made a series of assumptions about water availability and funding availability.[2] There is no need for this programmatic Restoration Plan to make similar projections, because the availability of water or funding for particular actions is something that will become known with certainty as the AFRP is implemented over the years.

DEVELOPING THE REVISED DRAFT RESTORATION PLAN

After release of the draft Restoration Plan in December 1995, Interior engaged in a substantial public outreach effort to describe the draft and solicit public comments. This effort began with general public workshops in four cities in northern California in early 1996, and has continued throughout 1996 and early 1997 as AFRP staff has attended over 50 technical workshops and meetings to discuss various aspects of the draft Restoration Plan.

The Revised Draft Restoration Plan includes summarized oral comments and copies of the written comments received from the public (Appendix I), along with a comprehensive response-to-comments document prepared by the AFRP staff (Appendix H). The release of the draft Restoration Plan generated substantial response from potential partners on those actions that will require a partner for

[2]For purposes of the PEIS to estimate how implementation of the AFRP would occur in the future and to model flows primarily on non-CVP-controlled streams, Interior will rely on four fundamental criteria to forecast the implementation of the water acquisition program consistent with the Restoration Plan. These include: (1) biological priorities (AFRP staff provided the PEIS staff with these priorities and the resulting guidelines for allocation of acquired water in a document titled ADraft guidelines for allocation of water acquired pursuant to Section 3406(b)(3) of the Central Valley Project Improvement Act,@ dated October 22, 1996); (2) water availability; (3) cost of water; and (4) fund availability.

implementation. Again, as was done with the draft, information about the availability or absence of a necessary partner is reflected in this Revised Draft Restoration Plan, even though this action-specific information more appropriately belongs in the detailed implementation plans described below. The AFRP staff have concluded that including this additional information about specific proposed actions presents a more complete portrayal of the current status of the AFRP, even though it risks confusing the programmatic-level analyses with action-specific detail.

DEVELOPING SPECIFIC IMPLEMENTATION PLANS

The third step in developing an AFRP will take place in the near future as Interior develops specific implementation plans. One of these will be the Implementation Plan, wherein Interior will identify specific actions from the Restoration Plan that are deemed the highest priority and the most readily implementable in the three-to-five year period. Interior will work closely with stakeholders, the interested public, and the CALFED Restoration Coordination Program of the CALFED Bay-Delta Program to identify the short-term priorities for the Implementation Plan.

Information contained in the Implementation Plan will primarily be organized into two categories, general and action-specific. The general information will include a more detailed description of the overall AFRP than this Restoration Plan; including processes such as public involvement and partnerships, proposal submission, environmental compliance, implementation, coordination and integration with other restoration programs, and coordination and integration among restoration actions.

Action-specific information will include current data concerning individual actions that are underway or have high potential for implementation in the near future. The information for each action will be organized in a format similar to the template in Appendix D of this Restoration Plan, and will include the action=s location, relevance to the AFRP, description, objectives, background, monitoring, costs, schedule, and involved parties. The Implementation Plan will also describe evaluations and monitoring activities supported by the AFRP.

In developing the Implementation Plan, USFWS and USBR are interested in receiving substantial input from interested parties and potential partners. To encourage input, the Implementation Plan will be developed in an open forum. Initial drafts of the various components of the Implementation Plan will be available on the AFRP Internet homepage (http:\\www.delta.dfg.ca.gov\usfws\afrp\afrp.html), and will be available in hard copy on request. Comments on any component are invited. In addition, USFWS and USBR will continue to consider action proposals they receive and to solicit action proposals to address specific problems. Proposals should be submitted to the Program Manager of the USFWS=s Central Valley Fish and Wildlife Restoration Program (CVFWRP) at the address listed in Appendix C, using a format similar to that described in Appendix D.

Interior anticipates that a first draft of the Implementation Plan will be released in 1997, but it will continue to be a living document. Because both general and action-specific details are in various stages of development and likely to evolve as information is gathered, partnerships are formed, and actions are implemented, the Implementation Plan must be responsive to change. The Implementation Plan will continue to be maintained on the Internet to allow interested parties and partners the opportunity to receive and comment on the most current information available concerning the AFRP and its implementation. Hard copies of the entire Implementation Plan will be made periodically to provide a record of its status, and it will be distributed to individuals upon request. Following development of the first Implementation Plan, the scope of the Implementation Plan will expand to include a three-to-five year period from the present.

One component of Restoration Plan implementation will be discussed in a separate implementation plan, the Water Management Plan. This Water Management Plan will guide Interior=s management of water for environmental purposes, including use of the water dedicated or acquired for environmental purposes under Sections 3406(b)(2) and (b)(3) of the CVPIA. The Water Management Plan will use a longer planning horizon (three-to-five years at a minimum), so as to enable water project operators to efficiently plan project operations to maximize environmental benefits while minimizing water supply impacts. Interior also intends that the Water Management Plan will contain a detailed description of the process for accounting for the dedication of (b)(2) water, and will include the basis for any potential Secretarial findings that (b))(2) water may not be necessary in certain circumstances under Section 3406(b)(2)(D) of the CVPIA.

Interior will make its final conclusions about the reasonableness of particular AFRP actions in these implementation plans. There are several possible reasons why an action that is reasonable at the programmatic level may become unreasonable at the specific action implementation level. First, in the process of developing specific implementation plans for actions and implementing the action, additional information will be collected on the action, including information developed during feasibility analyses and the environmental documentation process. This new information may show actions that were considered to be reasonable at the programmatic level to be unreasonable to implement. Second, the cost-sharing partner identified in the CVPIA for many of the actions or categories of actions may not be able or willing to participate on a particular project. Third, many actions in the Restoration Plan will be implementable only with the assistance and cooperation of state, local, or private party partners (for example, granting or selling easements or screening diversions). For actions that require the assistance or cooperation of partners, the Restoration Plan actions will be reasonable only to the extent that Interior can identify willing partners for cooperative projects. Finally, Interior recognizes that an authorized program that is reasonable at the programmatic level may become unreasonable if the particular implementation is carried out in an arbitrary manner as these plans prioritize the particular implementation scenarios.

IMPLEMENTATION PROCESS

This section of the Restoration Plan provides a general description of the implementation process, including prioritizing and implementing actions, monitoring and evaluating the effects of actions, dealing with varying degrees of scientific certainty, and public involvement. The implementation process is based on the implementation principles and approaches described in the strategies section of this Restoration Plan.

CRITERIA TO PRIORITIZE REASONABLE ACTIONS

Because resources are not sufficient to implement all reasonable actions simultaneously, an attempt will be made to implement high-priority items first. Priorities will be used to focus initial efforts. Monitoring will provide information to help in reevaluating priority for remaining actions. However, the implementation schedule should be flexible so the AFRP can take advantage of unique opportunities, even if it results in implementing actions that are not the highest priority.

Prioritization criteria primarily include biological considerations, which are derived from the implementation principles described in the strategies section of this Restoration Plan. In the following sections, watersheds are prioritized, followed by a list of criteria to prioritize types of actions within each watershed.

Watershed priority

Watersheds, or parts of watersheds, are prioritized based on a combination of biological and non-biological factors. Biological factors include the capacity to increase natural production within each watershed and the presence of species and races of anadromous fish with special status. Information used to prioritize watersheds are summarized in Appendix E.

Watersheds with a high capacity to increase fish production, relative to production during the baseline period, are assigned priority over those watersheds with a lower capacity to increase production. Thus, higher priority is generally placed on watersheds with severely degraded habitat than those with less severely degraded habitat.

Watersheds that support, or have the potential to support species or races of special status are assigned priority over those watersheds that do not.

A non-biological consideration is the ability of the Secretary to facilitate restoration. Because the CVPIA directs the AFRP to address effects of the CVP on anadromous fish and habitat, and provides more tools to the USFWS and USBR to implement restoration actions for such streams and facilities

than elsewhere, streams with CVP facilities or flows controlled primarily by the CVP are considered high priority.
The watershed of highest priority for restoration is assigned to the Sacramento-San Joaquin Delta because it is highly degraded, many anadromous fish rear in the Delta, and all anadromous fish in the Central Valley must pass through it as both juveniles and adults.

The following watersheds are assigned equal priority but rank below the Delta:

- The Sacramento River because it provides habitat for endangered winter-run chinook salmon, is the primary area for production of most species and races, and is strongly influenced by operation of the CVP.
- Tributaries of the upper Sacramento River that have high potential for sustaining natural production of spring-run chinook salmon and steelhead, and for promoting genetic diversity. These streams include Clear, Battle, Antelope, Mill, Deer, Big Chico, and Butte creeks.
- The American River because it is strongly influenced by operation of the CVP.
- The mainstem San Joaquin River and its tributaries below Mendota Pool, because fall-run chinook salmon there may be distinct from fall run in the Sacramento River, production of San Joaquin fall-run chinook salmon often falls to very low levels, and the tributaries are highly degraded.

Action priority

Within each watershed actions are prioritized. The criteria to prioritize actions address factors that limit natural production of anadromous fish. Limiting factors have been identified in the Working Paper (USFWS 1995) and through substantial comments and data supplied by various groups. In addition, these priorities comply with Section 3406(b)(1)(A) of the CVPIA and recognize the authorities of Interior.

In general, actions scored as a high priority if they promote natural channel and riparian habitat values and natural processes, such as those affecting stream flow, water temperature, water quality, and riparian areas. Actions are assigned a medium priority if they affect emigration or access to streams, such as sites of entrainment into diversions and migration barriers. Actions score a low priority if they do not directly affect habitat, such as hatchery practices and harvest regulations. Hatchery production should only be used as a last resort to supplement or to re-establish natural production, and then only after investigations on the desirability of developing and implementing additional hatchery production. In a few cases, actions that are likely to provide benefits disproportionate to the priority they would be assigned based on these criteria are assigned the appropriate priority. Where this occurs, the rationale for the assigned priority is given in a footnote. For example, in some watersheds, factors associated with fish access to habitat, rather than habitat quality, may be identified as the primary limiting factor. In these cases, actions to improve fish passage may be elevated to high priority, and so noted in a footnote to the action in the Actions and Evaluations section of this Restoration Plan.

IMPLEMENTING RESTORATION PLAN ACTIONS

The Secretary has several tools available to implement actions. These tools include the tools in the CVPIA and cooperating with others. Because these tools are in various stages of development and are likely to evolve as they are used and partnerships are formed, this section of the Restoration Plan describes these tools in general terms. We expect to provide detail as it becomes available on these tools in implementation plans.

Tools in the CVPIA

Tools available to the Secretary for achieving the goal of the AFRP include implementing all sections of the CVPIA. Sections 3406(b)(1)(B) through (21) of the CVPIA authorize and direct the Secretary, in consultation with other state and federal agencies, Indian tribes, and affected interests, to take specific actions. These actions are briefly described below. Details are provided in the CVPIA.

3406(b)(1)(B) - Modify CVP operations based on recommendations of USFWS after consultation with CDFG.

3406(b)(2) - Manage 800,000 acre-feet of CVP yield for fish, wildlife, and habitat restoration purposes after consultation with USBR and CDWR and in cooperation with CDFG.

3406(b)(3) - Acquire water to supplement the quantity of water dedicated for fish and wildlife water needs under (b)(2), including modifications of CVP operations; water banking; conservation; transfers; conjunctive use; and temporary and permanent land fallowing, including purchase, lease, and option of water, water rights, and associated agricultural land.

3406(b)(4) - Mitigate for Tracy Pumping Plant operations.

3406(b)(5) - Mitigate for Contra Costa Canal Pumping Plant operations.

3406(b)(6) - Install temperature control device at Shasta Dam.

3406(b)(7) - Meet flow standards that apply to CVP.

3406(b)(8) - Use pulse flows to increase migratory fish survival.

3406(b)(9) - Eliminate fish losses due to flow fluctuations of the CVP.

3406(b)(10) - Minimize fish passage problems at Red Bluff Diversion Dam.

3406(b)(11) - Implement Coleman National Fish Hatchery Development Plan and modify Keswick Dam Fish Trap.

3406(b)(12) - Provide increased flows and improve fish passage and restore habitat in Clear Creek.

3406(b)(13) - Replenish spawning gravel and restore riparian habitat below Shasta, Folsom, and New Melones reservoirs.

3406(b)(14) - Install new control structures at the Delta Cross Channel and Georgiana Slough.

3406(b)(15) - Construct, in cooperation with the State and in consultation with local interests, a seasonally operated barrier at head of Old River.

3406(b)(16) - In cooperation with independent entities and the State, monitor fish and wildlife resources in the Central Valley.

3406(b)(17) - Resolve fish passage and stranding problems at Anderson-Cottonwood Irrigation District Diversion Dam.

3406(b)(18) - If requested by the State, assist efforts to restore the striped bass fishery in the Bay-Delta estuary.

3406(b)(19) - Reevaluate carryover storage criteria for reservoirs on the Sacramento and Trinity rivers.

3406(b)(20) - Participate with the State and other federal agencies in the implementation of the on-going program to mitigate for the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant.

3406(b)(21) - Assist the State in efforts to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions.

In addition to these actions, Section 3406(e)(1 through 6) directs the Secretary to investigate and provide recommendations on the feasibility, cost, and desirability of implementing the actions listed below.

3406(e)(1) - Measures to maintain suitable temperatures for anadromous fish survival by controlling or relocating the discharge of irrigation return flows and sewage effluent, and by restoring riparian forests.

3406(e)(2) - Opportunities for additional hatchery production to mitigate the impacts of water development and operations on, or enhance efforts to increase Central Valley fisheries; Provided, That additional hatchery production shall only be used to supplement or to re-establish natural production while avoiding adverse effects on remaining wild stocks.

3406(e)(3) - Measures to eliminate barriers to upstream and downstream migration of salmonids.

3406(e)(4) - Installation and operation of temperature control devices at Trinity Dam and Reservoir.

3406(e)(5) - Measures to assist in the successful migration of anadromous fish at the Delta Cross Channel and Georgiana Slough.

3406(e)(6) - Other measures to protect, restore, and enhance natural production of salmon and steelhead in tributary streams of the Sacramento and San Joaquin rivers.

Finally, Section 3406(g) of the CVPIA directs the Secretary, in cooperation with the state of California, to develop models and data to evaluate the ecologic and hydrologic effects of existing and alternate operations of public and private water facilities and systems to improve scientific understanding and enable the Secretary to fulfill requirements of the CVPIA.

The CVPIA establishes the ACentral Valley Project Restoration Fund@ and gives the Secretary the authority to use the fund Ato carry out the habitat restoration, improvement and acquisition (from willing sellers) provisions@ of the CVPIA (Section 3407), including the actions listed above. Focus areas for expenditure of the Restoration Fund are being developed in coordination with interested parties and will be describ ed in a report to Congress in mid-1997 pursuant to sections 3407(a) and (f) of the CVPIA.

Some of the tools provided in the CVPIA involve the supplementation of stream flows on specific stream reaches. To guide the acquisition of water on both CVP and non-CVP streams, USFWS released a document titled ADraft guidelines for allocation of water acquired pursuant to Section 3406(b)(3) of the Central Valley Project Improvement Act,@ dated October 22, 1996. These guidelines are intended for use in developing the long-term Water Management Plan and the implementation plan for the water acquisition program, and were used in developing alternatives for analysis in the PEIS.

The specific instream flows implemented on non-CVP streams will be the result of water acquired from willing sellers as authorized by Section 3406(b)(3) of the CVPIA. Considerable uncertainty characterizes the water acquisition process due to the many complex factors influencing the sale of water. The PEIS analyzed stream flows on non-CVP streams that would likely result from a reasonable level of water acquisition based on the draft guidelines for allocation of acquired water and considering water availability, cost of water and fund availability in its modeling. While stream flows on a long-term basis on non-CVP streams are difficult to predict, water acquisition decisions will be defined in annual implementation plans.

Restoration actions using the tools listed above will be implemented by the USFWS and USBR to contribute to doubling production of anadromous fishes. Each of these tools is being managed separately under the coordination of the Program Manager for the CVFWRP. Actions not directly addressed by tools in the CVPIA will be managed by the AFRP Program Manager (address listed in Appendix C), and their implementation will depend on partnership with local watershed workgroups and other agencies, especially the CDFG. Managers of these tools and the AFRP will use this plan as a guide to help establish priorities and identify actions. Specific actions will be selected according to the overall strategies stated in the Introduction to this Restoration Plan. These managers will ensure that actions conducted pursuant to the CVPIA will be coordinated with and complementary to ongoing restoration actions of other groups in the Central Valley and Bay-Delta, such as CDFG, Category III of the Bay-Delta Agreement, the San Joaquin River Management Program, mitigation agreements, and ad hoc groups such as the Spring-Run Chinook Salmon Workgroup.

Several tools may contribute to goals other than increasing natural production of anadromous fish. For example, 3406(b)(18) and (e)(2) may include artificial production, or other contributions to total production, such as pen rearing of salvaged striped bass, that would not directly contribute to natural production (see the AFRP Position Paper in Appendix A for definition of natural production). In fact, some fishery interests believe that artificial production is needed to supplement reasonable habitat restoration actions to stabilize or increase total production of fall-run chinook salmon in the San Joaquin tributaries and striped bass. While the AFRP can not directly support artificial production and pen rearing, it will coordinate its efforts with these and similar efforts conducted under other subsections of the CVPIA to achieve the greatest benefit for fish and wildlife.

Tools available to the Secretary to implement actions on streams and in the Delta where flows are controlled primarily by CVP structures are greater than the tools available on streams where flows are not controlled by CVP structures. For example, modification of CVP operations (Section 3406(b)(1)(B)) and use of (b)(2) water (the 800,000 acre-feet of CVP yield dedicated for fish and wildlife and habitat restoration by Section 3406(b)(2)) are limited to CVP-controlled streams and the Delta. The CVP-controlled streams include the Sacramento, American, Stanislaus, and San Joaquin rivers and Clear Creek. (Restoration of anadromous fish habitat on the San Joaquin River is limited to

the section downstream of Mendota Pool.) In addition, the CVP controls exports at the Tracy Pumping Plant, located in the south Delta.
The long-term Water Management Plan and water accounting system are being developed and will focus on modifications to CVP operations, accounting for the management of (b)(2) water, and acquisition of supplemental water (Section 3406(b)(3)) to provide flows of suitable quality, quantity, and timing to meet fish, wildlife, and habitat restoration purposes. This long-term Water Management Plan, as well as appropriate annual water management plans (i.e., annual CVP operational forecasts), will integrate upstream and Delta flows to make efficient use of the water resources available.

During 1993 through 1997, the approach described in the May 28, 1996 memorandum titled AGuidelines for Section 3406(b)(2) Water for Fish and Wildlife Restoration@ (the approach was initially described in a December 1994 letter of agreement between the USFWS and USBR, also known as the Awhite paper@) was used to manage (b)(2) water, wherein the USFWS submitted annual habitat and flow objectives to the USBR for implementation in the Sacramento, American, and Stanislaus rivers, and the Delta. In 1995 through 1997, flow objectives for Clear Creek were also submitted to USBR. These objectives considered the projected hydrologic conditions and were developed annually in coordination with CDFG, CDWR, USBR, and other interested parties.

Cooperation with others

In most streams of the Central Valley, the Secretary does not have direct authority to implement actions to restore anadromous fish production because the CVP does not control facilities or flows. Streams not controlled by the CVP include Battle, Antelope, Mill, Deer, Big Chico, and Butte creeks and Feather, Yuba, Bear, Cosumnes, Mokelumne, Calaveras, Tuolumne and Merced rivers, as well as a portion of the Delta. Private land owners, public and private irrigation districts, utilities, the State Water Project (SWP), municipalities, and industry manage facilities and flows on these streams. To assist in restoration of these streams, the Secretary will need the cooperation of others. Cooperation through partnerships of the USFWS and USBR with other entities that have the authority, interests, or resources to facilitate restoration, provides a tool to implement actions. The USFWS and USBR encourage potential partners to enter into voluntary relationships with the agencies to conduct restoration actions. Potential partners needing CVPIA resources to implement habitat restoration actions consistent with the AFRP should send a request to the Program Manager of the CVFWRP at the address listed in Appendix C.

Mechanisms under which the USFWS and USBR can establish cooperative relationships are discussed in AConservation Partnerships: A Field Guide to Public-Private Partnering for Natural Resource Conservation@ (MIEB 1993). Selection of the appropriate mechanism will depend on the role of the USFWS or USBR in relation to the partners. Figure 2 is a guide for selecting mechanisms, which are briefly explained below:

- Interagency agreements--used when one agency is providing payments, goods or services to another agency. For federal agencies, the Economy Act allows for this if an efficiency gain can be realized.

- Procurement arrangements--used when an agency pays to receive a direct benefit. It is treated as a procurement action.

- Memoranda of understanding--most commonly used to establish partnerships and document specific responsibilities; signatories agree to work toward mutual goals, perform joint work, or share research results, but no obligation of funds may be included.

- Grants--allow the USFWS and USBR to transfer money, property, services or anything of value to an outside group for a project of mutual interest where substantial agency involvement is not anticipated.

- Cooperative agreements --allow the USFWS and USBR to transfer money, property, services or anything of value to an outside group for a project of mutual interest where substantial agency involvement is anticipated.

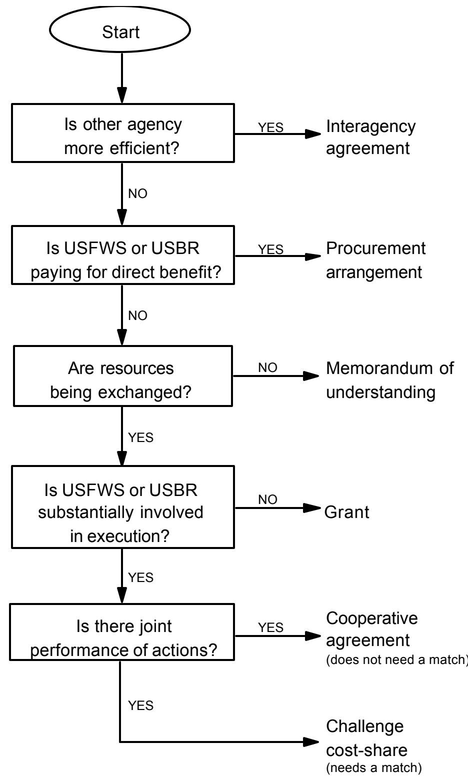

Figure 2. Mechanisms for working together (adapted from MIEB 1993).

- Challenge cost-sharing--allow the USFWS and USBR and other federal agencies to receive funds and requires recipients to match this money with non-federal funds, labor, materials, equipment or land and water, typically of one-to-one.

Through these mechanisms, the USFWS and USBR can make agreements and direct funds, including a portion of the Restoration Fund, or services to partners. The partners could then implement specific restoration actions. The CVPIA (Section 3407(e)) provides the Secretary with the flexibility to use several of the mechanisms for working together to fund non-federal partners by stating:

> AIf the Secretary determines that the State of California or an agency or subdivision thereof, an Indian tribe, or a non-profit entity concerned with restoration, protection, or enhancement of fish,

> wildlife, habitat, or environmental values is able to assist in implementing any action authorized by this title in an efficient, timely, and cost effective manner, the Secretary is authorized to provide funding to such entity on such terms and conditions as he deems necessary to assist in implementing the identified action.@

Funds dispersed through this section are subject to cost-share requirements contained in other sections of the CVPIA. Potential partners and possible mechanisms for working together are:

Local agencies and groups--Watershed workgroups, conservation groups, water districts, non-profit groups, organized school groups, and individual property owners can help implement restoration actions. Agreements can be reached with these groups, or funds and services can be directed to them through memoranda of understanding, grants, cooperative agreements, and challenge cost-sharing. In areas where there is local support but no watershed workgroups, the USFWS and USBR may provide funds and help for forming one. Information on forming and supporting local watershed workgroups is contained in the ACalifornia Coordinated Resource Management and Planning Handbook@ (CCRMP 1990). In addition, the USFWS and USBR are developing a grant program, Project Double, designed to allow small groups to participate in restoration actions.

State agencies--The CDFG, CDWR, Reclamation Board, State Water Resources Control Board (SWRCB), and other state agencies have expertise, abilities, experience, and are willing to assist in implementing many restoration actions. The USFWS and USBR can enter into procurement arrangements, memoranda of understanding, grants, and cooperative agreements with state agencies.

Other federal agencies--The Natural Resources Conservation Service (NRCS), U.S. Forest Service (USFS), Bureau of Land Management (BLM), NMFS, U.S. Geologic Survey (USGS), U.S. Army Corps of Engineers (COE), Western Area Power Administration and other federal agencies likely have specific expertise and abilities, and are willing to help implement specific actions. Through interagency and procurement arrangements, the USFWS and USBR can enter into agreements with other federal agencies to provide funding or services for development, review, and implementation of restoration actions.

MONITORING AND EVALUATION

Monitoring, using standardized and validated methods, is essential to obtain data on anadromous fish production and associated habitats to facilitate an evaluation of the effects of restoration actions. When possible, data collection should begin before specific restoration actions are implemented so that an adequate baseline is established. Data collected after implementation of actions can then be compared to the baseline. These data are essential for evaluating the contribution of actions to doubling natural production.

Most data used to establish the AFRP production targets were derived from sampling programs conducted by the CDFG (Mills and Fisher 1994). These programs consisted primarily of carcass counts, angler surveys, and ocean harvest records of salmonids; adult and juvenile population estimates and angler surveys of striped bass; an index of juvenile abundance of American shad; and adult population estimates of both white sturgeon and green sturgeon. These data represent the most complete data set on anadromous fish in most Central Valley streams and the Bay-Delta. The AFRP recommends that these programs continue and that efforts be made to refine methods and integrate the CDFG monitoring with that needed by the AFRP. This would reduce duplication and effectively allocate funding by both entities for monitoring throughout the Central Valley.

AFRP and CDFG monitoring will also be integrated and coordinated with existing programs such as the Interagency Ecological Program (IEP) and associated real-time monitoring, and others initiated to comply with mitigation requirements for specific projects. An oversight committee or forum is needed to coordinate activities of all those involved and to ensure that efforts are complementary, encourage an open exchange of information, and establish a repository or clearinghouse for data. An additional function of such a group would be to help direct monitoring activities by identifying deficiencies in the current data base. The IEP is an appropriate entity for coordinating monitoring in the Bay-Delta and for managing all data. An IEP project work team or similar forum, which would include experts in various watersheds, should be established to provide oversight for Central Valley streams. A scientific peer review process should be used to aid in evaluating the effects of restoration actions.

A diverse array of data will be required to fully evaluate restoration actions in the Central Valley and the Bay-Delta. The AFRP proposes a hierarchical approach to monitoring, from fine to coarse spatial and temporal scales (for example, action-specific, watershed-specific, and system-wide scales, and short- versus long-term temporal scales). Monitoring at all scales is needed so that restoration can be adaptively modified and refined.

Action-specific

Monitoring the effects of specific restoration actions shall facilitate evaluation at the finest spatial, and possibly temporal resolution. This could be a short-term process, intended to determine the immediate effectiveness of restoration actions. For example, the effectiveness of a fish screen, the revegetation of a restored streambank, and the effects of an operational change on flow and temperature would all be monitored. Results of action-specific evaluations will contribute to an evaluation of the overall success of Section 3406(b) of the CVPIA (described below).

Restoration actions implemented pursuant to Section 3406(b) of the CVPIA will include a plan to assess the effectiveness of each action. Ensuring that each action includes monitoring will be the responsibility of the AFRP, designated agencies, and partners.

Watershed-specific

The purpose of monitoring at the watershed level would be to evaluate the cumulative effects of all restoration actions within a single watershed. Data collected specifically for a watershed may span a short or long period, and should address the overall results of multiple actions. For example, monitoring at the watershed level could answer whether there has been an improvement in the abundance, timing, health and distribution of juvenile anadromous fish, or in selected habitat variables. The effectiveness of restoration actions in specific watersheds will be determined primarily by evaluation of indices of abundance, health and survival of juvenile life-history stages and estimates of adult production. Results of watershed-specific evaluations will also contribute to an evaluation of the overall success.

Systemwide and long-term

The long-term effects of restoration actions need to be assessed throughout the Central Valley and Bay-Delta. For example, the primary biological measure may be production of adult fish, but it could also include measures of abundance at adult or juvenile life stages. Production of adult fish should be monitored in all watersheds.

Systemwide monitoring needs to include hatchery-produced fish, primarily chinook salmon and steelhead. All or a constant fraction of hatchery salmonids released from Central Valley hatcheries should be uniquely marked according to site of origin and site and date of release. This would allow managers to differentiate between wild and hatchery fish spawning in streams, clarify the distribution of hatchery fish in the system, determine their relative contribution to commercial and sport harvest, and evaluate factors affecting fish survival. Specific studies should be designed to determine how hatchery fish interact with naturally produced fish so that the effects of hatchery practices on population genetics and dynamics can be evaluated.

Other components of the Central Valley ecosystem that will be monitored include long-term changes in characteristics of stream channels, riparian areas, and water quality. Additional sampling of fish assemblages could be incorporated into sampling protocols, and the resulting data used to evaluate fish community responses to restoration actions through time.

Section 3406(b)(16) of the CVPIA directs the Secretary to Aestablish in cooperation with independent entities and the State of California, a comprehensive assessment program to monitor fish and wildlife resources in the Central Valley to assess the biological results and effectiveness of actions implemented pursuant to this subsection.@ The Comprehensive Assessment and Monitoring Program (CAMP) was initiated pursuant to Section 3406(b)(16) and will assist in directing future monitoring activities. A draft implementation plan prepared for CAMP uses a watershed-specific approach for evaluating long-term trends in anadromous fish. Therefore, CAMP will not address action- or site-specific monitoring. It will rely on information from other monitoring programs to provide the basis for evaluating the overall success of restoration actions. Because the AFRP restoration targets are based on natural production of adult anadromous fish, CAMP will emphasize this attribute in selected watersheds. However, measures of hatchery production and harvest will be needed to determine success toward doubling natural production of anadromous fish.

DEALING WITH VARYING DEGREES OF SCIENTIFIC CERTAINTY

Biological resource management decisions are always made with varying degrees of scientific certainty. Primary factors contributing to scientific certainty are the variability of biological processes and the physical conditions on which they depend, and our ability to quantify variability. For anadromous fish, their large geographic range and long life-span restrict the ability of resource managers to employ many control and replicate groups in studies, as is common in other fields of science (Hilborn and Ludwig 1993). It is often difficult or impossible to gather enough data to describe key processes, evaluate important variables, and predict results of management actions with absolute certainty. Thus, analyses are subject to different interpretations by interest groups, and professional judgement plays a role in management decisions.

By acknowledging varying degrees of scientific certainty in making decisions, biological resource managers engage in risk assessment. Anyone making a decision must balance the certainty of a predicted effect of a management action with the need to act. An example is the certainty of effects resulting from acting to recover winter-run chinook salmon in the Sacramento River compared to the probable results of not acting, which are continued decline and likely extinction of the race. However, managers must also consider the human dimension as part of the system in making decisions. That is, they must assess the relationship between human activities and the resource, such as potential economic and social effects of implementing management actions versus not implementing management actions.

An approach to address scientific certainty about the effects of restoration actions is to employ adaptive management. The essence of adaptive management is that in the face of uncertainty, management actions should be treated as experiments, intended to yield information as well as to meet other goals. This approach can be separated into three phases:

- First, implement initial actions, based on available data and professional judgement.
- Second, monitor initial actions to evaluate their effectiveness.
- Third, modify actions, if necessary and reasonable, to improve their benefits, stop unnecessary actions, and respond to improved scientific certainty.

Actions in the Restoration Plan correspond to the first phase of adaptive management. To address the second phase, every action will be monitored so its effectiveness can be assessed. An additional benefit of monitoring is increased certainty of an action's effects on anadromous fish and their habitats. Many activities in the Restoration Plan are evaluations of potential problems affecting anadromous fish. Evaluations will provide insight into restoration opportunities by improving scientific certainty. The third phase will be addressed through annual evaluations and continued interaction with interest groups. Where appropriate, scientific peer review will be used in the adaptive management approach.

Evaluations are important for contested issues, especially where questions of scientific certainty surrounding an issue prevents progress toward restoration. The AFRP will encourage interest groups involved in such issues to agree in advance to take specific actions contingent upon the results of evaluations.

It is the position of the USFWS and USBR that the levels of scientific certainty used in developing the Restoration Plan are sufficient to support the recommended actions at the programmatic level. Considering the status of listed and potentially listed species and races of anadromous fish and the substantial declines in others, there is a real urgency for action to reverse these trends. In addition, delays to restore some anadromous fish stocks may ultimately reduce future management options, relegating options to more costly actions.

The USFWS and USBR will continue to use the best available scientific information to make and implement management decisions. In the biological sciences and in managing natural ecosystems, varying degrees of scientific certainty is a reality. Therefore, professional judgement will continue to be employed to make the best possible recommendations, especially when the need for restoration is great.

PUBLIC INVOLVEMENT

Section 3406(b)(1) of the CVPIA presents two great challenges. First, Congress directed the Secretary to determine actions that are reasonable to implement. Second, the Secretary=s authority is limited. This limitation emphasizes the need for voluntary partnerships to restore natural production in the Central Valley. Even for actions that the Secretary is authorized to take, partnerships are important if the actions are to be performed efficiently. Public support and local involvement are integral parts of the AFRP=s strategies and implementation.

The USFWS and USBR are committed to involving the public as much as possible in planning and implementing restoration actions.

Approach

There are two levels of public involvement for the AFRP. The first level is programmatic, and involves planning a comprehensive program. At this level, all areas of the Central Valley are included. To plan and implement a comprehensive program, the AFRP will require ongoing, intensive public involvement. The USFWS and USBR will work with the public to nurture a process which ensures consistent participation of interested parties.

The second level is action-specific and involves implementing specific actions in individual watersheds. At the action-specific level, the AFRP will work with local watershed workgroups, local agencies and interested parties to plan and implement actions. These local watershed workgroups involve local citizens, property owners, and public and private organizations in the planning and implementation of actions within their watershed. In 1996, the AFRP partnered with local watershed workgroups, including the Mill Creek, Deer Creek Watershed, and Butte Creek Watershed conservancies and the Lower Tuolumne River Technical Advisory Committee, and with Category III of the Bay-Delta Agreement to fund eleven actions, including funding to support planning efforts by several of the local watershed workgroups. The AFRP will continue to coordinate with local watershed workgroups, the CALFED Restoration Coordination Program of the CALFED Bay-Delta Program, and other partners to implement actions in the Restoration Plan.

Environmental documentation is an important public process that addresses both programmatic and action-specific restoration efforts. NEPA and California Environmental Quality Act (CEQA) processes require public involvement in the planning and assessment of actions prior to implementation. The PEIS provides a mechanism for programmatic-level public involvement in determining the broad impacts of implementing actions in the Restoration Plan. NEPA and CEQA processes will also be required prior to implementation of many of the individual actions, providing additional opportunity for public involvement at the action-specific level.

Programmatic public involvement activities to date

CVPIA signed by President Bush.	October 1992
Draft Plan of Action for the Central Valley Anadromous Fish Restoration Program released.	August 1993
Coalition of senior fish experts from the USFWS, USBR, NMFS, USEPA, CDFG, and CDWR formed the Core Group to direct the development of the AFRP.	October 1993
Public workshops held in Oakland, Fort Bragg, Sacramento, Fresno, and Red Bluff to introduce the AFRP and to discuss the draft Plan of Action.	October-November 1993
Core Group initiated efforts to develop actions deemed necessary to at least double natural production of anadromous fish.	March 1994
Final Plan of Action for the Central Valley Anadromous Fish	May 1994

Restoration Program rele ased.	
Public workshop held in Sacramento to discuss the final Plan of Action.	May 1994
Draft Position Paper for Development of the Anadromous Fish Restoration Program released.	July 1994
Public workshop held in Sacramento to discuss the draft Position Paper.	July 1994
Central Valley Anadromous Sport Fish Annual Run-size, Harvest, and Population Estimates, 1967 through 1991, Third Draft, released by CDFG.	August 1994
Public workshop held in Stockton to discuss CDFG=s Central Valley Anadromous Sport Fish Annual Run-size, Harvest, and Population Estimates.	October 1994
Working Paper on Restoration Needs released.	May 1995
Public workshops held in Oakland, Redding, Sacramento, Modesto, and Monterey to discuss the Working Paper on Restoration Needs; opportunity extended to public to comment orally or in writing on Working Paper.	June 1995
AFRP staff attended over 30 technical workshops and meetings to discuss the Working Paper and development of the draft Anadromous Fish Restoration Plan.	May-November 1995
Draft Anadromous Fish Restoration Plan released.	December 1995
Public workshops held in Oakland, Sacramento, Modesto, and Chico to discuss the draft Restoration Plan; opportunity extended to public to comment orally or in writing on the Restoration Plan.	January-February 1996
Public workshop held in Sacramento to release the draft guidelines for allocation of water acquired pursuant to Section 3406(b)(3) of the CVPIA.	October 1996

Public workshop held in Sacramento to review the proposed fish flow and habitat objectives and priorities for those Central Valley rivers and the Delta upon which the CVP has direct influence due to their operational facilities.	October 1996
AFRP staff attended over 50 technical workshops and meetings to discuss the draft Restoration Plan, development of the revised draft Restoration Plan, and implementation of actions in the Restoration Plan.	January 1996- February 1997
Revised Draft Restoration Plan for the AFRP released, including Appendix H which provides AFRP responses to comments on the December 1995 draft Restoration Plan.	May 1997

Future public involvement opportunities

- Programmatic

Develop and refine the Implementation Plan.	Beginning summer 1997

- Action-specifi

Implementation of specific actions in the Restoration Plan, including partnership formation, planning, environmental documentation, and permitting.

Ongoing

Public involvement mechanisms

Public participation is critical to successful implementation of the Restoration Plan. The following are public involvement mechanisms established to facilitate public input to the AFRP:

- Draft document review- Allows the public to contribute to document development.
- Final document- Reports progress and offers the public a road map for implementation.
- Press releases- Announce significant events and the opportunity for involvement.
- Letters to interested parties- Provide information.

- Workshops and meetings- Offer an informal, public setting for discussion and learning to occur both for the AFRP and the attending public.

- Educational materials- Provide summary or pertinent information about anadromous fish and the AFRP.

- Records of comments and responses- Summarize comments and AFRP responses.

- Environmental documentation- NEPA and CEQA compliance affords structured public involvement in scoping and review.

- Permitting- If required, regulatory permitting affords the public structured public involvement.

- Grapevine- Toll-free and automated information line that provides information on meeting schedules, document releases, workshop announcements, and other events. To reach this service, dial (800) 742-9474 or (916) 979-2330 and dial extension 542 after the recorded message begins.

- Internet home page- Provides up-to-date information on the AFRP and access to USFWS public release files. The Internet address is:

  http://www.delta.dfg.ca.gov/usfws/afrp/afrp.html

- Implementation Plan- Afford public the opportunity to receive and comment on implementation.

- Mailing lists- Will be maintained and updated as requested.

- Action implementation partnerships- The implementation program for specific actions will seek to effect public involvement in the form of action-oriented partnerships, preferably local watershed workgroups.

ACTIONS AND EVALUATIONS

The actions and evaluations that follow came from several sources, including the AFRP Working Paper, public and private organizations, and individual contributors. They were subjected to the process to determine reasonable actions described earlier in this Restoration Plan. Some actions from the Working Paper were determined to be unreasonable or in need of further evaluation, and are not included here. Some of those actions were replaced, while others were changed to evaluations rather than actions. With some actions, the language and intent were changed, perhaps reducing their potential biological benefit, to make them reasonable but still maintaining their contribution to increasing natural production of anadromous fish. Others were combined.

Actions and evaluations are categorized by stream or geographic area. Streams are categorized by basin, starting with the Sacramento River basin, moving to the lower Sacramento River and Delta tributaries, then to the San Joaquin basin, and finally the Delta. Within each basin, streams are organized geographically, generally starting upstream and moving downstream. For the Delta, which was assigned the highest priority in the watershed priority section, and for those streams that were assigned high priority, the priority is listed flush to the right margin on the same line as the header for the section on that stream or geographic area. Separate lists of actions and evaluations are presented Central Valley-wide and for the ocean. In general, actions identified in this plan are activities that will contributed to increases in natural production of anadromous fish. Evaluations are activities that generate information that may help define or contribute to development of actions for future implementation.

Under each stream or geographic area, actions and evaluations appear in separate tables. The tables consist of four columns. The first column describes the action or evaluation in one or two brief sentences. The second column lists the potential involved parties, including local watershed workgroups, and public and private organizations expected to be involved in implementation. The list of potential involved parties is not meant to limit involvement to the listed parties, rather the intention is to help start the process of partnership formation. The third column lists the CVPIA tools. The last column lists the priority for the action or evaluation in relation to others in the watershed.

Actions and evaluations with an arrow (•) preceding their description in the first column are underway or have high potential for implementation in the near future. These are actions that the USFWS and USBR, partners, or individual sponsors have indicated they are implementing or could begin to implement in the near future. In most cases, considerable design and engineering work, feasibility studies, environmental compliance documentation, or contract administration will be required prior to on-site activity.

It is important to note that the number of actions that can be implemented in the near future will be constrained by the resources available from the USFWS, USBR, and potential partners. This is true for both flow management actions that are greatly influenced by annual rainfall, snow pack, carryover storage, and willing sellers, and other habitat actions that rely on the availability of partners and funding. The Restoration Fund, along with additional agency and other partnership funds, will support implementation of the AFRP restoration actions (See Appendix F for a brief summary of CVPIA resources available in the near future for implementation of restoration actions).

Direct benefits to fish may not be immediately observed even though implementation has begun. In addition, costs to implement, operate and maintain a specific action often are greater than envisioned. Hence, it is likely that the number of actions implemented may be fewer than desired. Greater accomplishments may be possible through cost sharing with partners.

A total of 172 actions and 117 evaluations are identified. Of these, 103 actions and 40 evaluations have high potential for implementation in the near future.

SACRAMENTO RIVER BASIN

Upper mainstem Sacramento River

<table>
<tr><th>Action</th><th>Involved parties</th><th>Tools</th><th>Priority</th></tr>
<tr><td>•1. Implement a river flow regulation plan that balances carryover storage needs with instream flow needs consistent with the 1993 biological opinion for winter-run chinook salmon based on runoff and storage conditions, including the following minimum recommended flows at Keswick and Red Bluff Diversion dams.

Recommended minimum Sacramento River flows (cfs) at Keswick Dam for October 1 to April 30 based on October 1 carryover storage in Shasta Reservoir and critically dry runoff conditions (driest decile runoff of 2.5 maf) to produce a target April 30 Shasta Reservoir storage of 3.0-3.2 maf for temperature control.

<table>
<tr><th>Carryover storage (maf)</th><th>Keswick release (cfs)</th></tr>
<tr><td>1.9 to 2.1</td><td>3,250</td></tr>
<tr><td>2.2</td><td>3,500</td></tr>
<tr><td>2.3</td><td>3,750</td></tr>
<tr><td>2.4</td><td>4,000</td></tr>
<tr><td>2.5</td><td>4,250</td></tr>
<tr><td>2.6</td><td>4,500</td></tr>
<tr><td>2.7</td><td>4,750</td></tr>
<tr><td>2.8</td><td>5,000</td></tr>
<tr><td>2.9</td><td>5,250</td></tr>
<tr><td>3</td><td>5,500</td></tr>
</table>
</td><td>USFWS, USBR, NMFS, CDFG, Tehama-Colusa Canal Authority (TCCA)</td><td>3406(b)(1)(B), 3406(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•2. Implement a schedule for flow changes that avoids, to the extent controllable, dewatering redds and isolating or stranding juvenile anadromous salmonids, consistent with SWRCB Order 90-5.</td><td>USFWS, USBR, CDFG, SWRCB, NMFS</td><td>3406(b)(9)</td><td>High</td></tr>
<tr><td>•3. Continue to maintain water temperatures at or below 56°F from Keswick Dam to Bend Bridge to the extent controllable, consistent with the 1993</td><td>USFWS, USBR, CDFG, SWRCB,</td><td>3406(b)(1)(B)</td><td>High</td></tr>
</table>

Action	Involved parties	Tools	Priority
biological opinion for winter-run chinook salmon and with SWRCB Order 90-5.	NMFS		
•4. Continue to raise the gates of the Red Bluff Diversion Dam (RBDD) for a minimum duration from September 15 through at least May 14 to protect adult and juvenile chinook salmon migrations, consistent with the 1993 biological opinion for winter-run chinook salmon and with SWRCB Order 90-5, and accommodate water delivery using appropriate pumping facilities.	USFWS, USBR, SWRCB, NMFS, CDFG, TCCA	3406(b)(6)	High[3]
•5. Construct an escape channel for trapped adult chinook salmon and steelhead from the Keswick Dam stilling basin to the Sacramento River, as designed by NMFS and USBR.	USFWS, USBR, NMFS, CDFG	3406(b)(11)	Medium
•6. Continue to implement the Anadromous Fish Screen Program.[4]	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	High[5]
•7. Implement structural and operational modifications to the Glenn-Colusa Irrigation District's (GCID) water diversion facility to minimize impingement and entrainment of juvenile salmon.	GCID, USFWS, USBR, CDFG, NMFS, CDWR	3406(b)(20)	High[6]

[3]Although Action 4 addresses fish passage, it was assigned high priority because it significantly increases fish productivity. These findings are based on unpublished data and reports located in the Northern Central Valley Fish and Wildlife Office, USFWS, Red Bluff, California (Rich Johnson, personal communication 1995).

[4] Priorities for screening are being determined by the Anadromous Fish Screen Program.

[5]Although Action 6 addresses fish passage, it was assigned a high priority because it has a high potential to significantly increase fish production.

[6]Although Action 7 addresses solutions to impingement and entrainment of juvenile salmon, it was assigned a high priority because solutions can significantly enhance fish production on the upper mainstem Sacramento River.

Action	Involved parties	Tools	Priority
•8. Remedy water quality problems from toxic discharges associated with Iron Mountain Mine and water quality problems associated with metal sludges in Keswick Reservoir, consistent with the Comprehensive Environmental Response, Compensation, and Liability Act and the Clean Water Act.	USEPA, SWRCB USFWS, USBR, NMFS, CDFG		High
•9. Pursue opportunities, consistent with efforts conducted pursuant to Senate Bill 1086 (SB 1086), to create a meander belt from Keswick Dam to Colusa to recruit gravel and large woody debris, to moderate temperatures and to enhance nutrient input.	Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (USRFRHAC), CDFG, COE, USFWS, USBR, CDWR, NMFS	3406(b)(1)(B), 3406(b)(13)	High
•10. Implement operational modifications to Anderson-Cottonwood Irrigation District's (ACID) diversion dam to eliminate passage and stranding problems for chinook salmon and steelhead adults and early life stages; eliminate toxic discharges from the canal and implement structural modifications to improve the strength of the fish screens.	ACID, USFWS, USBR, CDFG, RWQCB, NMFS	3406(b)(17)	Medium
•11. Develop and implement a program for restoring and replenishing spawning gravel, where appropriate, in the Sacramento River.	CDFG, USFWS, USBR, NMFS, CDWR	3406(b)(13)	High

Evaluation	Involved parties	Tools	Priority
•1. Continue study to refine a river regulation program, consistent with SB 1086, that balances fish habitats with the flow regime and addresses temperatures, flushing flows, attraction flows, emigration, channel and riparian corridor maintenance.	USFWS, USBR, CDFG, SWRCB, NMFS, USRFRHAC	3406(e)(1)	High
•2. Evaluate opportunities to incorporate flows to restore riparian vegetation from Keswick Dam to Verona that are consistent with the overall river regulation plan.	USFWS, USBR, NMFS, CDFG, USRFRHAC	3406(b)(13), 3406(e)(1)	High
•3. Continue the evaluation to identify solutions to passage at RBDD, including measures to improve passage when the RBDD gates are in the raised position from September 15 through at least May 14.	USFWS, USBR, CDFG, TCCA, NMFS	3406(b)(10)	High
4. Evaluate the contribution of large woody debris and boulders in the upper mainstem Sacramento River to salmonid production and rearing habitat quality.	CDFG, USFWS, USBR, CDFG, RWQCB, NMFS	3406(e)(6)	Medium[7]
•5. Identify opportunities for restoring riparian forests in channelized sections of the upper mainstem Sacramento River that are appropriate with flood control and	USRFRHAC, The Nature Conservancy (TNC),	3406(b)(13)	High

[7]Although Action 4 contributes to natural habitat, it was assigned medium priority because of a lack of evidence of benefits to fish production.

Evaluation	Involved parties	Tools	Priority
other water management constraints.	CDFG, COE, USFWS, USBR, CDWR, NMFS		
•6. Identify and attempt to maintain adequate flows for white sturgeon and green sturgeon from February to May for spawning, emigration, egg incubation and rearing, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	USFWS, USBR, NMFS, CDFG	3406(b)(1)(B),3406(b)(2), 3406(b)(3)	High
•7. Identify and attempt to maintain adequate flows from April to June for spawning, incubation, and rearing of American shad, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	USFWS, USBR, NMFS, CDFG	3406(b)(1)(B),3406(b)(2), 3406(b)(3)	High
8. Identify and implement actions that will maintain mean daily water temperatures between 61°F and 65°F for at lease one month between April 1 and June 30 for American shad spawning below RBDD, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	USFWS, USBR, NMFS, CDFG	3406(b)(2), 3406(b)(3)	High
9. Identify the extent of entrainment of	USFWS,		Medium

Evaluation	Involved parties	Tools	Priority
juvenile sturgeon at diversions and pumps and minimize entrainment, if substantial.	USBR, CDFG, NMFS		
•10. Identify green sturgeon spawning sites and evaluate the availability, adequacy and use by adult sturgeon.	USFWS, USBR, CDFG, NMFS		High
11. Determine the effects of poaching and fishing on the number of spawning sturgeon.	USFWS, USBR, CDFG, NMFS		Low

Upper Sacramento River tributaries

- Clear Creek

Action	Involved parties	Tools	Priority
•1. Release 200 cfs October 1 to June 1 from Whiskeytown Dam for spring-, fall- and late fall-run chinook salmon spawning, egg incubation, emigration, gravel restoration, spring flushing and channel maintenance; release 150 cfs, or less, from July through September to maintain ≤60°F temperatures in stream sections utilized by spring-run chinook salmon. Both releases should be within the average total annual unimpaired flows to the Clear Creek watershed.	CDFG, USFWS, USBR, SWRCB	3406(b)(12)	High
•2. Halt further habitat degradation and restore channel conditions from the effects of past gravel mining.	CDFG, USFWS, USBR, BLM,	3406(b)(12)	High

Action	Involved parties	Tools	Priority
	Western Shasta Resource Conservation District (WSRCD), NPS NRCS		
•3. Remove sediment from behind McCormick-Saeltzer Dam and provide fish passage, either by removing the dam or improving fish passage facilities.	McCormick-Saeltzer Dam owners, CDFG, USFWS, USBR, NRCS, WSRCD	3406(b)(12)	High[8]
•4. Develop an erosion control and stream corridor protection program to prevent habitat degradation due to sedimentation and urbanization.	CDFG, USFWS, USBR, NRCS, BLM, WSRCD	3406(b)(12)	High
•5. Replenish gravel and restore gravel recruitment blocked by Whiskeytown Dam.	CDFG, USFWS, USBR, BLM, WSRCD	3406(b)(13)	High
•6. Preserve the productivity of habitat in the Clear Creek watershed through cooperative watershed management and development of a watershed management analysis and plan.	CDFG, USFWS, USBR, BLM,		High

[8]Although Action 3 address fish passage, it was assigned a high priority because implementation of other high priority actions in Clear Creek are dependent on completion of fish passage facilities over McCormick-Saeltzer Dam.

Action	Involved parties	Tools	Priority
	WSRCD		

Evaluation	Involved parties	Tools	Priority
•1. Evaluate the feasibility of reestablishing habitat for spring-run chinook salmon and steelhead; including ensuring that water temperatures five miles downstream of Whiskeytown Dam do not exceed upper temperature limits for each of the life history stages present in the creek from June 1 to November 1, ≤60°F for holding of prespawning adults and for rearing of juveniles, and ≤56°F for egg incubation.	CDFG, USFWS, USBR	3406(b)(1)(B),3406(b)(7), 3406(b)(12)	High

- Cow Creek

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to provide flows for suitable passage and spawning for fall-run chinook salmon adults and adequate summer rearing habitat for juvenile steelhead.	Diverters, CDFG, USFWS, USBR, SWRCB	3406(b)(3)	High
•2. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium

Action	Involved parties	Tools	Priority
•3. Improve passage at agricultural diversion dams.	Diverters, CDFG, USFWS, USBR		Medium
•4. Fence select riparian corridors within the watershed to exclude livestock.	NRCS, Landowners, CDFG, USFWS, USBR		High

- Bear Creek

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to allow suitable passage of juvenile and adult chinook salmon and steelhead during spring and early fall.	Diverters, CDFG, USFWS, USBR	3406(b)(3)	High
•2. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium

- Cottonwood Creek

Action	Involved parties	Tools	Priority
1. Establish limits on instream gravel mining operations by working with state and local agencies to protect spawning gravel and enhance recruitment of spawning gravel to the Sacramento River in the valley sections of Cottonwood Creek.	COE, Shasta and Tehama counties, California Division of Mines, CDFG, USFWS, USBR		High
2. Restore the stream channel to prevent ACID Siphon from becoming a barrier to migration of spring- and fall-run chinook salmon and steelhead.	ACID, Gravel miners, USFWS, USBR		Medium
3. Eliminate adult fall-run chinook stranding by stopping attraction flows in Crowley Gulch or by constructing a barrier at the mouth of Crowley Gulch.	ACID, CDFG, USFWS, USBR		Medium
4. Facilitate watershed protection and restoration to reduce water temperatures and siltation to improve holding, spawning, and rearing habitats for salmonids.	Landowners, CDFG, USFWS, USBR		High
5. Establish, restore, and maintain riparian habitat on Cottonwood Creek.	ACID, Gravel miners, Landowners, USFWS, USBR		High

- Battle Creek

Action	Involved parties	Tools	Priority
•1. Continue to allow adult spring-run chinook salmon and steelhead passage above the Coleman National Fish Hatchery (CNFH) weir. After a disease-safe water supply becomes available to the CNFH, allow passage of fall- and late-fall-run chinook salmon and steelhead above the CNFH weir. In the interim, prevent anadromous fish from entering the main hatchery water supply by blocking fish ladders at Wildcat Canyon, Eagle Canyon, and Coleman diversion dams.	CDFG, USFWS, USBR	3406(b)(11)	High[9]
•2. Acquire water from willing sellers consistent with applicable guidelines or negotiate agreements to increase flows past PG&E's hydropower diversions in two phases to provide adequate holding, spawning and rearing habitat for anadromous salmonids. (See flow table below.)	CDFG, PG&E, USFWS, USBR, NMFS, FERC	3406(b)(3)	High

Diversion	Months	Flow (cfs)[c]
Keswick ditch[b]	All year	30
North Battle Creek feeder [b]	September-November January-April May-August	40 40 30
Eagle Canyon [a]	May-November December-April	30 50
Wildcat [a]	May-November December-April	30 50
South [b]	May-November December-April	20 30
Inskip [b]	May-November December-April	30 40
Coleman [a]	September-April May-August	50 30

[a]First phase flows required to support winter- and spring-run chinook salmon between the Coleman Powerhouse and Eagle Canyon Diversion Dams while a disease-safe water supply is being developed for CNFH.
[b]Second phase flows required to support fall-run chinook salmon and steelhead above the CNFH weir, Coleman Powerhouse and Eagle Canyon Diversion Dams, after a disease-safe water supply is available to CNFH.
[c]Flows are intended as indicators of magnitude and subject to revision based on additional analyses.

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[9]Although Action 1 addresses fish passage, it was assigned high priority because a disease-safe water supply to CNFH substantially enhances production of anadromous salmonids by allowing them unrestricted access to the upper reaches of Battle Creek.

Action	Involved parties	Tools	Priority
•3. Construct barrier racks at the Gover Diversion dam and waste gates from the Gover Canal to prevent adult chinook salmon from entering Gover Diversion.	Gover Diversion Dam owners, CDFG, USFWS, USBR	3406(b)(21)	Medium
•4. Screen Orwick Diversion to prevent entrainment of juvenile salmonids and straying of adult chinook salmon.	Orwick Diversion Dam owners, USFWS, USBR, NMFS, CDFG, CDWR, BLM	3406(b)(21)	Medium
•5. Screen tailrace of Coleman Powerhouse to eliminate attraction of adult chinook salmon and steelhead into an area with little spawning habitat and contamination of the CNFH water supply.	CDFG, PG&E, USBR, USFWS	3406(b)(21)	Medium
•6. Construct fish screens on all PG&E diversions, as appropriate, after both phases of upstream flow actions (see Action 1) are completed and fish ladders on Coleman and Eagle Canyon diversion dams are opened.	PG&E, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
•7. Improve fish passage in Eagle Canyon by modifying a bedrock ledge and boulders that are potential barriers to adult salmonids, and rebuild fish ladders on Wildcat and Eagle Canyon diversion dams.	CDFG, USFWS, USBR		Medium

Action	Involved parties	Tools	Priority
•8. Screen CNFH intakes 2 and 3 to prevent entrainment of juvenile chinook salmon and steelhead.	USFWS, USBR, CDFG, WSRCD	3406(b)(21)	Medium

Evaluation	Involved parties	Tools	Priority
•1. Evaluate the effectiveness of fish ladders at PG&E diversions.	CDFG, PG&E, USFWS, USBR	3406(e)(3)	Medium
•2. Evaluate the feasibility of establishing naturally spawning populations of winter-run and spring-run chinook salmon and steelhead through a comprehensive plan to restore Battle Creek.	CDFG, USFWS, USBR, NMFS	3406(e)(6)	High[10]
•3. Evaluate alternatives for providing a disease-safe water supply to CNFH so that winter-, spring- and fall-run chinook salmon and steelhead would have access to an additional 41 miles of Battle Creek habitat.	USFWS, USBR, CDFG, NMFS	3406(e)(6)	High
•4. Develop a comprehensive restoration plan for Battle Creek that integrates CNFH operations.	WSRCD, CDFG, USFWS, USBR		High

[10] Although action priority criteria do not directly address endangered species, Action 2 was rated high because restoration of winter-run chinook salmon requires high priority restoration actions, flow enhancement and habitat and water quality improvements.

- Paynes Creek

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve spawning, rearing and migration opportunities for fall-run chinook salmon and steelhead.	Diverters, CDFG, BLM, USFWS, USBR, Tehama County RCD	3406(b)(3)	High
2. Restore and enhance spawning gravel.	CDFG, BLM, USFWS, USBR, Tehama County RCD		High

- Antelope Creek

Action	Involved parties	Tools	Priority
•1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to allow passage of juvenile and adult spring-, fall- and late-fall-run chinook salmon and steelhead.	Diverters, CDFG, USFWS, USBR, USFS	3406(b)(3)	High

Evaluation	Involved parties	Tools	Priority
•1. Evaluate the creation of a more defined stream channel to facilitate fish passage by minimizing water infiltration into the streambed and maintaining flows to the Sacramento River.	Landowners, CDFG, USFWS, USBR	3406(e)(3)	Medium

- Elder Creek

Action	Involved parties	Tools	Priority
1. Work with Tehama County to develop an erosion control ordinance to minimize sediment input into Elder Creek.	Tehama County, CDFG, USFWS, USBR, Tehama County RCD, NRCS		High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the feasibility of constructing a fish passage structure over the Corning Canal Siphon.	CDFG, USFWS, USBR, TCCA	3406(e)(3)	Medium

- Mill Creek

Action	Involved parties	Tools	Priority
•1. Continue to provide instream flows in the valley reach of Mill Creek to facilitate the passage of adult and juvenile spring-, fall- and late-fall-run chinook salmon and steelhead.	Mill Creek Conservancy (MCC), Landowners, CDFG, USFWS, USBR, CDWR	3406(b)(3)	High
•2. Preserve the habitat productivity of Mill Creek through cooperative watershed management and development of a watershed strategy.	CDFG, MCC, USFWS, USBR, Vina RCD		High
•3. Improve spawning habitats in lower Mill Creek for fall-run chinook salmon.	CDFG, MCC, USFWS, USBR, USFWS, Vina RCD		High
•4. Establish, restore, and maintain riparian habitat the riparian habitat along the lower reaches of Mill Creek.	County agencies, California State University at Chico, CDFG, USFWS, USBR, MCC, Los Molinos School		High

Action	Involved parties	Tools	Priority
	District, Vina RCD		

Evaluation	Involved parties	Tools	Priority
•1. Develop and implement an interim fish passage solution at Clough Dam until such time that a permanent solution is developed and accepted by landowners.	Diverters, MCC, Los Molinos Municipal Water Company, CDFG, CDWR, USFWS, USBR, Vina RCD	3406(e)(3)	Medium

- Thomes Creek

Action	Involved parties	Tools	Priority
1. Modify gravel mining methods to reduce their effects on salmonid spawning habitats.	Gravel miners, Tehama County Planning Commission, CDFG, CDWR, USFWS, USBR		High

Action	Involved parties	Tools	Priority
2. Employ the most ecologically sound timber extraction practices by implementing the Forest Plan on federal lands within the drainage.	Landowners, USFWS, USBR, USFS, California Department of Forestry and Fire Protection, TCCA		High
3. Modify and employ the most ecologically sound grazing practices by implementing the Forest Plan on federal lands and through partnerships on private and state-owned land within the drainage.	Landowners, USFS, USFWS, USBR, Tehama Colusa RCD		High
4. Reduce use of seasonal diversion dams that may be barriers to migrating chinook salmon and steelhead.	Henleyville and Paskenta diversion dam operators, CDFG, USFWS, USBR		Medium

Evaluation	Involved parties	Tools	Priority
1. Identify and evaluate restoring highly erodible watershed areas.	CDFG, USFWS, USBR	3406(e)(6)	High
2. Monitor water quality throughout the creek and identify	CDFG,		

Evaluation	Involved parties	Tools	Priority
limiting conditions for salmon.	USFWS, USBR		High

- Deer Creek

Action	Involved parties	Tools	Priority
•1. Acquire water from willing sellers consistent with applicable guidelines or negotiate agreements to supplement instream flows in the lower ten miles of Deer Creek to ensure passage of adult and juvenile spring- and fall-run chinook salmon and steelhead over three diversion dams.	Deer Creek Watershed Conservancy (DCWC), CDFG, USFWS, USBR	3406(b)(3)	High
•2. Develop a watershed management plan to preserve the chinook salmon and steelhead habitat in Deer Creek through cooperative watershed management.	DCWC, CDFG, USFWS, USBR		High
•3. Improve spawning habitats in lower Deer Creek for fall- and late-fall-run chinook salmon.	DCWC, CDFG, USFWS, USBR, Vina RCD		High
•4. Negotiate long-term agreements to restore and preserve riparian habitats along Deer Creek.	Landowners, DCWC, CDFG, USFWS, USBR, Vina RCD		High
•5. Plan and coordinate required flood management activities with least damage to the fishery resources and riparian habitats of lower Deer Creek; and establish, restore, and maintain riparian habitat on Deer Creek.	Tehama County Flood Control, DCWC, COE, CDFG, USFWS, USBR		High

- Stony Creek

Evaluation	Involved parties	Tools	Priority
1. Determine the feasibility of restoring anadromous salmonids by evaluating water releases from Black Butte Dam, water exchanges with the Tehama-Colusa Canal, interim and long-term water diversion solutions at Red Bluff Diversion Dam, water quality improvements, spawning gravel protection and restoration, riparian habitat protection and restoration, creek channel creation, and passage improvements at water diversions.	Stony Creek Task Force, TCCA, CDFG, COE, USFWS, USBR	3406(e)(1), 3406(e)(3), 3406(e)(6)	High

- Big Chico Creek

Action	Involved parties	Tools	Priority
•1. Relocate and screen the M&T Ranch diversion.	M&T Ranch owners, Western Canal Water District (WCWD), USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	High[11]

[11]Although Action 1 addresses a diversion, it was assigned a high priority because relocating the diversion and associated water rights from Big Chico Creek to the Sacramento River results in an additional 40 cfs in the upper reaches of Butte Creek, providing a significant benefit to spring-run chinook salmon production.

Action	Involved parties	Tools	Priority
•2. Repair the Iron Canyon fish ladder.	CDFG, USFWS, USBR, Big Chico Creek Task Force (BCCTF)		Medium
•3. Replenish spawning gravel in reaches modified for flood control.	Chico Parks Department, CDFG, USFWS, USBR, BCCTF		High
•4. Repair the Lindo Channel weir and fishway at the Lindo Channel box culvert at the Five-Mile Diversion.	Chico Parks Department, CDFG, CDWR, COE, USFWS, USBR, BCCTF		Medium
•5. Improve cleaning procedures at One-Mile Pool.	City of Chico, CDFG, USFWS, USBR		High
•6. Protect spring-run chinook salmon summer holding pools by obtaining from willing sellers titles or conservation easements on lands adjacent to the pools.	Landowners, CDFG, USFWS, USBR		High
•7. Cooperate with local landowners to encourage revegetation of denuded stream reaches; and establish,	Landowners, Sacramento River		High

Action	Involved parties	Tools	Priority
restore, and maintain riparian habitat on Big Chico Creek.	Preservation Trust, CDFG, California Department of Parks and Recreation, USFWS, USBR		
•8. Preserve the productivity of the habitat on Big Chico Creek through cooperative watershed management and development of a watershed management plan.	USFS, CDFG, USFWS, USBR		High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the water management operations between Big Chico Creek and Lindo Channel.	City of Chico, CDFG, CDWR, USFWS, USBR	3406(e)(6)	Medium
2. Evaluate the replenishment of gravel in the flood-diversion reach of Mud Creek.	Butte County, CDFG, CDWR, USFWS, USBR	3406(e)(6)	High

- Butte Creek

Action	Involved parties	Tools	Priority
•1. Obtain additional instream flows from Parrott-Phelan Diversion.	Diverters, Butte Creek Watershed Conservancy (BCWC), CDFG, USFWS, USBR	3406(b)(3)	High
•2. Maintain a minimum 40 cfs instream flow below Centerville Diversion Dam.	BCWC, CDFG, PG&E, USFWS, USBR	3406(b)(3)	High
•3. Purchase existing water rights from willing sellers.	Diverters, BCWC, CDFG, USFWS, USBR, SWRCB	3406(b)(3)	High
•4. Build a new high water volume fish ladder at Durham Mutual Dam.	Durham Mutual Water Company (DMWC), BCWC, CDFG, TNC, USFWS, USBR		Medium
•5. Install fish screens on both diversions at Durham	Diverters,	3406(b)(21)	Medium

Action	Involved parties	Tools	Priority
Mutual Dam.	DMWC, TNC, USFWS, USBR, NMFS, CDFG, CDWR		
•6. Remove the Western Canal Dam and construct the Western Canal Siphon.	Western Canal Water District (WCWD), BCWC, TNC CDFG, USBR, USFWS	3406(b)(21)	High[12]
•7. Remove McPherrin and McGowan dams and provide an alternate source of water as part of the Western Canal Dam removal and siphon construction.	Diverters, WCWD, BCWC, CDFG, USBR, USFWS	3406(b)(3), 3406(b)(21)	High[13]
•8. As available, acquire water rights as a part of the Western Canal Siphon project.	WCWD, BCWC, CDFG, SWRCB,	3406(b)(3)	High

[12]Although Action 6 addresses fish passage, it was assigned a high priority because the removal of Western Canal Dam and construction of the Western Canal Siphon returns the stream to natural conditions and enhances anadromous salmonid access to spawning habitats.

[13]Although Action 7 addresses fish passage, it was assigned high priority because removal of McPherrin and McGowan dams returns the stream channel to natural conditions and enhances anadromous salmonid access to spawning habitats.

Action	Involved parties	Tools	Priority
	USBR		
9. Adjudicate water rights and provide water master service for the entire creek.	Diverters, BCWC, CDFG, CDWR, SWRCB, USFWS, USBR		High
•10. Build a new high water volume fish ladder at Adams Dam.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
•11. Install fish screens on both diversions at Adams Dam.	Diverters, BCWC, CDFG, CDWR, NMFS, USFWS, USBR	3406(b)(21)	Medium
•12. Build a new high water volume fish ladder at Gorrill Dam.	Diverters, CDFG, USFWS, USBR		Medium
•13. Install a fish screen on the Gorrill Dam diversion.	Diverters, BCWC, CDFG, CDWR, NMFS, USFWS, USBR	3406(b)(21)	Medium
•14. Install a fish screen at White Mallard Dam.			

Action	Involved parties	Tools	Priority
	Diverters, BCWC, CDFG, CDWR, NMFS, USFWS, USBR	3406(b)(21)	Medium
•15. Eliminate chinook salmon stranding at White Mallard Duck Club outfall.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
16. Rebuild and maintain existing culvert and riser at Drumheller Slough outfall.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
•17. Install screened portable pumps in Butte Creek as an alternative to the Little Dry Creek diversion.	Diverters, BCWC, CDFG, CDWR, NMFS, USFWS, USBR	3406(b)(21)	Medium
18. Install a high water volume fish ladder at White Mallard Dam.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
•19. Develop land use plans that create buffer zones between the creek and agricultural, urban, and industrial developments; and restore, maintain, and protect riparian and spring-run chinook salmon summer-holding habitat	City and county government agencies,	3406(e)(6)	High

Action	Involved parties	Tools	Priority
along Butte Creek.	Conservation groups, BCWC, CDFG, USFWS, USBR		
•20. Install fish screens and fish ladder at Parrott-Phelan Diversion Dam.	Diverters, BCWC, CDFG, USFWS, USBR	3406(b)(21)	Medium
•21. Develop a watershed management program.	BCWC, CDFG, USFWS, USBR		High
22. Establish operational criteria for Sanborn Slough Bifurcation.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
23. Establish operational criteria for the East Barrow pit and West Barrow pit.	Diverters, BCWC, CDFG, USFWS, USBR		Medium
24. Establish operational criteria for Nelson Slough.	Diverters, BCWC, CDFG, USFWS, USBR		Medium

Evaluation	Involved parties	Tools	Priority
1. Develop and evaluate operational criteria and potential modifications to Butte Slough outfall.	Diverters, BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
2. Evaluate alternatives or build a new high water volume fish ladder at East-West Diversion Weir.	Diverters, BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
3. Evaluate operational alternatives and establish operational criteria for Sutter Bypass Weir #2.	Diverters, BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
4. Evaluate operational alternatives and establish operational criteria for Sutter Bypass Weir #1.	Diverters, BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
•5. Evaluate alternatives to help fish passage, including the installation of a fish screen, at Sanborn Slough Bifurcation Structure.	Diverters, BCWC, CDFG, CDWR, NMFS, USFWS, USBR	3406(e)(3)	High[14]
6. Evaluate alternatives to help fish passage, including the installation of fish screens, within Sutter Bypass where	Diverters, BCWC,	3406(e)(3)	Medium

[14]Although Evaluation 5 addresses fish passage, it was assigned a high priority because passage and screening solutions at the Sanborn Slough Bifurcation Structure can significantly enhance Butte Creek productivity.

Evaluation	Involved parties	Tools	Priority
necessary.	CDFG, CDWR, NMFS, USFWS, USBR		
7. Evaluate operational alternatives and establish operational criteria for Sutter Bypass Weir #5.	Diverters, BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
8. Evaluate alternatives to help fish passage, including the installation of a high water volume fish ladder, on Sutter Bypass Weir #2.	BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
9. Evaluate alternatives to help fish passage, including the installation of a high water volume fish ladder, on Sutter Bypass Weir #1.	BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
10. Evaluate alternatives to help fish passage, including the installation of a high water volume fish ladder, on Sutter Bypass Weir #5.	BCWC, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	Medium
11. Evaluate alternatives to help fish passage, including the installation of a high water volume fish ladder, on Sutter Bypass Weir #3.	BCWC, CDFG, USFWS,	3406(e)(3), 3406(e)(6)	Medium

Evaluation	Involved parties	Tools	Priority
	USBR		
•12. Evaluate enhancement of fish passage at a natural barrier below the Centerville Diversion Dam.	BCWC, PG&E, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	High[15]
•13. Evaluate fish passage enhancement at PG&E diversion dams and other barriers above Centerville Diversion Dam.	BCWC, Spring-run Chinook Salmon Workgroup, PG&E, CDFG, USFWS, USBR	3406(e)(3), 3406(e)(6)	High[15]
•14. Evaluate the juvenile life history of spring-run chinook salmon.	BCWC, CDFG, USFWS, USBR		Medium
15. Evaluate juvenile and adult chinook salmon stranding in Sutter Bypass and behind Tisdale, Moulton, and Colusa weirs during periods of receding flows on the upper mainstem Sacramento River.	BCWC, CDFG, USFWS, USBR		Medium

[15]Although evaluations 12 and 13 address fish passage, they were assigned high priority because actions resulting from these evaluations could provide access to four miles of deep holding pools and three miles of spawning habitat for spring-run chinook salmon in the vicinity of Centerville and Butte Creek diversion dams (Holtgrieve, D.G. and G.W. Holtgrieve. 1995. Physical stream survey: upper Butte Creek, Butte County, California. The Nature Conservancy and the Spring-run Chinook Salmon Work Group).

- Colusa Basin Drain (westside tributaries)

Action	Involved parties	Tools	Priority
1. Install an adult exclusion device at the Knights Landing outfall for Colusa Basin Drain as an interim action pending completion of Colusa Basin Drain Evaluation 1.	CDFG, USFWS, USBR	3406(e)(1), 3406(e)(6)	Medium

Evaluation	Involved parties	Tools	Priority
1. Investigate the feasibility of restoring the access of anadromous fish to westside tributaries through development of defined migrational routes, sufficient flows, and adequate water temperatures.	CDFG, USFWS, USBR	3406(e)(1), 3406(e)(6)	Medium

- Miscellaneous small tributaries

Evaluation	Involved parties	Tools	Priority
•1. Evaluate the contribution of small Sacramento River tributaries as rearing areas for juvenile winter-, spring-, fall- and late-fall-run chinook salmon and steelhead.	CDFG, USFWS, USBR, Chico State University	3406(e)(6)	High

LOWER SACRAMENTO RIVER AND DELTA TRIBUTARIES

Feather River

Action	Involved parties	Tools	Priority
•1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve conditions for all life history stages of fall- and spring-run chinook salmon and steelhead.	CDWR, CDFG, USFWS, USBR	3406(b)(3)	High
2. Improve flows for American shad migration, spawning, incubation and rearing from April to June, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	Diverters, CDWR, CDFG, USFWS, USBR	3406(b)(3)	High
•3. Develop and utilize a temperature model as a tool for river management.	CDWR		High

Evaluation	Involved parties	Tools	Priority
•1. Evaluate the response of spawning salmonids to increased flows in the low-flow channel.	CDWR, CDFG		High

Evaluation	Involved parties	Tools	Priority
•2. Evaluate the quality of spawning gravel in areas used by chinook salmon, and if indicated, consider gravel renovation or supplementation to enhance substrate quality.	CDWR		High
•3. Evaluate the distribution of Feather River Fish Hatchery chinook salmon in Central Valley stocks and determine the genetic integrity of Feather River spring-run chinook salmon.	CDWR, CDFG		Low
4. Identify and attempt to maintain adequate flows and temperatures for white sturgeon and green sturgeon migration, spawning, incubation and rearing from February to May, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	CDFG, CDWR		High
5. Identify and remove physical and water quality barriers that impede access for white sturgeon and green sturgeon to spawning habitat or facilitate passage around these barriers.	CDFG, CDWR		Medium
6. Identify the extent of white sturgeon and green sturgeon entrainment at diversions and pumps and reduce or eliminate entrainment if found to be substantial.	CDFG, CDWR		Medium
7. Identify white sturgeon and green sturgeon spawning sites and evaluate the availability and use by adult sturgeon of spawning habitat.	CDFG, CDWR		High
8. Determine the effects of poaching and fishing on the number of spawning white sturgeon and green sturgeon.	CDFG		Low
9. Identify and implement actions that maintain mean daily water temperatures between 61° F and 65°F for at least one month from April 1 to June 30 for American shad spawning, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	CDFG, CDWR		High

Yuba River

Action	Involved parties	Tools	Priority
•1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve conditions for all life history stages of chinook salmon and steelhead.	Yuba County Water Agency (YCWA), SWRCB, CDFG, USFWS, USBR	3406(b)(3)	High
2. Improve flows for American shad migration, spawning, incubation and rearing from April to June, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	YCWA, SWRCB, CDFG, USFWS, USBR	3406(b)(3)	High
3. Reduce and control flow fluctuations to avoid and minimize adverse effects to juvenile salmonids.	YCWA, PG&E, SWRCB, CDFG		High
4. Maintain adequate instream flows for temperature control.	YCWA, CDFG, USFWS, USBR	3406(b)(3)	High
•5. Improve efficiency of screening devices at Hallwood-Cordua and Brophy-South Yuba water diversions, and construct screens at the Brown=s Valley water diversion and other unscreened diversions.	Diverters, SWRCB, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
6. Construct or improve the fish bypasses at Hallwood-	Diverters,		Medium

Action	Involved parties	Tools	Priority
Cordua and Brophy-South Yuba water diversion.	SWRCB, USFWS, USBR, NMFS, CDFG, CDWR		
•7. Facilitate passage of spawning adult salmonids by maintaining appropriate flows through the fish ladders, or by modifying the fish ladders at Daguerre Point Dam.	YCWA, CDFG, COE, USFWS, USBR	3406(b)(3)	Medium
8. Purchase streambank conservation easements to improve salmonid habitat and instream cover.	Landowners, YCWA, BLM, USFWS, USBR		High
9. Facilitate passage of juvenile salmonids by modifying the dam face of Daguerre Point Dam.	YCWA, CDFG, COE		Medium
10. Operate reservoirs to provide adequate water temperatures for anadromous fish.	Yuba River Water Temperature Advisory Committee, SWRCB		High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the effectiveness of pulse flows to facilitate successful juvenile salmonid emigration.	YCWA, CDFG, USFWS, USBR	3406(e)(6)	High

Evaluation	Involved parties	Tools	Priority
2. Evaluate whether enhancement of water temperature control via shutter configuration and present management of the cold water pool at New Bullards Bar Dam is effective, and modify the water release outlets at Englebright Dam if enhancement of water temperature control via shutter configuration is effective.	YCWA, CDFG, PG&E, USFWS, USBR	3406(e)(6)	High
3. Identify and attempt to implement actions that will maintain mean daily water temperatures between 61°F and 65°F for at least one month from April 1 to June 30 for American shad, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	YCWA, CDFG, USFWS, USBR	3406(g)	High
•4. Evaluate the benefits of restoring stream channel and riparian habitats of the Yuba River, including the creation of side channels for spawning and rearing habitats for salmonids.	YCWA, PG&E, CDFG, USFWS	3406(e)(6)	High

Bear River

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve conditions for all life history stages of chinook salmon and steelhead.	South Sutter Water District (SSWD), SWRCB, CDFG, USFWS, USBR	3406(b)(3)	High
2. Provide adequate water temperatures for all life-stages of chinook salmon and steelhead.	SSWD, SWRCB,		High

Action	Involved parties CDFG	Tools	Priority
3. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
•4. Negotiate removal or modification of the culvert crossing at Patterson Sand and Gravel and other physical and chemical barriers impeding anadromous fish migration.	Patterson Sand and Gravel, CDFG, USFWS, USBR		Medium

Evaluation	Involved parties	Tools	Priority
1. Determine and evaluate instream flow requirements that ensure adequate flows for all life stages of all salmonids.	SSWD, CDFG, USFWS, USBR		High
2. Evaluate the extent that white sturgeon and green sturgeon use the Bear River for spawning and rearing.	CDFG, USFWS		High
3. Monitor water quality, particularly at agricultural return outfalls, and evaluate potential effects on anadromous fish.	Diverters, CDFG		High
4. Evaluate the extent that poaching or fishing reduces the numbers of adult sturgeon.	CDFG, USFWS		Low

American River

<table>
<tr><th>Action</th><th>Involved parties</th><th>Tools</th><th>Priority</th></tr>
<tr><td>•1. Develop and implement a river regulation plan that meets the following flow objectives by modifying CVP operations, using (b)(2) water, and acquiring water from willing sellers as needed.
<table>
<tr><th rowspan="2">Month</th><th colspan="4">American River minimum flow objectives[a] (cfs)</th></tr>
<tr><th>Wet[b]</th><th>Above and below normal</th><th>Dry and critical</th><th>Critical relaxation</th></tr>
<tr><td>October</td><td>2,500</td><td>2,000</td><td>1,750</td><td>800</td></tr>
<tr><td>November-February</td><td>2,500</td><td>2,000</td><td>1,750</td><td>1,200</td></tr>
<tr><td>March -May</td><td>4,500</td><td>3,000</td><td>2,000</td><td>1,500</td></tr>
<tr><td>June</td><td>4,500</td><td>3,000</td><td>2,000</td><td>500</td></tr>
<tr><td>July</td><td>2,500</td><td>2,500</td><td>1,500</td><td>500</td></tr>
<tr><td>August</td><td>2,500</td><td>2,000</td><td>1,000</td><td>500</td></tr>
<tr><td>September</td><td>2,500</td><td>1,500</td><td>500</td><td>500</td></tr>
</table>
[a] A multi-agency and interested party management team should be formed to review and adjust flows in consideration of carryover storage and hydrologic conditions as needed to provide for the long-term needs of anadromous fish. Flow objectives should be met for the entire reach of the American River downstream of Nimbus Dam.
[b] Year types should be based on an American River index, or on consideration of carryover storage and hydrologic conditions in the American River watershed.</td><td>Sacramento Area Water Forum (SAWF), CDFG, USBR, USFWS</td><td>3406(b)(1)(B), 3406(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•2. Develop a long-term water allocation plan for the American River watershed.</td><td>SAWF, CDFG, Other water users, USFWS, USBR</td><td>3406(b)(1)(B), 3406(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•3. Reduce and control flow fluctuations to avoid and minimize adverse effects on juvenile salmonids.</td><td>USFWS, USBR, CDFG</td><td>3406(b)(9)</td><td>High</td></tr>
<tr><td>•4. Reconfigure Folsom Dam shutters for improved management of Folsom Reservoir's cold water pool and better control over the temperature of water released downstream.</td><td>County of Sacramento, Sacramento Area Flood</td><td>3406(b)(1)(B)</td><td>High</td></tr>
</table>

Action	Involved parties	Tools	Priority
	Control Association (SAFCA), USFWS, USBR, CDFG		
5. Replenish spawning gravel and restore existing spawning grounds.	USFWS, USBR, CDFG	3406(b)(13)	High
6. Improve the fish screen at Fairbairn Water Treatment Plant.	City of Sacramento, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
7. Modify the timing and rate of water diverted from the river annually to reduce entrainment losses of juvenile salmonids.	City of Sacramento, Other water users, CDFG, USFWS, USBR	3406(b)(1)(B)	Medium
8. Develop a riparian corridor management plan to improve and protect riparian habitat and instream cover.	SAFCA, COE, USFWS, USBR, CDFG	3406(b)(13)	High
9. Terminate current programs that remove woody debris from the river channel.	County of Sacramento, City of Sacramento,		High

Action	Involved parties	Tools	Priority
	SAFCA, COE, USFWS, USBR, CDFG		
•10. Increase flows for American shad migration, spawning, incubation and rearing from April to June, by modifying CVP operations, by using dedicated water, and by acquiring water from willing sellers, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	SAWF, USFWS, USBR, CDFG	3406(b)(1)(B), 3406(b)(2), 3406(b)(3)	High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the effectiveness of pulse flows to facilitate successful emigration of juvenile salmonids.	USFWS, USBR, CDFG		High
2. Evaluate and refine a river regulation plan that provides flows to protect all life stages of anadromous fish based on water storage at Folsom Reservoir and predicted hydrologic conditions in the American River watershed.	SAWF, CDFG, USFWS, USBR	3406(g)	High
3. Identify and implement actions that maintain mean daily water temperatures between 61°F and 65°F for at least one month from April 1 to June 30 for American shad spawning, consistent with action to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	CDFG, CDWR		High

Mokelumne River

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve conditions for all life history stages of chinook salmon and steelhead.	East Bay Municipal Utility District (EBMUD), SWRCB, Woodbridge Irrigation District (WID), FERC, CDFG, USFWS	3406(b)(3)	High
•2. Replenish gravel suitable for salmonid spawning habitat.	CDFG, EBMUD		High
•3. Cleanse spawning gravel of fine sediments and prevent sedimentation of spawning gravel.	CDFG, EBMUD		High
4. Reduce and control flow fluctuations to avoid and minimize adverse effects to juvenile salmonids.	CDFG, EBMUD		High
5. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, CDFG, CDWR, USFWS, USBR, NMFS	3406(b)(21)	Medium
6. Maintain suitable water temperatures for all salmonid life stages.	EBMUD, CDFG		High
7. Enhance and maintain the riparian corridor to improve streambank and channel rearing habitat for juvenile salmonids.	Landowners, CDFG		High

Action	Involved parties	Tools	Priority
8. Establish and enforce water quality standards to provide optimal water quality for all life history stages of salmonids.	CDFG		High
9. Eliminate or restrict gravel mining operations in the Mokelumne River flood plain to prevent damage to potential spawning areas and encroachment of vegetation.	Gravel miners, CDFG		High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the effectiveness of pulse flows to facilitate successful emigration of juvenile salmonids in the spring, and determine the efficacy in all water year types.	EBMUD, CDFG, USFWS, USBR	3406(e)(6)	High
2. Evaluate and facilitate passage of spawning adult salmonids in the fall and juvenile salmonids in the spring past Woodbridge Irrigation District Diversion Dam and Lodi Lake.	WID, City of Lodi, EBMUD, CDFG, USFWS	3406(e)(3)	Medium
3. Evaluate the incidence of predation on juvenile salmonids emigrating past Woodbridge Dam, and investigate potential remedial actions if necessary.	WID, EBMUD, CDFG, USFWS, USBR	3406(e)(6)	Medium
4. Evaluate the effects of extending the closure of the fishing season from 31 December to 31 March (and possibly to 1 June) to protect juvenile salmonids and adult steelhead and prevent anglers from wading on redds.	CDFG		Low

Cosumnes River

Action	Involved parties	Tools	Priority
1. Acquire water from willing sellers consistent with applicable guidelines or negotiate agreements to reduce water diversions or augment instream flows during critical periods for salmonids.	Diverters, CDFG, USFWS, USBR	3406(b)(3)	High
2. Pursue opportunities to purchase existing water rights from willing sellers consistent with applicable guidelines to ensure adequate flows for all life stages of salmonids.	CDFG, The Nature Conservancy (TNC), USFWS, USBR	3406(b)(3)	High
•3. Enforce Fish and Game Codes that prohibit construction of unlicensed dams.	CDFG		Medium
4. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, CDFG, CDWR, USFWS, USBR, NMFS, TNC	3406(b)(21)	Medium
5. Establish a riparian corridor protection zone.	TNC, Landowners, CDFG		High
6. Rehabilitate damaged areas and remedy incompatible land practices to reduce sedimentation and instream water temperatures.	TNC, Landowners, CDFG		High

Evaluation	Involved parties	Tools	Priority
1. Determine and evaluate instream flow requirements that	Diverters,	3406(e)(6)	High

Evaluation	Involved parties	Tools	Priority
ensure adequate flows for all life stages of all salmonids.	TNC, CDFG, USFWS, USBR		
2. Evaluate and facilitate passage of adult and juvenile salmonids at existing diversion dams and barriers.	Diverters and dam builders, TNC, CDFG, USBR, USFWS	3406(e)(3)	Medium
3. Evaluate the feasibility of restoring and increasing available spawning and rearing habitat for salmonids.	TNC, CDFG, USBR, USFWS	3406(e)(6)	High

Calaveras River

Action	Involved parties	Tools	Priority
1. Supplement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements to improve conditions for all life history stages of chinook salmon.	Calaveras County Water District, Stockton East Water District (SEWD), CDFG, COE, USFWS, USBR	3406(b)(3)	High
2. Provide flows of suitable water temperatures for all salmonid life stages.	CDFG, USFWS, USBR	3406(b)(3)	High
3. Facilitate passage of adult and juvenile salmonids at existing diversion dams and barriers.	Diverters, CDFG		Medium
4. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, CDFG, CDWR, USFWS, NMFS, USBR	3406(b)(21)	Medium

Evaluation	Involved parties	Tools	Priority
1. Monitor sport fishing and evaluate the need for regulations to protect salmonids.	CDFG		Low

Evaluation	Involved parties	Tools	Priority
2. Evaluate instream flow, water temperature and fish habitat use in the Calaveras River to develop a real-time management program so that reservoir operations can maintain suitable habitat when fish are present.	CDFG, Diverters, USFWS		High

SAN JOAQUIN BASIN

Merced River

Action	Involved parties	Tools	Priority
•1. Supplement flows provided pursuant to the Davis-Grunsky Contract Number D-GGR17 and FERC License Number 2179 with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements as needed to improve conditions for all life history stages of chinook salmon.	Merced Irrigation District (MID), Diverters, CDFG, CDWR, USFWS, USBR	3406(b)(3)	High
2. Reduce adverse effects of rapid flow fluctuations.	MID, CDFG, USFWS, USBR		High
3. Improve watershed management to restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel.	Landowners, Merced County, NRCS, CDFG, USFWS, USBR		High

Action	Involved parties	Tools	Priority
4. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
5. Establish a streamwatch program to increase public participation in river management.	Public, CDFG, USFWS		Low

Evaluation	Involved parties	Tools	Priority
1. Identify and implement actions to provide suitable water temperatures for all life stages of chinook salmon; establish maximum temperature objectives of 56°F from October 15 to February 15 for incubation and 65°F from April 1 to May 31 for juvenile emigration.	Dam operators, CDFG, USFWS, USBR	3406(g)	High
•2. Evaluate and implement actions to reduce predation on juvenile chinook salmon, including actions to isolate Aponded@ sections of the river.	CDFG, USFWS, USBR	3406(e)(6)	Medium
3. Evaluate fall pulse flows for attraction and passage benefits to chinook salmon and steelhead.	Dam operators, CDFG, USFWS, USBR		High

Tuolumne River

Action	Involved parties	Tools	Priority
•1. Implement a flow schedule as specified in the terms of the FERC order resulting from the New Don Pedro Project (FERC Proceeding P-2299-024). Supplement FERC agreement flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements as needed to improve conditions for all life history stages of chinook salmon.	City and County of San Francisco, Turlock Irrigation District (TID), Modesto Irrigation District (MID), Lower Tuolumne River Technical Advisory Committee (LTTAC), FERC, USFWS, USBR	3406(b)(3)	High

Action	Involved parties	Tools	Priority
•2. Improve watershed management and restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel and performing an integrated evaluation of biological and geomorphic processes.	Landowners, NRCS, CDFG, USFWS, USBR, LTTAC		High
3. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, LTTAC, CDFG, CDWR, NMFS, USFWS, USBR	3406(b)(21)	Medium
4. Support the Tuolumne River Interpretive Center.	CDFG, LTTAC		Low
5. Establish a streamwatch program to increase public participation in river management.	Public, LTTAC, CDFG, USFWS		Low
6. Coordinate the AFRP with appropriate activities supported by the Riparian and Recreation Improvement fund that was established by the New Don Pedro Settlement Agreement.	LLTAC, USFWS, USBR		Low

Evaluation	Involved parties	Tools	Priority
1. Identify and implement actions to provide suitable water temperatures for all life stages of chinook salmon; establish maximum temperature objectives of 56°F from October 15 to	Dam operators, CDFG,	3406(g)	High

Evaluation	Involved parties	Tools	Priority
February 15 for incubation and 65°F from April 1 to May 31 for juvenile emigration.	USFWS, USBR, LTTAC		
•2. Evaluate and implement actions to reduce predation on juvenile chinook salmon, including actions to isolate ponded sections of the river.	TID, MID, LTTAC, CDFG, USFWS, USBR	3406(e)(6)	Medium
3. Evaluate the effects of flow fluctuations established by the guidelines of the FERC Settlement Agreement on spawning, incubation, and rearing of chinook salmon, and if substantial adverse effects are indicated, modify guidelines to reduce effects.	Diverters, Hydropower operators, LTTAC, CDFG, USFWS, USBR		High
4. Evaluate fall pulse flows for attraction and passage benefits to chinook salmon and steelhead.	Diverters, Hydropower operators, LTTAC, CDFG, USFWS, USBR		High

Stanislaus River

<table>
<tr><th>Action</th><th>Involved parties</th><th>Tools</th><th>Priority</th></tr>
<tr><td>•1. Implement an interim river regulation plan that meets the following flow schedule by supplementing the 1987 agreement between USBR and CDFG[a], through reoperation of New Melones Dam, use of (b)(2) water, and acquisition of water from willing sellers as needed.
<table>
<tr><th>Month</th><th colspan="5">Stanislaus River flow schedules (cfs) by year type[b]</th></tr>
<tr><th></th><th>Wet</th><th>Above normal</th><th>Below normal</th><th>Dry</th><th>Critical</th></tr>
<tr><td>October</td><td>350</td><td>350</td><td>250</td><td>250</td><td>200</td></tr>
<tr><td>November-March</td><td>400</td><td>350</td><td>300</td><td>275</td><td>250</td></tr>
<tr><td>April</td><td>1,500</td><td>1,500</td><td>300/1500[c]</td><td>300/1500[d]</td><td>300/1500[e]</td></tr>
<tr><td>May</td><td>1,500</td><td>1,500</td><td>1500/300[c]</td><td>1500/300[d]</td><td>1500/300[e]</td></tr>
<tr><td>June</td><td>1,500</td><td>800</td><td>250</td><td>200</td><td>200</td></tr>
<tr><td>July-September</td><td>300</td><td>300</td><td>250</td><td>200</td><td>200</td></tr>
<tr><td>Total (taf)</td><td>468</td><td>410</td><td>313</td><td>257</td><td>247</td></tr>
<tr><td>Baseline (taf)</td><td>1,015</td><td>722</td><td>406</td><td>242</td><td>269</td></tr>
<tr><td>Unimpaired (taf)</td><td>1,772</td><td>1,291</td><td>920</td><td>631</td><td>449</td></tr>
</table>
[a] Existing flow requirements are 98 to 302 taf, based on the 1987 agreement between CDFG and USBR (CDFG and USBR 1987); actual schedule is determined on an annual basis and depends on available yield, carryover storage, and hydrologic conditions.
[b] Year type based on San Joaquin basin 60-20-20 index. Flow schedules are releases from Goodwin Dam.
[c] In a below normal water year, April-May flow would be maintained for 45 days at 1500 cfs and 16 days at 300 cfs.
[d] In a dry water year, April-May flow would be maintained for 30 days at 1500 cfs and 31 days at 300 cfs.
[e] In a critical water year, April-May flow would be maintained at 1500 cfs for 30 days and at 300 cfs for 31 days.</td><td>CDFG, USFWS, USBR, Oakdale Irrigation District, South San Joaquin Irrigation District, Stockton East Water District, Central San Joaquin Water Conservation District, South Delta Water Agency (SDWA), COE</td><td>3406(b)(1)(B), 3046(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•2. Improve watershed management to restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel.</td><td>Landowners, CDFG, NRCS, COE, USFWS, USBR</td><td>3406(b)(13)</td><td>High</td></tr>
</table>

Action	Involved parties	Tools	Priority
3. Screen all diversions to protect all life history stages of anadromous fish.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium

Evaluation	Involved parties	Tools	Priority
•1. Identify and implement actions to provide suitable water temperatures for all life stages of chinook salmon, consistent with efforts to maintain adequate flows to provide fish habitat. Establish maximum temperature objectives of 56°F from October 15 to February 15 for incubation and 65°F from April 1 to May 31 for juvenile rearing and emigration.	Dam operators, CDFG, USFWS, USBR, COE	3406(g)	High
•2. Evaluate and implement actions to reduce predation on juvenile chinook salmon, including actions to isolate ponded sections of the river.	CDFG, USFWS, USBR, COE	3406(e)(6)	Medium
•3. Evaluate and refine a river regulation plan that provides adequate flows to protect all life stages of anadromous fish based on water storage at New Melones Reservoir, predicted hydrologic conditions, and current aquatic habitat conditions.	USFWS, USBR, CDFG, COE		High
4. Develop a carryover storage target for New Melones Reservoir to ensure Vernalis flow standards are met during the 30-day pulse flow period during the third year of a dry or critical period. This will protect at least one of three year classes of chinook salmon during emigration.	USFWS, USBR, CDFG, SEWD	3406(g)	High

Evaluation	Involved parties	Tools	Priority
5. Evaluate use of the Stanislaus River by American shad and consider increasing flows and maintaining mean daily water temperatures between 61°F and 65°F from April to June when hydrologic conditions are adequate to minimize adverse effects to water supply operations and in a manner consistent with actions to protect chinook salmon.	Dam operators, CDFG, USFWS, USBR	3406(g)	High
6. Evaluate fall pulse flows for attraction and passage benefits to chinook salmon and steelhead.	USFWS, USBR, CDFG, COE, SEWD		

Mainstem San Joaquin River

Action	Involved parties	Tools	Priority
•1. Coordinate with CDFG and others and acquire water from willing sellers consistent with applicable guidelines as needed to implement a flow schedule that improves conditions for all life stages of San Joaquin chinook salmon migrating through, or rearing in, the lower San Joaquin River.	River and tributary water managers and diverters, CDFG, SWRCB, USFWS, USBR	3406(b)(1)(B), 3406(b)(2), 3406(b)(3)	High
2. Develop an equitable, integrated San Joaquin Basin plan that will meet outflow:export objectives identified under Sacramento-San Joaquin Delta Operational Target 4 and Supplemental Actions Requiring Water 7, 8, and 9.	River and tributary water managers and diverters, CDFG, SWRCB, CDWR, USFWS, USBR		High
•3. Reduce or eliminate entrainment of juvenile chinook salmon at Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions by implementing the Anadromous Fish Screen Program in conjunction with other programs.	Diverters, USFWS, USBR, NMFS, CDFG, CDWR	3406(b)(21)	Medium
4. Reduce or eliminate entrainment of juvenile chinook salmon at smaller riparian pumps and diversions on the mainstem San Joaquin River.	Diverters, USFWS, USBR, NMFS,	3406(b)(21)	Medium

Action	Involved parties	Tools	Priority
	CDFG, CDWR		
5. Maintain the 6 mg/L dissolved oxygen standard during September through November in the San Joaquin River between Turner Cut and Stockton, as described in the SWRCB=s 1995 Water Quality Control Plan.	CDFG, CDWR, COE, City of Stockton, Port of Stockton		High
6. Establish a basin-wide conjunctive water use program.	River and tributary water managers and diverters, CDFG, CDWR, USBR, USFWS		High

Evaluation	Involved parties	Tools	Priority
1. Identify and implement actions to improve watershed management to restore and protect instream and riparian habitat.	Landowners, CDFG		High
2. Identify and implement actions to maintain suitable water temperatures or minimize length of exposure to unsuitable water temperatures for all life stages of chinook salmon in the San Joaquin River and Delta.	River and tributary water managers and diverters, CDFG,	3406(g)	High

Evaluation	Involved parties	Tools	Priority
	USFWS, USBR		
3. Identify and implement actions to reduce predation on juvenile chinook salmon.	CDFG, USFWS		Medium
4. Identify and attempt to maintain adequate flows for migration, spawning, incubation and rearing of white sturgeon and green sturgeon from February to May, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	River and tributary water managers and diverters, CDFG, CDWR		High
5. Identify and attempt to implement actions that will maintain mean daily water temperatures between 61°F and 65°F for at least one month from April 1 to June 30 for American shad, consistent with actions to protect chinook salmon and steelhead and when hydrologic conditions are adequate to minimize adverse effects to water supply operations.	CDFG, USFWS, USBR	3406(g)	High
6. Evaluate the potential to develop and implement a strategy of coordinating a variety of specific actions, such as coincident pulse flows on San Joaquin tributaries, reduced Delta exports, hatchery releases, and gravel cleaning to stimulate outmigration and reduce predation and entrainment.	River and tributary water managers and diverters, CDFG, USFWS, USBR		High
7. Identify, evaluate the need for, and, if needed, attempt to maintain adequate flows for migration of steelhead, consistent with efforts to maintain adequate flows for chinook salmon.	River and tributary water managers and	3406(b)(3)	High

Evaluation	Involved parties	Tools	Priority
	diverters, CDFG, USFWS, USBR		

SACRAMENTO-SAN JOAQUIN DELTA

Improvements to aquatic habitat in the Delta are essential to restore the natural production of anadromous fish in the Central Valley because habitat in the Delta is highly degraded and all species and races of fish use the Delta at some stage in their life history.

Recent actions to improve fish habitat in the Delta are described in the 15 December 1994, Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government (Bay-Delta Agreement) and in the State Water Resources Control Board=s May, 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP). The AFRP assumes that those actions will continue to be implemented in the future. Should changes occur in the 1995 WQCP objectives or the Bay-Delta Agreement, the AFRP will need to determine if new restoration actions in the Delta beyond those described below are needed in light of those changes.

Both the Bay-Delta Agreement and 1995 WQCP require operational flexibility of state and federal water projects to provide protection for anadromous fish. As described in the Bay-Delta Agreement, initial deliberation and operational decisions to achieve this flexibility will be made by the California Water Policy Council and Federal Ecosystem Directorate (CALFED) Coordination Group (Ops Group) in consultation with water users, environmentalists and fishery representatives. The Ops Group develops ways to use the operational flexibility of the State Water Project (SWP) and Central Valley Project (CVP) such that species using the estuary receive more protection than they would have received by strict adherence to 1995 WQCP standards.

Operational flexibility allows the Ops Group to meet operational targets that contribute to doubling natural production of anadromous fish, and the Bay-Delta Agreement=s criterion to maintain water quality conditions which, together with other measures in the watershed, would be sufficient to achieve a doubling of production of chinook salmon. The operational targets listed in the first table below are the AFRP recommendations to the Ops Group. These targets allow variability in the timing and nature of operations to meet requirements in the 1995 WQCP.

A second table lists supplemental actions requiring water that may involve changes in operations beyond the authority of the Ops Group that further contribute to meeting the AFRP goal. In this table, some supplemental actions are identical to operational targets because their full implementation may be beyond the authority of the Ops Group. Supplemental actions can be met through a combination of project reoperation (Section 3406(b)(1)), management of 800,000 acre-feet of CVP yield (Section 3406(b)(2)), and acquisition of water from willing sellers (Section 3406(b)(3)). The best combination of these three tools for achieving the actions will be determined through the preparation of annual implementation plans along with guidance from the long-term water management plan, which will seek to maximize the biological benefits of the actions while minimizing their water supply impacts. In some years, the three tools may not be sufficient to fully implement all actions, resulting in partial implementation of some actions. Sub-priorities are provided as guidance for partial implementation for some actions.

These supplemental actions (some in slightly modified form) are being used to develop an implementation plan in the form of the CVP operational forecast for water year 1997 and to develop a long-term CVP Water Management Plan that integrates these supplemental actions with upstream flow actions and Delta operational targets.

In addition, these supplemental actions requiring water formed the basis for the nine priorities that were provided to the PEIS team for their use in developing alternatives for the PEIS in a letter to interested parties dated October 25, 1996 announcing an AFRP workshop on proposed fish flow and habitat objectives for selected Central Valley rivers and the Delta.

Supplemental actions not requiring water include screens at diversions and a channel barrier. Some of these actions are not under the direct authority of the Ops Group or addressed by the 1995 WQCP, however, some actions may be addressed by Category III of the Bay-Delta Agreement.

In developing this Restoration Plan, Interior has made an initial programmatic-level determination of the reasonableness of the restoration actions included in the following tables. As USFWS and USBR move towards specific plans for implementation based on this Restoration Plan, they will continue to examine the reasonableness of a particular mix of restoration actions. The final decision to implement any action will be done through the implementation process and described in the implementation plans.

The following operational targets, supplemental actions, and evaluations are intended to be consistent with and supportive of the CALFED Bay-Delta process, the Bay-Delta Agreement=s criterion to maintain conditions sufficient to achieve a doubling of production of chinook salmon, and with the narrative water quality objective in the 1995 WQCP to maintain water quality conditions and other measures sufficient to achieve a doubling of natural production of chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law.

Operational target	Involved parties	Tools	Priority
•1. Close Delta Cross Channel (DCC) up to 45 days in the November through January period, when juvenile salmon enter the Delta or flow or turbidity changes trigger salmon migration. The DCC gates are to be closed within 24 hours when any of the following triggers occur: 1) daily average flow or turbidity of the Sacramento River at Freeport increases by 20% from the previous 3 day running average; 2) capture of at least one juvenile chinook salmon of spring-run size in the Sacramento River tributaries and in the Sutter Bypass, or in the Sacramento River at or below Knights Landing; 3) capture of at least two juvenile chinook salmon of any race in the Sacramento River at or below Knights Landing at any Interagency Ecological Program (IEP) sampling station in one day. The gate closure period will be for 10, 15 and 20 consecutive days in November, December and January, respectively, and will remain closed for another 10 consecutive days if any of the above triggers are met after the initial closure for that month.	CALFED agencies	WQCP, Bay-Delta Agreement, 3406(b)(1)(B)	High[1]
•2. When the DCC is closed during the November through January period, limit the average SWP and CVP exports to no greater than 35% of Delta inflow if Evaluation 3	CALFED agencies	WQCP, Bay-Delta Agreement,	High

[1]Although Operational target 1 addresses fish passage, it was assigned high priority because potential to increase fish production is great.

Operational target	Involved parties	Tools	Priority
determines that a relatively high ratio of Delta export to inflow limits juvenile salmon survival through the Sacramento River Delta. Sub-priorities: 1) January, 2) December, 3) November.		3406(b)(1)(B)	
•3. Maximize DCC closure from May 21 through June 15 when chinook salmon and other anadromous species are abundant in the lower Sacramento River, but keep open when the net benefit to striped bass and other sensitive species in the lower San Joaquin River is great.	CALFED agencies, United States Coast Guard, Boating interests	WQCP, Bay-Delta Agreement, 3406(b)(1)(B)	High[2]
•4. Maintain an average export to inflow ratio of no more than 45% during February in dry years by increasing the ratio to ~55% in early February and decreasing the ratio to ~35% in late February, when winter-run chinook salmon smolts are present.	CALFED agencies	WQCP, Bay-Delta Agreement, 3406(b)(1)(B)	High
•5. Minimize fish losses and predation at facilities by operating state and federal pumps interchangeably when this operation achieves a net benefit to anadromous fish production.	CALFED agencies	WQCP, Bay-Delta Agreement, 3406(b)(1)(B)	Medium

Supplemental action requiring water	Involved parties	Tools	Priority
•6. In conjunction with operation of a barrier at the head of Old River and consistent with efforts to conduct evaluations 1 and 2,	CALFED agencies	3406(b)(2), 3406(b)(3)	High

[2] Although Operational target 3 addresses fish passage, it was assigned high priority because potential to increase fish production is great.

<table>
<tr><th>Supplemental action requiring water</th><th>Involved parties</th><th>Tools</th><th>Priority</th></tr>
<tr><td>maximize the difference between flows and export rates at levels greater than those required under the Delta smelt biological opinion during the 30-day April and May pulse flow period.</td><td></td><td></td><td></td></tr>
<tr><td>•7. When a barrier at the head of Old River is not operational, limit the combined SWP and CVP exports to 1,500 cfs or maintain a Vernalis inflow to total export ratio of 5 to 1 during the 30-day April through May pulse flow period.</td><td>CALFED agencies</td><td>3406(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•8. Increase the level of protection targeted by the May and June X2 requirements to a 1962 level of development (LOD), as described below, where the number of days when X2 is required at Chipps Island in Table A of the 1995 WQCP is shown to the right of the requirements to meet a 1962 LOD and where PMI is the previous months eight river index in acre feet.
<table>
<tr><th></th><th>1962 LOD</th><th></th><th>IN WQCP</th><th></th></tr>
<tr><td>PMI</td><td>MAY</td><td>JUNE</td><td>MAY</td><td>JUNE</td></tr>
<tr><td>≤1500</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1750</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2000</td><td>4</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>2250</td><td>13</td><td>1</td><td>3</td><td>0</td></tr>
<tr><td>2500</td><td>24</td><td>3</td><td>11</td><td>1</td></tr>
<tr><td>2750</td><td>29</td><td>7</td><td>20</td><td>2</td></tr>
<tr><td>3000</td><td>30</td><td>12</td><td>27</td><td>4</td></tr>
<tr><td>3250</td><td>31</td><td>18</td><td>29</td><td>8</td></tr>
<tr><td>3500</td><td>31</td><td>23</td><td>30</td><td>13</td></tr>
<tr><td>3750</td><td>31</td><td>26</td><td>31</td><td>18</td></tr>
<tr><td>4000</td><td>31</td><td>28</td><td>31</td><td>23</td></tr>
<tr><td>4250</td><td>31</td><td>29</td><td>31</td><td>25</td></tr>
<tr><td>4500</td><td>31</td><td>29</td><td>31</td><td>27</td></tr>
<tr><td>4750</td><td>31</td><td>30</td><td>31</td><td>28</td></tr>
</table></td><td>CALFED agencies</td><td>3406(b)(2),</td><td>High</td></tr>
<tr><td>•9. During May, maintain at least 13,000 cfs daily flow in the Sacramento River at the I Street Bridge and 9,000 cfs at Knights Landing to improve transport of eggs and larval striped bass and other young anadromous fish and to reduce egg settling and mortality at low flows. Sub-priorities: 1) 13,000 cfs at I Street Bridge, 2) 9,000 cfs at Knights Landing.</td><td>CALFED agencies</td><td>3406(b)(2), 3406(b)(3)</td><td>High</td></tr>
<tr><td>•10. During the last half of May, ramp (linearly) the total SWP</td><td>CALFED</td><td>3406(b)(2),</td><td>High</td></tr>
</table>

Supplemental action requiring water	Involved parties	Tools	Priority
and CVP export level from what it is at the end of the 30-day April and May pulse flow period to that export level proposed by the SWP and CVP to meet the requirements of the 1995 WQCP on June 1.	agencies	3406(b)(3)	
•11. Close the DCC during the November through January period beyond the 45-day limit defined under Operational Target 1 should meeting one of the triggers stipulated in Operational Target 1 require additional closure.	CALFED agencies	3406(b)(2), 3406(b)(3),	High[1]
•12. Limit the average SWP and CVP exports to no greater than 35% of Delta inflow in July. Sub-priorities: 1) July 1 to July 14, 2) July 16 to July 31.	CALFED agencies	3406(b)(2), 3406(b)(3)	High
13. Supplement Delta outflow for migration and rearing of white sturgeon, green sturgeon, striped bass, and American shad by modifying CVP operations and using water available under the CVPIA (sections 3406(b)(2) and (3)), consistent with actions to protect chinook salmon and steelhead.	CALFED agencies	3406(b)(2), 3406(b)(3)	High
•14. When the DCC is closed during the November through January period, limit the average SWP and CVP exports to no greater than 35% of Delta inflow if Evaluation 3 determines that a relatively high ratio of export to inflow limits survival of juvenile chinook salmon migrating through the Sacramento River Delta. Sub-priorities: 1) January, 2) December, 3) November.	CALFED agencies	3406(b)(2), 3406(b)(3)	High

Supplemental action not requiring water	Involved parties	Tools	Priority
•15. Implement actions to reduce losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions in the Sacramento-San Joaquin Delta and	Diverters, CDFG, CDWR,	3406(b)(21)	Medium

[1]Although Supplemental action 11 addresses fish passage, it was assigned high priority because potential to increase fish production is great.

Supplemental action not requiring water	Involved parties	Tools	Priority
Suisun Marsh, if Evaluation 12 determines significant benefits to juvenile anadromous fish can be achieved by screening.	USFWS, USBR, NMFS, SWRCB, COE		
•16. Construct and operate a barrier at the head of Old River to improve conditions for chinook salmon migration and survival if Evaluation 1 determines that a barrier can be operated to improve conditions for salmon with minimal adverse effects on other Delta species.	CALFED agencies	3406(b)(2), 3406(b)(3), 3406(b)(15)	High[2]

[2] Although Supplemental Action 16 addresses fish passage, it was assigned high priority because potential to increase fish production is great.

Evaluation	Involved parties	Tools	Priority
•1. In conjunction with Evaluation 2, evaluate whether a temporary rock barrier at the head of Old River can be operated during the 30-day April through May pulse flow period to improve conditions for chinook salmon migration and survival with minimal adverse effects on other Delta species, consistent with the COE=s permit (PN 199600027) to the CDWR and USFWS=s Biological Opinion on delta smelt for the Temporary Barriers Project.	IEP agencies	3406(b)(15)	High[1]
•2. Evaluate in conjunction with Evaluation 1 the impacts of San Joaquin River Delta inflow and SWP and CVP export rates on salmon smolt survival through the San Joaquin Delta. This evaluation is intended to be consistent with the proposed adaptive management plan for the San Joaquin River and Delta that is being considered by involved parties.	IEP agencies	3406(b)(1), 3406(b)(2), 3406(b)(3)	High
•3. Evaluate the effect of a low (~35%) versus a high (~65%) SWP and CVP export to Delta inflow ratio on the survival of coded-wire-tagged, late-fall-run chinook salmon smolts migrating through the Delta when the DCC is closed.	IEP agencies	3406(b)(1), 3406(b)(2), 3406(b)(3)	High
•4. Evaluate potential benefits of and opportunities for increasing salmonid and other anadromous fish production through improved riparian habitats in the Delta.	SWP and CVP contractors, TNC, IEP agencies	3406(e)(1)	High
•5. Evaluate opportunities to provide modified operations and a new or improved control structure for the DCC and Georgiana Slough or other methods at those locations to assist in the successful migration of anadromous salmonids.	SWP and CVP contractors, IEP agencies	3406(b)(14), 3406(e)(5)	High[2]

[1]Although Evaluation 1 addresses fish passage, it was assigned high priority because resulting information is needed before Supplemental Action 16 can be implemented.

Evaluation	Involved parties	Tools	Priority
•6. Evaluate benefits of and opportunities for additional tidal shallow-water habitat as rearing habitat for anadromous fish in the Delta.	SWP and CVP contractors, TNC, IEP agencies		High
7. Evaluate the benefit of and opportunities for new technologies to improve water quality and to guide migrating fish.	SWP and CVP contractors, IEP agencies		Medium
•8. Evaluate the benefits of short-term pulsed Delta inflows (five days or less) on the migration rate and survival of anadromous fish.	SWP and CVP contractors, IEP agencies		High
•9. Continue to evaluate the effects of Delta hydraulic conditions such as net reverse flows on anadromous fish migration and distribution.	SWP and CVP contractors, IEP agencies	3406(g)	High
10. Evaluate the potential effects of reductions in food chain organisms in the Delta and Suisun Bay on anadromous fish production.	SWP and CVP contractors, IEP agencies	3406(g)	High
•11. Evaluate whether Delta inflow and export rates and other Delta hydrodynamic parameters effect juvenile salmon survival when the DCC is closed.	SWP and CVP contractors, IEP	3406(g)	High

[2]Although Evaluation 5 addresses fish passage, it was assigned high priority because the potential to increase fish production is great.

Evaluation	Involved parties	Tools	Priority
	agencies		
12. Evaluate the benefits to juvenile anadromous fish of and opportunities for screening diversions and re-locating riparian diversions in the Delta and Suisun Marsh.	SWP and CVP contractors, IEP agencies	3406(b)(21)	Medium
•13. Evaluate the potential effect of Delta export rate during the fall on the upstream migration of adult San Joaquin chinook salmon.	SWP and CVP contractors, IEP agencies	3406(b)(1)(B)	High

CENTRAL VALLEY-WIDE

Action	Involved parties	Tools	Priority
•1. Support programs to provide educational outreach and local involvement in restoration, including programs like Salmonids in the Classroom, Aquatic Wild, and Adopt a Watershed and school district environmental camps.	Local schools, CDFG, USFWS, NMFS		Low
2. Develop programs to educate the public about anadromous fish issues, such as the effects of poaching and environmental contaminants, especially contaminants in urban runoff.	CDFG, USFWS, NMFS, Water Education Foundation, California Teachers Association		Low
3. Reduce toxic chemical and trace element contamination.	CDFG,		High

Action	Involved parties	Tools	Priority
	USFWS, SWRCB, RWQCBs		
•4. Provide additional funding for increased law enforcement to reduce illegal take of anadromous fish, stream alteration, and water pollution and to ensure adequate protection for juvenile fish at pumps and diversions.	CDFG, USFWS, USBR, CDWR		High

Evaluation	Involved parties	Tools	Priority
1. Evaluate the need to revise harvest regulations to increase spawning escapement of naturally produced chinook salmon.	CDFG, Pacific Fisheries Management Council (PFMC), NMFS, USFWS		Low
2. Evaluate the potential to modify hatchery procedures to benefit native stocks of salmonids.	CDFG, CDWR, USFWS, USBR	3406(e)(2)	Low
3. Evaluate and avoid potential competitive displacement of naturally produced juvenile salmonids with hatchery-produced juveniles by implementing release strategies for hatchery-produced fish designed to minimize detrimental interactions.	CDFG, CDWR, USFWS, USBR	3406(e)(2)	Low
•4. Evaluate and implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and natural stocks.	CDFG, CDWR, USFWS, USBR	3406(e)(2)	Low
5. Evaluate the transfer of disease between hatchery and	CDFG,	3406(e)(2)	Low

Evaluation	Involved parties	Tools	Priority
natural stocks.	CDWR, USFWS, USBR		
6. Evaluate effects of trace elements and organic contaminants, especially selenium and PCBs, on the health of adult white sturgeon and green sturgeon, the viability of their gametes, and development of their offspring.	CDFG, USFWS		High
•7. Evaluate a program to tag and fin-clip all or a significant portion of hatchery-produced fish as a means of collecting better information regarding harvest rates on hatchery and naturally produced fish and effects of hatchery-produced fish on naturally produced fish.	CDFG, CDWR, USFWS, USBR, NMFS, EBMUD	3406(e)(2)	Low
8. Evaluate the direct and indirect effects of contaminants on production of anadromous fish.	CDFG, USFWS, RWQCBs, SWRCB		High
9. Evaluate the ability of streams for which target production levels exist for chinook salmon but not for steelhead to support natural production of steelhead.	CDFG, USFWS	3406(e)(6)	High
10. Evaluate the effects of exotic species on production of anadromous fish.	IEP agencies		Low
11. Encourage the restoration of small tributaries by evaluating the feasibility of screening or relocating diversions, switching to alternative sources of water for upstream diversions, restoring and maintaining a protected riparian strip, limit excessive erosion, enforcing dumping ordinances, removing toxic materials or controlling their source, replacing bridge and ford combinations with bridges or larger culverts and installing siphons to prevent truncation of small streams at irrigation canals.	CDFG, USFWS, USBR	3406(e)(6)	High

OCEAN

Evaluation	Involved parties	Tools	Priority
1. Evaluate the need to revise harvest regulations on both sport and commercial fishers to increase spawning escapement of naturally produced chinook salmon.	PFMC, CDFG, NMFS, USFWS		Low
2. Evaluate the effects of sea lion predation on chinook salmon production.	PFMC, CDFG, NMFS, USFWS		Low
3. Evaluate the effects of foreign, open-ocean harvest on Central Valley chinook salmon and steelhead stocks.	PFMC, NMFS, CDFG, USFWS		Low

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APPENDICES

A. AFRP Position Paper

Presented in its entirety below is the "Position Paper for Development of the Central Valley Anadromous Fish Restoration Program". The Position Paper was developed by the AFRP Core Group to guide program development. It was released to the public on July 18, 1994 and was slightly revised and re-released in Volume 2 of the Working Paper on Restoration Needs (USFWS 1995). Only the phone number and address to request copies has been revised since the last release.

POSITION PAPER FOR DEVELOPMENT OF THE CENTRAL VALLEY ANADROMOUS FISH RESTORATION PROGRAM

INTRODUCTION

The Plan of Action (POA) for the Central Valley Anadromous Fish Restoration Program (Program) identifies the steps necessary to develop the Program (USFWS 1994). One of the steps included the preparation of a Position Paper to be developed by the Core Group. This document is a draft of the Position Paper described in the POA.

This Position Paper is a reference document for use by the Core Group and the technical teams to guide Program development. Because it was impossible to anticipate all issues prior to drafting the Position Paper, this paper will be amended and supplements added as needed. To determine if your copy is current and to request copies of the Position Paper, contact the Public Information Officer, Central Valley Fish and Wildlife Restoration Program, 3310 El Camino Avenue, Sacramento, California 95821, (916) 979-2760.

The paper is divided into three sections: (1) Program goal and definitions, (2) Intent of Title 34, and (3) Implementation criteria. The first section states the Program goal and develops general definitions for each of the terms used in the Program goal. The second section presents and interprets the intent of Title 34 and reexamines some of the definitions presented in the first section. These first two sections lay the foundation for the last section.

In the last section, implementation criteria are discussed for the 1967-1991 (baseline) period and for the future. Discussions of implementation criteria are separated because the two periods require different criteria. As discussed later in this paper, limitations are imposed by the type or quantity of data collected during the baseline period. Future monitoring programs may be designed to avoid these limitations.

PURPOSE OF POSITION PAPER

The purposes of the Position Paper are two-fold: (1) to explain or clarify the Core Group's position on issues related to developing the Program and (2) to document reasons used to develop these positions.

PROGRAM GOAL AND RELATED DEFINITIONS

Title 34 requires that "...natural production of anadromous fish in Central Valley rivers and streams be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991..." (Section 3406[b][1]). Several terms need to be clearly defined before the program can be designed to meet this requirement: natural production, anadromous fish, Central Valley rivers and streams, sustainable, long-term basis, and average levels.

Natural Production

Title 34 defines natural production as: "... fish produced to adulthood without direct human intervention in the spawning, rearing, or migration processes" (Section 3403[h]). To apply this definition, we must develop an understanding of the meaning of each of the components of the definition. Important components that have been identified to date are the following: production, adulthood, and direct human intervention.

Production

Ricker (1958) defined production as "the total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time." Although Ricker's definition includes changes in mass as well as numbers of fish, Title 34 specifies "... fish produced to adulthood..." and therefore production will refer to numbers of fish produced.

Because a fish can only be "...produced to adulthood..." once in its lifetime, an individual fish should not be counted twice. In addition, production should be measured over a discrete time interval. Because all stocks under consideration are seasonal spawners, **a direct and simple approach will be to count the first-time spawners each spawning season**.

Ricker's definition also states that a fish is counted toward production for the time period over which production is being measured "...irrespective of whether or not it survives to the end of that time". Using Ricker's definition, juvenile fish that did not survive to adulthood would be counted. The definition of natural production in Title 34 specifies "... fish produced to adulthood..." and therefore does not count juvenile fish. On the other hand, Title 34 does not discriminate between adult fish that return to spawn and those taken in recreational and commercial fisheries. Because Ricker's definition includes fish that do not survive to the end of the time period, and because the definition of natural production in Title 34 specifies fish produced to adulthood, **all naturally produced, adult fish shall be counted, including those that are harvested prior to spawning**.

Including harvested fish is consistent with the definition of production in the California Salmon, Steelhead Trout and Anadromous Fisheries Program Act. The California Act defines production as "the survival of fish to adulthood as measured by abundance of the recreational and commercial catch together with the return of fish to the states spawning streams." Because both the Federal and State acts have similar purposes and goals, and because implementation of both acts should be coordinated, it is convenient that the definitions of production being implemented for both acts are similar.

Whether or not a fish attains adulthood is key to determining whether or not to count that fish toward the production goal. Adulthood is defined below.

Adulthood

Section 3403(h) includes the phrase "...fish produced to adulthood..." as part of the definition of natural production. Adulthood is not defined within Title 34. Adulthood is generally defined as the state, condition or quality of being fully developed and mature. Applying this definition to fish is complicated by the fact that most fish continue to grow throughout life (i.e., cessation of growth can't be used to indicate full development) and may become sexually mature several times during their lifetime (i.e., although developed gonads can be used to indicate maturity, lack of developed gonads cannot be used to indicate immaturity). Because the presence or absence of external characters can't always be used to identify adult fish, and because sexual maturity (i.e., developed gonads) is a transitory state, fishery managers often use size or age criteria to indicate maturity.

An adult fish will be defined as one that is capable of reproduction. Ability to reproduce should be based on some external characteristic, such as size. Because Title 34 requires that production be compared between baseline and goal periods, the same criteria for determination of adulthood will be applied to both periods.

Direct Human Intervention

The definition of natural production precludes "...direct human intervention..." in the spawning, rearing, or migration processes of an individual, naturally produced fish. A definition of direct human intervention is key to understanding the definition of natural production. Humans have pervasively intervened in the structure and function of the Sacramento-San Joaquin system. All anadromous fish that spawn in the system have been impacted by this intervention. Indeed, Title 34 has as one of its purposes "...to address impacts of the Central Valley Project on fish, wildlife, and associated habitats..." (Section 3402[b]). But not all human intervention is direct. The word direct is an important component of the phrase "...direct human intervention...".

Direct human intervention is any action taken in the absence of intervening elements. Any form of intervention that requires handling of fish is direct intervention due to a lack of intervening elements. Any action that includes one or more intervening elements would be considered indirect intervention.

Hatchery and artificial propagation, including supplementation and out-planting of eggs or any other life-stage, requires handling of fish by humans during the spawning and rearing processes and therefore are forms of direct intervention. Transporting fish, including truck and barge transport, and fish salvage require capture and handling of fish during the rearing or migration process and therefore are forms of direct intervention. Hatchery and artificial propagation, transport and salvage of fish, or any process that requires handling of any life-stage of fish will be considered direct human intervention.

Title 34 clearly states that fish produced with direct human intervention should not be included in counts of natural production. In developing the Program, we will avoid counting hatchery-produced fish or fish produced with any other form of direct human intervention in counts of natural production. The Core Group has determined that there will be one exception to this rule: the progeny of naturally spawning fish salvaged at the John E. Skinner Delta Fish Protective Facility and the Tracy Fish Protective Facility, if they reach adulthood, will be counted as naturally produced.

An example of a form of intervention that does not fit the definition of direct intervention is flow manipulation. When we manipulate flow to benefit fish, flow acts as the intervening element. Humans directly alter flows and flows alter fish spawning, rearing, or migration processes. Therefore, flow manipulation is not a direct but an indirect form of intervention. Construction of fish ladders, screens and barriers are forms of indirect intervention because each of these structures act as the intervening element. Reservoir or flow manipulations (including Delta flows and flows to maintain desired stream temperatures), ladders, screens, barriers, and other forms of habitat alteration and enhancement activities will not be considered direct human intervention because each of these is or has an intervening element and does not require handling of fish.

Because the definition of natural production in Title 34 includes the phrase "...produced to adulthood...", fish that are not subject to direct human intervention until after they reach adulthood would still be considered naturally produced. For example, a naturally produced fish that returned to a hatchery and was spawned in the hatchery would be considered naturally produced. Obviously, its progeny would not be considered naturally produced because they were produced in a hatchery. Similarly, naturally produced adult fish whose migration was subject to direct human intervention would still be considered naturally produced, although their progeny would not be considered naturally produced.

Anadromous Fish

Title 34 defines anadromous fish as "...those stocks of salmon (including steelhead), striped bass, sturgeon, and American shad that ascend the Sacramento and San Joaquin rivers and their tributaries and the Sacramento-San Joaquin Delta to reproduce after maturing in San Francisco Bay or the Pacific Ocean" (Section 3403[a]). This definition identifies five groups or species of fish: salmon, steelhead, striped bass, sturgeon, and American shad. The American Fisheries Society recognizes steelhead as the common name for the anadromous form of *Oncorhynchus mykiss* and striped bass and American shad as the common names for *Morone saxatilis* and *Alosa sapidissima* (AFS 1991). Clearly, Title 34 includes these species in the definition of anadromous fish. The names salmon and sturgeon both include multiple species of fish and the meaning of these terms in relation to Program development needs clarification. The term"stocks" in the definition of anadromous fish also needs clarification.

Salmon - Salmon is a common name for at least six species of fish. Five species of salmon have been observed in the Sacramento River: chinook (*O. tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon (Moyle 1976, Fry 1973). Chinook salmon are common in the Sacramento-San Joaquin system, the other four species are rare. Based on observations of adults during 1949 through 1958, Hallock and Fry (1967) concluded that sockeye, pink, and chum salmon entered the Sacramento River regularly enough to be regarded as very small runs, but that coho salmon were so scarce and irregular that they should be regarded as strays. Juvenile coho salmon were planted in Mill Creek in 1956, 1957, and 1958, but by 1963 coho salmon were almost as scarce as they had been before the introductions (Hallock and Fry 1967). During the baseline period, there is no evidence that coho, sockeye, pink, or chum salmon maintained self-sustaining spawning runs in the Central Valley (Fisher pers. comm.). Because the definition of anadromous fish specifies "...salmon... that ascend the Sacramento and San Joaquin rivers...to reproduce..." and because chinook salmon is the only salmon known to reproduce in the system on a regular basis during the baseline period, the use of the word salmon in the definition will be interpreted to mean chinook salmon.

Sturgeon - Two species of sturgeon are found in the Sacramento-San Joaquin system: white sturgeon (*Acipenser transmontanus*) and green sturgeon (*A. medirostris*) (Moyle 1976). Because both species of sturgeon reproduce in the Sacramento-San Joaquin system, the word sturgeon will be interpreted to include white and green sturgeon.

In summary, **the species of anadromous fish identified by Title 34 that reproduce in the Sacramento-San Joaquin system include chinook salmon, steelhead, striped bass, white sturgeon, green sturgeon, and American shad**. The Program will be designed to double the natural production of the anadromous forms of these six species.

Other anadromous fish - Title 34 does not identify several species of anadromous fish that spawn in Central Valley rivers and streams. These include threespine stickleback, brown trout, and two species of lamprey and smelt (Fry 1973). The Program will not establish restoration goals specific to these species.

Stocks

For purposes of the Program, **a stock is defined as a group of individuals which are more likely to mate with each other than with individuals not included in the group**. The term stock describes a fish population that spawns in a particular stream, or stream reach, at a particular season and that do not interbreed to a substantial degree with any group spawning in a different place, or in the same place at a different time. This definition does not rely upon absolute reproductive barriers. In fisheries management, stocks are recognized to maintain and improve the genetic basis for management.

Several stocks which meet this definition are already recognized. For example, chinook salmon are divided into several races based on the season during which they enter the rivers to begin their upstream spawning migrations as follows: fall, late-fall, winter, and spring runs. Others stocks which might be recognized in the future will likely become stocks of special concern.

Good evidence exists for salmon and steelhead that these species return to their natal streams to spawn. There is some evidence and little reason not to expect that the same relationship holds for some of the other anadromous species. As stated in the POA for the Program, the objective of the Program will be to double the natural production of all species and races within specific individual streams, and to preserve genetic stocks. If it proves unfeasible to double the natural production of a species or race within a specific stream, the unmet production increment will be transferred to other individual streams in the following order of priority: (1) another stream within the same drainage system, (2) another stream within the larger basin, such as the Sacramento River Basin, and (3) any stream within the Central Valley.

Central Valley Rivers and Streams

For the purposes of the Program, **Central Valley rivers and streams are defined as all rivers, streams, creeks, sloughs and other watercourses, regardless of volume and frequency of flow, that drain into the Sacramento River basin, the San Joaquin River basin downstream of Mendota Pool, or the Sacramento-San Joaquin Delta upstream of Chipps Island**.

Sustainable

Sustainable means capable of being maintained or kept in existence. In Title 34, sustainable refers to natural production, which is defined as "... fish produced to adulthood without direct human intervention...." Elimination of direct human intervention as a legitimate alternative requires reliance on restoration and maintenance of habitat conditions that allow anadromous fish populations to sustain themselves at levels consistent with numeric restoration goals. Therefore, in the context of Title 34, **sustainable is defined as capable of being maintained at target levels without direct human intervention in the spawning, rearing or migration processes**. Production levels specified by numeric goals will be considered sustainable when they are maintained under the entire range of conditions resulting from legal human activities, as superimposed on natural variability inherent in the system. Human activities shall include, but not be limited to, agricultural diversion and discharge, exports, flow manipulation, water pollution, dredge and fill, channel modification and damming.

There is an element of time implicit in sustainability. Therefore, if natural production is to be sustainable, modifications to system operations as well as improved physical habitat and water quality must be provided into the future. Title 34 requires that "...natural production...be sustainable, on a long-term basis" and provides for annual funding without a specified expiration date. The intent of Title 34 is that numeric restoration goals continue to be realized or exceeded in perpetuity.

Long-Term Basis

Long-term will encompass at least several generations of fish (not less than 5) over a variety of hydrologic conditions (to allow for natural variation in production) and will continue indefinitely.

Average Levels

As stated in Title 34, the goal is to sustain natural production "...at levels not less than twice the average levels attained during the period of 1967-1991..." To attach numeric values to this goal, we need to estimate average levels of production. One problem is that average is not a precise statistical term. In statistics, the term average can apply to several measures of central tendency (Langley 1971). The most commonly used measure of central tendency is the arithmetic mean (Lapin 1975). Consequently, the public generally understands average to mean arithmetic mean and it is reasonable to assume that this was the intent of the authors of Title 34. Therefore, **the definition of average will be the arithmetic mean**.

INTENT OF TITLE 34

Habitat Restoration

Of the six purposes of Title 34, three are particularly germane to discussion of the intent of Title 34 as it relates to the Program. These three purposes are listed below:

(1) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California (3402[a]);

(2) to address impacts of the Central Valley Project on fish, wildlife and associated habitats (3402[b]);

(3) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (3402[e]);

In addition, Section 3406(b)(1)(A) states that the Program "...shall give first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations, and implementation of the supporting measures mandated by this subsection..." Because Title 34 directs that the Program shall emphasize habitat restoration, **emphasis will be placed on restoring habitat**.

Natural versus Hatchery Production

Title 34 requires that "...natural production of anadromous fish in Central Valley rivers and streams be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991..." (Section 3406[b][1]). The requirement that natural production be sustainable on a long-term basis suggests that the intent of Title 34 is for the definition of natural production to extend between generations of fish. Natural production should be self-sustaining. **The Program should not depend on hatchery-produced fish to sustain populations of naturally spawning fish**.

In addition, Title 34 requires investigations of "...opportunities for additional hatchery production to mitigate the impacts of water development and operations on, or enhance efforts to increase Central Valley fisheries; Provided, That additional hatchery production shall only be used to supplement or to re-establish natural production while avoiding adverse effects on remaining wild stocks" (Section 3406[e][2]). This section provides insight into the intent of Title 34 as it relates to the roles of natural and hatchery production and emphasizes avoiding adverse effects of hatchery production on wild (naturally produced) stocks. Under Title 34, **hatchery production should only be used as a last resort to supplement or to re-establish natural production, and then only after investigations on the desirability of developing and implementing additional hatchery production**.

Adverse effects of hatchery production on natural stocks can include reductions in population size caused by competition, predation, disease or other factors (Sholes and Hallock 1979, Waples 1991). A large potential for negative interaction exists when these stocks interbreed (Hindar et al. 1991, Taylor 1991, Waples 1991). The adverse effects of interbreeding increase as hatchery-produced fish become more prevalent in the naturally spawning population. Interbreeding reduces interpopulation diversity and may lead to a reduction in overall productivity and a greater vulnerability to environmental change (Waples 1991). Outbreeding depression may also result from interbreeding. In addition, large populations of hatchery-produced fish that are indistinguishable from naturally produced fish may intensify effects of harvest on naturally produced fish (Wright 1993). The simplest way to avoid adverse effects on naturally produced stocks is to minimize the opportunities for interaction between naturally and hatchery-produced fish. **The Program should be designed to avoid adverse effects of hatchery production on natural stocks**.

Harvest

Title 34 does not directly address harvest. Title 34 defines natural production as: "... fish produced to adulthood..." (Section 3403[h]) and requires that natural production be increased. Inclusion of the term production, and especially production to adulthood, suggests that **Title 34 does not intend for restriction of harvest to be used as a means of achieving Program goals**. As stated in the definition of production, harvested fish should be included in counts of production. Sound harvest management is designed to harvest only excess production, allowing for enough fish to escape harvest to maintain production at the highest level the habitat can support.

Title 34 requires that natural production be increased. There are two mechanisms by which natural production can be increased: (1) increasing the productivity of the existing habitat, and (2) increasing the amount of habitat. These mechanisms are consistent with the emphasis Title 34 places on habitat restoration. Doubling productivity of existing habitat would provide more offspring from the same number of spawners. If existing spawning habitat is being fully utilized, then increasing the number of spawners by reducing harvest would not increase production. If production of naturally produced fish is doubled and escapement is held to present levels, then harvest of naturally produced fish could more than double.

The second mechanism, doubling the amount of habitat, would accommodate twice the number of spawners. This would also provide twice the number of offspring. Under this scenario, harvest of naturally produced fish could double. Under either mechanism, barring other harvest restrictions, we would expect at least a doubling of harvest of naturally produced fish. To meet the Intent of Title 34, **harvest should be maintained at levels that allow sufficient numbers of naturally produced fish to spawn to meet goals for at least doubling natural production**

IMPLEMENTATION CRITERIA

As stated earlier, criteria for determination of natural production will conform to the definition of natural production and intent of Title 34, including definitions and interpretations of intent discussed and refined in this Position Paper. Because determination of natural production in the past will require different criteria than in the future, criteria for these time periods will be discussed separately.

Criteria for the baseline period

In the past, data collection efforts have not focused on estimating natural production and existing data may not provide direct estimates of natural production. In order to establish numerical goals for the Program, average levels of natural production must be estimated for the baseline period. Estimates will require assessing existing data and developing criteria to determine which data are germane. Criteria may not strictly conform to the definitions in and intent of Title 34 but are a compromise necessitated by a lack of data on natural production.

As explained in the POA, the Core Group and technical teams are responsible for developing these criteria. Technical teams are asked to develop initial criteria and estimates of average levels of natural production for the baseline period.

Where data are lacking, technical teams will make assumptions to expand existing data, or put existing data in perspective. For example, run-size estimates for American shad exist for only two years. In addition, young American shad abundance has been sampled during the fall emigration each year since 1967, except for 1974 and 1979 (Mills and Fisher, in preparation). The American shad technical team could look at young American shad abundance data to determine if run-size estimates for adults are representative of the abundance of shad for the baseline period. This approach has assumptions (chief among these is that abundance of young American shad can tell us something about average adult run-sizes) which are probably violated to some degree and is only presented as an example of what might be considered. Technical teams will document options considered for estimating natural production in issue papers that will be appended to the Program Plan if not in the text. Data quantity and applicability toward estimating natural production varies between species and drainage. Each technical team will need to address these issues for each species and drainage separately. Criteria for determining natural production during the baseline period will be applicable to existing data.

Because there is a relative wealth of data for chinook salmon and because several Teams deal with chinook salmon, specific criteria are proposed for them. Most of the data necessary to estimate production of each stock of chinook salmon for the baseline period are compiled in Mills and Fisher (1994). The proposed procedure for estimating yearly production of each race of chinook salmon for each stream during the baseline period follows.

In the following explanations and formulas, P is for production, E is for escapement, H is for harvest, and *h* is for the portion of total production not produced naturally. Subscripted letters following the normal letters and prior to the first comma represent different races of chinook salmon as follows: F for fall, L for late-fall, W for winter, S for spring, and C for all races combined. Subscripted letters following the first comma represent the following: O for ocean, D for downstream, I for instream, N for natural, H for hatchery, and T for total. Subscripted letters following the second comma represent the following: CV for Central Valley, SF for San Francisco, M for Monterey, and other letter combinations correspond to specific streams (e.g., AM for American River). Subscripted letters following a third comma refer only to ocean harvest and are C for commercial and R for recreational. In all cases, a subscripted X acts as a "wildcard" place holder for an unspecified subscript.

1. A portion of production returns to spawn in each stream, both naturally and in the hatchery. Some of these fish are captured before spawning. These fish are counted toward production for the stream in which they spawned or were harvested according to the following:

   a. To determine the total spawning escapement ($E_{X,T,XX}$) for each race in each individual stream, sum the estimated number of each race of chinook salmon returning to spawn naturally ($E_{X,N,XX}$) and in hatcheries ($E_{X,H,XX}$) for each individual stream.

   $$E_{X,T,XX} = E_{X,N,XX} + E_{X,H,XX}$$

   b. To determine the portion of production for each race returning to each stream (in-river run-size, $P_{X,I,XX}$), add $E_{X,T,XX}$ to the estimated number of each race of chinook salmon harvested in each stream ($H_{X,I,XX}$). Estimates of $H_{X,I,XX}$ do not exist for all streams and all years. Where estimates are not available or are inadequate, best professional judgement must be used. Technical Teams should document options considered for estimation of $H_{X,I,XX}$ in the Program Plan or in issue papers that will be appended to the Program Plan.

   $$P_{X,I,XX} = E_{X,T,XX} + H_{X,I,XX}$$

   c. To determine the total number of each race of chinook salmon returning to the Central Valley ($P_{X,I,CV}$), sum $P_{X,I,XX}$ for all streams in the Central Valley ($\lessgtr P_{X,I,XX}$) .

   $$P_{X,I,CV} = \lessgtr P_{X,I,XX}$$

   d. To determine the total number of chinook salmon (all races combined) returning to the Central Valley ($P_{C,I,CV}$), sum $P_{X,I,CV}$ for all races of chinook salmon ($\lessgtr P_{X,I,CV}$) .

   $$P_{C,I,CV} = \lessgtr P_{X,I,CV}$$

2. A portion of production is harvested in the ocean and downstream of areas in rivers where the stream responsible for this production is not easily identified. To assign these harvested salmon to individual streams, the total number of salmon falling into this category is summed and subdivided to race and stream, proportional to the portion of production attributed to each race and returning to each stream, according to the following:

RECIRC2849

a. To determine the Central Valley component of ocean harvest ($H_{C,O,CV}$), sum commercial catch at San Francisco ($H_{C,O,SF,C}$) and Monterey ($H_{C,O,M,C}$), sum recreational catch at these same ports ($H_{C,O,SF,R} + H_{C,O,M,R}$), and add these together. This estimate of $H_{C,O,CV}$ is based on the Central Valley Index (CVI), where harvest of Central Valley stocks equals landings at major ports south of Point Arena (San Francisco and Monterey). Use of CVI to estimate the Central Valley component of ocean harvest assumes that the number of Central Valley chinook salmon harvested from ports north of San Francisco is balanced by the number of chinook salmon from drainages north of the Central Valley harvested from San Francisco and Monterey. To carry $H_{C,O,CV}$ forward in subsequent calculations, assume that each chinook salmon harvested in the ocean fishery is equivalent to an adult salmon returning to spawn.

$$H_{C,O,CV} = H_{C,O,SF,C} + H_{C,O,M,C} + H_{C,O,SF,R} + H_{C,O,M,R}$$

b. To account for that portion of inland harvest that occurs downstream of streams for which production is being estimated, estimate portion of inland recreational harvest captured downstream of spawning streams ($H_{C,D,CV}$). Information necessary to estimate $H_{C,D,CV}$ may not be available. If an estimate exists, use it. If an estimate of inland harvest for the entire Central Valley exists ($H_{X,I,CV}$), then sum all assignable inland harvest ($\lessgtr H_{X,I,XX}$) and subtract it from $H_{X,I,CV}$ to determine $H_{C,D,CV}$. If other options exist, these should be explored. $H_{C,D,CV}$ could be assumed to be small and therefore left out of the calculations or could be included in $H_{X,I,XX}$, in which case it would already to assigned to an individual stream.

c. To determine ocean and downstream inland harvest for the Central Valley ($H_{C,O+D,CV}$), sum $H_{C,O,CV}$ and $H_{C,D,CV}$.

$$H_{C,O+D,CV} = H_{C,O,CV} + H_{C,D,CV}$$

d. To assign portions of $H_{C,O+D,CV}$ to specific races, subdivide $H_{C,O+D,CV}$ to each race, proportional to the portion of production for each race returning to the entire Central Valley ($P_{X,I,CV}$) to the portion of production for all races combined returning to the entire Central Valley ($P_{X,I,CV}$).

$$H_{X,O+D,CV} = H_{C,O+D,CV} \bullet (P_{X,I,CV}/P_{C,I,CV})$$

e. To assign portions of $H_{X,O+D,CV}$ to specific streams, subdivide $H_{X,O+D,CV}$ to each stream, proportional to the portion of production for that race returning to each stream ($P_{X,I,XX}$) to the portion of production for that race returning to the entire Central Valley ($P_{X,I,CV}$).

$$H_{X,O+D,XX} = H_{X,O+D,CV} \bullet (P_{X,I,XX}/P_{X,I,CV})$$

3. To determine total production for each race and stream ($P_{X,T,XX}$), sum $P_{X,I,XX}$ and $H_{X,O+D,XX}$.

$$P_{X,T,XX} = P_{X,I,XX} + H_{X,O+D,XX}$$

4. A portion of the total production was not produced naturally (*h*). For the baseline period, only hatchery-produced salmon will be considered to be produced by other than natural means. To determine the natural production for each individual stream ($P_{X,N,XX}$), multiply $P_{X,T,XX}$ by (1-*h*). Technical Teams should document options considered and chosen for estimation of *h* in issue papers that will be appended to the Program Plan or in the text for the Program Plan.

$$P_{X,N,XX} = P_{X,T,XX} \bullet (1-h)$$

Numeric restoration goals for chinook salmon in each stream will be calculated as at least double the average of $P_{X,N,XX}$ for each of the years during the baseline period.

Criteria for the future

In the future, opportunities exist to improve estimates of natural production. These range from augmenting historic data collection activities with efforts to estimate the proportion of fish that are naturally produced, to designing new data collection to better account for natural production. The Core Group and technical teams are responsible for designing future monitoring programs.

The Core Group and technical teams have and will identify deficiencies in the baseline data. Future monitoring activities will be designed to address and avoid deficiencies. For example, monitoring programs should focus on estimating production, including harvest, on a consistent and regular basis, preferably yearly, in all of the streams in the Central Valley.

Monitoring programs should also estimate natural production, requiring some means of separating naturally produced fish from fish produced by other than natural means. At the very least, natural production must be discernable from hatchery production. Several methods can be used to separate naturally produced fish from hatchery-produced fish, including use of scale (Scarnecchia and Wagner 1980) or otolith (Paragamian et al. 1992) characteristics and constant fractional (Hankin 1982) or complete marking of hatchery-produced fish (Wright 1993), including incorporation of genetic markers (Waples 1991), inducement of otolith banding patterns (Volk et al. 1990), and more standard methods such as clipping fins. In addition, recommendations for the future should include managing naturally and hatchery-produced fish separately.

In addition, better estimates of harvest of Central Valley salmon in the ocean and of all anadromous fish in the Bay, Delta, and in each individual river and stream in the Central Valley should be developed. Harvest should be monitored continually.

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B. Production targets for chinook salmon in each stream

Preliminary estimated production targets for chinook salmon. Data for rivers without a race designation are for fall-run chinook salmon.

Race and river	Production targets
All races combined[a]	990,000
Fall run	750,000
Late-fall run	68,000
Winter run	110,000
Spring run	68,000
Sacramento River	
Fall run	230,000
Late-fall run	44,000
Winter run	110,000
Spring run	59,000
Clear Creek	7,100
Cow Creek	4,600
Cottonwood Creek	5,900
Battle Creek	
Fall run	10,000
Late-fall run	550
Paynes Creek	330
Antelope Creek	720
Mill Creek	
Fall run	4,200
Spring run	4,400
Deer Creek	
Fall run	1,500
Spring run	6,500
Miscellaneous creeks	1,100
Butte Creek	
Fall run	1,500
Spring run	2,000
Big Chico Creek	800
Feather River	170,000
Yuba River	66,000
Bear River	450
American River	160,000
Mokelumne River	9,300
Cosumnes River	3,300
Calaveras River Winter run	2,200*
Stanislaus River	22,000
Tuolumne River	38,000
Merced River	18,000

[a]Targets for each of the races of chinook salmon may not add up to the target for all races combined due to rounding.

*Production target no longer valid as winter-run is not native production for fall-run chinook salmon yet to be determined.

C. Contacts and sources of information.

For information on the Anadromous Fish Restoration Program, contact:

Martin A. Kjelson, Program Manager
U.S. Fish and Wildlife Service
Anadromous Fish Restoration Program
Sacramento-San Joaquin Estuary Fishery Resource Office
4001 North Wilson Way
Stockton, CA 95205
(209) 946-6400
E-mail address: martin_kjelson@fws.gov

For information on the Central Valley Fish and Wildlife Restoration Program, including information on other sections of the CVPIA that contribute to fish and wildlife restoration, contact:

James J. McKevitt, Program Manager
U.S. Fish and Wildlife Service
Central Valley Fish and Wildlife Restoration Program
3310 El Camino Avenue
Sacramento, CA 95821
(916) 979-2760
E-mail address: jim_mckevitt@fws.gov

For information on the CALFED Bay-Delta Program's near-term efforts to restore anadromous fish in the Central Valley, especially funding for restoration actions, contact:

Cindy Darling or Kate Hansel, Restoration Coordinators
CALFED Bay-Delta Program
Restoration Coordination Program
1416 Ninth Street, Suite 1155
Sacramento, CA 95814
(916) 657-2666 or 653-1103
E-mail address: cdarling@water.ca.gov or hanselk@water.ca.gov

For information on the CALFED Bay-Delta Program's long-term plan for ecosystem restoration, contact:

Dick Daniel, Assistant Director or
Terry Mills, Ecosystem Restoration Program Plan Manager
CALFED Bay-Delta Program
Ecosystem Restoration Program Plan
1416 Ninth Street, Suite 1155
Sacramento, CA 95814
(916) 657-2666
E-mail address: ddaniel@water.ca.gov

For information on the California Department of Fish and Game's efforts to restore anadromous fish in the Central Valley, contact:

Alan Baracco
California Department of Fish and Game
Inland Fisheries Division
1416 Ninth Street
Sacramento, CA 95814
(916) 653-4729

Copies of Conservation Partnership: A Field Guide to Public-Private Partnering for Natural Resource Conservation may be obtained from:

U.S. Fish and Wildlife Service
Office of Training and Education
4401 North Fairfax Drive
Arlington, VA 22203
(703) 358-1711

or

National Fish and Wildlife Foundation
1120 Connecticut Avenue, NW, Suite 900
Washington, DC 20036
(202) 857-0166

Copies of California Coordinated Resource Management and Planning Handbook may be obtained from:

CRMP Coordinator
California Association of Resource Conservation Districts
801 K Street, Suite 1318
Sacramento, CA 95814
(916) 447-7237
FAX (916) 447-2532

D. Template for organization of detailed information on specific actions

The AFRP has developed a draft template containing the following information for each of the actions listed in the Restoration Plan.

Watershed or geographic area: Identifies the drainage or geographic area under which the action or evaluation description appears in the Restoration Plan. *(Where)*

Watershed priority: Lists the priority as designated in the Restoration Plan for the watershed or geographic area, if applicable.

Action (or evaluation): Includes the text for the action or evaluation as it appears in the Restoration Plan, including the number assigned to the action or evaluation. *(What)*

Location: Identifies the specific location(s), if applicable, of the action or evaluation. Include the stream mile(s), city(ies) and county(ies) in which the action or evaluation would be taken. *(Where)*

AFRP action (or evaluation) priority: Lists the priority relative to other actions and evaluations in the drainage, as it appears in the Restoration Plan.

Objective: Briefly states the objective(s) of the action or evaluation. Identifies species or race(s) of anadromous fish primarily affected and problem(s) solved by or intended effect(s) of the action or evaluation. *(Why).*

Description: Describes the action or evaluation in detail, including how the action or evaluation will be implemented. Cites any literature that may provide further detail. *(More detail on what and a description of how.)*

Background: Describes the existing information leading up to development of the action or evaluation, including discussion of alternative actions and of work done to date. Cites any literature that may provide further detail. *(More detail on why.)*

Justification: Describes the reasons for implementing the action or evaluation. Cites any literature that may provide further detail. *(More detail on why.)*

Monitoring needs: Identifies activities, including variables to observe, needed to evaluate the effectiveness of the action or to complete the evaluation.

Predicted biological benefits: Identifies anticipated biological benefits, preferably in quantitative terms, focusing on anadromous fish and their habitat.

Issues: Identifies factors potentially influencing initiation and completion of the action or evaluation. These issues may include design constraints, potential impacts of the action or evaluation on the economy or on other segments of the ecosystem, ability to evaluate the success of the action or evaluation, or the inability of partners to secure funding. This section will also include identification and discussion of actions or evaluations that may increase or decrease the effectiveness of the action or evaluation described here.

Involved parties: Lists parties involved in implementing the action or evaluation. *(Who)*

Environmental documentation: Lists environmental documentation and permitting necessary to complete the action or evaluation. For example, list should include whether or not an EA and negative declaration or FONSI, an EIR, an EIS, or Biological Opinion is required. It will also list any county or municipal permits that may be required.

Deliverables: Lists products (e.g., initial design and feasibility reports, environmental documentation, progress reports, physical structures, and monitoring reports) that have been or will be completed as part of implementation and monitoring.

Schedule: Lists time frame for key events (e.g., start and completion dates for deliverables and other major activities necessary for implementation and monitoring) in chart format. Potential for schedule revisions should be identified. *(When)*

Estimated cost to completion: Lists total costs from planning to completion, including permits, environmental documentation, and monitoring. Potential for schedule and budget revisions will be identified. Both one-time and continuing annual costs will be identified.

Funding: Identifies funding sources (e.g., CVP Restoration Fund, Category III, Four Pumps Mitigation Agreement, specific public or private group, or individual) and funds committed each year to completion. Sources of both one-time and continuing annual funds will be identified, as available.

Status: Describes stage of development and accomplishments, and future activities and milestones, and impediments.

CVPIA implementation tools: Identifies applicable section(s) of the CVPIA.

Action coordinators: Identifies the coordinator(s) designated as an action manager or point of contact for each of the involved parties. If a lead coordinator exists, then it will note which coordinator is assigned lead. *(Who)*

Sources of information: Lists literature cited and additional sources of information on the action.

Report date: Lists date that the information was last updated.

E. Summary of information used to prioritize watersheds.

Table E-1. Production target for chinook salmon, presence of CVP flow control structures or facilities, and race or species present in each of the watersheds[1] for which actions are listed in the Restoration Plan.

River	Chinook salmon production target	CVP influence	Winter run	Spring run	Steelhead	Late-fall run	San Joaquin fall run	Fall run	Green sturgeon	White sturgeon	Striped bass	American shad
Sacramento River	990,000	X	X	X	X	X		X	X	X	X	X
Clear Creek	7,100	X			X			X				
Cow Creek	4,600			X[2]	X			X				
Cottonwood Creek	5,900			X	X	X		X				
Battle Creek	10,550	X	X[3]	X	X	X		X				
Paynes Creek	330				X			X				
Antelope Creek	720			X	X	X		X				
Mill Creek	8,600			X	X	X		X				
Deer Creek	8,000			X	X	X		X				
Misc. creeks	1,100				X			X				
Butte Creek	3,500			X	X	X		X				
Big Chico Creek	800			X	X	X		X				
Feather River	170,000			X[4]	X			X	X	X	X	X

[1]The presence of races or species in each of the watersheds is derived from CDFG=s document titled Restoring Central Valley Streams: A Plan for Action, dated November 1993, and authored by F.L. Reynolds, T.J. Mills, R. Benthin, and A. Low. Exceptions are footnoted.

[2]Although spring-run chinook salmon are sporadically observed in the Cow Creek watershed, there is no current potential for sustaining their production because of natural barriers and lack of over-summering holding pool habitat.

[3]Winter-run chinook salmon on Battle Creek are of hatchery origin.

[4]The present Feather River Hatchery spring-run chinook salmon is a combination of fall-run and spring-run chinook salmon races (An evaluation of the Feather River Hatchery as mitigation for construction of the California State Water Project=s Oroville Dam, Brown and Greene, Environmental Services Office, CDWR, 1995).

River	Chinook salmon production target	CVP influence	Winter run	Spring run	Steelhead	Late-fall run	San Joaquin fall run	Fall run	Green sturgeon	White sturgeon	Striped bass	American shad
Yuba River	66,000			X	X			X				X
Bear River	450				X			X	X	X		
American River	160,000	X			X			X			X	X
Mokelumne River	9,300				X			X			X	X
Cosumnes River	3,300							X				
Calaveras River	2,200		X					X				
Merced River	18,000				X	X	X					
Tuolumne River	38,000				X[5]	X	X					
Stanislaus River	22,000	X			X	X	X				X	X
San Joaquin River	---	X					X		?	X	X	X
Sacramento-San Joaquin Delta	---	X	X	X	X	X	X	X	X	X	X	X

River	Chinook salmon production target	CVP influence	Winter run	Spring run	Steelhead	Late-fall run	San Joaquin fall run	Fall run	Green sturgeon	White sturgeon	Striped bass	American shad
Sacramento River Joaquin Delta	---	X	X	X	X	X	X	X	X	X	X	X

[5] Steelhead were observed in the Tuolumne River in 1983 (Bill Loudermilk, CDFG Senior Fishery Biologist, personal communication, and In CDFG, Steelhead restoration and management plan for California, D. McEwan and T.A. Jackson, 1996).

F. Projected funding resources.

The CVP Restoration Fund, along with additional agency and other partner funds, if available, will be used to implement the AFRP restoration actions. Funds available from the CVP Restoration Fund to the AFRP for actions, evaluations, monitoring and assessment during the 1997 federal fiscal year (FY97) totaled $10 million, and is expected to continue at about $8 to $10 million for each of the years in FY98 to FY2002. Additional Restoration Fund dollars carried over from previous years are also available to supplement AFRP funds, if needed. In addition, the Restoration Fund provides sufficient flexibility to move funds to areas of greatest need, subject to certain limitations. Specific funding allocations and estimates are described each year in annual work plans for the AFRP and in similar work plans for each of the other programs conducted pursuant to the CVPIA.

G. List of acronyms and abbreviations.

Acronym or abbreviation	Description
af	acre-feet
AFRP	Anadromous Fish Restoration Program, established by Section 3406(b)(1) of the CVPIA
AFS	American Fisheries Society
(b)(2) water	Water managed pursuant to 3406(b)(2), sometimes referred to as the 800,000 af or dedicated water
Bay-Delta	San Francisco Bay and Sacramento-San Joaquin Delta Estuary
BCWC	Butte Creek Watershed Conservancy
Bay-Delta Agreement	15 December 1994, Principles of Agreement on Bay-Delta Standards between the State of California and the Federal Government
BLM	Bureau of Land Management
CALFED	A California and federal multi-agency partnership
CALFED agencies	California California Environmental Protection Agency State Water Resources Control Board The Resources Agency Department of Fish and Game Department of Water Resources Federal Department of Commerce National Marine Fisheries Service Department of the Interior Bureau of Reclamation Fish and Wildlife Service Environmental Protection Agency
CAMP	Comprehensive Assessment and Monitoring Program, established by Section 3406(b)(16) of the CVPIA
CCRMP	California Coordinated Resource Management and Planning
CCWD	Calaveras County Water District
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources

Acronym or abbreviation	Description
CEQA	California Environmental Quality Act
CNFH	Coleman National Fish Hatchery
COE	Corps of Engineers
Core Group	AFRP Core Group
CSLC	California State Lands Commission
cfs	cubic feet per second
CVFWRP	Central Valley Fish and Wildlife Restoration Program
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCWC	Deer Creek Watershed Conservancy
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin Delta
EBMUD	East Bay Municipal Utility District
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
GCID	Glenn-Colusa Irrigation District
IEP	Interagency Ecological Program for the Sacramento-San Joaquin Estuary
IEP agencies	California California Environmental Protection Agency State Water Resources Control Board The Resources Agency Department of Fish and Game Department of Water Resources Federal Department of Commerce National Marine Fisheries Service Department of Defense Army Corps of Engineers Department of the Interior

Acronym or abbreviation	Description
	Bureau of Reclamation Fish and Wildlife Service Geological Survey Environmental Protection Agency
Interior	Department of the Interior
maf	million acre-feet
MCC	Mill Creek Conservancy
MID	Modesto Irrigation District
MIEB	Management Institute for Environment and Business
MOU	Memorandum of Understanding
NEPA	National Environmental Protection Act
NMFS	National Marine Fisheries Service
NPS	National Park Service
NRCS	Natural Resources Conservation Service
PCB	Polychlorinated biphenyl
PEIS	Programmatic Environmental Impact Statement
PFMC	Pacific Fishery Management Council
PG&E	Pacific Gas and Electric
POA	Plan of Action for the Central Valley Anadromous Fish Restoration Program
Position Paper	Position Paper for Development of the Central Valley Anadromous Fish Restoration Program (Appendix A)
RBDD	Red Bluff Diversion Dam
RCD	Resource Conservation District
Restoration Fund	CVP Restoration Fund, established by Section 3407 of the CVPIA
Restoration Plan	AFRP Restoration Plan
RWQCB	Regional Water Quality Control Board
SAFCA	Sacramento Area Flood Control Association
SB 1086	Senate Bill 1086

Acronym or abbreviation	Description
SAWF	Sacramento Area Water Forum
Secretary	Secretary of the Interior
SEWD	Stockton East Water District
SSWD	South Sutter Water District
SWP	State Water Project
SWRCB	State Water Resources Control Board
taf	thousand acre-feet
TCCA	Tehama -Colusa Canal Authority
TID	Turlock Irrigation District
TNC	The Nature Conservancy
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USRFRHAC	Upper Sacramento River Fisheries and Riparian Habitat Advisory Council
WCWD	Western Canal Water District
WID	Woodbridge Irrigation District
Working Paper	Working Paper on Restoration Needs
WQCP	Water Quality Control Plan
WRCB	Water Resources Control Board
YCWA	Yuba County Water Agency

Working Paper on Restoration Needs

Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California

Volume 1

WORKING PAPER ON RESTORATION NEEDS

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TO DOUBLE NATURAL PRODUCTION OF ANADROMOUS FISH
IN THE CENTRAL VALLEY OF CALIFORNIA

Volume 1

Prepared for the U.S. Fish and Wildlife Service
under the direction of the
Anadromous Fish Restoration Program Core Group

May 9, 1995

ORGANIZATION OF THIS WORKING PAPER

This is Volume 1 of three volumes that comprise the Anadromous Fish Restoration Program (AFRP) Working Paper on Restoration Needs. The contents of the three volumes are as follows:

> **Volume 1** describes how the WORKING PAPER was developed, explains the process envisioned for completing a final Restoration Plan, and summarizes the production goals, limiting factors, and restoration actions sections developed by the AFRP technical teams. Interested parties should read the letter from Dale Hall and Wayne White that appears at the beginning of Volume 1.
>
> **Volume 2** provides descriptions of Central Valley rivers and streams, summarizes information on historic and existing conditions for anadromous fish, identifies the problems that have led to the decline of anadromous fish populations, and identifies roles and responsibilities of state and federal agencies in managing anadromous fish. It also includes two key documents that were used by the AFRP Core Group and technical teams to develop the WORKING PAPER.
>
> **Volume 3** includes the complete production goals, limiting factors, and restoration actions sections as submitted by the AFRP technical teams and edited by USFWS staff. Volume 3 also includes citations for all three volumes of the WORKING PAPER.

To request copies of this Working Paper, call the AFRP=s information line at (800) 742-9474 or (916) 979-2330 and dial extension 542 after the recorded message begins. You may also obtain copies by calling Roger Dunn, CVPIA Public Outreach, at (916) 979-2760 or by sending e-mail requests to roger_dunn@fws.gov. The Working Paper is available to be viewed and downloaded on the Internet at http://darkstar.dfg.ca.gov/usfws/fws_home.html.

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United States Department of the Interior

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MEMORANDUM April 14, 1995

To: Dale Hall, ARD,
Ecological Services, Portland

Wayne White
State Supervisor-California

From: Core Group Membership, Anadromous Fish Restoration Program (AFRP)
Central Valley Project Improvement Act (CVPIA)

Subject: Transmittal of working paper describing habitat restoration actions to double production of anadromous fish in the central valley of California

The attached working paper describes the habitat restoration actions the Core Group believes necessary to at least double the production of anadromous fish in the Central Valley, as required by Section 3406(b)(1) of the CVPIA.

We believe that this paper is a necessary technical platform upon which the participating agencies and the public can work cooperatively to achieve a sound, reasonable and implementable program.

This paper was developed by eight technical teams composed of experts possessing specific technical and biological knowledge of Central Valley drainages and anadromous fish stocks. Revisions by the Core Group and Service staff were primarily designed to improve readability and consistency in the document and to assure the restoration actions were justified as fully as possible on technical and biological merits.

The paper is the culmination of the initial phase of Program development. Using this working paper as baseline information, future efforts will evaluate the implementability and reasonableness of the actions described herein and other actions suggested by stakeholders and the interested public to finalize and implement the Anadromous Fish Restoration Program by October 31, 1995. A Preface to the paper describes the process of program development, and explains that reasonableness was not considered in developing the actions needed to double anadromous fish production.

While the Core Group members representing participating state (DFG and DWR) and federal (FWS, USBR, NMFS and EPA) agencies believe the paper provides a sound technical background from which to develop the final program, it does not mean that there is total agreement on the benefits of restoration actions either alone or in combination. Nor is there a commitment by any member or agency to implement any of the restoration actions noted herein.

We envision that each core agency will continue to participate in developing a sound and reasonable habitat restoration program in cooperation with key stakeholders and the interested public.

Martin A. Kjelson
Program Manager

United States Department of the Interior

FISH AND WILDLIFE SERVICE
911 N. E. 11th Avenue
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IN REPLY REFER TO:

April 27, 1995

Memorandum

To: Interested Parties

From: Assistant Regional Director, Ecological Services
Region 1, Portland, Oregon

State Supervisor, Ecological Services
Sacramento, California

Subject: The Consideration of "Reasonable Efforts" in Developing the Anadromous Fish Restoration Program (Section 3406(b)(1) of the Central Valley Project Improvement Act)

The purpose of this memorandum is to convey the U.S. Fish and Wildlife Service's position on the reasonableness of actions presented in the attached Anadromous Fish Restoration Program Working Paper (Working Paper) developed by fishery experts from throughout the Central Valley.

The Working Paper represents the best available information on the level of restoration needed to meet the goal of at least doubling natural production of anadromous fishes. No attempt was made by the technical experts to determine if these actions are reasonable or desirable based on the potential social or economic impacts. We are providing this Working Paper as a starting point so we can understand the biological needs as we collectively develop a draft Anadromous Fish Restoration Program (Restoration Program).

As we enter the development phase of the restoration program, the Service is committed to working with stakeholders and the interested public to develop a reasonable, implementable restoration plan that balances the needs of anadromous fish with those of all parties that have an interest in the wise management of California's natural resources.

In our review of the Working Paper we have identified habitat restoration actions that we believe are unreasonable such as: 1) setting fish flow standards that consistently require unimpaired flows; 2) dismantling major water storage reservoirs; and 3) restricting total delta exports to low levels for most of the year. During the development of the draft Restoration Plan, the Service working with the stakeholders may determine other actions to be unreasonable or we may develop additional actions that are reasonable.

It is important to emphasize that the Secretary of the Interior's final decision on which restoration actions should be implemented will be influenced by a variety of factors. These include input and cooperation from the involved public and governmental agencies, results of the programmatic environmental impact statement, the benefit per unit cost, the monetary resources in the restoration fund and the availability of supplemental water for purchase. The fact that actions authorized by the CVPIA are restricted to CVP streams and facilities alone and that other restoration measures will require cooperation from other federal, state and private entities to be implemented will help assure that the final Program will be reasonable.

In summary, this statement is intended to assure all interested parties that the Service is committed to developing a plan that is reasonable and will make significant progress toward doubling natural production of anadromous fish. The CVPIA, in combination with other ongoing restoration activities, offers an unprecedented opportunity to correct the fishery, wildlife, and habitat problems we face in the Central Valley. We invite and encourage your involvement and cooperation to assure successful development and implementation of the Anadromous Fish Restoration Program.

PREFACE

The Central Valley Project Improvement Act (CVPIA), requires the Secretary of the Interior to develop and implement Aa program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991@ (Section 3406[b][1]). This program is under development and is known as the Anadromous Fish Restoration Program (AFRP).

This working paper is the culmination of the initial phase of development of a final AFRP plan. The paper presents a package of habitat restoration actions that, if implemented, would achieve the goal of at least doubling natural production. It was developed to provide a platform on which the participating agencies and the public will develop actions to include in the final plan. Reasonableness was not considered in developing this working paper. For the final plan, reasonable actions will be selected from those described in this working paper and additional actions suggested by the public, including stakeholders, other interested parties, and public and private agencies.

This preface describes how the working paper was developed, how the final AFRP plan will be developed, and the process by which Areasonable efforts@ will be identified and included in the final plan.

The final AFRP plan is scheduled for completion by October 31, 1995. The AFRP is proceeding in three general phases: 1) production of the working paper, 2) production of the final AFRP plan, and 3) implementation of the plan.

PRODUCTION OF THE WORKING PAPER

The first phase covers the past efforts up to the release of this working paper. During this period, a coalition of senior fish experts from the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, National Marine Fisheries Service, U.S. Environmental Protection Agency, California Department of Fish and Game, and California Department of Water Resources--the ACore Group@--directed the development of the working paper. The Core Group formed eight AFRP technical teams. These teams consisted of experts from state and federal agencies, private industry, and academia with specific knowledge of anadromous fish species in Central Valley rivers and streams. They developed the restoration actions described in this working paper. The AFRP Core Group and USFWS staff then worked with the technical teams to revise the information based on the technical merits of the actions in meeting the restoration goals and to standardize format and improve readability. Additional guidelines used to develop this paper are found in the *CVPIA*, the *Plan of Action for the Central Valley AFRP*, and the *Draft Position Paper for Development of the AFRP*.

To arrive at the most conservative recommendations needed to double natural production of Central Valley anadromous fish stocks, and knowing that reasonableness would be addressed later by a broader group, the Core Group directed the technical team members to consider only the scientific basis for their recommended actions and to recommend actions whose implementation would ensure that production of anadromous fish would at least double.

It was clear early in the process of developing the working paper that predicting the benefits of specific restoration actions would be limited by available data. For example, fish population estimates were developed during the baseline period for other management purposes, and not for developing restoration goals. Despite the limitations, we believe the data, along with management models and the highly respected professional opinions of the many involved fishery experts, provide sound technical bases for the actions contained in this document.

Overall, the package of actions presented in this paper does not yet represent a fully integrated plan (e.g., integration of upstream and Delta actions has not been done in this paper). Most flow recommendations have been screened to ensure that they do not exceed unimpaired runoff or limits imposed by reservoir storage capacity. In some cases, the flow-carryover storage relationships have been evaluated to balance the needs of different fish species or stocks. Coordination with the programmatic environmental impact statement (PEIS) team has been helpful to clarify and resolve these issues. Further integration and balancing are required to develop a comprehensive program that meets the full intent of the CVPIA.

This working paper gives a clear picture of the types and levels of restoration actions necessary to achieve the goal of doubling natural production of Central Valley anadromous fish. By using this working paper as baseline information, future efforts, including public participation, will evaluate the reasonableness of actions.

PRODUCTION OF THE FINAL AFRP PLAN

The second phase begins with release of the working paper and will extend to completion of the final AFRP plan. In this phase, we will prioritize restoration actions and determine what the interested parties and agencies consider reasonable efforts. Determination of reasonableness will rely on public participation and on the independent analyses of social, economic, and environmental impacts conducted by the PEIS team. Reasonable actions will be selected from actions specified in this working paper and additional actions suggested by the public, including stakeholders, other interested parties, and public and private agencies.

Priority will primarily be based on benefits, costs, and feasibility of restoration actions. High priority will be assigned to actions that have the greatest potential to enhance production of anadromous fish at the least cost.

The final AFRP plan will include the habitat restoration actions mandated by the CVPIA in Section 3406 and under the authority of the Secretary of Interior and additional actions deemed reasonable efforts. We believe the mandated actions will improve survival and production of Central Valley anadromous fish but will not double production without implementation of additional actions specified in this paper.

IMPLEMENTATION OF THE PLAN

The third phase covers implementation and monitoring of the restoration actions and is discussed in more detail under the heading AImplementation Considerations@ in Section I, AIntroduction@. This period will extend beyond October 31, 1995. We envision that implementation of the actions authorized by the CVPIA will occur in phases due to limitations of time, resources, knowledge, funding, and the need to address many complex issues surrounding the implementation of the CVPIA. Phased implementation will provide opportunities for the public; private, public, and government agencies; and other interested parties to participate throughout the implementation process.

In addition, the Secretary of Interior has limited authority to implement the actions described in this working paper. Implementation of a comprehensive program will require the support and participation of the public; private, public, and government agencies; and other interested parties who have the authority to implement those actions not under authority of the Secretary. Limited authority reinforces the need for public support to help ensure that the actions in the final AFRP plan will be reasonable.

As implementation of the restoration actions continues, monitoring plans will be designed to assess the biological results and effectiveness of the habitat restoration actions. Results of efforts to monitor the effectiveness of the first actions to be implemented may be used to modify actions that will be implemented later. To avoid duplication and use available resources wisely, monitoring for the AFRP will be coordinated with the Comprehensive Assessment and Monitoring Program 3406 (b)(16) and other efforts to monitor anadromous fish in the Central Valley and Bay/Delta.

REQUEST FOR COMMENT AND PARTICIPATION

We request timely, constructive comment on this paper from those representing the many public and private interests involved with the CVPIA and the AFRP. Many interested parties have already had the opportunity to comment on our *Plan of Action*, *Draft Position Paper*, and the California Department of

Fish and Game's *Book of Numbers* and to participate in public workshops. Your participation is critical to successful development of the final plan.

We have five requests of each reviewer. First, we ask that you review the working paper for technical accuracy. If you observe factual errors, please provide corrections and support for your corrections so that we can use that information in the final AFRP plan. Second, you may find that an alternative set of actions can achieve the same goals as the package of restoration actions described in this working paper. Again, describing such alternatives and the justification to support their validity is important. Third, we are looking for opportunities to better integrate the upstream and Delta actions and invite assistance in this complex process. Fourth, quantifying the benefits of restoration actions is difficult, both individually and in combination. If you have additional information on the efficacy of specific actions, we would find that information useful. Fifth, while not addressed in this working paper, it is important that you convey to us how the implementation of the proposed actions, including criteria for reasonableness, would be most effectively addressed to achieve the goals of the CVPIA. Your suggested approaches to this important process will help all of us in efficiently planning and developing the final plan.

RESPONSIBILITIES

This working paper and the final AFRP plan are the responsibility of the USFWS as lead agency for the AFRP. The USFWS is indebted to the assistance of the technical teams and Core Group members; however, this working paper does not necessarily reflect a commitment by any member's agency or organization to implement any of the restoration actions noted herein. In that light, the reader should view this paper as a reference document whose contents will be modified and improved as we move toward the completion of a final, comprehensive restoration plan. Successful completion of the final plan will depend on the continued guidance of the Core Group and technical team members, participation of the public and interested parties, and support of involved state and federal agencies.

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SECTION I. INTRODUCTION TO THE WORKING PAPER

CENTRAL VALLEY PROJECT IMPROVEMENT ACT

This Working Paper discusses habitat restoration actions believed necessary to double the natural production of chinook salmon, steelhead, striped bass, American shad, and white and green sturgeon in the rivers and streams of California's Central Valley. The legal guidelines used to develop this paper can be found in the implementing legislation of the Central Valley Project Improvement Act (CVPIA), which is described below.

On October 30, 1992, the President signed into law the Reclamation Projects Authorization and Adjustment Act of 1992 (Public Law 102-575), including Title XXXIV, the CVPIA. The CVPIA amends the authorization of the Department of the Interior's California Central Valley Project (CVP) to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic uses and fish and wildlife enhancement as a purpose equal to power generation. The CVPIA identifies several specific measures to meet these new purposes and sets a broad goal of sustaining natural populations of anadromous fishes produced in Central Valley rivers and streams at double their recent average levels. The CVPIA also directs the Secretary of the Interior to operate the CVP consistent with these purposes, to meet the federal trust responsibilities to protect the fishery resources of affected federally recognized Indian tribes, and to meet all requirements of federal and California law.

The Department of the Interior is developing policies and programs to modify the operations, management, and physical facilities of the CVP to comply with the purposes and goals of the CVPIA and the revised purposes of the CVP. These policies and programs will define operational criteria and management and structural priorities for the CVP. The general purposes of the CVPIA, and of the action proposed by the Secretary of the Interior, were identified by Congress in Section 3402:

(a) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California;

(b) to address impacts of the CVP on fish, wildlife, and associated habitats;

(c) to improve the operational flexibility of the CVP;

(d) to increase water-related benefits provided by the CVP to the State of California through expanded use of voluntary water transfers and improved water conservation;

> (e) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta estuary; and
>
> (f) to achieve a reasonable balance among competing demands for use of CVP water, including the requirements of fish and wildlife, agriculture, municipal and industrial, and power contractors.

In addition, the CVPIA includes several specific and general measures, including the requirement to double natural production of anadromous fish, that, when implemented, will satisfy the purposes of the CVPIA and the revised purposes of the CVP.

These purposes respond to the need to improve the existing water management practices of the CVP. Fish and wildlife populations and the condition and extent of their habitats have declined drastically from historical levels. Construction and operation of the CVP have contributed to these declines and to the decline in water quality and other environmental conditions in the Sacramento-San Joaquin Delta (Delta). In recent years, the pattern of demand for water in California has changed; in particular, municipal and industrial demand has increased. Under previous laws and existing policies, CVP operations have been constrained from fully responding to these changing demands and priorities. As a result, existing operations do not display adequate flexibility or reflect a reasonable balance among competing demands. Despite these adverse effects, CVP facilities offer tremendous opportunities to restore fish populations and their associated habitats in numerous major California waterways. These opportunities are fully embodied in the CVPIA.

SECTION 3406

This document was developed under the authority of HR 429, Title 34 - Central Valley Project Improvement Act, and specifically Section 3406(b)(1):

> FISH AND WILDLIFE RESTORATION ACTIVITIES - The Secretary, immediately upon enactment of this title, shall operate the Central Valley Project to meet all obligations under state and federal law, including but not limited to the federal Endangered Species Act, 16 U.S. ' 1531, et seq., and all decisions of the California State Water Resources Control Board establishing conditions on applicable licenses and permits for the project. The Secretary, in consultation with other State and Federal agencies, Indian tribes, and affected interests, is further authorized and directed to:
>
> (1) develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-

1991; Provided, That this goal shall not apply to the San Joaquin River between Friant Dam and the Mendota Pool, for which a separate program is authorized under subsection 3406(c) of this title; Provided further, That the programs and activities authorized by this section shall, when fully implemented, be deemed to meet the mitigation, protection, restoration, and enhancement purposes established by subsection 3406(a) of this title; And provided further, That in the course of developing and implementing this program the Secretary shall make all reasonable efforts consistent with the requirements of this section to address other identified adverse environmental impacts of the Central Valley Project not specifically enumerated in this section.

(A) This program shall give first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations, and implementation of the supporting measures mandated by this subsection; shall be reviewed and updated every five years; and shall describe how the Secretary intends to operate the Central Valley Project to meet the fish, wildlife, and habitat restoration goals and requirements set forth in this title and other project purposes.

(B) As needed to achieve the goals of this program, the Secretary is authorized and directed to modify Central Valley Project operations to provide flows of suitable quality, quantity, and timing to protect all life stages of anadromous fish, except that such flows shall be provided from the quantity of water dedicated to fish, wildlife, and habitat restoration purposes under paragraph (2) of this subsection; from the water supplies acquired pursuant to paragraph (3) of this subsection; and from other sources which do not conflict with fulfillment of the Secretary's remaining contractual obligations to provide Central Valley Project water for other authorized purposes. Instream flow needs for all Central Valley Project controlled streams and rivers shall be determined by the Secretary based on recommendations of the U.S. Fish and Wildlife Service after consultation with the California Department of Fish and Game.

(C) The Secretary shall cooperate with the State of California to ensure that, to the greatest degree practicable, the specific quantities of yield dedicated to and managed for fish and wildlife purposes under this title are credited against any additional obligations of the Central Valley Project which may be imposed by the State of California following enactment of this title, including but not limited to increased flow and reduced export obligations which may be imposed by the California State Water Resources Control Board in implementing San Francisco Bay/Sacramento-San Joaquin Delta Estuary standards pursuant to the review ordered by the California Court of Appeals in U.S. v. State Water Resources

Control Board, 182 Cal.App.3rd 82 (1986), and that, to the greatest degree practicable, the programs and plans required by this title are developed and implemented in a way that avoids inconsistent or duplicative obligations from being imposed upon Central Valley Project water and power contractors.

(D) Costs associated with this paragraph shall be reimbursable pursuant to existing statutory and regulatory procedures.

IMPLEMENTATION CONSIDERATIONS

Three aspects of implementation are considered here: 1) prioritizing actions, 2) tools available to the Secretary of Interior for implementing actions, and 3) schedule for implementation. The implementation process provides an opportunity to ensure that the restoration actions taken are reasonable.

Prioritizing Actions

Setting priorities for actions will require public participation. Most prioritization should occur before the AFRP plan is completed. To set priorities for actions, criteria for assigning priority to actions must be developed. These criteria should assign high priority to actions that are likely to provide the greatest benefit to production of anadromous fish, especially those actions that protect and restore natural channel and riparian habitat values. Other criteria may include assigning high priority to actions that improve the habitat of species that are endangered, threatened, or of special concern; that improve production of multiple species; that can be implemented rapidly; that and the Secretary has authority or cooperation from others to implement. Actions that are not considered Areasonable efforts@ should not be assigned high priority.

Because not all actions can be implemented simultaneously, an attempt will be made to implement high-priority items first. Monitoring the success of implemented actions will provide information that will help reevaluate priorities for remaining actions. The implementation schedule should be flexible so that unique opportunities to implement actions can be taken advantage of, even if these actions are not the highest priority actions. Because implementation will continue well past the date the AFRP plan is completed, and because public participation will be necessary to implement many actions needed to double production of anadromous fish, participation will continue throughout the implementation process.

Tools Available to the Secretary of Interior for Implementing Actions

Tools in the CVPIA - The USFWS anticipates that the tools available to the Secretary of the Interior for achieving the goals of the AFRP include implementing all sections of the CVPIA. Sections 3406(b)(2) through (21) of the CVPIA authorize and direct the Secretary of Interior to take specific actions. These actions have been categorized as structural modifications, water management modifications, and operational modifications. Two elements do not fit these categories: element (b)(16), the comprehensive monitoring program, and element (b)(19), a reevaluation of carryover storage criteria. A brief description of the elements in each of the three categories is listed below. Further details are provided in the CVPIA.

Structural modifications -

3406(b)(4) - Mitigate for Tracy Pumping Plant operations.

3406(b)(5) - Mitigate for Contra Costa Canal Pumping Plant operations.

3406(b)(6) - Install temperature control device at Shasta Dam.

3406(b)(10) - Minimize fish passage problems at Red Bluff Diversion Dam.

3406(b)(11) - Implement Coleman National Fish Hatchery Plan and modify Keswick Dam Fish Trap.

3406(b)(12) - Improve fish passage and restore habitat in Clear Creek.

3406(b)(13) - Replenish spawning gravel and restore riparian habitat below Shasta, Folsom, and New Melones Reservoirs.

3406(b)(14) - Install new control structures at Delta Cross Channel and Georgiana Slough.

3406(b)(15) - Install barrier at head of Old River.

3406(b)(17) - Resolve fish passage and stranding problems at Anderson-Cottonwood Irrigation District Diversion Dam.

3406(b)(20) - Mitigate for the Glenn-Colusa Irrigation District=s Hamilton City Pumping Plant.

3406(b)(21) - Adequately screen diversions.

Water management modifications -

3406(b)(1)(B) - Modify CVP operations.

3406(b)(2) - Manage 800,000 af of CVP yield for fish, wildlife, and habitat restoration purposes.

3406(b)(3) - Acquire water to supplement the quantity of water dedicated for fish and wildlife water needs under (b)(2), including modifications of CVP operations; water banking; conservation; transfers; conjunctive use; and temporary and permanent land fallowing, including purchase, lease, and option of water, water rights, and associated agricultural land.

3406(b)(7) - Meet flow standards that apply to CVP.

3406(b)(8) - Use pulse flows to increase migratory fish survival.

3406(b)(12) - Provide increased flows in Clear Creek.

3406(b)(18) - Restore striped bass fishery in Bay/Delta.

Operational modifications -

3406(b)(1)(B) - Modify CVP operations.

3406(b)(4) - Mitigate for Tracy Pumping Plant operations.

3406(b)(5) - Mitigate for Contra Costa Canal Pumping Plant operations.

3406(b)(7) - Meet diversion limits that apply to the CVP.

3406(b)(9) - Eliminate fish losses due to flow fluctuations of CVP.

3406(b)(10) - Minimize fish passage problems at Red Bluff Diversion Dam.

3406(b)(14) - Improve operations at Delta Cross Channel and Georgiana Slough.

3406(b)(17) - Resolve fish passage and stranding problems at Anderson-Cottonwood Irrigation District Diversion Dam.

3406(b)(20) - Mitigate for GCID's Hamilton City Pumping Plant.

The CVPIA establishes the ACentral Valley Project Restoration Fund@ and gives the Secretary the authority to use the fund Ato carry out the habitat restoration, improvement and acquisition (from willing sellers) provisions@ of the CVPIA (Section 3407), including the actions listed above.

Tools for use on CVP vs. non-CVP streams - Tools available to the Secretary to implement actions on streams where flows are controlled primarily by CVP structures are greater than the tools available on streams where flows are not controlled by CVP structures. For example, modification of CVP operations and use of the 800,000 acre-feet are limited to CVP-controlled streams. The CVP-controlled streams include the Sacramento, American, Stanislaus, and San Joaquin rivers (although restoration of anadromous fish habitat on the San Joaquin River is limited to that section downstream of Mendota Pool). There are a number of entities involved or affected by the management of water supplies on these rivers.

Non-CVP controlled streams include Battle, Mill, Deer, Butte, Stony, Elder, and Thomas creeks and Feather, Yuba, Bear, Cosumnes, Mokelumne, Calaveras, Tuolumne and Merced rivers, as well as the Delta. Private land owners, public and private irrigation districts, utilities, the State Water Project, and municipalities and industry manage facilities and flows on these streams. The CVPIA does not provide the Secretary with the direct authority to implement actions on these streams.

Cooperation with others - To implement actions on streams or at facilities where the Secretary does not have authority, the Secretary will need the cooperation of the entities with the authority to implement the actions. These entities include SWRCB, the Federal Energy Regulation Commission (FERC), and others that may or do establish diversion restrictions and minimum flow requirements. Other regulatory processes under DFG, EPA, NMFS, the Corps, and other state, federal, county, and local agencies have significant potential to influence the implementation of specific restoration actions in the AFRP. Efficient and timely coordination and strong cooperative efforts with these organizations are essential to implement a comprehensive AFRP.

In addition, the "Principles for Agreement on Bay/Delta Standards between the State of California and the Federal Government", signed on December 15, 1994, has potential to supplement restoration actions in the CVPIA. Category III of the agreement provides for private funding of nonflow actions to improve fish protection. This element of the agreement is to be implemented immediately (1995) and the development of specific actions is currently in progress. Other ongoing restoration or mitigation efforts include the four pumps agreement (DWR and DFG 1986) and DFG efforts described in ARestoring Central Valley Streams: A Plan for Action@ (Reynolds et al. 1993) and the subsequent implementation report (DFG 1995). All of these activities contribute to restoration of anadromous fish habitat in the Central Valley and each of them is implementing actions described in the Working Paper. The challenge for the AFRP is to assist and augment these activities.

Schedule for Implementation

Limitations due to time restrictions, lack of money in the restoration fund, legal and administrative constraints, and the need to balance actions to meet other goals of the CVPIA, among others, will require that actions be implemented in phases. Given these limitations, it is difficult to predict how rapidly we can proceed with implementing actions.

The first restoration actions to be implemented are envisioned to be a combination of those mandated in the CVPIA and other non-CVP actions. Actions requiring structural, water management, and operational modifications are discussed below. For each of these categories, actions for which tools are provided in the CVPIA are discussed first, and actions for which tools other than those provided directly by the CVPIA (those actions that would need to be implemented through other authorities) are discussed second.

Structural modifications - Of the sections of the CVPIA categorized above as structural modifications, most could be implemented soon if given a high priority for use of restoration funds. Several have already been implemented, at least in part, or are being designed. These include mitigating for the Tracy fish facilities (b)(4); constructing the temperature control device at Shasta Dam (b)(6); minimizing fish passage problems at RBDD (b)(10); implementing CNFH Plan (b)(11); replenishing gravel below CVP reservoirs (b)(13); installing a (sound) barrier at Georgiana Slough (b)(14); installing a (temporary) barrier at the head of Old River (b)(15); and mitigating for GCID=s Hamilton City Pumping Plant (b)(20). Replenishing gravel below CVP reservoirs (b)(13) will be a continuous process and will take time to significantly restore habitat.

As noted earlier, a major potential to implement structural modifications in the near term may be provided through coordination with the actions carried out under Category III of the principles for agreement on Bay/Delta standards.

Water management modifications - Modifications to CVP operations to provide flows of suitable quality, quantity, and timing to protect all life stages of anadromous fish (b)(1)(B) are currently being implemented although there is potential for improvement with further effort and evaluation of the benefits achieved. These modifications affect CVP-controlled streams and the Delta.

Management of the 800,000 af for fishery and habitat restoration (b)(2) has been ongoing since 1993. This element has been affected by the Bay/Delta Framework Agreement, in that the CVP obligation for Delta flow needs is provided from the 800,000 af. Hence, the remaining portion of the 800,000 af of CVP yield will be available for the needs of the AFRP. The Bay/Delta agreement is to be in effect for the next 3 years.

Some amount of the restoration fund is available to acquire supplemental water supplies (b)(3) for use by the AFRP. This element stipulates the need to define how the Secretary intends to use CVP operational modifications; water banking, conservation, transfer, conjunctive use, and land fallowing. Land fallowing includes purchase and lease of agricultural lands and acquisition of associated water and water rights options. The acquisition of supplemental water would be effective in the Delta and would provide added tributary flows in both CVP and non-CVP Central Valley streams. Success of water acquisition in the near term will be influenced by the availability of restoration funds and the willingness of sellers to provide water for fishery purposes. Acquisition of supplemental water supplies brings in the major stakeholders in the water user community. Success in gaining supplemental water supplies for fishery restoration will depend on how well all parties can work together and cooperate.

Other actions from the CVPIA relate to flow standards required to be met by the CVP (b)(7) and pulse flows to increase migratory fish survival (b)(8). Both are ongoing under the Bay/Delta agreement, which requires the CVP and SWP to meet flow standards, export-to-inflow ratios, pulse flows, and Delta Cross Channel operational criteria. These actions are designed to provide fish protection sufficient for currently listed threatened and endangered species and to avoid additional listings.

Finally, there are ongoing regulatory processes by FERC and the SWRCB that may establish new minimum flow mitigation requirements for the Yuba, Mokelumne, and Tuolumne rivers in the near future. These processes provide improved tributary flows and Delta inflow, further aiding implementation of the restoration actions.

Operational modifications - Most of the operation modification elements of the CVPIA (b)(1[B],4,5,7,9,10,14,17 and 20) are currently being implemented to some extent although there is potential for improvements with further effort and evaluation of the benefits achieved. There is also potential for operational modifications on non-CVP streams that would provide benefits to anadromous fish.

EVALUATION OF FLOW NEEDS

To aid the reader in appreciating the complexity of defining flow needs for anadromous fish restoration, we have provided discussion of several key aspects of this issue.

Relations between Flows and Anadromous Fish Populations

The assumption that there is a relationship between river flow and anadromous fish populations may have initially stemmed from the observation that large rivers maintained large runs of fish, medium-sized rivers held medium-sized runs, and small streams produced relatively few fish, even in very wet years. A common-sense explanation is that there is relationship between the size of a river and the number of fish it will support and the size of a river and the amount of water running through it.

If the CVP is viewed as an experiment testing this assumption, various examples of the relationships between flow and fish can be observed. Flow and temperature changes after the construction of Shasta Dam created cold water habitat for a large population of winter-run chinook salmon in the 1950s and 1960s. This population subsequently declined as flow and flow-related conditions changed and, perhaps, as changing operations in the Delta reduced survival there. New Melones Dam on the Stanislaus River created conditions under which salmon populations were strong in wet years when flow patterns approximated a natural state and neared extinction under dry conditions when a greater proportion of unimpaired winter and spring runoff was retained in reservoirs.

Extirpation of anadromous fish from much of the mainstem San Joaquin River after the severe reduction in flow that followed the completion of Friant Dam provides additional evidence of the relationship between the size of the river and water flow and fish populations. Systemwide, except on the American and Feather rivers where the success of natural populations is very difficult to gauge because of the presence of large hatcheries, strong evidence suggests that reducing winter and spring flows tends to reduce populations of anadromous fish that rear and migrate in winter and spring. In addition to the effects of hatchery production, factors that confound the precise determination of optimum fish flows include differences in life history requirements, water quality problems, land use impacts, altered river and floodplain morphology, and obstruction of access to historical spawning reaches.

Difficulties in Evaluating Flow Needs

The value of a restoration action depends on how effectively it addresses the factors that are actually limiting to the population of a target species. For example, the value of a mechanical device designed to allow the release of warmer reservoir water to draw fish to spawning areas and the later release of cool water to improve egg survival would be diminished if fish were not drawn to spawning areas by warmer water or if overall productivity were primarily controlled by conditions in the estuary.

Identifying the flows needed to restore fish production in regulated streams is controversial because modifying flow regimes to meet the needs of fish may undermine the objectives of the groups who benefit from the existing management scheme. In the Central Valley, the primary objectives of water managers are typically flood control and water storage for later agricultural and urban uses. Consequently, rationales for changing flow patterns are often intensively debated among stakeholders, and close attention is applied to the biological judgments underlying them. Because they are perceived as being less costly, nonflow alternatives are seldom subjected to the same level of scrutiny. However, the degree of uncertainty associated with the benefits of actions such as gravel supplementation and screening is equal to or greater than that associated with modification of flow. For any restoration measure, the key decision is this: does it target a problem that is actually limiting to the target species? Intuitively, the benefits of screening agricultural diversions to prevent entrainment of juvenile fish appear obvious; however, there would be little value in spending limited funds on screening if fish excluded from upstream diversions were subsequently lost in the Delta as a result of direct and indirect effects of exports at the state and federal water projects. Similarly, there would be little value in increasing the quantity of available spawning gravel if the problem that actually limits juvenile production is lack of adequate rearing habitat.

Similar problems surround the evaluation of restoration proposals to improve fish habitat by changing flow regimes. As with most other restoration measures, improvements in fish production resulting from modified flow regimes cannot be quantitatively predicted at this time. CVPIA includes provisions intended to overcome this deficiency, notably Section 3406(b)(16), which requires development of a comprehensive program to assess the biological results and effectiveness of restoration actions, and Section 3406(g), which requires development of biological and water system models to improve scientific understanding of various elements of the Central Valley ecosystem.

Flow evaluation methods - One of the tools available for evaluating fishery flows is the Instream Flow Incremental Methodology (IFIM) developed by USFWS's Instream Flow Group, now the River Systems Management Section of the National Biological Service Mid-continent Ecological Sciences Center. IFIM provides a means of estimating the amounts of fish habitat available at various flows, commonly through PHABSIM, a series of computer programs simulating river hydraulics and fish habitat. Because available habitat can be presented over a range of flows, the methodology provides a means of evaluating tradeoffs between fish habitat and water supply.

The IFIM process for determining relationships between stream flow and habitat is at base simple and direct, consisting of three steps:

1. Observe fish in streams and measure the physical characteristics of the habitat they use.

2. Measure or estimate the amount of similar habitat available in a stream at various flows.

3. Compare the habitat available in the river under various flows to the habitat used by fish. The flow that provides the greatest amount of habitat, modified by macrohabitat constraints such as temperature and water quality, is the optimum flow for a given life stage. This information may then be used in any variety of ways to develop a larger view of the overall biological effect of flows.

The primary physical microhabitat variable addressed through currently applied IFIM methods is water velocity, because the area of river with usable velocity defines the area where fish can live. Substrate quality, an essential element of salmonid spawning habitat, is also usually characterized in a Central Valley IFIM habitat study. Depth is always included in flow studies because it is needed for velocity estimation at unmeasured flows, and because fish need a certain depth of water to swim and breathe. Other variables thought to be important to fish, such as cover and food production, can be included in IFIM microhabitat estimates, but this has not been seriously attempted in any Central Valley study, possibly because evidence of their relationship to long-term flows above a minimal level is inconclusive or difficult to obtain.

For Central Valley chinook salmon and steelhead, important flow-dependent life stages include adult spawning, egg incubation, and juvenile rearing and migration. Because habitat needs change as fish grow from fry to smolts, rearing fish are usually divided into two categories, fry and juveniles above about 50 millimeters (mm) long. Steelhead trout are generally divided into adult, fry, and juvenile life-stages. Useful

IFIM habitat criteria for shad, striped bass, and sturgeon have not been developed in California and probably will not be, given the difficulty of observing these fish in the open water or depths they inhabit.

IFIM techniques are often viewed as limited or deficient in estimating necessary fishery flows. Various criticisms are that PHABSIM processes posit an unreal relationship between habitat and fish production, they do not adequately account for cover or other variables sometimes thought to be flow related, or the relationship between where a fish lives and why it lives there is unclear. Whatever the merit of these criticisms, four main problems are faced by IFIM users in California:

1. No system of estimating proper fishery flows, including IFIM, has been verified by quantification of the relationships between fish habitat and fish production. A 10-year study is underway, however, to test the IFIM and determine whether changes in aquatic habitat caused by changes in the flow produce predictable changes in fish populations (Studley et al. 1993). To achieve this, it will be necessary to determine the numerical relationships between various life stages of fish with different or even conflicting habitat requirements, which has not been attempted in any Central Valley flow study. Such information is expected to be developed under Sections 3406(b)(16) and 3406(g) of the CVPIA, and various specific data needs are described in sections of this report.

2. Because young salmonids are small and comparatively weak, they need low velocities to survive in rivers. Chinook salmon ranging from about 33 to 50 mm long, for example, are most commonly found in still water near stream edges. Absolute areas of this slow water habitat generally increase with decreasing flow, so it is usually possible to interpret flow study results as showing that decreasing flow increases rearing habitat and that maximum fry habitat is provided by no flow at all, when the river becomes a series of still pools. This ignores the importance of flows for food transport, temperature moderation, and habitat diversity, but finding the point on a flow-versus-habitat curve where food transport and habitat diversity become of overriding importance is a matter of interpretation. Because of this, IFIM studies have sometimes become more a focus of debate than a means of resolution, with high-flow proponents rejecting estimated rearing flows and out-of-stream water users defending them.

3. Some Central Valley rivers have had average natural rearing flows reduced an order of magnitude or more so that the flows available for IFIM studies barely approach the lower limit of natural conditions. Most information available on anadromous fish and habitat condition in California is based on study of drastically altered streams, and little is known about the amounts of habitat that unimpaired flows provided. Doubling production implies a return to some approximation of preproject habitat conditions, but flows at preproject rearing-season levels have not been studied on any Central Valley stream. Flow studies have largely evaluated habitat in streams that are being operated like canals. To cite one example, available sampling techniques restricted the Yuba River flow study of 1991 to

measurement of a high flow of 1,035 cubic feet per second (cfs) in reaches where average natural rearing-season flows were well over 6,000 cfs. The resulting habitat estimates have been the basis for flow recommendations but may not include the flows that exploit the full habitat potential of the river.

4. Problems with IFIM methods are most pronounced for early life stages. Juvenile salmonids are small, mobile, and difficult to statistically enumerate in all but the smallest streams; direct knowledge of their behavior and habits in Central Valley streams is sparse, and commonly supplemented with inferences from studies of tagged hatchery fish or fragmentary capture records of variable quality. Consequently, flow studies and flow recommendations have been oriented toward spawning, which is relatively easily quantified; lack of data has sometimes limited consideration of juvenile life stages to providing flows for temperature control or to releasing brief flow pulses that may improve survival during migration.

IFIM has been widely applied, despite its imperfections, partly because no more technically sound yet feasible method is widely available. Some alternatives include rarely used IFIM precursors such as the USFS sag-tape and the PG&E-Waters method; arbitrary setting of flows at a statistical level of unimpaired flow; and, where sufficient flow and population records exist, analysis of historical trends such as the regressions used for San Joaquin tributary streams in this report.

A final and pervasive alternative method of flow evaluation is consideration of available biological data to develop a qualitatively derived flow schedule or to support and modify a flow schedule developed by largely intuitive processes. Most Central Valley flow recommendations, including those in this paper, use this method to some extent and are based substantially on professional judgment. A brief summary of the technical team approach by river system follows.

Approaches Taken by Technical Teams

With these complications in mind and with the legislated goal of determining conditions that would result in a doubling of natural production of anadromous fish, the AFRP technical teams have taken various approaches to developing draft flow recommendations.

Chinook salmon and steelhead - Mainstem Sacramento River recommendations have been constrained by two factors. Several distinct stocks of salmon, each with different habitat requirements, exist in the river; one of these species has been listed under the federal Endangered Species Act and must be given priority. The Sacramento River recommendations therefore call for operations that maintain a storage pool that will enable the delivery of cool water from Shasta Reservoir through spring and summer, when winter-run chinook salmon are in the river. Within this pattern, there has been an attempt to optimize fall- and late fall-run salmon spawning flows and to reduce fluctuations that could affect spawning and rearing success during winter. Although an IFIM study has been conducted on Clear Creek and a Mill Creek IFIM study is in progress, flow recommendations for the other tributaries to the upper Sacramento River are based largely on professional judgment and observation of fish population response to existing and historical flow. In several cases, recommendations are to restore minimal flow levels to reaches that would otherwise be entirely dewatered during periods of the year that are critical for salmon or steelhead. Authors have recommended that existing knowledge be improved by conducting IFIM studies on most of the important tributaries.

Flow recommendations for spawning and rearing in most of the lower Sacramento tributaries rely, at least in part, on conclusions drawn from IFIM studies. However, on the Feather, Yuba, Bear, American, and Mokelumne rivers, flows derived through IFIM have been modified to varying degrees based on knowledge of species= environmental requirements, additional observational data, professional judgment, carryover storage, and other water management imperatives such as flood control. IFIM studies have not been conducted on the Bear or Cosumnes rivers. On the former, fish flows were derived from knowledge of salmon requirements and a flow simulation model; on the latter, flow recommendations reflect the average conditions during baseline period years when production goals (as indicated by escapement) were actually met. Calaveras River flow recommendations are based on a USFWS IFIM study that sought to identify flow needs for a race of winter-run salmon.

Recommendations for the mainstem San Joaquin River are based on a regression of chinook salmon escapement on Vernalis flow and combined state and federal exports during April, May, and June in the year of outmigration. Allocation of total basin outflow between the tributaries and mainstem river was based on the by-year type percentages contributed to total San Joaquin Basin unimpaired runoff from 1922 to 1990. IFIM-based flow recommendations were applied to tributaries in dry year types when unimpaired flow in the reaches that are currently accessible to salmon and steelhead were inadequate for late rearing, spawning, and incubation. On the Merced River, where no IFIM study has been conducted, IFIM flows from a similarly sized drainage were used as a surrogate. DFG has plans to conduct an IFIM study on the Merced River in the near future.

Striped bass, American shad, white and green sturgeon - There are no studies that specifically identify flow requirements for striped bass, American shad, white sturgeon, or green sturgeon. Flow recommendations for striped bass are based on a modification of an existing DFG model that predicts the adult population based on Delta outflow, exports/diversions, and stocking rates. Recommendations for shad and both species of sturgeon reflect average flow during those baseline period years when data indicate that the production goals were actually met. For shad, April-May Delta outflow was related to abundance of juveniles in the DFG fall midwater trawl and was allocated to individual stream on the basis of percent contribution to unimpaired runoff. For sturgeon, flow to production estimates were identified on a river-by-river basis.

SECTION II. SUMMARY OF RESTORATION GOALS

Restoration goals for four races of chinook salmon, steelhead, striped bass, American shad, and white and green sturgeon are presented in the following table. The Core Group defined the restoration goal for anadromous fish to be equal to at least twice the mean estimated natural production for the baseline period (1967-1991). It defined natural production during the baseline period to be that portion of production not produced in hatcheries and defined production to be the number of fish that recruit to adulthood in a given year, including newly recruited fish that are harvested.

Volume 3, Section X, AReports from the Technical Teams,@ provides the details and methods for estimating restoration goals. In Section Xa and appendices A and B, production goal numbers for salmon and steelhead are broken down by stream and race. Methods for adult striped bass are discussed in Section Xf; for American shad in Section Xg; and for white and green sturgeon in Section Xh. Because there are no data to estimate the adult component of the American shad population for any years except 1976 and 1977, young-of-the-year abundance in the California Department of Fish and Game fall midwater trawl was used to estimate our numeric restoration goal.

AFRP goals for anadromous fish production in Central Valley rivers and streams.

Species	Goal
Chinook salmon, all races	990,000
Fall run	750,000
Late fall run	68,000
Winter run	110,000
Spring run	68,000
Steelhead	13,000
Striped bass	2,500,000
American shad	4,300[a]
White sturgeon	11,000

Species	Goal
Green sturgeon	2,000

[a] The goal for American shad is expressed as the juvenile index as derived from the DFG fall midwater trawl.

SECTION III. SUMMARY OF LIMITING FACTORS

Following are general categories of factors that were identified by the AFRP technical teams as limiting natural production of anadromous fish in Central Valley streams. Not all of these problems affect all species, life stages, or streams. The order in which these items appear in the list is a rough indication of how often they were identified as a problem by the technical teams. For example, inadequate flow was identified as a problem for virtually all species and streams. For more detailed information on the specific factors that affect particular species and streams, readers should refer to the appropriate sections in Volume 3 of this Working Paper.

1. Inadequate timing and/or magnitude of flow to provide suitable conditions for one or more life stage

2. Water temperatures that regularly exceed tolerances of one or more life stage

3. Loss of natural stream habitat

   a. Loss of spawning gravel; lack of spawning gravel recruitment

   b. Sedimentation resulting from riparian and upland land use impacts

   c. Loss of bank and riparian cover

   d. Loss of floodplain and other low-velocity stream habitat

4. Obstacles to fish passage

5. Entrainment of juveniles at riparian and Delta diversions

6. Direct and indirect impacts of Central Valley Project and State Water Project Delta pumping operations

7. Effects of point and nonpoint source discharge of organic pollutants, pesticides, and miscellaneous toxic chemicals

8. Legal and illegal harvest of adult fish

SECTION IV. SUMMARY OF RESTORATION ACTIONS

INTRODUCTION

Section IV summarizes the restoration actions that appear in their complete and original form in Volume 3. For purposes of the summary, organization and presentation has been changed by combining actions for all six anadromous fish species for each river or stream. Information for actions that do not involve modification of flow is limited to a brief, descriptive title, a statement of the objective with respect to improving conditions for anadromous fish, and a list of the species and races for which the action was proposed. Flow requirements for all six species are combined into tables by river, or, where the technical teams have made recommendations for multiple points on a single river, by flow station. Where flow needs for two or more species overlap within a river, or at a flow station, the flows presented in the table are those that would provide the greatest overall benefits for anadromous fish. Water year types are based on the Sacramento River Index and San Joaquin Basin 60-20-20 Index except as otherwise noted. Interested parties who wish to read more detailed descriptions of restoration actions, or would like to review the supporting technical information, can order copies of Volume 3 from the USFWS by calling 1-800-742-9474 or 1-916-979-2330 and dialing 542 after the recorded message begins. Copies may also be obtained by calling Roger Dunn, CVPIA Public Outreach, at 1-916-979-2760 or by sending e-mail requests to roger_dunn@fws.gov.

SACRAMENTO RIVER BASIN

Upper Mainstem Sacramento River

1. Develop and implement an integrated river regulation plan that balances carryover storage needs with instream flow needs based on runoff and storage conditions: Actively regulate river flows and reservoir storage in the upper Sacramento River system to provide necessary habitat for the production of all races of chinook salmon and the anadromous fish they coexist with, consistent with sound ecological management principles.

Minimum recommended Sacramento River flows (cfs)
at Keswick Dam (RM 302), for the period October 1 to April 30[a].

Carryover storage	Keswick Dam release	Carryover storage	Keswick Dam release
1.9	3,250	2.5	4,250
2.0	3,250	2.6	4,500
2.1	3,250	2.7	4,750
2.2	3,500	2.8	5,000
2.3	3,750	2.9	5,250
2.4	4,000	3.0	5,500

[a] Based on October 1 carryover storage (maf) in Shasta Reservoir and critically dry runoff conditions (driest decile runoff of 2.5 maf) to produce a target April 30 Shasta Reservoir storage of 3.0 to 3.2 maf for temperature control.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

2. Implement the Grimes flow schedule: Provide minimum or greater flows to ensure suitable conditions for adult American shad and white and green sturgeon to migrate upstream, spawn, and allow progeny to survive.

Month	Sacramento River flows (cfs) at Grimes (RM 125)				
	Wet	Above normal	Below normal	Dry	Critical
February-March	17,700[a]	17,700[a]	--	--	--
April-May	19,800[b]	17,700[a]	13,200[c]	9,300[c]	5,400[c]

[a] Flows needed for white and green sturgeon spawning. Flows of 15,200 cfs needed for American shad spawning during April-May of above-normal water years.

[b] Flows needed for American shad spawning. Flows of 17,700 cfs needed for white and green sturgeon spawning.

[c] Flows required for American shad spawning.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; American shad; white and green sturgeon

3. Maintain mean monthly flows of 31,000 cfs at Verona from February to May in wet and above-normal years: Provide minimum or greater flows to ensure suitable conditions for adult white and green sturgeon to migrate upstream, spawn, and allow progeny to survive.

Species: White and green sturgeon

4. Develop a flow regime that imitates natural flow changes and avoids dewatering redds or isolating or stranding juveniles on monthly and daily rates of change: Prevent redd dewatering or stranding or isolating adults and juveniles.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

5. Complete an integrated instream flow study (IFIM) to refine a river regulation program that actively balances fishery habitat with the flow regime, including needs for adequate temperature, flushing flows, outmigration, channel maintenance, attraction flows, and maintenance of a riparian corridor: Regulate CVP releases to provide adequate spawning and rearing habitat for salmon and steelhead and to minimize flow fluctuations to avoid dewatering redds and stranding or isolating adult and juvenile fish.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

6. Manage flow to restore riparian vegetation: Consider all features of how flow influences ecosystem.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

7. Maintain water temperatures at or below 56°F from Keswick Dam to Bend Bridge except in extreme water years: Develop a water management plan that will ensure USBR's ability to provide cold water during critical months and budget cold water reserves in reservoirs to maximize survival during critical months.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; American shad; white and green sturgeon

8. Raise RBDD gates for a minimum period from September 15 to June 30: Provide unimpeded adult and juvenile passage past RBDD and decrease juvenile mortality associated with predators.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; white and green sturgeon

9. Complete the process to find final solutions to passage problems at RBDD and improve passage conditions beyond opening the dam gates longer than 8 months: Provide unimpeded adult and juvenile passage and decrease juvenile mortality associated with predators.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; white and green sturgeon

10. Implement structural and operational modifications at ACID to eliminate stranding, toxic discharges, improve screens, and eliminate passage problems for chinook salmon and steelhead: Provide safe passage for adult and juvenile salmon past ACID.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

11. Construct escape channel from stilling basin to the Sacramento River at Keswick Dam: Avoid entrapment of salmonid adults at Keswick Dam stilling basin.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

12. Implement structural and operational modifications to eliminate entrainment at water diversions: Increase survival of outmigrating anadromous fish stocks by reducing entrainment through correcting unscreened or inadequately screened water diversions.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; white and green sturgeon

13. Implement structural and operational modifications to eliminate impingement and entrainment of juvenile salmon at GCID water diversion: Correct problems at the GCID water diversion.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; white and green sturgeon

14. Complete EPA Superfund cleanup of Iron Mountain Mine by 1996: Remedy water quality problems associated with Iron Mountain Mine and other toxic discharges.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; white and green sturgeon

15. Avoid potential competitive displacement of wild, naturally produced juveniles with hatchery-released juveniles by stabilizing hatchery production levels and implementing release strategies

designed to minimize detrimental interactions: Evaluate competitive displacement between hatchery and natural stocks.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

16. Implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and wild stocks: Maintain genetic diversity in hatchery stocks.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

17. Evaluate transfer of disease between hatchery and natural stocks: Evaluate disease relations between hatchery and natural stocks.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

18. Create a 50,000-acre meander belt from Red Bluff to Chico Landing to provide gravel recruitment, large woody debris, moderate air temperatures, and nutrient input to the lotic system: Restore and preserve riparian forests.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

19. Devise alternative methods other than the Gradient Restoration Facility to increase head differential for the Glenn-Colusa Irrigation District diversion: Facilitate sturgeon passage past GCID.

Species: White and green sturgeon

UPPER SACRAMENTO RIVER TRIBUTARIES

Clear Creek

1. Release 200 cfs of water from Whiskeytown Dam to Clear Creek from October to April and 150 cfs the remainder of the year with variable spring-time releases depending on water year type: Provide adequate instream flows, suitable water temperatures, and channel maintenance flows for all life stages of salmon and steelhead.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

2. Maintain water temperatures at or below 65°F during periods of juvenile rearing, at or below 60°F during adult holding and prespawn, and at or below 56°F during egg incubation: Increase salmonid production by providing optimum water temperatures at all critical life stages, especially for spring-run chinook salmon and steelhead.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

3. Restrict gravel mining and restore degraded channel: Eliminate the severe adverse effects of gravel mining.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

4. Provide effective fish passage above Saeltzer Dam: Provide salmon with access to habitat above McCormick-Saeltzer Dam.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

5. Prevent habitat degradation due to sedimentation and urbanization: Develop erosion and stream corridor protection programs.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

6. Restore gravel and spawning habitat: Compensate for lost spawning gravel recruitment and spawning areas blocked by Whiskeytown Dam.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

Cow Creek

1. Work with water right holders to obtain an agreement for adequate flows for fall-run salmon migration and spawning and juvenile steelhead: Provide suitable passage and early spawning flows (particularly in dry years) for fall-run chinook salmon adults and adequate flows for juvenile steelhead rearing.

Species: Fall-run chinook salmon; steelhead

2. Effectively screen agricultural diversions: Prevent loss of juvenile steelhead due to entrainment.

Species: Steelhead

3. Improve passage at agricultural diversion dams: Improve passage for adult steelhead and increase steelhead spawning and rearing habitat.

Species: Steelhead

Bear Creek

1. Restore instream flows: Provide adequate instream flows to permit safe passage of juvenile and adult salmon and steelhead at key times of the year.

Species: Fall-run chinook salmon; steelhead

2. Build and operate fish screens on all unscreened diversions: Prevent losses of migrating juvenile fall-run salmon and steelhead into agricultural diversions.

Species: Fall-run chinook salmon; steelhead

Cottonwood Creek

1. Protect and enhance spawning gravel: Increase spawning opportunities.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

2. Eliminate attraction flows in Crowley Gulch: Eliminate stranding mortalities.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

3. Improve land use practices: Reduce water temperatures to improve holding, spawning, and rearing habitat and reduce siltation and sedimentation of existing spawning gravel.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

Battle Creek

1. Treat CNFH water supply: Eliminate the potential for waterborne disease to adversely affect hatchery production.

Species: Fall- and late fall-run chinook salmon; steelhead

2. Allow passage above the CNFH weir: Increase available habitat for all salmonid runs and life stages.

Species: Fall- and late fall-run chinook salmon; steelhead

3. Increase bypass flows at PG&E's hydropower diversions according to the following table: Provide streamflow of sufficient quantity and quality to provide adequate holding, spawning, and rearing habitat.

Diversion	Months	Flow (cfs)
Keswick	All year	30
North Battle Creek Feeder	September-November	40
	January-April	40
	May-August	30
Eagle Canyon	May-November	30
	December-April	50
Wildcat	May-November	30
	December-April	50
South	May-November	20
	December-April	30
Inskip	May-November	30
	December-April	40
Coleman	September-April	50
	May-August	30

The following interim flows will be implemented during the initial phase. Optimum flows, which are listed in the table above, will not be required until the spring-run population numbers are sufficient to utilize all available habitat.

1. **Eagle Canyon Dam** - release 40 cfs at Eagle Canyon Dam from September 1 to April 1, and 30 cfs for the remainder of the year.

2. **Coleman Diversion** - release 50 cfs from Coleman Diversion from October 1 to February 1 and 30 cfs for the remainder of the year.

3. **Wildcat Diversion** - close Wildcat Diversion to allow all the spring-water to remain in the creek and avoid entraining juvenile outmigrants in the power canal.

4. **Coleman Forebay -** deliver canal water to Coleman Hatchery through a bypass pipe.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

4. Construct rack to prevent adult salmon from entering Gover diversion: Prevent loss of spawning adult fall-run chinook.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

5. Screen Orwick diversion: Prevent straying of spawning adult fall-run chinook salmon and prevent entrainment of juvenile salmonids.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

6. Screen tailrace of Coleman Powerhouse: Prevent straying of spawning adult chinook salmon and steelhead.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

7. Construct fish screens at the following PG&E water diversions: Wildcat, Eagle Canyon (only if barrier described in Action 9 is modified), Coleman, North Battle Creek Feeder, Inskip, and South: Minimize loss of both adult and juvenile salmonids.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

8. Evaluate effectiveness of fish ladders at PG&E diversions: Ensure that fish passage is occurring.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

9. Improve fish passage in Eagle Canyon: Facilitate movement of adult salmon and steelhead to habitat in North Battle Creek and above upper Eagle Canyon.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

10. Examine feasibility of establishing a spawning population of winter-run chinook salmon: Increase genetic diversity and current habitat of the endangered Sacramento River winter-run chinook salmon.

Species: Winter-run chinook salmon

Paynes Creek

1. Restore adequate instream flows: Provide minimum instream flows to improve spawning, rearing, and migration opportunities.

Species: Fall-run chinook salmon

2. Restore spawning gravel: Increase spawning potential.

Species: Fall-run chinook salmon

Antelope Creek

1. Restore instream flows: Provide adequate instream flows to permit safe passage of adult salmon at key times of the year.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

2. Create defined stream channel: Reduce infiltration losses and maintain flows to the Sacramento River.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

Elder Creek

1. Construct a fish passage structure over Corning Canal Siphon: Improve fish passage for chinook salmon and steelhead.

Species: Fall-run chinook salmon; steelhead

2. Adopt an erosion control ordinance to minimize sediment input into Elder Creek: Reduce sediment input into Elder Creek.

Species: Fall-run chinook salmon; steelhead

Mill Creek

1. Improve transportation flows in the valley reach of Mill Creek: Ensure that upstream migrating spring-run chinook and downstream migrating spring and late fall-run chinook and steelhead migrate safely through the lower portion of Mill Creek. Increased flows in fall will also improve spawning conditions for fall-run chinook salmon.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

2. Remove Clough Dam: Provide unimpaired passage where an existing structure presently obstructs migrating adults under certain flow conditions.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

3. Protect and restore anadromous salmonid fisheries habitat and preserve the long-term productivity of the upper Mill Creek aquatic ecosystem through cooperative watershed management: Identification of restoration priorities and protection of Mill Creek's aquatic ecosystem through cooperative land use management in the upper watershed.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

4. Improve salmon spawning areas in lower Mill Creek: Increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall- and late fall-run chinook salmon.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

5. Maintain and restore riparian habitat along lower reaches of Mill Creek: Help maintain cool water temperatures.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

Thomes Creek

1. Modify gravel mining methods: Improve land use practices.

Species: Fall- and spring-run chinook salmon; steelhead

2. Modify timber harvest practices: Improve land use practices.

Species: Fall- and spring-run chinook salmon; steelhead

3. Modify grazing practices: Improve land use practices.

Species: Fall- and spring-run chinook salmon; steelhead

4. Stabilize areas of high erosion: Reduce impacts of previous land use practices and improve habitat.

Species: Fall- and spring-run chinook salmon; steelhead

5. Replace Corning Canal Siphon: Improve fish passage.

Species: Fall- and spring-run chinook salmon; steelhead

6. Minimize diversion barriers usage: Improve fish passage.

Species: Fall- and spring-run chinook salmon; steelhead

7. Develop a release strategy for TCC into Thomes Creek between October and May. Until a strategy is developed, flows of 50 cfs should be released from TCC into Thomes Creek: Improve fish flows in Thomes Creek to ensure survival of all salmonid life stages.

Species: Fall-run chinook salmon; steelhead

8. Conduct regular water quality monitoring: Provide suitable water quality.

Species: Fall-run chinook salmon

Deer Creek

1. Improve transportation flows in the valley reach of Deer Creek: Ensure that upstream migrating spring-run chinook salmon and downstream migrating juvenile spring- and late fall-run chinook and steelhead can migrate safely through the lower 10 miles and pass over three diversion dams in lower Deer Creek. Also, provide improved flows for adult fall-run salmon.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

2. Protect and restore chinook salmon and steelhead habitat and preserve the long-term productivity of the upper Deer Creek aquatic ecosystem through cooperative watershed management: Reduce the effects of land use practices.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

3. Improve salmon spawning areas in lower Deer Creek: Increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall- and possibly late fall-run chinook salmon.

Species: Fall- and late fall-run chinook salmon

4. Maintain and restore riparian habitat along lower reaches of Deer Creek: Help maintain low water temperatures.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

5. Conduct flood management activities: Carry out required flood management activities with minimum damage to the fishery resources and riparian habitat in the lower 5 miles of Deer Creek.

Species: Fall-, late fall-, and spring-run chinook salmon; steelhead

Stony Creek

1. Install siphon under Stony Creek for GCID canal: Provide passage for all life stages and prevent entrainment of juvenile salmonids.

Species: Fall- and late fall-run chinook salmon

2. Develop water management release strategy for Black Butte Dam: Provide adequate flows.

Species: Fall- and late fall-run chinook salmon

3. Comply with RBDD mitigation by providing flows between 100 cfs and 500 cfs of water per day to Stony Creek via TCC: Provide adequate flows.

Species: Fall- and late fall-run chinook salmon

4. Modify gravel extraction permits: Provide suitable spawning habitat.

Species: Fall- and late fall-run chinook salmon

5. Add spawning gravel to Stony Creek: Provide suitable spawning habitat.

Species: Fall- and late fall-run chinook salmon

6. Develop a distinct creek channel: Provide suitable spawning habitat.

Species: Fall- and late fall-run chinook salmon

7. Develop plan to establish a riparian corridor: Provide suitable water temperatures.

Species: Fall- and late fall-run chinook salmon

8. Discontinue diversions to the TCC: Alleviate passage problems, ensure adequate flows, and prevent entrainment.

Species: Fall- and late fall-run chinook salmon

9. Correct problems associated with North Diversion Dam: Provide fish passage for all life stages, provide adequate flows past dam, and prevent entrainment.

Species: Fall- and late fall-run chinook salmon

10. Develop plan to assess water quality: Ensure adequate water quality for all life stages.

Species: Fall- and late fall-run chinook salmon

11. Conduct Instream Flow Incremental Methodology (IFIM): Determine preferred water flows for all life stages.

Species: Fall- and late fall-run chinook salmon

Big Chico Creek

1. Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch Pumps: Prevent loss of juvenile salmonids and permit sufficient attraction flows for adults.

Species: Fall-, late fall-, and spring-run chinook salmon

2. Repair Iron Canyon fish ladder: Facilitate movement of adult spring-run chinook and steelhead to favorable summer holding habitat.

Species: Fall-, late fall-, and spring-run chinook salmon

3. Split low flow between Big Chico Creek and Lindo Channel: Minimize trapping and subsequent loss of both adult and juvenile salmonids from periodic dewatering of Lindo Channel.

Species: Fall-, late fall-, and spring-run chinook salmon

4. Replace spawning gravel in the channels modified for flood control: Improve spawning habitat for fall- and late fall-run chinook.

Species: Fall- and late fall-run chinook salmon; steelhead

5. Repair the Lindo Channel weir and fishway: Facilitate upstream passage of spring chinook and steelhead from Lindo Channel.

Species: Fall-, late fall-, and spring-run chinook salmon

6. Improve cleaning procedure at One-Mile Pool: Reduce siltation of downstream spawning and rearing habitat.

Species: Fall-, late fall-, and spring-run chinook salmon

7. Preserve primary summer holding areas for spring-run chinook salmon: Obtain title or conservation easement on land adjacent to primary summer holding pools for spring-run chinook. This is especially important considering the marginal summer temperatures and possibility of residential development in those areas. Additional disturbance would cause significant mortality.

Species: Fall-, late fall-, and spring-run chinook salmon

8. Revegetate denuded stream reaches, restore and maintain a protected riparian strip: Expand the usable habitat and provide habitat diversity, cover from predators, and shade to keep the water cooler in late spring.

Species: Fall-, late fall-, and spring-run chinook salmon

9. Replace gravel in the flood-diversion reach of Mud Creek: Expand the usable habitat and provide habitat diversity for rearing salmon and their prey.

Species: Fall-, late fall-, and spring-run chinook salmon

Butte Creek

1(a). Obtain rights to approximately 105 cfs of water from Parrott-Phelan diversion: Provide adequate instream flows for all life stages of salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

1(b). Maintain a minimum 40 cfs instream flow below Centerville Diversion Dam: Provide suitable holding, spawning, and rearing habitat.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

1(c). Purchase existing water rights from diverters: Ensure adequate instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

2(a). Build new high-volume fish ladder at Durham Mutual Dam: Provide adequate passage for adult salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

2(b). Install fish screens on both diversions at Durham Mutual Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(a)(1). Develop and construct Western Canal Siphon: Eliminate adult passage and juvenile entrainment problems associated with five dams and obtain additional instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(a)(2). Investigate the possibility of consolidation or replacement of additional diversions below the Western Canal Siphon Project: Eliminate adult passage and juvenile entrainment problems and potentially obtain additional instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(a)(3). Acquire water rights as part of the Western Canal Siphon Project: Obtain adequate instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(b)(1). Adjudicate water rights and provide watermaster service or equivalent for entire creek: Ensure adequate instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(b)(2). Remove Western Canal Dam and replace with siphon: Expedite adult passage, eliminate straying of adults, and prevent entrainment of juveniles.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(b)(3). Establish operational criteria for Sanborn Slough Bifurcation: Provide better passage for adult salmonids and prevent entrainment of juveniles.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

3(b)(4). Develop operational criteria for, and potential modification to, Butte Slough outfall: Provide sufficient attraction and passage flows for adults and outmigration flows for juveniles.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(a)(1). Build new high-volume fish ladder at Adams Dam: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(a)(2). Install fish screens on both diversions at Adams Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(a)(3). Build new high-volume fish ladder at Gorrill Dam: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(a)(4). Install fish screens on diversions at McGowan Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(a)(5). Install fish screens on three diversions at McPherrin Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(b)(1). Install fish screens on both diversions at Western Canal Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(b)(2). Build new high-volume fish ladder at Western Canal Dam: Improve adult fish salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(b)(3). Install fish screens on both diversions at Gorrill Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(b)(4). Build new high-volume fish ladder at McPherrin Dam: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

4(c)(1). Build new high-volume fish ladder at McGowan Dam: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(1). Build new high-volume fish ladder at East-West Diversion Weir: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(2). Establish operational criteria for the East and West Barrows: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(3). Establish operational criteria for Sutter Bypass Weir #2: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(4). Establish operational criteria for Nelson Slough: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(5). Establish operational criteria for Sutter Bypass Weir #1: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(6). Install fish screens at Sanborn Slough Bifurcation: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(7). Install fish screens at White Mallard Dam: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(a)(8). Screen diversions within Sutter Bypass where necessary: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(b)(1). Install culvert and riser at White Mallard Duck Club outfall: Prevent straying of adult salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(b)(2). Rebuild and maintain existing culvert and riser at Drumheller Slough outfall: Prevent straying of adult salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(b)(3). Establish operational criteria for Sutter Bypass Weir #5: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

5(b)(4). Establish operational criteria for Sutter Bypass Weir #3: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(a)(1). Initiate legal action on diverters who are violating water right allocations: Ensure sufficient instream flows.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(a)(2). Install high-volume fish ladder on Sutter Bypass Weir #2: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(a)(3). Install high-volume fish ladder on Sutter Bypass Weir #1: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(a)(4). Install fish screens on Little Dry Creek pumps: Prevent entrainment of juvenile salmonids.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(a)(5). Increase law enforcement of fishing regulations: Eliminate or reduce poaching.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(b)(1). Install high-volume fish ladder on Sutter Bypass Weir #5: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

6(b)(2). Install high-volume fish ladder on Sutter Bypass Weir #3: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

7(a)(1). Install high-volume fish ladder at White Mallard Dam: Improve adult fish passage.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

7(a)(2). Develop and enforce land use plans that create buffer zones between the creek and development: Protect existing salmonid habitat from further human development.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

7(a)(3). Develop a watershed management program: Protect existing salmonid habitat while providing for human use of the resources.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

7(b). Enhance fish passage at natural barrier below Centerville Diversion Dam: Increase the amount of available salmonid habitat.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

8(a). Enhance fish passage at PG&E diversion dams: Increase the amount of available salmonid habitat.

Species: Fall- and spring-run chinook salmon; possibly late fall-run chinook salmon and steelhead

Colusa Basin Drain

1. Develop defined migrational routes: Provide direct access to Westside Tributaries

Species: Fall-run chinook salmon

2. Develop defined migrational flows: Provide direct access to Westside Tributaries

Species: Fall-run chinook salmon

3. Reduce water temperatures: Enhance survival in Colusa Drain and Westside Tributaries

Species: Fall-run chinook salmon

Miscellaneous small tributaries

Sacramento River tributaries that typically can provide rearing habitat only for salmonids:

Name	USGS Quad	Side of River
Streams known to support juvenile rearing		
Pine	Ord Ferry	east
Toomes	Vina	east
Dye	Los Molinos	east
Oat	Los Molinos	west
Coyote	Gerber	west
Reeds	Red Bluff East	west
Brewery	Red Bluff East	west
Dibble	Red Bluff East	west
Inks	Bend	east
Anderson	Ball's Ferry	west
Olney	Enterprise	west
Streams presumed to support juvenile rearing		
Burch	Foster Island	west
Jewett	Vina	west

Name	USGS Quad	Side of River
McLure	Vina	west
Red Bank	Red Bluff East	west
Salt	Red Bluff East	east
Ash	Ball:s Ferry	east
Stillwater	Ball:s Ferry	east
Churn	Cottonwood	east
Sulfur	Redding*	east
Streams with potential to support juvenile rearing		
Seven Mile	Red Bluff East	east
Frasier	Bend	west
Spring	Bend	west
Clover	Cottonwood	east
Middle	Redding*	west
Salt	Redding*	west
Jenny	Redding*	west
Rock	Redding*	west

[a] Indicates 15-minute topographic quadrangle map.

1. Revegetate denuded stream reaches and restore and maintain a protected riparian strip in all tributaries: Expand the usable rearing habitat and provide habitat diversity, cover from predators, and shade to keep the water cooler in late spring.

Species: Chinook salmon, runs unknown; steelhead

2. Move pumps to the Sacramento River, where sufficient bypass flow exists, to avoid entrainment of juvenile salmonids (screen pumps): Reduce loss of juveniles to agricultural diversion.

Species: Chinook salmon, runs unknown; steelhead

3. Find alternative sources of water for upstream diversions: Prevent early dewatering of stream reaches used for rearing.

Species: Chinook salmon, runs unknown; steelhead

4. Survey tributaries for toxic materials, follow with cleanup projects as needed; expand enforcement of dumping ordinance: Remove hazards and potential hazards such as car batteries, oil filters, and animal carcasses from streams. Prevent further use of streams for dumps.

Species: Chinook salmon, runs unknown; steelhead

5. Replace bridge/ford combinations with bridges or large culverts: Expand the usable habitat in some tributaries.

Species: Chinook salmon, runs unknown; steelhead

6. Provide siphons to get "beheaded" tributaries streams past irrigation canals: Expand the usable habitat.

Species: Chinook salmon, runs unknown; steelhead

LOWER SACRAMENTO RIVER AND DELTA TRIBUTARIES

Feather River

1. Increase flows in the low-flow channel: Enhance and maintain spawning and rearing habitat.

Month	Feather River flows (cfs) in the low-flow channel					
	Schedule A[a]					Schedule B[b]
	Wet	Above normal	Below normal	Dry	Critical	All year
September-May	2,500	2,500	2,500	1,700	1,700	800
June-August	1,100	1,100	1,100	800	800	800

[a] Schedules A and B are based on two different modeling scenarios presented in a draft IFIM report (Sommer 1994). The modeling scenarios differed in assumptions about depths preferred by spawning

chinook salmon. Schedule A is recommended for adoption and evaluation. If Schedule A results in reduced in spawning habitat, Schedule B flows (or flows derived from subsequent analyses) should be adopted. Flows in warmer months may be contingent on completion of the temperature model. Temperature model likely to require higher flows than specified to supply cold water downstream of Thermalito outlet for spring-run chinook salmon.

Species: Fall- and spring-run chinook salmon; steelhead

2. Consider providing experimental pulse flows: Stimulate outmigration of juvenile chinook salmon.

Species: Fall- and spring-run chinook salmon; steelhead

3. Consider providing experimental high-turbidity pulses: Stimulate outmigration of juvenile chinook salmon.

Species: Fall- and spring-run chinook salmon; steelhead

4. Restore gravel and create spawning habitat: Reduce armoring; increase spawning habitat.

Species: Fall- and spring-run chinook salmon; steelhead

5. Replenish gravel: Reduce spawning habitat degradation.

Species: Fall- and spring-run chinook salmon; steelhead

6. Complete temperature model: Develop a temperature model as a tool for river management.

Species: Fall- and spring-run chinook salmon; steelhead; possibly striped bass; American shad; white and green sturgeon

7. Conduct studies on the hatchery program: Determine distribution of Feather River Fish Hatchery chinook salmon in Central Valley stocks and determine genetic integrity of Feather River spring-run chinook salmon.

Species: Fall- and spring-run chinook salmon

8. Implement the Gridley flow schedule: Enhance and maintain spawning and rearing habitat for chinook salmon, steelhead, American shad, and white and green sturgeon.

Month	Feather River flows (cfs) at Gridley[a]				
	Wet	Above normal	Below normal	Dry	Critical
October-January	2,500[b]	2,500[b]	2,500[b]	1,700[b]	1,700[b]
February-March	7,000[c]	7,000[c]	2,500	1,700[b]	1,700[b]
April-May	7,000[d]	7,000[d]	3,000	2,100	2,100
June-August	1,000	1,000	1,000	1,000	1,000
September	2,500[e]	2,500[e]	2,500[e]	1,400[e]	1,400[e]

[a] Flows proposed on interim basis until completion of DWR=s instream flow study. Flows may be further modified for sturgeon reproduction.

[b] Flows needed for spawning and incubation of salmonids. Initial results from a DWR/DFG instream flow study indicate that spawning habitat in this reach would be maximized in the 750 to 2,750 cfs range (Sommer 1994).

[c] Flows needed for white and green sturgeon spawning. Flows needed for spawning and incubation of salmonids are 2,500 cfs in wet and above-normal years.

[d] Flows needed for white and green sturgeon spawning. Flows needed for spawning and incubation of salmonids are 3,000 cfs in wet and above-normal years.

[e] Flows contingent on completion of the temperature model. Temperature model likely to require flows to come from upstream of Thermalito outlet to meet temperature needs downstream.

Species: Fall- and spring-run chinook salmon; steelhead; white and green sturgeon

9. Implement the Nicolaus flow schedule: Provide adequate flows for spawning and progeny survival for American shad and white and green sturgeon.

Month	Feather River flows (cfs) at Nicolaus				
	Wet	Above normal	Below normal	Dry	Critical
February-March	11,500[a]				
April-May	15,700[b]	12,100[b]	10,500[b]	7,400[b]	4,300[b]

[a] Flows needed for white and green sturgeon spawning.

[b] Flows needed for American shad spawning. Flows needed for sturgeon spawning are 11,500 cfs in wet and above-normal years.

Species: American shad; white and green sturgeon

10. Maintain mean daily water temperatures below 63°F at Gridley and below 68°F throughout the Feather River between February and June for sturgeon spawning; maintain mean daily water temperatures between 61°F and 65°F for at least 1 month between April 1 and June 30 for American shad: Improve American shad and white and green sturgeon spawning success and egg survival by managing pumpback operations at Thermalito Reservoir.

Species: American shad; white and green sturgeon

11. Remove physical and water quality barriers that impede access to spawning habitat: Identify potential physical and water quality barriers, and determine extent of problem. Once barriers are identified, remove or facilitate passage around these barriers.

Species: White and green sturgeon

12. Reduce sturgeon entrainment: Identify extent of sturgeon entrainment. Increase survival of sturgeon larvae and juveniles by reducing or eliminating entrainment.

Species: White and green sturgeon

13. Determine effects of poaching and fishing on spawning stock size: Increase size of spawning stock if significantly reduced by fishing or poaching.

Species: White and green sturgeon

14. Improve water quality: Improve survival and condition of sturgeon.

Species: White and green sturgeon

15. Identify availability of suitable sturgeon spawning habitat: Identify potential sturgeon spawning sites and evaluate availability of such sites to adults. Take corrective actions if suitable spawning habitat is limiting.

Species: White and green sturgeon

Yuba River

1. Implement the Marysville flow schedule: Optimize migration, spawning, incubation, rearing, and outmigration conditions in the lower Yuba River for chinook salmon and American shad.

Month	Yuba River flows (cfs) at Marysville				
	Wet	Above normal	Below normal	Dry	Critical
October-March	700[a]	700[a]	700[a]	700[a]	700[a]
April-May	9,200[b]	7,000[b]	6,100[b]	4,300[b]	2,500[b]
June	1,500[c]	1,500[c]	1,500[c]	1,500[c]	1,500[c]
July-September	450[d]	450[d]	450[d]	450[d]	450[d]

[a] Flows needed for spawning, incubation, and rearing of chinook salmon and steelhead.

[b] Flows needed for American shad spawning. Flows needed for rearing and outmigration of chinook salmon and steelhead spawning were 1,000 cfs in April and 2,000 cfs in May for all water year types.

[c] Flows needed for rearing and outmigration of chinook salmon and steelhead and spawning of steelhead.

[d] Flows needed for steelhead rearing.

Species: Fall-run chinook salmon; steelhead; American shad

2. Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmon outmigration: Optimize outmigration success when water is in short supply (e.g., dry and critically dry water years).

Species: Fall-run chinook salmon; steelhead

3. Reduce and control instream flow ramping rates: Reduce hazards posed to juvenile salmonids when flow rates change rapidly.

Species: Fall-run chinook salmon; steelhead

4. Maintain adequate instream flows for temperature control: Enhance spawning, incubation, rearing, and outmigration conditions.

Species: Fall-run chinook salmon; steelhead; American shad

5. Evaluate and modify (if found to be effective) the water release outlets at Englebright Dam: Assess whether enhancement of control, via shutter configuration, over temperature of water released downstream, and management of the cold water pools, is warranted.

Species: Fall-run chinook salmon; steelhead

6. Improve efficiency of screening devices at Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversions: Reduce entrainment and related losses.

Species: Fall-run chinook salmon; steelhead

7. Improve efficiency of fish bypasses at Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversions: Reduce entrainment and related losses.

Species: Fall-run chinook salmon; steelhead

8. Exclude piscivores from areas around Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversions: Reduce predation losses of juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

9. Maintain a minimum flow of 175 cfs through the critical Simpson Lane reach during the spawning period in dry and critical years: Facilitate passage of spawning adults through the critically shallow portions of the Simpson Lane reach.

Species: Fall-run chinook salmon; steelhead

10. Modify fish ladders at Daguerre Point Dam: Facilitate passage of spawning adults.

Species: Fall-run chinook salmon; steelhead

11. Maintain appropriate flows through ladders at Daguerre Point Dam during the spawning season: Facilitate passage of spawning adults.

Species: Fall-run chinook salmon; steelhead

12. Purchase streambank conservation easements: Improve habitat and instream cover.

Species: Fall-run chinook salmon; steelhead

13. Terminate program to remove woody debris from stream channel: Provide instream cover for juvenile salmonids, especially upstream of Daguerre Point Dam.

Species: Fall-run chinook salmon; steelhead

14. Place large woody debris in stream channel: Provide instream cover for juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

15. Impose stricter harvest regulations on commercial fishers: Increase spawning escapement of naturally produced chinook salmon.

Species: Fall-run chinook salmon; steelhead

16. Conduct weekly on-river patrols in areas where poaching is a concern: Increase spawning escapement.

Species: Fall-run chinook salmon; steelhead

17. Modify the dam face of the Daguerre Point Dam: Reduce juvenile mortality from predation as outmigrants pass over the dam.

Species: Fall-run chinook salmon; steelhead

18. Maintain mean daily water temperatures between 61°F and 65°F for at least 1 month between April 1 and June 30 at Marysville: Improve American shad spawning success and egg survival using multilevel outlets.

Species: American shad

Bear River

1. Implement the Wheatland flow schedule: Provide a sufficient amount of water at preferred temperatures for migration, holding, spawning, incubation, rearing, and outmigration of chinook salmon and spawning of white and green sturgeon.

Month	Bear River flows (cfs) at Wheatland[a]		
	Wet	Above normal	Below normal
October 1-14	100[b]	100[b]	100[b]
October 15-December 31	250[b]	250[b]	250[b]
January	250[c]	250[c]	250[c]
February-March	900[d]	900[d]	250[c,d]
April-May	900[d]	900[d]	250[c]
June	250[e]	250[e]	250[e]
July-September	10[f]	10[f]	10[f]

[a] Salmonid flows apply for wet to below-normal years. Sturgeon flows are for above-normal and wet year types.

[b] Flows needed for spawning, incubation, and rearing of chinook salmon and steelhead.

[c] Flows needed for spawning, incubation, rearing and outmigration of chinook salmon and steelhead. Physical habitat needs alone (depth, velocity, and substrate in PHABSIM analyses) suggest that chinook salmon require at least 190 cfs from January to March and 100 cfs from April to June.

[d] Flows needed for white and green sturgeon spawning. Flows needed for spawning, incubation, and rearing (February-March) and rearing and outmigration (April-May) of chinook salmon and steelhead were 250 cfs in February through May.

[e] Flows needed for rearing and outmigration of chinook salmon and steelhead.

[f] Flows will need to be higher to address temperature requirements of steelhead.

Species: Fall-run chinook salmon; steelhead; white and green sturgeon

2. Conduct an IFIM study to determine instream flow and temperature requirements for all life stages of salmon and steelhead: Ensure that the available water is utilized to its fullest potential to benefit all life stages of salmon and steelhead.

Species: Fall-run chinook salmon; steelhead

3. Implement the Wheatland and Highway 70 water temperature standards: Protect all life stages of juvenile salmonids and white and green sturgeon. Develop operational criteria for Camp Far West and other upstream reservoirs to improve temperature conditions in the lower Bear River.

	Bear River water temperatures (°C)[a] at Wheatland and Highway 70 bridges (temperatures in parentheses are °F).	
Month	Wheatland	Highway 70
October 1-14	15.6 (60)	15.6 (60)
October 15-December 31	14.4 (58)	13.9 (57)
January-March	13.3[b] (56)	13.9[b] (57)
April-June	15.6[b] (60)	15.6[b] (60)
July-September	18.3 (65)	18.3 (65)

[a] Recommended mean daily temperatures to be maintained during wet, above-normal, and below-normal water years.

[b] Water temperatures maintained at or below 63°F for white and green sturgeon spawning, from just downstream of Camp Far West Reservoir to confluence with the Feather River, between February and May in wet and above-normal years.

Species: Fall-run chinook salmon; steelhead; white and green sturgeon

4. Effectively screen all diversions: Reduce loss of production to entrainment.

Species: Fall-run chinook salmon; steelhead; white and green sturgeon

5. Monitor water quality particularly at agricultural return outfalls: Ensure that suitable water quality exists for all life stages of salmonids. Take appropriate action to correct water quality problems.

Species: Fall-run chinook salmon; steelhead; white and green sturgeon

6. Negotiate removal or modification of the culvert crossing at Patterson Sand & Gravel and other physical and chemical barriers impeding anadromous fish migration: Provide uninhibited passage for all life stages of anadromous fish.

Species: Fall-run chinook salmon; steelhead; white and green sturgeon

7. Investigate the extent that poaching and/or fishing reduces adult spawning stock: Increase production by decreasing adult mortality associated with poaching and fishing.

Species: White and green sturgeon

American River

1. Implement the H Street Bridge flow schedule: Optimize migration, spawning, incubation, rearing, and outmigration conditions in the lower American River for chinook salmon, steelhead, and American shad.

Month	American River flows (cfs) at H Street Bridge					
	Wet	Above normal	Below normal	Dry[a]	Critical[a]	Critical relaxation[b]
October[c]	2,500	2,000	2,000	1,750	1,750	800
November-February[c]	2,500	2,000	2,000	1,750	1,750	1,200
March[d]	3,000	3,000	3,000	2,000	2,000	1,500
April-May[e]	11,200	8,600	7,400	5,300	3,100	1,500
June	4,500[d]	3,000[d]	3,000[d]	2,000[d]	2,000[d]	500[f]
July[f]	2,500	2,500	2,500	1,500	1,500	500
August[f]	2,500	2,000	2,000	1,000	1,000	500
September[f]	2,500	1,500	1,500	500	500	500

[a] The dry and critical flow regimes can accommodate all but the most severe drought conditions.

[b] The "critical relaxation" flow regime is intended for application to only the most severe drought years.

[c] Flows needed for chinook salmon spawning and incubation.

[d] Flows needed for salmonid rearing and outmigration.

[e] Flows needed for American shad spawning. Refer to flows in March for salmonid requirements.

[f] Flows for steelhead rearing.

Species: Fall-run chinook salmon; steelhead; American shad

2. Develop water allocation guidelines: Provide, through planning, a reasonable way to divide limited water resources among all appropriate users, including fish.

Species: Fall-run chinook salmon; steelhead

3. Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmonid outmigration: Optimize outmigration success when water is in short supply (e.g., dry and critically dry years).

Species: Fall-run chinook salmon; steelhead

4. Reduce and control instream flow ramping rates and flow fluctuation: Reduce hazards posed to juvenile salmonids when flow rates change quickly.

Species: Fall-run chinook salmon; steelhead

5. Reconfigure Folsom Dam (penstock inlet ports) "shutters": Enhance control over temperature of water released downstream and allow improved management of Folsom Reservoir's cold water pool.

Species: Fall-run chinook salmon; steelhead

6. Replenish spawning gravel and/or restore existing spawning grounds: Enhancement of spawning habitat.

Species: Fall-run chinook salmon; steelhead

7. Improve the fish screen at Fairbairn Water Treatment Plant: Reduce entrainment losses.

Species: Fall-run chinook salmon; steelhead

8. Modify timing and rate of water diverted from the river annually: Reduce entrainment losses. Focus effort toward minimizing the impacts of diversions during periods when juvenile salmonids migrate (e.g., April through June).

Species: Fall-run chinook salmon; steelhead

9. Develop a riparian corridor management plan: Improve and protect riparian habitat and instream cover.

Species: Fall-run chinook salmon; steelhead

10. Terminate current programs that remove woody debris from the river channel: Provide instream cover for juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

11. Impose stricter harvest regulations on both sport and commercial harvesters: Increase spawning escapement of naturally produced chinook salmon.

Species: Fall-run chinook salmon; steelhead

12. Conduct weekly on-river patrols in areas where poaching is a concern: Increase spawning escapement.

Species: Fall-run chinook salmon; steelhead

13. Change hatchery procedures to benefit native stocks: Rebuild native stocks.

Species: Fall-run chinook salmon; steelhead

Mokelumne River

1. Implement the Woodbridge Dam flow schedule: Increase escapement and survival of salmonids and American shad in the lower Mokelumne River.

Month	Mokelumne River flows[a] (cfs) just downstream of Woodbridge Dam				
	Wet	Above normal	Below normal	Dry	Critical
October[b]	300[c]	300[c]	300[c]	200[c]	200[c]
November-December[b]	350[c]	300[c]	300[c]	200[c]	200[c]
January[b]	400[d]	300[d]	300[d]	200[c]	200[c]
February[b]	450[d]	350[d]	350[d]	200[d]	200[d]
March	550[d]	350[d]	350[d]	250[d]	250[d]
April-May	3,700[e]	2,900[e]	2,500[e]	1,800[e]	1,000[e]

Month	Mokelumne River flows[a] (cfs) just downstream of Woodbridge Dam				
	Wet	Above normal	Below normal	Dry	Critical
June	950[d]	500[d]	500[d]	150[d]	150[d]
July	250[d]	100[d]	100[d]	60[f]	60[f]
August-September	60[f]	60[f]	60[f]	60[f]	60[f]

[a] Daily flow fluctuations shall not exceed 10% of the average flow within any 24-hour period, and weekly fluctuations shall not exceed 20% of the average flow within any 7-day period. Flows should not be reduced by more than 300 cfs during any 6-day period.

[b] Should flows exceed 400 cfs for any 7-day period during the peak spawning season (October-December), flows shall not be reduced below 400 cfs for the duration of the spawning/incubation period (October-February).

[c] Flows needed for chinook salmon spawning and incubation.

[d] Flows needed for chinook salmon rearing and outmigration.

[e] Flows needed for American shad spawning. Flows needed for salmon in April are 700 cfs (wet years), 600 cfs (above- and below-normal years) and 350 cfs (dry and critical years). Flows needed for salmon in May are 1,250 cfs (wet years), 900 cfs (above- and below-normal years) and 400 cfs (dry and critical years).

[f] Based on report of an instream barrier near Thornton that will prevent or impair the upstream migration of adult chinook salmon at flows less than 60 cfs (DFG 1991).

Species: Fall-run chinook salmon; steelhead; American shad

2. Provide flows maximizing suitable chinook salmon spawning habitat: Improve quantity of spawning habitat.

Species: Fall-run chinook salmon; steelhead

3. Replenish gravels suitable for salmonid spawning habitat: Improve quantity and quality of habitat.

Species: Fall-run chinook salmon; steelhead

4. Cleanse spawning gravels of fine sediments: Improve the quality of spawning habitat.

Species: Fall-run chinook salmon; steelhead

5. Prevent sedimentation of spawning gravel: Improve the quality of spawning habitat.

Species: Fall-run chinook salmon; steelhead

6. Restrict flow fluctuations and reductions: Prevent redd dewatering and stranding of juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

7. Remove Woodbridge Dam or delay installing dam flashboards until July: Reduce losses of salmon smolts to predation.

Species: Fall-run chinook salmon; steelhead

8. Reduce or eliminate mortality and delays of juvenile salmonids associated with passage past the Woodbridge Irrigation District diversion and Woodbridge Dam: Improve survival of juvenile salmonids past the Woodbridge Irrigation District diversion and Woodbridge Dam.

Species: Fall-run chinook salmon; steelhead

9. Eliminate barriers to efficient and timely migration of adult salmonids: Improve passage conditions at Woodbridge Dam for adult salmonid migration.

Species: Fall-run chinook salmon; steelhead and American shad

10. Screen all diversion in the lower Mokelumne River to DFG standards: Prevent entrainment or loss of juvenile salmonids.

Species: Fall-run chinook salmon; steelhead; American shad

11. Maintain suitable water temperatures for all salmonid life stages: Provide for timely migrations and increased survival of adult and juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

12. Enhance and maintain riparian corridor: Improve streambank and channel rearing for juvenile salmonids.

Species: Fall-run chinook salmon; steelhead

13. Set and enforce water quality standards: Provide optimal water quality for all life stages of salmonid.

Species: Fall-run chinook salmon; steelhead

14. Eliminate adverse effects of poaching and angling on salmonid production: Protect adult salmonid production.

Species: Fall-run chinook salmon; steelhead

15. Evaluate the feasibility of increasing available rearing habitat: Maximize suitable rearing habitat.

Species: Fall-run chinook salmon; steelhead

Cosumnes River

1. Determine and set instream flow requirements: Ensure adequate flows for all life stages of salmonids.

Species: Fall-run chinook salmon; possibly steelhead

2. Restrict water diversions during critical periods for salmonids: Ensure adequate instream flows for all life stages and provide better passage for adults and juveniles.

Species: Fall-run chinook salmon; possibly steelhead

3. Purchase existing water rights: Ensure adequate flows for all life stages of salmonids.

Species: Fall-run chinook salmon; possibly steelhead

4. Evaluate diversion dams and barriers for fish passage problems: Ensure passage problems for adult and juvenile salmonids.

Species: Fall-run chinook salmon; possibly steelhead

5. Remedy passage problems identified in Action 4: Ensure of passage adult and juvenile salmonids.

Species: Fall-run chinook salmon; possibly steelhead

6. Enforce Fish and Game Codes that prohibit construction of unlicensed dams: Ensure unimpeded passage of adult and juvenile salmonids.

Species: Fall-run chinook salmon; possibly steelhead

7. Effectively screen all diversions: Prevent loss of juvenile salmonids to entrainment.

Species: Fall-run chinook salmon; possibly steelhead

8. Establish riparian corridor protection zone: Preserve existing salmonid habitat from incompatible land use and moderate water temperature.

Species: Fall-run chinook salmon; possibly steelhead

9. Rehabilitate damaged areas: Remedy incompatible land use practices that have increased sedimentation of the river and elevate water temperatures.

Species: Fall-run chinook salmon; possibly steelhead

Calaveras River

1. Implement the Calaveras flow schedule: Optimize migration, spawning, incubation, rearing, and outmigration conditions for chinook salmon.

Month	Calaveras River flows (cfs)[a]				
	Wet	Above normal	Below normal	Dry	Critical
February 19-29	225[b]	70	70	50	50

Month	Calaveras River flows (cfs)[a]				
	Wet	Above normal	Below normal	Dry	Critical
March 1-20	225[b]	225[b]	225[b]	225[b]	225[b]
March 21-30	225[b]	225[b]	225[b]	120[c]	120[c]
March 31-September 15	200[c]	160[c]	160[c]	120[c]	120[c]
September 16-October 31	100[d]	100[d]	100[d]	100[d]	100[d]
November 1-February 18	70[e]	70[e]	70[e]	50[e]	50[e]

[a] Flows for spawning and incubation, rearing, and temperature control are needed only to Bellota because most fish remain above where the majority of diversions occur. However, 50 to 70 cfs left instream to tidewater would help maintain the overall health of the river system. Flows are proposed on an interim basis until more complete instream flow studies are conducted.

[b] Flows of 225 cfs are needed for attraction and passage of adults and smolts. Flows are required to mouth of San Joaquin River.

[c] Flows needed for spawning and incubation.

[d] Flows needed for juvenile rearing, including temperature protection.

[e] Flows needed for juvenile rearing.

Species: Winter-run chinook salmon

2. Manage water temperatures for all salmonid life stages, including spawning, incubation, rearing, juvenile outmigration, and adult migration: Provide suitable water temperatures for salmonid survival.

Species: Winter-run chinook salmon

3. Remove migration barriers affecting salmonids: Improve upstream and downstream migration.

Species: Winter-run chinook salmon

4. Evaluate screening needs and install screens as needed on existing diversions that may affect juvenile outmigrants: Protect outmigrants.

Species: Winter-run chinook salmon

5. Monitor sport fishing and regulations: Protect chinook and other salmonids.

SACRAMENTO-SAN JOAQUIN DELTA

1. Provide protection for juvenile salmonids migrating through the Delta from November 1 through June 30, equivalent to protection provided by restricting exports to minimal levels: Increase survival in Delta for all juvenile salmonid life stages (and potentially adults) affected by CVP and SWP exports. This includes juveniles migrating through the Delta using the mainstem rivers, as well as juveniles diverted into the central and southern portions of the Delta and juveniles emigrating from the San Joaquin Basin.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; striped bass

2. Establish a moratorium on net increases in Delta diversions and withdrawals at the Contra Costa Canal: Reduce direct and indirect losses of striped bass resulting from the operation of the pumps and diversions.

Species: Striped bass

3. Close the DCC gates from 1 October through 30 June: Increase the survival of juvenile fish migrating down the mainstem Sacramento River by reducing the number diverted into the central and southern Delta.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; American shad

4. Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30: Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for the San Joaquin Basin adults (October-December).

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; striped bass; American shad; white and green sturgeon

5. Increase mean monthly flow at Vernalis to 4,500 cfs, 6,000 cfs, 8,000 cfs, 12,000 cfs, and 21,000 cfs in critical, dry, below-normal, above-normal, and wet year types (60-20-20) during smolt migration period: Increase the survival of smolts migrating through the Delta originating from the San Joaquin Basin.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead

6. Implement the Delta outflow schedule: Increase production of striped bass, American shad; white and green sturgeon

Month	Delta outflow (cfs) measured at Chipps Island[a]				
	Wet	Above normal	Below normal	Dry	Critical
October	11,500	7,500	6,500	7,500	7,000
November	29,500	24,000	13,000	13,500	8,000
December	80,500	36,000	24,500	19,500	12,500
January	100,500	85,500	36,500	20,000	18,000
February	103,000	85,500	57,500	40,000	18,000
March	101,000	89,500	51,000	50,500	24,500
April	99,200[b]	76,100[b]	68,000[d]	49,500[d]	27,100[f]
May	99,500[c]	77,500[c]	66,100[e]	46,600[e]	27,100[f]
June	67,500	44,500	36,000	24,000	16,500
July	27,000	16,000	12,000	8,500	6,000
August	11,000	7,000	6,000	5,000	3,500
September	8,000	6,500	5,500	4,500	3,500

[a] Flows needed for striped bass except where noted.

[b] Flows needed for American shad. Flows needed for striped bass are 96,500 cfs and 73,000 cfs in wet and above-normal years, respectively. Flows needed for white and green sturgeon are 25,000 cfs; with minimum daily outflows not less than 20,000 cfs and 15,000 cfs in April and May, respectively.

[c] Flows needed for striped bass. Flows needed for American shad are 99,200 cfs and 76,100 cfs in wet and above-normal water years, respectively. Flows needed for white and green sturgeon are 25,000 cfs with minimum daily outflows not less than 20,000 cfs and 15,000 cfs in April and May, respectively.

[d] Flows needed for striped bass. Flows needed for American shad are 66,100 cfs and 46,500 cfs in below-normal and dry water years.

[e] Flows needed for American shad. Flows of 65,500 cfs, 46,500 cfs needed for striped bass in below-normal and dry water years, respectively.

[f] Flows needed for American shad. Flows needed for striped bass are 25,500 cfs and 27,000 cfs in April and May, respectively.

Species: Fall-, late fall-, winter-, and spring-run chinook salmon; steelhead; striped bass; American shad; white and green sturgeon

7. Reduce predation at and near the SWP and CVP pumps: Improve survival of striped bass eggs, larvae, and juveniles entrained by the SWP and CVP pumps.

Species: Striped bass

8. Improve CVP and SWP salvage operations: Improve survival of eggs, larvae, and juveniles.

Species: Striped bass; white and green sturgeon

9. Minimize loss and/or entrainment of eggs, larvae, and juveniles at the Contra Costa Canal diversion: Improve survival of eggs, larvae, and juveniles as they enter historical nursery areas.

Species: Striped bass; white and green sturgeon

10. Minimize loss and/or entrainment of eggs, larvae, and juveniles at the PG&E power generating plants: Improve survival of eggs, larvae, and juveniles as they enter historical nursery areas.

Species: Striped bass; white and green sturgeon

11. Eliminate, relocate, or reduce Sherman and Twitchell Island diversions: Improve survival of eggs, larvae, and juveniles as they enter historical nursery areas.

Species: Striped bass; white and green sturgeon

12. Minimize loss and/or entrainment of eggs, larvae, and juveniles at private agricultural diversions: Improve survival of eggs, larvae, and juveniles as they enter historical nursery areas.

Species: Striped bass; white and green sturgeon

13. Support measures to prevent development of a water quality barrier to adult striped bass migration in the San Joaquin River near Stockton: Ensure access to spawning areas in the San Joaquin River upstream of Stockton.

Species: Striped bass

14. Reduce toxic chemical and trace metal pollution: Provide better water quality for all life stages of anadromous fish.

Species: Striped bass; white and green sturgeon

15. Eliminate or reduce dredging and dredge spoil contribution to water pollution: Provide better water quality for all life stages of anadromous fish.

Species: Striped bass; white and green sturgeon

16. Reduce or eliminate unnecessary landfill projects: Reduce or eliminate habitat loss due to filling of Bay and Delta tidelands.

Species: Striped bass

17. Reduce or eliminate illegal take and poaching: Reduce impacts of illegal fishing on striped bass populations.

Species: Striped bass

18. Reduce or eliminate the annual summer die-off of adult striped bass: Reduce mortality of adult striped bass.

Species: Striped bass

19. Minimize incidental take of adult striped bass by commercial bay shrimp fishery: Increase young-of-the-year striped bass survival.

Species: Striped bass

20. Reduce or eliminate introduction of exotic aquatic organisms: Reduce impacts that exotic species have on striped bass and their food supply.

Species: Striped bass

SAN JOAQUIN RIVER BASIN

Lower San Joaquin River Tributaries

Merced River -

1. Implement the Merced River flow schedule: Manage flows to benefit all life stages of chinook salmon.

Month	Merced River flows (cfs) at Crocker-Hoffman Diversion to confluence with the San Joaquin River (flows rounded to nearest 50 cfs)				
	Wet[a]	Above normal	Below normal	Dry	Critical
October	350[b]	300[b]	300[b]	250[b]	250[b]
November	350[b]	350[b]	300[b]	300[b]	250[b]
December	600[c]	550[c]	300[b]	300[b]	250[b]
January	1,100[c]	600[c]	300[b]	300[g]	250[g]
February	1,450[c]	1,050[c]	500[g]	300[g]	250[g]
March	1,500[c]	1,050[c]	600[g]	450[g]	400[g]
April	1,800[d]	1,350[d]	1,150[d]	950[d]	750[d]
May	2,950[d]	2,300[d]	1,750[d]	1,200[d]	850[d]
June	2,850[d]	1,450[d]	1,150[d]	650[d]	450[d]
July	1,150[e]	400[e]	250	200[f]	200[f]
August	350[f]	300[f]	25[f]	200[f]	200[f]
September	350[f]	300[f]	25[f]	200[f]	200[f]

[a] Year types based on San Joaquin Basin 60-20-20 Index.

[b] Based on IFIM spawning flow recommendations for similar size drainages (Reynolds 1993) and the assumption that greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[c] Based on historical (1922-1991) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[d] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[e] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[f] Based on IFIM recommendations for similar size drainages (Reynolds 1993) and the assumption that greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[g] Based on IFIM flow recommendations for similar size drainages and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

Species: Fall-run chinook salmon

2. Adjust flow schedule to maintain water temperatures at 56°F between October 15 and February 15, and at 65°F between April 1 and May 31: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Species: Fall-run chinook salmon

3. Reduce impacts of rapid flow fluctuations: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Species: Fall-run chinook salmon

4. Restore and protect instream and riparian habitat: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of stream ecosystem.

Species: Fall-run chinook salmon

5. Install and maintain fish protection devices at riparian pumps and diversion: Reduce or eliminate loss of juvenile chinook salmon due to entrainment by pumps and diversions.

Species: Fall-run chinook salmon

6. Provide additional law enforcement: Increase spawning success, reduce entrainment, and prevent additional destruction of stream habitat.

Species: Fall-run chinook salmon

7. Provide fish passage around reservoirs: Increase production and minimize impacts on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.
Species: Fall-run chinook salmon; steelhead

Tuolumne River -

1. Implement the Tuolumne River flow schedule: Manage flows to benefit all life stages of chinook salmon.

Month	Tuolumne River flows (cfs) at LaGrange Dam to confluence with the San Joaquin River (flows rounded to nearest 50 cfs)				
	Wet[a]	Above normal	Below normal	Dry	Critical
October	750[b]	300[b]	300[b]	200[b]	150[b]
November	1250[c]	800[c]	350[b]	300[b]	150[b]
December	1,400[c]	1,050[c]	350[b]	350[b]	200[c]
January	1,700[c]	1,150[c]	500[c]	400[b]	250[c]
February	2,100[c]	1700[c]	950[c]	700[c]	500[c]
March	2,300[c]	1,700[c]	1,300[c]	1,000[c]	900[c]
April	2,950[d]	2,450[d]	2,350[d]	1,900[d]	1,500[d]
May	5,150[d]	4,200[d]	3,350[d]	2,500[d]	1,850[d]
June	5,000[d]	3,250[d]	2,600[d]	1,550[d]	1,000[d]
July	2,150[e]	900[e]	650[e]	250[e]	200[e]

Month	Tuolumne River flows (cfs) at LaGrange Dam to confluence with the San Joaquin River (flows rounded to nearest 50 cfs)				
	Wet[a]	Above normal	Below normal	Dry	Critical
August	450[e]	200[e]	100[f]	100[f]	50[f]
September	350[f]	150[f]	150[f]	100[f]	50[f]

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Based on USFWS IFIM flow recommendations (USFWS unpublished data) and the assumption that greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[c] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Tuolumne River Basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[d] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[e] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff.

[f] Flow based on USFWS IFIM recommendations.

Species: Fall-run chinook salmon

2. Adjust flow schedule to maintain water temperatures at 56°F between October 15 and February 15 and at 65°F between April 1 and May 31: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Species: Fall-run chinook salmon

3. Reduce impacts of rapid flow fluctuations: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Species: Fall-run chinook salmon

4. Restore and protect instream and riparian habitat: Ensure the sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Species: Fall-run chinook salmon

5. Install and maintain fish protection devices at riparian pumps and diversions: Prevent or eliminate loss of juvenile chinook salmon due to entrainment.

Species: Fall-run chinook salmon

6. Provide additional law enforcement for illegal take of salmon, stream alteration, and water pollution and to ensure adequate protection for juvenile salmon at pumps and diversions: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Species: Fall-run chinook salmon

7. Provide fish passage around reservoirs: Increase production and minimize impacts on water impacts by providing access to additional spawning/rearing habitat upstream of reservoirs.

Species: Fall-run chinook salmon

Stanislaus River -

1. Implement the Stanislaus River flow schedule: Manage flows to benefit all life stages of chinook salmon.

Month	Stanislaus River flows (cfs) from Goodwin Dam to confluence with the San Joaquin River (flows rounded to nearest 50 cfs)				
	Wet[a]	Above normal	Below normal	Dry	Critical
October	350[b]	350[b]	300[b]	250[b]	250[b]
November	400[b]	350[b]	300[b]	300[b]	250[b]
December	850[c]	650[c]	300[b]	300[b]	250[b]
January	1,150[c]	800[c]	300[d]	300[d]	250[d]

Month	Stanislaus River flows (cfs) from Goodwin Dam to confluence with the San Joaquin River (flows rounded to nearest 50 cfs)				
	Wet[a]	Above normal	Below normal	Dry	Critical
February	1,450[c]	1,150[c]	700[c]	450[d]	300[d]
March	1,550[c]	1,150[c]	850[c]	650[c]	550[c]
April-May	5,600[e]	4,300[e]	3,800[e]	2,700[e]	1,500[e]
June	2,650[f]	1,600[f]	1,300[f]	700[f]	450[f]
July	900[g]	400[g]	350[h]	200[h]	250[h]
August	350[h]	300[h]	250[h]	200[h]	200[h]
September	350[h]	300[h]	250[h]	200[h]	200[h]

[a] Year types based on San Joaquin Basin 60-20-20 Index.

[b] Flow based on IFIM Recommendations and the assumption that greater than historical flows are needed to compensate for elimination of access to upstream spawning habitat.

[c] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[d] Based on USFWS IFIM spawning flow recommendations and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering and stranding of rearing juveniles.

[e] Flows needed for American shad spawning. Flows needed for salmon during April are 2,100 cfs, 1,800 cfs, 1,750 cfs, 1,250 cfs, and 950 cfs in wet, above-normal, below-normal, dry, and critical water years. Flows needed for salmon during May are 3,500 cfs, 2,750 cfs, 2,050 cfs, 1,400 cfs, and 900 cfs in wet, above-normal, below-normal, dry, and critical water years. Stanislaus River contribution to Vernalis flow standard. Based on historical monthly contribution of the Stanislaus River to total unimpaired runoff for the San Joaquin River Basin, 1922-1990.

[f] Stanislaus River contribution to Vernalis flow standard. Based on historical monthly contribution of the Stanislaus River to total unimpaired runoff for the San Joaquin River Basin, 1922-1990.

[g] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River basin.

[h] Based on USFWS IFIM flow and assumption that greater than unimpaired flow is needed to compensate for eliminations of access to upstream habitat.

Species: Fall-run chinook salmon

2. Operate New Melones, Tulloch, and Goodwin reservoirs to maintain water temperatures at 56°F between October 15 and February 15 and at 65°F between April 1 and May 31: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Species: Fall-run chinook salmon

3. Restore and protect instream and riparian habitat: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Species: Fall-run chinook salmon

4. Reduce impacts of rapid flow fluctuations: Increase hatching success and juvenile survival by reducing flow fluctuation rates resulting from peaking power and other reservoir operations.

Species: Fall-run chinook salmon

5. Install and maintain fish protection devices at riparian pumps and diversions: Reduce or eliminate loss juvenile chinook salmon due to entrainment by pumps and diversions.

Species: Fall-run chinook salmon

6. Provide additional law enforcement for illegal take of salmon, stream alterations, water pollution and to ensure adequate screening of pumps and diversions: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Species: Fall-run chinook salmon

7. Remove or modify of Old Melones Dam: Reduce fall water temperatures in the Stanislaus River.

Species: Fall-run chinook salmon

8. Provide fish passage around reservoirs: Increase production and minimize impacts of anadromous fish restoration on water interests by providing access to additional spawning and rearing habitat upstream of reservoirs.

Species: Fall-run chinook salmon; steelhead

Lower San Joaquin River

1. Implement the Stevinson flow schedule: Manage flows to benefit all life stages of chinook salmon.

Month	San Joaquin flows (cfs)[a] at Stevinson (flows rounded to nearest 50 cfs)				
	Wet[b]	Above normal	Below normal	Dry	Critical
April	5,150	2,650	2,050	1,750	1,250
May	7,000	4,450	3,050	2,300	1,600
June	6,800	3,450	2,600	1,700	1,050

[a] San Joaquin contribution to Vernalis flow standard. Based on Vernalis flow standards and the historical percent contribution of the San Joaquin River to total unimpaired San Joaquin Basin runoff.

[b] Year types based on San Joaquin Basin 60-20-20 Index.

Species: Fall-run chinook salmon

2. Provide mean monthly flows of at least 7,000 cfs at Newman between February and May in wet and above-normal water years: Increase sturgeon production by providing adequate flows for upstream migration, spawning, and progeny survival.

Species: White and green sturgeon

3. Implement the Vernalis flow schedule: Manage flows to benefit all life stages of chinook salmon, American shad, and white and green sturgeon.

Month	San Joaquin River flows (cfs) at Vernalis				
	Wet[a]	Above normal	Below normal	Dry	Critical
October	1,450[b]	950[b]	900[b]	700[b]	650[b]
November	2,000[b]	1,500[b]	950[b]	900[b]	650[b]
December	2,850[b]	2,250[b]	950[b]	950[b]	700[b]
January	3,950[b]	2,550[b]	1,100[b]	1,000[b]	750[b]
February	14,000[c]	14,000[c]	2,150[b]	1,450[b]	1,050[b]
March	14,000[c]	14,000[c]	2,750[b]	2,100[b]	1,850[b]
April	28,400[d]	21,800[d]	18,900[d]	13,500[d]	7,800[d]
May	28,400[d]	21,800[d]	18,900[d]	13,500[d]	7,800[d]
June	17,300[e]	9,750[e]	7,650[e]	4,600[e]	2,950[e]
July	4,200[d]	1,700[d]	1,250[d]	650[d]	650[d]
August	1,150[d]	800[d]	600[d]	500[d]	450[d]
September	1,050[d]	750[d]	650[d]	500[d]	450[d]

[a] Year types based on San Joaquin Basin 60-20-20 Index.

[b] Sum of flow from the Stanislaus, Tuolumne, and Merced rivers.

[c] Flows needed for sturgeon spawning. Flows needed for salmon in February are 5,000 cfs (wet years) and 3,900 cfs (above-normal years). Flows needed for salmon in March are 5,350 cfs (wet years) and 3,900 (above-normal years) in March. Salmon flows are sum of flows from the Stanislaus, Tuolumne, and Merced rivers.

[d] Flows needed for American shad spawning. Flows needed for salmon in April are 12,000 cfs (wet years), 8,250 cfs (above-normal years), 7,300 cfs (below-normal years), 5,850 cfs (dry years), and 4,450 cfs (critical years). Flows needed for salmon in May are 18,600 cfs (wet years), 13,700 cfs (above-normal years), 10,200 cfs (below-normal years), 7,400 cfs (dry years), and 5,200 cfs (critical

years). See footnote [e] for explanation on flow derivation. Flows needed for white and green sturgeon spawning are 14,000 cfs in wet and above-normal water years.

[e] Flow required to meet salmon production goals based on regression relationship:

$$E_{S,T} = (1.820Q_V)-(0.051X_{F,S})-18{,}417.3$$ (Carl Mesick Consultants 1994)

Where, for a given year class, $E_{S,T}$ is the sum of escapement into the Stanislaus and Tuolumne rivers as 2- and 3-year-old fish, Q_V is average San Joaquin River flow (cfs) at Vernalis from April 1 through June 30 in the year of outmigration, and $X_{F,S}$ is total combined monthly exports (af) for the federal (CVP) and state (SWP) water projects, from April 1 through June 30 in the year of outmigration. Flow is allocated between April, May, and June on the basis of historical occurrence of unimpaired runoff.

Species: Fall-run chinook salmon; American shad; white and green sturgeon

4. Install and maintain fish protection devices at Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by the four largest diversions on the San Joaquin River.

Species: Fall-run chinook salmon; depending on mesh aperture could have benefits for striped bass, American shad, juvenile white and green sturgeon

5. Install and maintain fish protection devices at small agricultural diversions: Increase survival of juvenile salmon by reducing or eliminating entrainment.

Species: Fall-run chinook salmon; depending on mesh aperture could have benefits for striped bass, American shad, juvenile white and green sturgeon

6. Continue prohibition on sport harvest of chinook salmon in the San Joaquin Basin upstream of Mossdale; extend closure on the mainstem San Joaquin River downstream to Chipps Island: Increase spawning success by preventing harvest of salmon escaping into San Joaquin River tributaries.

Species: Fall-run chinook salmon

7. Prohibit dredging of Stockton ship channel during critical periods: Prevent dissolved oxygen stage during periods when adult or juvenile salmon are migrating through the lower San Joaquin River and Delta.

Species: Fall-run chinook salmon

8. Operate head of Old River barrier to protect migrating adults and juveniles: Improve water quality for migrating adults, reduce entrainment of outmigrating smolts.

Species: Fall-run chinook salmon; white and green sturgeon

9. Modify reservoir operation to maintain mainstem San Joaquin River water temperatures at 56°F between October 15 and February 15 and at 65°F between April 1 and May 31 for chinook salmon; maintain water temperatures between 61°F and 65°F for 1 month between April 1 and June 30 for American shad; and maintain water temperatures below 63°F in spawning areas and below 68°F throughout the San Joaquin River in wet and above-normal water years between February and May for white and green sturgeon: Prevent delays in adult migration and associated higher rates of egg mortality and increase survival of outmigrating juveniles by reducing stress and mortality associated with high water temperatures. Water temperatures also provide for sturgeon migration, final stages of sexual maturation, spawning, and progeny survival.

Species: Fall-run chinook salmon; American shad; white and green sturgeon

10. Establish a basinwide Conjunctive Water Use Program: Obtain adequate water to meet anadromous fish-flow requirements while minimizing impacts on other water users.

Species: Fall-run chinook salmon

11. Reduce predator populations: Increase survival of juvenile salmon by reducing predator populations.

Species: Fall-run chinook salmon

12. Remove barriers to sturgeon migration: Remove barriers that prevent or slow the migration of sturgeon to areas where sturgeon spawn.

Species: White and green sturgeon

13. Adopt gear restrictions eliminating illegal harvest of white and green sturgeon: Increase size of spawning stock.

Species: White and green sturgeon

14. Improve water quality: Improve survival and condition of sturgeon.

Species: White and green sturgeon

WORKING PAPER ON RESTORATION NEEDS

HABITAT RESTORATION ACTIONS
TO DOUBLE NATURAL PRODUCTION OF ANADROMOUS FISH
IN THE CENTRAL VALLEY OF CALIFORNIA

Volume 2

Prepared for the U.S. Fish and Wildlife Service
under the direction of the
Anadromous Fish Restoration Program Core Group

May 9, 1995

ORGANIZATION OF THIS WORKING PAPER

This is Volume 2 of three volumes that comprise the Anadromous Fish Restoration Program Working Paper (AFRP) on Restoration Needs. The contents of the three volumes are as follows:

Volume 1 describes how the WORKING PAPER was developed, explains the process envisioned for completing a final Restoration Plan, and summarizes the production goals, limiting factors, and restoration actions sections developed by the AFRP technical teams. Interested parties should read the letter from Dale Hall and Wayne White that appears at the beginning of Volume 1.

Volume 2 provides descriptions of Central Valley rivers and streams, summarizes information on historic and existing conditions for anadromous fish, identifies the problems that have led to the decline of anadromous fish populations, and identifies roles and responsibilities of state and federal agencies in managing anadromous fish. It also includes two key documents that were used by the AFRP Core Group and technical teams to develop the WORKING PAPER.

Volume 3 includes the complete production goals, limiting factors, and restoration actions sections as submitted by the AFRP technical teams and edited by USFWS staff. Volume 3 also includes citations for all three volumes of the WORKING PAPER. To request copies of this working paper, call the Anadromous Fish Restoration Program's information line at (800) 742-9474 or (916) 979-2330 and dial extension 542 after the recorded message begins. You may also obtain copies by calling Roger Dunn, CVPIA Public Outreach, at (916) 979-2760 or by sending e-mail requests to roger_dunn@fws.gov. The Working Paper is available to be viewed and downloaded on the Internet at http://darkstar.dfg.ca.gov/usfws/fws_home.html.

This document should be cited as:

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SECTION V. DESCRIPTION OF CENTRAL VALLEY RIVERS AND STREAMS

SACRAMENTO BASIN

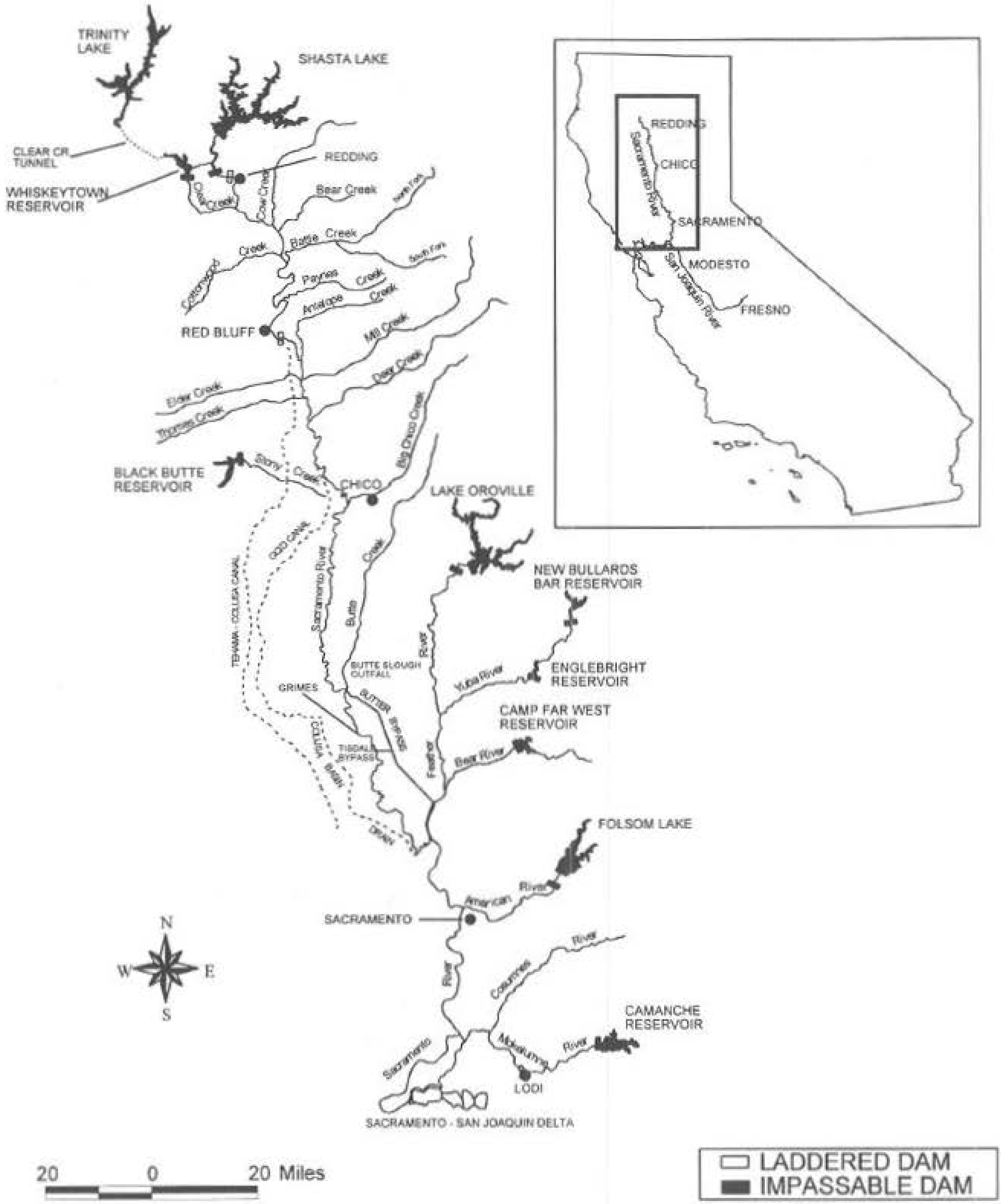
Upper Mainstem Sacramento River

The Sacramento River, the largest river system in California, yields 35% of the state's water supply. This river system supports one of the largest contiguous riverine and wetland ecosystems in the Central Valley (Figure 2-V-1). The median historical unimpaired run-off above Red Bluff is 7.2 million acre-feet (maf), with a range of 3.3-16.2 maf (Figure 2-V-2). At least eight state-listed and federally listed endangered and threatened species and several species of special concern exist in the river and adjacent riparian forest. The chinook salmon populations of the Sacramento River provide most of the state's sport and commercial catch.

Most of the Sacramento River flow is controlled by the U.S. Bureau of Reclamation's (USBR's) Shasta Dam, which stores up to 4.5 maf of water. River flow is augmented in an average year by transfer of up to 1 maf of Trinity River water through a tunnel to Keswick Reservoir. USBR operates the Shasta-Trinity Division of the Central Valley Project (CVP), which includes Shasta, Keswick, Trinity, Lewiston, Whiskeytown, and Spring Creek Debris dams; Red Bluff Diversion Dam (RBDD); and the Tehama-Colusa Canal (TCC) and Corning Canal. Other small- to medium-sized impoundments in the watershed, including Lake McCloud, Lake Britton, Iron Canyon Reservoir, and Big Sage Reservoir, can retain an additional 300+ thousand acre-feet (taf).

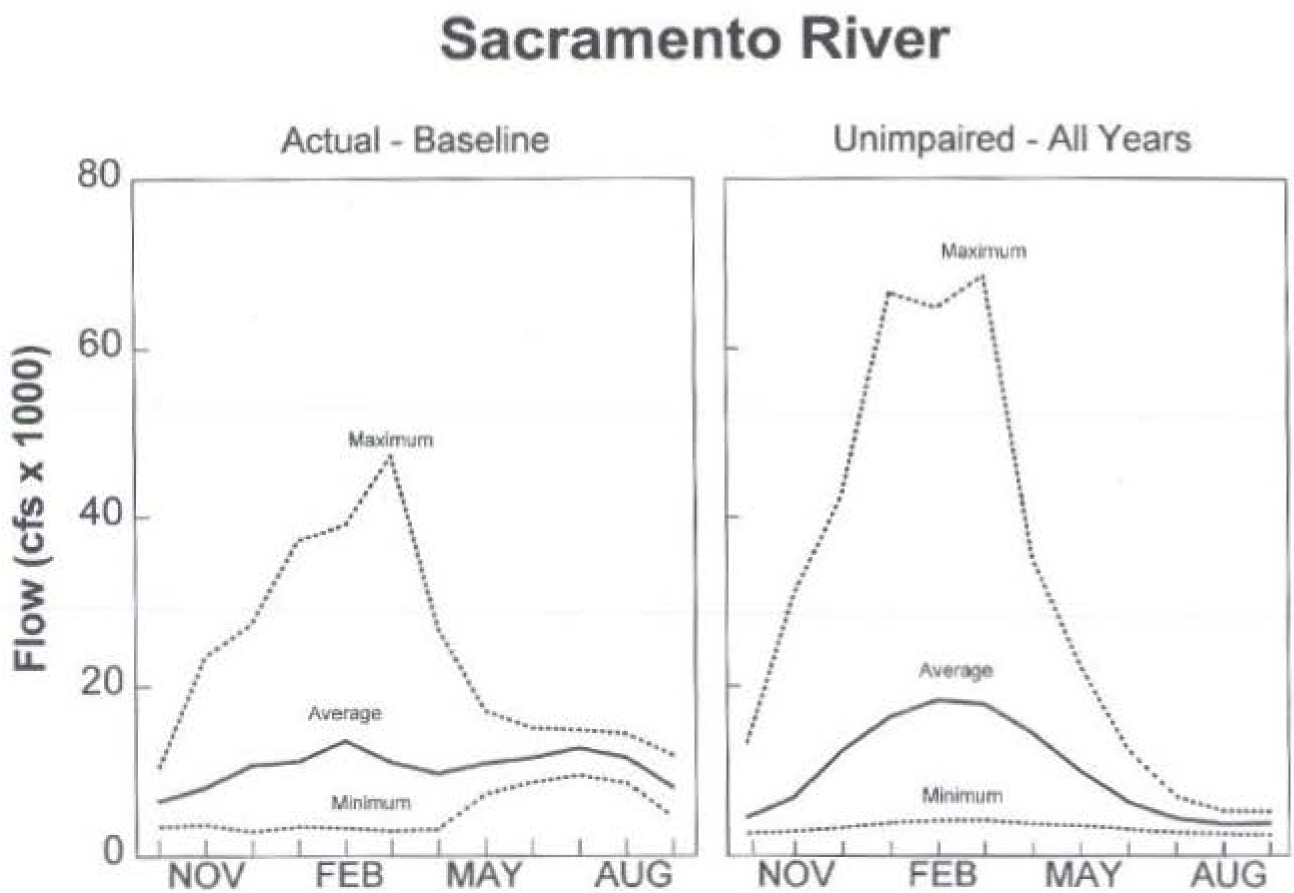
Upper Sacramento River Tributaries

Clear Creek - Clear Creek, the first major tributary to the Sacramento River below Shasta Dam (Figure 2-V-3), drains approximately 238 square miles. It originates in the mountains east of Clair Engle Reservoir and flows approximately 35 miles to its confluence with the Sacramento River just south of the Redding city limits. The median historical unimpaired run-off is 69 taf, with a range of 0-421 taf (Figure 2-V-4). Two dams are located on the creek. Whiskeytown Dam, constructed in 1963 near river mile (RM) 16.5, stores and regulates run-off from the Clear Creek drainage area and diversions from the Trinity River. The water is then diverted through the Spring Creek Tunnel to Keswick Reservoir where it provides water and power for use in the CVP. The second dam is the McCormick-Saeltzer Dam, constructed in 1903 and located approximately 10 miles downstream from Whiskeytown Dam at RM 6.5. This dam diverts 10 cubic feet per second (cfs) of water into the Townsend Flat water ditch for irrigation use.



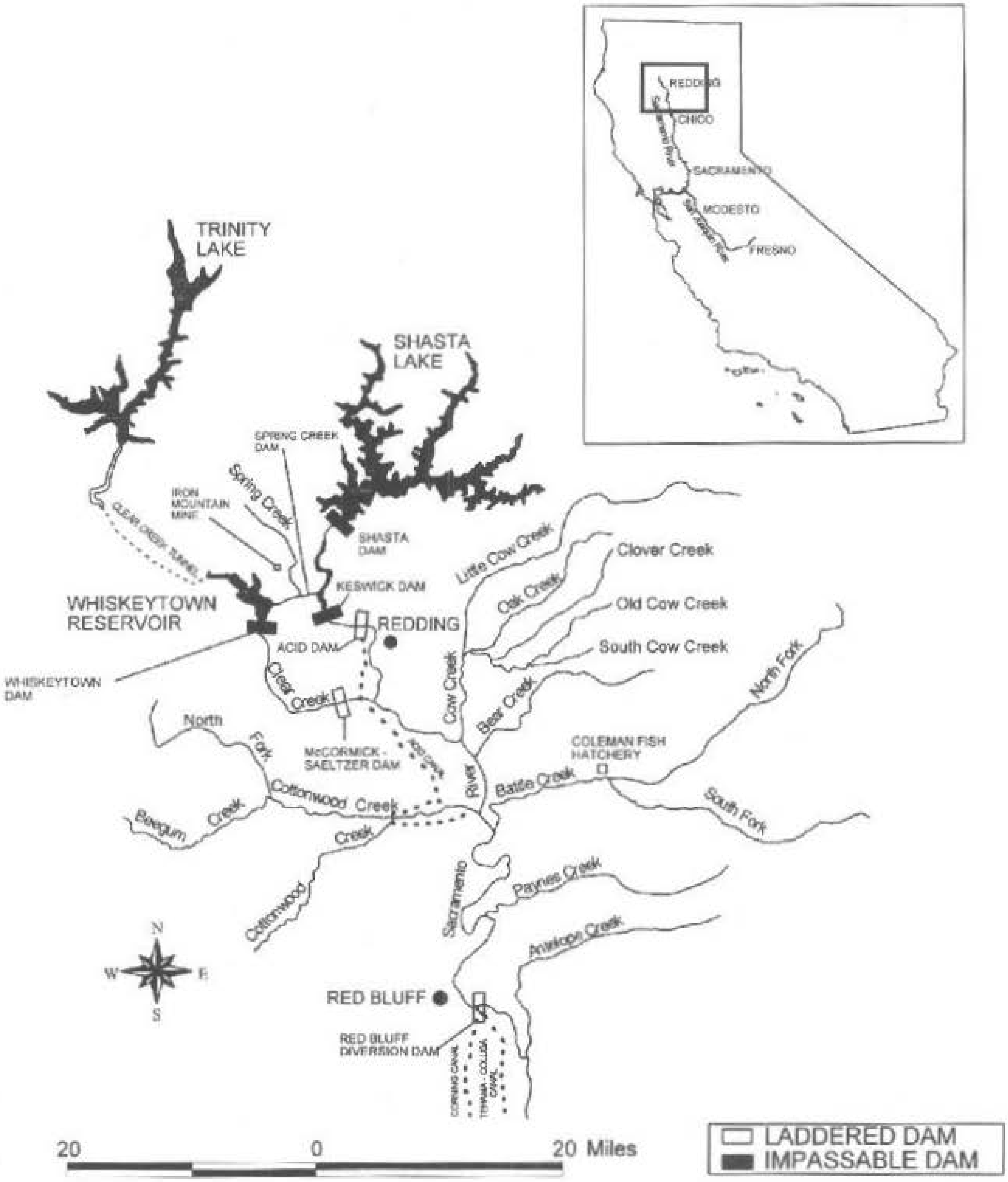
MAP OF THE SACRAMENTO RIVER BASIN

FIGURE 2-V-1



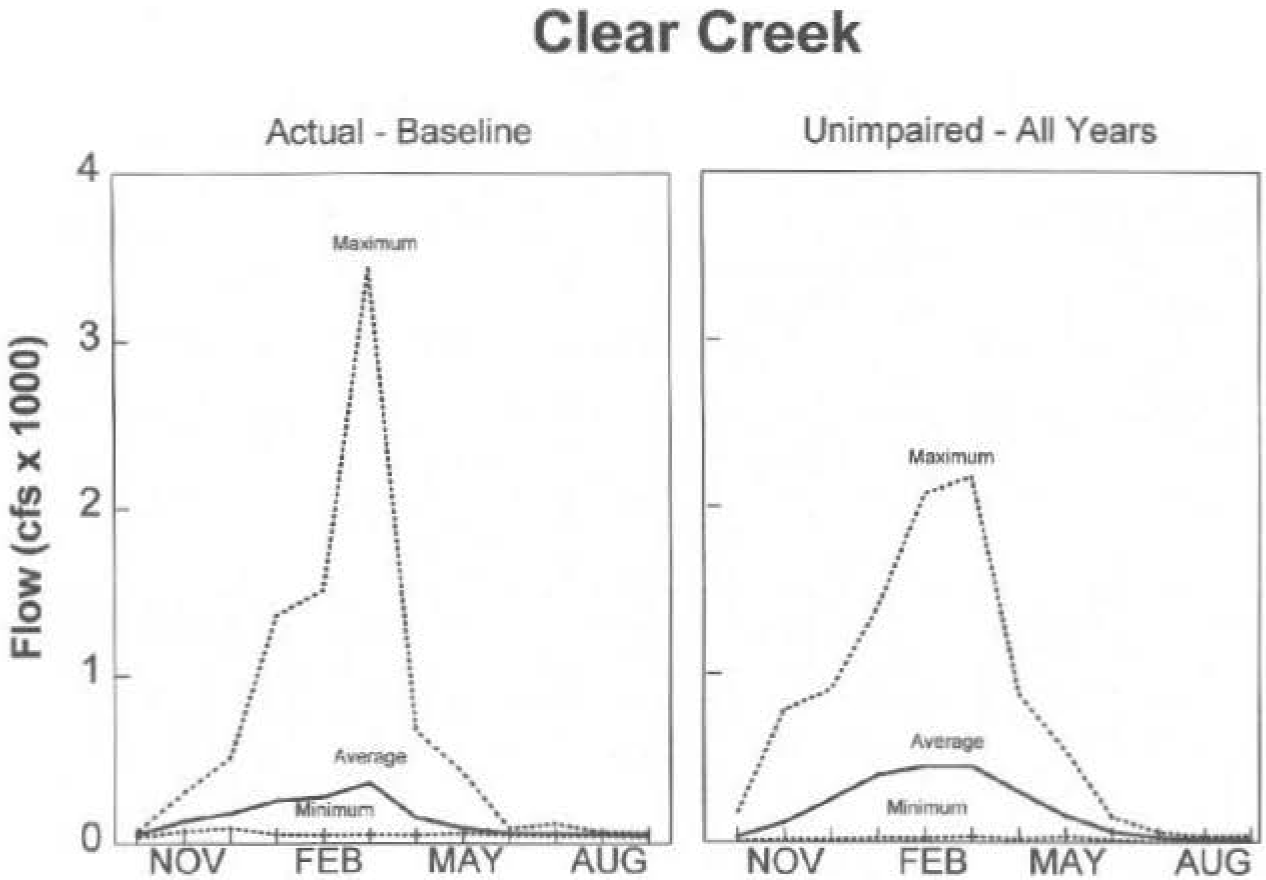
SACRAMENTO RIVER MEAN MONTHLY FLOW: ACTUAL (AT KESWICK, 1967-1991) AND UNIMPAIRED (NEAR RED BLUFF, 1922-1991)

FIGURE 2-V-2



MAP OF THE UPPER SACRAMENTO VALLEY DEPICTING LOCATIONS OF THE SACRAMENTO RIVER AND ITS TRIBUTARIES

FIGURE 2-V-3



CLEAR CREEK MEAN MONTHLY FLOW AT FRENCH GULCH: ACTUAL (1967-1991) AND UNIMPAIRED (1922-1991)

FIGURE 2-V-4

Cow Creek - Cow Creek flows through the southwestern foothills of the Cascade Range and enters the Sacramento River at RM 280, 4 miles east of the town of Anderson in Shasta County (Figure 2-V-3). Cow Creek has five major tributaries: Little (North) Cow, Oak Run, Clover, Old Cow, and South Cow creeks. Old Cow and South Cow creeks are the largest tributaries. The drainage area is approximately 425 square miles, and the average annual discharge is more than 500 taf (Reynolds et al. 1993). The total length of streambed in the drainage is about 66 miles. Headwaters for most of the tributaries originate between 5,000 and 7,000 feet in elevation, and the stream gradient in the upper reaches of the tributaries is relatively steep. Mixed conifer forest of ponderosa pine, Douglas-fir, incense cedar, and California black oak is the predominant vegetation in the higher elevations. In the lower foothills that abut the valley floor, the oak-digger pine association is predominant. The valley floor is dominated by oak grassland and pasture. Fall-run and late fall-run chinook salmon spawn in the creek on the valley floor and in all five tributaries.

Bear Creek - Bear Creek originates south of Latour Butte in Shasta County at an elevation of about 6,800 feet. It enters the Sacramento River 5 miles below Anderson as a small eastside tributary approximately 4 miles north of Battle Creek (Figure 2-V-3). Approximately 24 miles of habitat are available to salmon before the first natural barrier. The stream has low streamflow in spring through fall of most years and no flow during periods of below-normal rainfall. During spring and summer, the limited natural streamflow is further reduced by unscreened irrigation diversions in the lower reaches where the stream enters the valley floor. Although adequate streamflows in fall and spring are prerequisites for anadromous fish migration and reproduction, the drainage is known to support fall-run salmon and some steelhead.

Cottonwood Creek - Cottonwood Creek originates on the east side of a rugged section of the Coast Ranges in the Yolla Bolly-Middle Eel Wilderness in Tehama County at an elevation of approximately 4,000 feet. Cottonwood Creek drains the west side of the Central Valley and enters the Sacramento River a short distance downstream from the Redding-Anderson area (Figure 2-V-3). It has a drainage area of approximately 929 square miles. The three forks of Cottonwood Creek and tributaries encompass approximately 83 miles of habitat available to salmon. Cottonwood Creek responds quickly to rainfall and is prone to flash flooding. Poor land use practices resulting from overgrazing, timber harvest, road building, and development have significantly degraded existing fish habitat. The results have been high silt levels, armoring of gravel beds, and elevated water temperatures. Extensive gravel mining in the valley section of Cottonwood Creek has not only damaged in-creek spawning but significantly reduced gravel recruitment to the Sacramento River. Rainbow Lake is a small impoundment in the upper watershed with a capacity of 3,600 af.

Battle Creek - Battle Creek drains the western flank of Mount Lassen and enters the Sacramento River at RM 271, approximately 5 miles southeast of the Shasta County town of Cottonwood (Figure 2-V-3). Its two main branches, the North Fork and the South Fork, join 16.6 miles above the mouth and flow into the Sacramento Valley from the east, draining a watershed of approximately 360 square miles. Although boulder-laden areas can impede fish migration in the Eagle Canyon section of the North Fork, all diversion dams on Battle Creek have fish ladders (McCumber Reservoir Dam and North Battle Creek Reservoir

Dam are above barrier falls). Because of high summer (June-October) base flows of about 290 cfs (Payne & Associates 1991c) and the relative lack of consumptive water use, Battle Creek has the greatest restoration potential of the Sacramento River tributaries. Most of the Battle Creek drainage is privately owned. One other small impoundment in the watershed is Baldwin Reservoir.

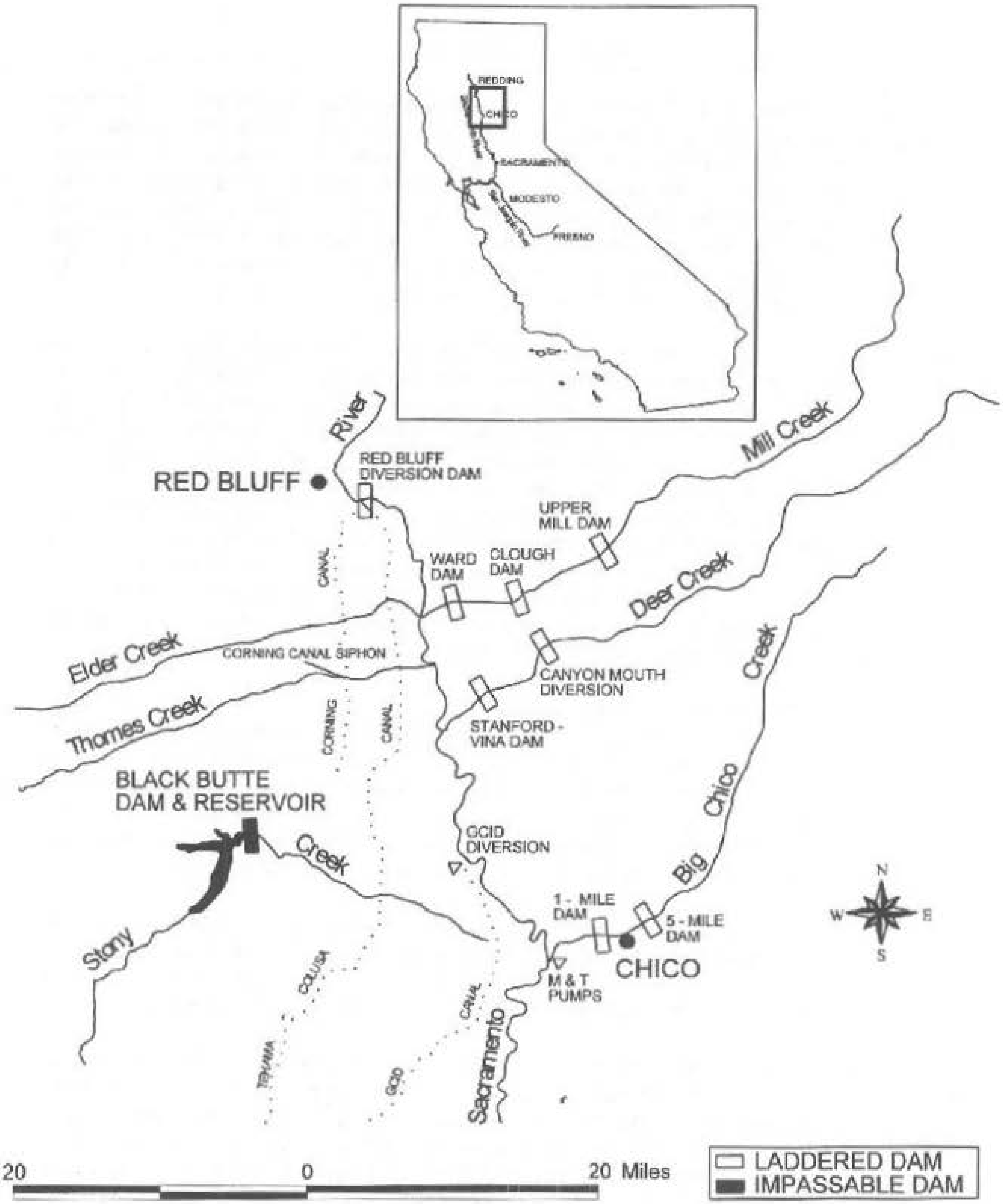
Paynes Creek - Paynes Creek enters the Sacramento River at RM 253, 5 miles north of the town of Red Bluff (Figure 2-V-3). It flows into the Sacramento Valley from the east, draining a watershed of approximately 93 square miles. Paynes Creek originates in a series of small lava springs about 6 miles west of the town of Mineral. Although the stream has no significant dams, flows in Paynes Creek have been significantly affected by the recent drought conditions, as well as by 16 seasonal diversions for irrigation, stock watering, and fish culture. The lowermost irrigation diversion, about 2 miles upstream from the mouth, is the largest, with a capacity of approximately 8 cfs. It provides water to irrigate the Bend District. The California Department of Fish and Game (DFG) owns and operates a screen on this diversion.

Paynes Creek is known to support fall-run salmon when water conditions are adequate. Low flow and inadequate spawning gravel have been identified as significant factors limiting salmon production in Paynes Creek, however. In 1988, DFG built five spawning riffles using 1,000 tons of spawning gravel. Because of low flows attributable principally to the recent drought, however, the reconstructed riffles have been sparsely used.

Antelope Creek - Antelope Creek originates in the Lassen National Forest in Tehama County at an elevation of about 6,800 feet. The creek flows southwest from the foothills of the Cascade Range and enters the Sacramento River at RM 235, 9 miles southeast of the town of Red Bluff (Figure 2-V-3). The drainage is approximately 123 square miles and the average stream discharge is 107 taf per year. The fish habitat of Antelope Creek is relatively unaltered above the valley floor, but the lack of adequate migratory flows from the Sacramento River to this habitat prevents optimum use by anadromous fish.

Water diversions and a braided channel near the canyon mouth often create problems for fish passage during the typical diversion period from April 1 through October 31. One diversion is operated by the Edwards Ranch with a water right of 50 cfs, and the other is run by the Los Molinos Mutual Water Company with a water right of 70 cfs. Because the average annual flow during April through October from 1940 to 1980 was 92 cfs, the lower reach of the stream is usually dry when both diversions are operating. Thus, adult fall-run and spring-run chinook salmon are generally unable to enter the stream during the diversion season.

Elder Creek - Elder Creek enters the Sacramento River at RM 230, 12 miles south of the town of Red Bluff (Figure 2-V-5). The stream flows into the Sacramento Valley from the west, draining a watershed of approximately 142 square miles. There are no significant dams on the stream, but several small water diversions are present. The stream is generally intermittent with a highly fluctuating flow regime. Flow



MAP OF THE CENTRAL SACRAMENTO VALLEY DEPICTING LOCATIONS OF THE SACRAMENTO RIVER, AND MILL, DEER, AND BIG CHICO CREEKS

FIGURE 2-V-5

records indicate peak flows of more than 11,000 cfs, but the stream is normally dry from July to November. In recent years, it has supported only an occasional, small run of fall-run chinook salmon.

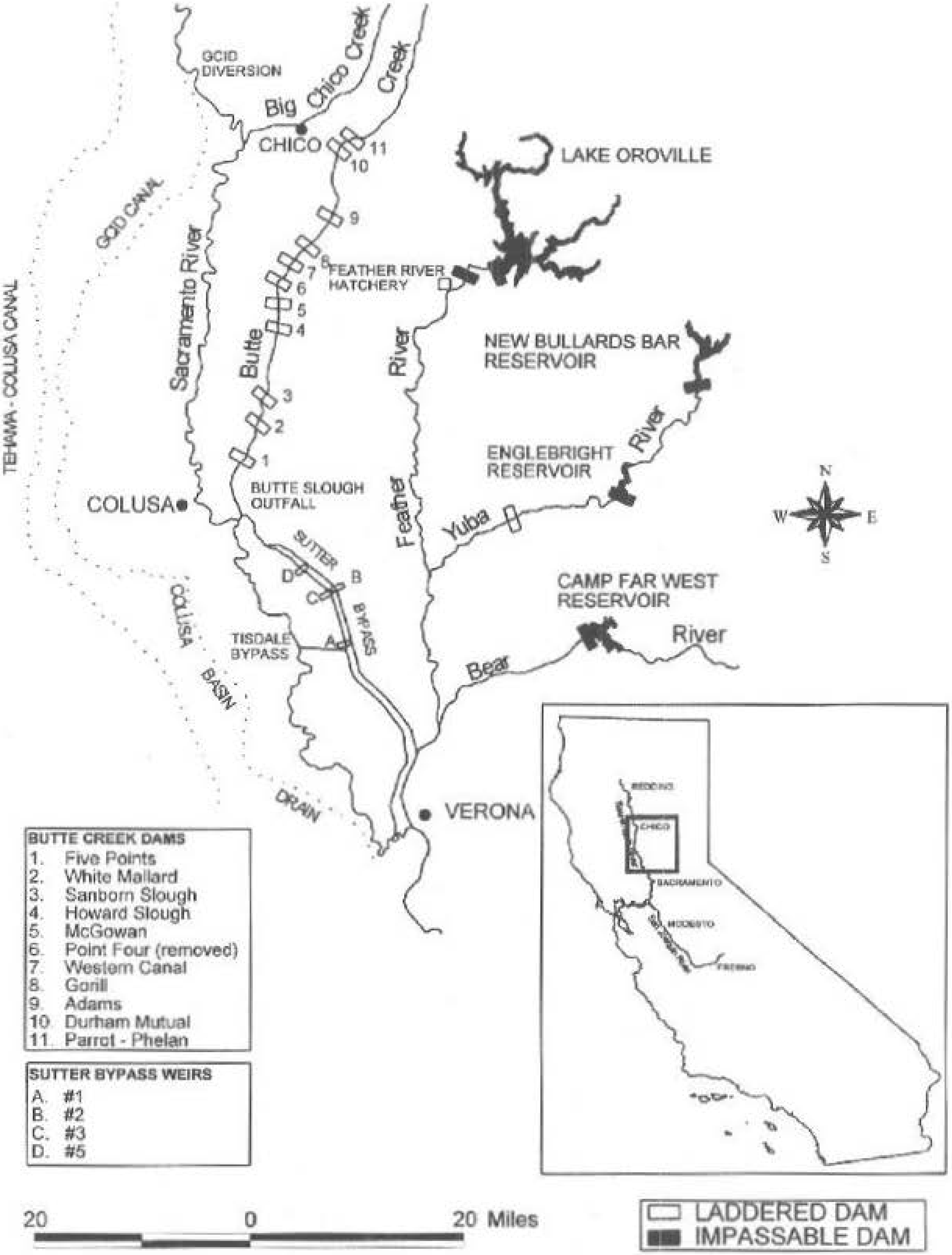
The stream reach from Rancho Tehama to the mouth is a low-gradient, braided channel with poor spawning and rearing conditions. A seasonal swimming area is created in summer by the placement of a gravel dam in the stream at Rancho Tehama, a rural housing development. Higher quality spawning gravel is located between Rancho Tehama and the point where the stream enters the valley floor. The U.S. Fish and Wildlife Service (USFWS) has recently purchased property near the confluence of Elder Creek and the Sacramento River as part of the Middle Sacramento River Wildlife Refuge. Approximately 20 miles upstream of the valley floor, the stream gradient increases rapidly in a rugged canyon area that supports resident trout and possibly a few steelhead.

Mill Creek - Mill Creek is a major tributary of the Sacramento River, flowing from the southern slopes of Mount Lassen and entering the Sacramento River at RM 230, 1 mile north of the town of Tehama (Figure 2-V-5). The stream originates at an elevation of approximately 8,000 feet and descends to 200 feet at its confluence with the Sacramento River. The watershed drains 134 square miles, and the stream is approximately 60 miles in length. The creek is confined within a steep-sided, relatively inaccessible canyon in the upper watershed. During the irrigation season, three dams on the lower 8 miles of the stream divert most of the natural flow, particularly during dry years. Most of the creek is bordered by U.S. Forest Service (USFS) land. Private land holdings exist only in the extreme headwaters and on the valley floor. The streamflows through the Ishi Wilderness Area and the Gray Davis Dry Creek Reserve, which is managed by The Nature Conservancy. Mill Creek spring-run chinook salmon are unique for spawning at an elevation of more than 5,000 feet, the highest elevation known for salmon spawning in North America.

Thomes Creek - Thomes Creek enters the Sacramento River at RM 225, 4 miles north of the town of Corning (Figure 2-V-5). It flows into the Sacramento Valley from the west, draining a watershed of approximately 188 square miles. No significant dams are located on the stream other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are operated seasonally in the stream. The stream is usually dry or flows intermittently below the U.S. Geological Survey (USGS) stream gauge near Paskenta until the first heavy fall rains. Fall-run chinook salmon enter and spawn in Thomes Creek in years of sufficient rainfall.

Deer Creek - Deer Creek, a major tributary to the Sacramento River, originates from several small springs near Childs Meadows to the north and from the northern slopes of Butt Mountain to the south. It enters the Sacramento River at RM 220, approximately 1.5 miles north of Woodson Bridge State Park (Figure 2-V-5). The watershed drains 200 square miles and is 60 miles long.

Below its source, Deer Creek flows through many miles of rugged canyon cut deeply through an ancient lava flow. At higher elevations, the terrain is forested with coniferous trees and, in lower regions, the cover is the typical valley oak-grassland association. State Highway 32 parallels about 25 miles of the upper stream. The lower 10 miles flow through the Sacramento Valley where most of the flow is diverted. In



MAP OF THE SACRAMENTO VALLEY FROM CHICO TO VERONA, INCLUDING THE FEATHER, YUBA, AND BEAR RIVER DRAINAGES AND BUTTE CREEK

FIGURE 2-V-6

many years, diversions at three dams deplete all of the natural flow from mid-spring to fall. All of the diversion structures have fish ladders and screens. Of all Sacramento Valley streams, Deer Creek has the greatest potential for spring-run chinook salmon restoration.

Stony Creek - Stony Creek is a westside stream originating in the Coast Ranges and draining into the Sacramento River south of Hamilton City in Glenn County (Figure 2-V-5). The watershed has three storage reservoirs with a combined storage capacity of more than 260 taf: Black Butte, Stony Gorge, and East Park. The lowermost dam, Black Butte, is a barrier to anadromous fish. The Glenn-Colusa Irrigation District (GCID) canal, which crosses Stony Creek downstream of Black Butte Dam, consists of a seasonal gravel dam constructed across the creek on the downstream side of the canal. This crossing allows the canal to continue flowing south and allows capture of Stony Creek water and thus acts as a complete barrier to salmon migration. Stony Creek supports fall-run chinook salmon in years when flow reaches the Sacramento River.

Big Chico Creek - Big Chico Creek originates on Colby Mountain and flows 45 miles west to its confluence with the Sacramento River at RM 193, 5 miles west of the City of Chico (Figure 2-V-5). The watershed ranges from about 121 feet in elevation at the mouth to 5,700 feet, draining a watershed of approximately 72 square miles. No significant impoundments are present on the stream, and the only major water diversion is within 1 mile of the mouth.

Most of Big Chico Creek is bordered by private land with smaller holdings by the USFS and U.S. Bureau of Land Management (BLM). The creek flows through Bidwell Park, the third largest municipal park in the United States; downtown Chico; and the California State University campus. The chief human impacts in the drainage basin upstream of Chico are logging, recreation, and associated road construction. A small, abandoned placer gold mine is located about midway between the origin of the creek and its confluence with the Sacramento River, but this mine is not known to significantly affect water quality. Habitat in areas upstream of the Five-Mile Diversion is relatively pristine because of the rugged nature of the canyon. Summer (June-October) base flow in Big Chico Creek above Five-Mile Diversion is typically 20-25 cfs. Most of this base flow is lost to infiltration in the region of the creek's outwash fan (roughly the city of Chico) so that, by late summer of most years, surface flow does not extend downstream of Rose Avenue.

Big Chico Creek has carved a deep canyon through the foothills. Upstream from Higgin's Hole (at RM 23), it has cut through metamorphic rock, creating a narrow canyon with big boulders, bedrock potholes, and spectacular waterfalls. In years when migration corresponds exactly to high flow, salmon might navigate this canyon to the waterfall at Bear Lake, but this would be unusual. For all practical purposes, Higgin's Hole is the upstream limit for anadromous fish. The size of the waterfalls and the scenic nature of the upstream canyon preclude construction of fishways.

Big Chico Creek tributaries -- Mud and Rock Creeks - Mud Creek and Rock Creek join Big Chico Creek about 0.75 mile before it enters the Sacramento River. These two tributaries are similar to each other but quite different from Big Chico Creek. Their channels are shorter and dendritic. They drain from the surface of the tilted Tuscan formation at relatively lower elevations than most of the Big Chico Creek drainage and receive their precipitation chiefly as rain, rather than snow. Accordingly, they are seasonal (flowing from about November to June in the Central Valley portion of their channels) and warm up more quickly in spring.

The drainage basins of Mud and Rock creeks are similar as well. The headwaters are in privately held forest land, foothill reaches are mostly pastured brush land or woodland, and Central Valley reaches traverse agricultural land. Both creeks pass through suburbs of Chico, with Mud Creek potentially being subject to pollution from the industrial park and airport. Both have minor agricultural diversions. In addition, Mud Creek is impounded for domestic water supply at Richardson Springs, a small resort. The Sycamore Diversion passes floodwater from Big Chico Creek to Mud Creek. Mud Creek is also subject to substantial illegal dumping from the West Sacramento Avenue Bridge.

Butte Creek - Butte Creek originates in the Jonesville Basin, Lassen National Forest, on the western slope of the Sierra Nevada, at an elevation of about 6,500 feet. The watershed area comprises approximately 150 square miles in the northeastern portion of Butte County. The creek enters the Sacramento Valley southeast of Chico and meanders in a southwesterly direction to the initial point of entry into the Sacramento River at Butte Slough (RM 139). A second point of entry into the Sacramento River is through the Sutter Bypass and Sacramento Slough (RM 80) (Figure 2-V-6).

Several small tributaries converge in the Butte Meadows basin, an area characterized by a series of wide meadows and repeating series of pools and riffles. Pine, cedar, and fir dominate the upper portion of the area, whereas the predominant riparian vegetation types in the meadow areas are alder and willow. Butte Creek flows from the Butte Meadows area approximately 25 miles through a steep canyon to the point where it enters the valley floor near Chico. Numerous small tributaries and springs enter the creek in the canyon area. Deep, shaded pools are interspersed throughout the upper section of the canyon above Centerville, whereas the area below has a shallower gradient and a riparian canopy of alder, oak, and willow.

Flows from the West Branch of the Feather River, diverted by Pacific Gas and Electric Company (PG&E) for power generation, enter Butte Creek via the Hendricks and Toadtown Canals at the Desabla Powerhouse. Two dams built by PG&E in 1917 divert water from Butte Creek for power generation. The lowermost, the Centerville Diversion Dam, located immediately below the Desabla Powerhouse, is generally considered to be the upper limit of anadromous fish migration. Anecdotal reports suggest that under extremely high flows, steelhead have been observed traversing this dam. Small impoundments in the watershed, including Magalia Reservoir, Paradise Lake, and Desabla Reservoir, store a combined 14.7 taf.

The upper watershed area above the valley floor comprises primarily private land holdings, with some national forest lands at the extreme upstream portion. Development in the upper watershed area of the mainstem of Butte Creek has been limited, although Little Butte Creek is regulated by two dams that provide domestic water for the town of Paradise. The Paradise area is being intensively developed and is currently undergoing a severe water shortage. Currently, except under extremely high, unregulated winter flows, Little Butte Creek makes only a minimal contribution to the flows of Butte Creek. Increased development, primarily residential, is occurring below the Centerville Powerhouse and along Butte Creek as far as Durham.

Colusa Basin Drain - The drainage area of the Colusa Basin extends from the Coast Ranges on the west to the Sacramento River on the east. Stony Creek and Cache Creek define the approximate northern and southern boundaries. The drainage area encompasses approximately 1,500 square miles in Glenn, Colusa, and Yolo counties. Of this area, approximately 570 square miles make up the watersheds of the various westside tributaries and the remainder are located in the relatively flat valley bottom. The watershed contains 67 individual streams, including forks and branches; approximately 11 of these currently empty directly into the Colusa Basin Drain (Table 2-V-1).

The main conveyance system within the Colusa Basin is known as the Colusa Trough, Reclamation District 2047 Drain, Colusa Basin Drainage Canal, or Colusa Basin Drain (Figure 2-V-6). Historically, the area within the basin was subject to periodic flooding from the Sacramento River. Flows in the basin generally discharged back into the river in a southeasterly direction through various sloughs. During the 1850s, reclamation efforts were begun that eventually eliminated much of the wetland area to provide land for agriculture. Levees were constructed along the west bank of the Sacramento River upstream from Knights Landing, beginning in approximately 1868. These levees blocked the natural drainage of the westside tributaries. Flows from the tributaries were instead routed through the Colusa Basin Drain to rejoin the Sacramento River near Knights Landing.

Before reclamation efforts began in the Colusa Basin, most of the westside tributaries were probably intermittent streams with little or no flow during summer. Most probably provided only opportunistic and sporadic access for salmon and steelhead. Until the drain was completed, the estuarine portions of the individual tributaries at the Sacramento River probably provided nursery and rearing habitat for juvenile salmon and steelhead. After completion of the Colusa Basin Drain, salmon are believed to have entered westside tributaries through the outfall at Knights Landing. In most instances, access to the upper portions of any of the westside tributaries would be blocked by the GCID canal and potentially the TCC and Corning Canal.

Following completion of the levee system and development of the Colusa Basin for agriculture, natural floodflows from westside tributaries could no longer dissipate rapidly to the Sacramento River. The result has been periodic flooding of various areas within the basin. Several investigations have been conducted to develop remedies for this situation. Studies conducted by the California Department of Water Resources (DWR) identified the potential for construction of small foothill reservoirs to dampen floodflows. The original investigation identified 17 sites (Table 2-V-1) that would encompass approximately 80% of the foothill portion of the watershed. Currently, the reservoir option is not being actively pursued; however, if reservoirs are subsequently constructed, potential might exist for controlled releases to facilitate salmon and steelhead spawning and rearing.

Miscellaneous small tributaries - Along the Sacramento River are many small, often ephemeral, tributaries that are not used to any significant extent by spawning anadromous salmonids. Maslin and McKinney (1994) have shown that these tributaries may be used as rearing habitat by juvenile salmonids. Only a few of the potential tributaries have been investigated, but those that have been examined contained juvenile chinook salmon. In some cases, the juveniles had gone as far as 14 miles upstream from the river. Most of these tributaries also have resident rainbow trout populations in upstream perennial reaches. For many, there are anecdotal accounts of steelhead runs in the past.

Table 2-V-1. Tributaries contributing flow to the Colusa Basin Drain.

Major tributary entering drain	Tributaries entering major tributary	Reservoir capacity (af)	Drainage area (square mile)
Willow Creek	Walker Creek	0	175
	Wilson Creek	2,200	
	French Creek	11,000	
	Unnamed Creek	2,200	
	Willow Creek	12,600	
Hunters Creek	Logan Creek	3,300	36
	Hunters Creek	2,500	
Stone Corral Creek	Funks Creek	7,600	84
	Stone Corral Creek	5,800	
Lurline Creek	Lurline Creek	0	Unknown
Freshwater Creek	Freshwater Creek	7,000	60
	Salt Creek		
	Spring Creek	2,700	
Cortina Creek	Cortina Creek	5,300	34
	North Branch Sand Creek	0	
South Branch Sand	South Branch Sand Creek	0	Unknown

Major tributary entering drain	Tributaries entering major tributary	Reservoir capacity (af)	Drainage area (square mile)
Creek			
Salt Creek	Salt Creek	3,000	19
Buckeye Creek	Buckeye Creek	5,000	31
Bird Creek	Bird Creek	1,300	8
Oat Creek	Oat Creek	4,300	27

For this report, a list was compiled of small tributaries in which juvenile salmon had been reported. Characteristics of these known rearing streams were then compared to those of streams for which no information was available. Table 2-V-2 lists small Sacramento tributaries thought to be unimportant for salmonid spawning and divides them into the following types:

- those known to support juvenile rearing,
- those similar in morphometry and location to known rearing streams and thus presumed to support juvenile rearing, and
- those that have steep gradients near the river or that enter the river upstream from any spawning habitat and therefore are presumed to have low potential to support juvenile rearing.

Table 2-V-2. Sacramento tributaries that typically provide only rearing habitat for salmonids.

Name	USGS Quad	Side of Tributary
Tributaries known to support juvenile salmonid rearing		
Pine	Ord Ferry	east
Toomes	Vina	east
Dye	Los Molinos	east
Oat	Los Molinos	west
Coyote	Gerber	west
Reeds	Red Bluff East	west

Name	USGS Quad	Side of Tributary
Brewery	Red Bluff East	west
Blue Tent	Red Bluff East	west
Dibble	Red Bluff East	west
Inks	Bend	east
Anderson	Ball's Ferry	west
Olney	Enterprise	west
Tributaries presumed to support juvenile salmonid rearing		
Burch	Foster Island	west
Jewett	Vina	west
McLure	Vina	west
Red Bank	Red Bluff East	west
Salt	Red Bluff East	east
Ash	Ball's Ferry	east
Stillwater	Ball's Ferry	east
Churn	Cottonwood	east
Sulfur	Redding*	east
Tributaries with low potential to support juvenile salmonid rearing		
Seven Mile	Red Bluff East	east
Frasier	Bend	west
Spring	Bend	west
Clover	Cottonwood	east
Middle	Redding[a]	west
Salt	Redding[a]	west
Jenny	Redding[a]	west
Rock	Redding[a]	west

[a] Indicates 15-minute topographical quadrangle map.

Many small streams that feed larger tributaries may be found to be important for salmonid rearing. Even though these small streams may have characteristics and problems similar to those listed in Table 2-V-2, for convenience they will be discussed along with the main tributary.

In addition to its many tributaries, the Sacramento River has many sloughs (partially abandoned river or creek channels). The dynamics of the river change sloughs too rapidly for topographic maps to be useful in locating or describing them. Therefore, this report can address them only generally. Sloughs that are open to the river, particularly if they have any flow from seepage, small tributaries, or agricultural drainage, have potential to provide rearing habitat. These sloughs have characteristics and habitat needs similar to tributaries.

North westside tributaries - Small streams draining the west side of the Sacramento Valley in the Redding-Anderson municipal area include Olney, Anderson, Salt, Middle, and Churn creeks. These creeks do not have natural flow during the dry season. During the wet season, however, they have large flows for the small size of the watersheds. The high flash-flood potential of the streamflow regime is attributable to the intensity of rainstorms at the north end of the valley and is further amplified by urbanization of the watershed. These tributaries enter the Sacramento River downstream of Shasta Reservoir.

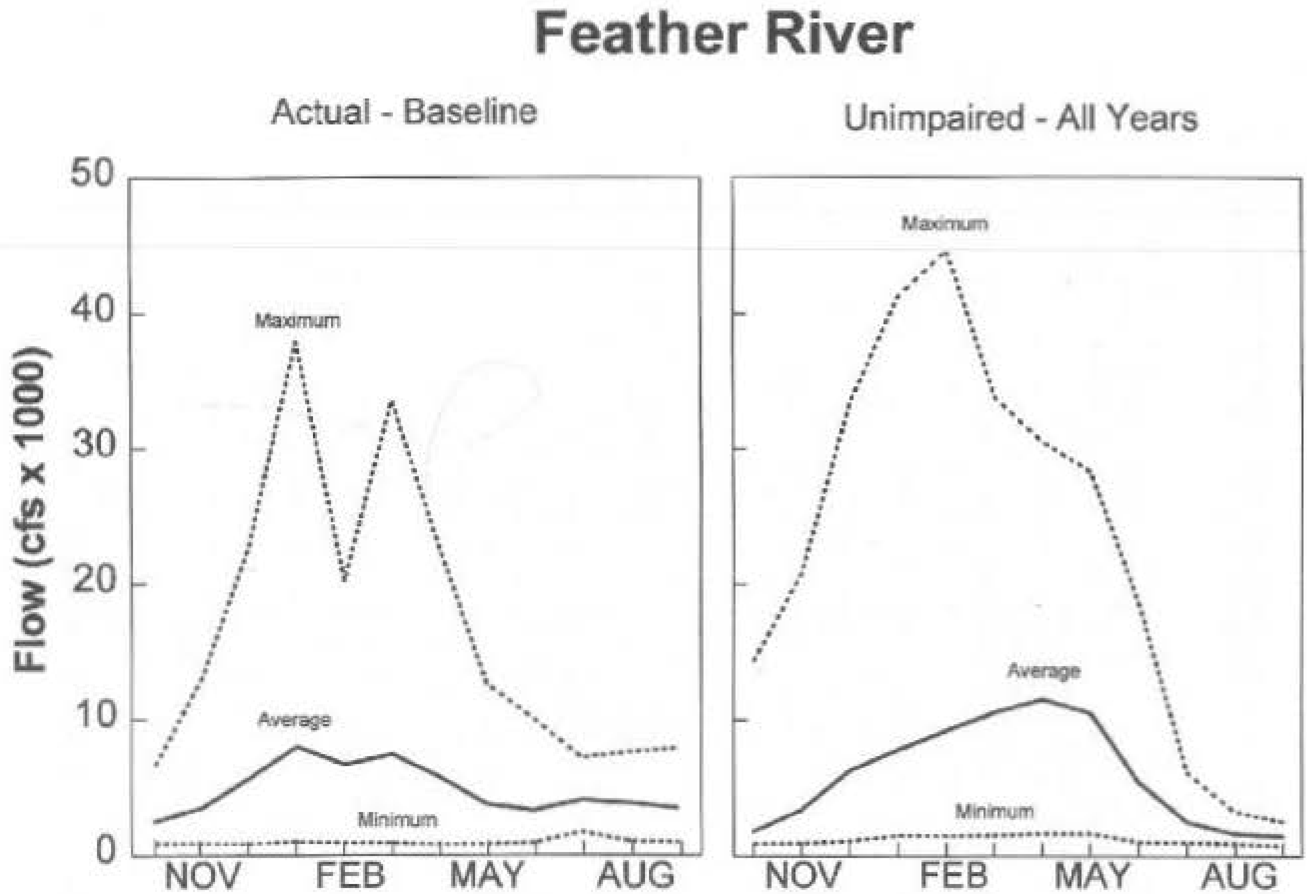
The watersheds of these streams drain parts of the Coast Ranges and Klamath Mountains. The soils in these mountains are moderately to severely erodible in contrast to the soils of the eastside Sierra Nevada watersheds. Also in contrast with the eastside tributaries, the geology of the west side of the valley is not as conducive to the large groundwater springs that provide cold, sustained flows in the dry season.

The rainfall on the west side of the Central Valley is less than that on the east side, with mean seasonal precipitation in the higher elevations of about 60 inches. The lower elevations near Redding receive 40 inches of precipitation, whereas low elevations near Red Bluff receive only 20 inches of precipitation. Thus, these smaller tributaries draining the region below the northern end of the Central Valley have inconsistent streamflow.

Large peak flows attract salmon from the Sacramento River into these streams. The influence of these attraction flows on salmon is probably increased because the river flow does not increase proportionally during the storms. Instead, Shasta Dam, upstream from the confluence of the tributaries, captures most of the storm run-off.

Lower Sacramento River and Delta Tributaries

Feather River - The Feather River, with a drainage area of 3,607 square miles, is the largest tributary of the Sacramento River below Shasta Dam (Figure 2-V-6). The median historical unimpaired run-off is 3.8 maf,



FEATHER RIVER MEAN MONTHLY FLOW: ACTUAL (BELOW THERMOLITO AFTERBAY, 1967-1991) AND UNIMPAIRED (NEAR OROVILLE, 1922-1991)

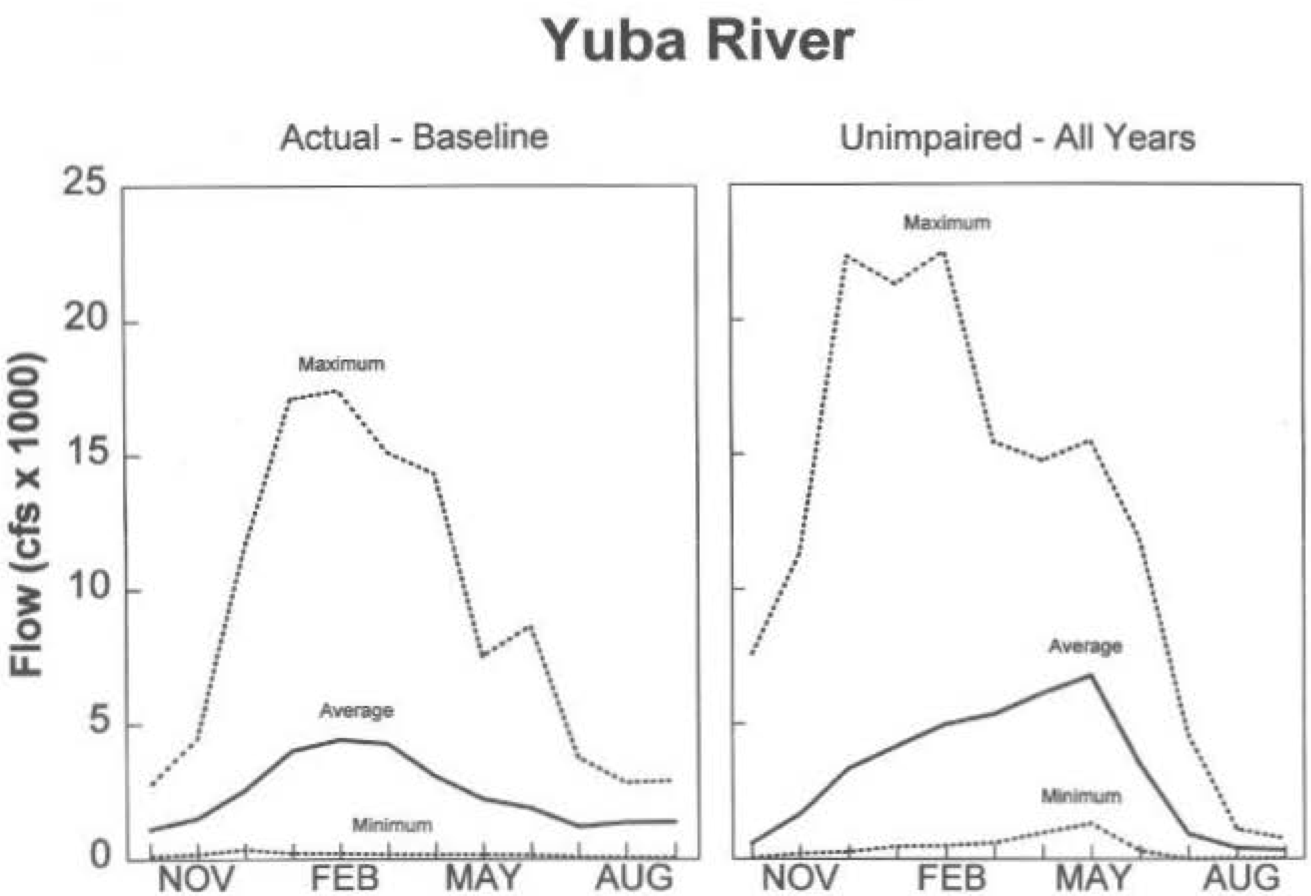
FIGURE 2-V-7

with a range of 1.0-9.4 maf (Figure 2-V-7). Oroville Reservoir, the lowermost reservoir on the river and the upstream limit for anadromous fish, is the keystone of the State Water Project (SWP) and is operated by DWR. Lake Oroville has a storage capacity of more than 3.5 maf. Water is released from Oroville Dam through a multilevel outlet to provide appropriate water temperatures for the operation of the Feather River Hatchery and to protect downstream fisheries. Approximately 5 miles downstream from Oroville Dam, water is diverted at the Thermalito Diversion Dam into the Thermalito Power Canal, thence to the Thermalito Forebay and another powerhouse, and finally into the Thermalito Afterbay. Water can be pumped from the Thermalito Diversion Pool back into Oroville Reservoir to generate peaking power. The Oroville-Thermalito complex, completed in 1968, provides water conservation, hydroelectric power, recreation, flood control, and fisheries benefits. The other major impoundment in the watershed is Lake Almanor, with a storage capacity of more than 1.1 maf. A number of other small- to medium-sized impoundments, including Mountain Meadows Reservoir, Bucks Lake, Little Grass Valley Reservoir, Lake Davis, Frenchman Lake, Butt Valley Reservoir, Sly Creek Reservoir, and Antelope Lake, store an additional 450 taf or more.

Feather River flows between the Thermalito Diversion Dam and the Thermalito Afterbay outlet are a constant 600 cfs. This section is often referred to as the "low-flow" river section. Water is released through a powerhouse, then through the fish barrier dam to the Feather River Hatchery, and finally into the low-flow section of the Feather River. Thermalito Afterbay has a dual purpose as an afterbay for upstream peaking-power releases to ensure constant river and irrigation canal flows and as a warming basin for irrigation water being diverted to rice fields. Thus, water temperatures in the approximately 14 miles of salmon spawning area from the Thermalito Afterbay outlet to the mouth of Honcut Creek (referred to as the "high-flow" section) are always higher than those in the 8 miles of the low-flow section.

Yuba River - The Yuba River watershed drains 1,339 square miles of the western slope of the Sierra Nevada and includes portions of Sierra, Placer, Yuba, and Nevada counties. The Yuba River is tributary to the Feather River (Figure 2-V-6), which in turn feeds into the Sacramento River. The median historical unimpaired run-off is 2.1 maf, with a range of 0.4-4.9 maf (Figure 2-V-8). The major impoundment in the watershed, Bullards Bar Reservoir, is operated by the Yuba County Water Agency, and has a storage capacity of just under 1 maf. Other small- to medium-sized impoundments in the watershed, including Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Reservoir, Lake Fordyce, and Scotts Flat Reservoir, are able to store an additional 475 taf or more.

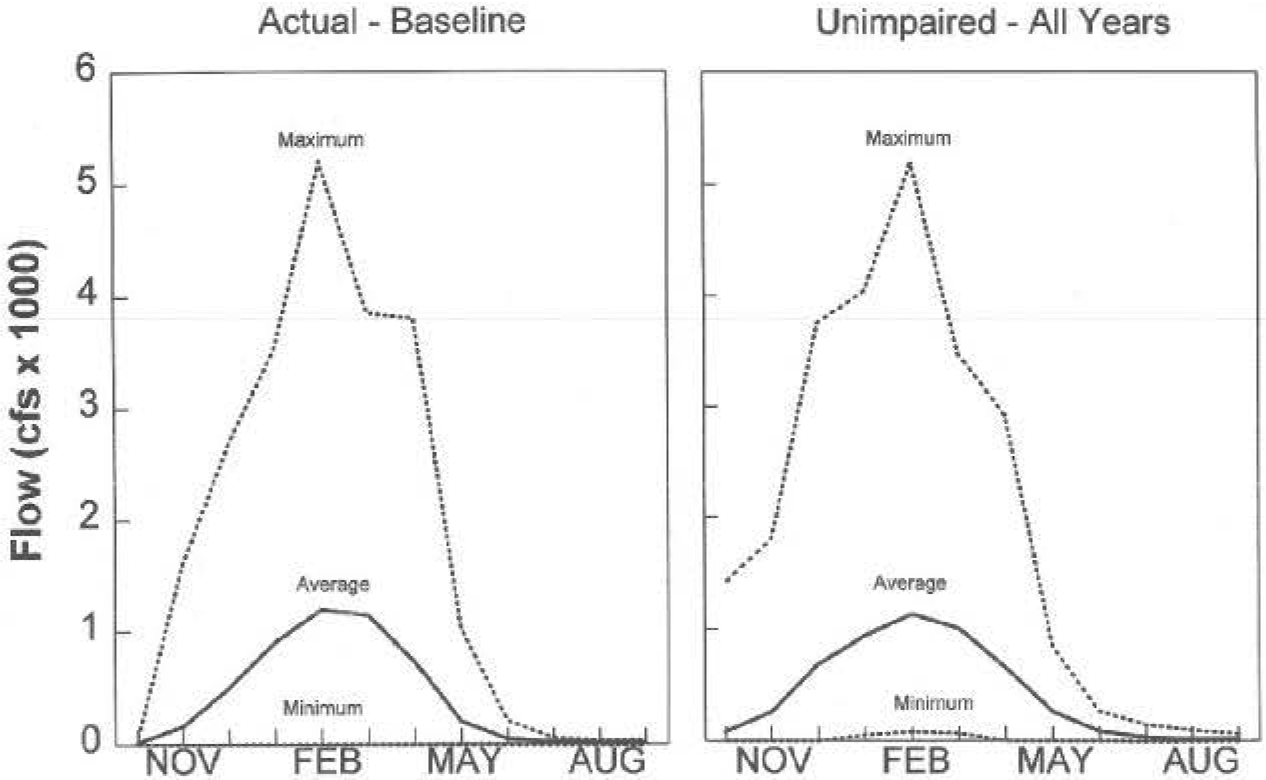
Most of the water from Englebright Dam, the lowermost dam on the river and the upstream limit of anadromous fish, is released through the Narrows 1 and 2 powerhouses for hydroelectric power generation. The 0.2-mile stretch of river between the dam and the two powerhouses has no flowing water except when the reservoir is spilling. The 0.7-mile stretch of river downstream of the Narrows 1 and 2 powerhouses to the mouth of Deer Creek is characterized by steep rock walls; long, deep pools; and short rapids. Below this area, the river cuts through 1.3 miles of sheer rock gorge called the Narrows, where the river forms a large, deep, boulder-strewn pool.



YUBA RIVER MEAN MONTHLY FLOW: ACTUAL (AT MARYSVILLE, 1967-1991) AND UNIMPAIRED (AT SMARTVILLE, 1922-1991)

FIGURE 2-V-8

Bear River



BEAR RIVER MEAN MONTHLY FLOW BELOW CAMP FAR WEST RESERVOIR: ACTUAL (1967-1991) AND UNIMPAIRED (1922-1991)

FIGURE 2-V-9

The river canyon opens into a wide floodplain at the downstream end of the Narrows where large quantities of hydraulic mining debris have been deposited during past gold mining operations. This 18.5-mile section is typified as open valley plain. Daguerre Point Dam, located 12.5 miles downstream from Englebright Dam, is the major diversion point on the lower river. The open valley plain continues 7.8 miles below Daguerre Point Dam to beyond the downstream terminus of the Yuba Goldfields. This section is composed primarily of alternating pools, runs, and riffles with a gravel and cobble substrate. By virtue of the quality and size of the substrate, this section contains most of the suitable chinook salmon spawning habitat found in the lower Yuba River. The remaining section of the lower Yuba River extends approximately 3.5 miles to the confluence with the Feather River. This section of river is bordered by levees and is subject to backwater influence of the Feather River.

Bear River - The Bear River is the second largest tributary to the Feather River, entering the Feather River at RM 12, immediately upstream from the town of Nicolaus (Figure 2-V-6). The median historical unimpaired run-off is 272 taf, with a range of 20-740 taf (Figure 2-V-9). The upstream limit of anadromous fish is the South Sutter Irrigation District's diversion dam, approximately 15 miles above the confluence with the Feather River. The largest impoundment in the watershed, Camp Far West Reservoir, is operated by the South Sutter Water District and has a storage capacity of 104 taf. Other small impoundments in the watershed include Rollins Reservoir and Lake Combie, which store an additional 70 taf or more.

American River - The American River is a major tributary entering the Sacramento River at RM 60 in the City of Sacramento, Sacramento County (Figure 2-V-10). It accounts for approximately 15% of the total Sacramento River flow. The American River drains about 1,900 square miles and ranges in elevation from 23 feet to more than 10,000 feet. Average annual precipitation over the watershed ranges from 23 inches on the valley floor to 58 inches at the river's headwaters. Snowmelt is the source of approximately 40% of the American River flow. Average historical unimpaired run-off at Folsom Dam, near the border between Sacramento and Placer counties, is 2.8 maf. The median historical unimpaired run-off is 2.5 maf, with a range of 0.3-6.4 maf (Figure 2-V-11). The American River has three major branches: the South Fork, the Middle Fork, and the North Fork.

Development on the American River began in the earliest days of the California Gold Rush of the late 1840s, when numerous small dams and canals were constructed. Today, 13 major reservoirs exist in the drainage with total storage capacity of 1.9 maf. Folsom Lake, the largest reservoir in the drainage, was constructed in 1956 and has a capacity of 974 taf. Additional water projects proposed for development in the basin include the 2.3-maf Auburn Dam and the 225-taf South Fork American River project. Folsom Dam, approximately 30 miles upstream from the mouth, is a major element of the CVP. The dam is operated by USBR as an integrated system to meet contractual water demands and instream flow and water quality requirements.

The American River historically provided for steelhead and chinook salmon that spawned principally in the watershed above the valley floor. Completion of Folsom and Nimbus dams in 1955 blocked access to the historical spawning and rearing habitat for each race and altered the flow regime in the lower American River.

Mokelumne River - The Mokelumne River drains approximately 661 square miles, with its headwaters at 10,000 feet on the crest of the Sierra Nevada mountains. It is a major tributary to the Sacramento-San Joaquin Delta, entering the lower San Joaquin River northwest of Stockton (Figure 2-V-13). The median historical unimpaired runoff is 696 taf, with a range of 129 taf-1.8 maf (Figure 2-V-12). The Mokelumne River has had a long history of water development. Existing developments on the Mokelumne River upstream of Comanche Reservoir include facilities for hydroelectric, irrigation, and municipal use. Downstream of Comanche Reservoir, developments include both hydroelectric and irrigation facilities. Three major impoundments in the watershed (Comanche, Pardee, and Salt Springs Reservoirs) are operated by East Bay Municipal Utilities District and PG&E. These impoundments have a combined storage capacity of more than 750 taf. One other small impoundment in the watershed, Lower Bear River Reservoir, stores 52 taf.

Four species of anadromous fishes are present in the Mokelumne River below Comanche Dam: fall-run chinook salmon, steelhead, American shad, and striped bass. The condition of the aquatic habitat and the variation of conditions in the lower Mokelumne River have resulted in widely varying population levels of these species.

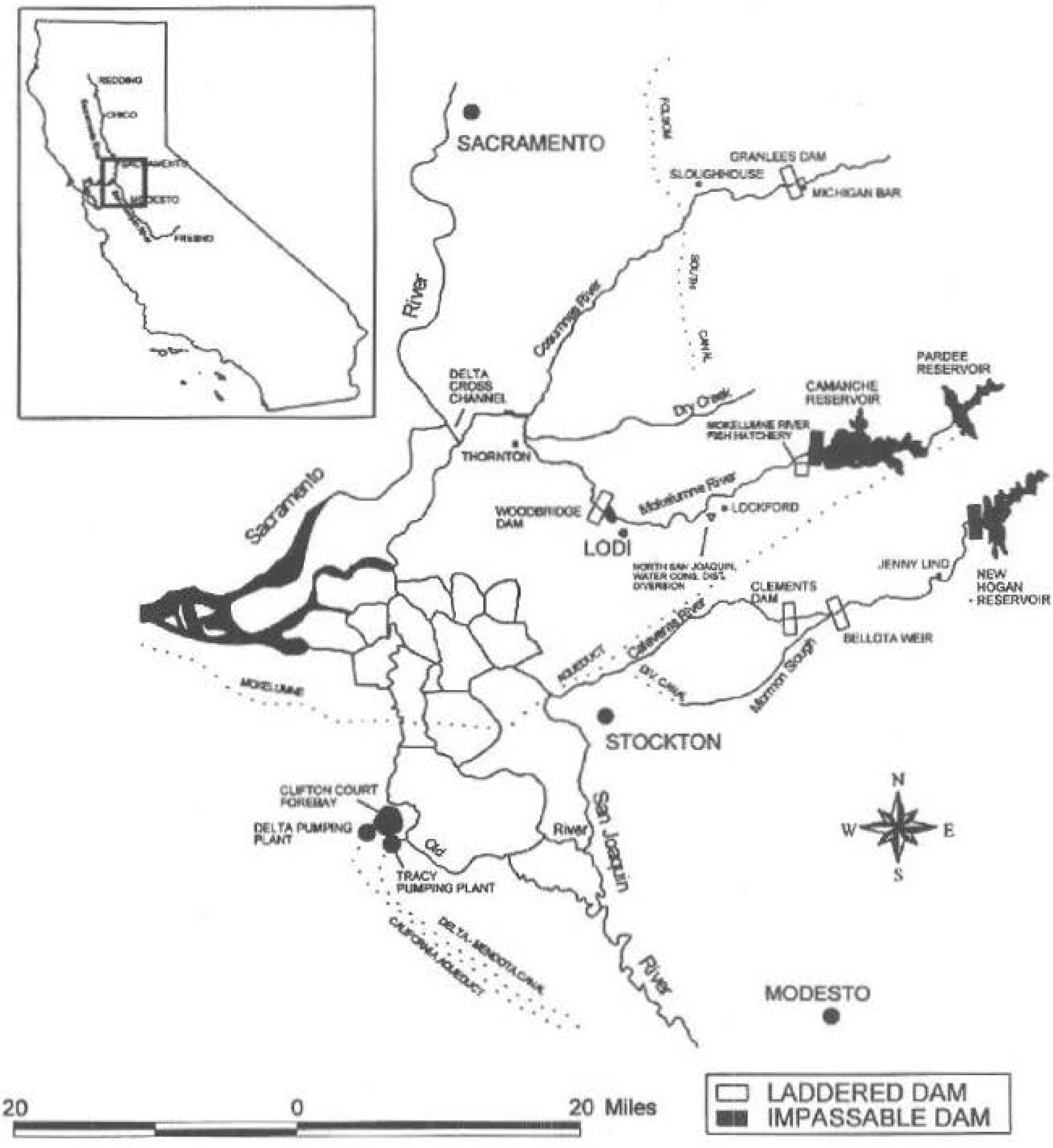
Cosumnes River - The Cosumnes River is tributary to the Mokelumne River, joining from the north near the town of Thornton (Figure 2-V-13). There are no water storage reservoirs on this system, and, because of the low elevation of its headwaters, the river receives most of its water from rainfall.

The Cosumnes River historically supported an average annual run of approximately 1,000 chinook salmon, although in recent years escapement estimates have generally been 100 fish or less. The river has extensive gravel areas suitable for salmon spawning and provides good rearing conditions for juvenile salmon.

There is one diversion dam (Granlees Diversion Dam) on the river, located approximately 1 mile upstream from the Highway 16 crossing (Figure 2-V-13). This dam has two functional fishways.

Calaveras River - The Calaveras River, tributary to the Delta, enters the San Joaquin River at Stockton (Figure 2-V-13). The river drains approximately 362 square miles and has an average annual runoff of 166 taf. The median historical unimpaired runoff is 130 taf, with a range of 8-600 taf (Figure 2-V-14). River flows are controlled by New Hogan Dam, constructed by the U.S. Army Corps of Engineers (Corps) and operated by USBR since 1964. Conservation yield from New Hogan Reservoir, with a gross pool capacity of approximately 325 taf, is contracted to Calaveras County Water District and Stockton East Water District. The dam and reservoir are located in western Calaveras County near Valley Springs.

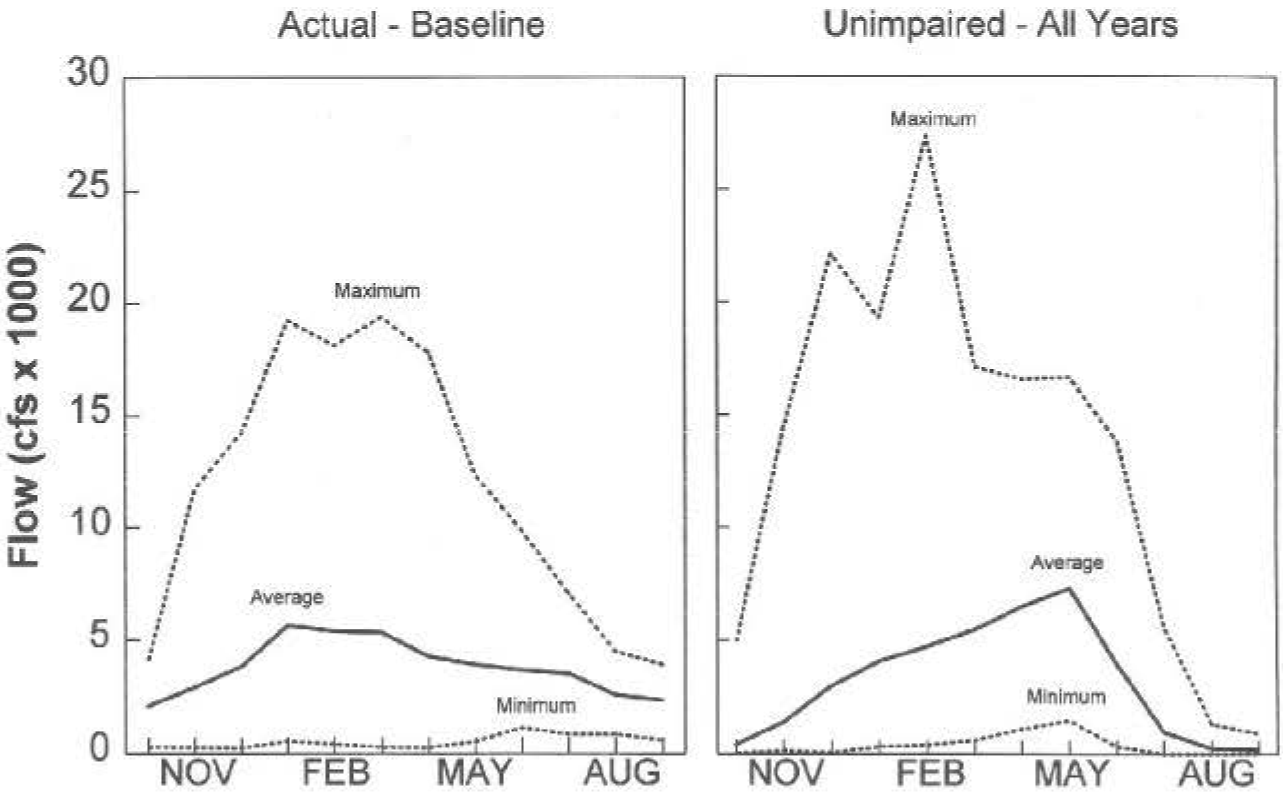
The Calaveras River drainage is almost entirely below the effective average snow level (5,000 feet in elevation) and thus receives runoff primarily as rainfall. About 93% of the runoff occurs from November



MAP OF THE LOWER SACRAMENTO AND SAN JOAQUIN RIVERS DEPICTING THE EASTSIDE TRIBUTARY STREAMS

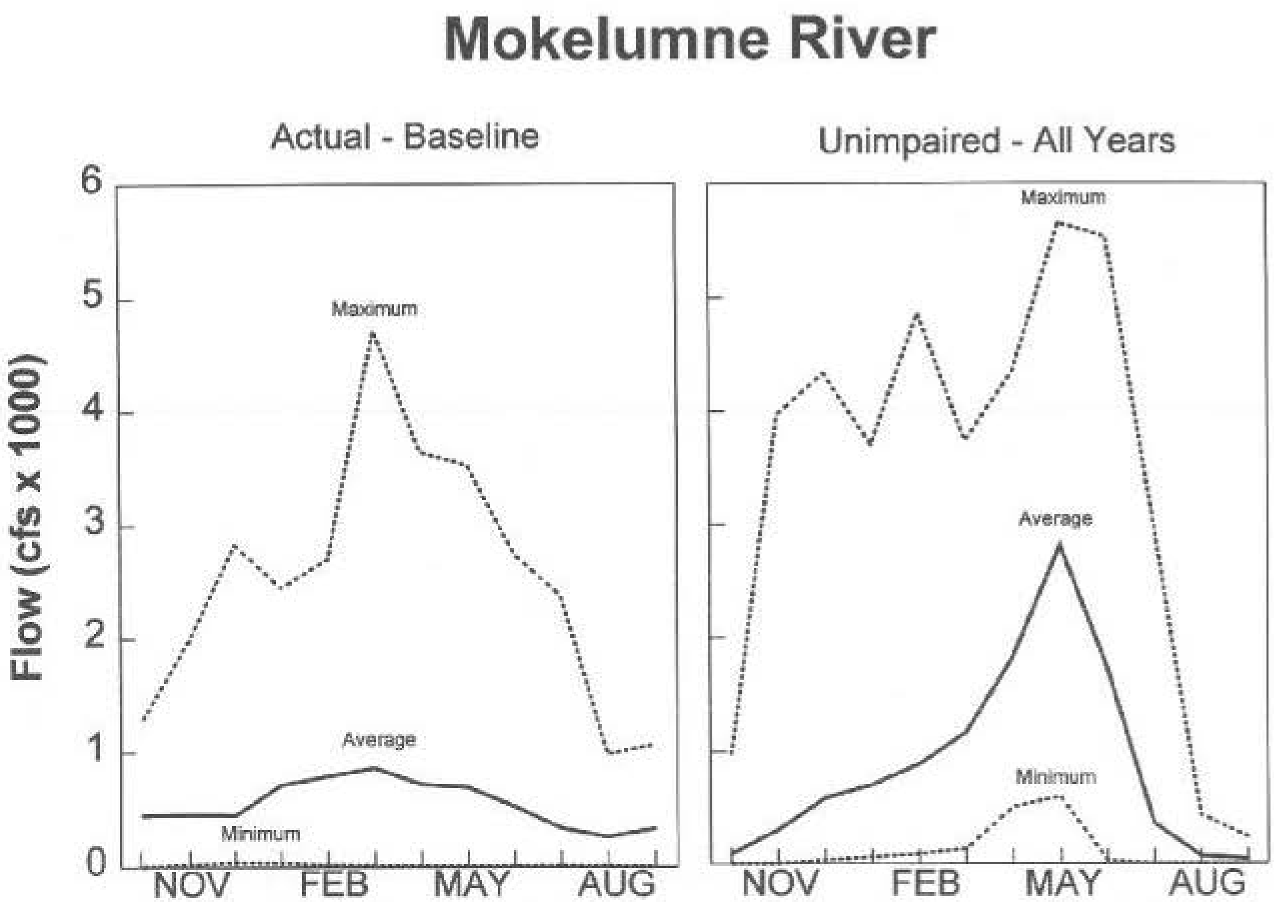
FIGURE 2-V-10

American River



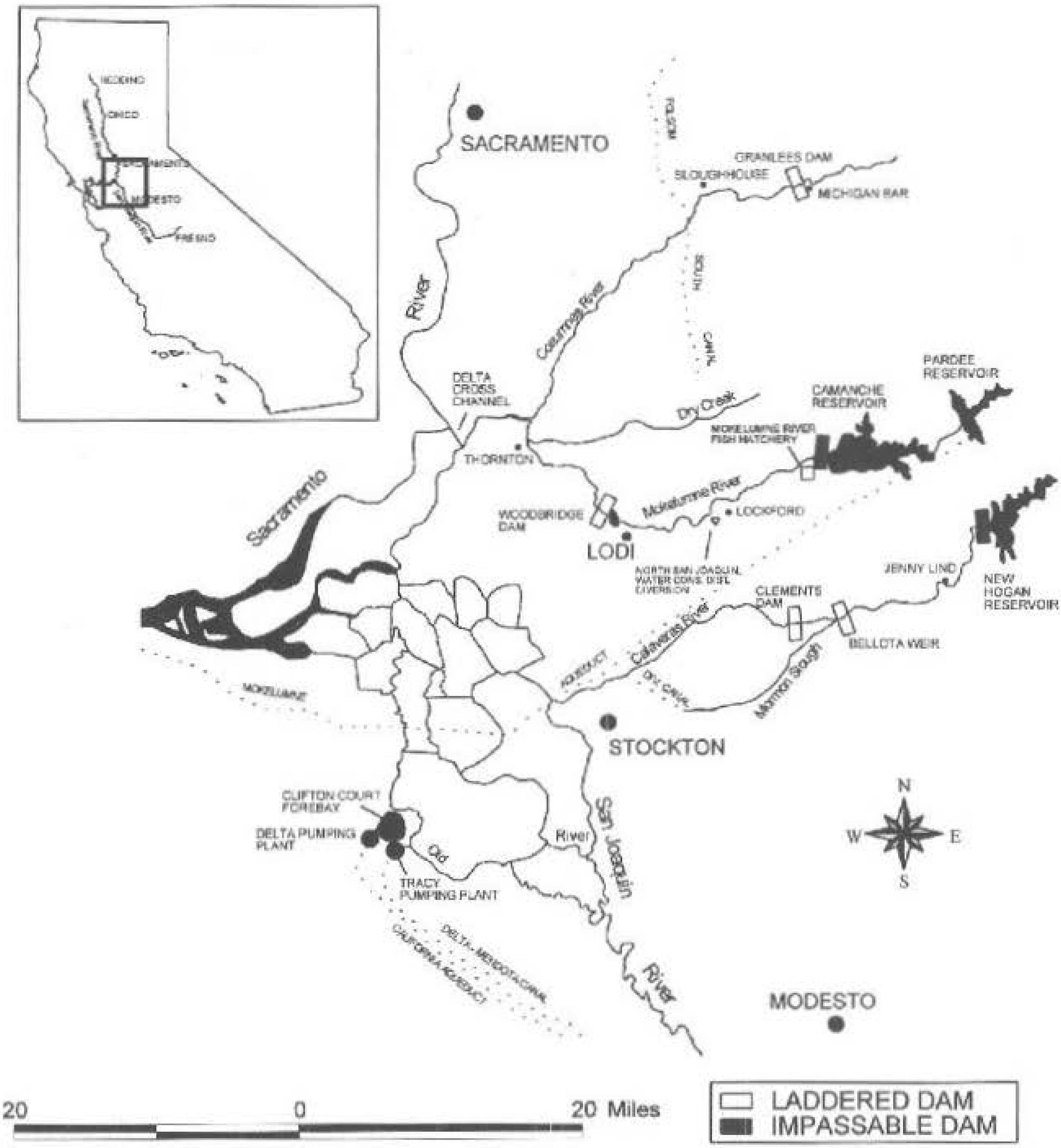
AMERICAN RIVER MEAN MONTHLY FLOW AT FAIR OAKS: ACTUAL (1967-1991) AND UNIMPAIRED (1922-1991)

FIGURE 2-V-11



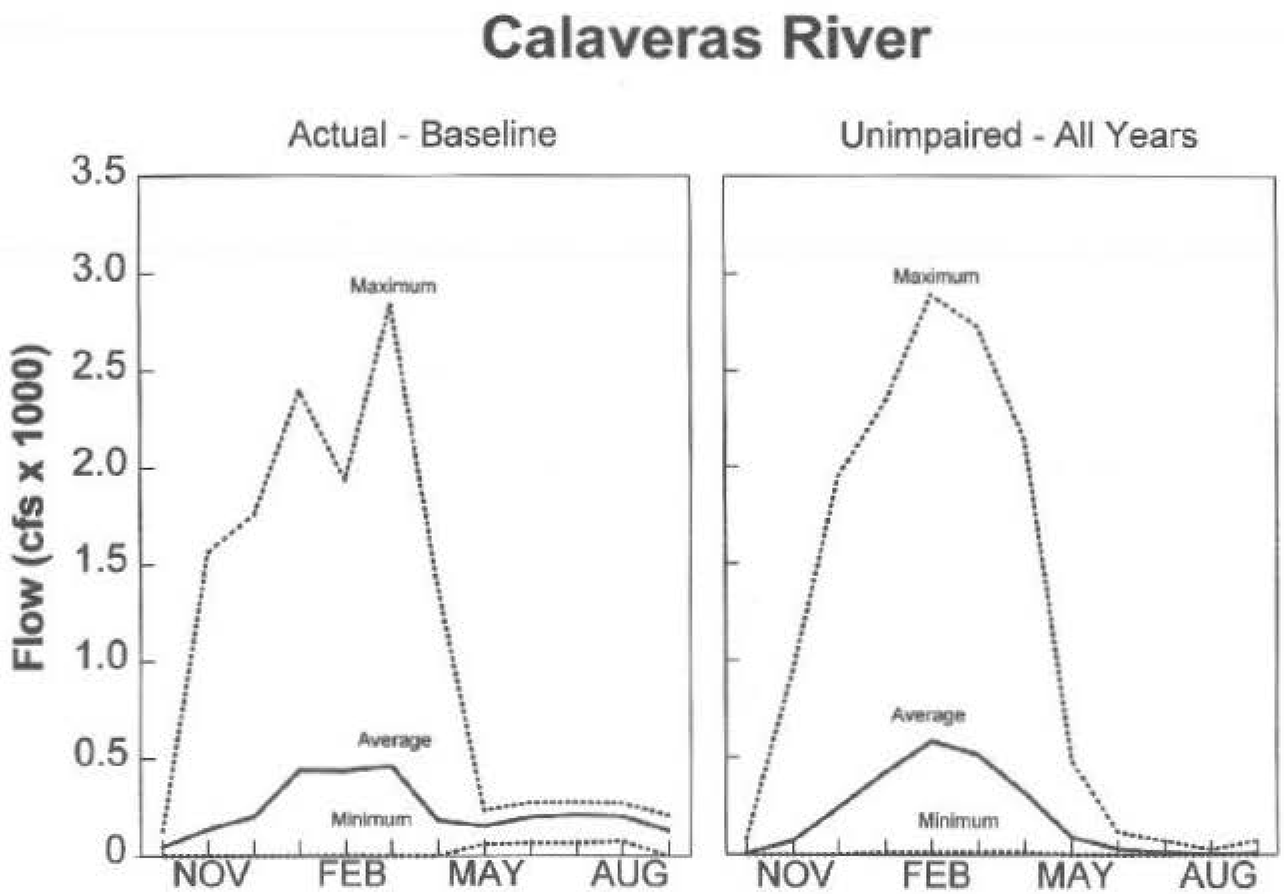
MOKELUMNE RIVER MEAN MONTHLY FLOW: ACTUAL (AT WOODBRIDGE, 1967-1991) AND UNIMPAIRED (AT PARDEE RESERVOIR, 1922-1991)

FIGURE 2-V-12



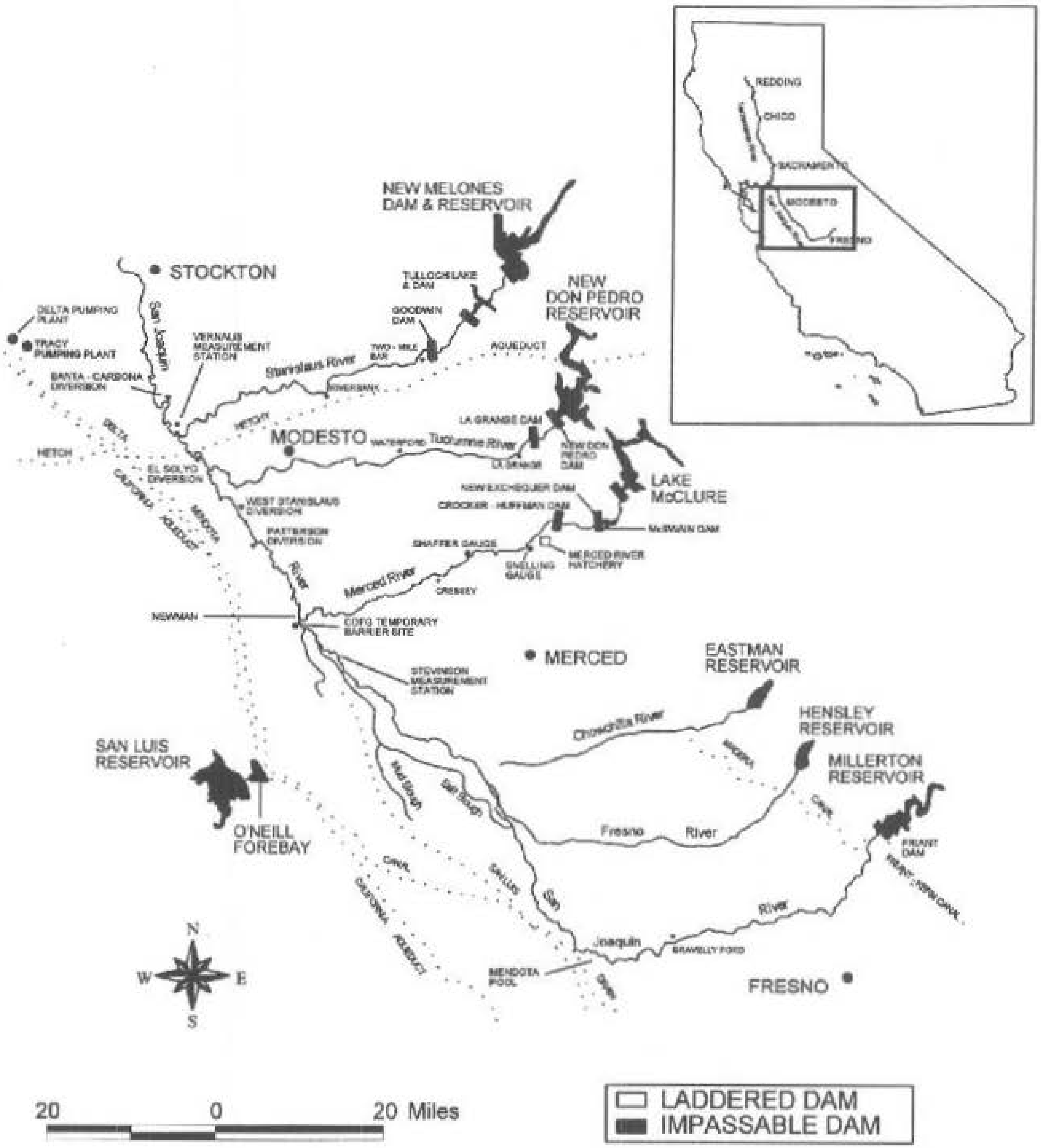
MAP OF THE LOWER SACRAMENTO AND SAN JOAQUIN RIVERS DEPICTING THE EASTSIDE TRIBUTARY STREAMS

FIGURE 2-V-13



CALAVERAS RIVER MEAN MONTHLY FLOW BELOW NEW HOGAN RESERVOIR: ACTUAL (1967-1991) AND UNIMPAIRED (1922-1991)

FIGURE 2-V-14



MAP OF THE SAN JOAQUIN BASIN DEPICTING LOCATIONS OF THE STANISLAUS, TUOLUMNE, MERCED, AND SAN JOAQUIN RIVERS

FIGURE 2-V-15

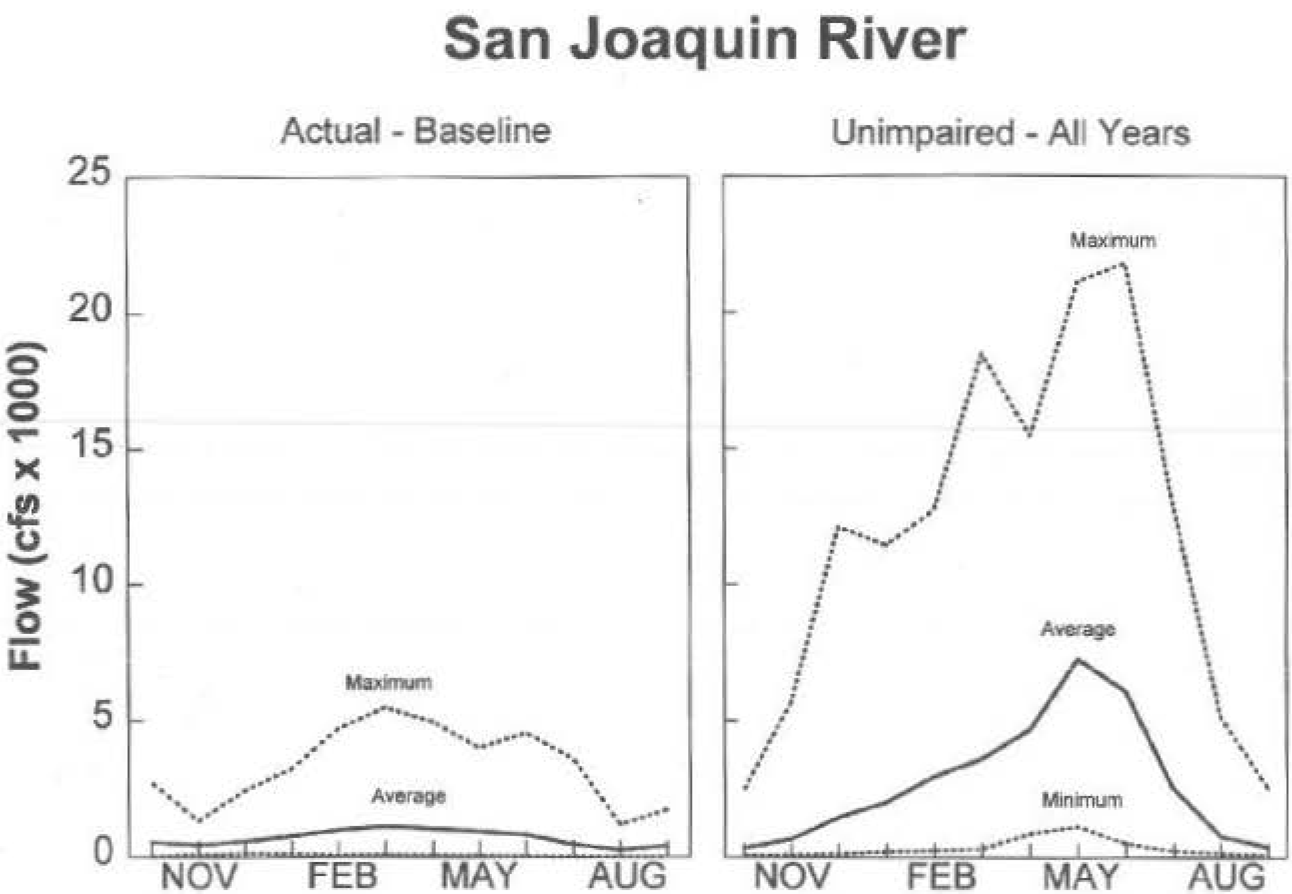
through April. The portion of the river in the valley commonly is subject to periods of low or even no flow for many days or weeks in late summer and early fall. However, deep pools do exist in the approximately 6-mile-long reach from New Hogan Dam to Jenny Lind, providing suitable holding areas for salmon and resident trout in all but the driest of years.

SAN JOAQUIN RIVER BASIN

Lower Mainstem San Joaquin River

The 250-mile-long San Joaquin Valley makes up the southern half of the Central Valley. The Tulare Lake basin to the south is normally considered a separate drainage basin, but during wet years it has historically contributed occasional flood overflows and subsurface flows to the San Joaquin River. The San Joaquin River basin is bounded on the west by the Coast Range and on the east by the Sierra Nevada. The San Joaquin River drains west from the Sierra Nevada, turns sharply north at the center of the valley floor, and flows north through the valley into the Sacramento-San Joaquin Delta (Figure 2-V-15). On the arid westside of the basin, relatively small intermittent streams drain the eastern flanks of the Coast Range but rarely reach the San Joaquin River. Natural runoff from westside sloughs is augmented by agricultural drainage and spill flows. On the eastside, numerous streams and three major rivers drain from the west slope of the Sierra Nevada and contribute flow to the San Joaquin River. The major eastside tributaries south of the Delta, all of which support salmon spawning and rearing, are the Stanislaus, Tuolumne, and Merced rivers.

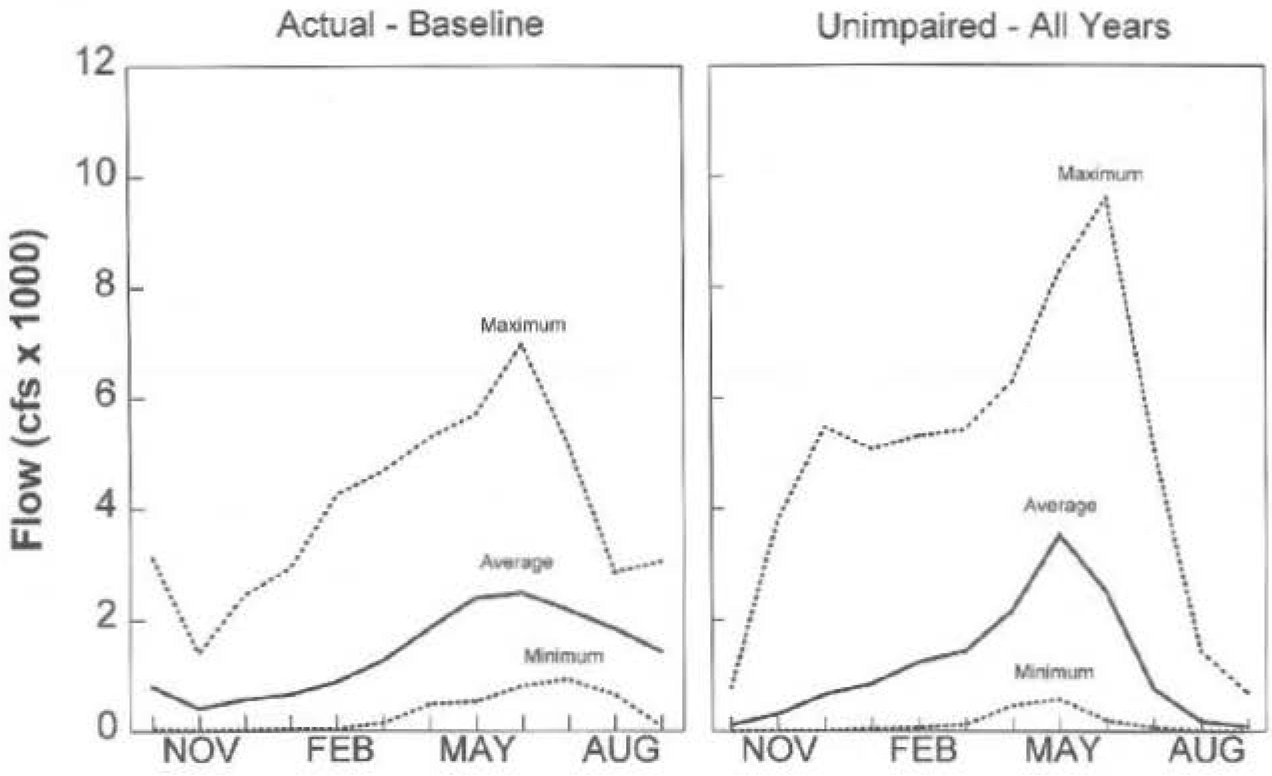
Precipitation in the San Joaquin River basin averages about 27.3 inches per year. Runoff from snowmelt is the major source of water to the upper San Joaquin River and the larger eastside tributaries. The median historical unimpaired runoff is 1.4 maf, with a range of 0.4-4.6 maf (Figure 2-V-16). Historically, peak flows occurred in May and June and flooding occurred in most years along all the major rivers. When flood flows reached the valley floor, they spread out over the lowlands, creating several hundred thousand acres of permanent tule marshes and more than 1.5 million acres of seasonally flooded wetlands. The rich alluvial soils of natural levees once supported large, diverse riparian forests. It has been estimated that as much as 2 million acres of riparian vegetation grew on levees, floodplains, and along small stream courses. Above the floodplain, the riparian zone graded into valley oak savanna and native grasslands interspersed with vernal pools.



SAN JOAQUIN RIVER MEAN MONTHLY FLOW: ACTUAL (AT STEVINSON, 1967-1991) AND UNIMPAIRED (AT MILLERTON RESERVOIR, 1922-1991)

FIGURE 2-V-16

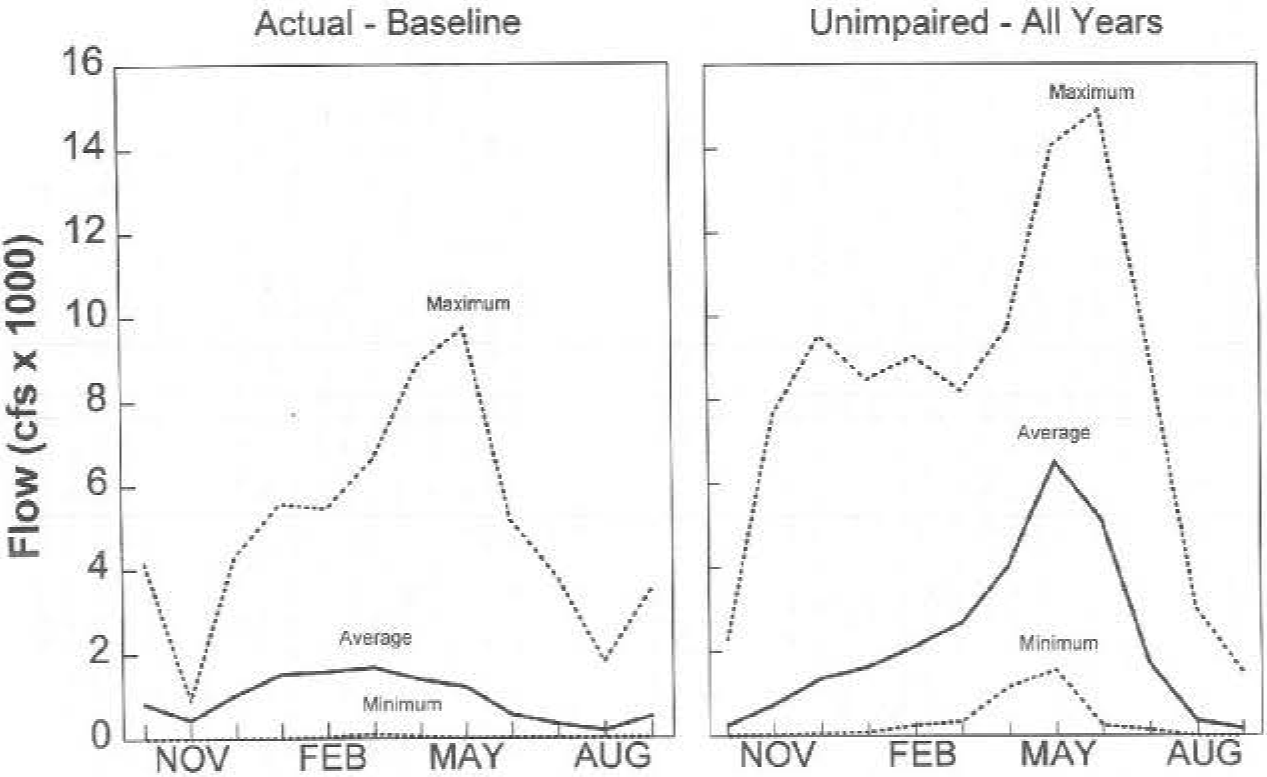
Merced River



MERCED RIVER MEAN MONTHLY FLOW: ACTUAL (BELOW MERCED FALLS DAM, 1967-1991) AND UNIMPAIRED (BELOW NEW EXCHEQUER DAM, 1922-1991)

FIGURE 2-V-17

Tuolumne River



TUOLUMNE RIVER MEAN MONTHLY FLOW: ACTUAL (BELOW LA GRANGE DAM, 1967-1991) AND UNIMPAIRED (AT NEW DON PEDRO RESERVOIR, 1922-1991)

FIGURE 2-V-18

Lower San Joaquin River Tributaries

Merced River - The Merced River is presently the southernmost stream used by chinook salmon in the San Joaquin River basin and in California. The river flows westward into the valley, draining approximately 1,040 square miles (Figure 2-V-15). The average unimpaired runoff in the basin is approximately 1.0 maf, similar to the Stanislaus River drainage. The median historical unimpaired runoff is 0.8 maf, with a range of 0.2-2.8 maf (Figure 2-V-17).

Agricultural development began in the 1850s, and significant changes have been made to the hydrologic system since that time. The enlarged New Exchequer Dam, forming Lake McClure with a gross storage capacity of 1.0 maf, was constructed in the late 1960s and now regulates releases to the lower Merced River. The dam is operated by Merced Irrigation District for power production, irrigation, and flood control. The river is also regulated by McSwain Dam (an afterbay for New Exchequer Dam) and Merced Falls and Crocker-Huffman dams located downstream. Crocker-Huffman Dam near the town of Snelling is the upstream barrier for salmon migration.

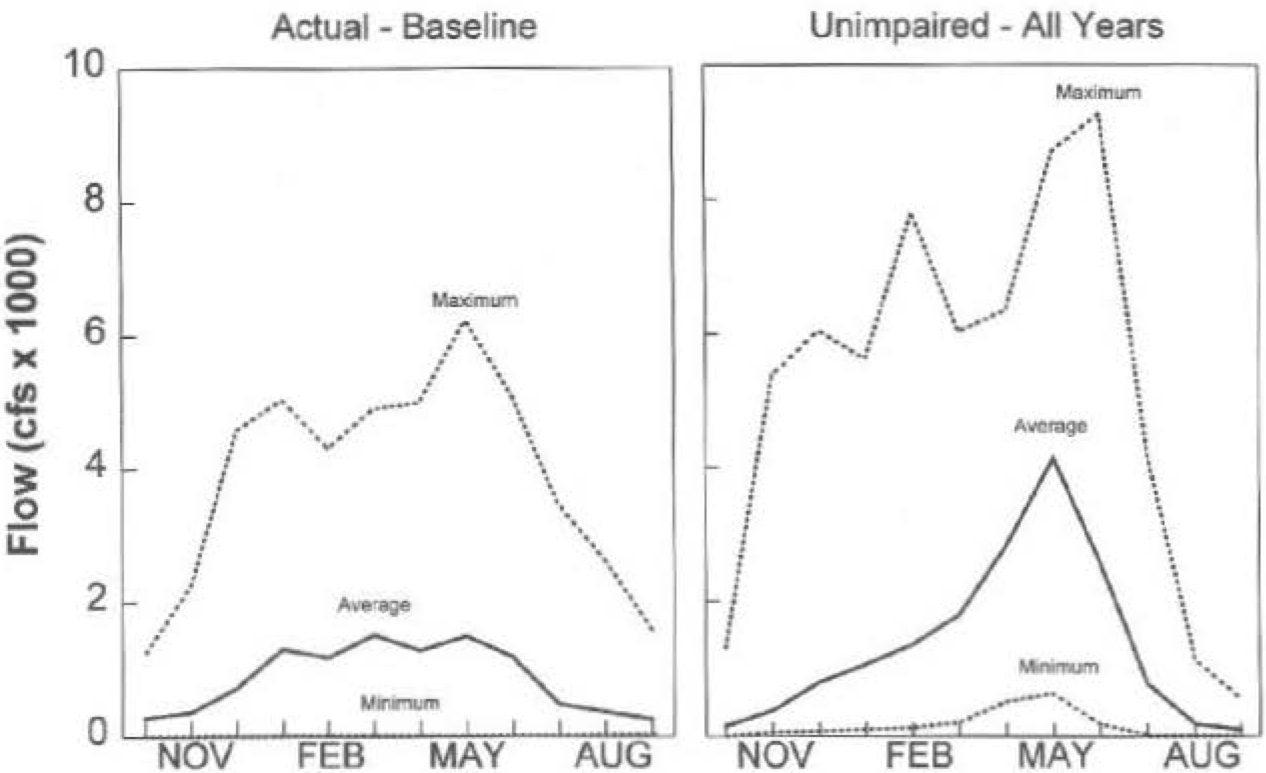
Salmon spawn in the 24-mile reach between Crocker-Huffman Dam and the town of Cressy. Rearing habitat extends downstream of the designated spawning reach, requiring the protection of the entire tributary from Crocker-Huffman Dam to its mouth.

Tuolumne River - The Tuolumne River is the largest tributary in the San Joaquin River basin, with an average annual runoff of 1.95 maf, and a drainage area of approximately 1,540 square miles (Figure 2-V-15). The median historical unimpaired runoff is 1.8 maf, with a range of 0.4-4.6 maf (Figure 2-V-18). The Modesto and Turlock Irrigation Districts jointly regulate the flow to the lower river from New Don Pedro Reservoir, which has a gross storage capacity of 2.0 maf. The reservoir, completed in 1970, provides power, irrigation, and flood control protection. The river above New Don Pedro is regulated by three reservoirs (Cherry Lake, Lake Eleanor, and Hetch Hetchy Reservoir) owned and operated by the City and County of San Francisco. These reservoirs have a combined storage capacity of 800 taf or more. During each of the past 10 years, approximately 220 taf of Tuolumne River water has been annually exported to San Francisco. Other small impoundments in the watershed include Modesto Reservoir (29 taf) and Turlock Lake (45.6 taf). LaGrange Dam, located downstream from New Don Pedro Dam, diverts approximately 900 af per year for power, irrigation, and domestic purposes. LaGrange Dam is the upstream barrier to salmon migration.

Salmon spawn in the 25-mile reach between LaGrange Dam and the town of Waterford and rear in the entire lower river. The river now supports fall-run chinook salmon and a small population of late fall-run chinook salmon.

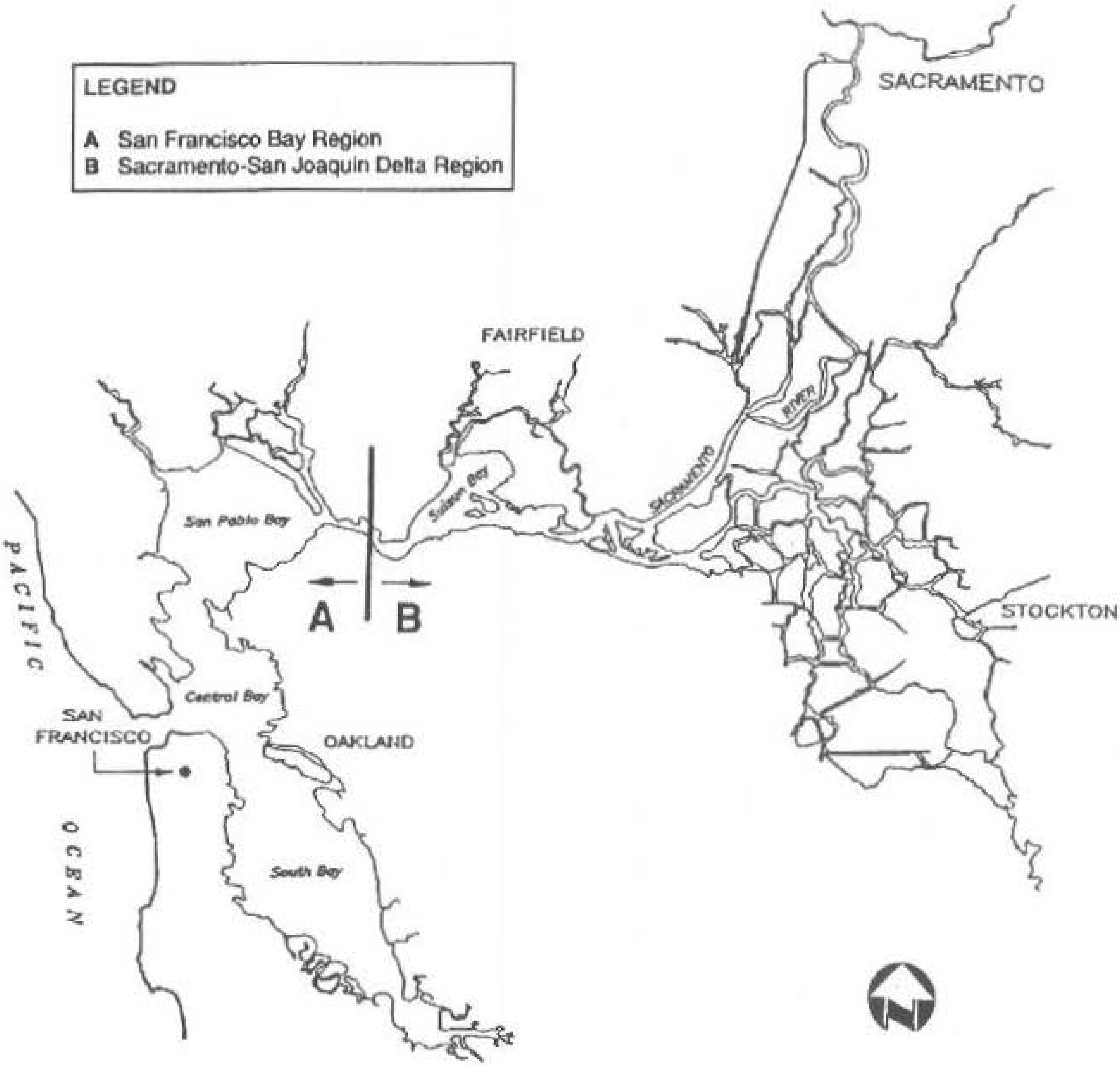
Stanislaus River - The Stanislaus River is the northernmost tributary in the San Joaquin River basin used by chinook salmon. The river flows westward into the valley, draining approximately 900 square miles (Figure 2-V-15). The average unimpaired runoff in the basin is about 1.2 maf. The median historical unimpaired

Stanislaus River



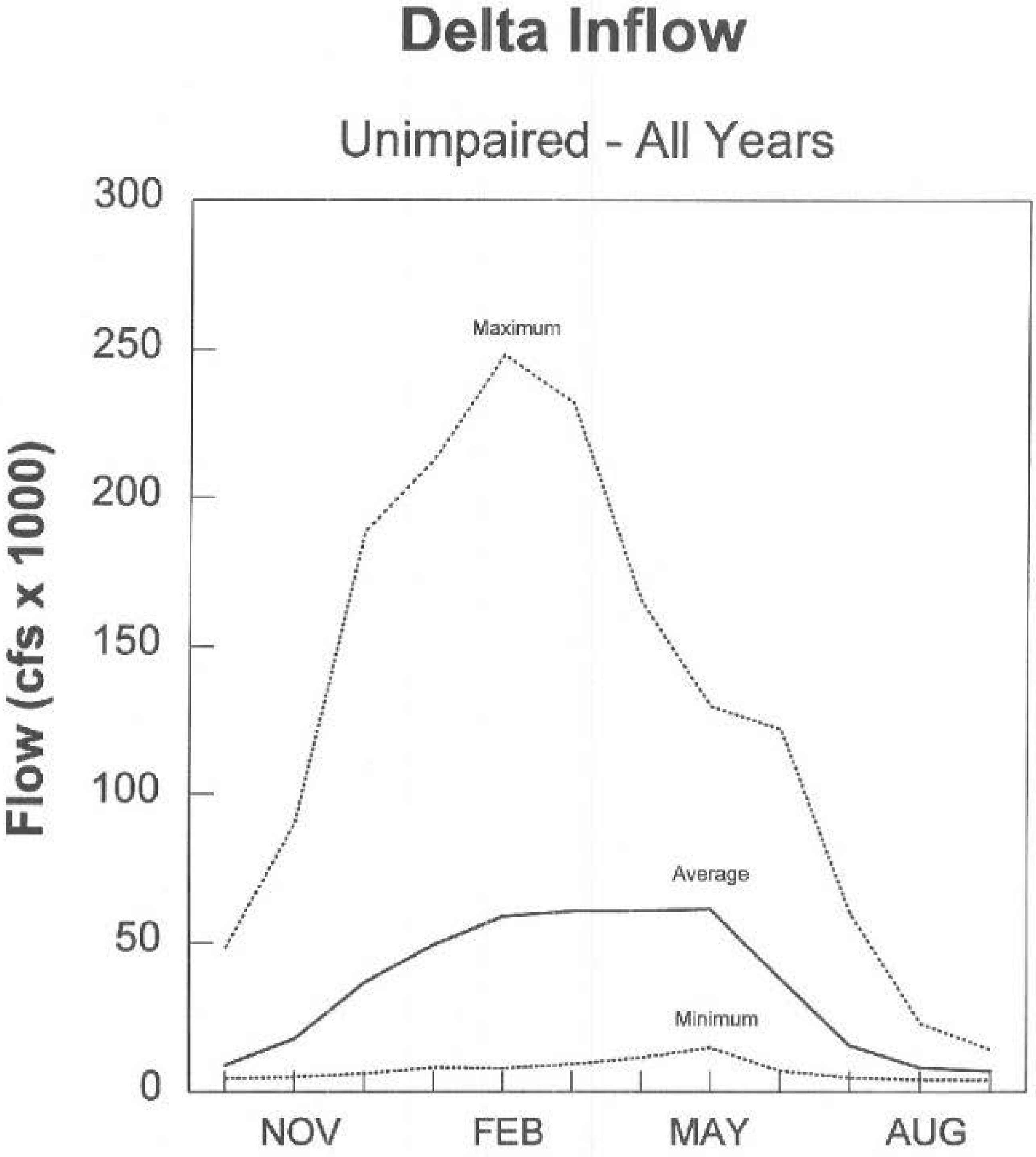
STANISLAUS RIVER MEAN MONTHLY FLOW: ACTUAL (BELOW GOODWIN DAM, 1967-1991) AND UNIMPAIRED (AT NEW MELONES RESERVOIR, 1922-1991)

FIGURE 2-V-19



SACRAMENTO-SAN JOAQUIN DELTA AND SAN FRANCISCO BAY REGIONS

FIGURE 2-V-20



MEAN MONTHLY DELTA INFLOW: UNIMPAIRED (1922-1991)

FIGURE 2-V-21

runoff is 1.1 maf, with a range of 0.2-3.0 maf (Figure 2-V-19). Significant changes have been made in the basin hydrology since agricultural development began in the 1850s. New Melones Dam, completed by the Corps in 1978 and approved for filling in 1981, is now the largest storage reservoir in the Stanislaus basin, with a gross storage capacity of 2.4 maf. The project is operated by USBR as part of the CVP. Downstream from New Melones Dam, Tulloch Reservoir, with a gross storage capacity of 68 taf, regulates water releases from New Melones Dam. Goodwin Dam, also downstream, regulates releases from Tulloch Reservoir and diverts water for power and irrigation to South San Joaquin Irrigation District and Oakdale Irrigation District. Goodwin Dam is the upstream barrier for salmon migration. Other impoundments in the watershed include Beardsley Reservoir and Donnell Reservoirs, with a combined storage capacity of more than 130 taf.

Salmon spawn in the 23-mile reach between Goodwin Dam and the town of Riverbank and rear in the entire lower river. The river now supports fall-run chinook salmon and small populations of late fall-run chinook salmon and steelhead.

SACRAMENTO-SAN JOAQUIN DELTA

The Delta is located at the confluence of the Sacramento and San Joaquin rivers and represents the most important, complex, and controversial geographic area both for anadromous fisheries production and distribution of California water resources for numerous beneficial uses (Figure 2-V-20). Approximately 42% of the state's annual runoff flows through the Delta's maze of channels and sloughs surrounding 57 major reclaimed islands and nearly 800 unleveed islands (Water Education Foundation 1992b). The median historical unimpaired runoff is 25.5 maf, with a range of 6.8-72.8 maf (Figure 2-V-21). The Delta includes almost 700 miles of waterways and more than 1,000 miles of levees in it's 1,150 square miles (DWR 1993). The Delta's channels are used to transport water from upstream reservoirs to the south Delta, where federal and state facilities (Tracy Pumping Plant and Harvey O. Banks Delta Pumping Plant, respectively) pump water into the CVP and SWP canals. Other Delta diversions include the Contra Costa Canal, North Bay Aqueduct, and more than 1,800 agricultural users.

An estimated 25% of all warmwater and anadromous sport fishing and 80% of the state's commercial fishery depend on species that live in or migrate through the Delta. The Delta serves as a migration path for all anadromous species returning to their natal rivers to spawn. Adult chinook salmon move through the Delta every month. Salmon and steelhead juveniles depend on the Delta as transient rearing habitat during migration through the system to the ocean and may rear for several months, feeding in marshes, tidal flats, and sloughs. All life stages of striped bass and American shad are found in the Delta; approximately 45% of striped bass spawn in the Delta, as do some American shad. Numerous resident native and introduced species live in the Delta year-round, including native Delta smelt (a species federally listed as threatened) and Sacramento splittail (a species proposed for federal listing as threatened).

Most of the flows into the Sacramento-San Joaquin Delta are provided by the Sacramento, San Joaquin, Mokelumne, and Calaveras rivers. The Sacramento River supports chinook salmon populations that provide most of the state's sport and commercial catch, as well as steelhead, striped bass, American shad, and white and green sturgeon. The San Joaquin River's eastside tributaries support severely depressed yet potentially significant chinook salmon populations, while chinook salmon in the upper San Joaquin River are essentially gone. The San Joaquin River also supports unknown sizes of populations of striped bass and sturgeon. The Calaveras, Mokelumne, and Cosumnes (a tributary to the Mokelumne) rivers are minor tributaries to the Delta, supporting small chinook salmon and steelhead populations. No chinook salmon have been observed in the Calaveras River since 1984.

SECTION VI. CENTRAL VALLEY ANADROMOUS FISHES - HISTORIC AND EXISTING CONDITIONS

LIFE HISTORIES

Chinook Salmon

General chinook salmon life history traits are described below, along with a review of traits that distinguish each of the four races of salmon. Figure 2-VI-1 illustrates the general chinook salmon life cycle. Figure 2-VI-2 shows the location of major spawning and rearing areas for each chinook salmon race. Figures 2-VI-3 through 2-VI-5 summarize the timing and abundance of chinook salmon races by life stage in the Sacramento River basin, the timing of adult upstream migration through the Delta, and the general timing and abundance of juvenile chinook salmon in the Delta.

Based on variations in their life histories, chinook salmon can be grouped into either stream- or ocean-"types". These variations in behavior patterns appear to have evolved to spread the risk of mortality across years and habitats (Healey 1991).

Stream-type chinook salmon are most common in populations north of 56^0N along the North American coast (Healey 1991). This group of races is characterized by long freshwater residence as juveniles (1+ years). Adults generally migrate upstream in spring and summer and hold in cool-water pools prior to spawning approximately 2-3 months later. The fecundity of adult females is relatively high.

Ocean-type chinook salmon are more common in populations found along the North American coast south of 56^0N (Healey 1991). This race is characterized by short freshwater residence as juveniles (2-3 months). Adults migrate upstream in summer and fall and spawn shortly after. The fecundity of adult females is relatively low.

Chinook salmon of the Sacramento-San Joaquin system are 10-18% stream type (spring and late fall runs) and 82-90% ocean type (fall run). The winter-run fish appear to have characteristics of both steam- and ocean-type life histories, with delayed spawning after river entry (stream type) and short stays in the river system before migration to sea (ocean type) (Healey 1991).

Run timing, spawning periods, and early life history phases of the four races (fall, late fall, winter, and spring) that occur in the Sacramento River all overlap; thus spawning may occur virtually year-round, and each of the freshwater life stages of chinook salmon may be found every month of the year.

Upstream migration and spawning - Salmon in general return to their natal stream to spawn with considerable fidelity. While the straying of chinook salmon from their natal stream is documented for hatchery-raised fish, it is not known to what extent this occurs with naturally produced fish.
Adult fall-run chinook salmon migrate through the Sacramento-San Joaquin Delta and into Central Valley rivers from July through December and spawn from October through December. Peak spawning activity usually occurs in October and November.

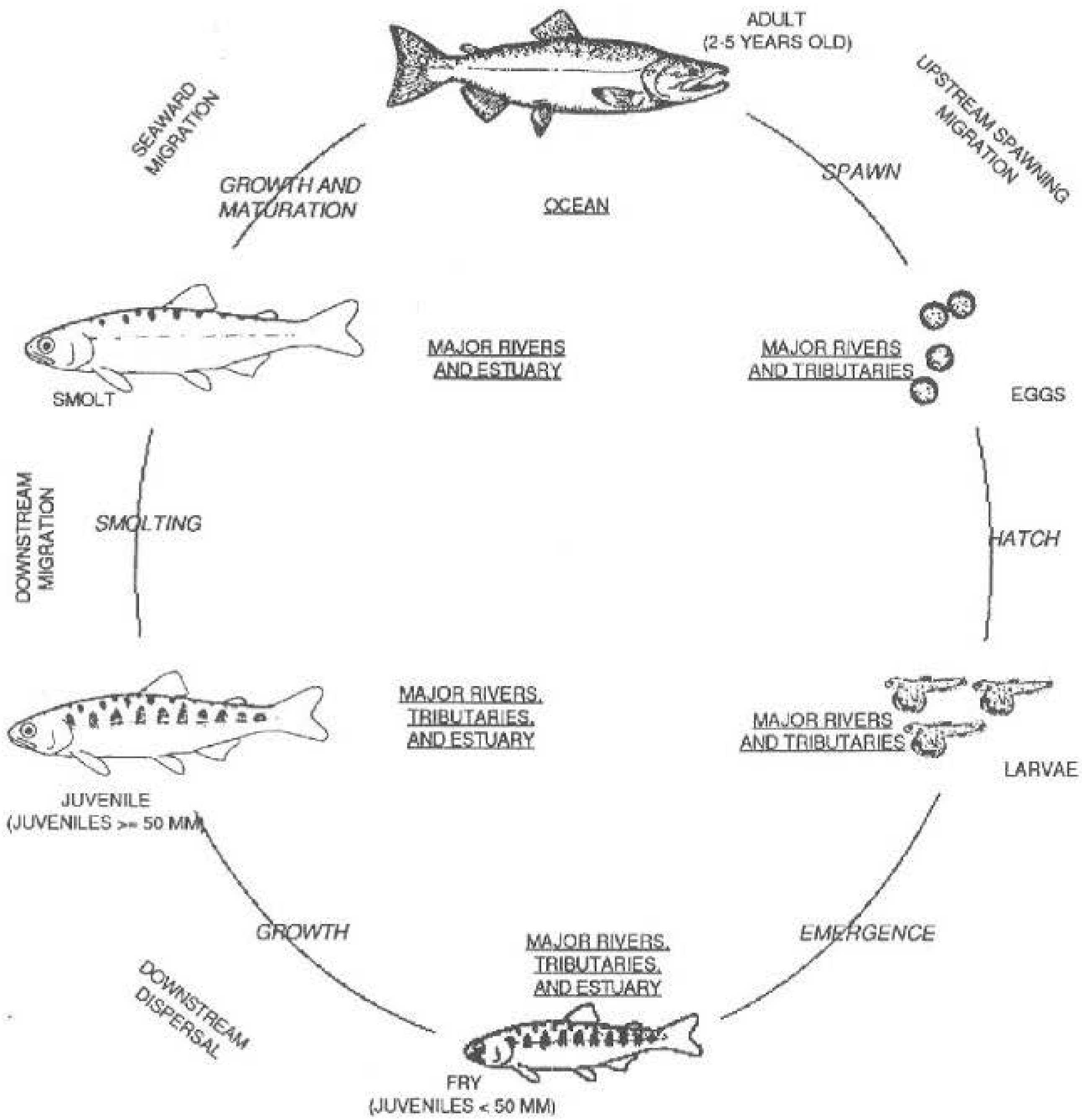
Adult late fall-run chinook salmon migrate through the Delta and into the Sacramento River from October through April and may wait 1-3 months before spawning from January through April. Peak spawning activity occurs in February and March.

Adult winter-run chinook salmon migrate through the Delta and into the Sacramento River from December through July. Winter-run chinook salmon do not spawn immediately but remain in the river up to several months before spawning. Spawning occurs from April through July, with peak spawning activity in May and June.

Adult spring-run chinook salmon migrate through the Delta and into the Sacramento River from March through September and remain in the river up to several months before spawning. Spawning occurs from August through October, with peak spawning activity in September.

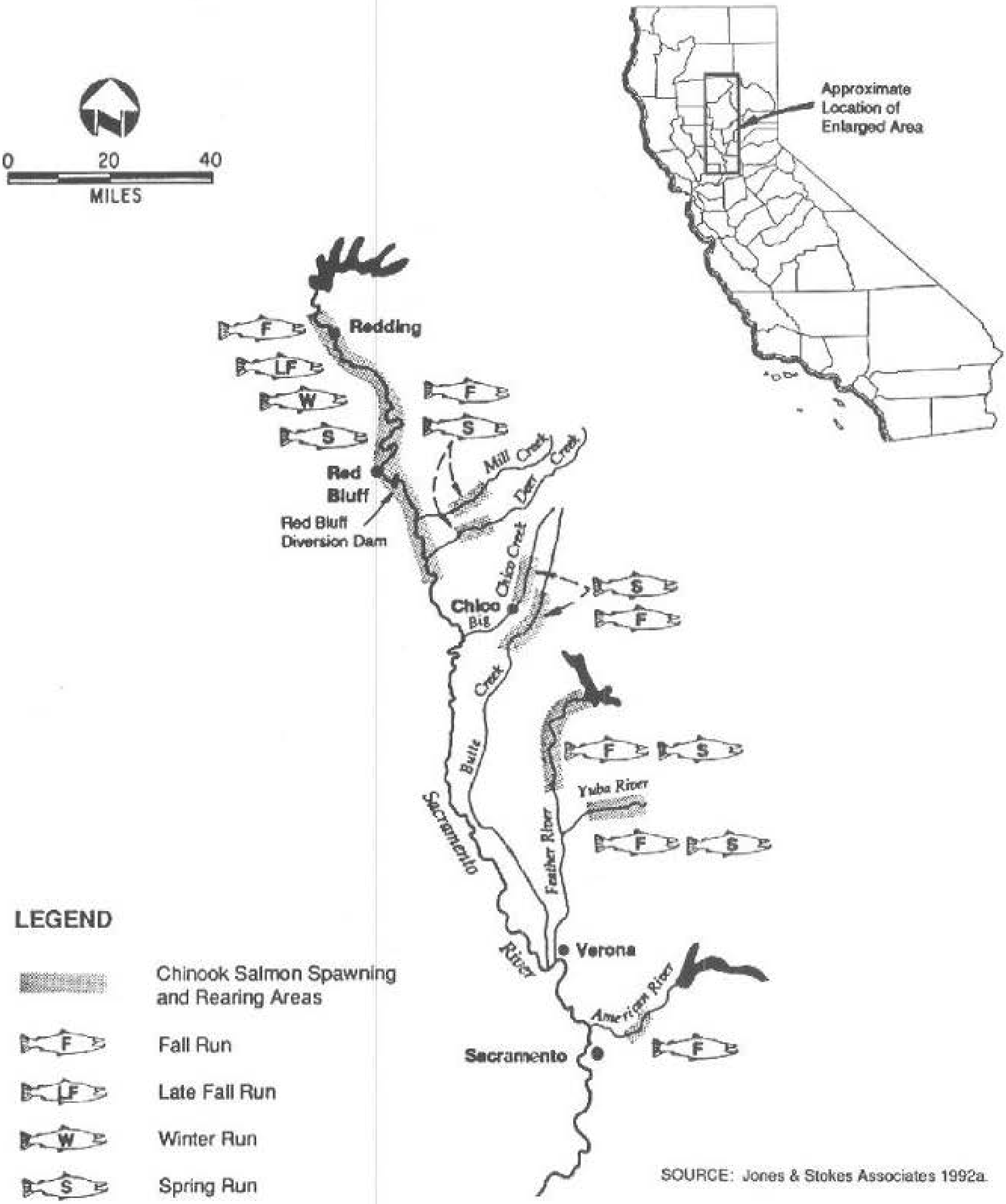
In preparation for spawning, a female chinook salmon digs a shallow depression in the gravel of the stream bottom in an area of relatively swift water by performing vigorous swimming movements on her side near the bottom. Gravel and sand thrown out of the depression accumulate in a mound, or "tailspill", at the downstream margin of the depression. During the act of spawning, the female deposits a group or "pocket" of eggs in the depression and then covers it with gravel. Over the course of one to several days, the female deposits four or five such egg pockets in a line running upstream, enlarging the spawning excavation in an upstream direction as she does so. The total area of excavation, including the tailspill, is termed a "redd". The eggs are fertilized by one or more males, after which the female buries the eggs by displacing gravels upstream of the redd. The size of a chinook salmon redd is highly variable and can range from 2.4 to 54 square yards (Chapman et al. 1986). Fecundity varies among different populations, between individuals within a population, and between years (Healey 1991). The Sacramento River population has an unusually high fecundity for one so far south. Body size appears to contribute to variations in fecundity to a lesser degree for chinook salmon than for other fishes. Healey and Heard (1984) found the fecundity of chinook females in 18 populations surveyed ranged from fewer than 2,000 to more than 17,000 eggs. All adult chinook salmon die after spawning.

Incubation - Egg incubation for Central Valley fall-run chinook salmon begins with spawning in October and can extend into March. Egg incubation for late fall-run salmon occurs from January through June. Winter-run chinook egg incubation occurs from April through October, although most fry have emerged by the end of September. Incubation of spring-run eggs occurs from August through December, except for Mill and Deer creeks, where eggs incubate from September through March (Fisher pers. comm.).



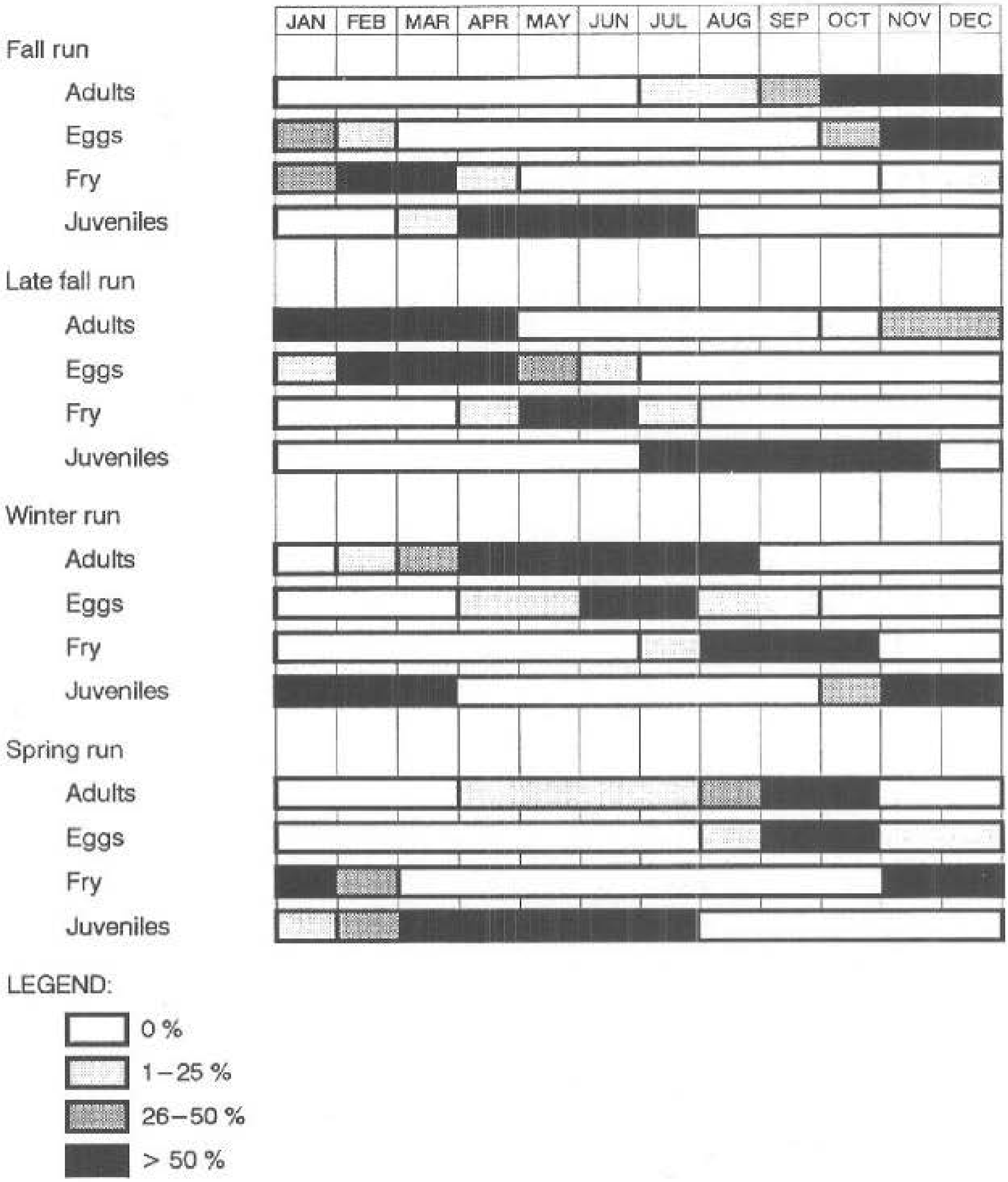
LIFE HISTORY OF CHINOOK SALMON

FIGURE 2-VI-1



MAJOR CHINOOK SALMON SPAWNING AND REARING AREAS IN THE SACRAMENTO RIVER BASIN

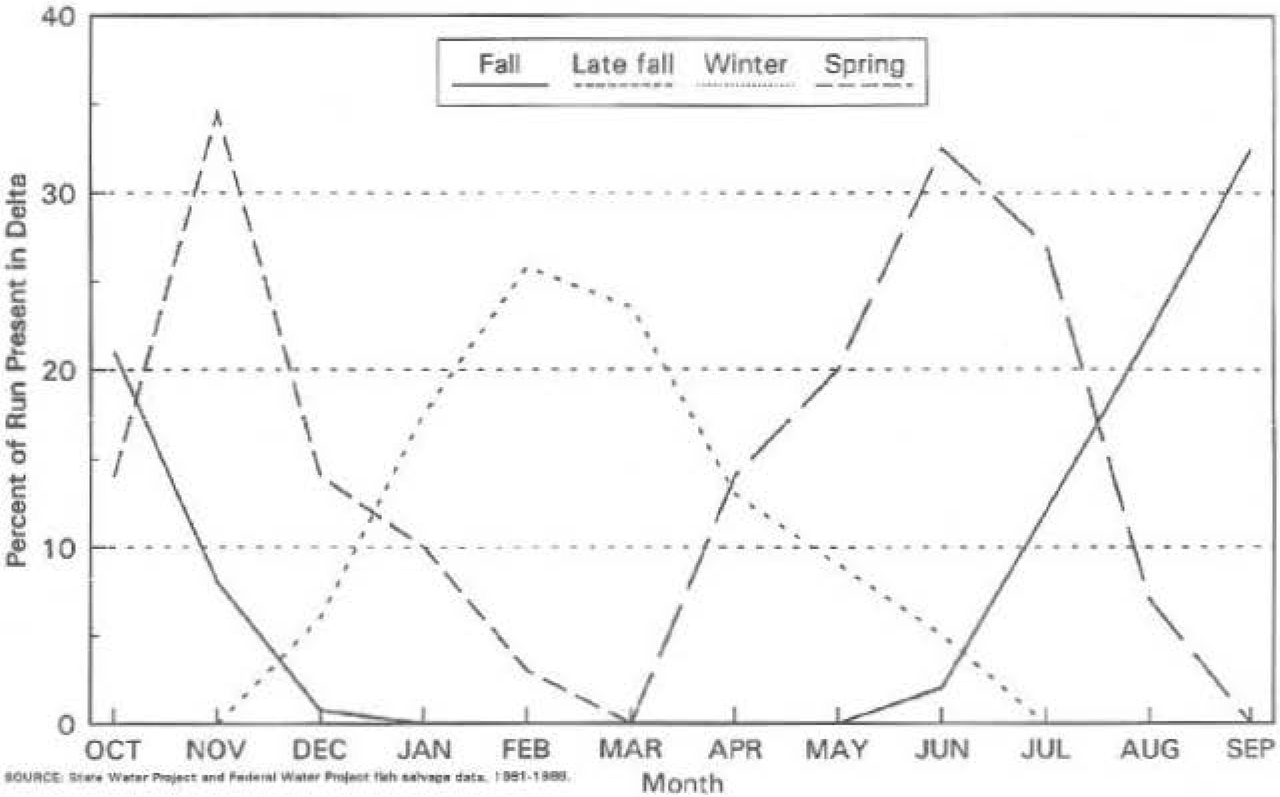
FIGURE 2-VI-2



NOTES: Adults are in cumulative percent.
Other life stages are the percent of year's brood.

OCCURRENCE OF CHINOOK SALMON BY LIFE STAGE IN THE SACRAMENTO RIVER BASIN

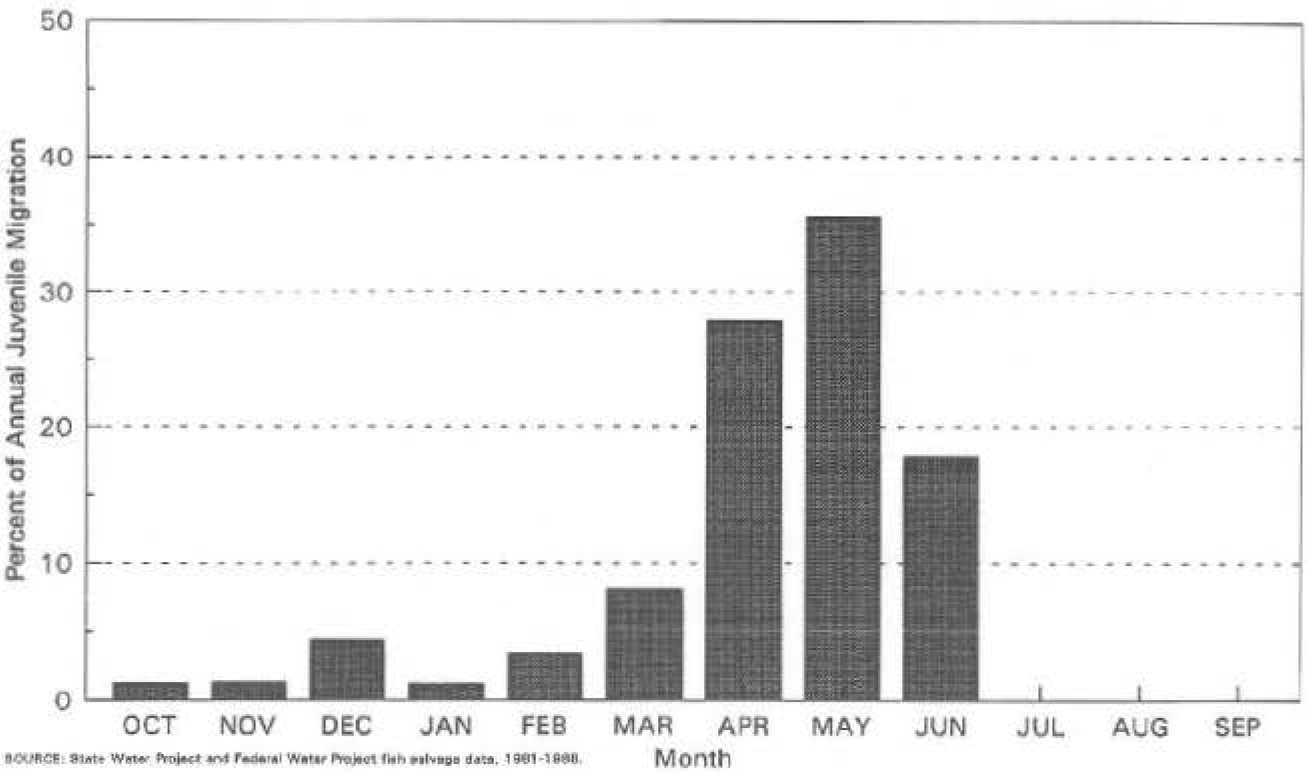
FIGURE 2-VI-3



SOURCE: State Water Project and Federal Water Project fish salvage data, 1981-1986.

TIMING OF ADULT CHINOOK SALMON MIGRATION THROUGH THE SACRAMENTO-SAN JOAQUIN DELTA

FIGURE 2-VI-4



SOURCE: State Water Project and Federal Water Project fish salvage data, 1981-1988.

TIMING OF JUVENILE CHINOOK SALMON MIGRATION THROUGH THE SACRAMENTO-SAN JOAQUIN DELTA

FIGURE 2-VI-5

Incubation time is inversely related to water temperature. Eggs generally hatch in approximately 6-9 weeks, and newly emerged fry remain in the gravel for another 2-4 weeks until the yolk is absorbed. The survival of eggs in undisturbed natural redds appears to be quite good (Briggs 1953, Vronskiy 1972).

Rearing - The timing and dynamics of the rearing and downstream migration periods of each run of Sacramento River chinook salmon, though not as well understood as the timing of spawning activities, are described below.

Fall-run chinook salmon fry (i.e., juveniles less than 2 inches long) generally emerge from December through March, with peak emergence occurring by the end of January. Most fall-run fry can be found rearing in freshwater from December through June, with emigration as smolts occurring from April through June. A very small number (generally considered <5%) of fall-run juveniles spend over a year in fresh water and emigrate as yearling smolts the following November through April.

Late fall-run chinook salmon fry generally emerge from April through June. Late fall-run fry can be found rearing in freshwater from April through the following April and emigrating as smolts from November through April.

Winter-run chinook salmon fry emerge from July through October. Winter-run fry can be found rearing in freshwater from July through May and emigrating as smolts from January through May.

Most spring-run fry emerge from November through January. True stream-type spring-run fry, thought to be found only in Deer and Mill creeks in the Central Valley system (Fisher pers. comm.), rear in fresh water for more than a year and emigrate as yearling smolts the following November through April. Mainstem spring-run fry, exhibiting a strategy similar to fall-run chinook fry, can be found rearing in fresh water from November through June and emigrating as smolts from March through June.

Although not well documented, emergence appears to be a difficult time for fry (Healey 1991). In systems studied, under natural conditions, 30% or less of the potential eggs deposited resulted in emergent fry or fry and fingerling migrants. After emerging, chinook salmon fry swim, or are displaced, downstream and begin to feed and grow in the stream environment. Ocean-type juveniles typically rear in fresh water for 2-3 months, while stream-type juveniles remain in freshwater 1+ years prior to outmigrating during the following winter or spring (Healey 1991).

Downstream migration - Most chinook salmon stocks of the Central Valley are characterized by an ocean-type life history pattern, in which juveniles migrate seaward as smolts in their first year of life. During the smolting process, juvenile chinook salmon undergo physiological, morphological, and behavioral changes that stimulate emigration and prepare them for ocean life.

Generally, fry emigrate from December through March and smolt from April through June. A small proportion of the population emigrates as yearlings from October through December.

Two principal movements of juvenile fall-run chinook salmon into the Sacramento-San Joaquin estuary have been identified. Fry begin entering the estuary in January, with peak abundance occurring in February and March. In general, fry abundance in the Delta increases following high winter flows. A later emigration of smolts occurs from April through June. Fry continue to rear in the upper estuary and emigrate as smolts during the normal smolt emigration period. Smolts arriving in the estuary from upstream rearing areas migrate quickly through the Delta and Suisun and San Pablo bays.

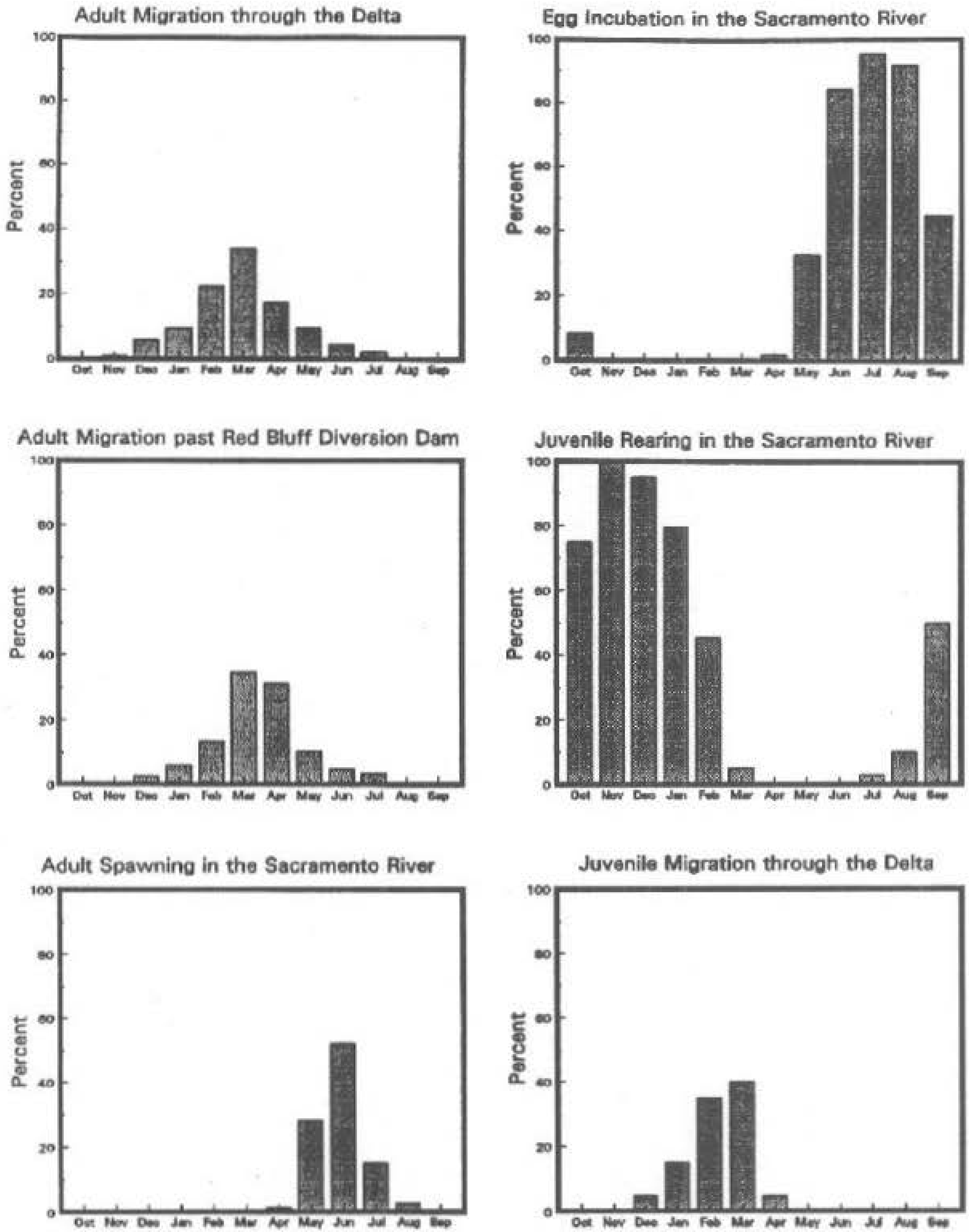
Rearing and emigration of late fall-run fry and smolts occur from April through December. Winter-run chinook salmon can appear in the Delta beginning in December, but smolts migrate through the Delta primarily from January through March. Figure 2-VI-6 summarizes the distribution and relative monthly abundance of winter-run chinook salmon by life stage and location.

Ocean life - The stream-type chinook salmon move offshore early in their ocean life, whereas ocean-type chinook remain in sheltered coastal waters. Stream-type fish maintain a more offshore distribution throughout their ocean life than do ocean-type fish. Available data suggest a northward dispersal of juveniles along the coast, followed by a southward homing migration of maturing adults (Healey 1991). The diet of chinook salmon in the ocean can vary regionally, annually, and seasonally, with small fish (e.g., herring, anchovy, and rockfish), squid, and euphausiids as typical prey items. Chinook salmon typically spend 2-4 years maturing in the ocean before returning to their natal streams to spawn. Historically, most Sacramento River chinook salmon returning to spawn have been 4 years of age (Clark 1929). It has been documented for the Sacramento River that a few male chinook may mature without migrating to sea (Rich 1920), and it may be that this type of maturation is characteristic of stream-type chinook (Healey 1991).

Steelhead

Steelhead are generally classified into two noninterbreeding races--winter steelhead and summer steelhead--depending on the time of year they enter fresh water on their upstream migration. Only winter steelhead occur in the Sacramento River system. Summer steelhead have been introduced into the basin, however, as have strains of winter steelhead from the Eel and Mad rivers and even Oregon (Rogue River) and Washington (Washougal River) river basins. Consequently, the genetic composition of the native steelhead has been significantly modified. Because of the modified genetic composition and the influence of modified and unnatural flow and temperature regimes throughout the basin, the current Central Valley steelhead strains can be found as adults in fresh water in every month of the year. The general life history pattern followed by a "typical" steelhead is described below and presented in Figure 2-VI-7.

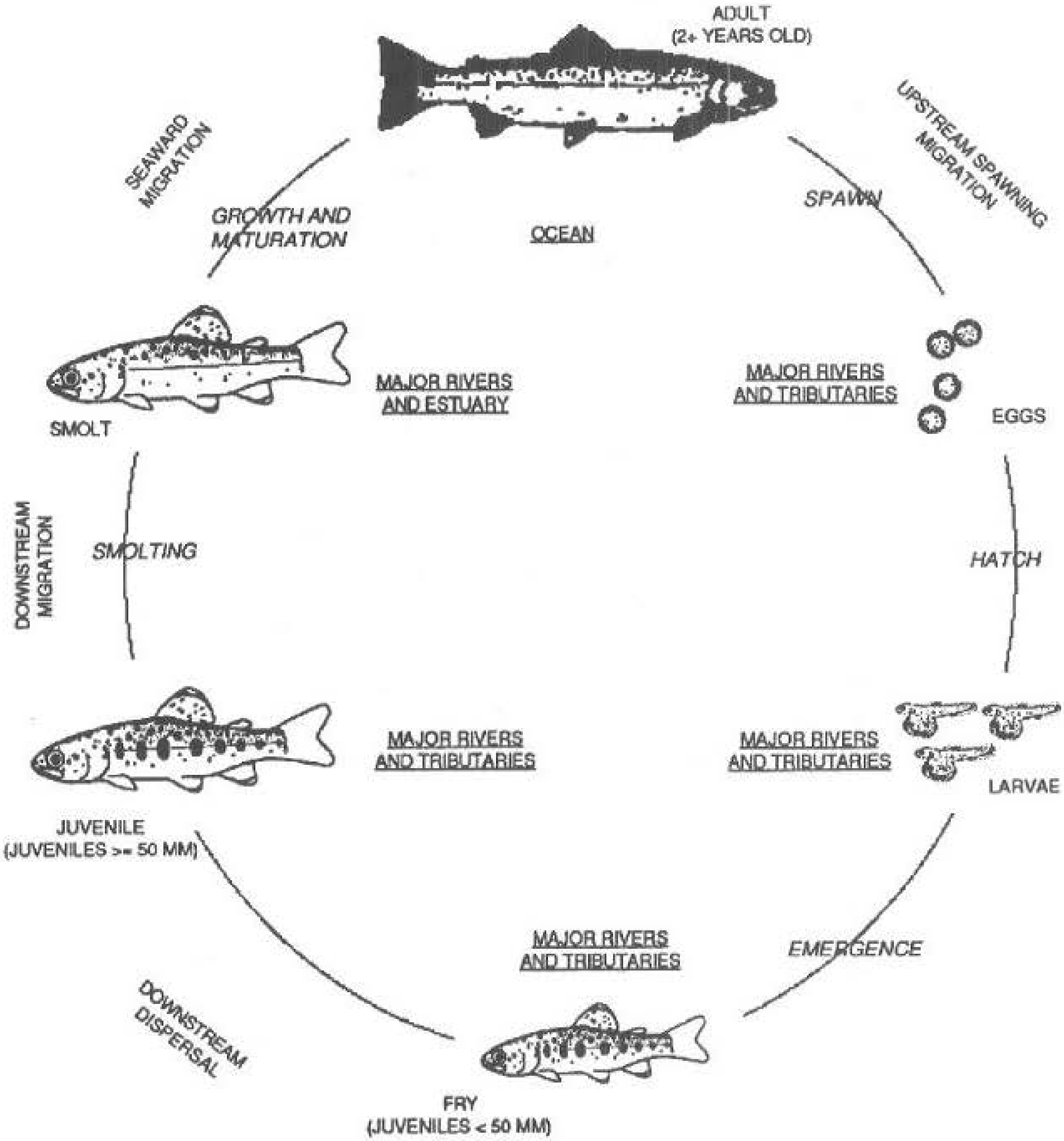
Upstream migration - Steelhead, like salmon, are anadromous species, migrating to sea as juveniles and typically returning to inland waterways as 2- to 4-year-old adults to spawn. Upstream migration occurs in August through March as a result of interbreeding with numerous hatchery strains and altered flow and



SOURCE: Jones and Stokes Associates 1992b.

DISTRIBUTION AND RELATIVE MONTHLY ABUNDANCE OF WINTER-RUN CHINOOK SALMON BY LIFE STAGE AND LOCATION

FIGURE 2-VI-6



LIFE HISTORY OF STEELHEAD TROUT
FIGURE 2-VI-7

temperature conditions below major dams. Reservoir releases of cold and high water occasionally occur in major Sacramento River tributaries and can attract steelhead into the tributaries as early as August. In addition to sexually mature adults, a small portion of the upstream-migrating run is composed of immature grilse, which have spent only a few months at sea.

It is unknown whether separate fall and winter runs of steelhead exist in the Sacramento River system. The smaller and younger steelhead that enter the river starting in July, peak in November, spawn primarily in late December and January, and complete spawning by mid-February are sometimes called fall-run steelhead. The larger winter-run steelhead migrate upstream during mid-December through February and spawn in late January through early March, and the run is over by April 1.

Because of the mixed genetic stock, Sacramento River steelhead have higher straying rates than native fish. Consequently, steelhead stocks in the Sacramento River are subject to a greater degree to environmental conditions than are pure native stocks.

Life history aspects of the few steelhead in the San Joaquin River system are assumed to be similar to those described for the Sacramento River system. Upstream spawning migration runs in the Mokelumne River extend from September through January (California Department of Fish and Game [DFG] 1991).

Adult steelhead rarely eat, and they grow very little while they are in fresh water (Pauley et al. 1986).

Spawning - Natural spawning of steelhead in the Sacramento River system has been greatly reduced by dams and other artificial barriers to historical spawning grounds and by reduced spawning flows and other forms of habitat degradation in the stream reaches to which they have access. As a result, steelhead depend highly on hatchery operations to maintain their populations. Spawning in the Sacramento River basin occurs in December through April, with most spawning occurring from January through March.

Unlike chinook and other Pacific salmon, most steelhead do not die after spawning, and a small portion of these survive to become repeat spawners. During spawning, the female digs a redd and deposits her eggs, which are then fertilized by the male. The number of eggs is largely a function of the size of the female. Female steelhead in the American River each carry an average of 3,500 eggs, or a range of 1,500 to 4,500 eggs (Mills and Fisher 1993). Female steelhead in the Sacramento River are smaller, and each carrying an average of approximately 1,500 eggs (Bell 1990). Females may deposit from a few hundred to more than 1,000 eggs per redd and require up to six or seven redds to complete spawning (Skinner 1962). Females have a higher survival rate than males during and after spawning, and a few females may spawn up to four times. Spawning males usually spawn with more than one female, remain in the stream up to 2 weeks longer than females after spawning, and experience more physical exertion (Barnhart 1986). Individual adult steelhead that survive spawning return to the sea between April and June (Mills and Fisher 1993).

Incubation - Steelhead embryology is similar to that of salmon and of other trout.

Rearing - Juvenile steelhead generally rear in fresh water for nearly 1 year or longer before emigrating, generally in spring. Rearing juveniles feed on a variety of aquatic and terrestrial insects and other small invertebrates, and newly emerged fry sometimes become prey of older steelhead.

Downstream migration - Juvenile steelhead generally emigrate downstream to the ocean in November through May (Schaffter 1980), although most Sacramento River steelhead migrate in spring and early summer (Reynolds et al. 1993). Sacramento River steelhead generally migrate as 1-year-old fish at a length of 6-8 inches (Barnhart 1986, Reynolds et al. 1993).

Ocean life - Much of the life of steelhead in the ocean remains a mystery. Steelhead can live 1-4 years in the ocean, but usually they survive only 1-2 years. They grow rapidly, reaching an average length of 23 inches after 2 years in the ocean. Immature grilse grow about 1.2 inches each month they are in the ocean.

Steelhead migration patterns at sea are not well known. They appear to tend to migrate north and south along the Continental Shelf, and at least some spend part of their ocean life in the Alaskan gyre (Barnhart 1986, Pauley et al. 1986).

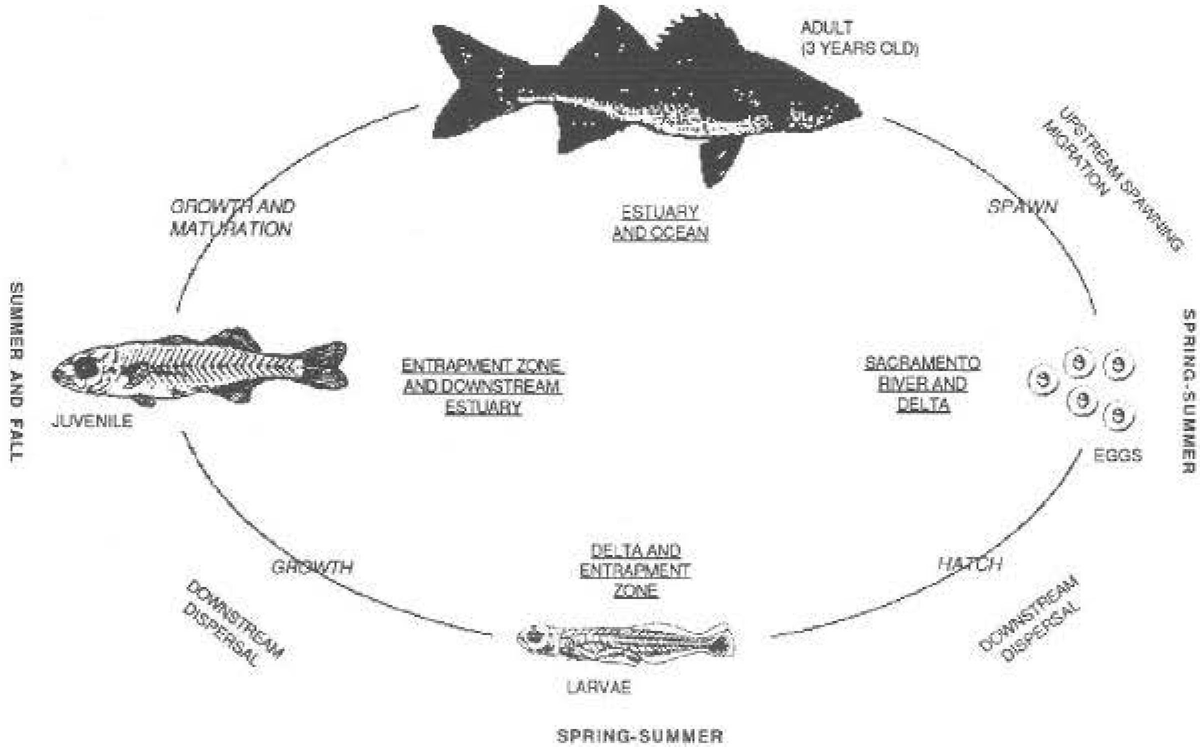
Striped Bass

Striped bass inhabit fresh and ocean waters (Figure 2-VI-8). They require riverine habitat for spawning with currents sufficient to keep the eggs suspended off the bottom (Moyle 1976). Estuarine habitat with high invertebrate densities is needed to support larval and early juvenile bass. Adult bass survive and grow best in water bodies supporting a large prey base (i.e., large populations of forage fishes). The Sacramento and San Joaquin rivers, the Delta, Suisun Bay, San Francisco Bay, and the Pacific Ocean provide conditions that have sustained the striped bass population for more than 100 years since the species' introduction to California in the late 1800s.

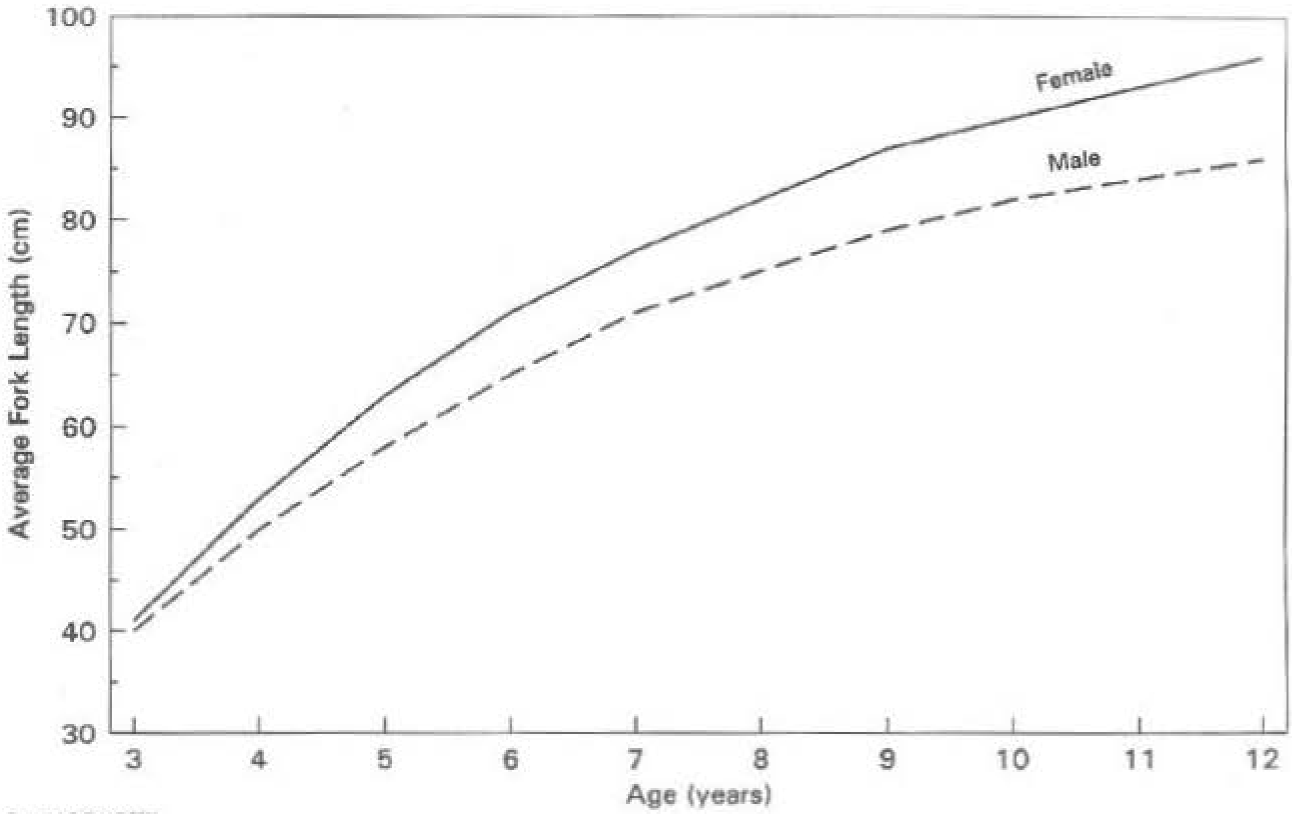
Striped bass are considered adults at 3 years old (when they are approximately 15.2 inches long) and may live for more than 30 years (Moyle 1976). Most adult striped bass in the Sacramento-San Joaquin estuary are between 3 and 8 years old. Female striped bass grow faster than males, and most 6-year-old females are the same size as 7-year-old males (Figure 2-VI-9) (Collins 1981). Most growth occurs during May to November. In California, striped bass can grow to approximately 54 inches long and weigh more than 60 pounds.

Upstream migration and spawning - Male striped bass may be sexually mature at the end of their first year, but most reach sexual maturity after 2-3 years (Moyle 1976). Sexual maturity occurs at a later age in females, usually after 4-6 years.

Striped bass always spawn in fresh water (DFG 1987). Striped bass spawn in the Sacramento River between Sacramento and Colusa (including the Feather River below Marysville [Wang 1986]) and in the

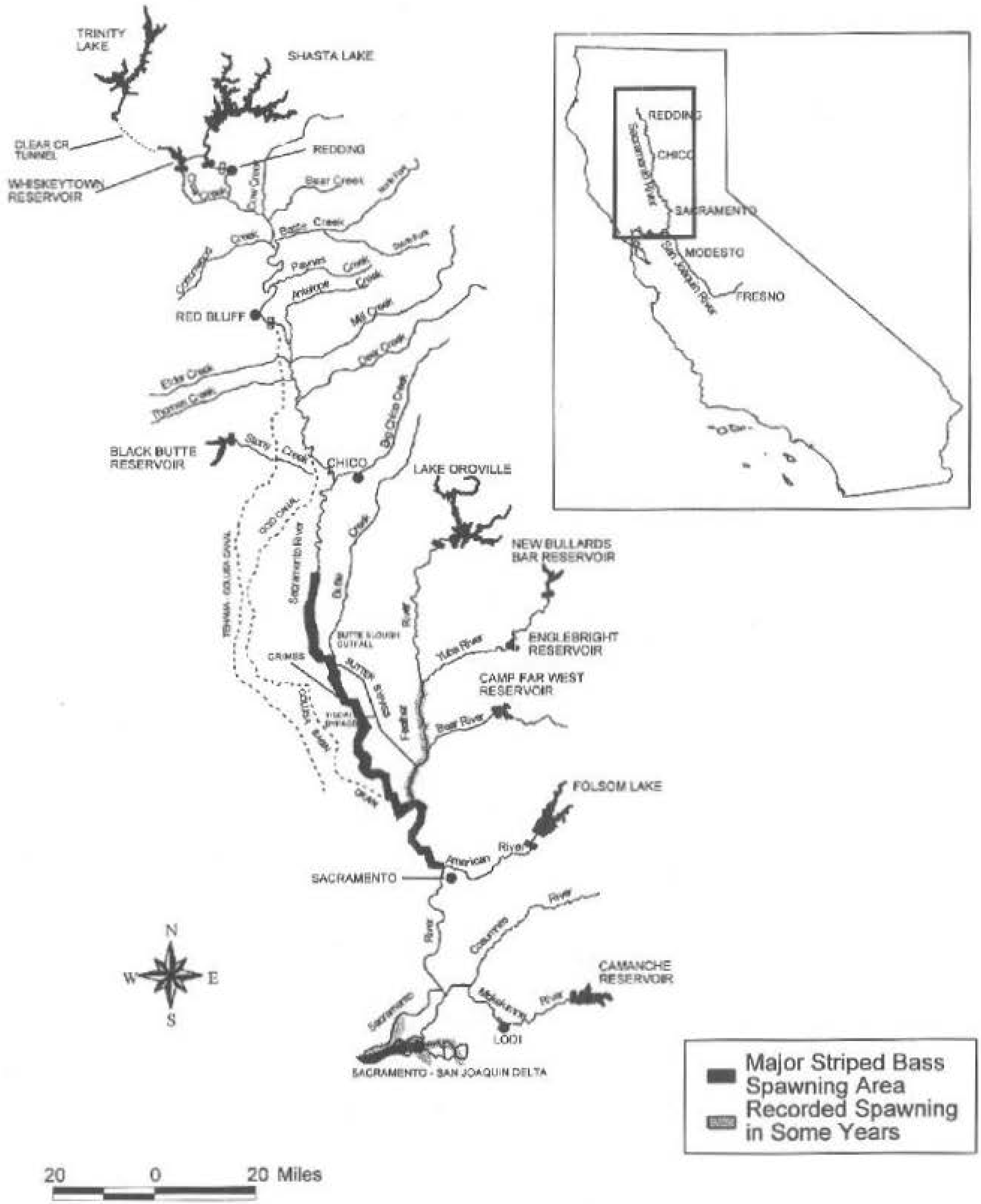


LIFE HISTORY OF STRIPED BASS
FIGURE 2-VI-8



Source: Collins (1981).

GROWTH OF ADULT STRIPED BASS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY
FIGURE 2-VI-9



STRIPED BASS SPAWNING AREAS IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM

FIGURE 2-VI-10

San Joaquin River part of the Delta between Antioch and Venice Island (Figure 2-VI-10). Spawning has also been recorded in the lower San Joaquin River above the Delta (Turner 1976). Usually, approximately 60% of the spawning population uses the Sacramento River, and 40% spawn in the Delta. The proportion spawning in each area varies annually, but 50-66% of the annual egg production is from the Sacramento River spawn. Spawning in the Sacramento River occurs farther upstream during years of high flow (Turner 1976).

Spawning begins first in the Delta, usually in mid- to late April, and continues sporadically over 3-5 weeks (Mitchell 1987, DFG 1987). Spawning in the Sacramento River takes place an average of 15 days later than spawning in the Delta and usually begins in early or late May and ends in early June (Turner 1976). Cooler water temperatures delay spawning in the Sacramento River relative to the Delta. High flow tends to dampen increases in temperature, and the delay period is greater during high-flow years.

Striped bass are mass spawners, broadcasting eggs and sperm into the water column (Moyle 1976, Wang 1986). Groups consisting of 5-30 striped bass, predominantly males, move into the main current of the river to spawn near the surface. Spawning can occur any time of day but generally takes place in the late afternoon and evening. Females are prolific, producing from 11,000 to more than 2,000,000 eggs each. The number of eggs produced is a function of size. A 4-year-old female produces more than 200,000 eggs, an 8-year-old female produces more than 1,000,000 eggs, and a 12-year-old female produces more than 1,800,000 eggs (DFG 1987).

Incubation - Eggs are slightly denser than fresh water, and in the absence of current, sink slowly to the bottom (Moyle 1976). In the Sacramento River near Verona, where flows are turbulent in the relatively narrow and shallow river, egg densities were variable but tended to be greatest at the surface (Fujimura 1991). Apparently, eggs suspended by turbulent flow remain near the surface where they were spawned by the female bass. Farther downstream near Walnut Grove, eggs are generally concentrated at mid-depth and near the bottom. The river near Walnut Grove is wider, deeper, and has more uniform laminar flow, and currents slow when flood tides back up against the downstream river flow. Eggs transported downstream from the spawning areas sink slowly and are generally concentrated within a few meters of the bottom (Turner 1976, Wang 1986).

Eggs hatch in approximately 2 days at 18-19^{o}C (Moyle 1976, Wang 1986). Larvae measuring approximately .12-.16 inch long at hatching are sustained by their yolk sac for 7-9 days, after which they exceed .24-.28 inch in length and begin feeding on small zooplankton. As larvae increase in size, their swimming ability and control over position in the water column increases (Fujimura 1991). Until the transition to external feeding, however, larvae are weak swimmers and are passively dispersed by currents.

Rearing - Larval stages last 4-5 weeks, and, when they reach about .72 inch long, the young bass have developed all the features characteristic of juveniles (Wang 1986, DFG 1987). Within another 4-5 weeks (usually in July), depending on water temperature and food availability, juvenile bass will have grown to lengths of 1.52 inches. By September, the length of the juveniles in the current year-class ranges from 20 to 48 inches (Sasaki 1966). By August of the following year, the length of juveniles ranges from 4.8 to 9.2 inches. By the end of their third year, the average length is 15.2 inches and the young bass are considered adults.

Striped bass larvae eat several species of copepods (including *Eurytemora* sp., *Sinocalanus* sp., and *Cyclopidae*), several species of Cladocerans (including *Bosmina longirostrus* and *Daphnia* spp.), and the mysid *Neomysis* sp. The copepod *Eurytemora* sp. is the preferred food of larval striped bass in the Sacramento-San Joaquin estuary. In the San Joaquin River portion of the Delta, the Cladoceran *Bosmina longirostrus* is sometimes heavily selected as prey by striped bass larvae.

Larval striped bass generally select prey larger than .04 inch within each species and each species group. *Neomysis* is generally too large for larvae to consume but becomes progressively more important in the diet as larvae increase in size.

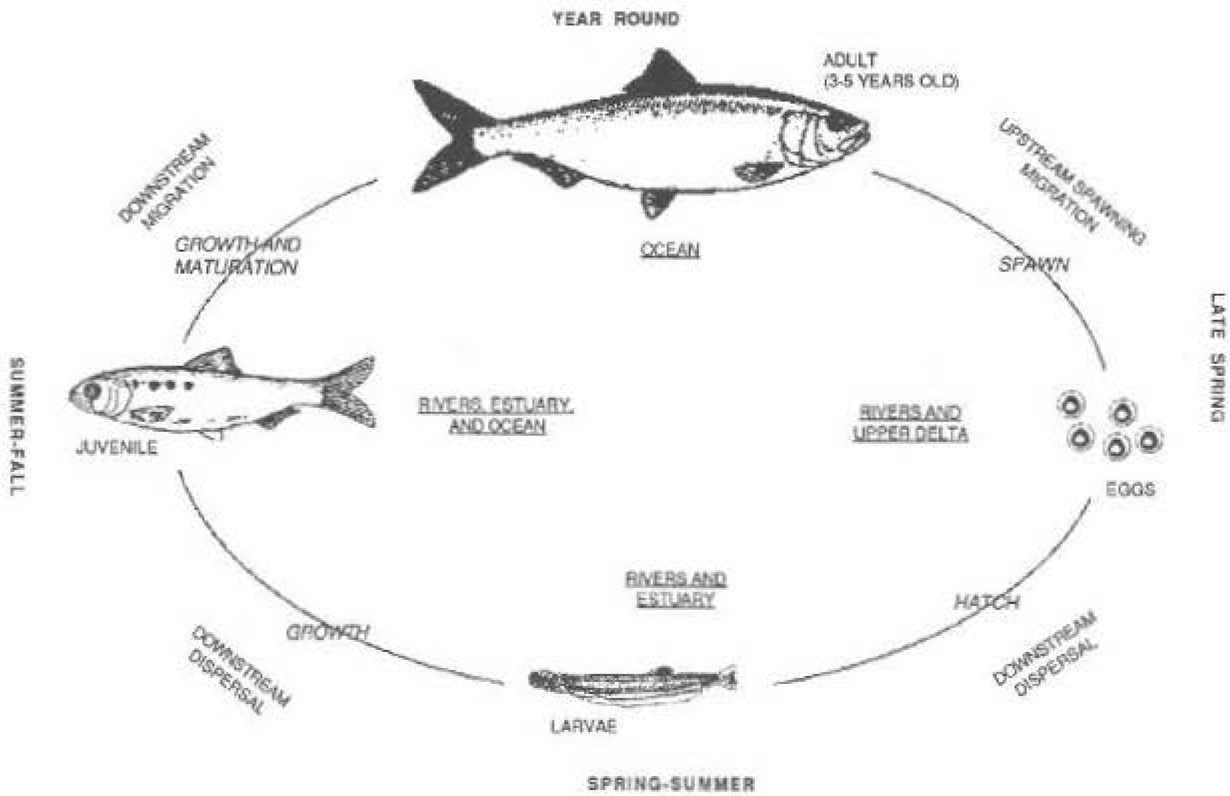
Similar to larvae, juvenile striped bass select progressively larger prey as they grow (Thomas 1967). The primary prey of juvenile bass during their first year is *Neomysis* sp. and amphipods in the genus *Corophium* (Stevens 1966). As the bass grow, the diet of juvenile bass shifts more to fish and becomes similar to the diet of adult striped bass.

For adults in the Central Valley, food preference is primarily a function of prey availability, which depends on habitat and season. In general, adult striped bass feed on fish, including smaller striped bass. In the Delta, adult bass prey primarily on threadfin shad, American shad, and young striped bass (Stevens 1966). Anchovies, chinook salmon, Delta smelt, and mysids are seasonally eaten in the lower Delta and Suisun Bay (Thomas 1967). In San Pablo and San Francisco Bay, anchovies, bay shrimp (*Crangon* sp.), and shiner perch are the primary prey items. When striped bass inhabit rivers, juvenile chinook salmon and carp are key prey species.

Estuarine and ocean migration - Adult bass are found throughout the year in rivers (the Sacramento, San Joaquin, and Mokelumne rivers, and their major tributaries), the Delta, San Francisco Bay, and the Pacific Ocean, but they show definitive migration patterns. In fall, adult striped bass migrate upstream to Suisun Bay and the Delta, where they overwinter (Chadwick 1967, Mitchell 1987). During spring, bass disperse throughout the Delta and into the tributary rivers to spawn. Migration back to the Delta, Suisun Bay, and San Francisco Bay occurs during summer. After the mid-1960s, however, most striped bass have inhabited Suisun Bay and the Delta during summer and fall; migration to San Francisco Bay and the Pacific Ocean has declined.

American Shad

With only a few exceptions, American shad are anadromous, spending most of their life in the ocean and returning as adults to spawn in freshwater rivers. Adult spawning migrations occur primarily in April-June, with most spawning taking place in the American, Feather, Yuba, and upper Sacramento rivers. Some



LIFE HISTORY OF AMERICAN SHAD
FIGURE 2-VI-11

spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus rivers. Spawning occurs in moderate currents sufficient to keep eggs suspended off the bottom. The young can rear for several months in the Feather and Sacramento rivers or migrate downstream soon after hatching, lingering in the Delta for several weeks to several months. Information presented on American shad life history is based primarily on Moyle (1976), Painter et al. (1980), Stier and Crance (1985), Wang (1986), and Jones & Stokes Associates (1990). American shad life history is summarized in Figure 2-VI-11.

Upstream migration and spawning - American shad become sexually mature while in the ocean at an average age of 3-5 years; the oldest fish on record lived to be 11 years old (Painter 1980). Most males reach maturity at 3-4 years, and most females become sexually mature at 4-5 years (Painter et al. 1980). Some shad have been found to spawn as young as 2 years of age. At maturity, male shad typically average 3 pounds, and female shad average almost 4 pounds; shad as large as 6-8 pounds are rare (Skinner 1962). Although shad are strongly anadromous, they are capable of surviving and reproducing while landlocked in freshwater reservoirs (Moyle 1976). In California, all American shad except the Millerton Lake shad populations have an anadromous life cycle.

Unripe, male shad make up most of the early run and smaller, unripe females are known to precede the larger, later-migrating ripe females (Moyle 1976, Painter et al. 1980). The ratio of males to females was found on the Yuba River to be 1:1 during the first half of the season and over 3:1 during the last half of the season (Jones & Stokes Associates 1990). Most migrating shad are 3-year-old males and 4-year-old females ranging in size from 12 to 30 inches (Wixom 1981). Approximately 70% of the shad run in central California are fish that are spawning for the first time (i.e., virgin spawners) (Painter et al. 1980).

Adult American shad initiate their spawning migration as early as February; however, most adults do not migrate into the Delta until March or early April (Skinner 1962). Studies suggest that adults require 2-3 days to adapt to fresh water (Stier and Crance 1985). Typically, most migrating adults need 3 months (March-May) to pass through the Sacramento-San Joaquin estuary (Painter et al. 1980). The exact timing of shad migration appears to be regulated by water temperatures in the ocean and natal rivers. Typically, adult shad do not enter fresh water until water temperatures approach 52°F.

Peak spawning migration into spawning habitats takes place when water temperatures are much higher (59-68°F), usually in late May or early June (Moyle 1976). During studies in the western Delta (1976-1977), DFG tagged the most migrating shad when water temperatures were between 57 and 66°F (Painter et al. 1980). Despite the importance of temperature, studies on both the Feather River (Painter et al. 1977, 1980) and the Yuba River (Jones & Stokes Associates 1990) suggest that increased flows, not water temperatures, were the primary factors responsible for attracting shad into these streams. Migration appears to decline after water temperatures exceed 68°F, usually in early July (Moyle 1976). Peak migration in the Sacramento River upstream of the Feather River occurs in May, and angling surveys indicate that peak migration in the Feather and Yuba rivers occurs during June (Stevens 1972, Jones & Stokes Associates 1990).

American shad spawn exclusively in freshwater, although spawning may be possible in brackish water (Wang 1986). There does not appear to be a specific distance upstream of brackish water required for spawning to occur (Painter et al. 1980). American shad spawn in the main channels of the Sacramento River from Red Bluff downstream to Hood; the American, Feather and Yuba rivers; the lower reaches of the San Joaquin River; and the Mokelumne and Stanislaus rivers (Wang 1986). It unknown if shad return to their natal rivers to spawn.

Spawning can occur at any time of day but usually takes place at night as a mass affair, often among small schools. Spawning is initiated when a male swims alongside a female and the two adults swim rapidly side by side. The males fertilize the eggs as the female releases them into the water column. Each fish spawns repeatedly and some survive the spawn and return the following year after emigrating to the ocean. Postspawning adults emigrate through the Delta and Suisun Bay as late as August and September. Spawning mortality appears to be greater at higher water temperatures, especially above 68^{o}F (Moyle 1976).

Unlike shad on the Atlantic Coast, adult shad in the Delta feed while in fresh water, probably because of the abundance of large zooplankters. However, not all adult shad feed while in the Delta, and most feeding ceases once they enter the main rivers (Moyle 1976). While in the Delta, adult shad feed primarily on opossum shrimp (*Neomysis mercedis*), followed by copepods, cladocerans, and amphipods (*Corophium* sp.) (Moyle 1976). The presence of these zooplankters in shad stomachs appears to be directly related to zooplankton concentrations in the Delta (Stevens 1966). On occasion, adult shad have been known to prey on clams and fish larvae.

Incubation - American shad eggs are slightly heavier than water and are suspended in the water column by the slightest current. Although shad eggs can be found throughout the water column, the greatest concentration appears to be near the river bottom. The eggs drift with the current and hatch in 3-6 days at water temperatures of 52 to 79^{o}F (Stevens 1972). Although hatching occurs sooner at higher water temperatures, egg survival is reduced.

Rearing - Larval shad range from .23 to .40 inch long at hatching and grow rapidly, tripling their length in the first month. Larval stages last approximately 30-40 days, and the young shad have developed adult features and are classified as juveniles when they grow to .96-1.12 inches long (Painter et al. 1980). The newly hatched larvae are pelagic (i.e., they inhabit open water), are most abundant at the water surface, and feed on zooplankton within 4-5 days of hatching (Painter et al. 1980, Wang 1986). Larval shad initially prey predominantly on cladocerans but increasingly feed on ostracods, insects, insect larvae, and copepods as they grow. Shad larvae usually consume food items that are most readily available (Painter et al. 1980). Newly hatched larvae are found downstream of spawning areas and can be rapidly transported downstream by river currents because of their small size.

Season-long rearing of juvenile shad occurs in the Mokelumne River near the Delta Cross Channel to the San Joaquin River, the lower Sacramento River below Knights Landing, the Feather River below Yuba City, and the Delta. No rearing occurs in the American and Yuba rivers. (Painter et al. 1980.)

Some juvenile shad appear to rear in the Delta for up to a year or more before emigrating to the ocean. While in the Delta, juvenile shad are opportunistic feeders and prey on *Neomysis* sp., copepods, amphipods, chironomid midge larvae, and surface insects (Moyle 1976). Depending on water temperature and food availability, young-of-year (YOY) shad in the Delta are an average length of 1.2 inches in July, 3.24 inches in September, and 4.56 inches in November (Stevens 1972). By the time they enter saltwater, shad range in size from 3.2 to 7.2 inches long.

Downstream migration - Presumably, all juvenile shad eventually emigrate to the ocean because immature shad greater than 8 inches long are rarely caught in the Delta (Moyle 1976). Most shad enter saltwater when they are between 80 and 7.2 inches long. Seaward migration of juvenile shad in the Delta begins in late June and continues through November, with peak migration occurring between September and November (Stevens 1972, Painter et al. 1980).

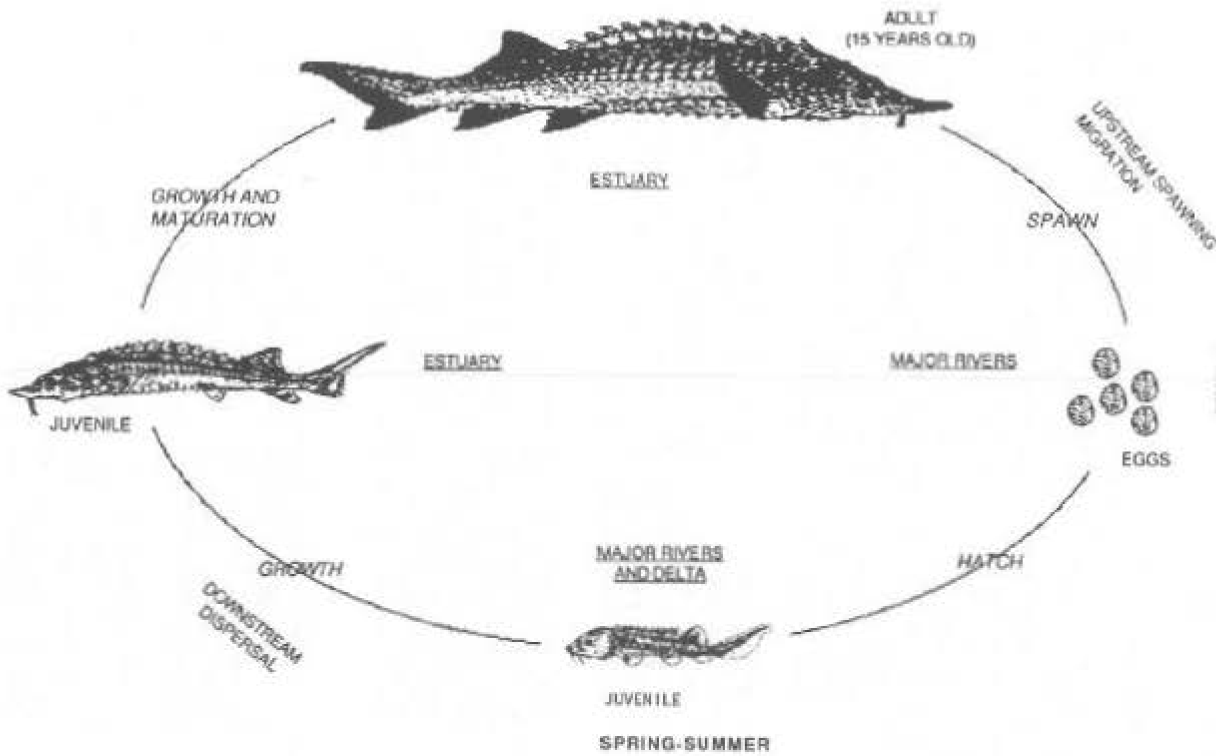
Ocean life - Little is known about the oceanic ecology and behavior of juvenile and adult American shad. As stated earlier, shad are found in the Pacific Ocean from Baja California to Alaska; however, they are seldom found south of Monterey, California (Fry 1973). Their wide distribution along the Pacific Coast suggests that shad in the Pacific Ocean may exhibit migrational patterns similar to those of Atlantic Ocean shad (Moyle 1976, Painter et al. 1980).

White Sturgeon

White sturgeon are the largest freshwater or anadromous fish species in North America, reaching weights in excess of 1,300 pounds. Historically, white sturgeon populations ranged from Alaska to central California (Scott and Crossman 1973). However, major spawning populations are now limited to the Fraser (British Columbia, Canada) and Columbia (Oregon) rivers and the Sacramento-San Joaquin River system.

Compared to salmon and steelhead, less is known about sturgeon life history. This is due in part to limited scientific investigations and to variances in life history between and within populations. To overcome these deficiencies in Central Valley sturgeon, life history is augmented with information from other northeast Pacific population. White sturgeon life history is summarized in Figure 2-VI-12.

Upstream migration - Each year, a portion of the adult population moves upriver from the San Francisco and San Pablo bays, the estuary, and the Delta to spawn. Data from the Sacramento River indicate that sturgeon start migrating into the river in October and spawn as early as February (Schaffter pers. comm.). Most spawning in the Central Valley occurs during March through May, and approximately 20-30% of the sturgeon spawn in February and June (Doroshov pers. comm.). Studies conducted by DFG indicate most spawning occurs between Knights Landing (river mile [RM] 85) and Princeton (RM 164), with primary



LIFE HISTORY OF WHITE STURGEON
FIGURE 2-VI-12

spawning areas near Colusa (RM 144). Juvenile sturgeon have been found as far upriver as the Glenn-Colusa Canal near Hamilton City, indicating that some sturgeon may migrate farther upriver (Kohlhorst 1976). Some spawning may also occur as far upstream as the Red Bluff Diversion Dam (RBDD) (RM 243), as indicated by larval and juvenile entrainment noted there (Brown pers. comm.).

Tag recoveries and catches in the sport fishery indicate that some adult sturgeon also migrate into the San Joaquin River. Adult sturgeon are caught in the sport fishery between Mossdale and the mouth of the Merced River in late winter and early spring, which suggests this is a spawning run (Kohlhorst 1976). Based on the ratio of tags recovered, Kohlhorst et al. (1991) estimated that approximately 10% of the Sacramento-San Joaquin River system spawning population migrates up the San Joaquin River. However, no studies have been conducted to definitively determine whether and where sturgeon spawn in the San Joaquin River.

Evidence also suggests that sturgeon reproduction occurs in both the Feather and Bear rivers. Adult sturgeon migrated into the Feather River historically and in more recent times. Several articles recount large sturgeon caught in the Feather River in the early 1900s (Talbitzer 1959, Anonymous 1918). More recent accounts include recovery of one tagged adult sturgeon in April 1968 (Miller 1972a). Green sturgeon were caught every year during the mid-1970s to early 1980s (Anonymous pers. comm.). Most catches occurred between March and May, with occasional catches in July and August. During spring 1991, two radio-tagged adult sturgeon were tracked 6.4 miles up the Feather River. Subsequent efforts to relocate these fish were unsuccessful (Schaffter 1991). Finally, during spring 1993, several adult green sturgeon (of lengths from 60.8 to 73.2 inches) were caught at Thermalito Afterbay outlet (Foley pers. comm.). Green and white sturgeon are also known to enter the Bear River typically during the spring of most wet and some normal water years (Lenihan and Myers pers. comms.). Adult sturgeon were observed in shallow pools between the Highways 70 and 65 bridges during spring 1989, 1990, and 1992 (Lenihan pers. comm.).

During July 1989, approximately 100 sturgeon were trapped in pools between the Highways 70 and 65 bridges as a result of reduced flows (Myers pers. comm.). At least 30-40 sturgeon (weighing from 60 to 100 pounds and at least 5 feet long) were poached from this area during a 2-week period in July. Of the seven sturgeon confiscated by DFG game wardens, all were white sturgeon. Though no spawning or presence of larvae or juveniles has been documented, reproduction is believed to occur in the Feather and Bear rivers because of the presence of adults.

Upstream migration is probably triggered by both endogenous (i.e., sexual maturation) and abiotic (i.e., temperature, flow, and photoperiod) factors, although these factors are not well understood. Mature fish may be stimulated to migrate upstream by cues triggering the final stages of gonadal development, which may include flow velocity, photoperiod (i.e., the number of daylight hours best suited to the growth and maturation of an organism), or temperature (Pacific States Marine Fisheries Commission 1992). The speed of instream movement of radio-tagged white sturgeon in the Sacramento River was as high as 15 mile per day and was often stimulated by small increases in river flow (Schaffter 1991).

Spawning - Sturgeon spawn in the Sacramento River between mid-February and late May, with a peak in spawning (93%) occurring between March and April (Kohlhorst 1976). Not all adults migrate upstream to spawn each year. Sexual cycles in sturgeon are complex because these fish mature at a late age and adults do not spawn every year. It is likely that mature sturgeon migrate upriver to spawn and most immature fish or fish in resting stages remain in the estuary.

Chapman (1989) studied sexual maturation in 836 white sturgeon collected over several years from the Delta. The sex ratio in the overall population was approximately 1:1. The ratio of mature males to mature females was 2:1. The size range of adult sturgeon was bimodal, with the average length of males (52 inches) smaller than that of females (57 inches). Fish less than 35 inches showed no gonadal development. There were no fish less than 39 inches with mature gonads. Of the fish studied, 44% were immature or in a resting phase of gonadal development, 31% showed active egg and sperm development, and 28% contained mature gonads. The youngest mature fish were a 12-year-old male and a 14-year-old female. A higher percentage of the males (37%) were ripe than were females (15%).

Fecundity and periodicity of spawning of female sturgeon appear to depend on female age or size (Pacific States Marine Fisheries Commission 1992). Depending on age and size, mature female sturgeon may carry 0.1 million to 7 million eggs, representing 7-30% of a female's weight. Recent analyses of sturgeon in the Sacramento-San Joaquin River suggest that females spawn every 4 years and males spawn in alternate years (Kohlhorst pers. comm.). Females also appear to have the ability to reabsorb eggs and forego spawning under unfavorable environmental conditions. Sturgeon stocks outside of the Central Valley are known to spawn in streams with gravel or rock bottoms, moderate to fast currents (Dees 1961, Nikolskii 1961), and depths exceeding 9 feet (Galbreath 1979, Doroshov 1985). Spawning habitat requirements for white sturgeon in the Sacramento-San Joaquin River system have not been definitively identified.

Few observations of wild sturgeon spawning have been reported. Apparently sturgeon broadcast spawn in swift water. It is unknown if eggs are fertilized while they are in the water column or after they contact the bottom. The current initially disperses the adhesive eggs, which sink and adhere to gravel and rock. Adhesive eggs allow spawning and retention of eggs within swift current environments.

Incubation - Incubation and emergence of white sturgeon have been studied under laboratory conditions to determine protocols for hatchery rearing. Egg incubation can last 4-14 days after fertilization; yolk depletion can occur 15-30 days after fertilization (Wang et al. 1985, Conte et al. 1988). Hatching time depends on water temperature. Temperatures between 10 and 17 °C (52-63 °F) are considered optimum for spawning, incubation, and development (Pacific States Marine Fisheries Commission 1992). The most sensitive stage in development is the first 24 hours after fertilization.

Rearing - Nursery areas for juvenile white sturgeon extend downriver from spawning areas to the Delta. Distribution of juvenile white sturgeon within the Sacramento River system is determined by river flow. Larvae are distributed farther downriver during wet years and remain further upstream during drier years

(Stevens and Miller 1970, Kohlhorst 1976). Eggs and larvae have been collected primarily near Colusa, Knights Landing, and the mouth of the Feather River; however, YOY white sturgeon have been found as far upstream as Hamilton City (Stevens and Miller 1970, Kohlhorst 1976). Larvae and YOY fish have been found in the Delta between Collinsville and Rio Vista and as far downriver as Suisun Bay (Radtke 1966, Stevens and Miller 1970).

Laboratory studies indicate that larval white sturgeon demonstrate three behavioral phases after emergence: swim-up and dispersal, hiding, and feeding (Brannon et al. 1986, Brewer 1987, Duke et al. 1990, Miller et al. 1991). After hatching, yolk sac larvae swim up into the water column where currents disperse them downstream of spawning areas. Larvae swim toward or to the surface, then passively sink to the bottom (Brewer 1987). Immediately or shortly after touching bottom, the larvae repeat the swimming activity. The duration of this phase varies, lasting from 1 to 5 days (Brewer 1987). However, Brewer (1987) indicated larvae initiated the hiding phase more rapidly at higher flow velocities (0.3 feet per second [fps]).

When larvae enter the hiding phase, they are still nourished from the yolk sac. To hide, larvae place their heads within substrates (either rock or vegetation) and maintain a constant tail beat to maintain their position. During this phase, larvae exhibit negative phototaxis (movement away from light), seeking dark substrates. This hiding behavior is thought to provide protection from predation as the larvae develop (Brewer 1987). Despite this behavior, larvae between .32 and .88 inch still drift downstream with the current if they are caught in stationary nets (Kohlhorst pers. comm.).

Larvae develop mouth and olfactory organs needed for feeding before the yolk sac is completely absorbed. Although feeding can occur during the hiding phase if food is present at the hiding site (Brewer 1987), exogenous feeding does not occur until 12 days after hatching at temperatures of 63^{o}F (17^{o}C) (Buddington and Doroshov 1984). During the feeding phase, larvae move from hiding to active food forage. Young sturgeon appear to be opportunistic feeders, using both olfactory and chemoreception to locate food items. No field studies have been conducted to determine wild sturgeon larvae diet. However, periphyton and/or benthos probably dominate larval sturgeon diet (Brannon et al. 1984).

Sturgeon diet becomes more diverse as the fish become larger. YOY sturgeon (<8 inches long) feed on small crustaceans, insect larvae, and potentially small fish. The most common prey of juvenile sturgeon in the Sacramento-San Joaquin River system were amphipods (Schreiber 1962).

Sturgeon continue to be opportunistic feeders as adults. Adult sturgeon caught in San Pablo and Suisun bays fed primarily on benthic invertebrates (i.e. clams, barnacles, crab, and shrimp) (McKechnie and Fenner 1971). Seasonally, herring eggs and small fish (i.e., striped bass, flounder, goby, and herring) are important prey items. Although numerous in the estuary, worms, such as polycheates and nematodes, were seldom consumed.

Downstream, estuarine, and ocean migration - There is no defined age or size at which juvenile sturgeon from anadromous populations enter the estuarine environment (Binkowski and Doroshov 1985). In the

Central Valley, the older and larger a sturgeon is the greater its chance of inhabiting estuarine or marine environments (Kohlhorst pers. comm.).

Both adult and subadult sturgeon inhabit Suisun, San Pablo, and San Francisco bays and the Delta year-round (Miller 1972b, Shirley 1987, Kohlhorst et al. 1991). Delta distribution is thought to depend primarily on river flow and consequent salinity.

Shirley (1987) studied the age structure of adult sturgeon in the estuary and found differences in age structure of fish from different regions of the estuary. Relatively young fish were captured from Suisun and Grizzly bays and near Candlestick Park in San Francisco Bay, while older fish were caught in Carquinez Strait, San Pablo Bay, and near Tiburon. Sturgeon captured near Tiburon (close to the mouth of San Francisco Bay) had a significantly older age structure. Very few sturgeon (four) older than 20 years were caught at locations other than Tiburon. At Tiburon, 34 fish were older than 20 years, with the oldest fish estimated to be 27 years old. Age structures of all groups had peaks in the age distribution between 11 and 15 years old.

Some coastal migrations have been noted for adult sturgeon. Tagged white sturgeon, landed by commercial fishing near Bristol Bay in southwest Alaska, originated in the Columbia River in 1983 2,000 miles away. However, these represent less than 1% of total recoveries of tagged white sturgeon. White sturgeon tagged in the Sacramento-San Joaquin River system were captured in Oregon estuaries (Yaquina and Umpqua rivers and Tillamook Bay) and in Washington (the Columbia, Chehalis, and Willapa rivers) (Chadwick 1959, Kohlhorst et al. 1991). Tag recoveries of Sacramento-San Joaquin River sturgeon in distant coastal systems from recent tagging studies may be related to drought conditions, which have persisted between 1987 and 1992 (Kohlhorst pers. comm. cited in Pacific States Marine Fisheries Commission 1992).

Green Sturgeon

Little is known about green sturgeon life history. Brief summaries are found in Moyle (1976) and Kohlhorst et al. (1991).

Green sturgeon are smaller than white sturgeon, reaching average weights of 350 pounds and lengths of 7 feet. Green sturgeon are relatively short lived, reaching a maximum of 40 years.

In California, green sturgeon are found in the lower reaches of the Sacramento-San Joaquin River basin and the Eel, Mad, Klamath, and Smith rivers. Currently, green sturgeon seem to be the most common sturgeon in the Klamath and Trinity rivers (Moyle 1976), but it is only a minor component of the Central Valley populations. Green to white sturgeon ratios in the Delta have ranged from 1:39 to 1:164 (Mills and Fisher 1993) (Table 2-VI-1).

Table 2-VI-1. Annual estimates of adult white and green sturgeon in the Central Valley (1967-1991)

Year	Sturgeon abundance	Years abundance estimated	Ratio of white to green sturgeon	Green sturgeon abundance
1967	14,700	X	62.0:1	1,850
1968	40,000	X	38.6:1	1,040
1969	36,783			900
1970	33,567			760
1971	30,350			620
1972	27,133			480
1973	23,917			340
1974	20,700	X	101.9:1	200
1975	31,460			444
1976	42,220			688
1977	52,980			932
1978	63,740			1,176
1979	74,500	X	52.6:1	1,420
1980	83,120			1,378
1981	91,740			1,336
1982	100,360			1,294
1983	108,980			1,252
1984	117,600	X	106.3:1	1,210
1985	107,700	X	127.3:1	760
1986	96,850			635
1987	86,000	X	163.7:1	510
1988	66,267			520
1989	46,553			530
1990	26,800	X	49.7:1	540
1991	--			--
Average	63,501			867

Source: Mills and Fisher 1993.

Upstream migration - Virtually no information is available for upstream migration of green sturgeon in the Sacramento-San Joaquin system. On March 7, 1991, a male green sturgeon, 73.6 inches long, was caught, radiotagged, and released into the Sacramento River between Courtland (RM 34.8) and Freeport (RM 46). It was last located on March 13, 1991, near the mouth of the Feather River (RM 67.1) (Kohlhorst pers. comm.). Seven adult green sturgeon were caught by fishers during spring 1993 at the Thermalito Afterbay Outlet in the Feather River. Sizes ranged from 60.9 to more than 73.2 inches.

During April and May 199l, several adult green sturgeon were observed in the Sacramento River within a 10-mile stretch below the RBDD (Brown pers. comm.). A dead adult green sturgeon was recovered on April 18, 1991. A combined total of 18 sightings were made at Patterson riffle (RM 144.5), Ohm Riffle (RM 145.4), lower Todd Riffle (RM 236), and upper Todd Riffle (RM 147.9). Additional sightings were made in 1992 (Brown pers. comm.).

The extent of inland migrations in the Sacramento system is unclear, but landlocked populations of the sturgeon are currently unknown. There are no records of green sturgeon from Lake Shasta or Lake Oroville. However, anecdotal information suggests that sturgeon have been seen jumping and breaching in Lake Oroville (Hodges pers. comm.). The theoretical limit to upstream migration in the mainstem Sacramento River is Keswick Dam. Passage above the RBDD is possible, but only when the gates are raised. The theoretical limit to upstream migration in the Feather River is the Fish Barrier Dam. Shanghai and Sunshine Pumps may be migrational impediments under certain conditions.

Data on the upstream migration of green sturgeon in the Klamath Basin have been collected by the U.S. Fish and Wildlife Service (USFWS) from 1981 to 1994. At this latitude (41^{o} 34'N), it appears that mature green sturgeon begin entering the Klamath River as early as March. However, native fishing effort is usually decreased during winter and early migrants may have been missed. Most spawners move upstream from April through June, with some ripe fish having been seen into July. A few fish may enter the river during fall, overwinter in the system, and spawn the following spring, but this remains to be proven.

The effects of environmental cues on sturgeon migrations are not understood. In general, a positive correlation exists between increasing flow, increasing photoperiod, increasing temperatures, and upstream migration. Increasing water temperature is generally associated with upstream migration. Surface temperatures for the Klamath River at Cappell Creek (RM 33.2) were taken intermittently during the 1990 spawning run. A surface temperature of 6.9^{o}C was recorded on March 13, and sturgeon were absent from the local native fishery. By March 24, surface temperatures had increased to 10^{o}C-11^{o}C and natives began taking spawning migrants. Sturgeon continued to be caught into April, but, by the end of the month, the number taken throughout the lower 43.5 miles had decreased. Surface temperatures were near 16^{o}C.

In 1987, Artyukhin and Andronov (1990) collected six spawning migrants from the estuary of the Tumnin River, Russia. Six additional migrants were captured in 1991 (Artyukhin and Andronov 1994). Collections were made from late May through early July as water temperatures varied from 7.2 °C to 11.5 °C.

Parasitological evidence indicates that some green sturgeon rapidly travel upstream after leaving the marine environment. The external marine trematodes *Paradiclybothrium pacificum* and *Nitzschta quadritestes* were collected from a green sturgeon at RM 43.5 in the Klamath River. These parasites would be expected to drop off their host shortly after entering fresh water, but the exact timing is unknown.

Spawning - Distinct sexual characteristics are generally absent, but male and female sturgeon can be distinguished in the final stages before spawning (Dadswell et al. 1984). The time to reach sexual maturation is variable and can range from 10 to 30 years in wild populations (Doroshov 1994). In culture, the onset of puberty occurs at a younger age, and evidence suggests that gonadal development depends more on size than on age (Conte et al. 1988). Chapman (1989) hypothesized that poor nutrition may delay the onset of puberty. Males generally reach sexual maturation at a smaller size and younger age than females. Gonads in both sexes are bilateral. Mature ovaries are proportionately larger than mature testes. Female sturgeon are gymnoovarian; in some species, fecundity may reach over 1,000,000 eggs.

Almost all Acipenserids spawn in spring and summer (Detlaff et al. 1993). Only l-20% of an indigenous adult population will participate in a typical spawning run (Conte et al. 1988). Spawning individuals vary in size and represent several different age classes. Detlaff et al. (1993) characterized Acipenserid spawning areas as having swift currents and dense substrates. Males typically outnumber females on the spawning grounds. Fertilization is external and parental care is lacking. Sturgeon may live to an advanced age (Moyle and Cech 1982).

Although most green sturgeon spawn in spring, it has been suggested that some individuals may spawn in winter. However, there are no confirmed observations of green sturgeon spawning activity. Moyle (1976) suggested that leaping and other frantic behavior may be indicative of spawning or courtship. Newly spawned adhesive eggs from white sturgeon were collected in conjunction with observations of breaching fish (Underwood and Beckman 1989). Spawning habits are currently unknown.

Evidence suggests that green and white sturgeon are reproductively isolated, even in basins in which both species are known to spawn. Wild hybrids are not currently recognized, but hybridization is theoretically possible. A California aquaculturist in the 1980s allegedly produced hybrid green sturgeon x white sturgeon by using milt from a green sturgeon and eggs from a white sturgeon. All progeny were subsequently destroyed by DFG.

Green sturgeon eggs are relatively large. Tracy (1990) indicated eggs are about 0.15 inch in diameter. In 1990, 30 eggs from a migrating Klamath River female collected at RM 41.3 were examined. Sizes ranged from 0.15 to 0.16 inch. Shape was ovoid and slightly pointed. The basic color was olive-gray with some mottling. The animal pole was lighter compared to the vegetal pole. Germinal vesicles were located near the animal pole, estimated to be in position 4 or 5 described by Lutes et al. (1987).

Specific information on spawning of green sturgeon in the Sacramento-San Joaquin system is limited. Kohlhorst (1976) found sturgeon eggs and larvae in the Sacramento River from mid-February through late May, but specific identifications were not made.

Klamath Basin green sturgeon were initially thought to enter the spawning population at age 16 or older (USFWS 1982, 1983). More recent investigations, however, have suggested that this may be an overestimate and males may enter the spawning population as early as 8 years of age (Kisanuki pers. comm.). Females appear to be slightly older before they enter the spawning population, and their sexual maturation may not occur until age 13 (Kisanuki pers. comm.).

Incubation - No information is available on green sturgeon egg incubation.

Rearing - No information is available on green sturgeon rearing.

Downstream, estuarine, and ocean migration - Juveniles inhabit the estuary until they are about 4-6 years old, when they migrate to the ocean (Kohlhorst et al. 1991). Green sturgeon can make extensive ocean migrations. Green sturgeon tagged in San Pablo Bay have been recovered in rivers and estuaries in Oregon and Washington. Juvenile fish have been collected in the Sacramento River, near Hamilton City, and in the Delta and San Francisco Bay. Adults have been observed near RBDD in late winter and early spring.

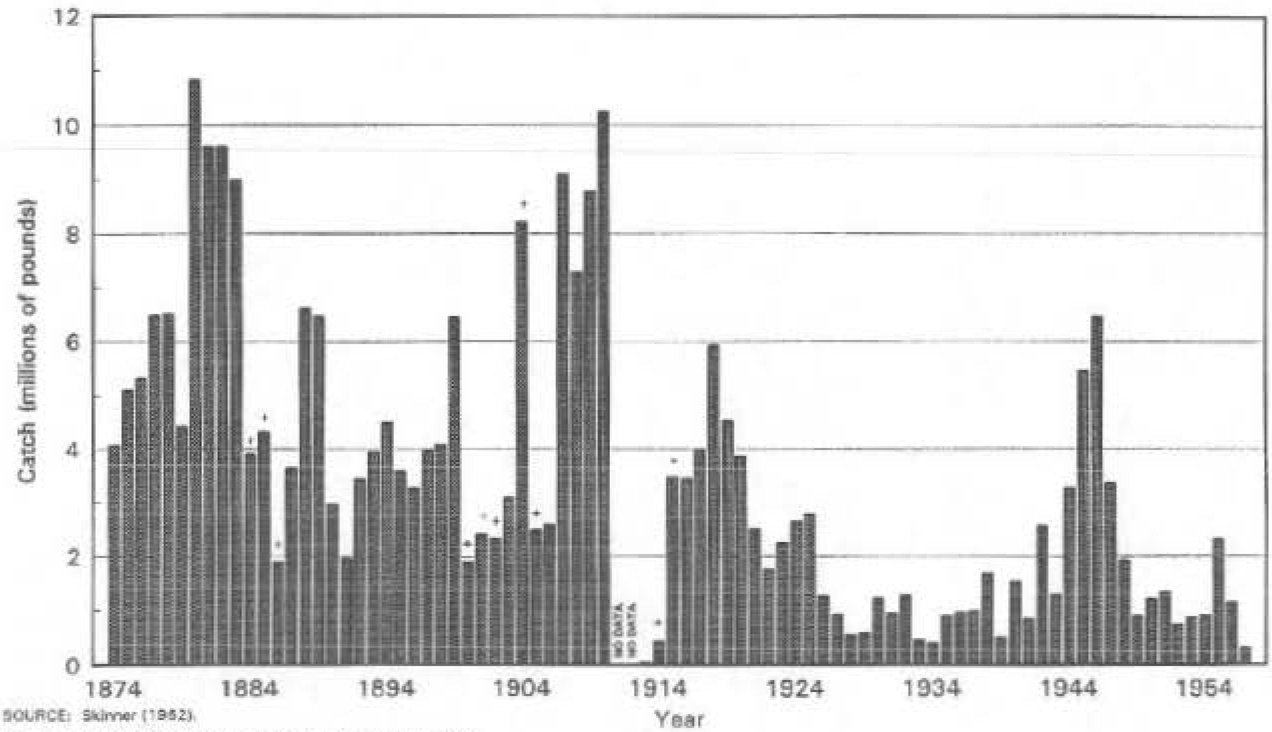
The diet of adult green sturgeon appears to be similar to that of white sturgeon: bottom invertebrates and small fish (Ganssle 1966). Juveniles in the Delta feed on opossum shrimp and amphipods, such as *Corophium* (Radtke 1966). Little information is available about green sturgeon age and growth; in the Delta they seldom exceed 4 feet in length (Skinner 1962, Moyle 1976).

ABUNDANCE AND DISTRIBUTION (PRE-1967)

Chinook Salmon

Early trends in Central Valley chinook salmon populations were indirectly monitored by commercial catch records dating back to 1874 when complete records of commercial gill net landings were first available. These records are of limited use in determining population trends for specific streams or runs but provide an indicator of major trends in the abundance of Central Valley chinook salmon.

Early accounts indicate that the commercial salmon fishery in California began around 1850. The Gold Rush and the ensuing human population growth in California led to rapid expansion of the fishery. Hydraulic



SOURCE: Skinner (1962).

NOTE: Gillnet fishery discontinued by legislative action in 1957.

+ Indicates that total pounds in that year are based on recorded pack of canned salmon only.

SACRAMENTO-SAN JOAQUIN RIVER COMMERCIAL GILLNET SALMON LANDINGS (1874-1957)

FIGURE 2-VI-13

gold mining, logging, agricultural, and grazing activities also increased rapidly, leading to the first major human impacts on stream habitat and fish populations in the Sacramento River basin (Buer et al. 1984). Later, construction of agricultural, power generation, and debris dams accelerated declines in chinook salmon populations by preventing access to historical spawning and rearing habitat or substantially reducing the amount of available habitat (Clark 1929).

Between 1874 and 1910, total gill net landings fluctuated between 2 million and 11 million pounds and averaged about 6 million pounds. A distinct downward trend in gill net landings after 1910 led to a period of extremely poor catches between 1926 and 1943, in which annual yields ranged from 0.4 to 2.5 million pounds per year and averaged approximately 1 million pounds per year (Skinner 1962) (Figure 2-VI-13). This decline coincided with a decline in the number of adult salmon returning to hatchery facilities in the Sacramento River between 1915 and 1924 (Clark 1929). The California ocean troll fishery, the dominant commercial salmon fishery by 1916, also had catches reduced from about 6 million pounds per year before 1920 to an average of about 4 million pounds per year during the 1920s and 1930s, despite increasing effort. Clark concluded that the Sacramento-San Joaquin salmon fishery was in a "state of serious depletion" by 1929, citing overfishing, loss of spawning areas from dam construction, loss of young salmon in overflow basins, and losses to predatory fishes as principal causes. Following a brief increase to approximately 6.5 million pounds in 1946, annual gill net landings returned to an average of approximately 1 million pounds per year through the 1950s (Skinner 1962).

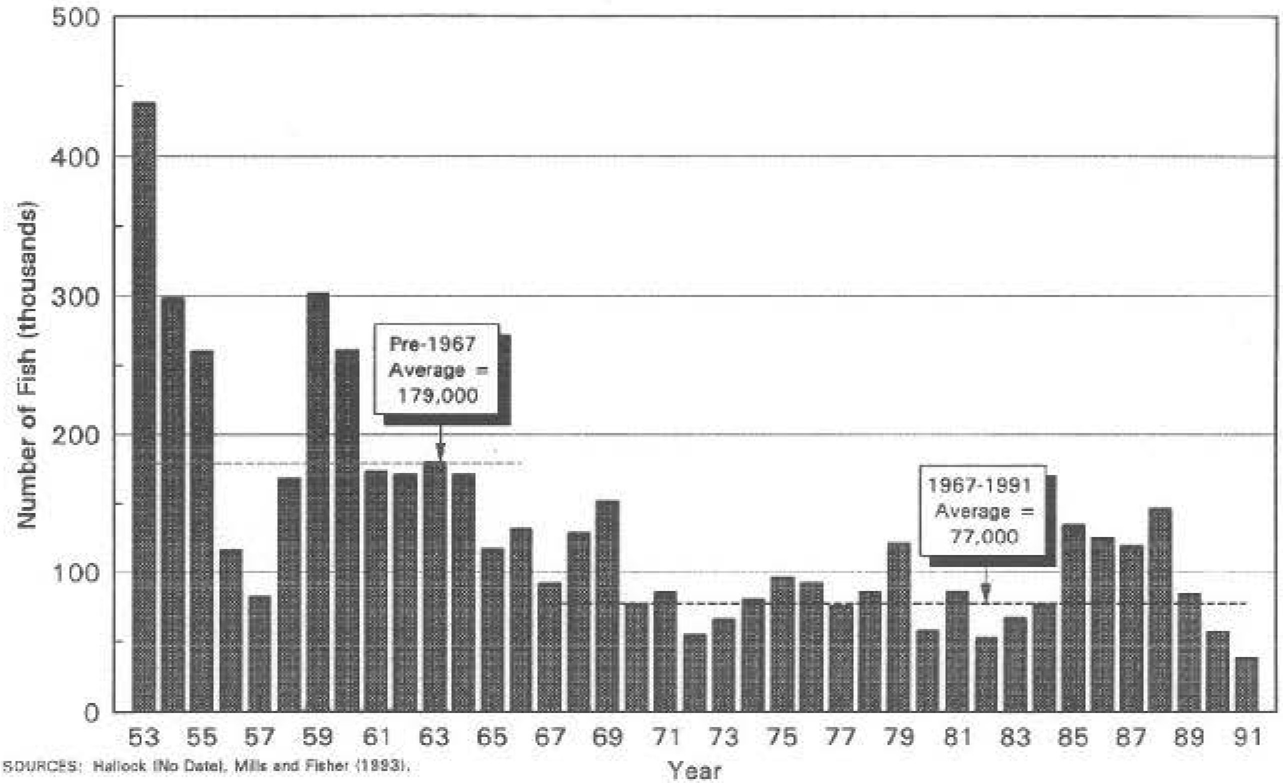
Four races of chinook salmon, recognized by the season of their upstream migration, are found in the Sacramento basin: fall-, late fall-, winter-, and spring-run chinook salmon.

Sacramento River -

Fall-run chinook salmon - Historically, fall-run chinook salmon were one of the more abundant salmon races in the Central Valley. Counts of adult salmon as they passed over the Anderson-Cottonwood Irrigation District Dam were obtained as early as 1937, but complete estimates of fall-run chinook salmon abundance in the Sacramento River and its major tributaries were not made until 1953 (Hallock n.d.). Annual estimates of spawning escapement (i.e., the total number of adult salmon [age 2 and older] that "escape" the fishery and return to spawn) in the mainstem Sacramento River reveal a gradual but steady decline during the 1950s and 1960s; annual run size declined from an average of 179,000 adults during 1953-1966 to an average of 77,000 adults during 1967-1991 (Figure 2-VI-14).

Late fall-run chinook salmon - Because of high flows and turbid conditions that generally prevail during the late fall-run chinook salmon spawning period, annual abundance estimates were possible only after construction of the RBDD and its associated fish counting facilities in 1967.

Winter-run chinook salmon - Before construction of Shasta and Keswick Dams in 1945 and 1950, respectively, winter-run chinook salmon were reported to spawn in the upper reaches of the Little Sacramento, McCloud, and lower Pit rivers (Moyle et al. 1989). Specific data relative to historical run



SOURCES: Hallock (No Date), Mills and Fisher (1993).

ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1953-1991)

FIGURE 2-VI-14

sizes prior to 1967 are sparse and mostly anecdotal. Slater (1963) is frequently cited to indicate that winter-run populations were small and limited to the McCloud River before construction of Shasta Dam. Recent DFG research in the California State Archives indicates that the winter-run chinook salmon population may have numbered over 200,000 (Rectenwald and Fox pers. comms.). Cold hypolimnetic releases from Shasta Reservoir enabled the run to spawn successfully in the Sacramento River below Keswick Dam. Under these favorable habitat conditions, the run was maintained at more than 80,000 adults by the mid 1960s (U.S. Bureau of Reclamation [USBR] 1986).

Spring-run chinook salmon - Historically, spring-run chinook salmon were one of the more abundant salmon races in the Central Valley. The principal holding and spawning areas were in the middle reaches of the San Joaquin, Feather, upper Sacramento, McCloud, and Pit rivers upstream of the present location of major dams. Smaller runs occurred in tributaries large and cold enough to support adults during the summer holding period.

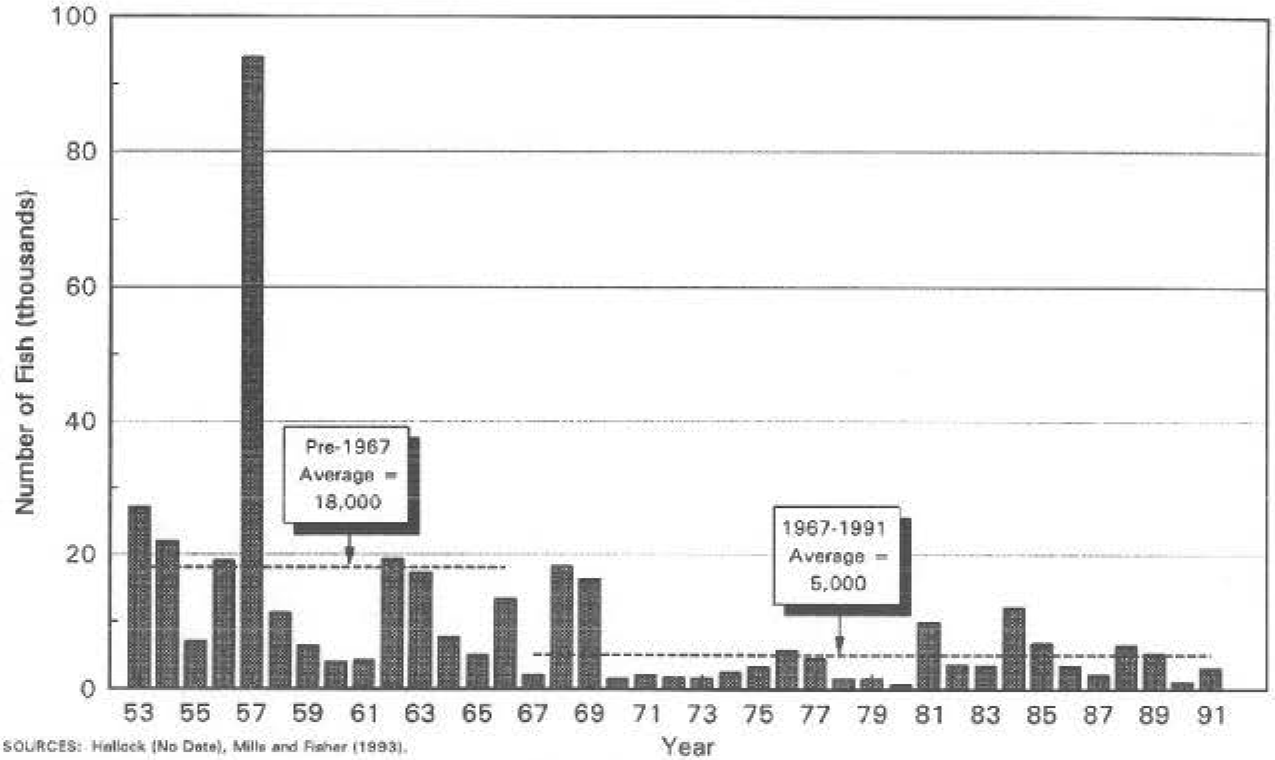
Gold mining, agricultural diversions, logging, and overharvest caused the first major declines in spring-run chinook populations. By 1930, agricultural and sediment control dams on tributary streams had caused severe declines and extirpation of tributary stocks by preventing spring-run adults from reaching critical summer holding and spawning habitat. Further extirpations occurred following the construction of major storage reservoirs on the Sacramento River and major tributaries in the 1940s and 1950s. By 1966, only remnant populations of spring-run chinook salmon were present below these dams.

Considerable overlap in spawning period with fall-run on the mainstem Sacramento River and major tributaries has probably resulted in significant introgression (i.e., loss of genetic purity) of spring-run stocks (Slater 1963).

Sacramento river tributaries - Fall-run chinook salmon runs in minor Sacramento River tributaries, including Clear Creek, Cow Creek, Cottonwood Creek, Antelope Creek, Mill Creek, and Deer Creek, were not regularly monitored, although declines in abundance are evident since 1953 (Figure 2-VI-15). Annual spawning escapement in Battle Creek during 1953-1966 exhibited a general decline similar to the pattern observed in the mainstem Sacramento River. Total run size averaged 17,000 adults, with an average 9,000 adults spawning in Battle Creek and 8,000 spawning in Coleman National Fish Hatchery (CNFH) (Figure 2-VI-16).

Genetically pure spring-run chinook stocks may occur only in two minor Sacramento River tributaries: Mill and Deer creeks.

Average annual run size in the American River averaged approximately 26,000 adults before construction of Folsom Dam and Nimbus Salmon and Steelhead Hatchery in 1955 (Fry 1961). By 1966, average run size, including river and hatchery spawners, had increased to approximately 39,000 adults. Average annual spawning escapement in the American River during 1953-1966 was approximately 30,000 adults; on average, 19,000 adults spawned in the river, while 11,000 were spawned in the hatchery (Figure 2-VI-17).

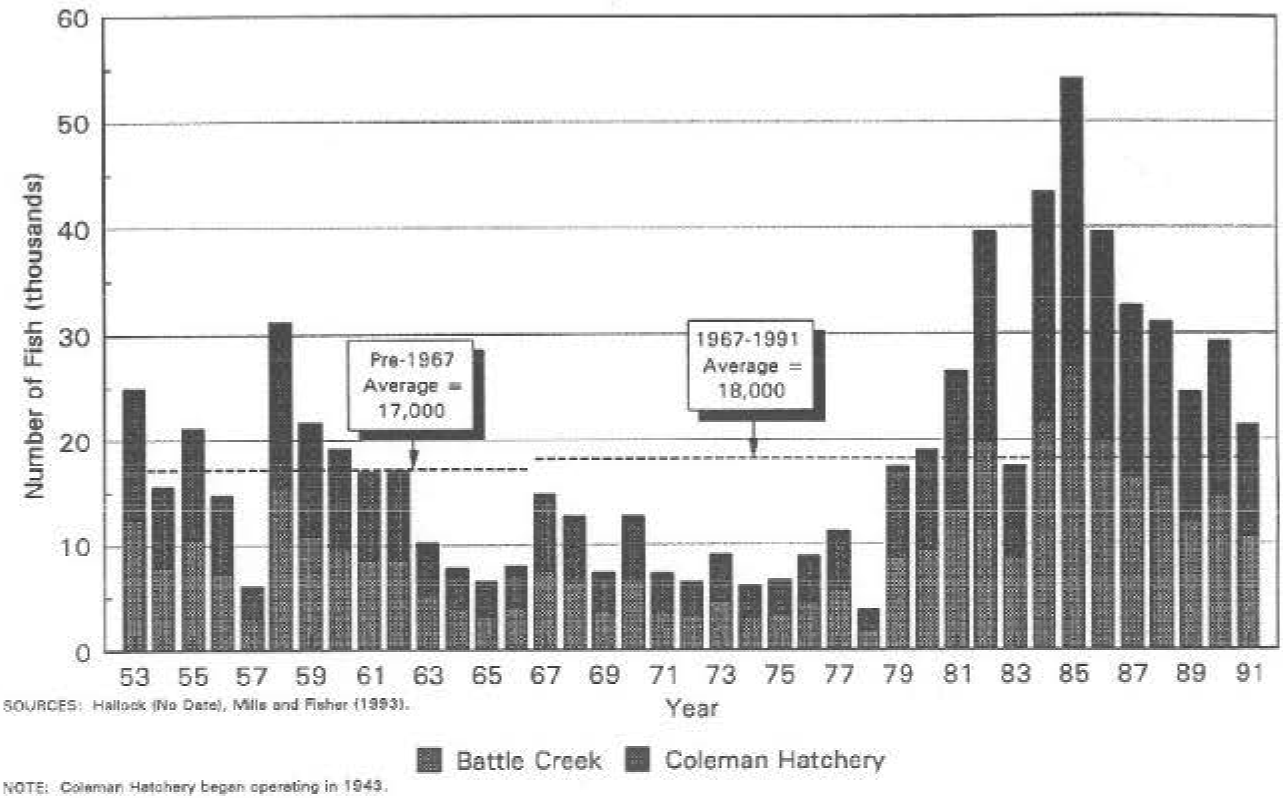


SOURCES: Hallock (No Date), Mills and Fisher (1993).

NOTE: Annual estimates are not strictly comparable because of inconsistent monitoring of tributary salmon runs.

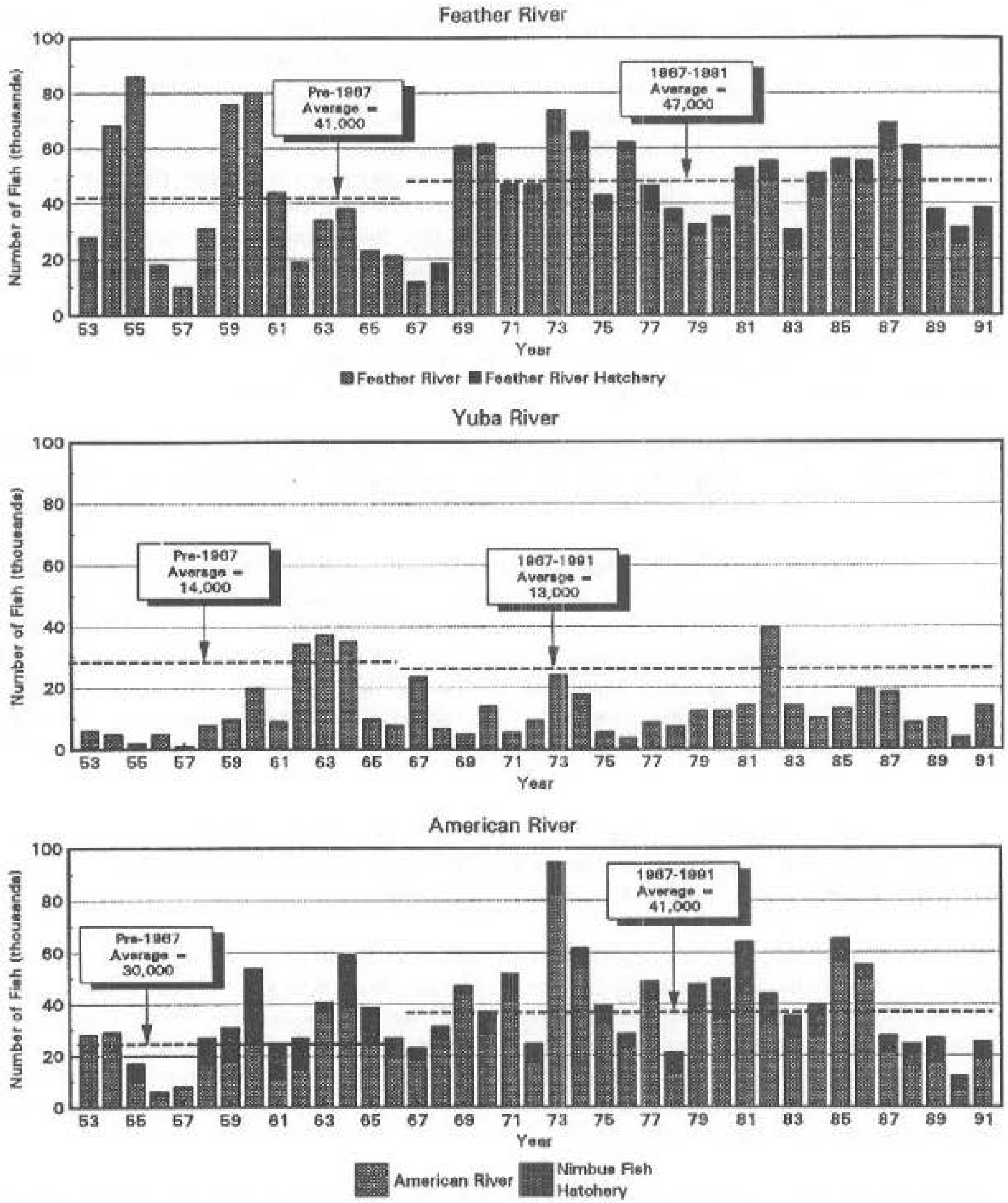
ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN MINOR SACRAMENTO RIVER TRIBUTARIES (1953-1991)

FIGURE 2-VI-15



ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN BATTLE CREEK AND COLEMAN NATIONAL FISH HATCHERY (1953-1991)

FIGURE 2-VI-16



SOURCES: Hallock (No Date), Mills and Fisher (1993).

ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE FEATHER, YUBA, AND AMERICAN RIVERS (1953-1991)

FIGURE 2-VI-17

Feather River basin - Fall-run chinook salmon in the major Sacramento River tributaries exhibited variable abundance patterns during the 1950s and 1960s. Between 1953 and 1966, annual spawning escapement in the Feather River fluctuated widely and averaged about 41,000 adults (Figure 2-VI-17). During this period, the Yuba River, a major tributary of the Feather River, underwent a marked increase in annual run size from an average level of 5,000 adults in the 1950s to a peak of 37,000 adults in 1963. Average annual spawning escapement in the Yuba River during 1953-1966 was approximately 14,000 adults (Figure 2-VI-17).

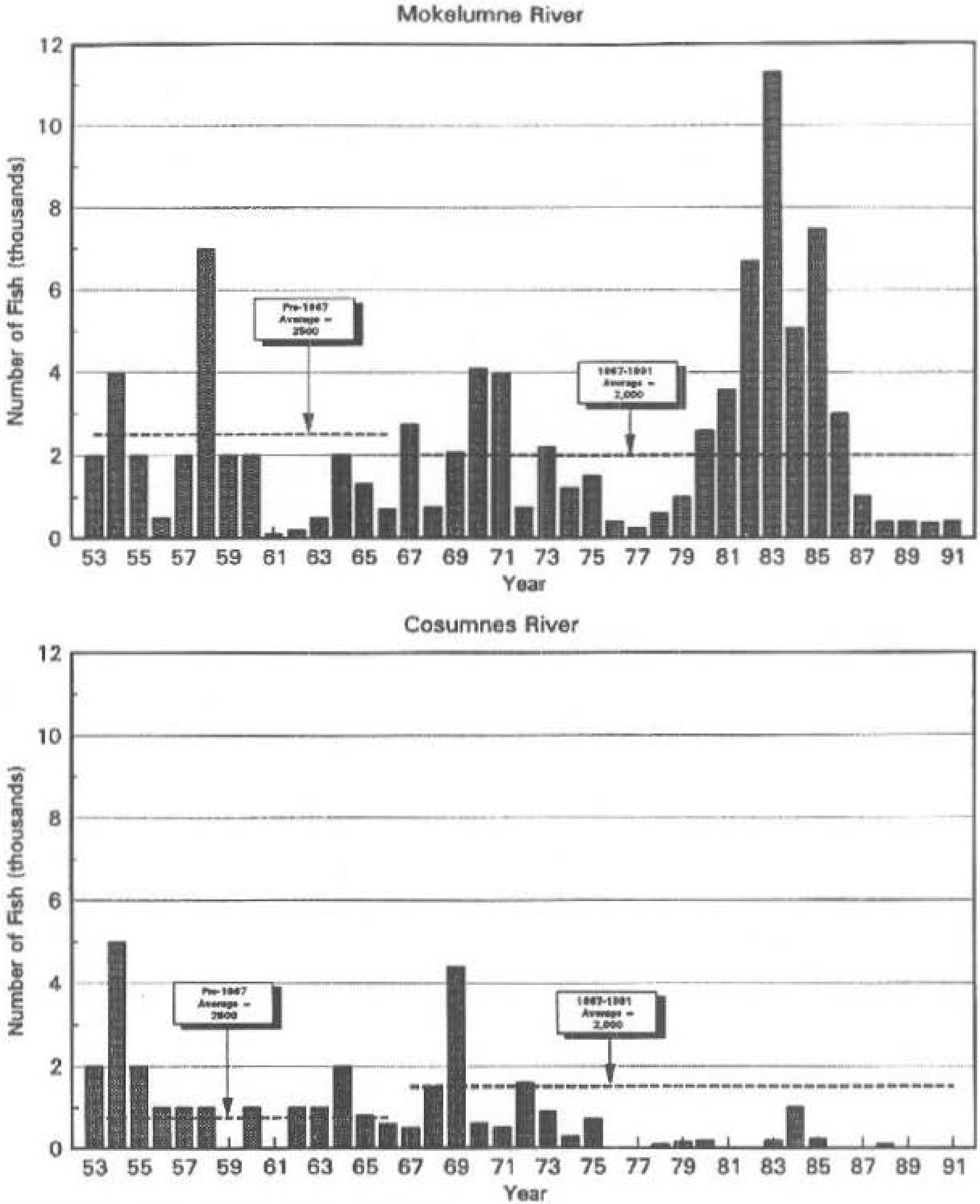
Eastside tributaries - The earliest records indicate that fall-run chinook salmon occurred in the Mokelumne, Cosumnes, and Calaveras rivers (Clark 1929). Spring-run chinook salmon were probably present in the Mokelumne River before the construction of Pardee Dam in 1929. Dams, poaching, and sedimentation caused by gold mining eliminated the spring-run chinook salmon in the Mokelumne River (Reynolds et al. 1990).

Declines in fall-run chinook salmon stocks probably paralleled declines occurring in major San Joaquin tributaries. Since the early 1900s, chinook salmon in the lower Mokelumne River were adversely affected by poor water quality associated with winery and mine wastes, fish losses at unscreened diversions, and migration barriers due to dams (DFG 1991). Runs up to 12,000 fish were recorded in the early 1940s. Since 1953, fall-run chinook salmon run size has varied considerably, with peak salmon abundance generally corresponding to similar peaks in the Stanislaus, Tuolumne, and Merced rivers. Annual spawning escapement fluctuated between 100 fish in 1961 and 7,000 fish in 1958 and averaged about 1,900 fish (Figure 2-VI-18). Mokelumne River Fish Hatchery was constructed in 1964 as mitigation for loss of spawning habitat between Camanche and Pardee Dam. The hatchery has received an average of about 500 chinook salmon adults between 1967 and 1991.

Between 1953 and 1966, annual fall-run chinook salmon spawning escapement in the Cosumnes River ranged from zero in 1961 to 5,000 fish in 1954 and averaged 2,500 fish (Figure 2-VI-18).

A small population of fall-run chinook salmon may have been present in the Calaveras River before the construction of New Hogan Dam in 1963 (White pers. comm.). Historically, chinook salmon production in the Calaveras River was limited by low, intermittent flows during summer and fall.

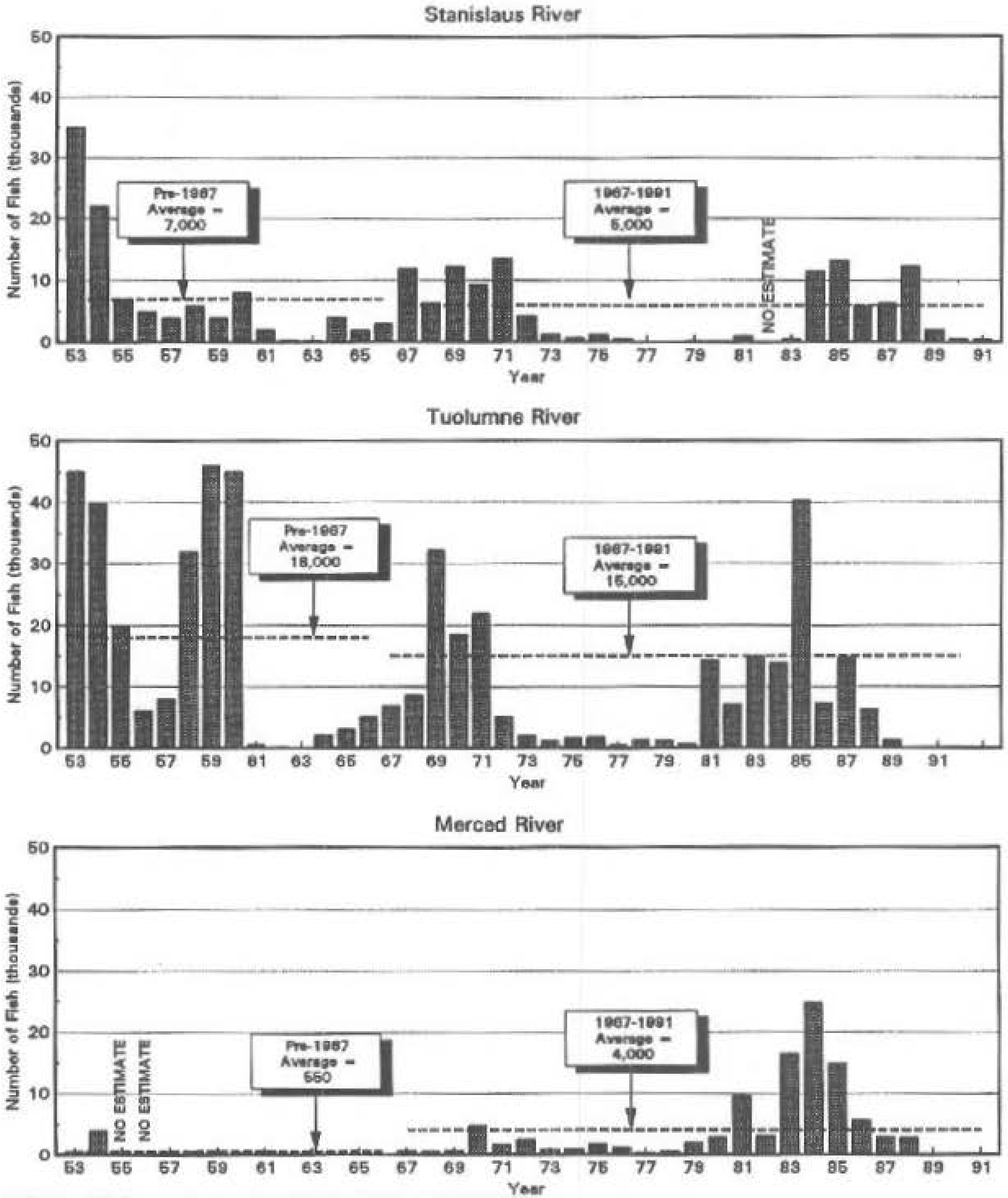
San Joaquin River - Early impacts on chinook salmon in the San Joaquin basin were caused by gold mining activities, agricultural and power diversions, and overfishing (Clark 1929). The most abundant salmon race, spring-run chinook salmon, was completely eliminated after 1947 above the Merced River confluence following construction of Friant Dam, which blocked access to historical holding and spawning habitat and severely reduced flows in the San Joaquin River below the dam (DFG 1987b). Fall-run chinook also have been extirpated in the San Joaquin River from Friant Dam downstream to the confluence with the Merced River due to insufficient flow releases from Friant Dam.



SOURCES: U.S. Bureau of Reclamation (1988b) and Mills and Fisher (1993).

ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE MOKELUMNE AND COSUMNES RIVERS (1953-1991)

FIGURE 2-VI-18



SOURCES: U.S. Bureau of Reclamation (1986b) and Mills and Fisher (1993).

ANNUAL ESTIMATES OF FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE STANISLAUS, TUOLUMNE, AND MERCED RIVERS

FIGURE 2-VI-19

San Joaquin River tributaries - Annual spawning escapement estimates of fall-run chinook salmon in the San Joaquin River basin have been made since 1940, but early estimates are often incomplete and based on subjective methods (USBR 1986b).

Fall-run chinook salmon have undergone major reductions since the 1940s but have persisted as small but fluctuating populations below major dams on the Merced, Tuolumne, and Stanislaus rivers. Low returns of fall-run salmon to all three tributaries in 1961 were attributed to a fall migration barrier caused by low San Joaquin River flows, flow reversals, and low dissolved oxygen levels in the lower San Joaquin River and south Delta channels (Figure 2-VI-19). Nearly complete run failures in 1962 and 1963 appeared to be related to low spring flows in 1959, 1960, and 1961 rather than fall migration conditions (Hallock et al. 1970).

Spring-run chinook salmon on the Stanislaus, Tuolumne, and Merced rivers were probably eliminated by 1930 as a result of dam construction.

Steelhead

Unlike chinook salmon, there are few specific data regarding historical steelhead abundance. There has never been a commercial fishery for steelhead, and quantitative estimates of population abundance were not developed until the 1950s (and later than that in most streams).

Sacramento River - Historically, steelhead spawned and reared in the most upstream portions of the upper Sacramento River and most, if not all, of its perennial tributaries. Because they have greater swimming and leaping abilities than chinook salmon, steelhead could migrate farther into headwater streams where water temperatures were generally cooler. Hanson et al. (1940) estimates that 187 miles of accessible rivers and streams were blocked to chinook salmon by Keswick and Shasta Dams alone; even more miles would have been blocked for steelhead. Dams and diversions for water supply, flood control, and sediment control were located on each of the major tributaries and blocked steelhead migrations to preferred spawning and rearing habitats.

Annual estimates of total (natural spawning and hatchery returns) Sacramento River steelhead runs upstream of both the American and Feather rivers at the Fremont Weir ranged from 14,340 to 28,400 from 1953-1959, and averaged 20,500 (Skinner 1962). The average estimated natural spawning portion of these runs was 88.6%.

Sacramento River tributaries - Historically, steelhead runs were sustained in all tributaries with adequate flow and habitat qualities, although no firm estimates of steelhead abundance exist. Counts conducted before 1967 enumerated populations in excess of 1,000 steelhead in both Mill and Deer creeks (Mills and Fisher 1993). Average estimates for the 1950s and 1960s were approximately 300 steelhead in Antelope Creek and 150 steelhead in Big Chico Creek. These general estimates, however, were developed after water diversions, barriers, and habitat degradation had occurred on most sections of these streams; steelhead runs were likely much larger in these streams before the 1900s.

No definitive population estimates exist for steelhead in the American River historically. The steelhead run is estimated to have exceeded 100,000 fish annually before the completion of Folsom and Nimbus Dams in 1955, but before 1970, steelhead runs were estimated to average about 5,000 fish (Reynolds et al. 1993).

Feather and Yuba Rivers - No definitive population estimates exist for steelhead in the Feather or Yuba rivers. It is likely that both river systems supported large steelhead runs in the 1800s. Hydraulic mining and diversion and storage dams on both rivers significantly reduced steelhead populations. For example, from 1910 to 1949 there was complete or nearly complete blockage of upstream migration at Daguerre Point Dam, located on the Yuba River only 12 miles from its mouth (Dunn et al. 1992).

Steelhead populations of the Feather River before construction of Oroville Dam were estimated to average about 1,000 fish above the dam site (Reynolds et al. 1990). Wooster and Wickwire (1970) estimated that about 200 steelhead spawned annually in the Yuba River before 1970.

Eastside tributaries - Steelhead historically had sustained annual runs up the Mokelumne River. No information exists on the size of these runs.

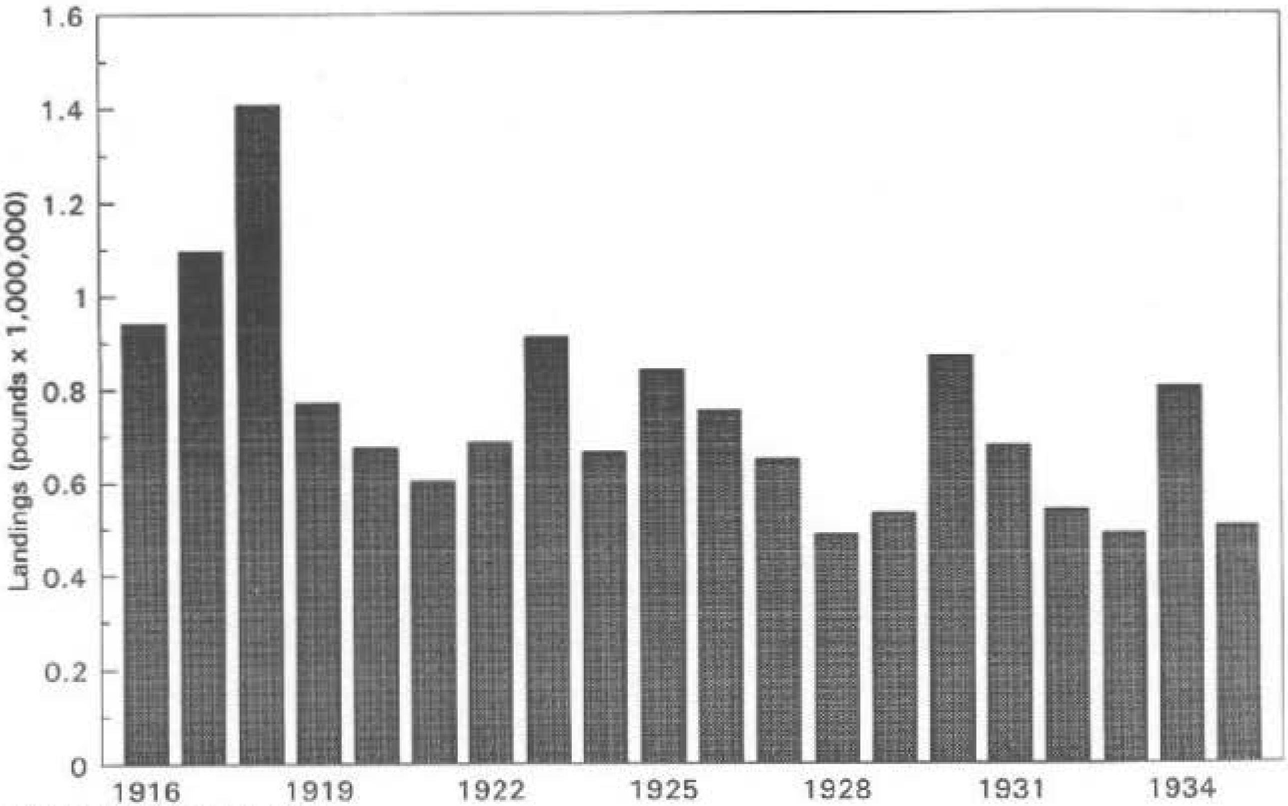
San Joaquin River - Presumably, steelhead had access upstream of the present location of Friant Dam on the mainstem San Joaquin River. No information exists on the size of these runs.

San Joaquin River tributaries - Steelhead historically had sustained annual runs up the San Joaquin, Mokelumne, Stanislaus, Tuolumne, and Merced rivers. Steelhead runs would also have occurred in any other smaller tributaries having accessible headwaters, cool water temperatures, and appropriately sized gravels. Water development facilities and operations and other forms of habitat loss and degradation substantially reduced steelhead resources to remnant levels.

Striped Bass

Striped bass are native to the east coast of the United States. Juvenile striped bass were taken from rivers in New Jersey and introduced to California waters; approximately 130 juvenile fish were released in Carquinez Strait in 1879, and another 300 fish were released in Suisun Bay in 1882 (California Bureau of Marine Fisheries 1949, Skinner 1962). Successful reproduction was observed before 1882, and the population quickly multiplied to several million adult bass.

A few of the fish planted in 1879 were reportedly caught in 1880, and striped bass weighing more than 16 pounds were caught in 1883 and 1884 (California Bureau of Marine Fisheries 1949, Skinner 1962). By 1888, striped bass supported a significant fishery in San Francisco Bay and several thousand fish were



Source: U. S. Bureau of Marine Fisheries (1949).

COMMERCIAL LANDINGS OF STRIPED BASS (1916-1935)

FIGURE 2-VI-20

available in local fish markets. A minimum size limit of 8 pounds, the first fishing regulation for striped bass in California, was enacted in 1890. State regulations set a minimum size limit of 3 pounds in 1897.

The 1899 commercial catch was reported as 1,234,000 pounds (Skinner 1962), and commercial landings in 1916-1935 ranged from 0.5 million to 1.5 million pounds (Figure 2-VI-20). Sport fishing for striped bass became increasingly popular after 1895, leading to more restrictive commercial fishing regulations. Commercial fishing for striped bass with nets was prohibited in 1931, and all commercial striped bass fishing was prohibited after 1935.

From 1936 on, the striped bass fishery was reserved exclusively for sport anglers. Annual striped bass landings by the sport fishery were reported to be much larger than commercial striped bass landings ever were (California Bureau of Marine Fisheries 1949). By 1955, more than 200,000 anglers participated in the fishery, catching more than 1 million striped bass annually with an aggregate weight of approximately 4 million pounds (Skinner 1962).

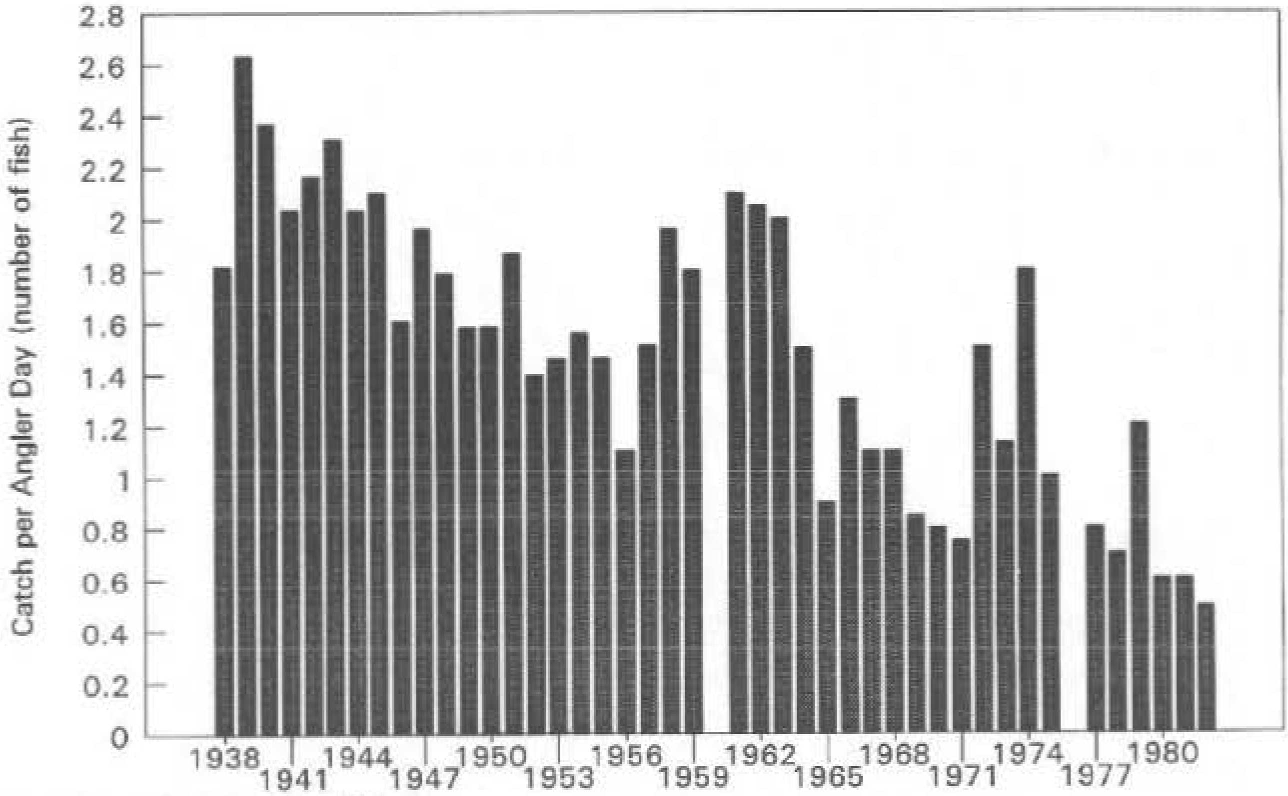
Analysis of sport catch records and other data showed a decline in the fishery after 1944 and a severely depleted adult striped bass population by 1970 (Skinner 1962, DFG 1989). Data from the sport fishery and mark-recapture studies indicate that the population declined from approximately 3 million bass in the early 1960s to a population level of approximately 1.7 million by the late 1960s.

Charter boat records provide the best information on the striped bass fishery from 1938 to 1982. The catch per angler-day was greatest during the early years of the charter boat fishery and decreased over time (Figure 2-VI-21). The reduction in the catch per angler-day may indicate decreasing striped bass population abundance; however, changes in fishing regulations and sport-fishing efforts affect statistics on catch per angler-day.

Factors contributing to increased mortality before 1967 include fishing, entrainment in diversions, exposure to toxic materials, and habitat loss. Sport fishing annually removed 20-30% of the striped bass population longer than 16 inches.

Incidental catch in net fisheries targeting other species may have caused annual mortality approaching 50,000 adult striped bass before the net fisheries were prohibited in 1957. Entrainment in the Contra Costa Steam Plant (Pacific Gas and Electric Company [PG&E]) and the Tracy Pumping Plant diversions may have reduced the juvenile striped bass population by more than 20% each year. Salvage operations at both facilities greatly reduced the number of fish destroyed, but losses continued to occur after 1957.

In the Napa River and San Francisco Bay, anecdotal information indicates pollution by tannery, chemical company, and garage discharges may have resulted in substantial mortality of striped bass as early as 1924.



Sources: Skinner (1982), State Water Contractors (1987).

CATCH OF STRIPED BASS PER ANGLER DAY FOR CHARTER BOATS (1938-1982)

FIGURE 2-VI-21

Between 1860 and 1959, nearly half of the estimated 570 square miles of marsh and tidal habitat were filled and leveed off (DFG 1989). Sloughs that formerly afforded good fishing and habitat were no longer accessible to striped bass. Diking and filling not only restricted striped bass habitat, but also reduced tidal mixing (i.e., potential for reduced dilution of toxic materials) and overall estuary productivity.

American Shad

American shad are native to the east coast of the United States. Juvenile shad were transported from New York and introduced into California in 1871, when approximately 10,000 juveniles were released in the Sacramento River near Tehama (Painter et al. 1980). An additional 824,000 juvenile shad were introduced into California from 1873 to 1881 (Skinner 1962). The shad quickly multiplied and by 1880 were found as far north as the Columbia River in Washington (Fry 1973). A commercial fishery for shad developed by 1879, and by 1886, the State Board of Fish Commissioners estimated that 1 million mature fish were taken (Skinner 1962).

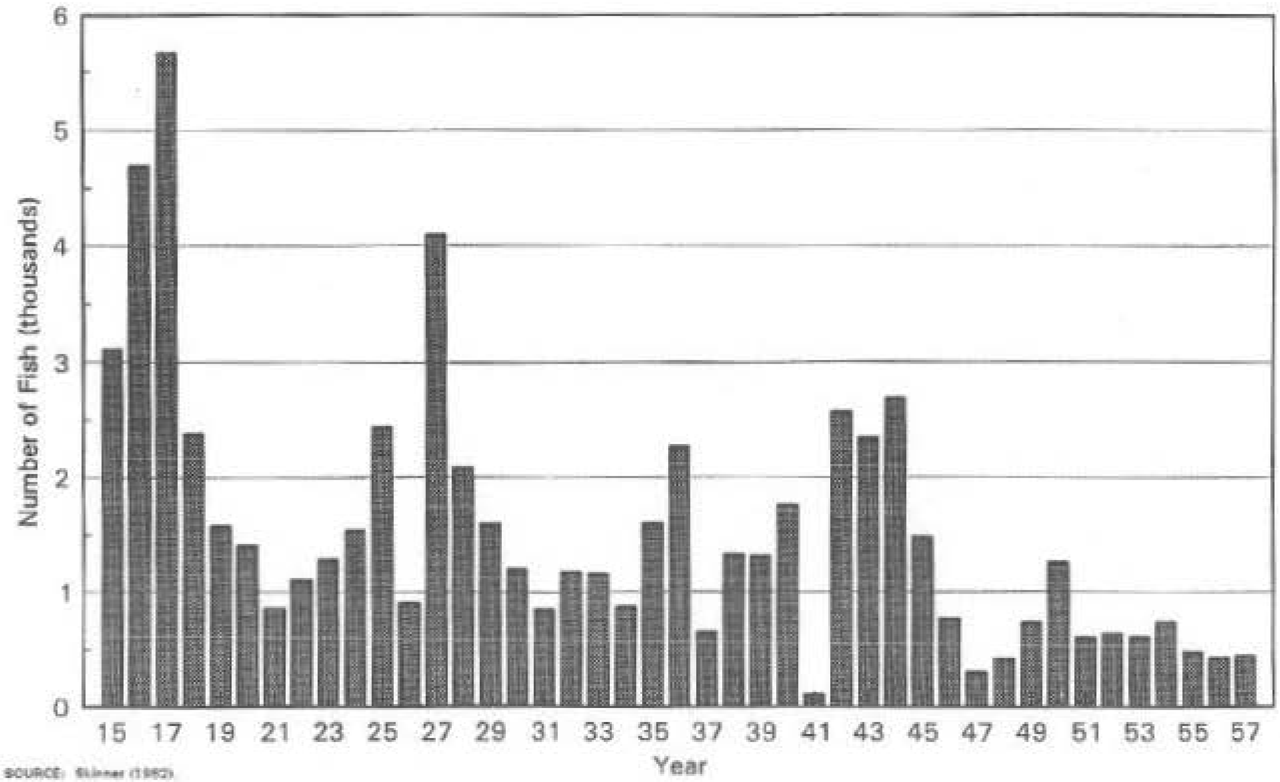
Before 1899, the commercial catch never exceeded 1 million pounds. From 1899 to 1914, commercial catch data are limited but indicate that commercial landings ranged from 620,891 to 1,169,000 pounds (Skinner 1962). Commercial landings from 1915 to 1945 ranged from approximately 0.1 to 5.5 million pounds; however, commercial landings below 1 million pounds were rare. After 1945, commercial shad landings exceeded 1 million pounds only once (Figure 2-VI-22). The commercial gill net fishery in the Sacramento-San Joaquin River estuary was eliminated through legislation in 1957 (Skinner 1962).

It is unknown when sport fishing for shad first occurred, although some angling was reported in the 1930s and 1940s (Painter et al. 1980). After 1950, sport fishing for shad became extremely popular. One popular method of taking shad, called "bumping", was conducted from boats using hand-held nets. Anecdotal information indicates that 2,500 anglers operating out of a single recreational fishing business caught 30,000 shad in 1954 using this method (Skinner 1962). No reliable sport catch records are available to determine the relative proportion of the fishery caught by sport anglers; however, by the mid-1960s, an estimated 100,000 angler days per year were spent sport fishing for shad (Painter et al. 1980).

Analyzing commercial and sport catch data to determine shad abundance is difficult because commercial landings were more influenced by market, economic, and angling factors than by shad abundance (California Bureau of Marine Fisheries 1949). Therefore, commercial catch data do not provide an accurate measure of shad abundance during this period.

White Sturgeon

Little information is available concerning white sturgeon abundance in the Sacramento-San Joaquin system prior to 1967. Skinner (1962) summarized U.S. Commissioner of Fisheries annual reports to provide commercial catch statistics (by weight) for many years prior to 1918. With substantial assumptions, these



SOURCE: Skinner (1962)

COMMERCIAL LANDINGS OF AMERICAN SHAD (1915-1957)

FIGURE 2-VI-22

can be used to construct likely population parameters during the late 1800s for comparison with present population characteristics. These assumptions include:

1) The initial (1875) mean weight of harvested fish was 120 lbs, based on the Report of the Commissioners of Fisheries of the State of California for the Years 1878 and 1879 that indicated a mean weight of harvested sturgeon of 75 and 86 lbs, respectively, in these 2 years. It was further assumed that mean weight decreased to 50 lbs in 1891 and to 25 lbs by 1899 as large, old fish were removed by the fishery.

2) Initial abundance was 220,000 fish ≥ 40 inches total length, which corresponds to potential abundance with no fishing mortality projected by an age-structured model of the population developed to evaluate alternative angling regulations (Kohlhorst 1993). Postulating alternative initial abundances when formulating this assumption indicated that values less than 216,000 led to extinction.

3) The white sturgeon population exhibited no compensation in terms of increased growth rate, increased fecundity, or increased natural survival in response to elevated exploitation rate.

With these assumptions, it can be postulated that white sturgeon abundance decreased from 220,000 fish ≥40 inches in 1875 to only 5,200 fish in 1901 (Table 2-VI-2), when the commercial fishery was closed by the Legislature. During this time, exploitation rate increased irregularly from <1% to about 47% in 1899. Harvest in numbers of fish reached a peak of 23,700 in 1887.

The commercial sturgeon fishery was reopened in 1916, but only about 500 fish were caught that year and about 300 were caught in 1917. Because the population had not rebounded, both commercial and sport fishing were prohibited starting in 1917.

When a sportfishing-only season was initiated in 1954, the first tagging program to estimate abundance, harvest rate, age composition, and growth was undertaken. This research provided not only the first direct abundance estimate (11,200 fish ≥ 40 inches TL), but evidence from the age composition of the tagging catch that any recovery of the population up to that time was largely due to the extremely strong 1938 year class (Pycha 1956).

White sturgeon occur in rivers and estuaries along the west coast of North America, primarily the Fraser, Columbia, Sacramento, and San Joaquin rivers, but their distribution in the Sacramento-San Joaquin system before 1967 is even less well described than abundance. The earliest mention of sturgeon occurrence in the Sacramento River dates from October 1837, when large sturgeon-like fish were observed jumping in the vicinity of the mouth of the Feather River (Belcher 1843); it is unknown whether these were white or green sturgeon. In the early 1900s, large white sturgeon were occasionally caught during late summer in the Feather River from Biggs to Oroville (Anonymous 1918; Anonymous 1959).

DFG Region 1 files provide some information about white sturgeon distribution in the upper Sacramento River drainage before and after construction of Shasta Dam (T. P. Healey, California Department of Fish and Game, personal communication). Sturgeon probably inhabited the entire Pit River up to Pit River Falls prior to construction of Britton Dam by PG&E in 1925. A substantial number of white sturgeon were trapped in and above Lake Shasta when Shasta Dam was closed in 1944. These fish and their progeny primarily used the Pit River arm of the lake. Successful reproduction apparently continued until the early 1960s, when construction of additional hydropower dams on the Pit River just above Lake Shasta eliminated the last of the sturgeon spawning habitat.

Other information about historical sturgeon distribution is provided by Skinner (1962), who states that "white sturgeon appear to make a general migration out of the Bay into upstream waters in the spring but data are lacking to support this point". He also reports sturgeon in the San Joaquin River at the face of Mendota Dam in 1947. He indicates that 5- to 6-inch sturgeon were found at water diversion sites in the Delta and that 18- to 30-inch fish were common in the Delta and Bay Area.

Table 2-VI-2. Estimates of potential historical white sturgeon population parameters from catch statistics in Skinner (1962) and mean weights interpolated from weights for 1878 and 1879 in the Report of the Commissioners of Fisheries of the State of California for the Years 1878 and 1879.

Year	Catch (lbs)	Mean weight (lbs)	Catch (number)	Harvest rate	Abundance	Recruits
1875	118,350	120	986	0.004	220,000	22,000
1876	274,375	110	2,494	0.011	219,014	21,901
1877	295,650	90	3,285	0.015	216,519	21,652
1878	334,500	75	4,460	0.021	213,234	21,323
1879	607,800	86	7,067	0.034	208,774	20,877
1880			5,353	0.027	201,707	20,171
1881	291,050	80	3,638	0.019	196,354	19,635
1882	251,700	75	3,356	0.017	192,716	19,272
1883	125,850	75	1,678	0.009	189,360	18,936
1884			7,180	0.038	187,682	18,768
1885			12,682	0.070	180,502	18,050
1886			18,184	0.108	167,820	16,782
1887	1,658,000	70	23,686	0.158	149,637	14,964
1888	460,000	60	7,667	0.061	125,951	12,595

Year	Catch (lbs)	Mean weight (lbs)	Catch (number)	Harvest rate	Abundance	Recruits
1889	495,000	55	9,000	0.076	118,284	11,828
1890	587,625	55	10,684	0.098	109,284	10,928
1891	715,795	50	14,316	0.145	98,600	9,860
1892	765,297	45	17,007	0.202	84,284	8,428
1893			13,835	0.206	67,278	6,728
1894			10,664	0.200	53,442	5,344
1895	299,729	40	7,493	0.175	42,778	4,278
1896	175,675	35	5,019	0.142	35,284	3,528
1897	190,445	30	6,348	0.210	30,265	3,027
1898			6,500	0.272	23,917	2,392
1899	205,659	25	8,226	0.472	17,417	1,742
1900			4,000	0.435	9,191	919
1901					5,191	519
1902					5,191	519
1903					5,191	519
1904					5,191	519
1905					5,191	519
1906					5,191	519
1907					5,191	519
1908					5,191	519
1909					5,191	519
1910					5,191	519
1911					5,191	519
1912					5,191	519
1913					5,191	519
1914					5,191	519
1915					5,191	519
1916	15,178	30	506	0.097	5,191	519
1917	9,822	30	327	0.070	4,685	468

Note: It is assumed that a natural mortality rate of 0.10 was exactly balanced by recruitment and that the population showed no compensatory response to higher mortality and reduced abundance.

Green Sturgeon

Information on the distribution and abundance on green sturgeon before 1967 is extremely limited.

ABUNDANCE AND DISTRIBUTION (1967-1991)

Chinook Salmon

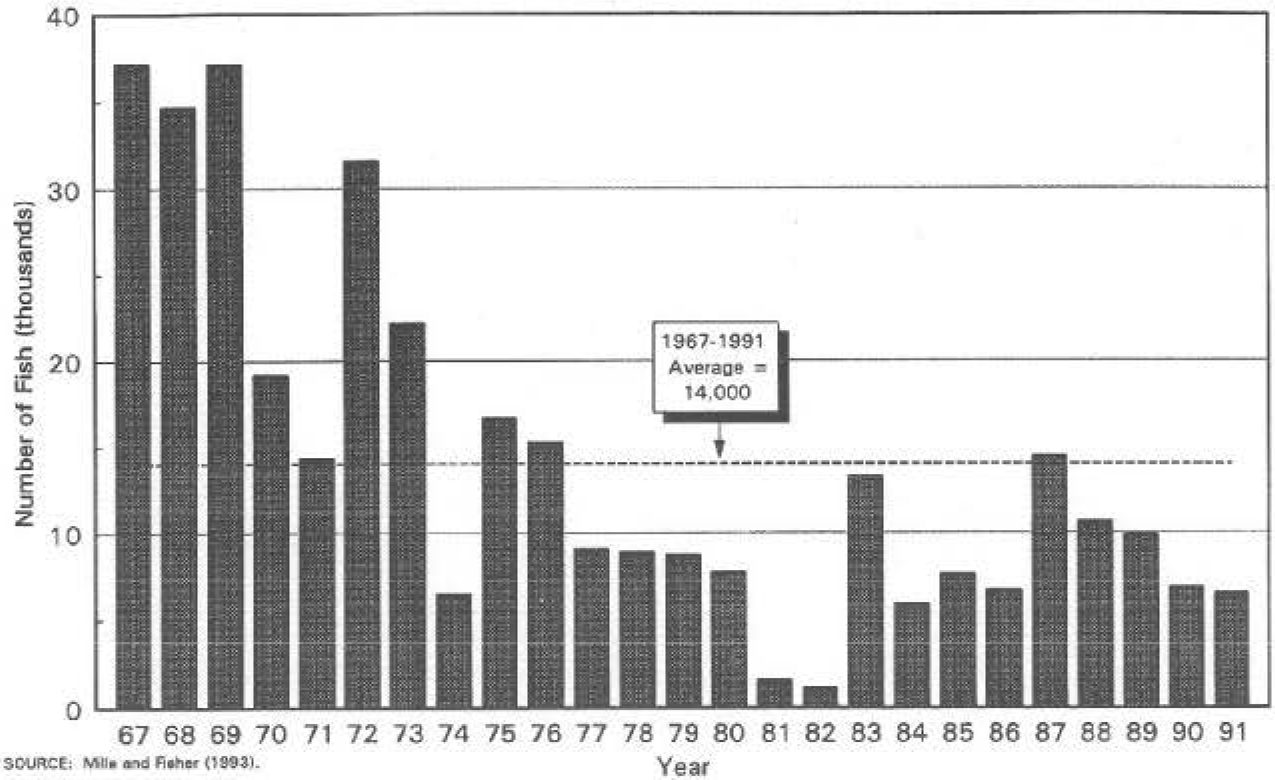
Sacramento River -

Fall-run chinook salmon - The overall decline in mainstem Sacramento River fall-run chinook salmon abundance during the 1950s and 1960s was followed by low but relatively stable population levels during the 1970s and 1980s. A decline during the recent drought, however, led to a record low spawning escapement of about 29,000 adults in 1991. Average annual spawning escapement of fall-run chinook salmon in the Sacramento River during 1967-1991 was approximately 77,000 fish (Figure 2-VI-14).

Late fall-run chinook salmon - Counts of chinook salmon passing the RBDD since 1967 provide the most reasonable indication of overall trends in late fall-, winter, and spring-run chinook salmon abundance in the upper Sacramento River. The number of late fall-run chinook salmon passing the RBDD declined from an average 35,000 adults in the late 1960s to an average of 7,000 adults in recent years (Figure 2-VI-23). Hatchery returns to CNFH during this period have fluctuated between 200 and 3,000 fish, with record low returns in 1990 and 1991 (Figure 2-VI-24).

Winter-run chinook salmon - Winter-run chinook salmon suffered a precipitous decline from an average of approximately 80,000 adults in the late 1960s to estimated run sizes of 547, 441, and 191 in 1989, 1990, and 1991, respectively (Figure 2-VI-25). Estimated run sizes in 1992 and 1993 were 1,180 and 341, respectively. Factors contributing to this decline include water temperature impacts associated with operation of Shasta and Keswick Reservoirs, adult and juvenile passage problems at the RBDD, modification and loss of spawning and rearing habitat, predation, pollution, and entrainment in water diversions on the Sacramento River and in the Delta. The recent drought in California (1987-1992) exacerbated these impacts. (National Marine Fisheries Service [NMFS] 1992.)

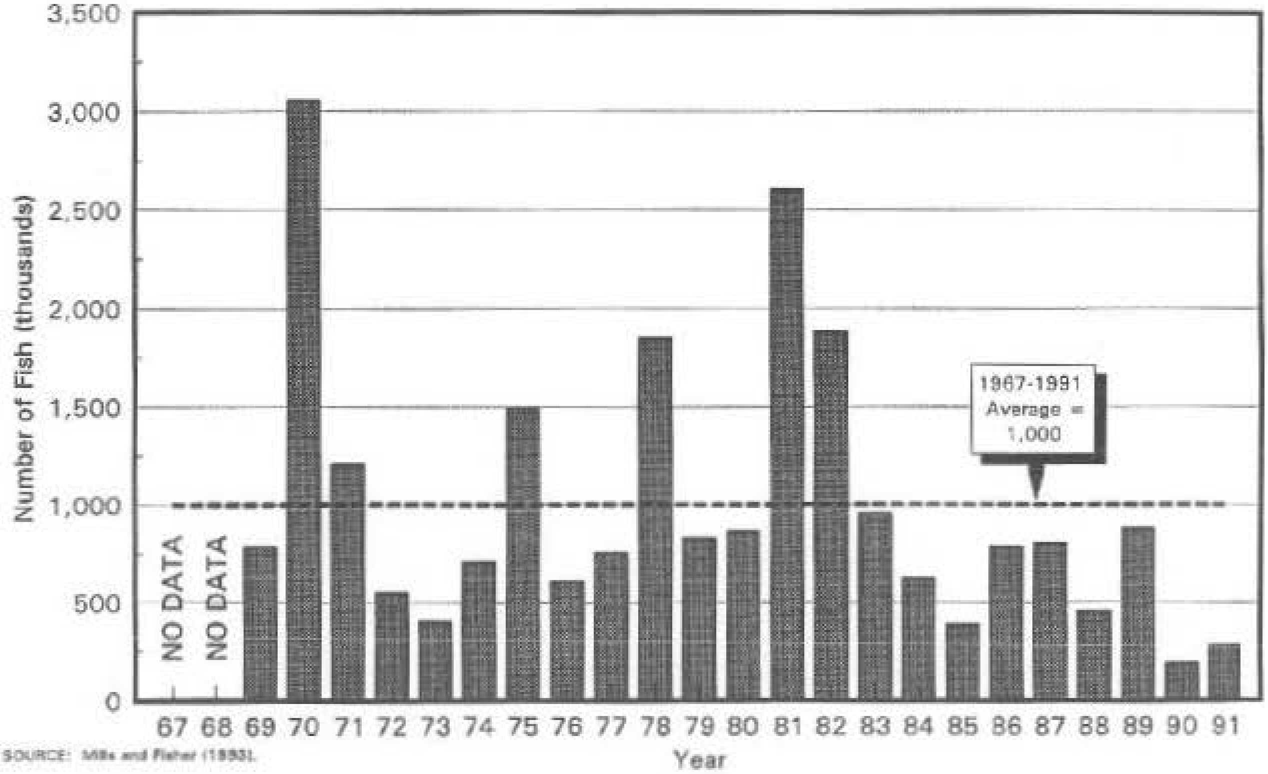
The return of an estimated 550 adults in 1989 prompted listing of the winter-run chinook salmon as an endangered species by the State of California and as a threatened species by the federal government. Another record low spawning escapement of 191 fish in 1991 prompted review and subsequent reclassification of the winter-run chinook salmon to endangered status under the federal Endangered Species Act (NMFS 1992).



SOURCE: Mills and Fisher (1993).

ANNUAL ESTIMATES OF LATE FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1967-1991)

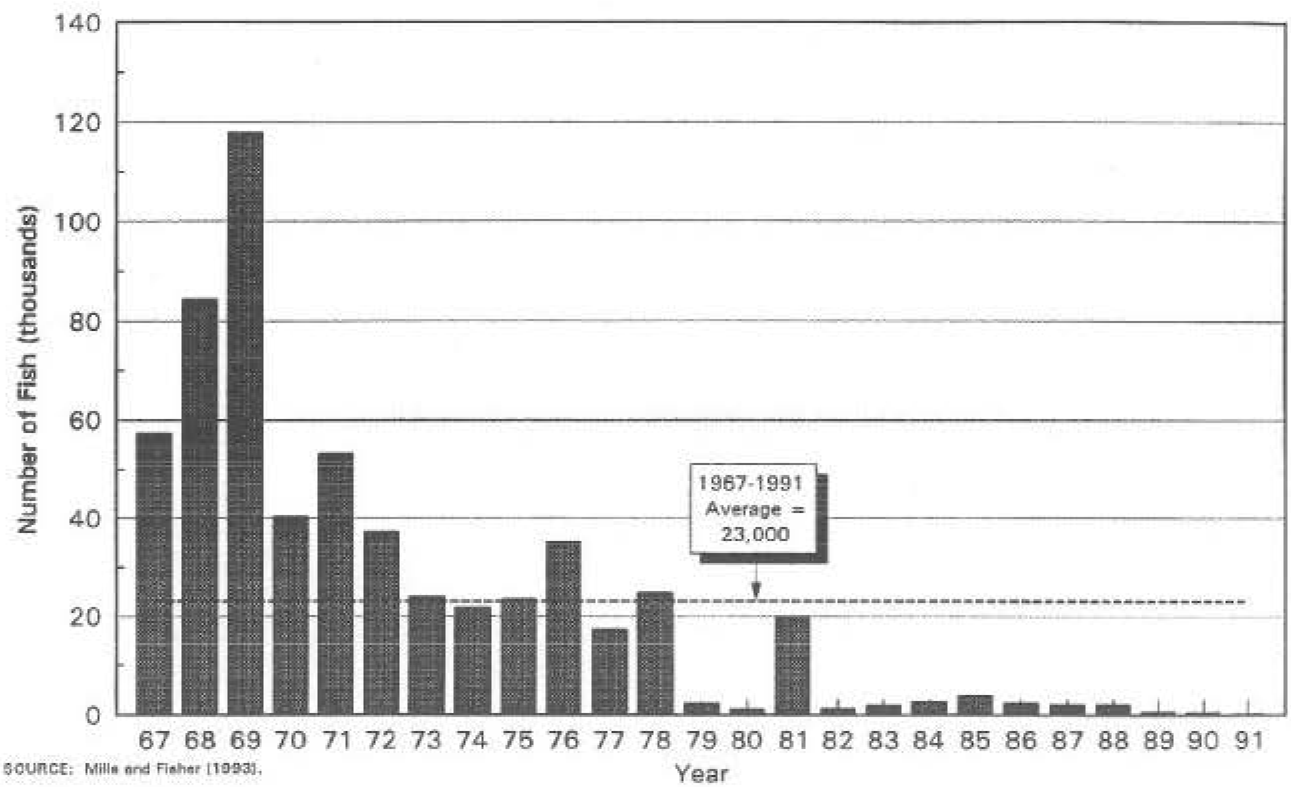
FIGURE 2-VI-23



SOURCE: Mills and Fisher (1993).

ANNUAL RETURNS OF LATE FALL-RUN CHINOOK SALMON TO COLEMAN NATIONAL FISH HATCHERY (1967-1991)

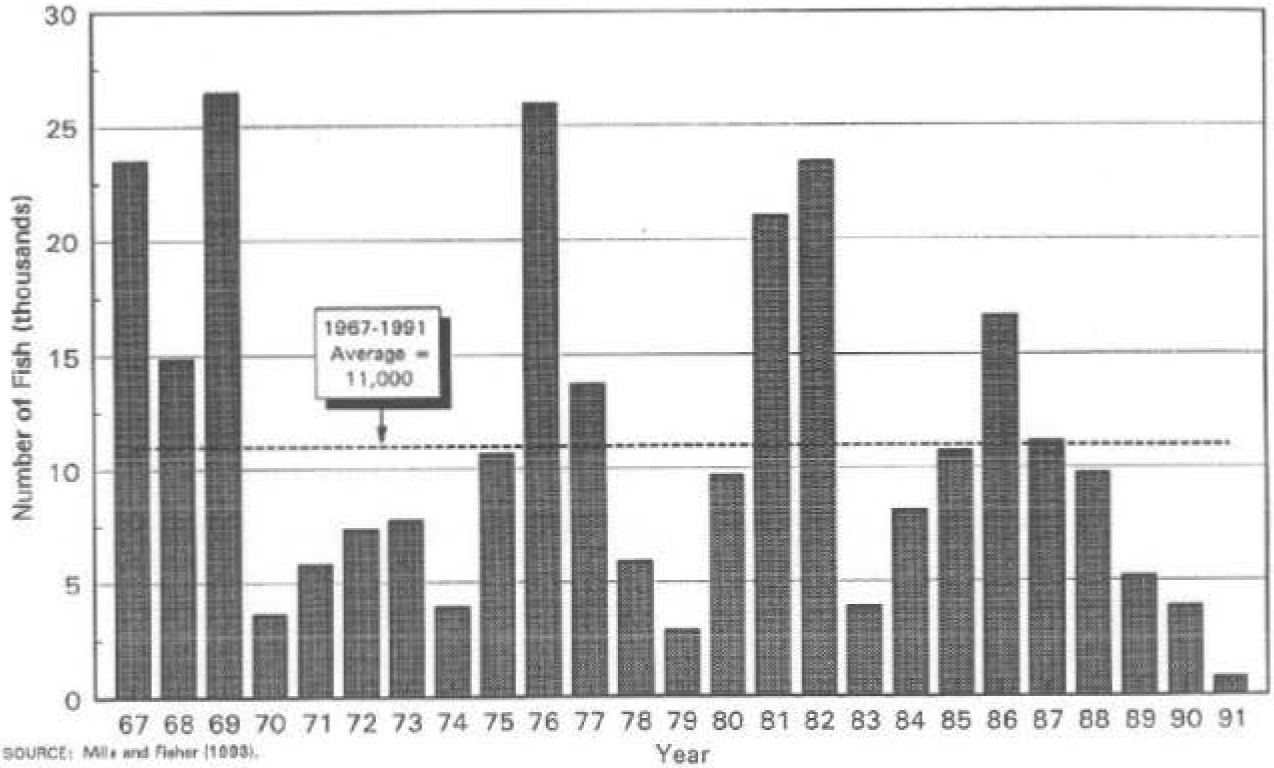
FIGURE 2-VI-24



SOURCE: Mills and Fisher (1993).

ANNUAL ESTIMATES OF WINTER-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1967-1991)

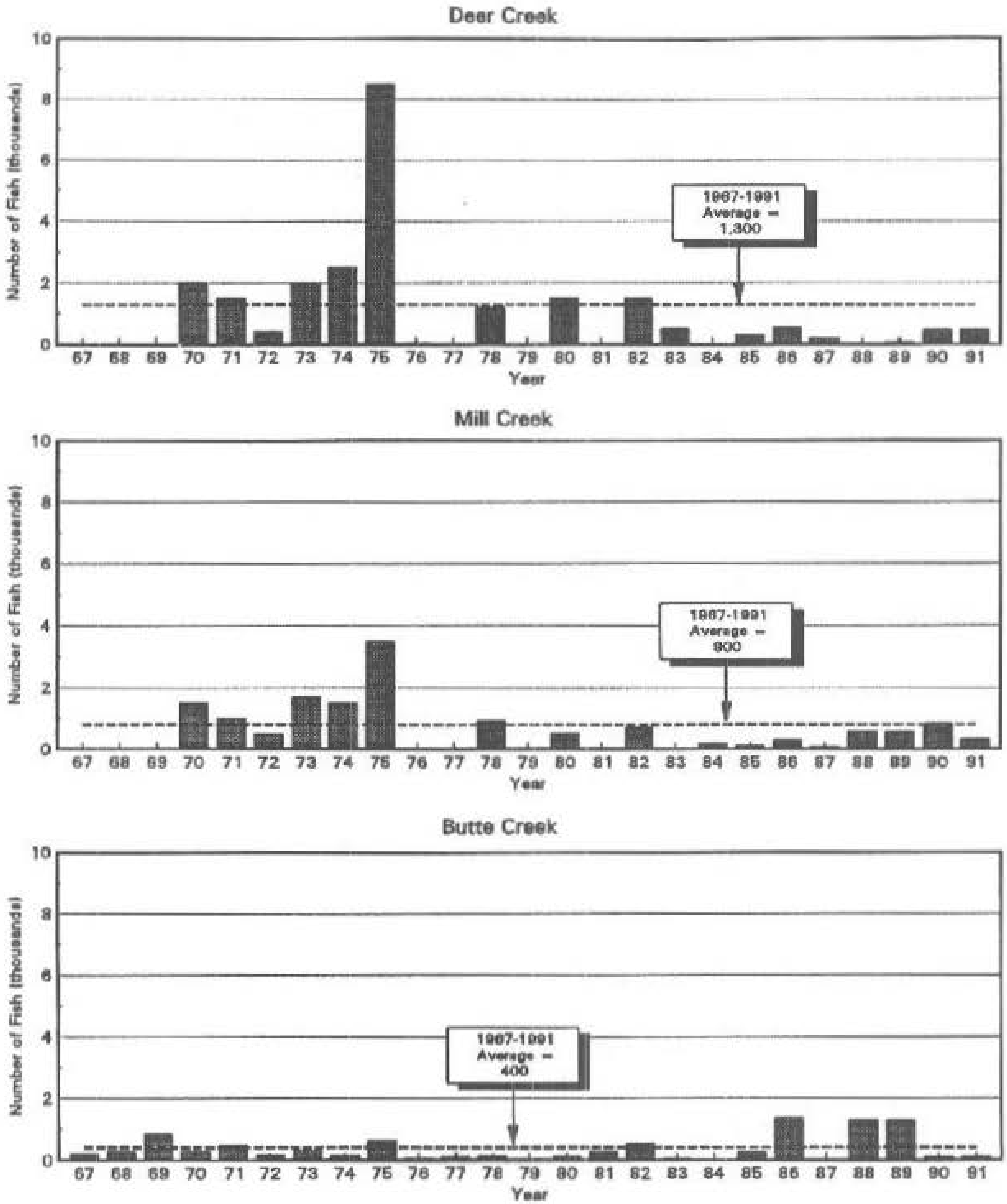
FIGURE 2-VI-25



SOURCE: Mills and Fisher (1993).

ANNUAL ESTIMATES OF SPRING-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN THE MAINSTEM SACRAMENTO RIVER (1967-1991)

FIGURE 2-VI-26



SOURCE: Mills and Fisher (1993).

ANNUAL ESTIMATES OF SPRING-RUN CHINOOK SALMON SPAWNING ESCAPEMENT IN DEER, MILL, AND BUTTE CREEKS (1967-1991)

FIGURE 2-VI-27

Spring-run chinook salmon - The number of adults passing the RBDD has fluctuated between highs of more than 25,000 fish to a record low of 773 fish in 1991 (Figure 2-VI-26). An average of approximately 11,000 fish migrated past the dam between 1967 and 1991.

Sacramento River tributaries - Estimates of fall-run chinook salmon spawning escapement in minor Sacramento River tributaries (excluding Battle Creek) are incomplete for the 1967-1991 period. No trends in run size are apparent for Clear Creek, Cow Creek, Cottonwood Creek, Paynes Creek, Antelope Creek, Mill Creek, Deer Creek, and Butte Creek, although record low escapements occurred in most of these creeks in recent years (Figure 2-VI-15). Annual spawning escapement in Battle Creek during 1967-1991 averaged approximately 18,000 adults; on the average, approximately 8,000 adults spawned in Battle Creek while 10,000 were spawned in CNFH (Figure 2-VI-16). Increases in production capacity and improved water quality, temperature, and disease control techniques at CNFH resulted in record run sizes in recent years (USBR 1985).

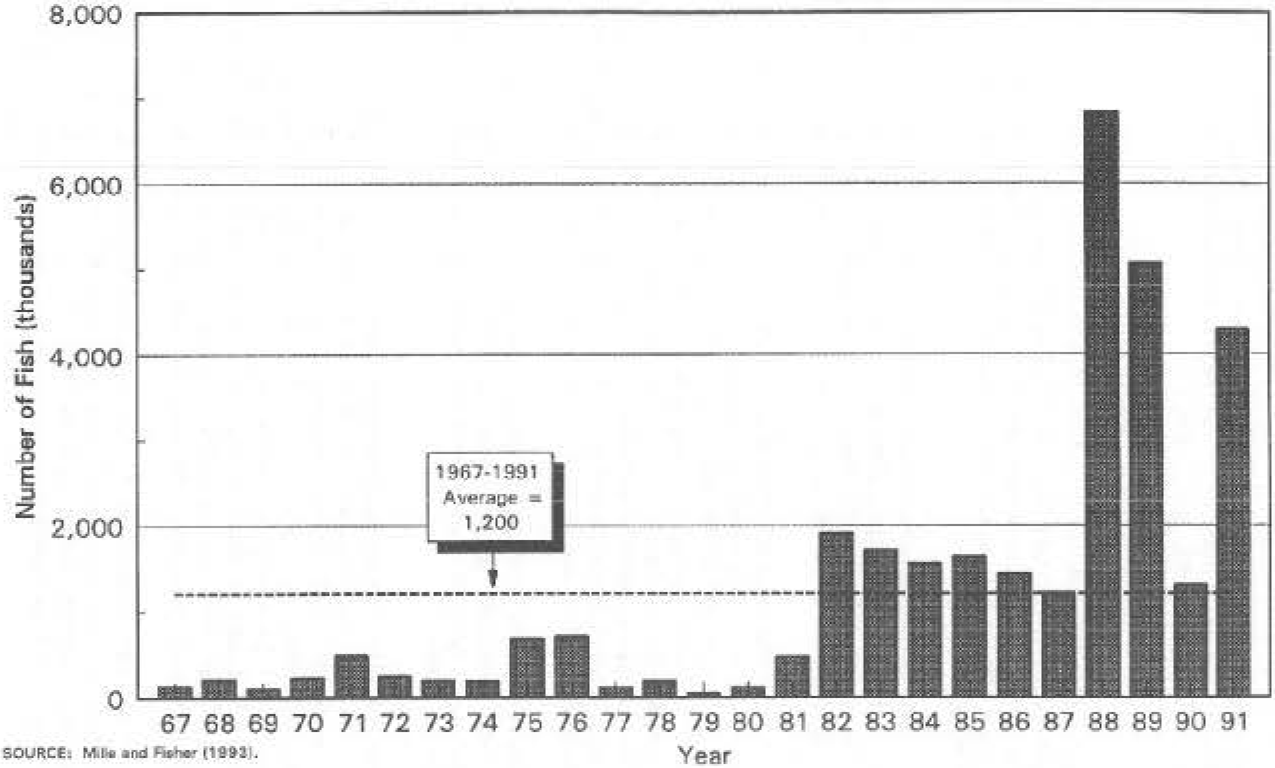
The 1967-1991 average spawning escapement of spring-run chinook salmon in Deer and Mill creeks was 1,300 and 800 adults, respectively (Figure 2-VI-27). Run sizes have declined by 85% in Mill Creek and 80% in Deer Creek since 1967. A small run averaging approximately 400 fish spawns in Butte Creek (Figure 2-VI-27). This run has been supported by natural reproduction and plants of chinook salmon smolts from Feather River Hatchery.

Fall-run chinook salmon spawning escapement in the American River during 1967-1991 averaged 41,000 adults; on the average, 32,000 adults spawned in the river, while 9,000 were spawned in Nimbus Fish Hatchery (Figure 2-VI-17).

Feather River - Annual fall-run chinook salmon spawning escapement in the Feather River increased and became less variable following completion of Oroville Dam and Feather River Salmon and Steelhead Hatchery in 1968; average run size increased sharply in 1969 and remained relatively high through 1991. Annual spawning escapement of fall-run chinook salmon in the Feather River during 1967-1991 averaged approximately 47,000 adults; on the average, 41,000 adults spawned in the river, while 6,000 were spawned in the hatchery (Figure 2-VI-17). Annual spawning escapement in the Yuba River during 1967-1991 averaged approximately 13,000 adults with no apparent trend (Figure 2-VI-17).

Numbers of spring-run chinook salmon entering Feather River Hatchery increased from an average of approximately 300 adults from 1967-1981 to an average of approximately 2,000 adults from 1982-1991 (Figure 2-VI-28). Increased returns are associated with the recent practice of trucking and releasing large numbers of hatchery smolts in the lower Sacramento River and Delta. Annual hatchery returns are based on the assumption that all salmon entering the hatchery before October 1 are spring-run fish. Fish entering after that date are considered to be fall-run fish. Small numbers of spring-run chinook salmon migrate into the Yuba River, but these fish appear to be primarily strays originating from the Feather River Fish Hatchery.

Eastside tributaries - Since 1967, annual fall-run chinook salmon spawning escapement in the Mokelumne River has fluctuated between 250 and 11,000 fish and averaged about 2,600 fish (Figure 2-VI-18).



SOURCE: Mills and Fisher (1993).

ANNUAL RETURNS OF SPRING-RUN CHINOOK SALMON TO FEATHER RIVER SALMON AND STEELHEAD HATCHERY (1967-1991)

FIGURE 2-VI-28

Increased abundance during the 1980s has been attributed to increased smolt survival resulting from several high spring runoff years and increased production of juvenile salmon at Merced River Fish Facility. Annual run size declined steadily following a peak in 1982 and has remained low during the recent drought period (1987-1992).

Annual fall-run chinook salmon spawning escapement in the Cosumnes River since 1967 ranged from zero to 4,400 fish and averaged about 750 fish (Figure 2-VI-18). Since 1987, 3 years of no streamflow during the spawning season have precluded perpetuation of a natural run (Reynolds et al. 1990).

Operation of New Hogan Reservoir since 1963 resulted in sustained flows in the lower Calaveras River during summer and fall. Several hundred winter-run chinook salmon and smaller runs of fall-run chinook salmon and steelhead were thought to have entered the Calaveras River before the recent drought period. Since 1987, low flows and high water temperatures appear to have eliminated these runs (White pers. comm.).

San Joaquin River and tributaries - All successful chinook salmon spawning in the San Joaquin River basin takes place in three major tributaries. Recent spawning escapement levels of fall-run chinook salmon in the Merced, Tuolumne, and Stanislaus rivers show considerable annual variability, with peak abundance generally following high spring runoff years (Figure 2-VI-19). Conversely, small spawning escapements generally occur following below-normal or dry runoff years. Very low spawning escapements since 1990 are related to recent drought conditions (1987-1992).

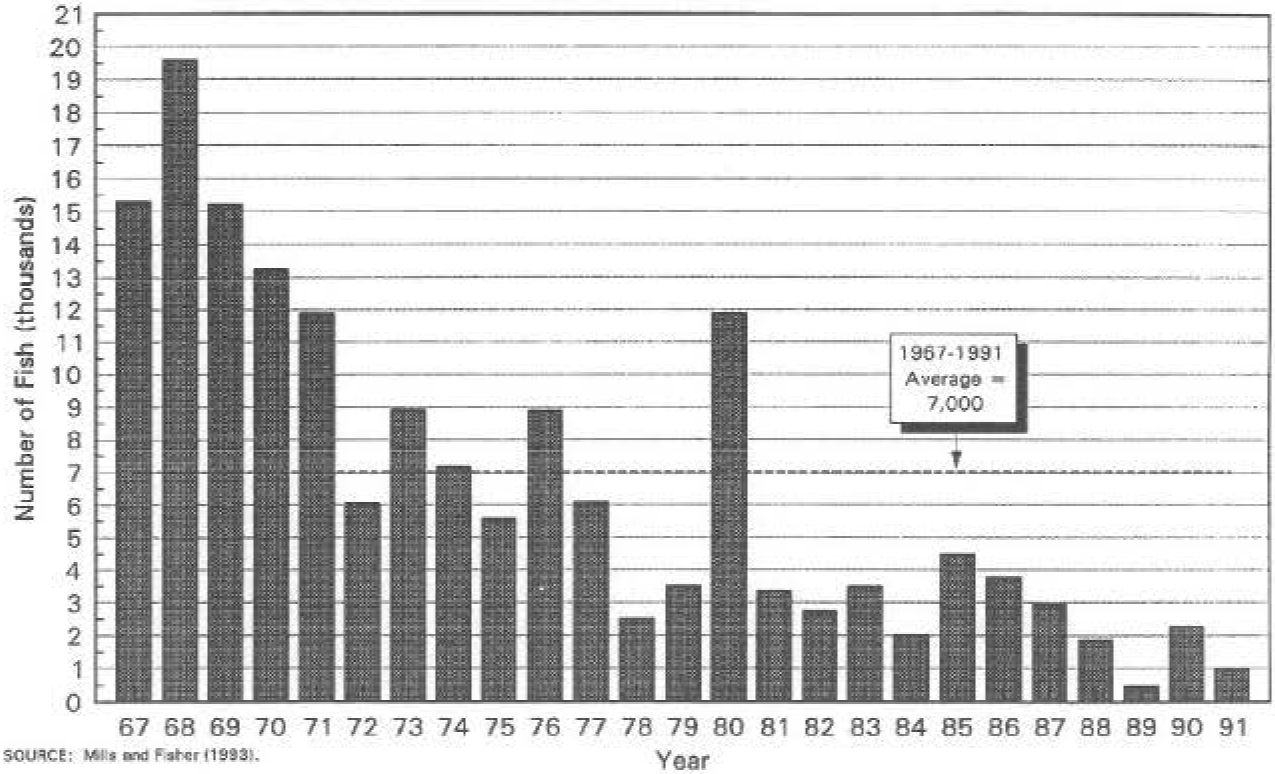
The Merced River run has been partially sustained by production of yearling fall-run chinook salmon at the Merced River Fish Facility since 1972. The hatchery contribution to San Joaquin River chinook salmon stocks is less than 5%. (DFG 1987b.)

Steelhead

Throughout the Central Valley, a 95% reduction (6,000-300 miles) of river available to anadromous fish (Reynolds et al. 1993) affects steelhead the most because of its migratory prowess. Although in some cases dams created favorable temperature conditions downstream, the physical habitat in the lower portions of these streams is not as conducive to steelhead spawning and rearing as are stream reaches higher in the watersheds.

The average annual total steelhead run in the Sacramento River system was estimated by DFG in 1990 to be about 35,000 fish, primarily hatchery-produced fish from CNFH, Feather River Fish Hatchery, and Nimbus Fish Hatchery. More than 90% of the annual steelhead run in the Central Valley is the result of hatchery-raised fish stocked as smolts or fingerlings (Reynolds et al. 1990).

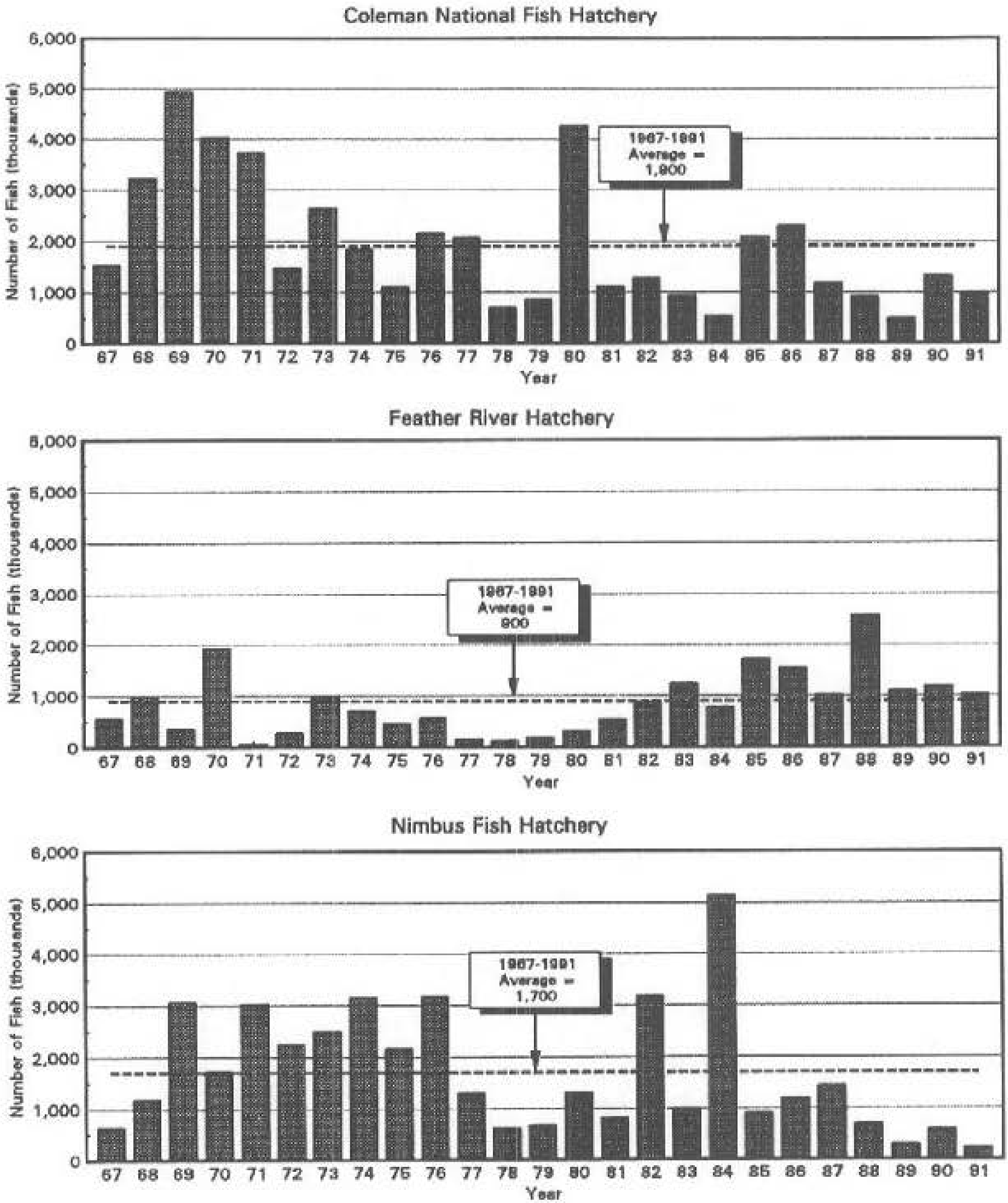
Sacramento River - Following completion of RBDD in 1967, steelhead runs could be counted at that location, although the counts underestimate the total natural spawning run in the drainage because an



SOURCE: Mills and Fisher (1993).

ANNUAL ESTIMATES OF ADULT STEELHEAD TROUT ABUNDANCE IN THE UPPER SACRAMENTO RIVER (1967-1991)

FIGURE 2-VI-29



SOURCE: Mills and Fisher (1993)

ANNUAL RETURNS OF ADULT STEELHEAD TROUT TO SACRAMENTO RIVER HATCHERIES (1967-1991)

FIGURE 2-VI-30

unknown number remain below RBDD and spawn in the lower river and tributaries. With that limitation, less the number of steelhead returning to the CNFH, an estimated average of 6,574 steelhead spawned naturally in the Sacramento River system above RBDD in the 1967-1991 period (Figure 2-VI-29). Maximum and minimum estimated runs were 19,615 fish in 1968 and 470 fish in 1989, respectively. A distinct decline has occurred, with the estimated average run size decreasing from 15,055 fish in the first 5 years of the 25-year period to only 1,714 fish in the last 5 years.

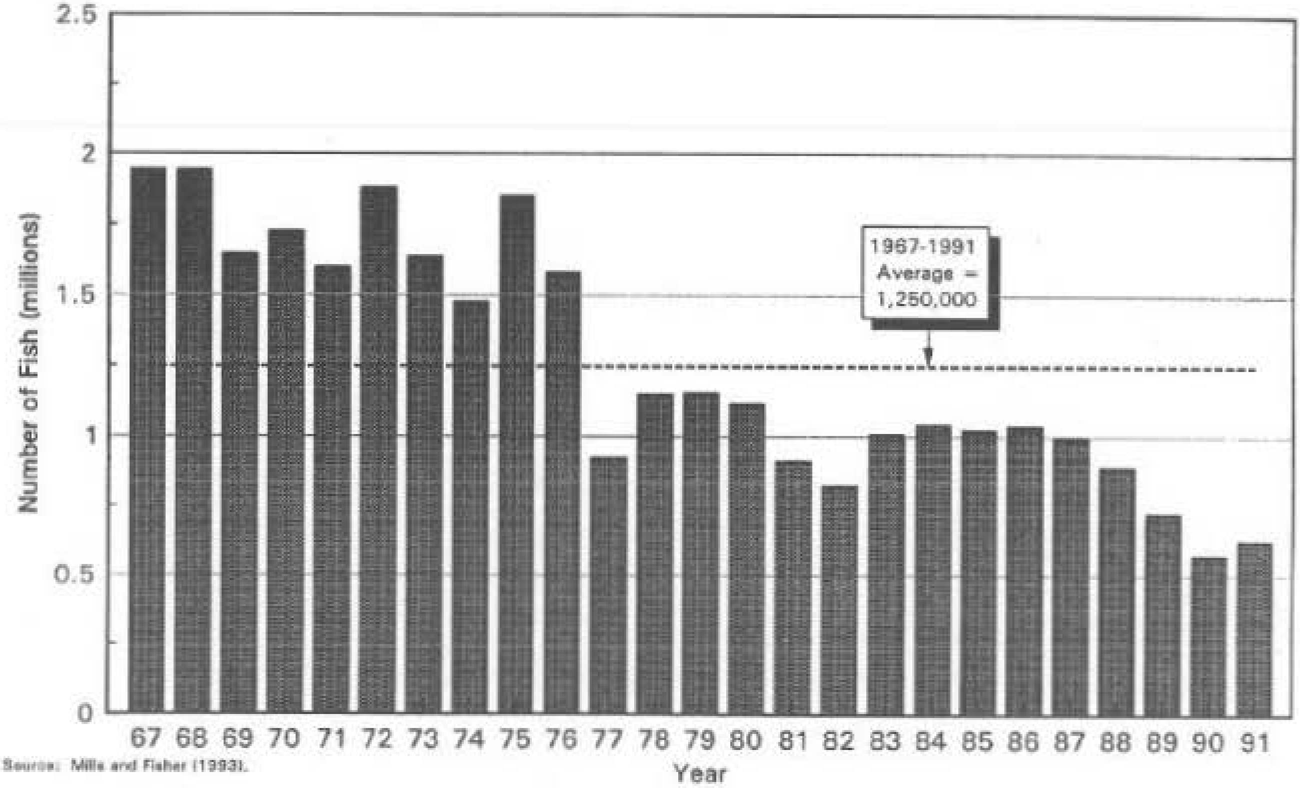
Average steelhead returns to the CNFH over the same 25 years averaged 1,910 fish, averaging 3,498 fish in the first 5 years and 979 fish in the last 5 years, a decline of nearly 75% (Figure 2-VI-30). The hatchery produces approximately 65-70% of the steelhead run to the upper Sacramento River (USBR 1985, Reynolds et al. 1990).

Sacramento River tributaries - Because counts of steelhead generally come only from hatcheries or are incidental to counts of chinook salmon, no firm estimates of steelhead run sizes exist for minor Sacramento River tributaries. Steelhead runs are believed to have declined since the 1950s and 1960s in most of these streams. Runs in the larger tributaries, Big Chico, Mill, Deer, and Antelope creeks, are probably about 50-200 fish annually. Even smaller (but unknown) numbers of steelhead also use Clear, Cow, Cottonwood, Battle (in addition to those going to CNFH), Paynes, and Butte creeks and Bear River (Reynolds et al. 1993). An estimated 25% of all steelhead migrating into the upper Sacramento River system spawn in Deer, Mill, and Antelope creeks (Hayes and Lindquist 1967).

Steelhead migrate up the American River to Nimbus Dam and the Nimbus Fish Hatchery, 23 miles up from its mouth. Adults returning to Nimbus Fish Hatchery averaged 1,694 fish in the 1967-1991 period, with no particular trend until the decline during the last 4 years (Figure 2-VI-30). Nearly all steelhead in the American River are believed to be hatchery produced, and many of the steelhead produced at the Coleman National Fish Feather River Fish Hatcheries stray and return to the American River.

Feather River - Steelhead currently spawn in the Feather River up to the fish barrier dam below Lake Oroville and in the Yuba River up to Englebright Dam. Steelhead in the Feather River primarily originate from the Feather River Fish Hatchery; there is only limited natural production in the Feather River. Steelhead runs immediately before 1967 were maintained during the 1967-1975 period after Oroville Dam and the Feather River Fish Hatchery were in operation in 1967 (Painter et al. 1977). Overall, hatchery returns averaged 858 fish in the 1967-1991 period, with an increasing trend from an average of 790 in the first 5 years of the period to 1,386 fish in the last 5 years (Figure 2-VI-30). Annual angler catches of steelhead in the Feather River have been estimated as high as 7,875 fish in the past 10 years (Reynolds et al. 1993).

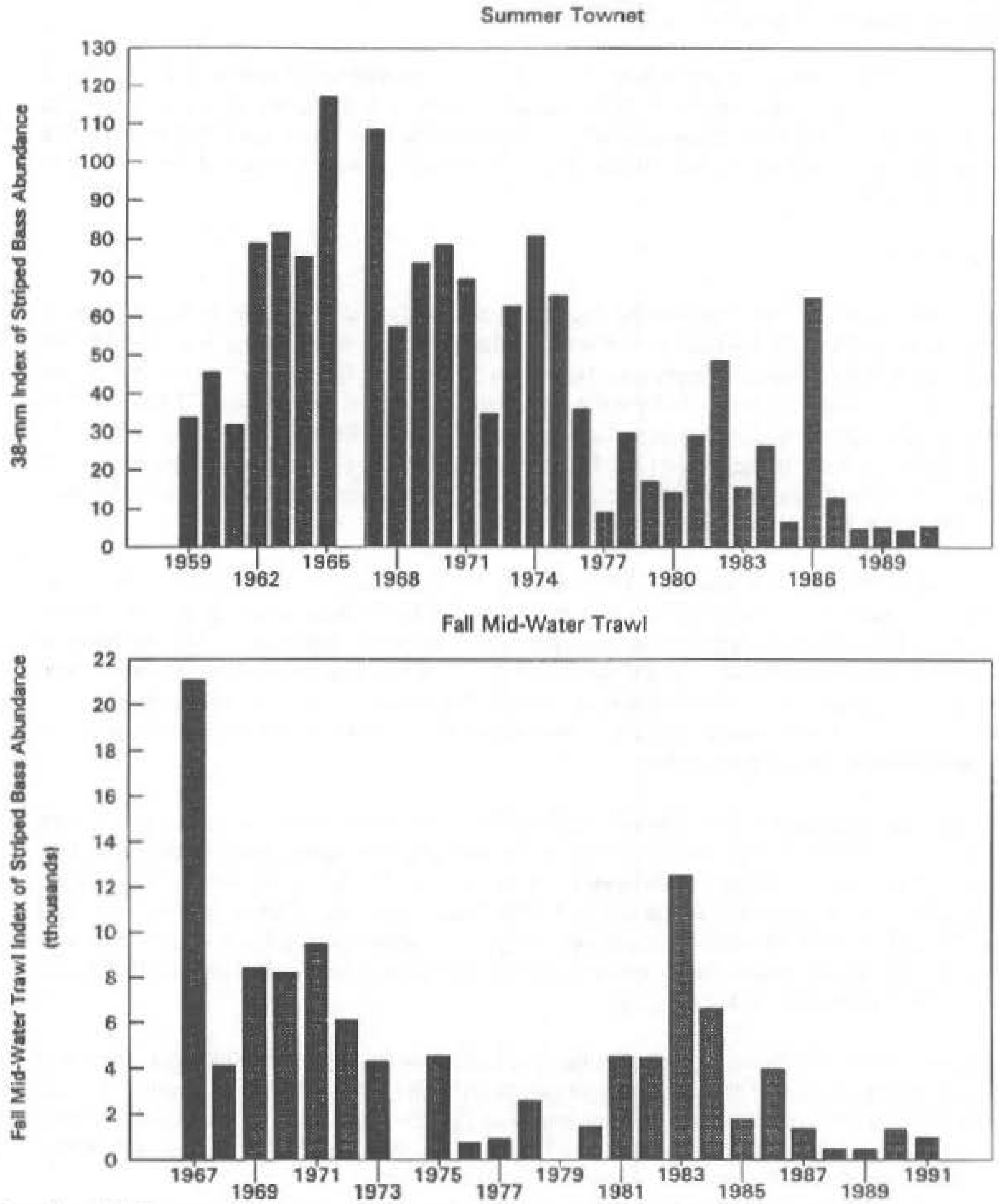
Yuba River - Limited information indicates that steelhead populations have increased on the Yuba River since New Bullards Bar Dam and Reservoir, which provided cooler summer rearing temperatures, were



Source: Mills and Fisher (1993).

ANNUAL ESTIMATES OF ADULT STRIPED BASS ABUNDANCE IN THE CENTRAL VALLEY (1967-1991)

FIGURE 2-VI-31



YOUNG-OF-YEAR STRIPED BASS ABUNDANCE IN THE SACRAMENTO-SAN JOAQUIN ESTUARY (1959-1991)

FIGURE 2-VI-32

constructed in 1970. DFG planted hatchery-raised steelhead smolts and fingerlings in most years from 1971 through 1983, and DFG estimated the 1975 run at 2,000 fish (Rogers pers. comm.).

Eastside tributaries - Steelhead populations in east side tributaries are generally small.

San Joaquin River and tributaries - Few, if any, naturally produced steelhead populations exist in the San Joaquin River system.

Striped Bass

Although the striped bass population had declined from historical levels by 1967, the period over which the decline occurred is unclear (Turner 1987). A more precipitous decline was documented after 1967 and continues to the present (Figure 2-VI-31). The average adult population size in the late 1960s and early 1970s of approximately 1.7 million striped bass declined to an average adult population size of less than 1 million in the 1980s (DFG 1989). The average adult striped bass population size for the 1967-1991 period was approximately 1.25 million fish. A record low population of 680,000 adult striped bass was estimated in 1990, including approximately 90,000 bass that were raised in hatcheries and stocked in the Delta and Bay (DFG 1992a).

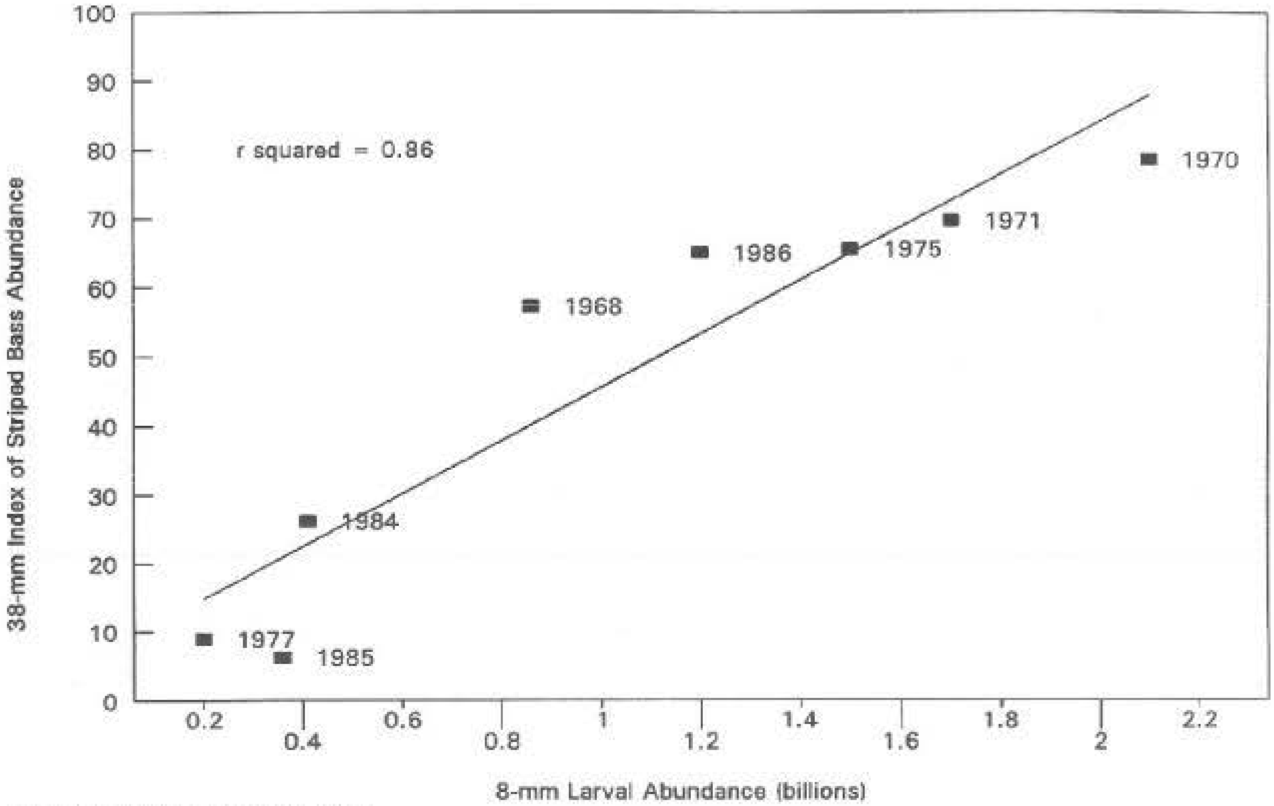
The adult population decline primarily reflects a decline in the number of new fish reaching legal size. The youngest and most numerous component of the adult striped bass population (i.e., 3-year-old fish) had declined to record lows by 1990 (DFG 1992a).

A summer tow-net survey was initiated in 1959 by DFG to provide an index of YOY abundance (i.e., the 1.52-inch index). The 1.52-inch index declined coincidentally with the decline in adult abundance since the mid 1960s (Figure 2-VI-32). The peak 1.52-inch index was 117 in 1965, and the lowest index was 4.3 in 1991 (DFG 1992a). The index averaged 1.52 for the 1967-1991 period. The fall midwater trawl surveys initiated in 1967 also provided an index of YOY abundance during September-December (Figure 2-VI-32).

Reduced populations of larvae larger than .32 inch have contributed to the decline in the 1.52-inch index (DFG 1987). Low abundance of 1.52-inch index juveniles was preceded by low abundance of .32-inch-long or larger larvae (Figure 2-VI-33). Although low larval abundance may indicate that year-class abundance will remain low, high 1.52-inch indices likely reflect increased survival during and after the larval period.

American Shad

Presently, American shad are found on the Pacific Coast from Todos Santos Bay in Baja California northward to Alaska. In California, anadromous shad populations are found seasonally in the Sacramento and San Joaquin rivers and Delta; the Feather, Yuba, and American rivers; the Mokelumne and Stanislaus



Source: Interagency Ecological Study Program (1987).

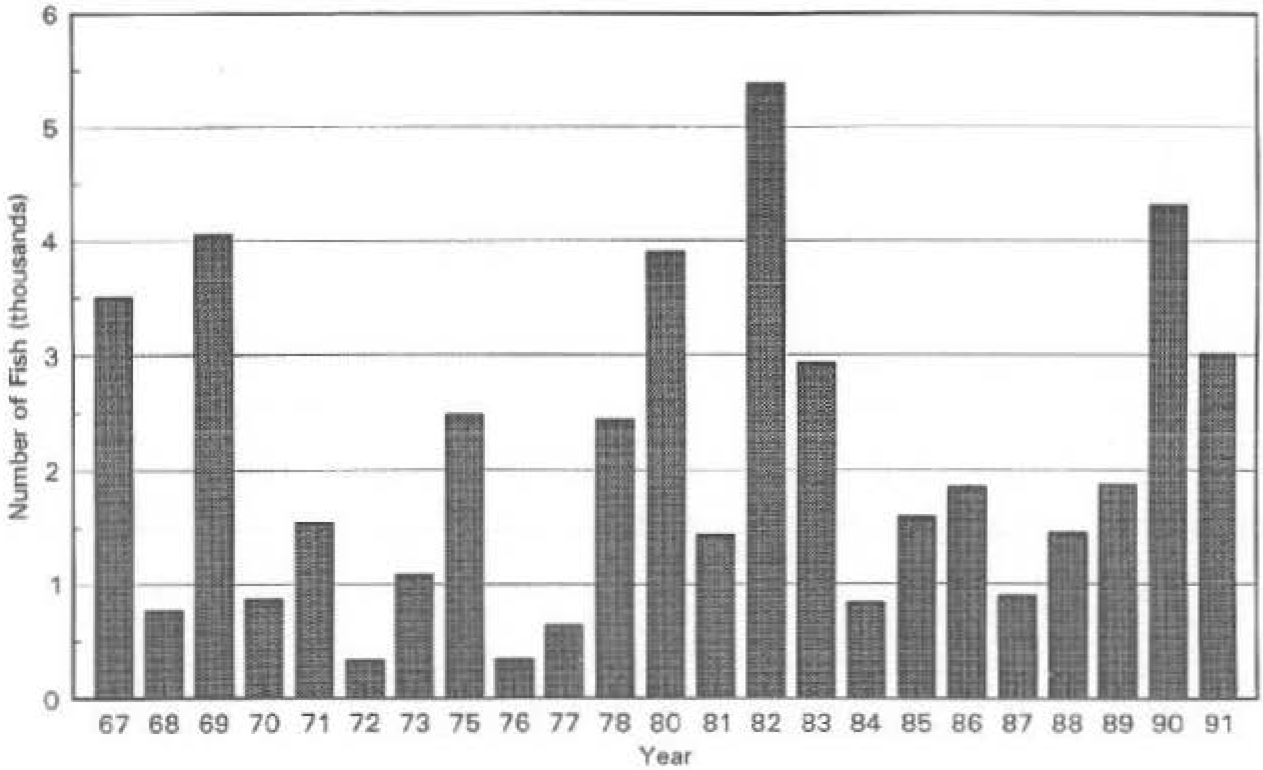
RELATIONSHIP BETWEEN 8-MM LARVAL STRIPED BASS ABUNDANCE AND 38-MM JUVENILE STRIPED BASS ABUNDANCE

FIGURE 2-VI-33

SOURCE: Moyle 1993.

DISTRIBUTION OF AMERICAN SHAD IN CALIFORNIA

FIGURE 2-VI-34



YOUNG-OF-YEAR AMERICAN SHAD ABUNDANCE IN THE SACRAMENTO-SAN JOAQUIN ESTUARY (1967-1991)

FIGURE 2-VI-35

rivers; and the Klamath, Russian, and Eel rivers (Figure 2-VI-34). The greatest proportion of the population is found in the Sacramento River drainage (Skinner 1962). Smaller shad runs occur in the Mokelumne River, Stanislaus River, sloughs of the south Delta, and the San Joaquin River (Stevens 1972, Moyle 1976). A landlocked population also exists in Millerton Lake (Fresno and Madera counties).

The upstream limit of shad migration is presently dictated by impassable barriers such as dams and water diversion structures. Adult shad do not appear to utilize fish ladders to any appreciable extent, although passage over these barriers is believed possible given proper hydraulic conditions (Skinner 1962). In the Sacramento River drainage, shad migrate up the Sacramento River as far upstream as the RBDD, the Feather River as far upstream as Oroville, the Yuba River as far upstream as Daguerre Point Dam, and the American River as far upstream as Nimbus Dam. Shad are occasionally seen upstream of RBDD and Daguerre Dam.

DFG conducted population estimates in 1976 and 1977 using mark-recapture techniques to estimate the size of the spawning run of adult shad. Fish were captured using gill nets and marked with tags that ensured a reward to anglers as an incentive to return the tags. These studies provide the only specific attempt to estimate adult shad abundance. DFG estimated that the shad population numbered 3.04 million adults and 2.79 million adults in 1976 and 1977, respectively. DFG estimates that these population estimates are approximately one-third to one-half the number present during 1917, based on commercial catch data. (DFG 1987.)

During 1976-1978, the mean annual sport catch ranged from 86,200 to 152,000 adult shad, and angling effort ranged from 35,000 to 55,000 angler-days (Meinz 1981). During this period, 60% of the annual catch was taken from the Sacramento River (Meinz 1981). Angler surveys in 1977 and 1978 determined that sport anglers harvested 79,000 and 140,000 shad, respectively (DFG 1987).

Fall midwater trawl surveys provide an index of YOY abundance in the Delta during September-December (Figure 2-VI-35). These annual surveys have been conducted since 1967 and provide the longest, most accurate index of shad abundance. The peak abundance index was 5,386 in 1982 and the lowest index was 334 in 1972. The index averaged 2,070 during the 1967-1991 period and the median index was 1,596 (occurring in 1985).

White Sturgeon

Mark-recapture population estimates for white sturgeon ≥ 40 inches TL are available from intermittent tagging between 1967 and 1994 (Kohlhorst et al. 1991; California Department of Fish and Game, unpublished data). Estimated abundance was high in 1967 (115,000 fish), decreased to about 21,000 in 1974, then increased to another peak of 120,000 in 1984. Since 1984, the estimated population has decreased again to 37,000 in 1990. Mean estimated white sturgeon abundance from 1967 to 1991 was 77,500.

Catch and catch per net-hour during tagging are generally consistent with the changes in abundance portrayed by the mark-recapture estimates. This does not verify the absolute magnitude of the abundance estimates, but does suggest that they accurately depict general population trends.

Using a maturation schedule and spawning frequency derived from data presented by Doroshov et al. (1988), size composition of the tagging catch, and the mark-recapture population estimates, the number of white sturgeon spawning each year can be estimated (Table 2-VI-3). Since 1967, the spawning population has varied from highs of 25,000-27,000 fish in 1967, 1984, and 1985 to a low of 4,700 fish in 1993. Due to earlier maturation and more frequent spawning, the spawning population consists of about four times as many males as females. In 1990, the most recent year between 1967 and 1991 for which an abundance estimate is available, about 2,200 females spawned (Table 2-VI-3).

Annual recruitment of adults was estimated from abundance estimates and age-composition data. Age composition was estimated by interpreting age from cross sections of the first pectoral fin rays from a sample of fish (1967-1976) or by applying an age-length key derived from these data to lengths of a sample of fish (1979-1993). Age 15 was assumed to be the age of recruitment to adulthood as that is approximately the mean age of first spawning for female white sturgeon in the Sacramento-San Joaquin system. From 1967 to 1991, the number of age 15 recruits varied from about 1,400 in 1974 to 11,500 in 1967. Mean recruitment for this period was 5,600.

Tag returns from anglers catching tagged fish provide an accurate picture of seasonal and annual changes in distribution of white sturgeon if angling effort is distributed similarly to the fish. From 1974 to 1994, 66% of tag returns were received from the Suisun and San Pablo Bay area (Table 2-VI-4). Many sturgeon are found in these two bays throughout the year, but peak fishing in Suisun Bay occurs from November through February; it occurs from December through March in San Pablo Bay (Table 2-VI-4). In San Francisco Bay, over half the annual catch is taken from January through March and almost no fish are caught from August through October.

Some sturgeon move into the Delta in fall and their numbers increase in winter (Table 2-VI-4). A portion of these fish, presumably those that are mature and ready to spawn, move up the Sacramento River and are at highest abundance there from March through May.

Movement of white sturgeon into the San Joaquin River in the spring (Table 2-VI-4) suggests spawning occurs there also. If the number of tag returns from each river is a valid indicator of the relative number of spawning fish, ten times (spring tag return ratio of 60:6; Table 2-VI-4) as many white sturgeon spawn in the Sacramento River as in the San Joaquin River.

In recent years, some white sturgeon have moved out of the estuary and migrated up the coast to Oregon and Washington. Chadwick (1959) reported one white sturgeon tagged in 1954 was returned from the Columbia River, but no additional evidence of coastwise migration was seen until 1985 when a white sturgeon tagged in 1979 was captured in the Chehalis River, Washington. Since then, 15 more tagged white sturgeon have been caught in six river systems north of California. In spite of a large-scale white sturgeon tagging program in the Columbia River in recent years, no Columbia River fish have been recaptured in the Sacramento-San Joaquin system.

The distribution of the white sturgeon catch within the Sacramento-San Joaquin Estuary has changed over the years. Recently, the percentage of tag returns from the delta has increased substantially while returns from San Francisco Bay have declined (Table 2-VI-5). Whether this reflects a change in sturgeon behavior or only a shift in angler effort is unknown.

Another prominent change in the distribution of tag returns occurred in the early 1980s when catches in Suisun Bay decreased and catches in San Pablo Bay increased (Table 2-VI-5). This probably reflects a response to the two extremely wet years (1982 and 1983) in this period because white sturgeon appear to move within the estuary in response to flow, which affects salinity. They are farther upstream when saline water encroaches eastward in dry years and farther downstream when brackish water is pushed westward in wet years. In dry years, 31% of tag returns came from Suisun Bay and 22% from San Pablo Bay. In wet years, 17% of tag returns came from Suisun Bay and 47% from San Pablo Bay.

Table 2-VI-3. Estimate of the number of white sturgeon spawning each year in the Sacramento and San Joaquin rivers.

Year	1954	1967	1968	1974	1979	1984	1985	1987	1990	1993
Abundance	11200	114700	40000	20700	74500	119800	107700	106100	36700	23100
Size composition										
100-120 cm	0.1666	0.4341	0.4341	0.386	0.5985	0.5413	0.4126	0.442	0.3977	0.6993
121-140 cm	0.2102	0.3492	0.3492	0.2641	0.2744	0.3486	0.4376	0.3821	0.3324	0.1812
141-160 cm	0.4723	0.1614	0.1614	0.2596	0.089	0.087	0.1207	0.1366	0.2031	0.082
161-180 cm	0.1295	0.041	0.041	0.077	0.034	0.02	0.025	0.031	0.048	0.031
>180 cm	0.021	0.014	0.014	0.014	0	0	0	0.01	0.019	0.01
Fraction mature		Males	Females							

100-120 cm		0.28	0.05							
121-140 cm		0.41	0.12							
141-160 cm		0.47	0.20							
161-180 cm		0.54	0.27							
>180 cm		0.33	0.26							
Spawners (by size group)										
Year	1954	1967	1968	1974	1979	1984	1985	1987	1990	1993
Males										
100-120 cm	261	6971	2431	1119	6242	9079	6221	6565	2043	2262
121-140 cm	483	8211	2863	1121	4191	8561	9662	8311	2501	858
141-160 cm	1243	4350	1517	1263	1560	2444	3055	3406	1752	442
161-180 cm	392	1273	444	429	676	634	715	874	479	192
>180 cm	40	269	94	46	54	75	78	154	112	27
Total males	2418	21074	7349	3978	12723	20793	19731	19310	6886	3782
Females										
100-120 cm	47	1245	434	200	1115	1621	1111	1172	365	404
121-140 cm	141	2403	838	328	1227	2506	2828	2432	732	251
141-160 cm	529	1851	646	537	664	1040	1300	1449	745	188
161-180 cm	196	636	222	215	338	317	358	437	239	96
>180 cm	31	212	74	36	43	59	62	121	88	22
Total females	944	6347	2214	1316	3386	5543	5658	5612	2170	961
Total spawners	3362	27421	9563	5294	16109	26336	25389	24922	9056	4742

Note: Abundance estimates in 1991 and 1993 are based on the ratio of tagging catch per net-hour in those years to catch per net-hour in 1990.

Table 2-VI-4. Tag returns by area and month for white sturgeon tagged in the Sacramento-San Joaquin Estuary and recovered by anglers from 1974 to 1994.

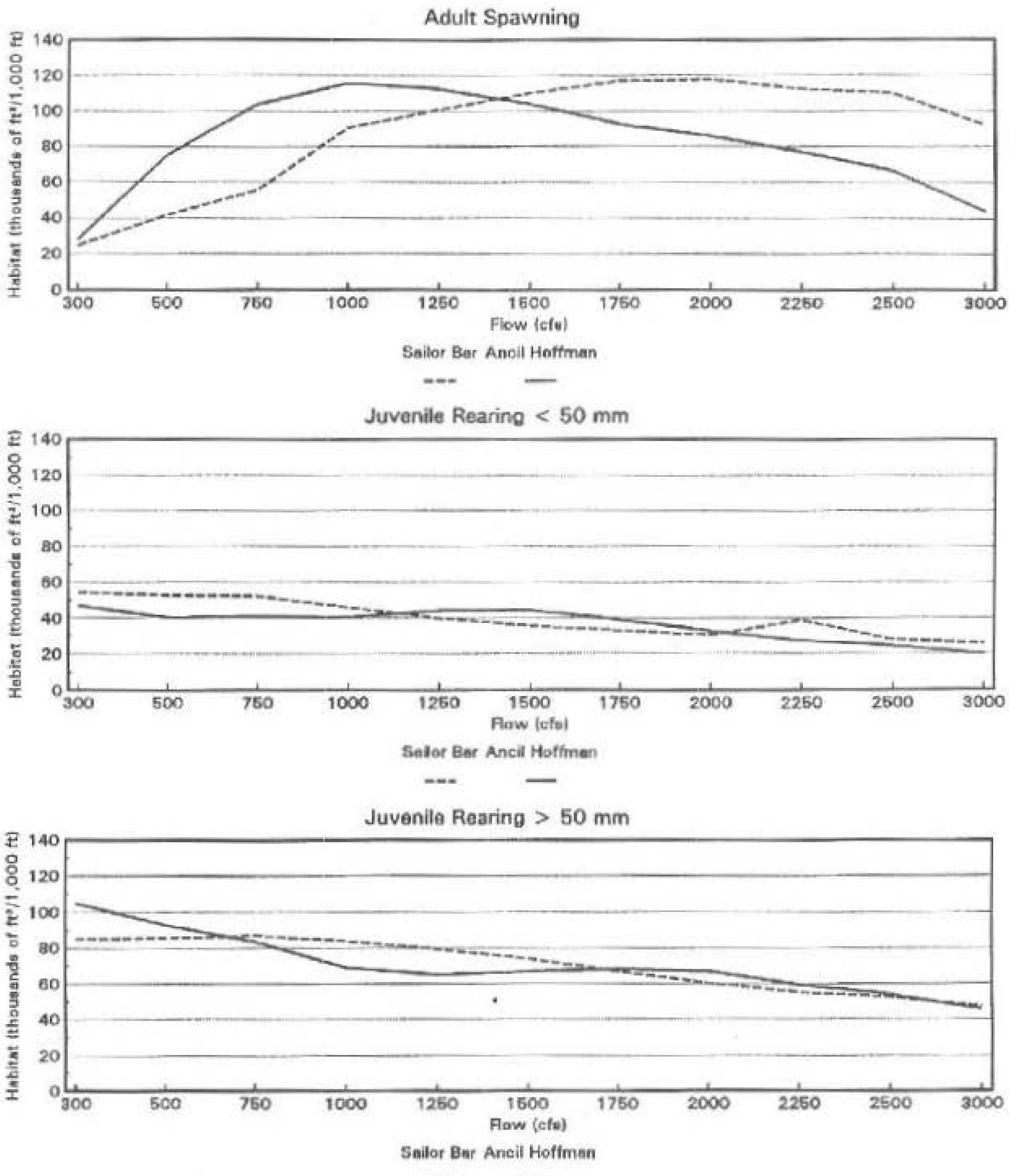
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sacramento River	3	2	20	30	10	3	1	0	0	0	1	2	72
Feather River	0	0	0	0	0	0	1	0	0	0	0	0	1
San Joaquin River	0	0	4	1	1	0	0	0	0	0	0	0	6
Delta	30	34	31	20	10	4	0	0	7	6	17	16	175
Suisun Bay	69	50	35	32	33	32	28	24	26	34	55	71	489
San Pablo Bay	82	91	141	61	48	43	22	16	16	36	43	82	681
San Francisco Bay	58	51	84	46	19	5	2	1	1	1	14	49	331
Pacific Ocean	0	0	1	1	0	1	0	0	0	0	0	0	3
Oregon-Washington	0	4	2	2	0	1	4	2	1	0	0	0	16
Total	242	232	318	193	121	89	58	43	51	77	130	220	1774
Percent of total	14	13	18	11	7	5	3	2	3	4	7	12	

Table 2-VI-5. Tag returns by area and 5-year period for white sturgeon tagged in the Sacramento-San Joaquin Estuary and recovered by anglers from 1975 to 1994.

Location	1975-1979	1980-1984	1985-1989	1990-1994
Sacramento River	5	5	3	6

Location	1975-1979	1980-1984	1985-1989	1990-1994
Feather River	0	0	<1	0
San Joaquin River	1	1	<1	<1
Delta	9	9	8	21
Suisun Bay	28	14	30	32
San Pablo Bay	43	53	36	31
San Francisco Bay	14	18	22	7
Pacific Ocean	0	<1	<1	<1
Oregon-Washington	0	0	1	2

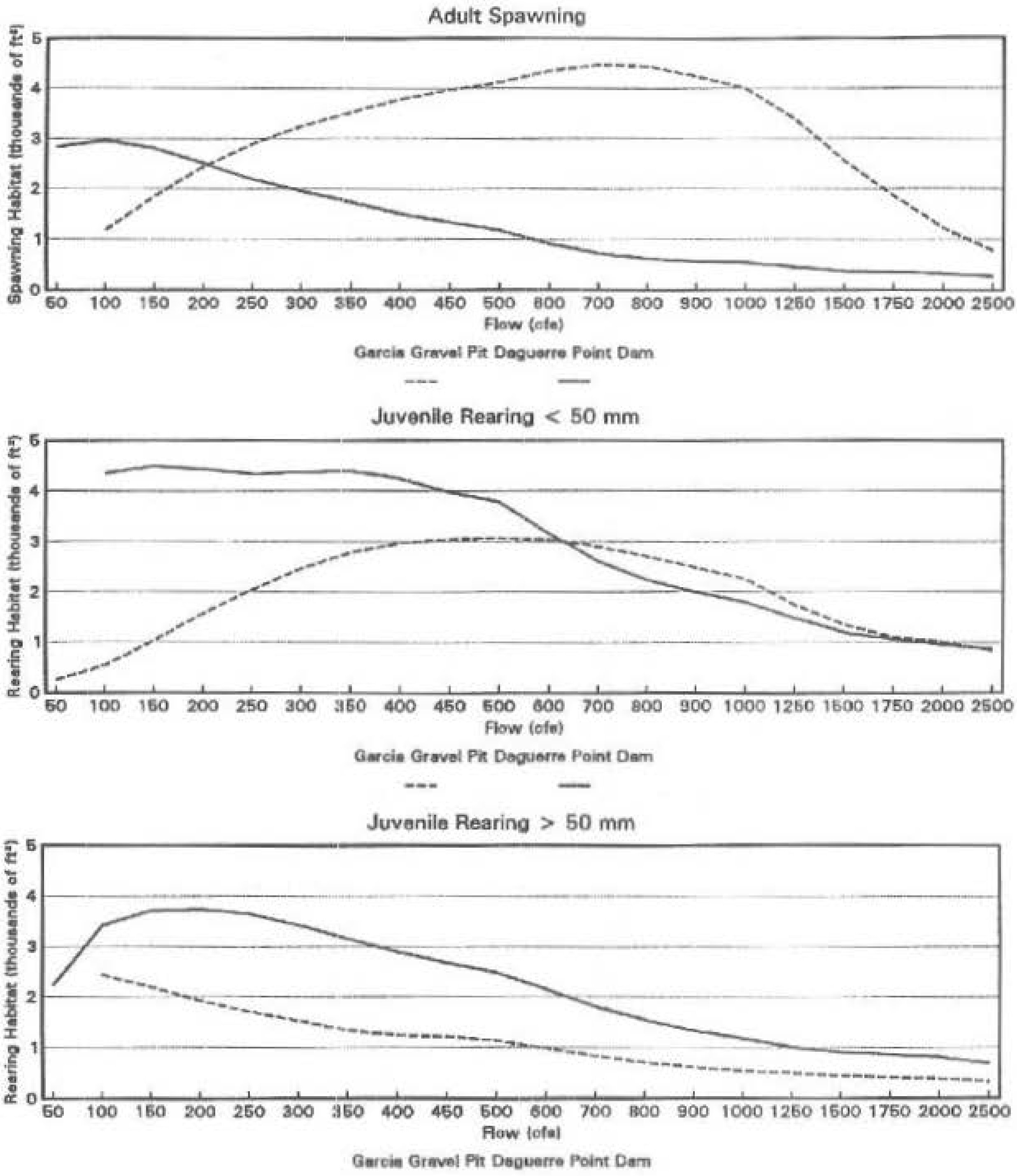
Note: Values in the table are percentages of the total 5-year period tag returns.



SOURCE: U. S. Fish and Wildlife Service (1985).

FLOW VERSUS HABITAT AVAILABILITY FOR CHINOOK SALMON SPAWNING AND JUVENILE REARING IN SELECTED REACHES OF THE LOWER AMERICAN RIVER

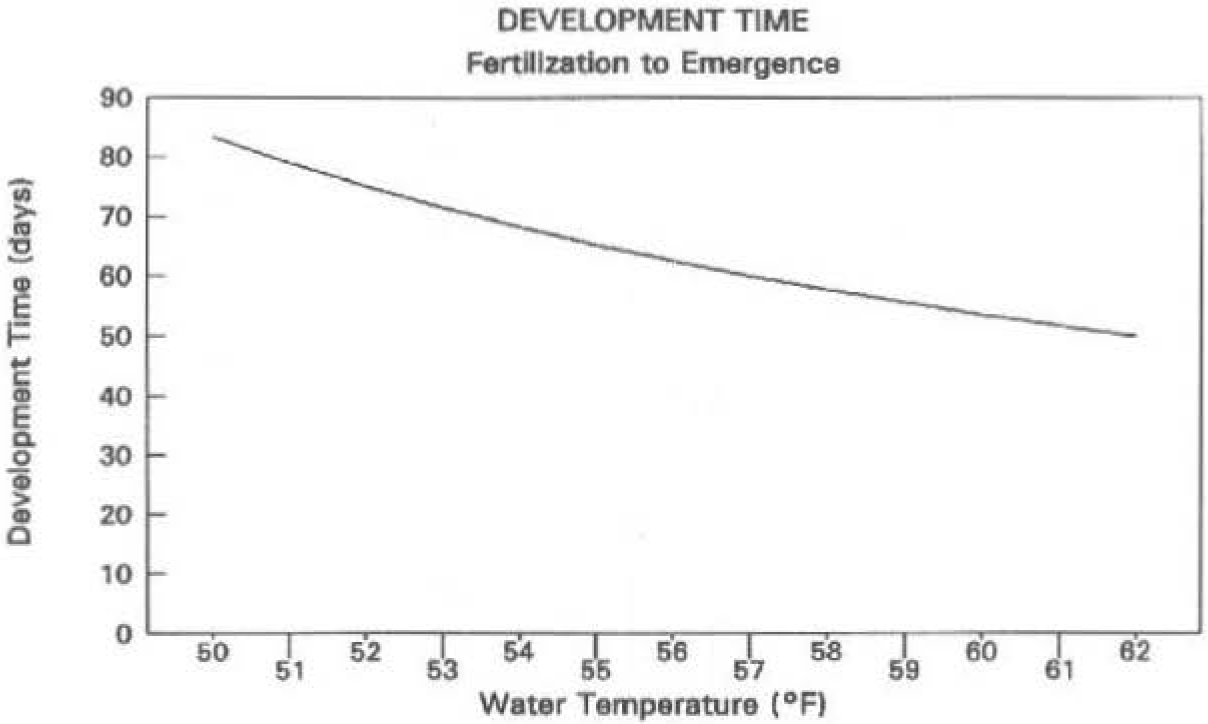
FIGURE 2-VI-36

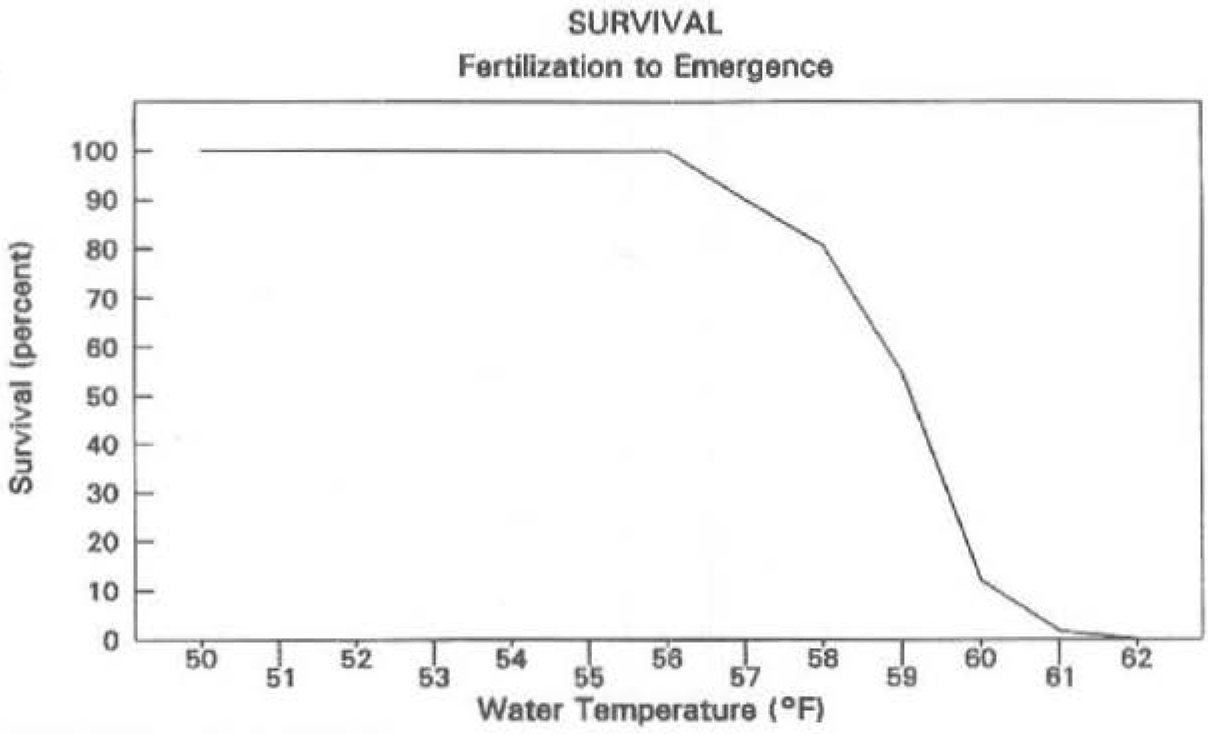


SOURCE: Beak (1989).

FLOW VERSUS HABITAT AVAILABILITY FOR CHINOOK SALMON SPAWNING AND JUVENILE REARING IN SELECTED REACHES OF THE YUBA RIVER

FIGURE 2-VI-37





SOURCE: U. S. Bureau of Reclamation 1992a.

CHINOOK SALMON EGG AND LARVAL DEVELOPMENT TIME AND SURVIVAL VERSUS WATER TEMPERATURE

FIGURE 2-VI-38

Green Sturgeon

During the baseline period, 143 green sturgeon were tagged, and an additional 26 fish were tagged between 1954 and 1965. None have been recaptured during subsequent sampling, so no independent estimates of abundance is possible. As an alternative, green sturgeon abundance in the estuary in the fall was estimated by dividing white sturgeon abundance estimates by the ratio of white to green sturgeon observed during tagging. Because the number of green sturgeon captured each year was so low, no length-age analysis was available to provide information regarding production.

During the baseline period, green sturgeon populations varied from a high of 1,850 fish in 1967 to a low of 203 fish in 1974. The estimate of average baseline population was 983 fish.

ENVIRONMENTAL REQUIREMENTS

Chinook Salmon

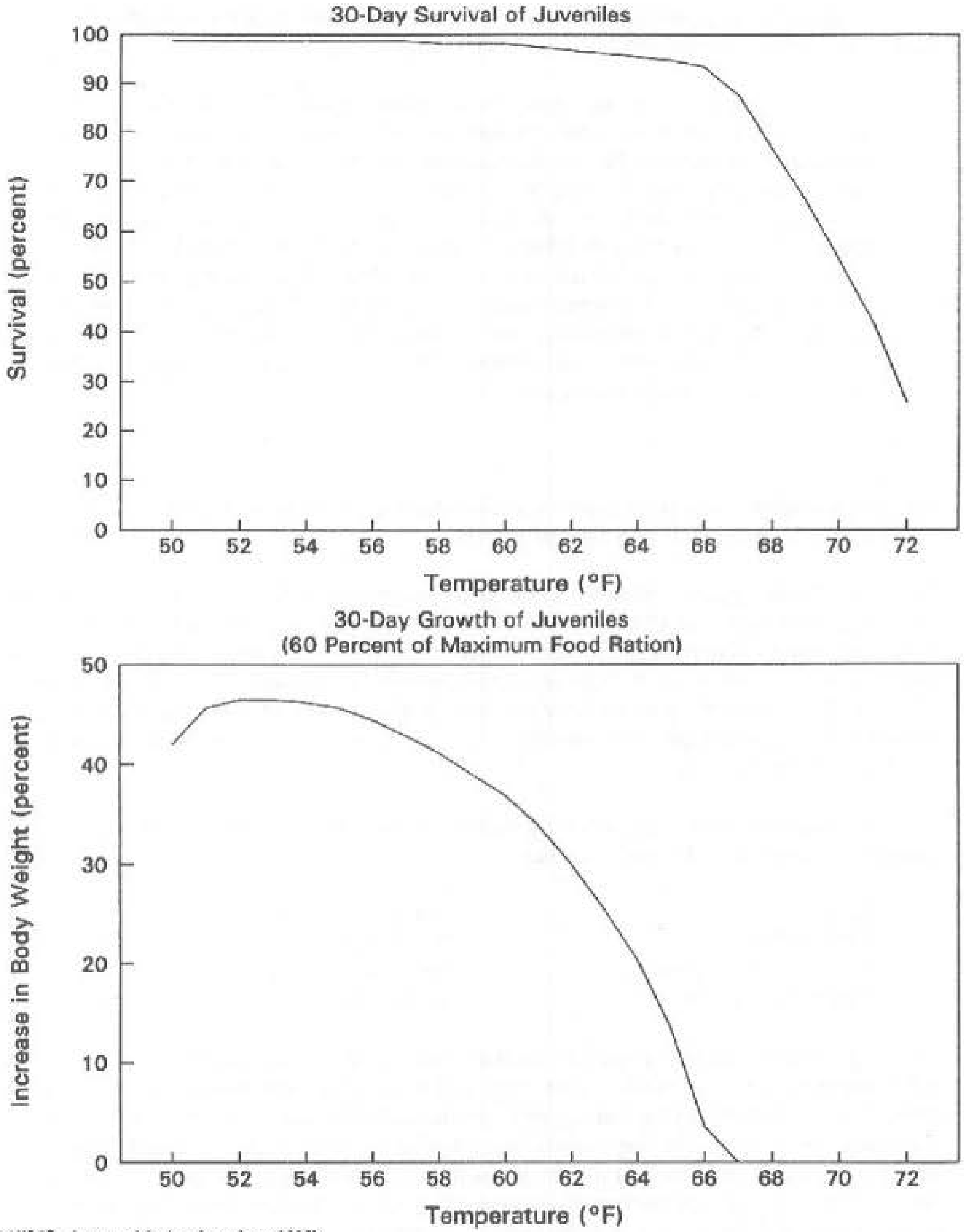
Upstream migration - Seasonal increases in streamflow provide an important migration cue for adult chinook salmon. Higher flows and associated lower water temperatures in the fall stimulate upstream migration of fall-run chinook salmon.

Upstream migrations of fall-run chinook salmon generally coincide with decreasing water temperatures in fall. Water temperatures during upstream migration usually range from 51°F to 67°F (Bell 1973). Hallock (1970) found that chinook salmon initiated migration into the lower San Joaquin River as water temperatures declined from 72°F to 66°F.

Minimum depths are necessary for successful upstream migration of adult salmon. For chinook salmon, Thompson (1972) recommended that a minimum depth of 0.8 foot extend over at least a 10% continuous portion of the stream's cross-sectional profile. In addition, the minimum depth should extend over at least 25% of the stream's cross-sectional profile overall.

Spawning - Spawning typically occurs at the lower end of a pool or head of a riffle. Females generally prefer gravel ranging from 1 to 6 inches in diameter, depths exceeding 0.5 foot deep, and water velocities ranging from 1.5 to 2.5 fps (Vogel and Marine 1991), although the range in depths, water velocities, and substrate composition that chinook salmon find acceptable is very broad (Healey 1991). Provided the condition of good subgravel flow is met, chinook salmon apparently will spawn in water that is shallow or deep, slow, or fast and where the gravel is coarse or fine.

Streamflow influences the quantity, quality, and distribution of chinook salmon spawning habitat. Streamflow directly affects the amount of available spawning habitat by defining the stream area with



SOURCE: Jones and Stokes Associates 1992b.

JUVENILE CHINOOK SALMON GROWTH AND SURVIVAL VERSUS WATER TEMPERATURE

FIGURE 2-VI-39

appropriate combinations of water depths, velocities, and streambed characteristics (e.g., substrate composition). Indirect effects of flow on spawning habitat include effects on water temperature and water quality, which influence the longitudinal extent and seasonal availability of suitable spawning habitat.

Relationships between streamflow and chinook salmon spawning habitat availability have been developed for several streams in the Sacramento basin through application of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982) and related techniques. The results have formed the basis for assessing instream flow requirements or evaluating alternative operations and reservoir release schedules. Habitat-discharge relationships are currently available for the American River (USFWS 1985) and Yuba River (Beak 1989) (Figures 2-VI-36 and 2-VI-37) and are being developed for the Feather and upper Sacramento rivers.

Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females subjected to lower water temperatures. Extremely cold water (less than 38°F) also results in poor adult survival and egg viability (Hinze 1959).

Incubation - Incubation time declines with increasing water temperatures. Maximum survival of incubating eggs and yolk-sac larvae occurs at water temperatures between 41°F and 56°F. At constant water temperatures, survival through emergence decreases at water temperatures exceeding 56°F, with no survival occurring at 62°F or higher (Figure 2-VI-38). The effects of hourly or daily fluctuations in water temperature above 56°F on eggs and yolk-sac larvae are largely unknown.

Hatching success is also adversely affected by reductions in dissolved oxygen and increases in metabolic waste products resulting from inadequate water flow through the redd. Inadequate intragravel flow may be caused by streamflow reductions following spawning or increases in the quantity of fine sediments in the gravel. Incubating eggs and larvae require dissolved oxygen at saturation levels. Optimum levels equal or exceed 8 milligrams per liter at temperatures between 44°F and 50°F and equal or exceed 12 milligrams per liter at temperatures above 50°F (Raleigh et al. 1986).

Rearing - Chinook salmon fry tend to seek shallow, nearshore habitat with low water velocities and move to progressively deeper, faster water as they grow. In streams, chinook salmon fry feed mainly on drifting terrestrial and aquatic insects, but zooplankton become more important in the lower river reaches and estuaries.

Streamflow is a dominant variable affecting chinook salmon rearing habitat. Streamflow directly determines the amount of physical habitat with appropriate combinations of depth, velocity, substrate, and cover for chinook salmon rearing. Streamflow also influences the extent of suitable water temperatures, water quality conditions, and habitat for production of aquatic invertebrates, a major food source for juvenile salmonids in fresh water. Relationships between streamflow and juvenile rearing habitat have been developed for the American and Yuba rivers through application of IFIM (Bovee 1982) (Figures 2-VI-36 and 2-VI-37).

The habitat preferences of juvenile chinook salmon change with increasing body size; newly emerged chinook salmon fry typically occur along marginal areas of streams but seek faster, deeper water as they grow (Lister and Genoe 1970, Everest and Chapman 1972). Generally, chinook salmon fry prefer depths of 0.5-3 feet and water velocities of 0.1-1 fps (Raleigh et al. 1986).

In general, juvenile chinook salmon tolerate water temperatures from 32°F to 75°F, but the optimal range for survival and growth is from 53°F to 64°F (Raleigh et al. 1986). In the natural environment, water temperature affects juvenile chinook salmon growth and survival through complex physiological responses that can be modified by acclimation and behavior. In general, responses to water temperature vary depending on fish size; the duration and frequency of exposure to a given water temperature; physical habitat conditions; food availability; and the presence of competitors, predators, or disease.

Figure 2-VI-40 presents survival and growth rates of juvenile chinook salmon fed maximum rations and exposed to different water temperatures under laboratory conditions. Because maximum feeding levels are probably seldom realized in the natural environment, the growth curve was modified based on a 60% ration level.

Downstream migration - Flow influences distribution, abundance, and survival of emigrating juvenile salmonids. Generally, higher flows improve survival and migration success of juvenile salmonids by increasing migration rates, reducing exposure to diversions (i.e., reducing the proportion of flow diverted), and maintaining favorable water quality conditions (e.g., water temperature). Other factors that may influence the success and timing of juvenile chinook downstream migrations include growth rate, interspecific competition, and genetic makeup (i.e., ocean-versus stream-type life history strategies).

Ocean life - Overall salmon production depends on both freshwater conditions (factors affecting adult migration, spawning, incubation, rearing, and emigration) and ocean conditions (factors affecting ocean salmon growth, survival, and migration back to fresh water). Much more is known about the freshwater life history, biology, and environmental requirements of salmon. The ocean ecology of salmon has been generally neglected, and studies of the factors affecting chinook salmon populations in the ocean have only recently been initiated (Pearcy 1992).

Ocean survival of salmon depends on a complex interaction of oceanographic, meteorologic, and biologic factors. Increased marine survival of Pacific salmon is commonly associated with upwelling events that bring cold nutrient-rich water from deep ocean layers to the surface along the eastern Pacific Coast during spring and summer (Lichatowich 1993). El Niño events, which transport warm, low-salinity water from subtropical regions, can suppress or reduce the intensity of upwelling, leading to poor marine survival and reduced abundance of adult salmon. The periodic, southward transport of subarctic waters also enhances productivity off California. In addition, increased marine exploitation of important forage species (e.g., California sardine, hake, and anchovy) has likely affected ocean salmon production. Overall, forage fish biomass in the California current declined from approximately 25 million tons in 1905 to 4.5 million tons by

1950 and has remained well below historical levels. Before the collapse of the California sardine market, the sardine may have been an exceptionally rich energy source for salmon and a buffer against predation during the species' first summer at sea (Lichatowich 1993). Lichatowich stated:

> If the California current has undergone a "change in state" that influences salmon production then it follows that the state of the freshwater links in the chain may become more important. Healthy freshwater habitats may become more critical when oceanic productivities are lower and marine mortality higher. Our degradation of freshwater habitat combined with cyclic changes in ocean productivity and high harvest rates may have had the effect of "burning the candle at both ends." Cycles of ocean productivity can at the very least mask the effects of improvements in freshwater habitat or hatchery production or cause us to falsely attribute increased marine survival to restoration effects in freshwater. However, there may be important additive or multiplicative consequences of freshwater habitat degradation in the troughs of ocean productivity cycles.

Steelhead

Upstream migration - Upstream migrations of steelhead generally coincide with flow increases and temperature decreases, similar to chinook salmon.

Spawning - Spawning flow needs for steelhead are a function of the flow necessary over suitable spawning gravels to provide appropriate water depths and current velocities for successful spawning. The water also must be of sufficient temperature and quality. Barnhart (1986) reported steelhead spawning in water depths of 5-28 inches, and Bovee (1978) reported an average water depth of 14 inches. Barnhart (1986) also reported steelhead spawning in water velocities of 0.5-3.6 fps, and Bovee (1978) reported a preferred velocity of 2.0 fps. Reynolds et al. (1993) reported a spawning velocity preference of 1.5 fps.

From various experiments and literature sources, Leidy and Li (1987) reported the following temperature ranges for steelhead spawning:

Optimum	46.0-52.0^{o}F
Chronic low stress	52.1-57.5^{o}F
Chronic medium stress	57.6-61.0^{o}F
Chronic high stress	Greater than 61.0^{o}F

Spawning redd sites selected by steelhead generally have gravel particle sizes that are 0.25-3.0 inches in diameter (Reynolds et al. 1993). The average redd size for Sacramento River basin steelhead also appears to be smaller than the average redd size in California streams reported as 56 square feet (Reynolds et al. 1993). Spawning success (egg hatching and fry emergence) is highly dependent on flow, temperature, and dissolved oxygen surrounding the developing embryos. Gravels with high permeability and few fines (less than 5% sand and silt by weight) were reported by Barnhart (1986) as existing in highly productive steelhead spawning streams.

Incubation - Egg incubation time in the gravel is determined by water temperature, varying from about 19 days at an average water temperature of 60^{o}F to about 80 days at an average temperature of 40^{o}F. Up to 80-90% of the eggs hatch under favorable conditions (Skinner 1962). Steelhead seem to tolerate fewer fines than chinook salmon, probably because oxygen requirements for developing embryos are higher (Reynolds et al. 1990). Positive correlations have been demonstrated between steelhead egg and embryo survival and both the percolation rate of water through gravels and the oxygen content of the water (Reynolds et al. 1990). Steelhead fry usually emerge from the gravel 2-8 weeks after hatching (Barnhart 1986, Reynolds et al. 1993), which usually occurs in April and May on the American River (McEwan and Nelson 1991).

In order for the fry to emerge, physical and chemical conditions must remain fairly constant within the indicated ranges throughout the approximate 2-month period that the eggs and pre-emergent fry are in the gravel.

Rearing - Steelhead fry usually live in small schools in shallow water along stream banks following emergence from the gravel. Mortality is high in the first few months after emergence. As the steelhead grow, the schools break up and the fish establish individual feeding territories. Though most live in riffles in their first year of life, some of the larger steelhead live in deeper, faster runs or pools. Their appearance and life are similar to that of nonanadromous resident rainbow trout.

Habitat and other related factors affecting juvenile steelhead in the Sacramento River system are similar to those described for juvenile chinook salmon. Chinook salmon generally emigrate within a few months after emergence, however, and steelhead rear to a larger size than salmon. Consequently, juvenile steelhead are more dependent on larger and more abundant food resources than are salmon and also utilize deeper and faster runs and pools as they grow to larger sizes before emigration.

Another major difference between salmon and steelhead juvenile rearing is that steelhead juveniles must have suitable summer habitats (e.g., flows and water temperatures); juvenile chinook salmon generally are not present in tributary streams during summer. Juvenile steelhead summer rearing habitat in the form of suitable flows and water temperatures is generally characterized as the major factor limiting steelhead abundance. The presence of upstream barriers, typically large dams, also limits steelhead rearing to physical habitats (typically large, mainstem tributary rivers) that are not optimal or suitable for steelhead rearing.

Rearing flows need to be adequate to provide the physical habitat needed by steelhead fry and juveniles, as well as that needed to produce the aquatic insects and other invertebrates on which they feed. Bovee (1978) shows steelhead fry using water approximately 2-15 inches deep but preferring water about 8 inches deep. Suitable water velocities are generally 0.3 to 1.0 fps, with optimal velocities about 0.6 fps. Bovee (1978) shows steelhead juveniles using deeper and faster water with water depths approximately 7-24 inches deep, with optimal depths about 14 inches, and velocities about 0.3-1.5 fps, with optimal velocities about 0.9 fps. The existence of pools can be especially important in streams that are naturally or artificially subjected to low-flow conditions in summer and fall.

From various experiments and literature sources, Leidy and Li (1987) generated the following temperature ranges for steelhead fry and juvenile rearing in the American River:

Optimum	55.0-60.0°F
Chronic low stress	60.1-68.0°F
Chronic medium stress	68.1-72.5°F
Chronic high stress	Greater than 72.5°F

The actual effects of chronic low, medium, or high stress temperatures on abundance, however, depend on several factors, including exposure duration, acclimation abilities, food availability, water quality, and groundwater dynamics. Numerous other water temperature criteria available for steelhead fry and juvenile that are not presented here are the basis of the criteria developed by Leidy and Li (1987).

Juvenile downstream migration - Juvenile steelhead emigration rates are influenced by water temperatures and current velocities. Although some steelhead have been collected in most months at the state and federal pumping plants in the Delta, the peak numbers salvaged at these facilities have been primarily in March and April in most years.

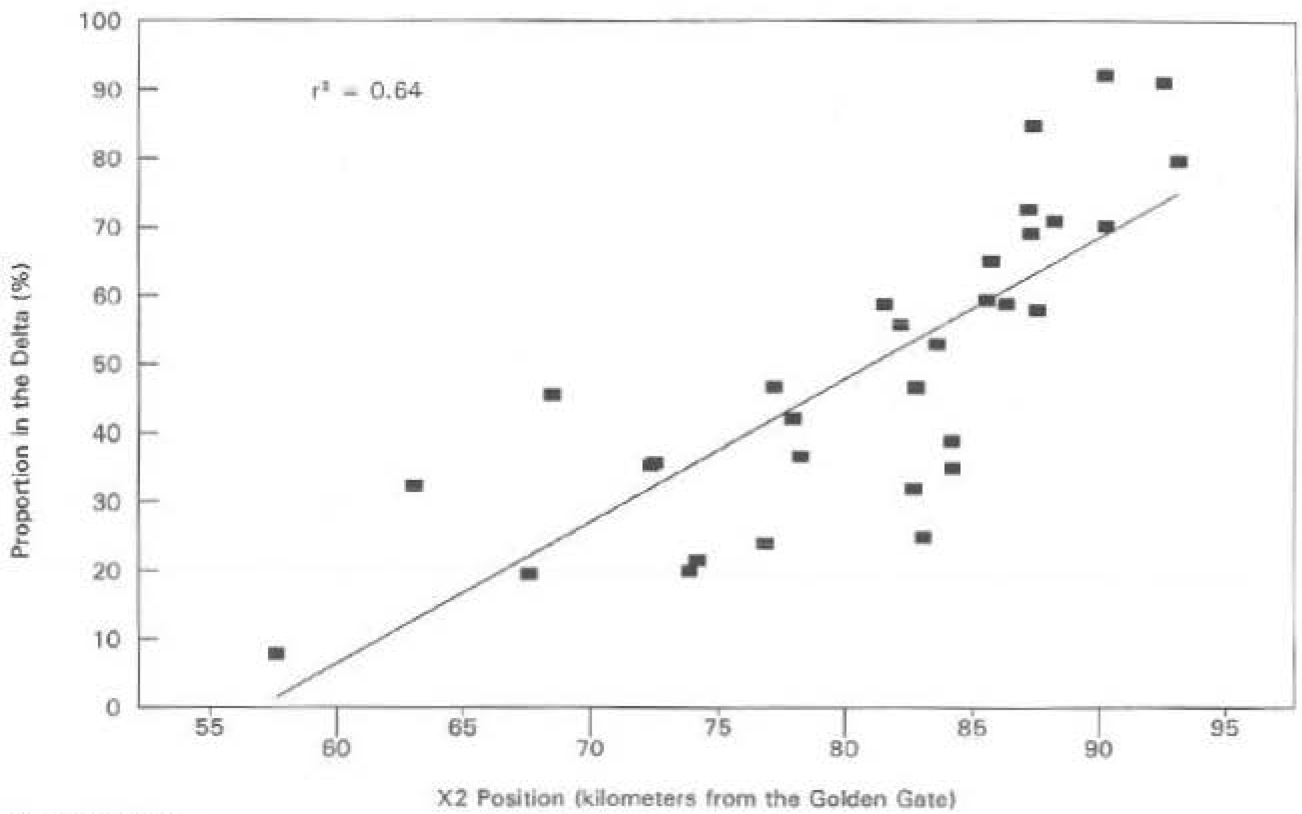
From various experiments and literature sources, Leidy and Li (1987) reported the following temperature ranges for steelhead emigration and smoltification:

Optimum	44.4-52.3°F
Chronic low stress	52.4-59.3°F
Chronic medium stress	59.4-63.2°F
Chronic high stress	Greater than 63.2°F

Again, these are general ranges and the actual effects of these temperature ranges on steelhead emigration survival depend on numerous other factors. Additional sources of information that cite temperature criteria or preferences for steelhead are available.

In their review, Raleigh et al. (1984) reported that photoperiod appeared to be the dominant triggering mechanism for smolt transformation, with temperature affecting the rate of transformation. Juvenile steelhead kept in water warmer than 55.4°F from March through June were reported to sustain reduced levels of smoltification. However, reduced flows and coincident warming spring water temperatures, a natural phenomena prior to dams, and high flows or freshets may also trigger juvenile emigration.

Ocean life - Little is known about steelhead and their environmental requirements during the 1 or 2 years that most spend in the ocean. Mortalities during this period are almost exclusively from natural conditions in



Source: Hempsell (1993).

PROPORTION OF THE YOUNG-OF-YEAR STRIPED BASS POPULATION (38-MM INDEX) IN THE DELTA RELATIVE TO THE LOCATION OF X2 (2 PPT SALINITY OR ABOUT 3,000 μS EC) IN JULY (1959-1991)

FIGURE 2-VI-40

the ocean environment. There is no commercial or sport fishery for steelhead in the ocean, and for unknown reasons, they are rarely taken by commercial or sport salmon trollers (Skinner 1962).

Striped Bass

Upstream migration - Upstream migration of striped bass is likely controlled by flow, water temperature, and seasonal factors in the Sacramento-San Joaquin River system.

Spawning - Spawning may begin after the water temperature exceeds approximately 58^{o}F and during, or immediately following, an average temperature rise of 34-36^{o}F (Turner 1976). Spawning generally occurs when temperatures are increasing and is most intense at water temperatures from 63-68^{o}F to (Turner 1976, Mitchell 1987). Most eggs are spawned during peaks that may last one or several days (Interagency Ecological Studies Program 1991, 1993). During the spawning season, two to four peaks encompass most of the annual egg production.

Spawning peaks in the Sacramento River and the Delta have occurred over a temperature range of 58-71^{o}F. The average water temperature during a peak spawning event was 64^{o} F.

Although spawning in the Delta has occurred when salinity exceeded 1,500 microsiemens (uS) electrical conductivity (EC), the effect on egg and larva survival is unknown (DFG 1987). Laboratory studies indicate that salinities less than 1,500 uS EC do not adversely affect egg survival.

The downstream extent of spawning is usually near Antioch, but in years when salinity intruded into the Delta, spawning occurred several miles farther upstream (DFG 1987). The shift in spawning has not always avoided higher than normal salinity, and spawning has been recorded in salinities exceeding 1,500 uS EC. Striped bass generally return to the same spawning area each year, but regular occurrence of high salinities may gradually reduce the use of the lower San Joaquin River in the Delta as a spawning area because of the preference of fresh water for spawning.

Incubation - In the Sacramento River, eggs and larvae are transported downstream of Rio Vista within a few days and arrive in the Delta before larvae begin feeding (Low and Miller 1986). The destination of egg and larval striped bass appears to be a function of flow conditions (Turner 1987). Under high Sacramento River flow and high Delta outflow, eggs and larvae from both the Sacramento River and Delta spawnings are concentrated downstream in Suisun Bay. Under low-flow conditions, eggs and larvae are generally concentrated in the Delta.

The movement of eggs and larvae downstream in the Sacramento River is clearly a function of flow, with higher flows moving eggs and larvae more rapidly downstream. Once eggs and larvae are in the Delta, movement downstream may become more dependent on larval and juvenile behavior and the location of the entrapment zone (i.e., the zone where salinity is between 2,000 and 10,000 uS EC).

Larval striped bass accumulate in or upstream of the entrapment zone (i.e., near or upstream of salinity greater than 2,000 uS EC) (Fujimura 1991, Kimmerer 1992). Larvae are concentrated in the entrapment zone and slightly upstream, consistent with larval behavior to avoid the surface and to concentrate at mid-depth and near the bottom (Fujimura 1991). Striped bass do not appear to undergo diel (i.e., night and day) vertical movements to maintain position with their prey. Position in the water column may be a function of factors other than feeding.

Rearing - Similar to larvae, early juveniles at least 1.52 inches long accumulate in or upstream of the entrapment zone (i.e., near or upstream of salinity greater than 2,000 uS EC) (Fujimura 1991, Kimmerer 1992) (Figure 2-VI-40). During high-flow years, the entrapment zone and most YOY striped bass are located in Suisun Bay into fall (Turner and Chadwick 1972). During low-flow years, the entrapment zone and most YOY striped bass are located in the Delta. YOY bass tend to move out of the Delta and into Suisun and San Pablo bays during late fall and winter (Sasaki 1966a, 1966b; Turner and Chadwick 1972). Movement downstream is more apparent in low-flow years and obscured during high flow years. After the winter of the first year, movements of juvenile striped bass appear to be similar to adult bass.

American Shad

Upstream migration and spawning - Instream flows and water temperatures are the most critical environmental requirements for successful shad migration and spawning. Flow relationships are important for determining the spawning river chosen by virgin shad, and temperature is an important factor triggering migration and spawning behavior.

The timing of spawning migrations is highly correlated with water temperature. Upstream migration of adult shad generally occurs as water temperatures increase during spring. However, adult shad may discontinue their upstream migration if water temperatures exceed 68°F (Stier and Crance 1985). Furthermore, water temperatures exceeding 68°F are known to increase mortality among postspawning adults (Moyle 1976). The initiation of spawning is also correlated with water temperatures; spawning is generally delayed until water temperatures exceed 60°F.

Water temperature appears to be the most important factor that determines the timing of shad spawning. Spawning may occur at water temperatures as low as 50°F, but the general range appears to be 60-75°F. The optimum range is likely 62-68 °F (Skinner 1962). In the Feather River, shad spawning does not occur until water temperatures reach 60°F and peaks at 70°F (Painter et al. 1977). In the Yuba River, shad spawning did not occur until mean daily temperature reached 61°F (Jones & Stokes Associates 1990). Most shad spawning occurs in May and June.

Spawning typically occurs over sand to gravel substrates in depths of 3-30 feet (Painter et al. 1980). Jones & Stokes Associates (1990) concurred with the depth findings but found spawners concentrated within a specific range of mean water velocities of 1.5-2.4 fps on the Yuba River. Because shad spawning is pelagic and not limited to a fixed site, as is salmon and steelhead spawning, it can occur repeatedly at the same locations without any apparent adverse effect on egg survival.

Dissolved oxygen concentrations of 5.0 milligrams per liter or more are required throughout spawning areas (Walburg and Nichols 1967).

Incubation - Egg survival is closely related to water temperatures. Temperatures for maximum hatching and survival of eggs and larvae are 60°F to 79°F. Leach (1925) reported that 52°F is very near minimum temperature for successful egg incubation. Water temperatures exceeding 80°F are unsuitable for egg hatching and eventual larval development (Carlson 1968). Young shad appear to be extremely tolerant of salinity and salinity changes, beginning at the earliest stages of life. (Steir and Crantz 1985.)

Rearing - Water temperature is an important factor affecting growth and survival of juvenile American shad. The lower thermal tolerance limit is about 36°F, but sublethal effects suggest that prolonged exposure to 40-43°F cannot be tolerated. Juveniles have been generally found in water temperatures ranging from 50°F to 85°F. (Steir and Crance 1985.)

Dissolved oxygen concentration requirements for juvenile rearing are similar to those for adults during upstream migration and spawning.

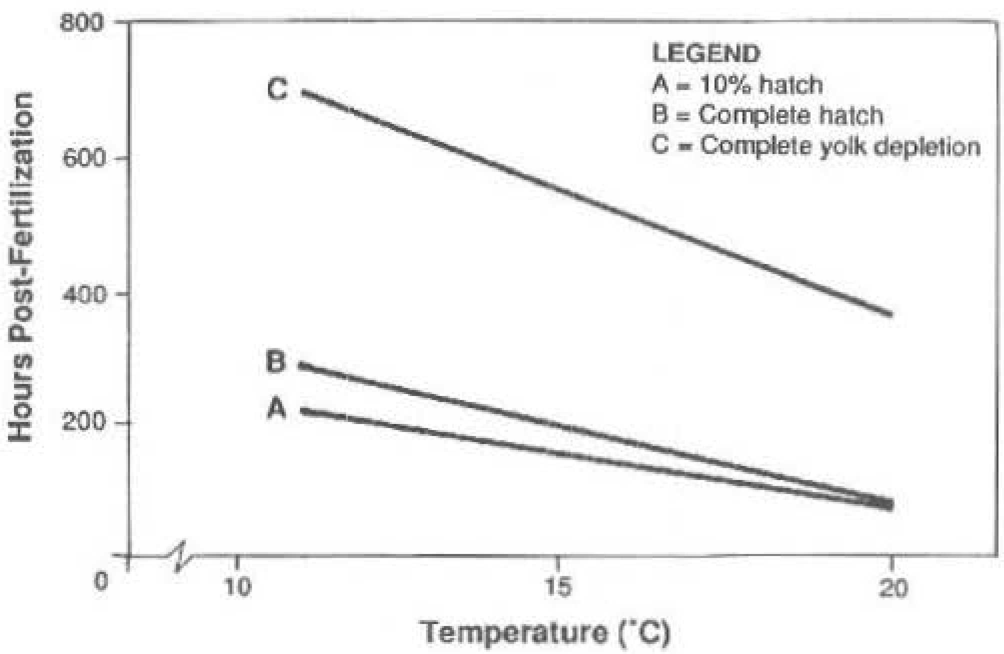
It appears that shad larvae are much less tolerant of suspended sediments than are eggs. Auld and Schubel (1978) reported that concentrations of suspended sediments greater than 100 parts per million significantly reduced survival of shad larvae continuously exposed for 96 hours. (Stier and Crance 1985.)

Food availability could be an important factor for some shad populations. The most critical time in the life cycle apparently occurs when the larvae have first absorbed the yolk and must find their own food (Hildebrand 1963). May (1974), however, does not believe that available data support Hildebrand's hypothesis.

Downstream migration - Little specific information exists on downstream migrations of American shad in California. Juveniles begin emigrating from rivers when water temperatures drop below 60°F (Leggett and Whitney 1972). Environmental requirements are likely similar to those for rearing.

White Sturgeon

Upstream migration - Little information is available concerning the abilities of white sturgeon to negotiate upstream passage barriers. A recent literature search failed to locate information on cruising, sustaining, and darting speeds for white sturgeon (Jones & Stokes Associates 1992). However, sturgeon do spawn in relatively swift water with velocities as high as 10 fps measured in areas where sampling has determined the presence of sturgeon eggs (Parsley et al. 1989).



Source: Wang 1984.

DEVELOPMENTAL TIME OF WHITE STURGEON

FIGURE 2-VI-41

Sturgeon are bottom-oriented fish with limited jumping abilities and have little success migrating past barriers. Warren and Beckman (1991) report that modified fish ladders in the Columbia River that provided orifices through the weirs at the ladder floor increased passage of white sturgeon over several Columbia River dams.

Though limited data exist on environmental conditions required to cue spawning, evidence from the Central Valley indicates that increases in flow may trigger adult movement and spawning. For example, no spawning was detected near Colusa with flows less than 6,356 cubic feet per second (cfs), but spawning did occur after 1 to 3 days of increased flow over that level (Schaffter 1991).

Little is known of the effects of water temperature on upstream migration of white sturgeon in the Sacramento-San Joaquin River system. Water temperature and photoperiod could promote the final stages of egg maturation and initiate upstream migration. Chapman (1989) found that temperature did affect sperm production and hypothesized that it likely affected egg production. Although it has not been shown in the literature for the Sacramento-San Joaquin River system, a threshold temperature may initiate upstream migration and spawning in some populations. Haynes et al. (1978) found that sturgeon migrations in the Columbia River occurred only at temperatures above 55^{o}F. However, sturgeon in the Sacramento River have migrated at temperatures as low as 46^{o}F (Kohlhorst 1976).

Spawning - Little information relating environmental conditions to the initiation or success of spawning in sturgeon is available. In particular, few data exist relating flow with sturgeon spawning habitat or success. White sturgeon in the lower Columbia River spawned in the swiftest water available (2.6 to >9.2 fps mean column velocity) (Parsley et al. 1992). Some preliminary data suggest that flow velocity may trigger spawning in female sturgeon (Schaffter 1990). River flow acts to disperse eggs and prevent clumping of the adhesive eggs.

Sturgeon in the Sacramento-San Joaquin River system spawn within temperature ranges of 46-64^{o}F, with most spawning occurring when water temperatures are 58^{o}F (Kohlhorst 1976); however, Kohlhorst did not note a temperature effect on the intensity of spawning or a temperature threshold for spawning.

Substrate requirements for spawning have not been determined. However, Schaffter (1991) collected fertilized eggs where substrates were primarily gravel and rubble. Because of the adhesive nature of sturgeon eggs, areas of silt-free gravel appear to be required for successful sturgeon spawning. The nature of spawning site selection and the availability of clean gravel spawning areas with sufficient flow are unknown.

Incubation - There are no published data relating environmental conditions to egg incubation and hatching in the wild. Data presented below are from laboratory studies.

Optimum temperatures for incubation and hatching range from 52^{o}F to 63^{o}F; higher temperatures result in greater mortality and premature hatching (Wang et al. 1985, 1987). Under culture conditions, white sturgeon eggs hatch synchronously (Brewer 1987, Conte et al. 1988). Mass hatching of sturgeon eggs generally occurs during darkness (Brewer 1987). Both synchronous hatching and hatching during darkness may be adaptive mechanisms to minimize predation on larvae.

River flow is important to maintain oxygen levels and remove waste products at the egg surface. After sturgeon larvae hatch, the currents act to disperse the larvae downstream from the spawning grounds. Several authors have reported the effects of temperature on incubation and early development of sturgeon (Wang 1984, Wang et al. 1985, Doroshov 1985, Conte et al. 1988). Wang (1984) found a strong inverse correlation between temperature (52-68^{o}F) and incubation period (-0.9567), and temperatures and yolk depletion (-0.9943) in the temperature range of normal development (Figure 2-VI-41). Egg incubation can last 4-14 days after fertilization, while yolk depletion can occur 15-30 days after fertilization. Optimum temperatures for white sturgeon incubation and larval development are between 52^{o}F and 63 ^{o}F (Wang et al. 1987). Higher mortality and premature hatching occurs at 64-68^{o}F. Temperatures of 73-79^{o}F are lethal to sturgeon embryos (Wang 1984). A lower temperature limit has not been defined; however, Wang et al. (1987) suggest that it might be between 43^{o}F and 46^{o}F. Based on Wang's (1984) correlations, incubation and yolk depletion at temperatures reached during the peak spawning season (58^{o}F) (Kohlhorst 1976) would be approximately 9 days and 24 days after fertilization, respectively.

Effects of most water quality parameters on incubation and emergence of white sturgeon are not well documented.

Rearing - Water temperature can affect juvenile sturgeon growth and health. Under laboratory conditions, maximum growth occurs at rearing temperatures of 68^{o}F, but rearing at lower temperatures (61-65^{o}F) reduces the incidence of disease (Cech et al. 1984, Conte et al. 1988).

Daily food ration needs for wild fish are unknown. Under culture conditions promoting maximum growth, young sturgeon are fed 20-30% of their body weight per day until they reach 3 grams and 15% of their body weight until they reach 15 grams (Doroshov et al. 1983). Sturgeon that weigh over 28 grams are fed 1-1.5% of their body weight per day. Because sturgeon primarily feed on benthic organisms, reduced populations of these organisms would likely have the most detrimental effect on sturgeon growth and survival.

Juvenile sturgeon are known to be sensitive to salinity (McEnroe and Cech 1985, Brannon et al. 1985, Brewer 1987), but the effects of other water quality parameters are relatively unknown. Young Sacramento River white sturgeon had low survival in 10 parts per thousand (ppt) salinity (McEnroe and Cech 1985). Salinity tolerance did not appear to change with age or size in larval and juvenile Columbia River white sturgeon (1-83 days before hatching) (Brannon et al. 1985). Larvae and juveniles could not tolerate direct salinity increases to 11 ppt, and no fish survived transfer to aquaria with 16 ppt. Those fish that survived 11 ppt salinity were sluggish in response. Acclimation of larger fish improved tolerance to 15 ppt. Brannon et al. (1985) also demonstrated that sturgeon larvae and fry can respond to salinity gradients by avoiding higher salinity areas in aquaria.

Downstream migration - Adult and subadult Sacramento River white sturgeon currently use San Francisco, San Pablo, and Suisun bays and the Delta year-round (Miller 1972b). Sturgeon distribution in the Delta is significantly correlated to river flow, which also influences salinity regimes (Kohlhorst et al. 1991). As river flow is decreased, the marine waters penetrate farther up into the Delta. During dry years, more tagged fish have been recaptured in Suisun Bay than areas farther downriver. During wet years with higher river flows, more tagged fish were recaptured in San Pablo Bay and areas farther downstream.

Green Sturgeon

Environmental requirements for green sturgeon are largely unknown, but are assumed to be similar to those of white sturgeon.

SECTION VII. PROBLEMS FOR CENTRAL VALLEY ANADROMOUS FISHES

CHINOOK SALMON

General Problems

Upstream migration - Reservoir operations have altered the natural flow regime of Central Valley streams by changing the frequency, magnitude, and timing of flow. These changes potentially affect all chinook salmon lifestages. Extremely low or high flows can block or delay migration to spawning areas by preventing passage over shallow riffles or creating excessive water velocities.

Water temperature affects the timing of chinook salmon spawning migrations, although the migratory response to water temperature may differ among chinook salmon races. Low flows and higher water temperatures can inhibit or delay migration to spawning areas.

Spawning - Water temperatures limit the geographic range in which chinook salmon can successfully spawn and adversely affect survival at temperatures above 56^{o}F.

Declining flows and consequent water surface elevations during the chinook salmon incubation period can cause mortality of eggs and alevins by dewatering redds, reducing flow rates through the redd, or increasing water temperatures. For example, fall-run chinook salmon redds are subject to potential dewatering as a result of streamflow reductions during the reservoir storage phase, which may begin during the winter incubation period. Redd dewatering impacts have generally been assessed using stage-discharge relationships for known spawning areas and chinook salmon spawning depth criteria (Jones & Stokes Associates 1991, 1992c).

Rearing - Rapid flow fluctuations can cause stranding of juvenile chinook salmon and subsequent mortality of juveniles unable to return to the river. Causes of mortality include elevated water temperatures, low dissolved oxygen levels, and predation.

Elevated water temperatures affect juvenile survival directly through acute (i.e., lethal) effects and indirectly through chronic (i.e., sublethal) effects. Water temperature becomes lethal at 75^{o}F. Chronic temperature effects occur at lower temperatures and include physiological stress, reduced growth rates, and increased vulnerability to disease and predation. Under laboratory conditions, American River juvenile chinook salmon experienced increasing levels of chronic thermal stress as water temperatures increased from 60^{o}F to 75^{o}F (Rich 1987).

Water diversions reduce survival of emigrating juvenile salmonids through direct losses at unscreened or inadequately screened diversions and indirect losses associated with reduced streamflows. Fish screening and salvage efforts at major agricultural diversions have met with variable success, and many smaller unscreened or inadequately screened diversions continue to operate. Fish losses at diversions can occur through physical injury, impingement, or entrainment. Delayed passage, increased stress, and increased vulnerability to predation are also factors contributing to mortality at diversions. Diversion impacts on anadromous fish populations depend on diversion timing and magnitude, river discharge, species (i.e., race), life stage, and other factors.

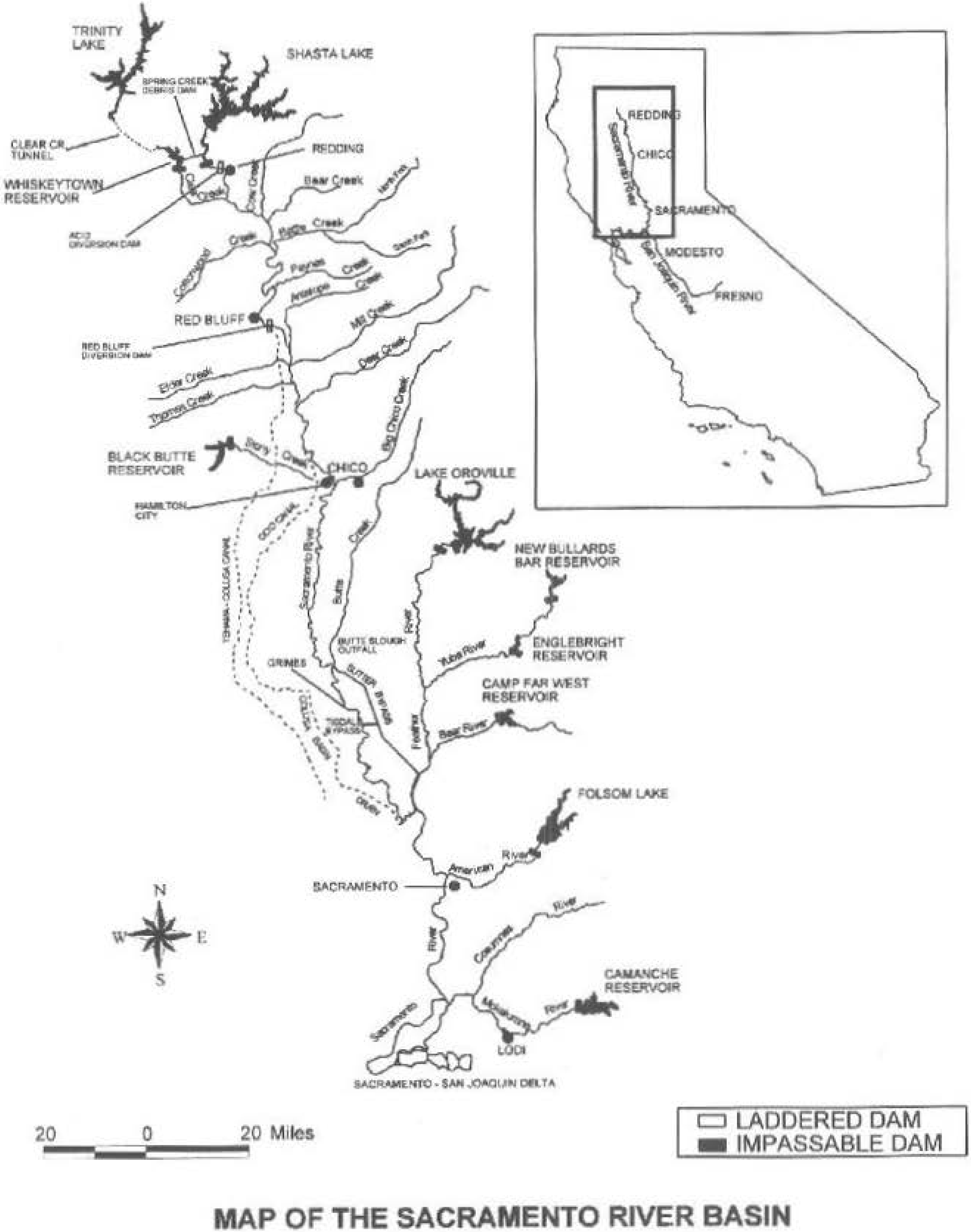
Predation on emigrating salmonids is probably of minor significance in unobstructed portions of the Sacramento River system, but predator efficiency increases at artificial structures and impoundments where fish are concentrated, stressed, or delayed in their downstream migration (U.S. Bureau of Reclamation [USBR] 1983b).

Substantial losses in streamside riparian vegetation adversely affect chinook salmon throughout their Central Valley distribution. Riparian vegetation performs critical functions in stream ecosystems by maintaining bank stability, providing overhead and instream cover for aquatic organisms, moderating water temperatures, contributing nutrients and energy, and providing habitat diversity. The presence of riparian vegetation along natural streambanks greatly enhances the quality of nearshore aquatic habitat for juvenile chinook salmon. Overhanging and submerged branches and root systems provide favorable hydraulic characteristics for resting and feeding; food inputs (primarily terrestrial insects); and shelter from strong, light, swift currents, and predators. In addition, naturally eroding streambanks are a valuable source of large woody material (e.g., fallen trees) in the stream, providing important instream cover and contributing to channel and habitat diversity.

Sacramento River

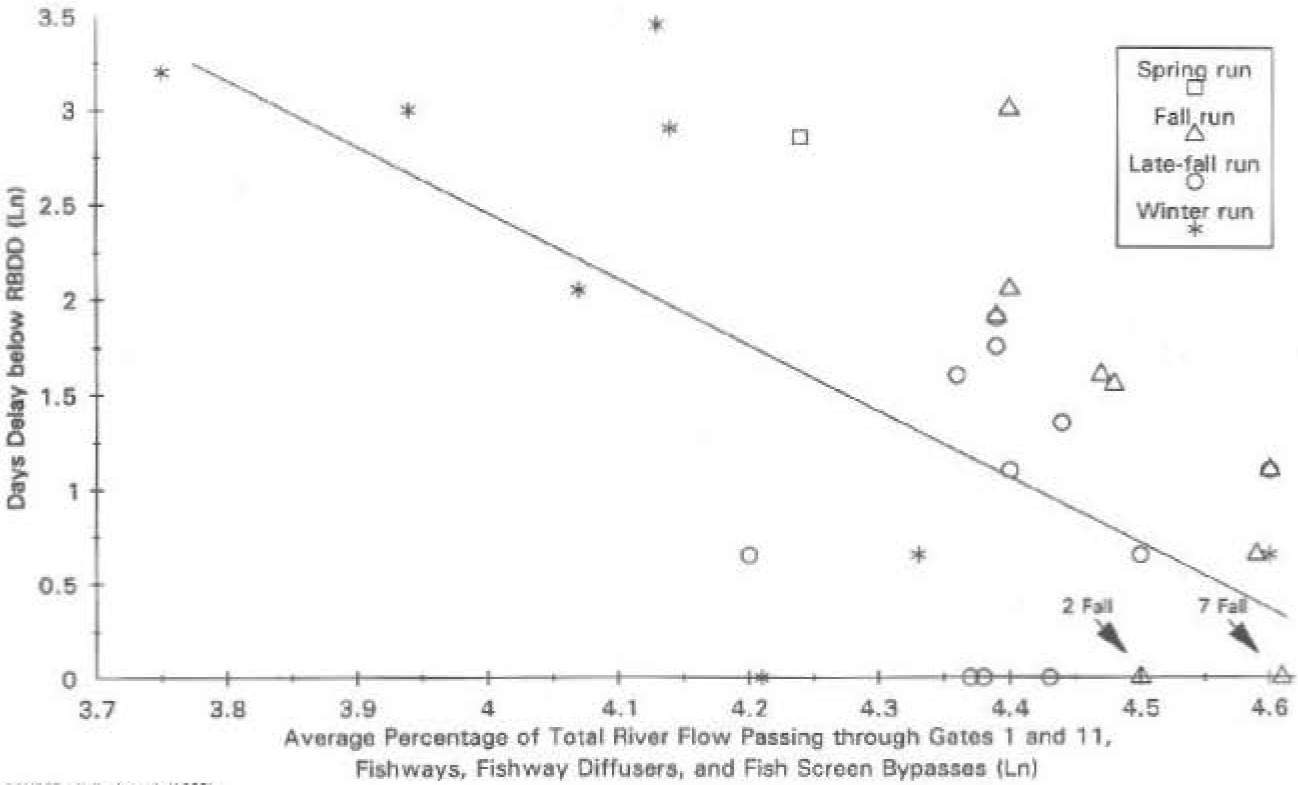
Upstream migration and spawning -

Passage barriers - On the upper Sacramento River, the Red Bluff Diversion Dam (RBDD) is a major impediment to upstream migration of adult salmon (Hallock et al. 1982, Vogel et al. 1988) (Figure 2-VII-1). After completion of the RBDD in 1966, the proportion of fall-run chinook salmon spawning above the dam declined from an estimated average of 94% during 1964-1968 to an average of 63% during 1977-1981 (USBR 1985). The extent of delay and blockage was found to increase with increasing river discharge as a result of decreases in the proportion of total discharge passing through or adjacent to the fish ladders (Figure 2-VII-2). Blockage of fall-, late fall-, winter-, and spring-run chinook salmon ranged from 8% to 44% and can be related to the extent of delay (Figure 2-VII-3). Vogel et al. (1988) concluded that adult salmon passage problems at the RBDD were caused primarily by insufficient attraction flows in the fish ladders, operation and maintenance problems, and improper configuration of the fish ladder entrances.



MAP OF THE SACRAMENTO RIVER BASIN

FIGURE 2-VII-1

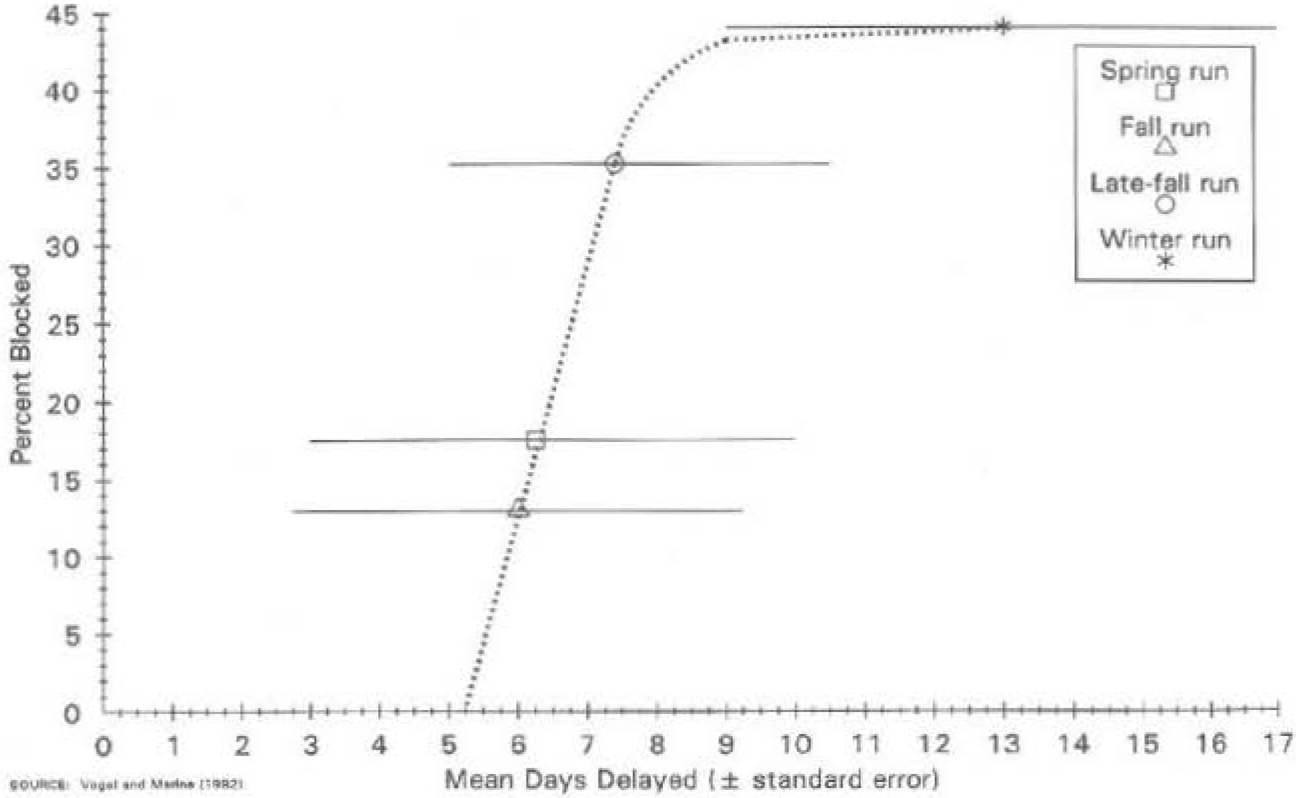


SOURCE: Hallock et al. (1982).

NOTE: All data transformed to natural logarithms.

DELAY OF RADIO-TAGGED SALMON THAT PASSED RED BLUFF DIVERSION DAM VERSUS MEAN PROPORTION OF TOTAL RIVER FLOW PASSING THROUGH OR NEAR THE FISHWAYS

FIGURE 2-VII-2



DELAY VERSUS BLOCKAGE OF CHINOOK SALMON AT RED BLUFF DIVERSION DAM

FIGURE 2-VII-3

Potential effects of blocked or delayed migration of adult chinook salmon include pre-spawning mortality, reduced egg viability, and shifts in spawning distribution. Obstructions can cause excessive delay and energy expenditure, which can result in pre-spawning mortality of adults and reduced fecundity. Fall-run and late fall-run chinook salmon are probably most susceptible to this source of mortality because they spawn immediately after migration. Winter-run chinook salmon that do not reach spawning areas above the dam generally have poor spawning success because water temperatures in the Sacramento River below the RBDD frequently exceed tolerance levels for eggs and fry during the summer incubation period (Hallock and Fisher 1985).

Raising the RBDD gates during the nonirrigation season (November 1-April 30) is currently being implemented to facilitate upstream passage of adult winter-run chinook salmon. USBR is currently investigating alternatives that would permit the RBDD gates to be raised permanently or for longer periods to provide unimpeded passage of adult and juvenile chinook salmon.

The Anderson-Cottonwood Irrigation District's (ACID's) diversion dam, a seasonal flashboard dam on the Sacramento River near Redding, California (Figure 2-VII-1), has caused fish passage problems since its construction in 1917. A fish ladder, completed in 1927 and still in place today, does not effectively attract and convey upstream migrating chinook salmon past the dam (USBR 1983a). A new fishway was recently installed on the opposite side of the dam, but its passage effectiveness has not yet been evaluated. The ACID's dam is usually installed in early April and removed in late October or early November, resulting in potential delay and blockage of winter-, spring-, and fall-run chinook salmon to upstream spawning areas.

Water temperature and spawning gravels - In the upper Sacramento River, high water temperatures observed during summer and fall limit the range of successful spawning for winter-, spring-, and fall-run salmon during July-October (Vogel and Rectenwald 1987). The downstream limit of suitable water temperatures for fall-run chinook salmon in most years is near Hamilton City, whereas suitable temperatures for winter- and spring-run salmon are typically limited to the reach above the RBDD (Figure 2-VII-1).

Construction of Shasta and Keswick dams blocked the recruitment of spawning gravels from upstream sources to the upper Sacramento River. Lack of gravel recruitment and increases in the average size of streambed materials have degraded spawning habitat below Keswick Dam to at least Clear Creek. Below Clear Creek, tributary streams increase in importance as a source of spawning gravels to the Sacramento River. Intensive gravel mining in most of these tributaries has reduced gravel recruitment to the mainstem Sacramento River by more than 50%. Below Red Bluff, gravel recruitment principally occurs from the natural erosion of historical deposits along the banks of the Sacramento River. Bank protection and levee projects in the middle and lower Sacramento River have substantially reduced gravel recruitment into these reaches. (Buer et al. 1984.)

Existing gravel supplies are adequate to support current population levels of chinook salmon in the upper Sacramento River. With future population increases, however, spawning gravel may become limited and gravel restoration would be necessary. Recent restoration efforts by the California Department of Fish and Game (DFG) and the California Department of Water Resources (DWR) have included placement of spawning gravel to restore degraded spawning riffles in the upper Sacramento River above Clear Creek. (DWR 1992.)

Incubation -

Water temperature - Appropriate water temperatures for egg incubation and emergence are a critical concern for Sacramento River chinook salmon. Historically, fall water temperatures were warm in the lower reaches of the upper Sacramento, Feather, Yuba, and American rivers, particularly during dry water years. Spring-run chinook salmon was a dominant race and spawned at higher elevations, where temperatures were not a major limiting factor. Fall-run chinook salmon spawned at lower elevations, but in fall to avoid lethal water temperatures. In general, immediately after dam construction, reservoirs were kept relatively high and provided colder water in the lower reaches of these rivers. Fall-run chinook salmon populations responded to the colder flows earlier in the year, mixed genetically with hatchery salmon, and began to spawn much earlier than historical salmon runs. Coincidentally with these earlier runs, Sacramento River basin reservoirs have, over time, reached lower elevations because of greater demands for spring and summer releases for agricultural and municipal demands. These lower elevations, particularly during dry water years, now frequently result in warm water being released from the reservoirs, which causes high mortalities to incubating fall-run chinook salmon eggs.

Increasing water demands and prevailing drought conditions in recent years have limited the ability to maintain suitable water temperatures in the principal winter-run chinook salmon spawning area in the upper Sacramento River. During the recent drought period, USBR initiated alternative reservoir operations, including increases in the relative amount of cold water from the Trinity River system and low-level bypass releases at Shasta Dam, in an effort to reduce the severity and extent of deleterious water temperatures. A proposed outflow temperature control structure would improve USBR's ability to control water temperatures and significantly benefit winter-run chinook salmon without foregoing power generation. The planning report and final environmental impact statement for the Shasta outflow temperature control device have been completed (USBR 1992b).

Water quality - Water quality impacts on aquatic resources vary by location and season in response to variable streamflows and pollutant levels in point-source and non-point-source agricultural, municipal, and industrial discharges. Although largely unquantified, water quality impacts on fish populations in the Sacramento River and its tributaries include effects related to heavy metal pollution; high levels of suspended sediments; and elevated levels of nutrients, herbicides, and pesticides from agricultural drainage.

Simpson Paper Company, which operates a pulp and paper mill near Anderson, has achieved an approximate 98% reduction in the discharge rate of dioxins and related compounds in recent years. As a result, dioxin concentrations in fish tissues from the Sacramento River have been reduced 80-90%, and the current health advisory on consumption of fish taken from the Sacramento River between Redding and Red Bluff may be lifted in the near future (Sacramento River Information Center 1993).

Heavy metal pollution caused by acid mine runoff principally from the Spring Creek basin continues to be a major source of water quality degradation and fish mortality in the upper Sacramento River. The Spring Creek Debris Dam (Figure 2-VII-1) was constructed by USBR in 1963 to control toxic discharges by coordinating releases with dilution flows from Shasta Reservoir and the Spring Creek Power Plant. Because of limited storage in Spring Creek Reservoir and availability of dilution flows, copper and zinc levels in downstream waters periodically exceed levels considered toxic to aquatic life (The Resources Agency 1989).

In 1984, the Central Valley Regional Water Quality Control Board (CVRWQCB) adopted water quality objectives for copper, zinc, and cadmium in the Sacramento River based on criteria developed by DFG (Table 2-VII-1).

The U.S. Environmental Protection Agency (EPA) listed the Spring Creek basin as an EPA Superfund cleanup site. EPA actions have reduced acid mine drainage and ongoing efforts are aimed at further remediation of toxic discharges. EPA selected a neutralization treatment plant as an interim strategy that will virtually eliminate existing threats to the Sacramento River fishery and the Redding municipal water supply (Sacramento River Information Center 1993).

Rearing -

Flow fluctuations and diversions - Fish losses due to stranding have not been well monitored or documented in Central Valley streams. Stranding of juvenile winter-run chinook salmon has occurred in the upper Sacramento River following rapid flow reductions associated with operation of the ACID's dam. Since 1970, limitations on flow reduction rates at Keswick Dam have minimized stranding losses (USBR 1983a).

Table 2-VII-1. Lethal concentrations of dissolved metals

Metal	96-hour LC10 (mg/l)	96-hour LC50 (mg/l)
Copper	19	32
Zinc	40	84
Cadmium	0.8	1.1

Note: mg/l = milligrams per liter.

Source: Vogel and Rectenwald (1987).

Flood control structures on the Sacramento River (Moulton, Colusa, Tisdale, and Fremont Weirs) divert Sacramento River water from the main river into the Butte Creek basin and the Sutter and Yolo Bypasses during major flood events. As a result, juvenile chinook salmon and other anadromous species migrating down the Sacramento River can be diverted into the bypasses, where they are subject to potential migration delays or entrapment as floodflows recede. Although juvenile fall-, spring-, and winter-run chinook salmon are likely to be present in the bypasses during major winter floods, survival rates associated with these migration routes are unknown. Adult salmon entering the bypasses during their upstream migration may be delayed or blocked by control structures in the bypass channels, but efforts have been made to alleviate passage problems by installing or upgrading fish ladders at known obstructions.

Riparian habitat - Riparian vegetation has been significantly reduced along much of the Sacramento River and its major tributaries as a result of agricultural conversion, urbanization, timber and fuel harvesting, channelization, levee construction, streambank protection, streamflow regulation, bank erosion, and other land use activities. Existing riparian woodland along the Sacramento River is less than 5% of its historical acreage and river edge vegetation is less than 50% of its historical extent (The Resources Agency 1989). Approximately 5-15% of the historical acreage remains on tributary streams (Mills and Fisher 1993).

Riparian loss has been greatest in the middle and lower reaches of the Sacramento River and Delta as a result of levee construction and bank protection projects. The most significant fisheries impacts are attributable to bank protection projects, which typically require removal of nearshore riparian vegetation, grading of the bank slope, and placement of rock revetment over the graded slope. Shaded riverine aquatic habitat is of greatest concern because of the unique fishery values associated with this habitat type and substantial losses that have already occurred. Replacement of naturally eroding banks with rock revetment has been shown to locally reduce densities of juvenile chinook salmon; chinook salmon densities in undisturbed areas are typically 4-12 times higher than in riprapped sites (Michny and Hampton 1984, Michny and Deibel 1986).

Levees and other flood control structures have drastically reduced the occurrence and extent of temporarily flooded terrestrial habitat that seasonally provided thousands of acres of potential rearing habitat for juvenile chinook salmon.

Since 1971, the U.S. Army Corps of Engineers (Corps) incorporated several features into the Chico Landing to Red Bluff Bank Protection Project to mitigate project impacts on fish and wildlife resources. The primary mitigation measures were using rock fill to save riparian vegetation that would otherwise be removed, replanting affected areas with riparian vegetation, and constructing artificial rearing benches or fish slopes.

Little information is available to assess food availability for juvenile chinook salmon in relation to environmental variation. Comparative studies of invertebrate production in revetted versus natural bank areas have not been conducted. Drift densities of invertebrate prey species were not substantially different between revetted and natural banks (Schaffter et al. 1983).

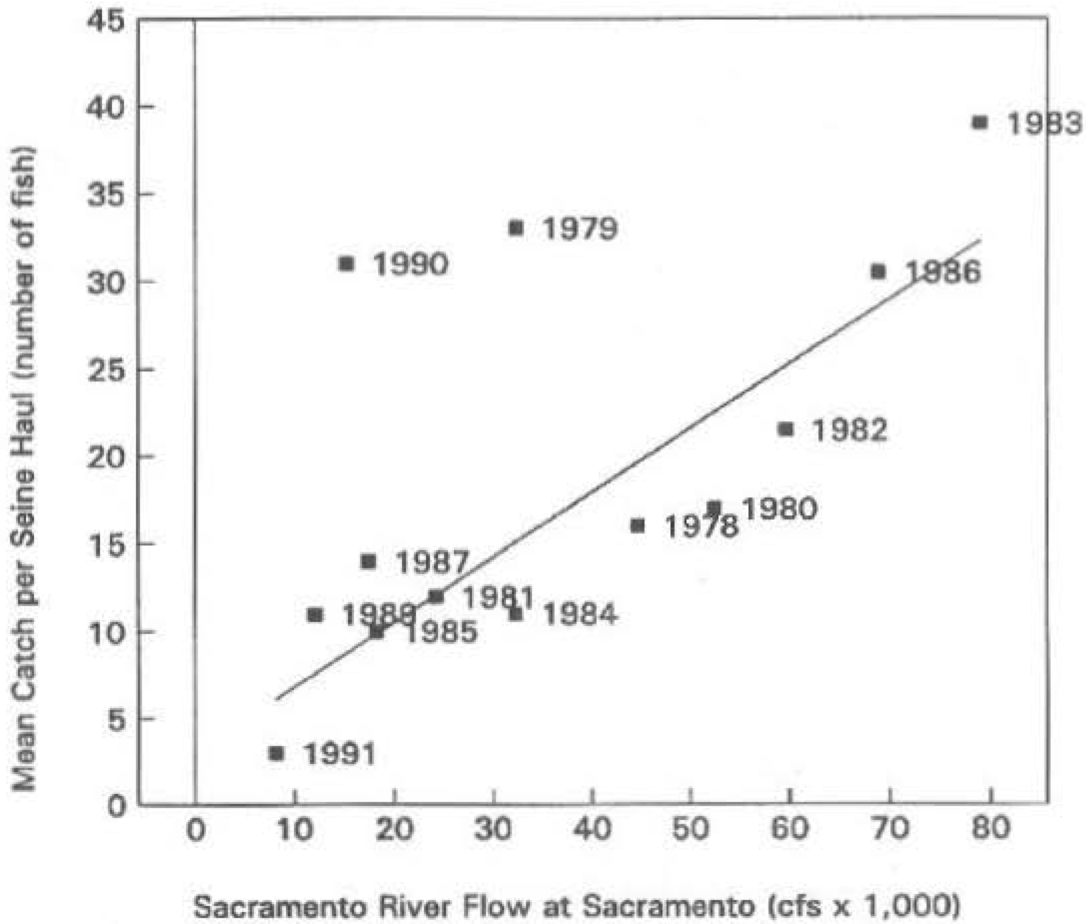
Downstream migration -

Flow and water temperature - In recent years, increased flow releases from Keswick Reservoir (up to 14,000 cubic feet per second [cfs]) and reduced diversions in May have been designed to assist the downstream migration of hatchery juveniles released in the upper Sacramento River (USBR 1986a). Correlations between Sacramento River flows during the chinook salmon smolt emigration period and the number of adults returning to Sacramento River tributaries (Dettman et al. 1987) indicate that flow, or factors related to flow, significantly affect chinook salmon survival and abundance.

The timing and distribution of chinook salmon emigration in the Sacramento system are affected by runoff conditions. In general, high flows during the early rearing period result in downstream displacement or active migration of large numbers of fry. Under low-flow conditions, most fry remain in upstream rearing areas and emigrate during the normal smolt emigration period. Fall-run chinook salmon fry abundance in the lower Sacramento River and northern Delta during the winter months generally increases as Delta inflow increases (Figure 2-VII-4). Peak numbers of fry in the lower Sacramento and Delta are associated with high winter flows or flow pulses in the Sacramento River (U.S. Fish and Wildlife Service [USFWS] 1993).

Figure 2-VII-5 shows a general relationship between average monthly Sacramento River flow to the Delta and the proportion of juveniles moving downstream. Factors influencing smolt emigration timing appear to be more closely related to growth rate, fish size, and water temperature, although increased flow may act to stimulate downstream migration (Wedemeyer et al. 1980). Downstream movement of juvenile chinook salmon may also be triggered by declining flow and rising water temperatures during the late spring months. Peak emigration rates generally occur at night or during periods of high turbidity (Vogel et al. 1988).

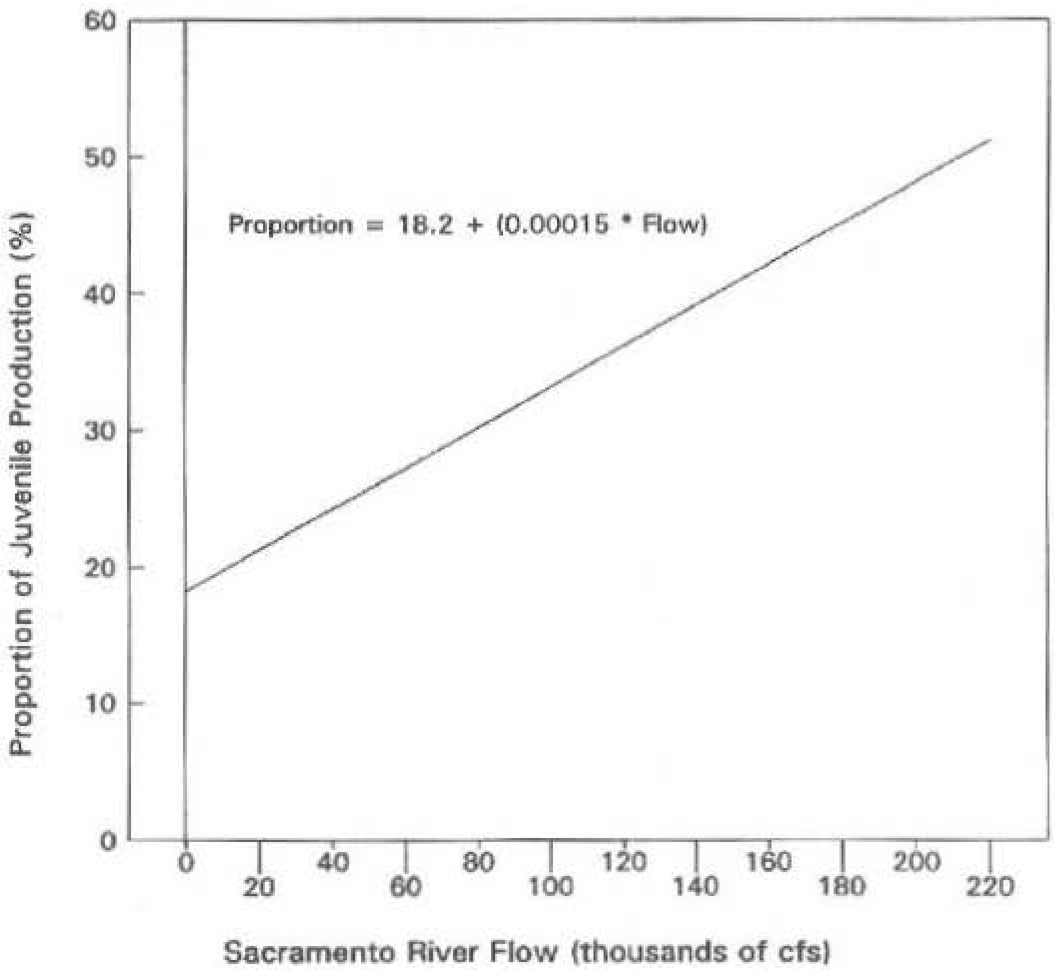
Mark-recapture studies of fall-run chinook salmon smolts demonstrated that smolt survival through the Delta was positively correlated with Sacramento River flows and negatively correlated with water temperatures and the fraction of Sacramento River flow diverted into the Delta Cross Channel (DCC) and Georgiana Slough during the April-June emigration period (USFWS 1987). Further studies designed to estimate the independent effects of these variables indicated that water temperature and diversions were key causal factors affecting smolt survival (Kjelson and Brandes 1988). A regression model was developed to estimate Delta smolt mortality as a function of Sacramento River water temperatures at Freeport, the fraction of Sacramento River flow diverted at Walnut Grove, and total State Water Project (SWP) and Central Valley Project (CVP) exports in the south Delta (Kjelson et al. 1989). Figure 2-VII-6 illustrates



SOURCE: U.S. Fish and Wildlife Service (1992).

RELATIVE ABUNDANCE OF CHINOOK SALMON FRY IN THE SACRAMENTO-SAN JOAQUIN DELTA VERSUS SACRAMENTO RIVER FLOW IN FEBRUARY (1978-1991)

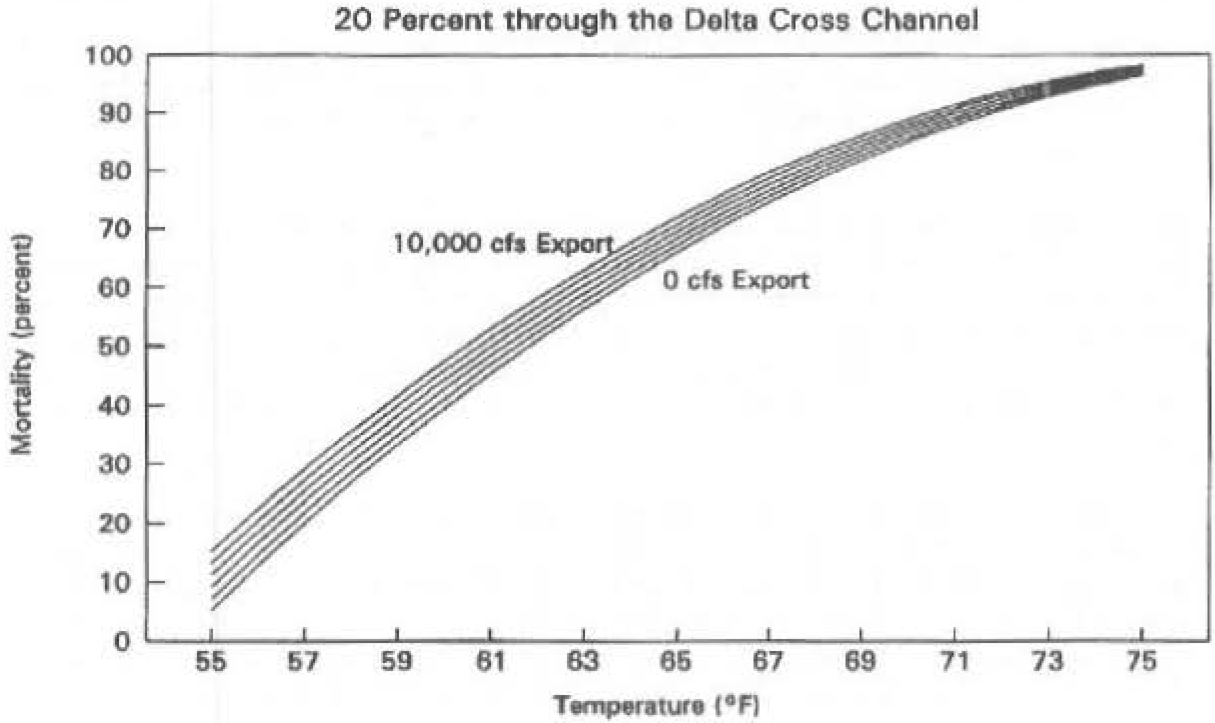
FIGURE 2-VII-4

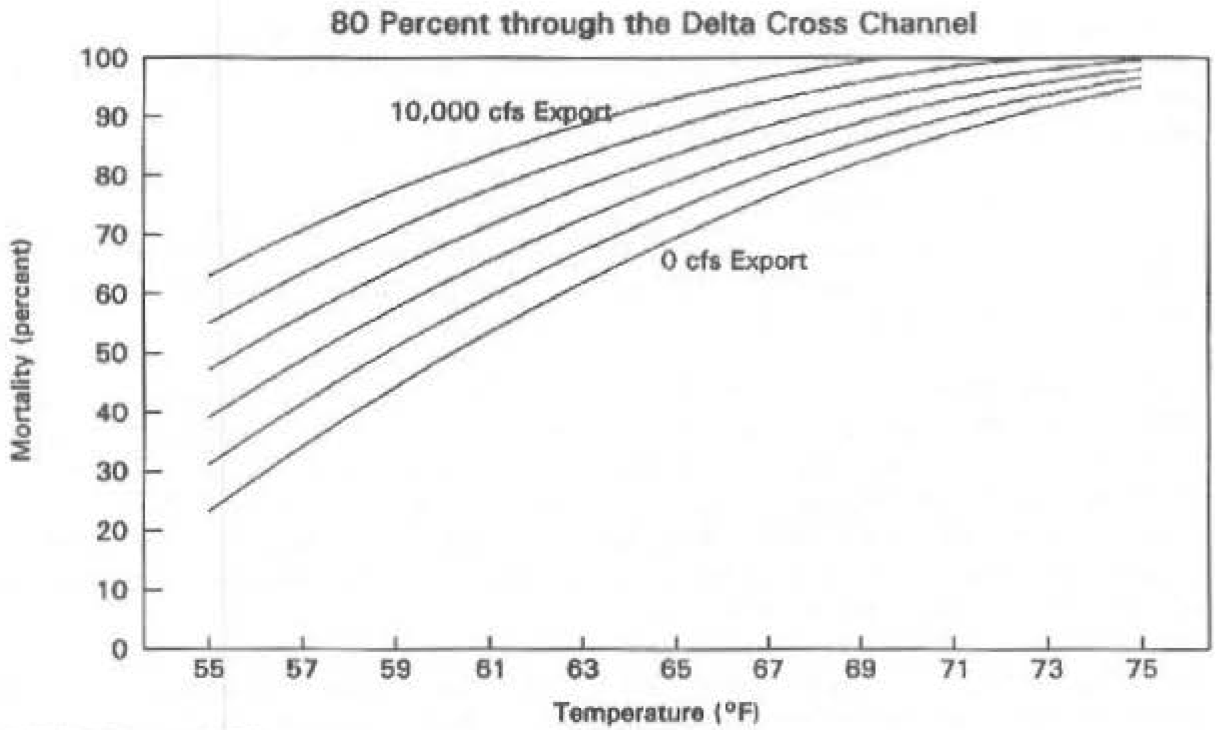


SOURCES: Hillaire (1992) and U.S. Geological Survey (1992).

AVERAGE MONTHLY SACRAMENTO FLOW TO THE DELTA VERSUS PROPORTION OF JUVENILE PRODUCTION MOVING DOWNSTREAM

FIGURE 2-VII-5





SOURCE: Kjelson et al. (1989).

PREDICTED SACRAMENTO RIVER CHINOOK SALMON SMOLT MORTALITY THROUGH THE DELTA VERSUS SACRAMENTO RIVER WATER TEMPERATURE AND DELTA EXPORT PUMPING RATES

FIGURE 2-VII-6

model predictions for various combinations of water temperature, export pumping rates, and diversion fractions.

A general increase in the frequency of suboptimum water temperatures for juvenile chinook salmon in the lower Sacramento River appears to have occurred since the mid-1970s (Reuter and Mitchell 1987).

Diversions -

General - Fall-run and late fall-run chinook salmon juveniles are particularly vulnerable to diversion-related mortality because the smolt emigration period (April-June) generally coincides with the onset of the irrigation season (April-October). Chinook salmon losses are minimal during the summer irrigation season because juvenile salmon do not actively migrate during summer.

Winter-run chinook salmon are subject to diversion losses during the latter part of the irrigation season (September-October), after which diversions are negligible. Because of their earlier emergence time, spring-run chinook are likely somewhat less vulnerable to irrigation diversions than other races.

Annual variation in runoff conditions also affects the magnitude of diversion losses. High river flows during winter or early spring may displace large numbers of fall-run juveniles downstream of most of the unscreened diversions on the Sacramento River before diversion activity begins. Continued high spring flows delay the onset of diversions and maintain favorable survival conditions, including a high ratio of river discharge to volume diverted. Fish losses are generally increased under low-flow conditions because of little downstream displacement, earlier diversion activity, and less favorable survival conditions.

Total Sacramento River diversions, including riparian rights and CVP contract diverters, are 2.7 million acre-feet (maf) per year, plus an estimated 500,000 acre-feet of uncontracted diversions by riparian rights holders. Ten diverters account for most of the water diverted from the Sacramento River, and only three of these have fish screens or bypass systems. More than 300 unscreened diversions account for 1.2 Maf of water diverted annually in the Sacramento River. Annual losses of juvenile salmon in these diversions may reach 10 million fish (The Resources Agency 1989).

USBR initiated a Pilot Fish Screen Demonstration Program in 1993 to assist diverters in screening existing unscreened diversions along the Sacramento River. The main objective of the program is to participate with diverters in demonstrating approved fish screen technologies and experimenting with other technologies to evaluate their effectiveness in guiding fish safely past water diversions.

Specific - The ACID's diversion canal is screened but requires frequent maintenance and inspection. In general, potential impacts on downstream migrating salmon are considered minor because of the small proportion of juvenile salmon produced in the Sacramento River above the district's diversion canal (USBR 1986).

Losses of downstream migrating chinook salmon past the Tehama-Colusa Canal (TCC) and the RBDD during the winter and spring chinook salmon emigration period occur as a result of entrainment through the TCC headworks, physical injury as juveniles pass through the headworks fish bypass system, and predation as juvenile salmon pass under the RBDD gates or through the fish bypass system (Vogel et al. 1988). Maximum estimated losses attributable to entrainment and physical injury were 0.6% and 4.1%, respectively. Predation presumably accounted for the remainder of estimated losses, ranging from 16% to 55%.

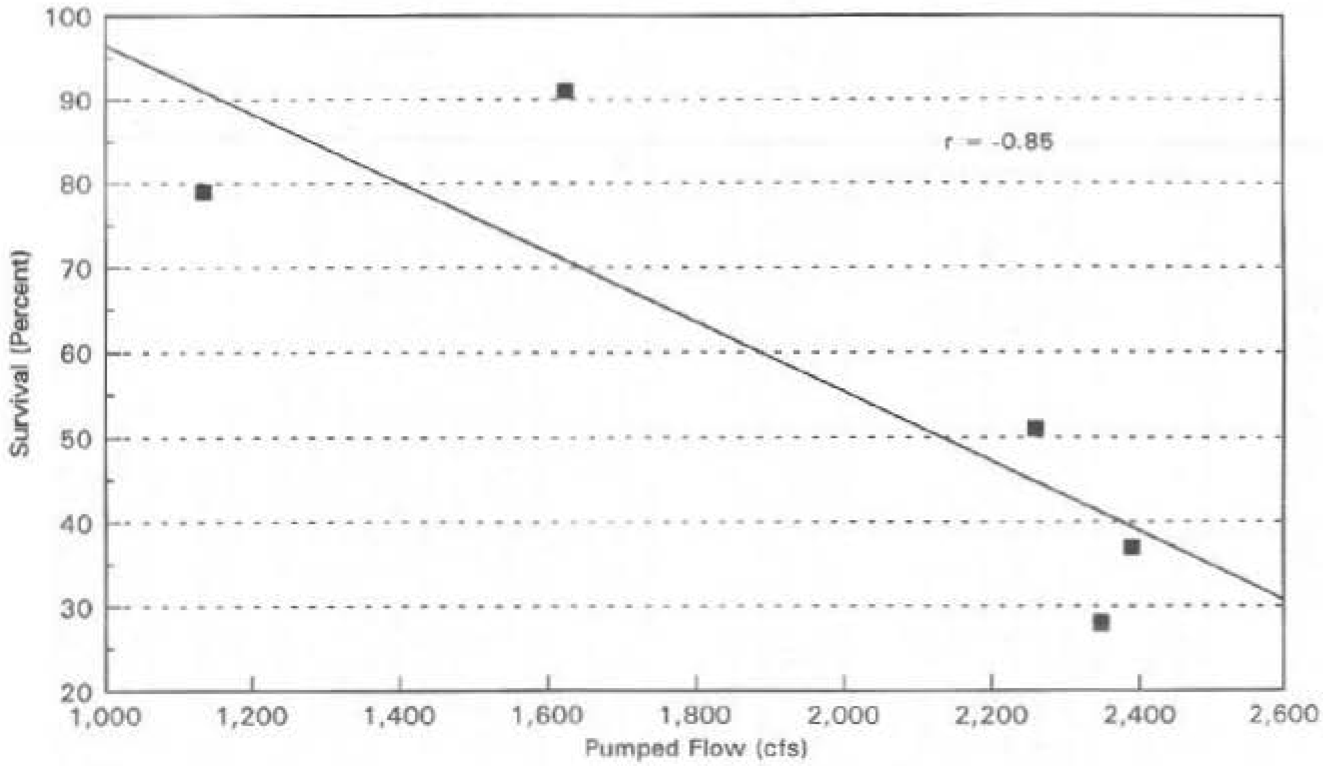
Raising the RBDD gates during the nonirrigation season is currently being implemented to facilitate upstream passage of adult winter-run chinook salmon. Downstream migrating juvenile salmon (primarily late fall- and winter-run salmon) also benefit from this measure because of unimpeded flow conditions past the dam, although predation rates during this period are thought to be low. The TCC headworks louver fish screens and bypass system were replaced with "state-of-the-art" rotary drum screens and an improved fish bypass system in 1990.

Past evaluations of screen efficiency and fish mortality at the Glenn-Colusa Irrigation District's (GCID's) diversion near Hamilton City have identified major problems in design and operation of the facility that have caused significant losses of downstream migrating salmonids. These problems included an inadequate bypass system, excessive approach velocities, and inadequate bypass flows. After construction of the present fish screens in 1972, natural degradation of the Sacramento River channel lowered the water elevation at the fish screen by 4 feet, causing excessive water velocities (up to 0.78 feet per second [fps]) at the screen face (relative to DFG's current criterion of 0.33 fps) at pumped flows over 1,500 cfs. (GCID et al. 1989.)

Recent mark-recapture studies using fall-run chinook salmon juveniles showed that the survival rates (i.e., fish bypass efficiencies) were negatively correlated to pumping flows (Figure 2-VII-7), indicating that fish losses were being caused by impingement, entrainment, or predation at the screen. The data also indicated that chinook salmon fry (less than 2 inches long) were more vulnerable to loss than larger juveniles or smolts; in general, fish bypass efficiency increased as fish size increased (Cramer et al. 1990).

An injunction obtained by the National Marine Fisheries Service (NMFS) against the GCID for the illegal take of winter-run chinook salmon requires the district to operate the diversion within specific criteria designed to avoid or minimize losses of winter-run chinook salmon. An environmental impact report/EIS is currently being prepared to identify a permanent solution to diversion impacts on all anadromous fish species (Beak Environmental Consultants in press). Potential solutions being evaluated include improving the existing screens and bypass system, constructing new screens, relocating the intake, restoring the gradient of the Sacramento River at the head of the GCID's diversion channel, or some combination thereof (58 FR 194, October 8, 1993).

Predation - Vogel et al. (1988) concluded that predation is the primary cause of downstream migrant salmon mortality at RBDD, accounting for losses ranging from 16% to 55%. Disorientation of downstream



SOURCE: Cramer et al. (1990).

ESTIMATED CHINOOK SALMON SURVIVAL RATE THROUGH GLENN-COLUSA IRRIGATION DISTRICT DIVERSION CHANNEL VERSUS FLOW PUMPED

FIGURE 2-VII-7

migrants as they pass under the dam gates or through the Tehama-Colusa headworks fish bypass system increases their vulnerability to predators. Predation by squawfish is particularly evident in spring when adult squawfish congregate at the RBDD during the emigration period for fall-run chinook salmon.

Yuba River

Downstream migration - Water temperature influences chinook salmon emigration timing. In the Yuba River, an extended period of cold water lasting into summer delays smolt emigration. Later emigrating smolts may experience higher water temperatures and increased mortality on reaching the lower Sacramento River and Delta (Jones & Stokes Associates 1992c).

Eastside Tributaries

Nearly all information on factors affecting abundance in Delta tributaries pertains to the Mokelumne River.
Upstream migration -

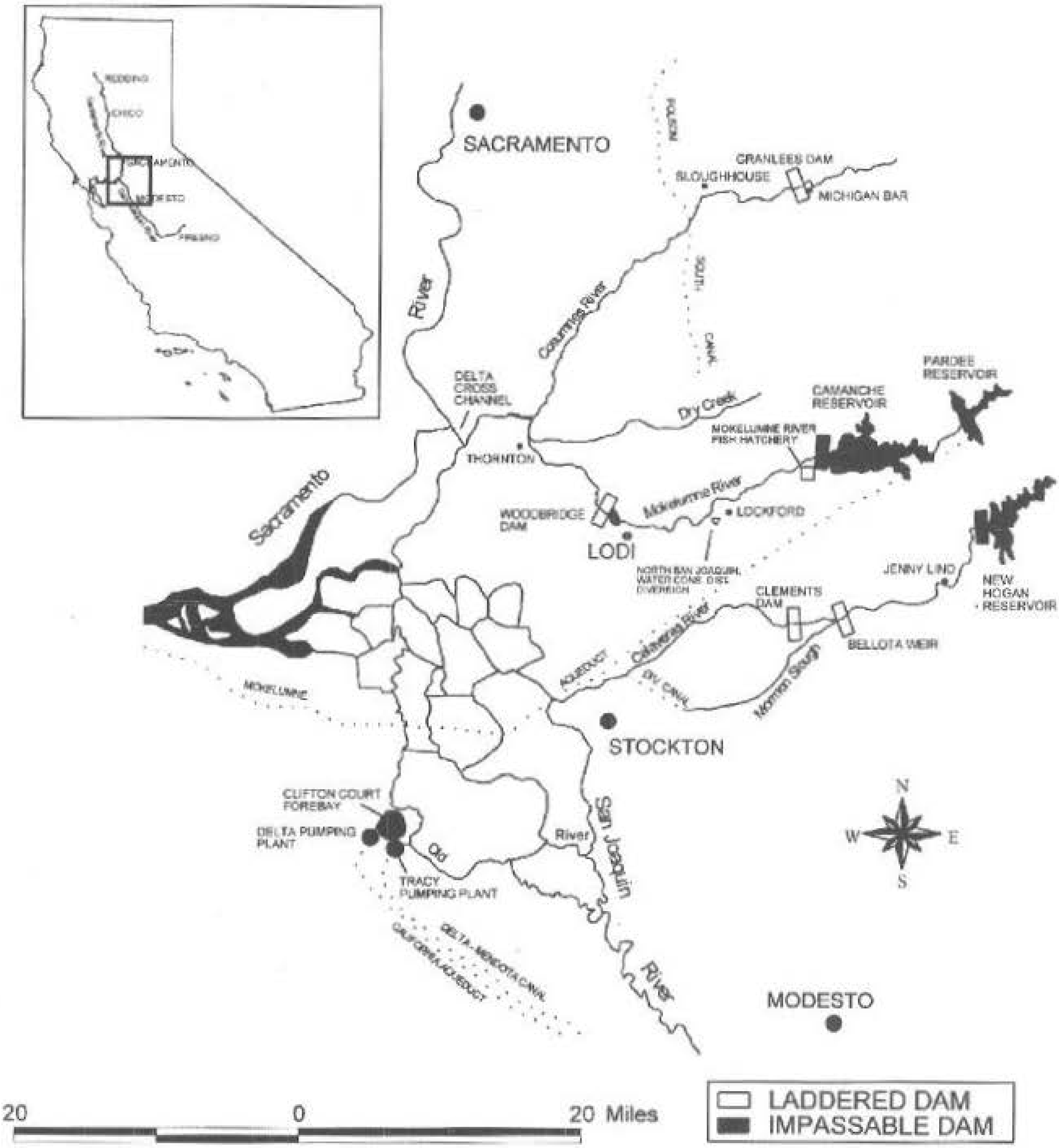
Passage barriers and flow - Using Thompson's (1972) criteria, DFG identified a shallow portion of the Mokelumne River near Thornton as a migration barrier to adult chinook salmon at flows less than 60 cfs (DFG 1991).

The major barrier to upstream migrating chinook salmon adults on the Mokelumne River is Woodbridge Dam. Woodbridge Dam, a flashboard dam constructed on the lower Mokelumne River in 1910, contained no fish ladder until 1925. Fish passage depended on river flows and the length of the irrigation season. Upstream migration of adult chinook salmon was generally possible only after the flashboards were removed at the end of the irrigation season (October). The fish ladder proved to be ineffective and was reconstructed in 1955. Recent analyses of passage conditions indicate that migration of adult chinook salmon past the dam is potentially impaired by spills that attract fish away from the fish ladder (DFG 1991).

Inadequate attraction and migration flows (generally less than 50 cfs) below Woodbridge Dam (Figure 2-VII-8) during October and November have resulted in poor adult returns to the Mokelumne River and Merced River Fish Facility. The failure of returning adults to detect Mokelumne River outflow may be exacerbated by diversion of proportionately large volumes of Sacramento River water into the lower Mokelumne River via the DCC and reverse flows in the lower San Joaquin River and south Delta channels.

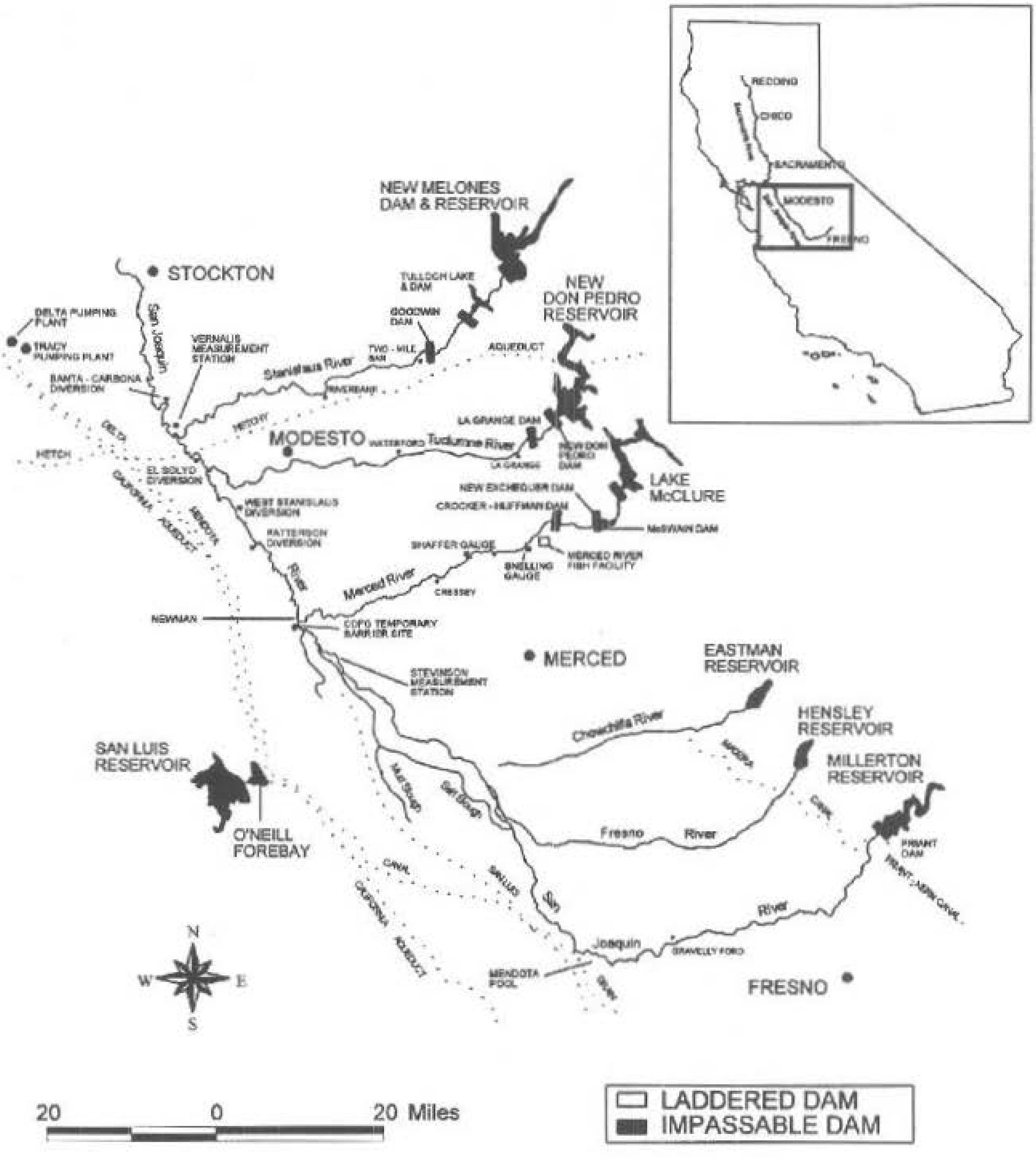
Water temperature and water quality - Upstream migration of adult chinook salmon in the Mokelumne River can be delayed by high water temperatures below Woodbridge Dam, which can persist until early November, even during a normal water year (DFG 1991).

Poor water quality conditions below Camanche Reservoir may adversely affect chinook salmon by inhibiting upstream migration of adult chinook to spawning areas. Water quality problems in the Mokelumne River have been associated with heavy metal pollution from Penn Mine, drought conditions, and Pardee and



MAP OF THE LOWER SACRAMENTO AND SAN JOAQUIN RIVERS DEPICTING THE EASTSIDE TRIBUTARY STREAMS

FIGURE 2-VII-8



MAP OF THE SAN JOAQUIN BASIN DEPICTING LOCATIONS OF THE STANISLAUS, TUOLUMNE, MERCED, AND SAN JOAQUIN RIVERS

FIGURE 2-VII-9

Comanche Reservoir operations. Recent fish kills at the Merced River Fish Facility were attributed to Camanche Reservoir discharges containing toxic levels of copper and zinc, low dissolved oxygen levels, and high concentrations of hydrogen sulfide. These conditions were associated with low inflows from Pardee Reservoir; record low reservoir levels; and hypolimnetic mixing, which may have mobilized sediments during the late summer and fall turnover of the reservoir (DFG 1991). DFG (1991) recommended water quality standards to protect aquatic resources in the receiving waters below Camanche Dam.

Spawning - Figure 2-VII-9 presents relationships between chinook salmon spawning habitat availability and flow for the Mokelumne River.

Suitable water temperatures for chinook salmon spawning in the Mokelumne River below Camanche Dam generally do not occur until early November during a normal water year. Water quality standards have been recommended by DFG, including water temperatures to protect aquatic resources, including adult chinook salmon spawners. (DFG 1991).

Camanche Dam also prevents the natural recruitment of gravel from upstream sources to spawning areas below the dam. Net losses of spawning gravels and a general increase in the size of streambed materials have reduced the amount of suitable spawning area. In addition, armoring or compaction of spawning substrate has reduced spawning gravel quality.

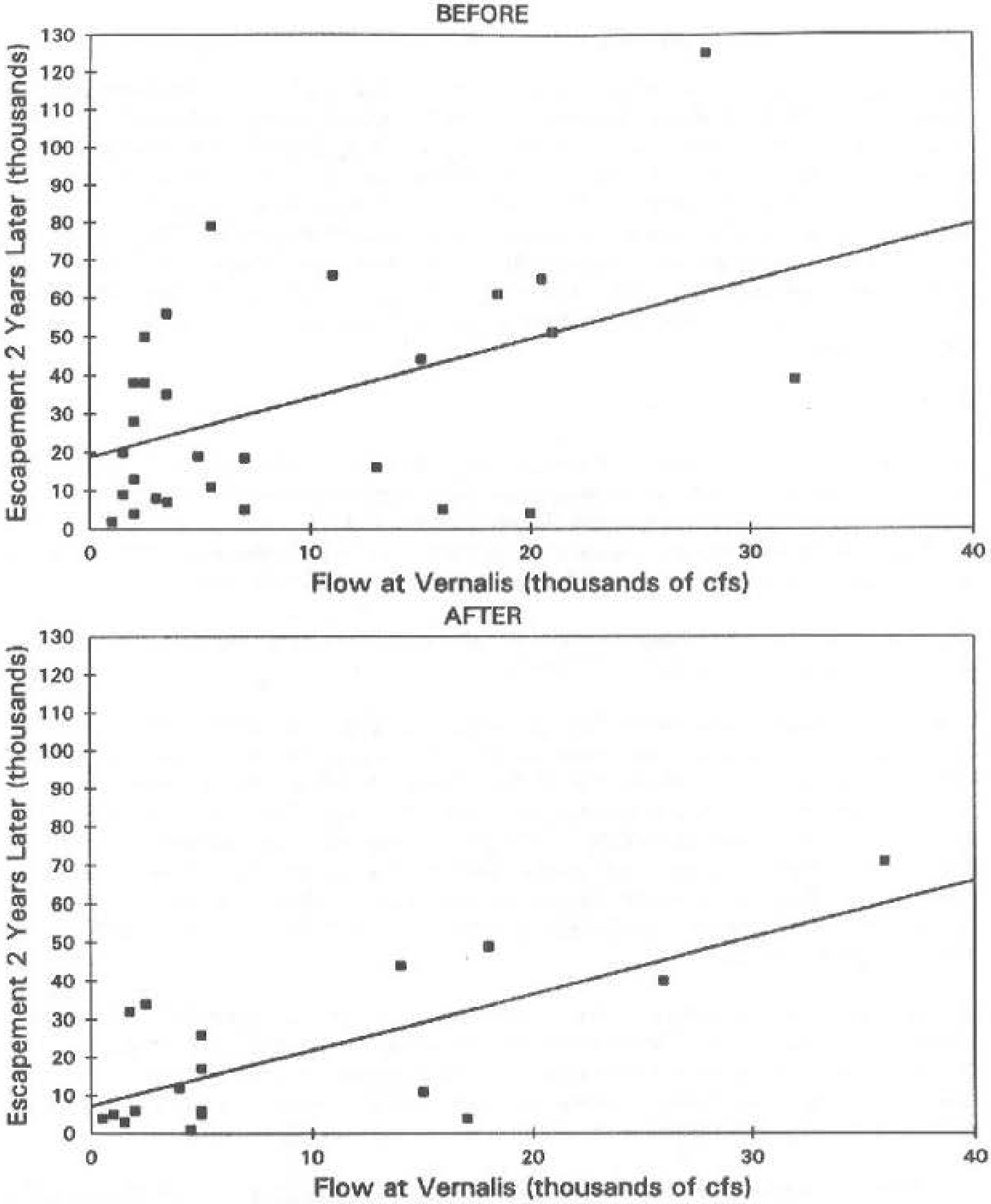
Incubation - Suitable water temperatures for chinook salmon incubation and emergence in the Mokelumne River below Camanche Dam generally do not occur until early November during a normal water year. Water quality and temperature standards recommended by DFG are designed to protect aquatic resources, including incubating eggs and fry. (DFG 1991).

Rearing - Figure 2-VII-10 presents relationships between chinook salmon rearing habitat availability and flow for the Mokelumne River.

Potential stranding of juvenile salmonids as a result of flow fluctuations was evaluated in several reaches downstream of Camanche Dam based on predicted changes in wet surface area over a range of flows. The stranding potential increased at flows below 400 cfs. Rapid flow reductions also increased the stranding potential. (DFG 1991.)

Water temperatures in the Mokelumne River below Camanche Dam remained within suitable levels for juvenile rearing and emigration through June during a normal water year. Water temperatures exceed suitable levels from March to early June at Woodbridge Dam during all water year types examined. Under existing project operations, water temperatures at Woodbridge Dam are strongly influenced by air temperatures. (DFG 1991.)

Water temperatures exceed suitable levels by April to early May at the Cosumnes River confluence.



SOURCE: California Department of Fish and Game (1987b).

TOTAL ESCAPEMENT IN THE SAN JOAQUIN DRAINAGE AND VERNALIS FLOWS BEFORE AND AFTER THE EXISTING STATE WATER PROJECT IN THE SOUTH DELTA VERSUS MAJOR STORAGE INCREASES IN THE SAN JOAQUIN DRAINAGE

FIGURE 2-VII-10

Downstream migration - Dry year flows in the lower Mokelumne River below Woodbridge Dam during the spring chinook salmon emigration period are inadequate to effectively convey juvenile chinook salmon migrants downstream and through the Delta. Juvenile chinook salmon in the Mokelumne River are allowed to migrate naturally to the ocean in wet year types but are trapped at Woodbridge Dam and trucked to Rio Vista in drier years. In general, peak adult returns to the Mokelumne River indicate favorable rearing and emigration conditions during preceding wet years. Nearly all chinook salmon produced at the Merced River Fish Facility are trucked as yearlings to release locations in the western Delta.

Major diversions affecting juvenile chinook salmon emigrants from the Mokelumne River are the Woodbridge Canal diversion and the south Delta SWP and CVP export facilities. The Woodbridge Canal diversion was screened in 1968 and currently operates from April to October, depending on irrigation demands. The Woodbridge Canal fish screen currently does not meet current DFG fish screen velocity and design criteria but has not been shown to result in significant losses of downstream migrants. Delta export facilities effects on juvenile salmon are discussed under the "Sacramento River" section.

Smolts migrating naturally out of the Mokelumne River are exposed to Delta flow patterns in the central and south Delta. Mark-recapture studies indicate that juvenile chinook salmon released in the lower Mokelumne River experience higher mortality than those released in the Sacramento River below the DCC under dry year conditions (USFWS 1987). Reverse flows caused by CVP and SWP export pumping in the south Delta contribute to poor survival of juvenile chinook salmon that enter the central Delta from the Mokelumne River or from the Sacramento River via the DCC or Georgiana Slough. Other mortality factors associated with this migration route are high water temperatures, predation, unscreened agricultural diversions, and direct entrainment losses at the south Delta pumps. These factors would also affect downstream migrant chinook salmon from the Cosumnes and Calaveras rivers.

San Joaquin River

Upstream migration and spawning - For many years, attraction flows from the Merced River have been inadequate during October, resulting in straying of adult salmon into agricultural drainage ditches, primarily Mud and Salt Sloughs (Figure 2-VII-8). Barriers (electrical and physical) were installed across the San Joaquin River upstream of the Merced River confluence in 1992 to prevent salmon migration into these sloughs and help guide them into the Merced River.

Hallock et al. (1970) found that chinook salmon initiated migration into the lower San Joaquin River as water temperatures declined from 72^{o}F to 66^{o}F.

Low dissolved oxygen levels (less than 5 parts per million) and high water temperatures (greater than 66^{o}F) in the San Joaquin River near Stockton delayed or blocked the migration of adult chinook salmon during the 1960s (Hallock et al. 1970). Since 1964, fall migration problems have been reduced by improved wastewater treatment and installation of a physical barrier at the head of Old River in dry years to direct most of the San Joaquin flows down the main channel past Stockton. Despite these efforts, low dissolved oxygen levels recurred during recent drought conditions. Remedial measures that are currently proposed include increasing tributary outflow, evaluating and monitoring dredging activity in the Delta, and further evaluating the fall barrier at Old River (The Resources Agency 1992).

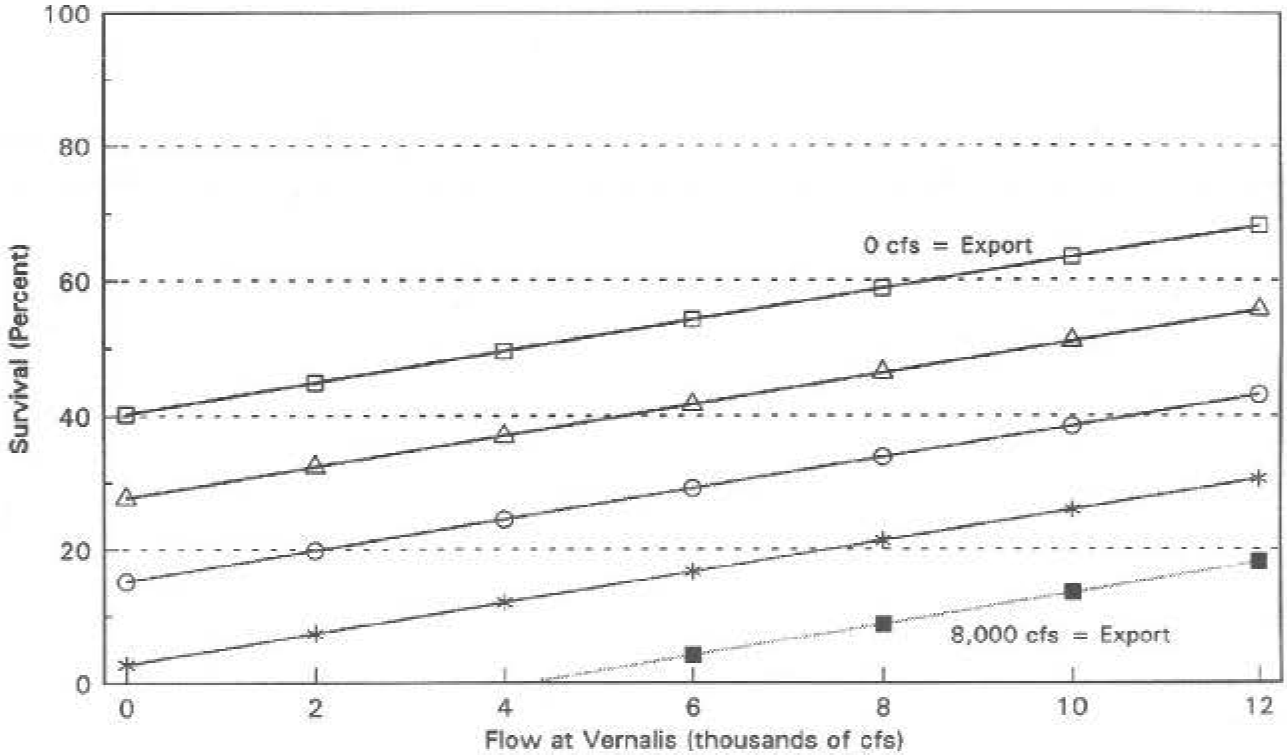
Rearing - Selenium in agricultural drainage water poses a potential risk to juvenile chinook salmon in the main San Joaquin River. Selenium is directly toxic to fish at elevated levels in the water column and through bioaccumulation in body tissues. Growth and survival of juvenile chinook salmon are adversely affected by exposure to dissolved and dietary selenium, but harmful levels have not been detected in the major San Joaquin River and tributary rearing areas (DFG 1987b).

Downstream migration - Spring flows in the San Joaquin River and major tributaries during the chinook salmon emigration period appear to have a major influence on the number of adults returning to San Joaquin River basin. Significant positive correlations exist between spring flows in the San Joaquin River and total chinook salmon spawning escapement 2.5 years later (Figure 2-VII-10). Similar relationships for San Joaquin River tributary stocks indicate that the flow required to maintain a given spawning escapement level increased following operation of the CVP and SWP. Over time, increases in the significance of other mortality factors, such as increased Delta exports, have diminished the positive effects of incremental increases in spring flows. (DFG 1987b.)

Declining streamflow during the spring emigration period of fall-run chinook salmon coincides with rising air temperatures and increased agricultural return flows to the San Joaquin River, often resulting in deleterious water temperatures along much of the emigration route in the lower San Joaquin River. In May, water temperatures in the San Joaquin River near Vernalis often reach high chronic stress levels (greater than 67.6^{o}F) at flows of 5,000 cfs or less. Under these conditions, up to half the production of San Joaquin River chinook salmon can be subjected to harmful water temperatures. (DFG 1987b.)

Smolts migrating down the San Joaquin River and through the southern Delta frequently encounter low flows, high temperatures, and high diversion rates. Currently proposed spring outflow recommendations for the Merced, Tuolumne, and Stanislaus rivers are designed to improve survival of juvenile salmon migrating down the tributaries, mainstem San Joaquin River, and through the Delta. Recent evaluations have focused on the effectiveness of releasing short-duration, high-amplitude flows (i.e., pulsed flows) from tributary streams in conjunction with reduced Delta exports.

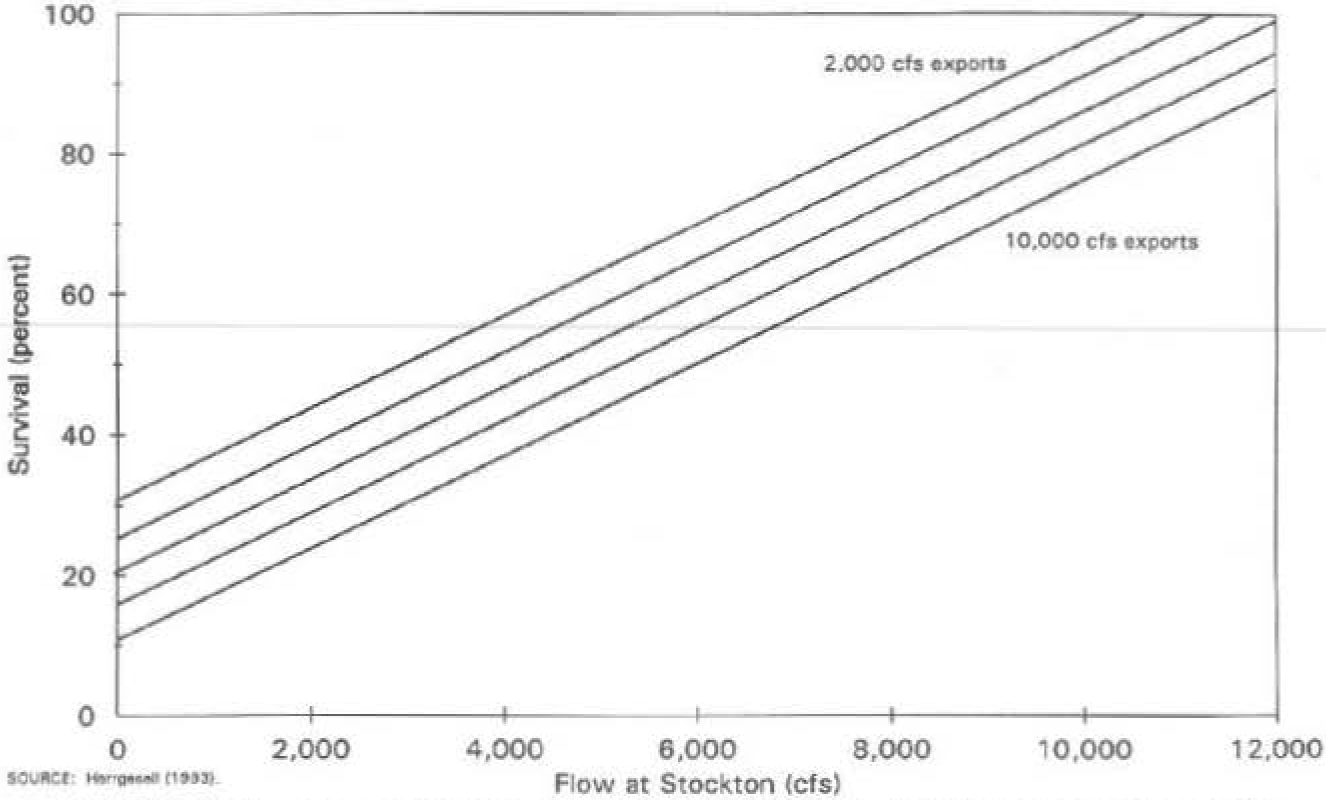
Existing data indicate that pumping by the CVP and SWP export facilities in the south Delta has a major impact on survival of emigrating juvenile chinook salmon. High juvenile mortality in the lower San Joaquin River and Delta is associated with low spring outflows and corresponding increases in the proportion of San Joaquin River flow diverted by CVP and SWP export facilities. At low San Joaquin River flow, high diversion rates increase the proportion of San Joaquin River flow drawn toward the pumps via Old River. Juvenile salmon, diverted with the flow, experience reduced survival associated with increased migration time, high water temperatures, predation, entrainment in unscreened agricultural diversions, and Delta export



SOURCE: Hangasell (1993).

PREDICTED SAN JOAQUIN RIVER CHINOOK SALMON SMOLT SURVIVAL VERSUS FLOW AT VERNALIS AND COMBINED CENTRAL VALLEY PROJECT/STATE WATER PROJECT EXPORTS

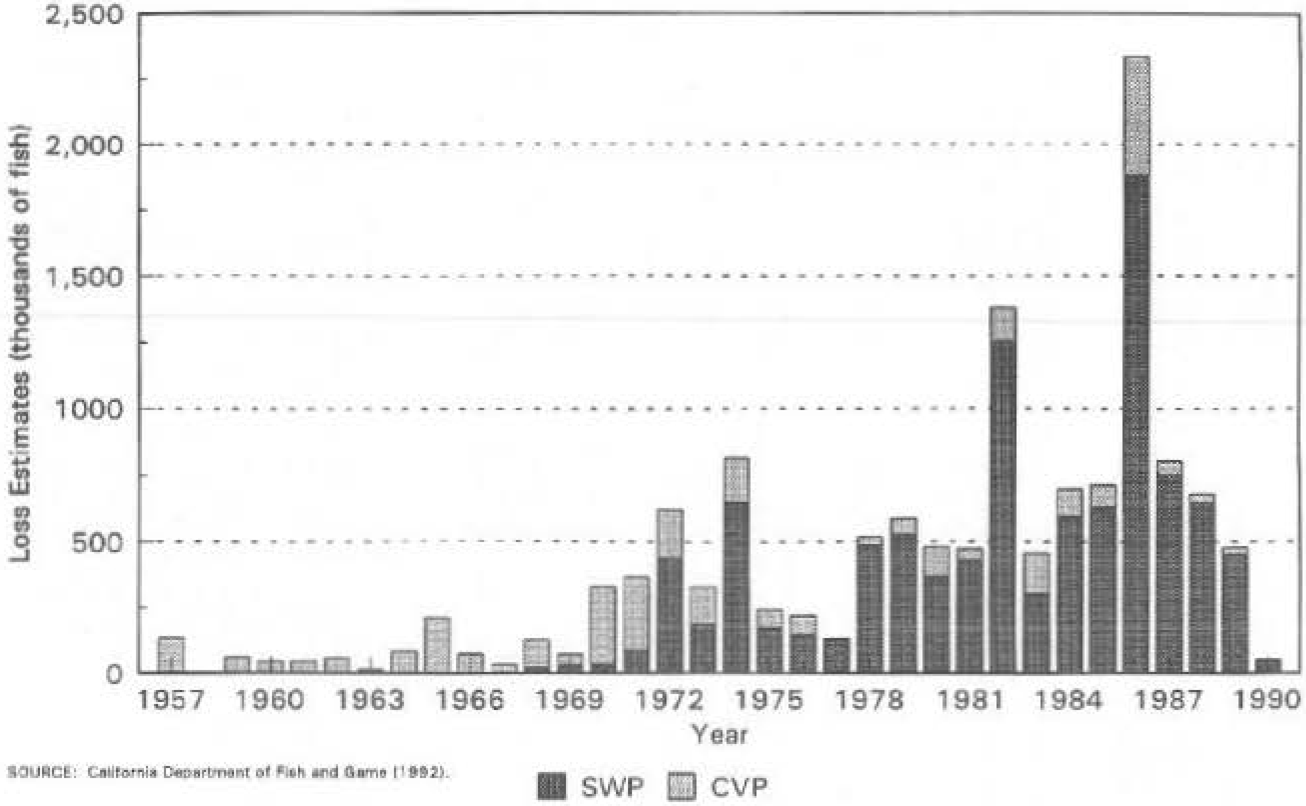
FIGURE 2-VII-11



SOURCE: Herrgesell (1993).

PREDICTED SAN JOAQUIN RIVER CHINOOK SALMON SMOLT SURVIVAL THROUGH THE DELTA VERSUS FLOW AT STOCKTON AND COMBINED CENTRAL VALLEY PROJECT/ STATE WATER PROJECT EXPORTS WITH A BARRIER AT THE HEAD OF OLD RIVER

FIGURE 2-VII-12



SOURCE: California Department of Fish and Game (1992).

CHINOOK SALMON LOSS ESTIMATES FOR THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT FACILITIES (1957-1990)

FIGURE 2-VII-13

pumping. Mark-recapture studies since 1985 demonstrated that chinook salmon smolts released in the San Joaquin River downstream of the head of Old River survived better than those released into upper Old River (USFWS 1987, 1990) (Figure 2-VII-11). Maximum survival benefits are expected by installing a barrier at the head of Old River during the spring emigration period in combination with reduced exports and increased San Joaquin flows (USFWS 1993) (Figure 2-VII-12).

Most chinook salmon reaching the CVP and SWP export facilities in the south Delta are from the San Joaquin basin (USBR 1986b). Monthly salvage estimates at the CVP and SWP export facilities indicate the primary periods when juvenile chinook salmon are vulnerable to direct entrainment losses and mortality associated with salvage operations (Figure 2-VII-13).

San Joaquin River Tributaries

Upstream migration and spawning - Figure 2-VII-18 presents relationships between chinook salmon spawning habitat availability and flow for the Merced, Tuolumne, and Stanislaus rivers.

Water temperatures below major reservoirs in the San Joaquin River tributaries frequently do not permit successful spawning of fall-run chinook salmon until November.

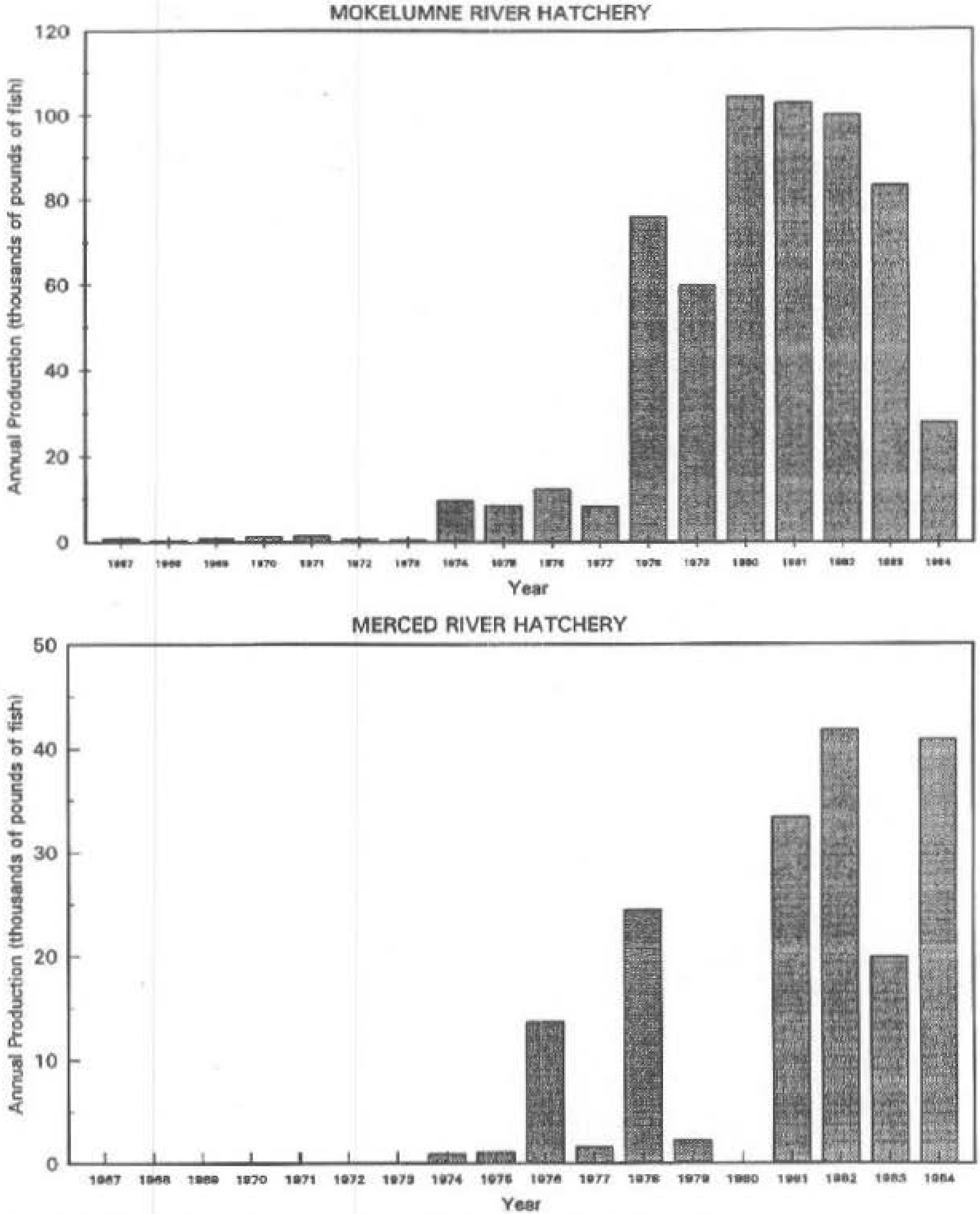
Although spawning habitat does not appear to be limiting recovery of fall-run chinook salmon stocks in the San Joaquin River basin, spawning gravel restoration may be needed in the future to offset gravel depletions below dams and provide sufficient spawning habitat to accommodate future adult populations.

The fishery management agencies have proposed an interim temperature objective of 42-56^{o}F throughout the designated chinook salmon spawning reaches in the Tuolumne, Merced, and Stanislaus rivers during the fall-run spawning and incubation periods. Special water operations using this objective were implemented on the Stanislaus River in 1991 and 1992 (The Resources Agency 1992).

Rearing - Figure 2-VII-14 presents relationships between chinook salmon rearing habitat availability and flow for the Merced, Tuolumne, and Stanislaus rivers.

Streamflow has been identified as the primary factor affecting abundance of chinook salmon stocks in the San Joaquin River basin. Streamflow reductions after April and May in the Merced and Tuolumne rivers result in poor survival conditions for chinook salmon juveniles that remain in these tributaries beyond these months. High mortality is generally the result of reduced living space, high water temperatures, and increased predation. Current interim instream flow requirements in the Stanislaus River provide adequate flow conditions through the chinook salmon rearing period.

Generally, water temperatures below major dams on the San Joaquin River tributaries become unsuitable for chinook salmon rearing in May or June, causing high mortality of juvenile chinook salmon that have not emigrated. In the Stanislaus River, however, releases of cold hypolimnetic water from New Melones



SOURCES: California Trout, Salmon, and Warmwater Fish Production and Costs (1967-85).

ANNUAL PRODUCTION OF CHINOOK SALMON AT MOKELUMNE AND MERCED RIVER HATCHERIES (1967-1991)

FIGURE 2-VII-14

Reservoir have improved water temperatures during the late spring rearing period relative to preimpoundment conditions (USBR 1986b).

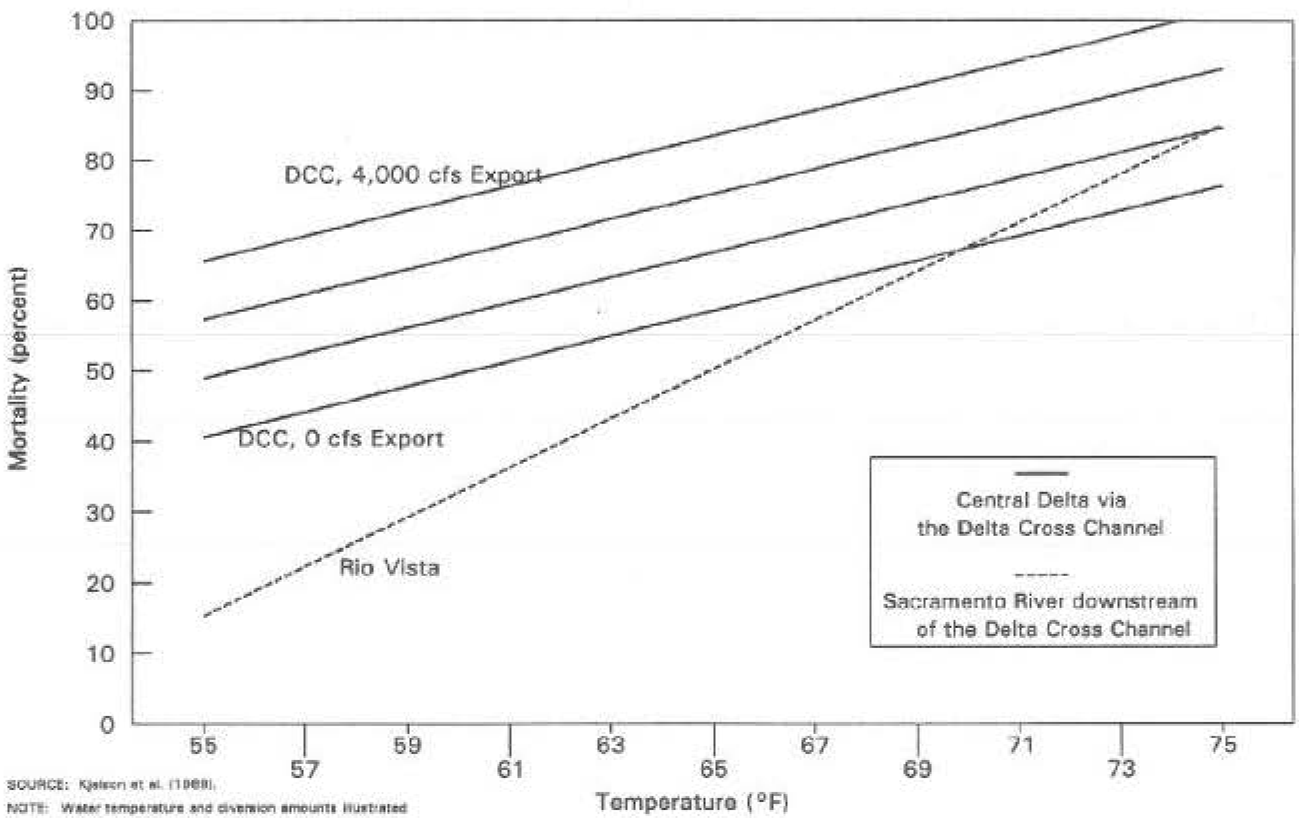
Delta/Bay

Upstream migration - High export pumping and diversion of Sacramento River water into the central and south Delta may increase the number of adult salmon gaining access to the Sacramento River via the Mokelumne River and DCC or Georgiana Slough. During upstream migration, adult salmon primarily use their sense of smell to find their home stream. Thus, salmon destined for the Sacramento River that are drawn into the central Delta may be delayed by the longer migration distance and greater number of channels that must be negotiated in this portion of the Delta. Large volumes of Sacramento River water and reverse flows in the lower San Joaquin River can also inhibit or delay migration of San Joaquin River spawners (Hallock et al. 1970).

Downstream migration - The SWP (Banks) and CVP (Tracy) export facilities in the south Delta adversely affect anadromous fish survival in the Delta through direct entrainment losses and indirect effects related to changes in the magnitude and direction of flow in the Delta channels. Increases in upstream storage and diversions over the last 20 years have significantly reduced inflow to the Delta. Reduced inflow, in combination with increased diversions from the Delta, has caused increasing adverse impacts on anadromous and resident species by reducing net flow through the Delta and Delta outflow; causing reverse flow conditions in central and south Delta channels; and increasing entrainment of fish eggs, larvae, and juveniles. Unscreened Delta diversions have contributed to fish losses.

Fall-run salmon smolts diverted from the Sacramento River into the central Delta via the DCC or Georgiana Slough experience higher mortality rates than smolts that remain in the Sacramento River (Figure 2-VII-15). At a given water temperature, the survival of hatchery fall-run chinook salmon smolts that enter the DCC averages about 50% less than for smolts released in the Sacramento River below the DCC diversion when Delta exports total about 3,000 cfs. Poor survival of smolts diverted into the central Delta is attributed to increased migration time, high water temperatures, predation, entrainment in unscreened agricultural diversions, and exposure to reverse flows in the central and south Delta channels. The proportion of Sacramento River flow diverted and total Delta exports are important regression variables in the U.S. Fish and Wildlife Service's Delta mortality model for chinook salmon smolt (Kjelson et al. 1989). Recent mark-recapture experiments provide evidence that a positive net flow at Jersey Point increases the survival of salmon migrating down both the Sacramento and San Joaquin rivers, including those migrants that are diverted from the Sacramento River into the central Delta and move to the San Joaquin via the Mokelumne River (USFWS 1993) (Figure 2-VII-16).

Delta flow and operational criteria established by the NMFS for protection of winter-run chinook salmon for February 15, 1993, through February 15, 1994, included closing the DCC gates during the main emigration period through the Delta and operating the CVP and SWP Delta export facilities to maintain

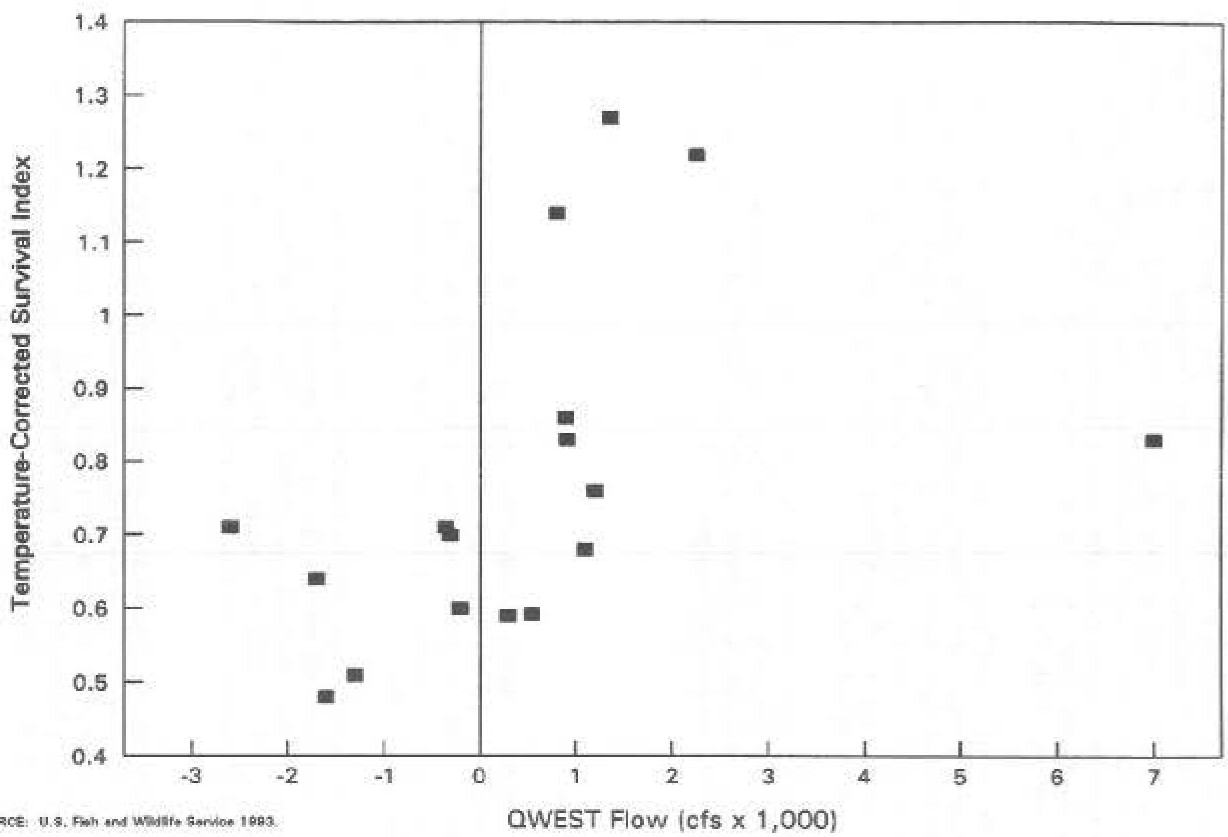


SOURCE: Kjelson et al. (1989).

NOTE: Water temperature and diversion amounts illustrated for the Delta Cross Channel route only.

PREDICTED SACRAMENTO RIVER CHINOOK SALMON SMOLT MORTALITY FOR TWO DELTA MIGRATION PATHWAYS VERSUS SACRAMENTO RIVER WATER TEMPERATURE

FIGURE 2-VII-15



SOURCE: U.S. Fish and Wildlife Service 1993.

TEMPERATURE-CORRECTED SURVIVAL FOR FISH RELEASED AT RYDE VERSUS QWEST FLOW (1984-1992)

FIGURE 2-VII-16

specific minimum running average QWEST (i.e., computed net flow at Jersey Point) values during the Delta rearing and emigration periods (NMFS 1993).

Entrainment - Annual losses of chinook salmon at the SWP and CVP Delta export facilities have usually ranged from 400,000 to 800,000 in recent years, assuming 75% mortality in Clifton Court Forebay (CCF) (Figure 2-VII-13). Salvage records from the SWP pumping plant indicate salmon fry and smolts are entrained year-round, but peak levels generally occur in late winter and spring when fall-run chinook salmon pass through the Delta (Figure 2-VII-5). Juvenile chinook salmon salvaged at the SWP export facility during December 1992-April 1993 were classified according to race based on size criteria developed by DFG. Although fall-run chinook salmon produced in the Sacramento River presently constitute about 80% of the total number of chinook salmon passing through the estuary, only a small percentage of chinook salmon juveniles released in the Sacramento River typically reach the CVP and SWP export pumps (USFWS 1987). Most salmon juveniles salvaged at the Delta pumps during the spring are from the San Joaquin River.

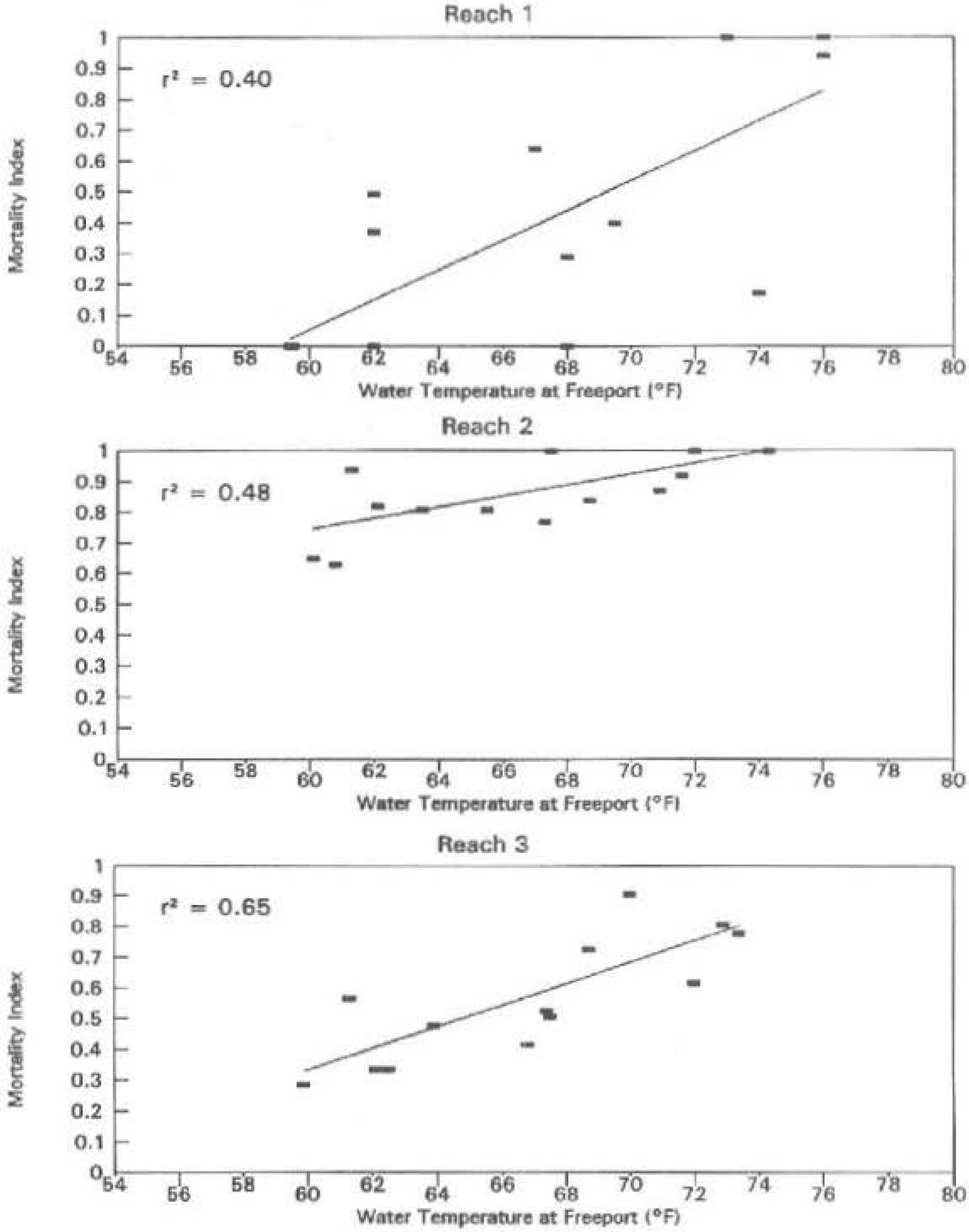
Unknown numbers of salmon are also entrained in other Delta diversions, including over 1,800 unscreened agricultural diversions; the Contra Costa Canal; the City of Vallejo diversion; and western Delta industry diversions (DWR 1993).

Water temperature - The Delta chinook salmon smolt mortality model includes three predictive relationships describing changes in smolt mortality as a linear function of water temperature for three major Delta reaches (Figure 2-VII-17). Based on multiple regression analysis, water temperature was found to be the best predictor of smolt mortality among the major environmental variables thought to influence smolt survival in each of the three reaches (Kjelson et al. 1989). Smolt survival appears to decline at temperatures above 60°F, indicating that sublethal effects may be occurring at relatively low water temperatures in the Delta.

Predation - Predation by striped bass is considered the primary cause of high pre-screening mortality of juvenile chinook salmon at the SWP export facility in the south Delta. Although data are limited, estimated losses of juvenile chinook salmon entrained into CCF range from 63% to 86% (DFG 1987a). Predation losses at the CVP export facility are assumed to be lower because of the absence of extensive predator habitat. The significance of predation at other diversion facilities and in the Delta has not been adequately evaluated.

Suisun Marsh Salinity Control Structure - The Suisun Marsh Salinity Control Structure, designed to improve water quality in Montezuma Slough and Suisun Marsh during periods of low to moderate Delta outflow, may delay upstream migration of adult chinook salmon and other anadromous species when it is operating (Herrgesell 1993) (Figure 2-VII-18).

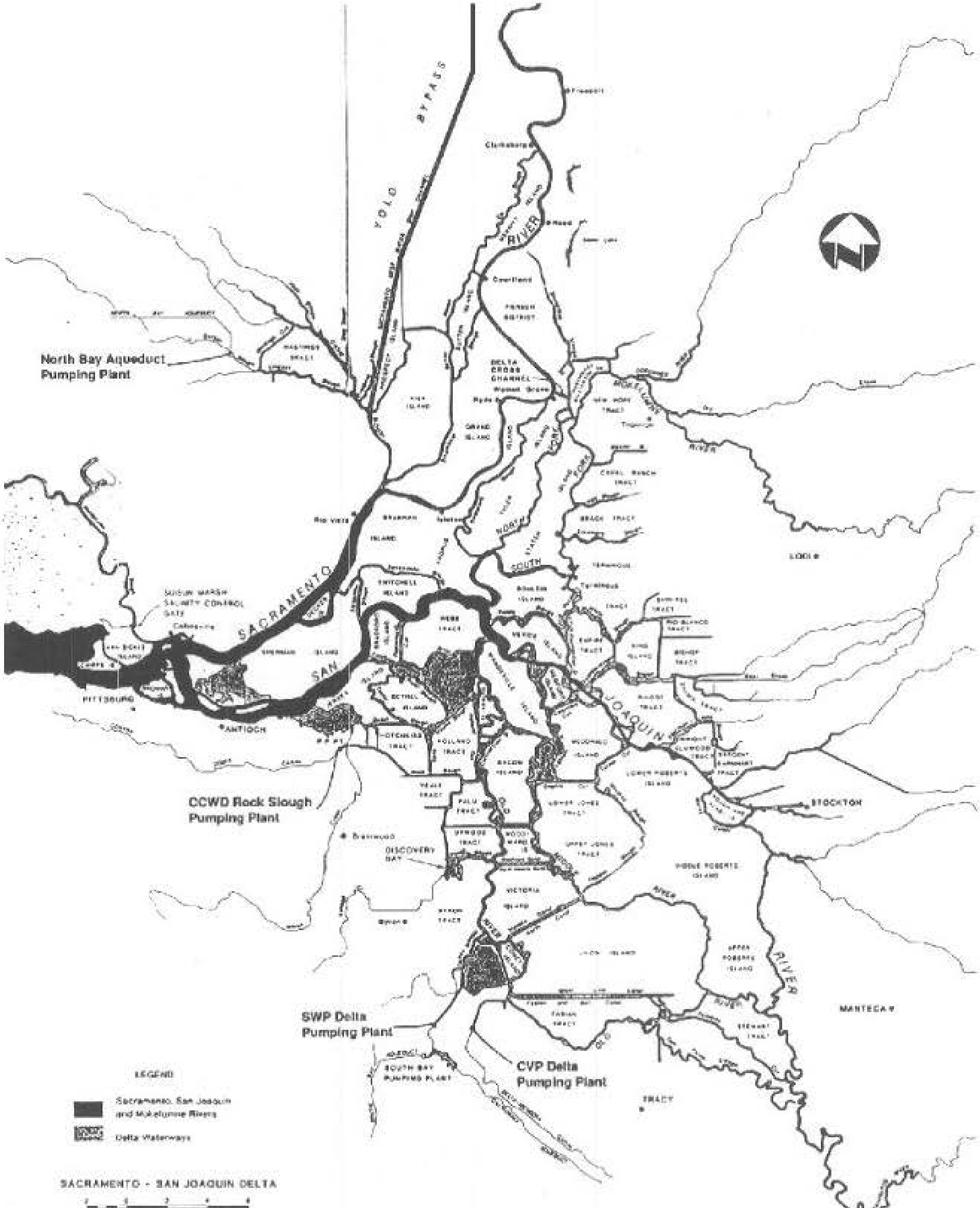
STEELHEAD



SOURCE: Kjelson et al. (1989).

ESTIMATED CHINOOK SALMON SMOLT MORTALITY VERSUS AVERAGE DAILY WATER TEMPERATURE AT FREEPORT ON RELEASE DAY, REACHES 1-3

FIGURE 2-VII-17



SACRAMENTO-SAN JOAQUIN DELTA

FIGURE 2-VII-18

General Problems

Upstream migration, spawning, and incubation - Passage at natural riffles is not as much of a concern for steelhead as it is with chinook salmon because steelhead are smaller and better swimmers and can better negotiate natural riffles and partial barriers. Nonetheless, minimum migration flows during major migration months are necessary to ensure that steelhead reach upstream spawning habitats, which are preferred.

Flow fluctuation, water temperature, and water quality-related factors affecting successful steelhead spawning, egg incubation, and emergence for steelhead are basically the same for chinook salmon. Flow fluctuation factors, in particular, can significantly reduce egg incubation and fry emergence success. Eggs are most susceptible to mortality during the early stages of development, and sudden changes in water temperature, oxygen availability, or percolation rates around the eggs can increase mortalities.

Rearing and downstream migration - Factors affecting juvenile steelhead rearing and emigration in the Sacramento River system are similar to those affecting fall-run chinook salmon because of similarities in the timing and environmental needs of these two species during downstream migration. The principal difference between the two species is that steelhead juveniles rear longer and are larger than most salmon emigrants. Other than their greater swimming ability, which can help them avoid or escape some sources of mortality better than salmon, steelhead are subject to the same sources of mortality and mechanisms as salmon. For the most part, steelhead emigrate during spring.

Because steelhead rear year round, suitable flows must be provided year-round, although in most streams, the critical limiting factors occurs during summer. Steelhead are also susceptible to flow fluctuations and other flow characteristics year round, unlike juvenile salmon, and are therefore exposed to in-river mortality factors for a longer time.

Water temperature is obviously related to flow and is the factor that is most likely currently limiting natural steelhead production on many streams. While coldwater releases occur below some dams, the amount (and quality) of habitat available for steelhead rearing below these dams is a fraction of what it was before human disturbances. In addition, coldwater releases are not available below many migration barriers or are only possible when reservoirs are full. Appropriate water temperature regimes below many dams are not consistently maintained as they were naturally in the well-shaded upper watersheds before human disturbances.

Sacramento River

Upstream migration and spawning - The timing of upstream steelhead migration coincides with the timing of upstream migration of fall-, late fall-, and winter-run chinook salmon. Consequently, flow, water temperature, and passage-related factors affecting upstream migration of adult steelhead in the Sacramento River system are similar to those affecting chinook salmon.

Hallock (1989) estimated that passage problems at RBDD alone had reduced annual adult steelhead runs in the upper Sacramento River system by about 6,000 fish. That number would undoubtedly be larger now due to the subsequent recorded declines in steelhead counts at RBDD. In general, steelhead are attracted to high, cold flows, and such conditions provide optimal migration opportunities. Without removal of entire dams, however, steelhead production is probably not currently limited by barriers below the major dams.

Several instream flow studies have been conducted in the Sacramento River basin and have developed spawning habitat-discharge relationships for steelhead. Information involving these spawning habitat-discharge relationships have been developed incidental to studies for chinook salmon. Implementation of flows providing optimal spawning habitat may or may not increase steelhead abundance, depending on the limiting factors in each drainage. Arguably, spawning habitat may not be a limiting factor for steelhead production in most of the Sacramento River basin.

Because steelhead spawning in the Sacramento River and its tributaries occurs from December through April (primarily January through March), water temperature is not considered a limiting factor for steelhead spawning in most of the Sacramento River basin.

Most of the natural production of steelhead occurs in tributaries to the upper Sacramento River because mainstem spawning is limited by the shortage of smaller sized gravel, which occurs principally in the wide, braided areas of the river (Reynolds et al. 1990). Although steelhead generally select somewhat smaller sized spawning gravels than do chinook salmon, the factors affecting spawning gravels for steelhead production in the Sacramento River system are similar to those affecting spawning gravels for fall-run chinook salmon production, particularly in the larger stream systems and downstream of the larger dams. In some of the minor tributaries where passage is available during the spawning season, some steelhead ascend higher in the watershed than salmon, where they find suitable pockets of gravel to spawn.

Downstream migration - Extended coldwater releases below dams may actually retard emigration until late spring, when increasing water temperatures and diversions in the mainstem Sacramento River and Delta result in a larger mortality factor for steelhead smolts.

Sacramento River Tributaries

Low summer flows and high temperatures have been identified as creating unfavorable conditions in Clear, Cottonwood, Mill, Deer, and Butte creeks for steelhead rearing (The Resources Agency 1989).

In the lower American River, water temperatures are commonly 60-77^{o}F from July through October and are not conducive to juvenile steelhead survival. Steelhead generally do not survive the extended warm waters in many years and move prematurely out of the American River to seek cooler water (McEwan and Nelson 1991). These temperatures have been a major contributing factor to natural production contributing less than 5% of the adult steelhead population in the American River.

San Joaquin River and Tributaries

Factors affecting steelhead abundance in the San Joaquin River basin are assumed to be similar to those described in detail for San Joaquin River fall-run chinook salmon. The primary factors limiting abundance and distribution are dams, water diversions, poor water quality, and riparian impacts. Low summer flows and concurrent high water temperatures preclude the necessary year-round rearing habitat for steelhead below the lowermost impassable dams (Friant, Crocker Huffman, LaGrange, Goodwin, and Camanche dams) that exist on the mainstem San Joaquin River and its major tributaries.

Delta/Bay

Delta flows and exports may affect the abundance of downstream migrating steelhead much the same way as they affect fall-run chinook salmon.

The average annual number of steelhead salvaged at the SWP intake for 1968-1980 was 2,453 (DFG 1981). Table 2-VII-2 lists the number of steelhead salvaged at these two pumping plants during the primary emigration months of February-May.

Table 2-VII-2. Number of steelhead trout salvaged at SWP and CVP Delta Pumping Plants in February-May (1979-1991).

Year	February		March		April		May	
	SWP Intake	CVP Intake	SWP Intake	CVP Intake	SWP Intake	CVP Intake	SWP Intake	CVP Intake
1979	25	372	454	444	1,407	1,080	969	0
1980	835	0	74	90	118	243	210	126
1981	1,509	1,258	3,088	1,008	4,902	168	0	267
1982	1,432	0	1,110	0	10,965	0	2,441	297
1983	89	0	0	0	0	0	256	0
1984	0	0	41	146	357	187	18	70
1985	325	83	1,221	134	1,165	127	647	101
1986	139	524	54	127	1,328	505	446	238
1987	69	112	3,387	718	976	776	446	275

	February		March		April		May	
1988	2,403	0	823	491	2,116	1,039	426	1,646
1989	499	252	4,767	5,051	2,105	3,139	404	1,212
1990	1,317	1,085	3,115	2,139	1,039	786	19	0
1991	23	109	5,799	4,412	2,692	1,263	91	98

Source: California Department of Fish and Game salvage database.

Table 2-VII-3 provides losses of yearling equivalent steelhead at the SWP intake estimated by a formula negotiated between DFG and DWR. Salvaged steelhead are trucked to either the north or south side of Sherman Island or near Antioch. Some of these fish are lost to predation and stress associated with handling and trucking. Reverse flows in Delta channels caused by pumping operations can also cause disorientation, delay, and additional predation in Delta channels for steelhead not affected directly by the pumping facilities. Although both pumping plants have louver fish screens that may be 90% effective for downstream migrating steelhead, prescreening losses are probably 75% at SWP pumping facilities, mostly due to predation in CCF, and are probably 15% at Tracy.

Table 2-VII-3. Estimated annual losses of steelhead trout at the SWP Delta intake (1982-1991).

Year	Calculated steelhead lost	
	Young-of-year	Yearling
1982	0	73,748
1983	0	2,945
1984	0	1,713
1985	0	15,621
1986	0	15,663
1987	747	21,266
1988	0	25,080
1989	253	32,571

1990	0	19,187
1991	0	38,430

Note: Estimates use the formula established under the 1986 pumping plant agreement between DWR and DFG.

Source: California Department of Water Resources 1993.

Unscreened diversions at the Contra Costa Water District's (CCWD's) intake at Rock Slough and at more than 1,500 agricultural water diversions in the Delta also cause unknown losses of emigrating steelhead. No steelhead have been caught in routine entrainment and impingement sampling at the screened intakes of Pacific Gas and Electric Company's (PG&E's) power plants at Antioch and Pittsburg in the western Delta (Running 1993).

A portion of the water flowing down the Sacramento River is diverted into Georgiana Slough, the DCC, and Threemile Slough into the lower San Joaquin River. A portion of the juvenile steelhead migrating down the Sacramento River enter these channels, and many are subsequently drawn toward the SWP Banks Pumping Plant and the CVP Tracy Pumping Plant.

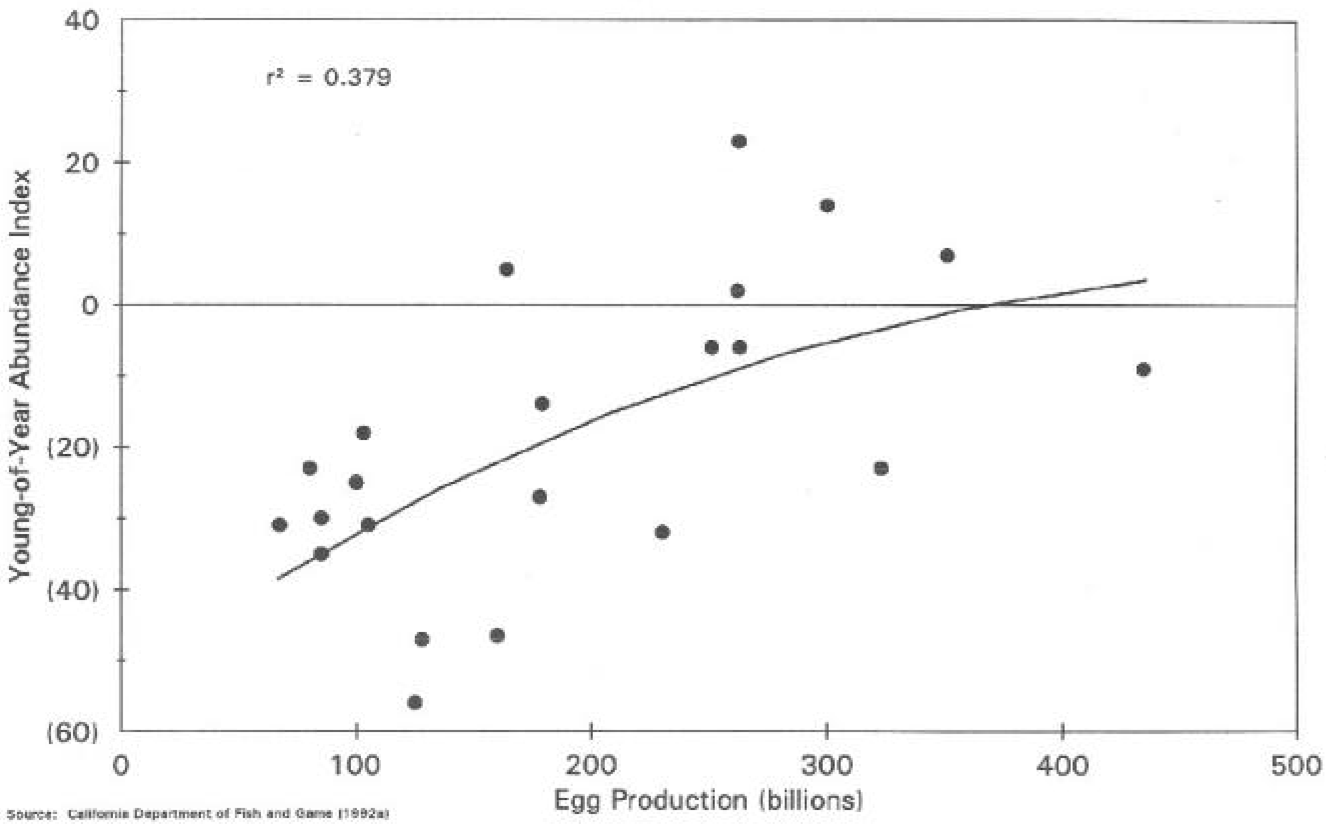
STRIPED BASS

General Problems

The decline of the striped bass population in the Sacramento-San Joaquin estuary has generated substantial evaluation of causal factors. The decline in population abundance is a result of increased mortality and reduced reproduction. This section provides information on stock-recruitment and other life stage relationships, as well as on the specific problems that may be increasing mortality and reducing fecundity and fertility. The focus of this section is on anthropogenic (i.e., human-caused) factors that may continue to affect abundance, especially factors that are affected by CVP facilities and operations. In addition, information is provided on environmental conditions that may exacerbate the effects of CVP operations and facilities on conditions that may suppress the benefits of actions implemented under the CVPIA.

Factors that may have contributed to increased mortality after 1967 include the same factors that affected mortality before 1967 (i.e., fishing, entrainment in diversions, exposure to toxic materials, and habitat loss). Additional factors that affect mortality include reduced Delta inflow and outflow, altered Delta flow patterns, dredging and spoil disposal, diseases and parasites, and introduction of exotic species.

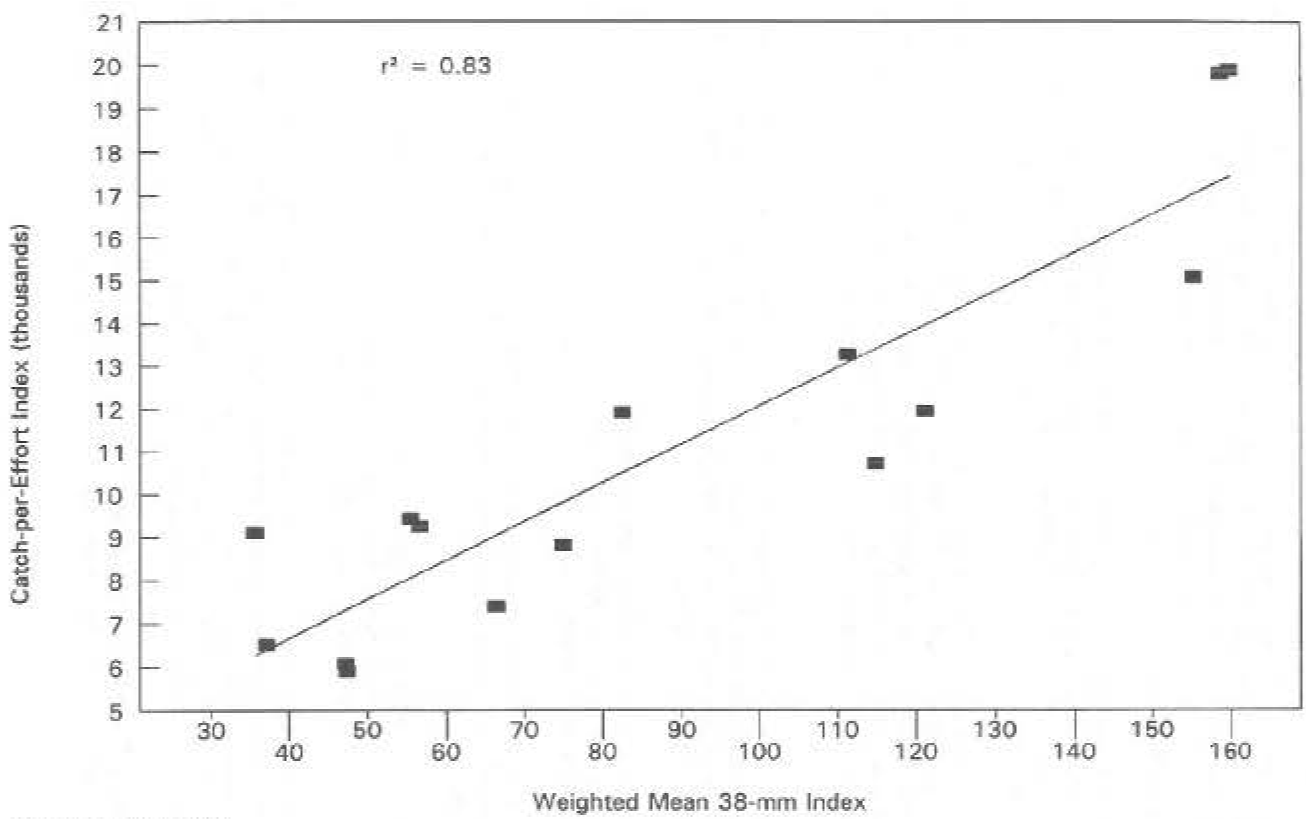
Stock-recruitment and other life stage relationships - DFG (Kohlhorst et al. 1992) has suggested that a significant stock-recruit relationship exists for striped bass (i.e., the number of bass produced in any given



Source: California Department of Fish and Game (1992a)

RELATIONSHIP BETWEEN YOUNG-OF-YEAR ABUNDANCE INDEX AND EGG PRODUCTION IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

FIGURE 2-VII-19



Source: Kohlhorst et al. (1992).

RELATIONSHIP BETWEEN ADULT POPULATION ABUNDANCE (STRIPED BASS TAGGING STUDY CATCH-PER-EFFORT INDEX) AND WEIGHTED MEAN YOUNG-OF-YEAR INDEX 3-7 YEARS EARLIER

FIGURE 2-VII-20

year depends to some extent on egg production) (Figure 2-VII-19). If the stock-recruit relationship is valid, the existing adult striped bass population may be unable to produce sufficient numbers of eggs to sustain existing mortality rates on all life stages. Increased mortality of the adult striped bass population and reduced recruitment to the adult population would result in continued decline. However, reduced adult mortality, in combination with improved habitat conditions, could enhance the ability of the population to recover to historical levels.

Adult population abundance is correlated with the 1,52-inch index (Figure 2-VII-20), indicating that reduced recruitment to the adult population has been the major cause of declining adult abundance (Kohlhorst et al. 1992). Lower recruitment is estimated to account for 75% of the adult decline, while lower adult survival rates account for the remaining 25%.

Annual adult striped bass mortality rates increased from approximately 40% in the early 1970s to 53% in recent years (DFG 1987). The cause of increased adult mortality rates may be attributed to habitat loss, increased levels of toxic materials, sport and illegal fishing, and other factors.

As discussed above, lower recruitment is estimated to account for 75% of the adult decline that has occurred since the late 1960s. Recruitment to the adult population depends on survival of eggs, larvae, and juvenile bass. Studies have shown a significant relationship between the annual abundance of larval striped bass (0.32 inch long) and juvenile striped bass (1.52-inch index), and between juvenile striped bass and recruitment to the population 4 years later, indicating that year-class strength of the population is set early in the life cycle (Turner 1987) (Figures 2-VII-19 and 2-VII-20). The number of 0.32-inch-long larvae is a function of the number of viable eggs spawned, spawning timing and location, flow conditions, direct diversion effects, and development rates (a function of water temperature). Many of the factors affecting abundance of eggs and larvae equally apply to the early juvenile stages (greater than 1.52 inch long).

Although year-class strength of the population is set early in the life cycle of striped bass, perhaps before the juvenile life stage, survival of juveniles ultimately determines the number of bass recruited to the adult population. Losses of juvenile striped bass are important in determining adult abundance (Kohlhorst et al. 1992).

Decreased fecundity and fertility - Reduced reproduction results from fewer fertile eggs being produced by the population each year. Factors that may have affected the number of fertile eggs produced include factors affecting the abundance, size, and health of female striped bass. Mortality rates determine the abundance of female bass. Factors affecting size and health of female striped bass include accumulation of toxic materials by the female bass, diseases and parasites, and reduced food availability.

Egg production depends on the abundance and fecundity of adult female striped bass. From the early 1970s to the present, the number of eggs produced by the population declined, the result of reduced adult striped bass abundance (DFG 1987). Average egg production during 1981-1986 was 17% of the 1969-1973 average egg production.

Flow and water temperature - Other than the relationship of Delta inflow to exports and Delta outflow to location of X2 (area in which salinity is 2 parts per thousand or approximately 3,000 uS EC), flow likely has minimal direct effects on juvenile striped bass.

High water temperature has not caused substantial direct mortality of eggs and larvae and has not played a major role in the recent decline of young striped bass in the Sacramento-San Joaquin River system (Mitchell 1987).

Habitat - The effects of habitat loss on eggs and juvenile striped bass are currently unknown. Effects on overall estuary productivity, however, may have had substantial adverse effects on larval survival, but this does not account for the population decline after 1970.

Toxic substances - Larval striped bass survival may have been reduced by the toxic effects of insecticides, herbicides, trace elements, and other toxic materials that have entered the estuary from agricultural runoff and municipal and industrial discharge. Toxic materials can affect larval bass directly and indirectly, causing mortality within a short period (days) or adversely affecting growth and development, which limit the chances for survival (Brown 1987).

Although the decline in striped bass abundance that has occurred over the last 20 years is not attributable to toxic materials alone, toxics may have substantially reduced survival of striped bass compared to other estuaries. The issue of toxic materials needs to be addressed in much greater detail to determine the effect on striped bass abundance.

Competition and predation - The effects of competition and predation are difficult to evaluate in wild populations. Parallel trends (i.e., abundance declines of one species during the same period that abundance of a competing or predator species increases) would suggest competition or predation effects. A consistent increase in the abundance of species that compete with or prey on striped bass is not apparent from analysis of available data (DFG 1987).

Introduction of exotic organisms has substantially altered the biological structure of the estuary. Exotic organisms affect striped bass through competition, predation, and change in trophic dynamics (i.e., the availability of prey). Although numerous introduced fish and invertebrate species have become abundant (Brown 1992), the effect on striped bass survival is unknown.

Prey availability - Decline in the copepod *Eurytemora*, the preferred prey of larval striped bass, occurred during the period that striped bass declined in abundance (DFG 1992a, Obrebski et al. 1992). The composition and abundance of larval striped bass prey have changed dramatically since 1979; some species increased in abundance while others declined. Although the introduced *Sinocalanus* has replaced declining populations of *Eurytemora* (Herbold et al. 1992), striped bass larvae do not effectively feed on the recently abundant *Sinocalanus*.

Laboratory experiments show that striped bass mortality is negatively correlated with prey density (Herbold et al. 1992). Field studies indicated that prey density in the estuary was low relative to densities needed to support high survival in the laboratory. Larvae collected from the estuary do not show signs of starvation, but low densities may result in slower larval growth rates and increased mortality from predation. Larval mortality in the estuary was estimated to be higher than larval mortality for similar prey densities in the laboratory.

Reduced abundance of striped bass attributable to reduced prey abundance should be reflected in reduced larval survival rates for any given level of outflow and diversion (DFG 1992a). Larval survival over the historical period (1969-1990), however, appeared to be unchanged, except for the effects of diversion and outflow. Additional studies are needed to resolve questions on prey availability and the effect on striped bass survival.

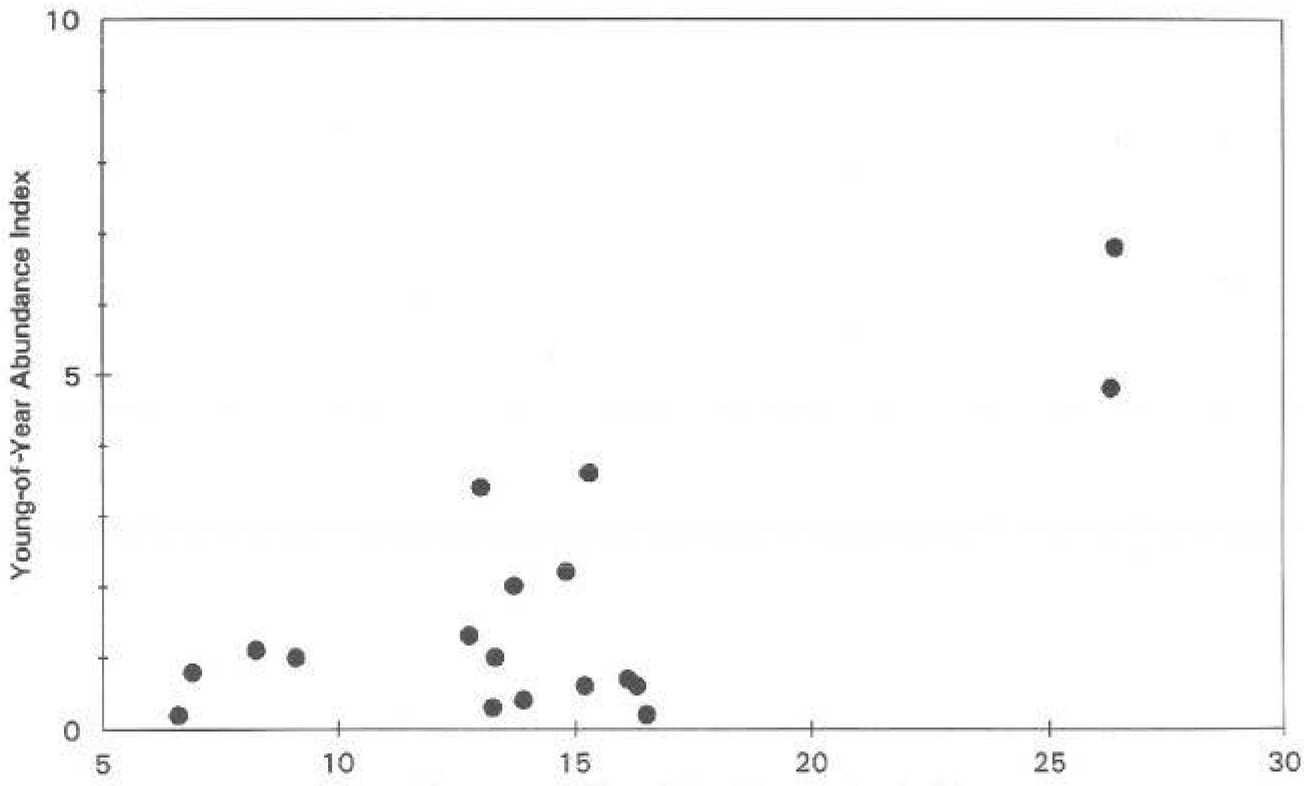
As discussed for larvae, additional studies are needed to resolve questions on prey availability and the effect on striped bass survival. As discussed under "Life History," juvenile striped bass (especially during their first year of life) feed primarily on the mysid *Neomysis*. *Neomysis* declined in abundance during the 1970s, but declines were significant only during fall (Obrebski et al. 1992). Reduced abundance of prey could slow the growth of striped bass and increase mortality from predation.

Sacramento River

Flow - The survival (survival index) between the egg and the 0.24-inch-long larvae stage in the Sacramento River is low when Sacramento River flow is low (Figure 2-VII-21) (DFG 1992a). Survival is always low when flow is less than 13,000 cfs. The following mechanisms may explain reduced survival at lower Sacramento River flows:

- Eggs and larvae settle to the river bottom and die when they encounter near zero velocity in tidally affected reaches.
- Larval survival is reduced because arrival in higher quality downstream nursery areas is delayed.
- Larvae are subjected to increased exposure to toxic substances carried by the river.
- A higher proportion of larvae are drawn through the DCC, Georgiana Slough, and Threemile Slough into the central Delta where vulnerability to entrainment in diversions is greater.

Feeding efficiency, and thus growth and survival, may be greater in downstream reaches because the density of striped bass prey in the Sacramento River is higher in the reaches below Rio Vista (DFG 1992a).



Source: California Department of Fish and Game (1992a).

RELATIONSHIP BETWEEN SURVIVAL OF STRIPED BASS (EGGS TO 6MM) AND SACRAMENTO RIVER FLOW

FIGURE 2-VII-21

Assuming that the proportion of eggs and larvae drawn into the DCC, Georgiana Slough, and Threemile Slough depends on the proportion of Sacramento River flow diverted, more eggs and larvae would be drawn into the central Delta at lower flows than at higher flows.

In addition to flow effects on survival, diversions from the Sacramento River may entrain eggs and larvae and reduce river flow. In proportion to Sacramento River flow, diversions from the Sacramento River in the spawning reach (between Sacramento and Colusa) are small. The effect of Sacramento River diversions on striped bass, although they contribute to the cumulative effect of total diversions and upstream storage, would also be expected to be relatively small.

Toxic substances - Recent studies indicate that larvae from the Sacramento River show a higher incidence of liver malformation than larvae from other areas of the estuary. Contamination of the Sacramento River increased substantially in the mid-1970s when application of rice pesticides increased (Herbold et al. 1992). Measured toxic concentrations were sufficient to kill fish in sloughs draining rice fields, and estimated toxic concentrations for the Sacramento River during 1970-1988 may have deleteriously affected striped bass larvae (Bailey 1992). Discharge of contaminated rice field water coincides with striped bass spawning and may account for part of the decline in striped bass abundance. Pesticide application has correlated with young striped bass abundance, but direct relationships are inconclusive.

San Joaquin River

The farther upstream X2 is located, the farther upstream spawning generally occurs (Figure 2-VII-22). Eggs spawned upstream in the Delta (in the lower San Joaquin River) are more vulnerable to entrainment in water exports from the south Delta (DFG 1992a). Existing Delta water quality requirements (California State Water Resources Control Board 1978) do not require sufficient outflow to encourage striped bass spawning in the lowermost 10-kilometer reach of the San Joaquin River.

Wendt (1987) showed that flow in the lower San Joaquin River (along with export volume and striped bass abundance and size) was significantly correlated with entrainment losses at the CVP and SWP Delta pumping facilities. Lower San Joaquin River flow, however, is determined by Delta inflow and export, as is the location of X2 in the estuary (San Francisco Estuary Project 1993). For juvenile striped bass, their location in the estuary may be more important than flow in determining the effect of other factors (i.e., entrainment).

Delta/Bay

Flow - Delta outflow is highly variable across years, seasonally, and, at times, weekly. In general, month-to-month outflows in any given year are highly autocorrelated, whereas year-to-year outflows are not. This generally means that high outflows occur across several months in wet years (Herbold et al. 1992). In any given year, outflow has ranged from less than 10 maf to more than 50 maf.

Although dependent on the natural hydrology of the Sacramento-San Joaquin River system, the timing and volume of Delta outflow have been substantially modified by changes in system characteristics; channelization and flood control projects; and by operations of water project facilities, reservoirs, and diversions (Herbold et al. 1992). Channelization and flood control projects (not including reservoir storage) enable water to move more quickly to the Delta. Reservoir storage reduces peak flows and changes the timing of water movement down the rivers. Consumptive diversions remove water from the system.

In general, water projects have increased summer and fall outflow and reduced winter and spring outflow (Herbold et al. 1992). Total annual Delta outflow can be reduced by 50-60% of the outflow expected in the absence of storage and diversions, with less proportional change in wet years and greater in dry years.

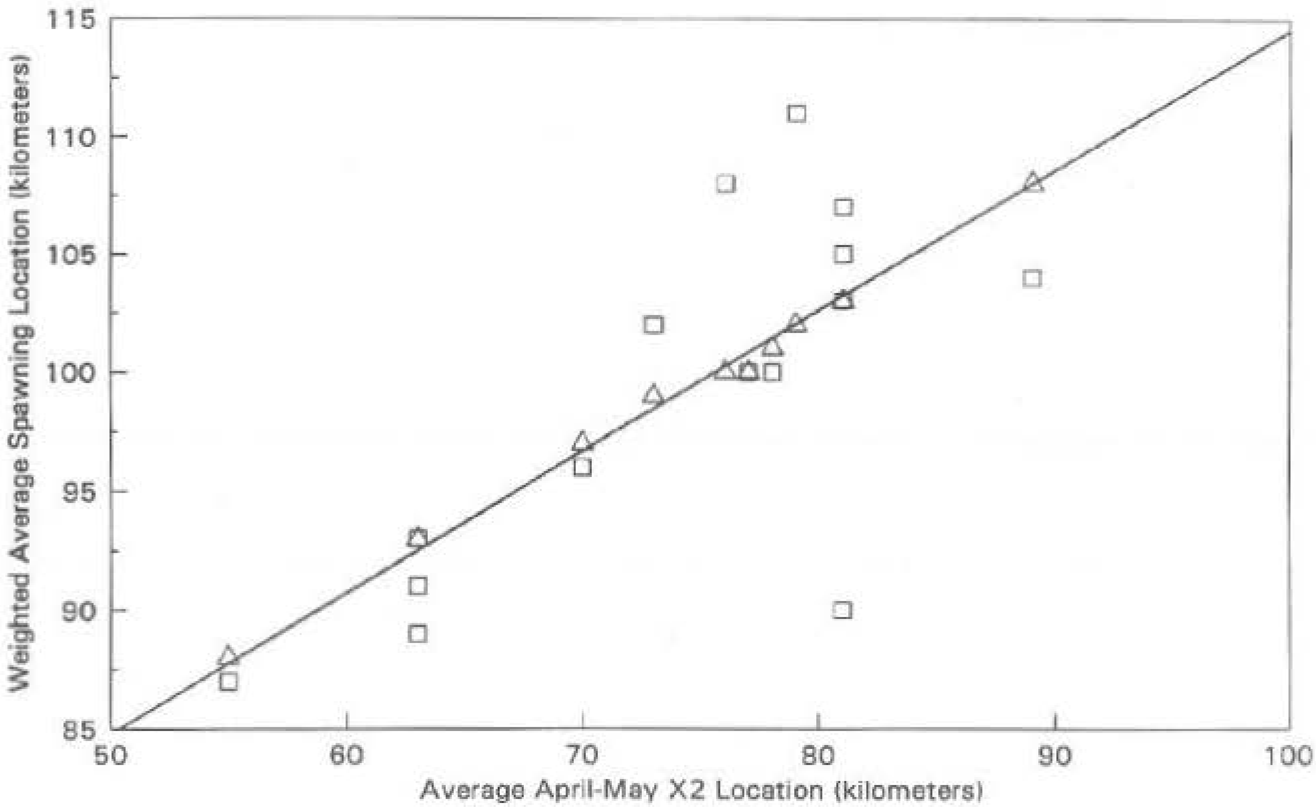
Delta outflow and diversions are considered by DFG to be the primary factors contributing to the continuing 20-year decline of striped bass in the Sacramento-San Joaquin estuary (DFG 1992a). The decline in striped bass abundance correlates significantly with numerous flow-related variables, including water temperature, Delta inflow, Delta outflow, salinity, and diversions (Turner and Chadwick 1972). Because the variables are highly interdependent, the mechanisms causing the decline are unclear.

Delta outflow affects the distribution of striped bass larvae. The location of X2 in the estuary is indicative of the level of Delta outflow; as outflow increases, X2 moves farther downstream (San Francisco Estuary Project 1993). When X2 is in Suisun Bay, larvae density is greatest in Suisun Bay; when X2 is in the Delta, larvae density is greatest in the Delta. Figure 2-VII-41 shows a similar relationship for 1.52-inch-long striped bass juveniles. The mechanism of distribution (i.e., whether outflow transports the larvae downstream or larvae actively maintain their position relative to the entrapment zone) is not known, but the location of larvae relative to X2 is consistent with larval avoidance of the surface.

Striped bass survival from egg size to 1.52 inches long and from 0.36 to 1.52 inches long is higher at higher outflows (i.e., when X2 is farther downstream) (DFG 1992a, San Francisco Estuary Project 1993) (Figure 2-VII-23). High outflow may benefit larval striped bass by:

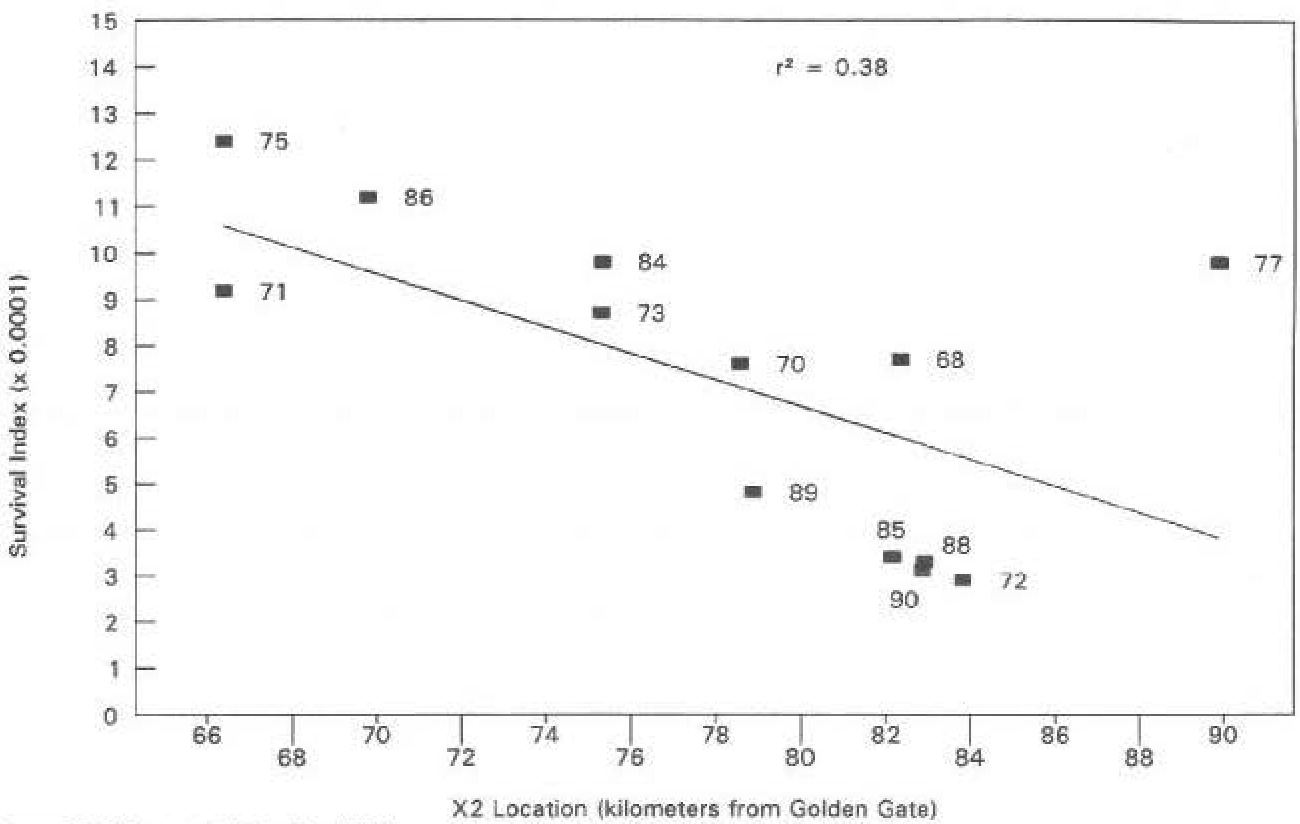
- increasing the nursery area and reducing intraspecific competition,
- increasing shallow habitat area and food abundance,
- diluting toxic materials,
- increasing turbidity and reducing predation, and
- reducing vulnerability to entrainment in Delta diversions (Herbold et al. 1992).

The Suisun Marsh Control Structure affects flows in Suisun Marsh and also may affect striped bass survival. After installation and operation of the Suisun Marsh Control Structure in 1989, the flow in Montezuma Slough greatly increased, averaging more than 2,000 cfs toward Suisun Marsh during operation of the structure. The timing of operations extends through the striped bass egg and larval period. The effect on striped bass is currently unknown, but operations could reduce survival through increased predation at the



RELATIONSHIP BETWEEN THE LOCATION OF STRIPED BASS SPAWNING IN THE LOWER SAN JOAQUIN RIVER PORTION OF THE DELTA AND THE LOCATION OF X2 (KILOMETERS FROM THE GOLDEN GATE BRIDGE) IN THE ESTUARY

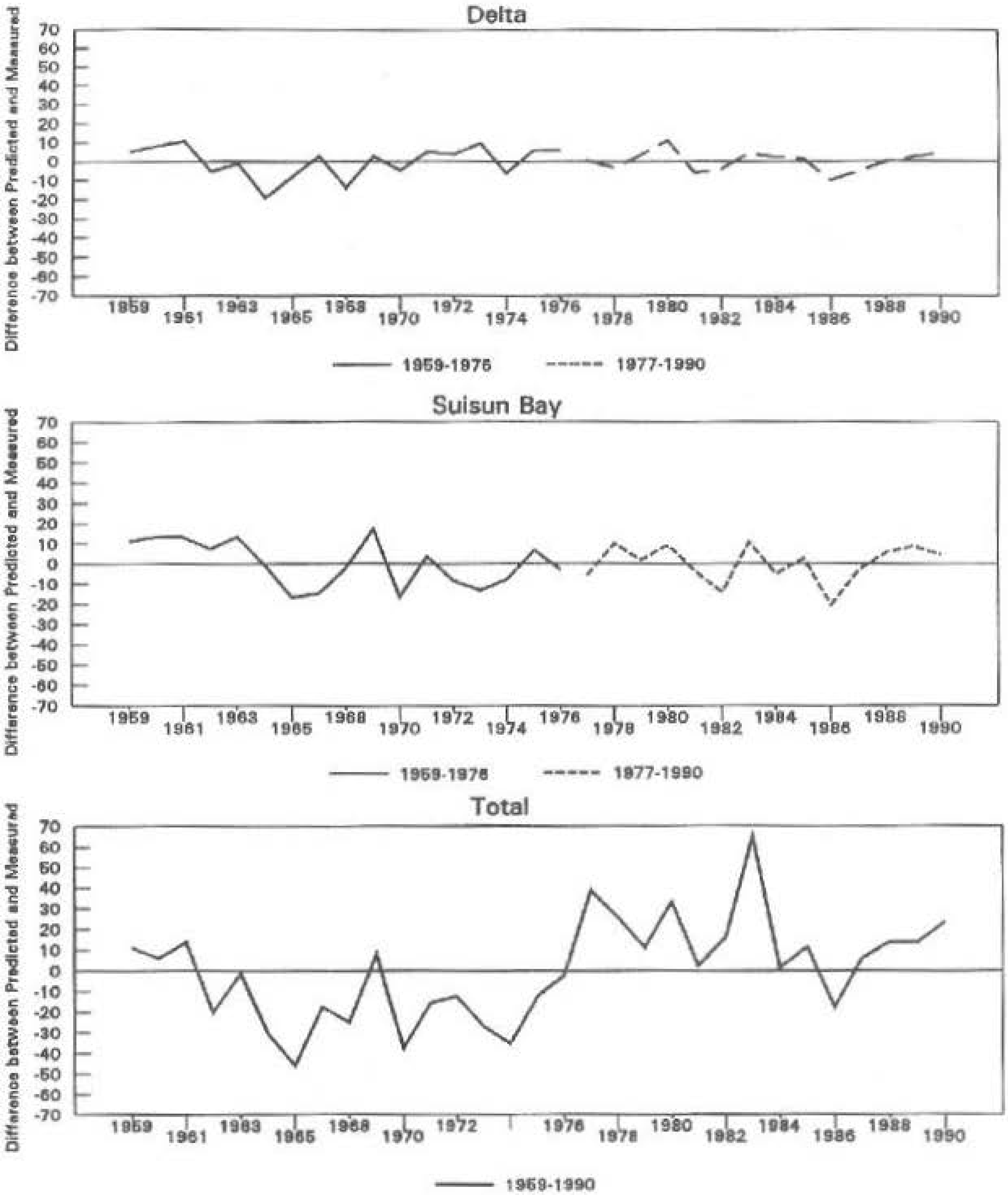
FIGURE 2-VII-22



Source: California Department of Fish and Game (1992e).

RELATIONSHIP BETWEEN THE SURVIVAL INDEX (FOR 9-MM TO 38-MM STRIPED BASS) AND THE LOCATION OF X2

FIGURE 2-VII-23

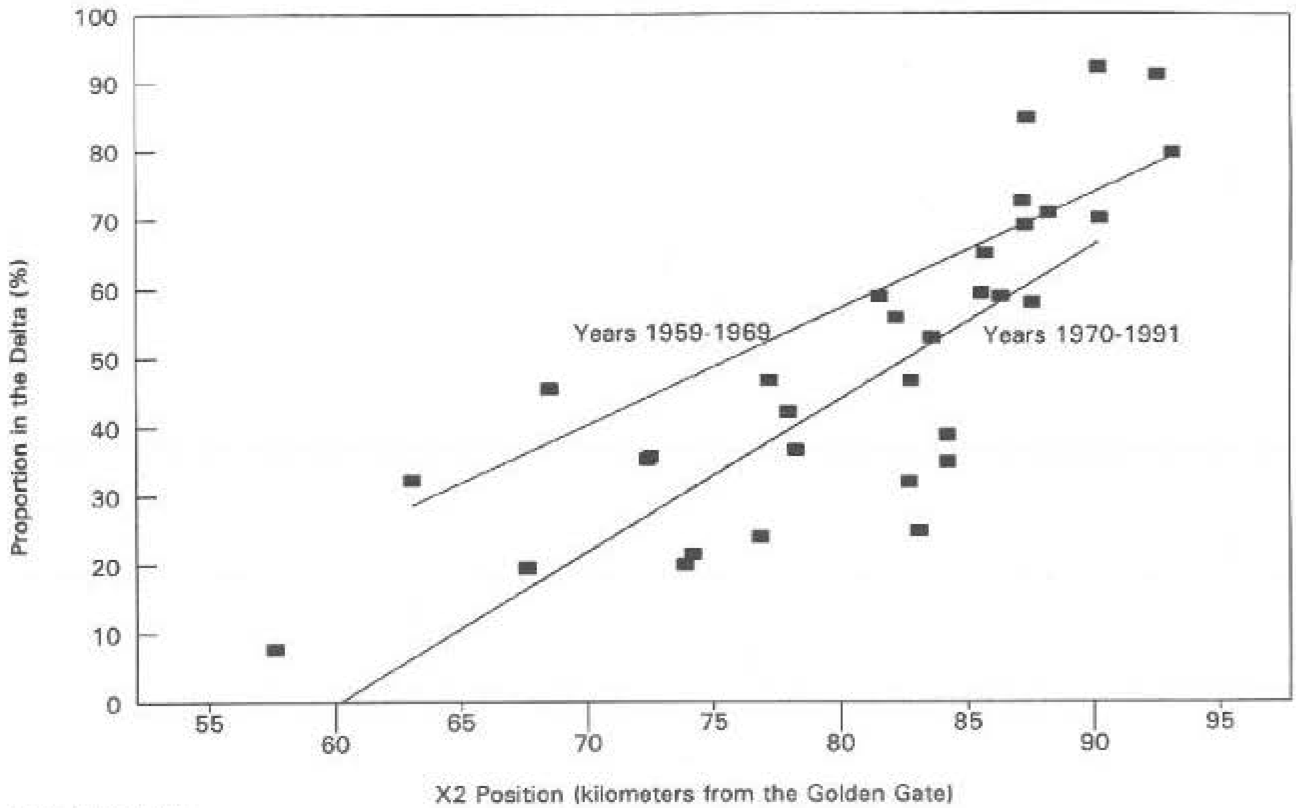


Sources: California Department of Fish and Game (1992a), Herrgesell (1993)

Note: Different equations were used for 1959-1976 and 1977-1990 to calculate the Delta and Suisun Bay indices.

DIFFERENCE BETWEEN THE PREDICTED AND MEASURED ABUNDANCE INDICES FOR STRIPED BASS IN THE DELTA, SUISUN BAY, AND IN BOTH THE DELTA AND SUISUN BAY (TOTAL)

FIGURE 2-VII-24



Source: Herrgesell (1993).

COMPARISON OF THE 1959-1969 AND 1970-1991 RELATIONSHIPS BETWEEN THE PROPORTION OF STRIPED BASS IN THE DELTA AND THE LOCATION OF X2

FIGURE 2-VII-25

Suisun Marsh Control Structure (Herrgesell 1993) and exposure to conditions within Montezuma Slough that may be less conducive to survival than conditions in Suisun Bay.

Also, the effect of the diversion by the Suisun Marsh Control Structure on the location of X2 is unknown. If diversion causes X2 to be located farther upstream relative to the location of X2 without operation of the Suisun Marsh Control Structure, survival of striped bass could be reduced (Figure 2-VII-23).

Salinity - Approximately 40% of the striped bass population spawns in the Delta, generally in the lower San Joaquin River, from Venice Island downstream to Antioch. Salinity in the western Delta affects the spawning distribution in the Delta (DFG 1987). The lowest salinity occurs immediately downstream of the confluence of the San Joaquin and Mokelumne rivers, where fresh water from the Mokelumne and Sacramento rivers enters the San Joaquin River. To the east, the San Joaquin River discharges water contaminated with salty agricultural drainage. To the west, seawater intrusion increases the salinity. Adult striped bass react to increasing salinity from agricultural salts in the San Joaquin River and do not migrate through salinity exceeding 550 uS EC (Radtke 1966, DFG 1987).

Diversions - Consumptive diversions from the Delta include the CVP and SWP Delta pumping facilities; more than 1,800 agricultural diversions; CCWD's Rock Slough diversion; the North Bay Aqueduct; and numerous other municipal and industrial diversions. Up to 4,600 cfs and 10,300 cfs can be diverted from the CVP and SWP Delta pumping facilities, respectively. CCWD has a maximum diversion capacity of approximately 300 cfs, and the North Bay Aqueduct has a maximum capacity of approximately 140 cfs. Maximum agricultural diversions during the peak summer irrigation season may exceed 4,000 cfs (DWR 1993a). Total diversions from the Delta can exceed 80% of the total Delta inflow (Turner and Chadwick 1972, DWR 1993b).

Diversions entrain striped bass (discussed below under "Entrainment") and affect Delta outflow and flows in the Delta channels. Considering the historical magnitude and location of diversions relative to striped bass distribution and life history patterns, Delta diversions could have been a major factor contributing to reduced striped bass survival. Delta diversions, primarily by the CVP and SWP, are considered by DFG to be responsible for the depleted state of the striped bass population (DFG 1992a).

Over the 1959-1990 period, the abundance of striped bass (1.52-inch index) was negatively correlated with the combined effects of Delta diversions and outflow (DFG 1987, 1992). If data for the entire 1959-1990 period are used to develop the regression equation, the total predicted abundance is generally less than the total measured abundance for 1959-1976 and greater than measured abundance for 1977-1990 (Figure 2-VII-24). When separate equations are used for 1959-1976 and 1977-1990 for Suisun Bay (using Delta outflow only) and for the Delta (diversion and outflow), the predictions are greatly improved (Figure 2-VII-24).

DFG has hypothesized that the difference between the 1959-1976 and 1977-1990 relationships is attributable to the decline of the adult population to a level that caused egg production to become limiting (i.e., the stock-recruit relationship is partially controlling abundance) (Figure 2-VII-20) (DFG 1992a). Changes in estuarine productivity, toxic materials entering the estuary, and other factors may also explain the change in the relationship between abundance and the combined effects of diversion and outflow during the 1970s.

After 1970, striped bass survival in Delta habitats appears to have declined (DFG 1992a). The difference in the relationships between the proportion of striped bass in the Delta and the location of X2 for the 1959-1969 and 1970-1991 periods (r squared = 0.85 and 0.62, respectively) indicates that use of the Delta as a nursery may have declined or that survival may have been lower for the 1970-1991 period (Figure 2-VII-25). The lower position of the line representing the 1970-1991 correlation between the proportion of striped bass in the Delta and the location of X2 indicates that fewer bass were in the Delta during similar outflow conditions (i.e., X2 locations).

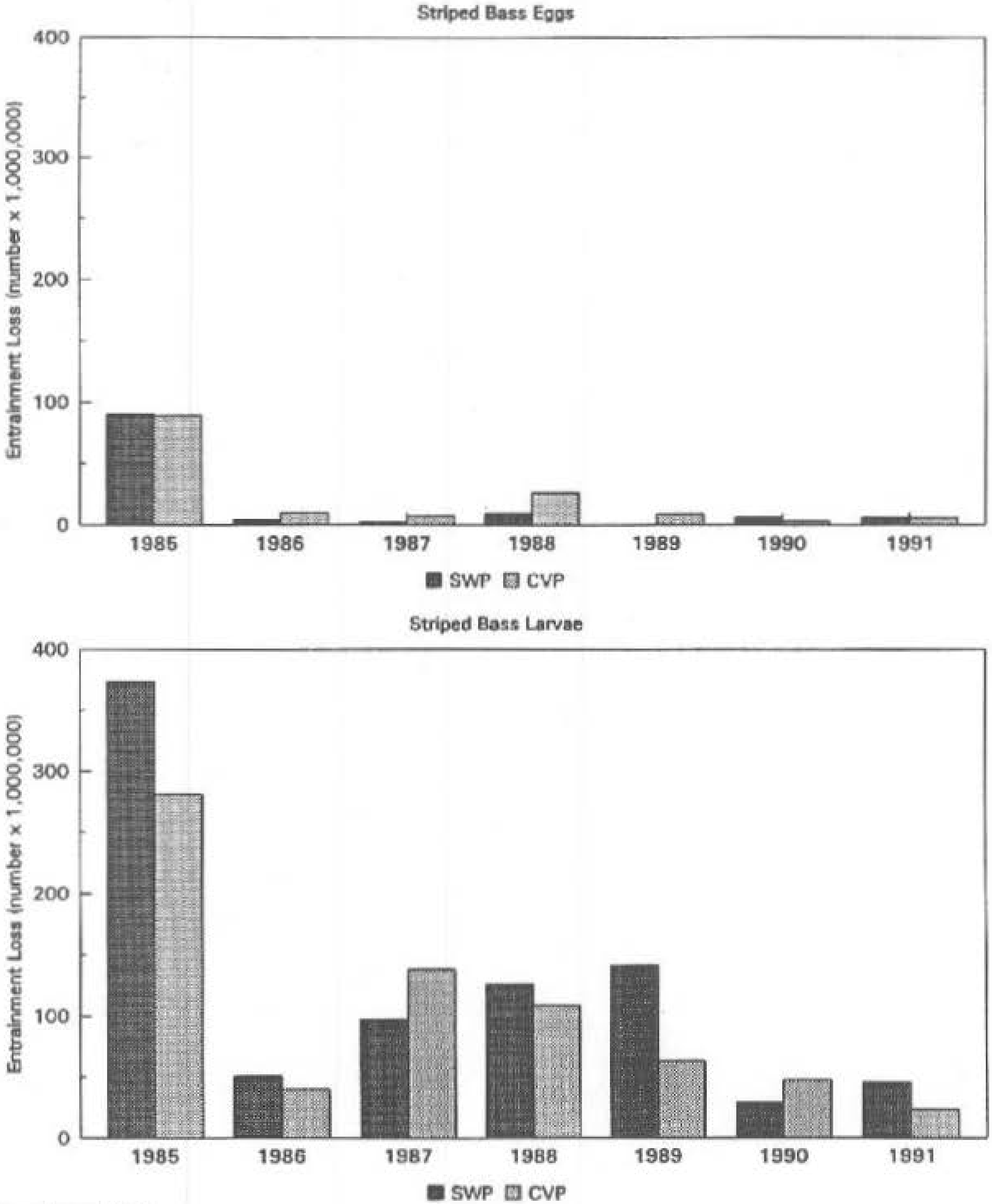
If survival rates in the Delta declined after 1970, reduced survival could be attributed to the SWP Delta pumping facilities. The SWP began exporting water after 1968 and began significant pumping by 1970. Other factors may have contributed to the decline (e.g., toxic materials entering the estuary), but insufficient data may exist for evaluation.

Entrainment - Entrainment losses were at least partly responsible for the decline in striped bass after 1970. Entrainment losses appear to be greater in low-flow years, as evidenced by greater losses at the CVP Delta pumping facilities and by the close relationship between striped bass abundance and the percentage of inflow diverted (DFG 1987).

High adult abundance results from year classes that experience minimal late summer through winter losses to export pumping (Kohlhorst et al. 1992). The magnitude of juvenile striped bass losses is potentially affected by the abundance and distribution of juvenile bass and the magnitude of exports (Wendt 1987, Kohlhorst et al. 1992).

CVP and SWP Delta pumping facilities - As discussed previously, the CVP and SWP Delta pumping facilities are the largest diversions from the Delta. Millions of striped bass eggs and larvae are lost to annual entrainment in export by the CVP and SWP Delta pumping facilities (Figure 2-VII-26). Based on estimated egg and larval survival rates (Figure 2-VII-27), the adult equivalent loss amounts to thousands of yearling striped bass each year (Figure 2-VII-28).

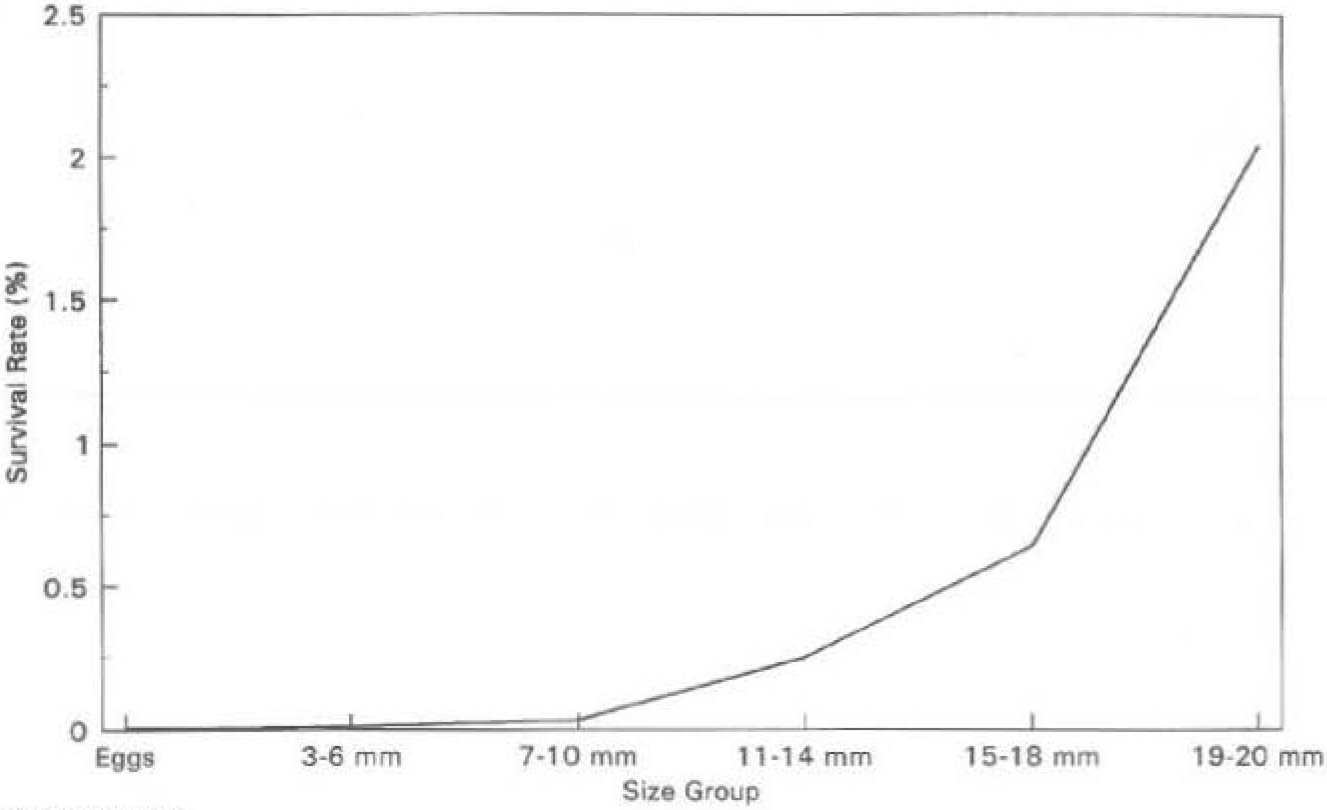
Millions of juvenile striped bass (greater than 0.8 inches long) are entrained in diversions at the CVP and SWP Delta pumping facilities each year. Most of the entrained striped bass are lost (Figure 2-VII-29), although 5-30% of all juvenile bass entrained were salvaged and returned to the Delta alive (DFG 1992b). The proportion salvaged depended on screen efficiency (a function of screen design and pumping volume),



Source: [illegible] (1993).

ENTRAINMENT LOSS OF STRIPED BASS EGGS AND LARVAE IN DIVERSIONS BY THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT DELTA PUMPING FACILITIES (1985-1991)

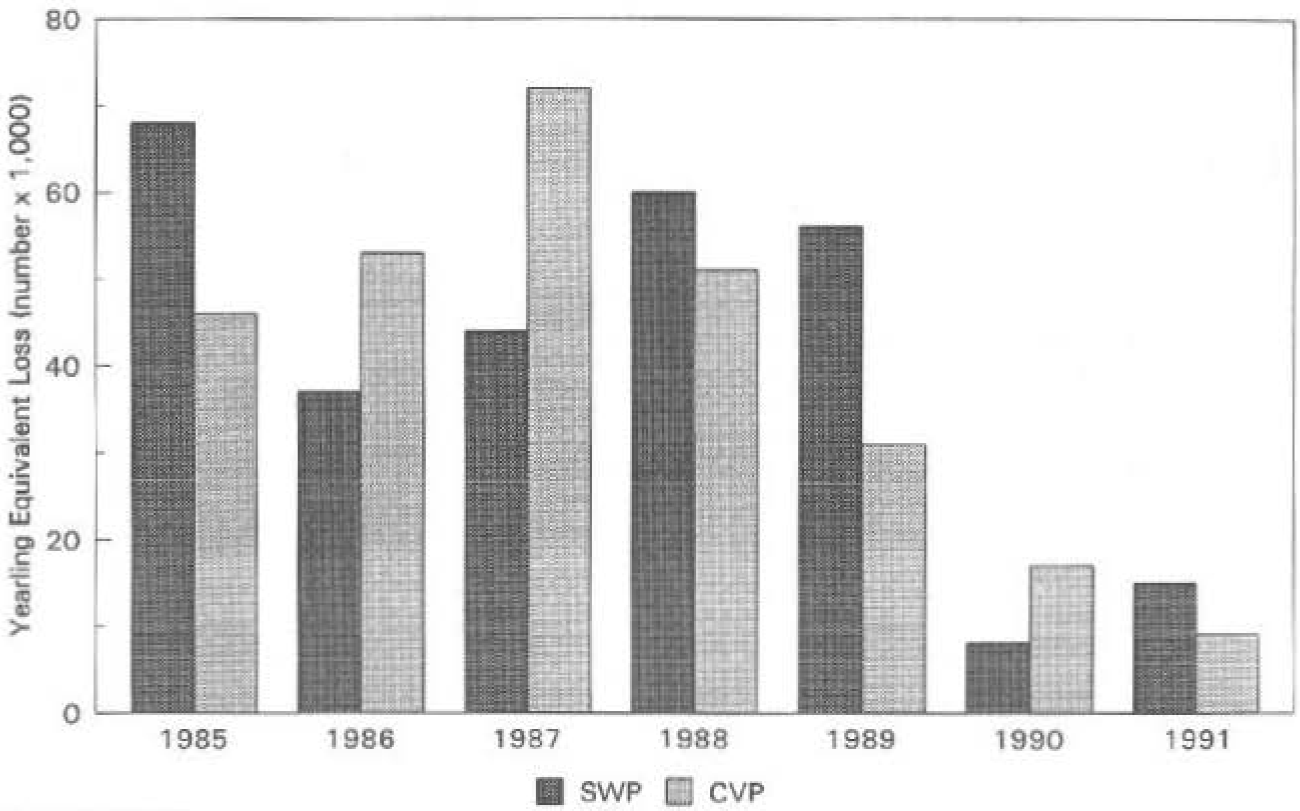
FIGURE 2-VII-26



Source: Hengesall (1993).

SURVIVAL RATES USED TO CONVERT EGG AND LARVAL ENTRAINMENT LOSSES TO YEARLING EQUIVALENTS

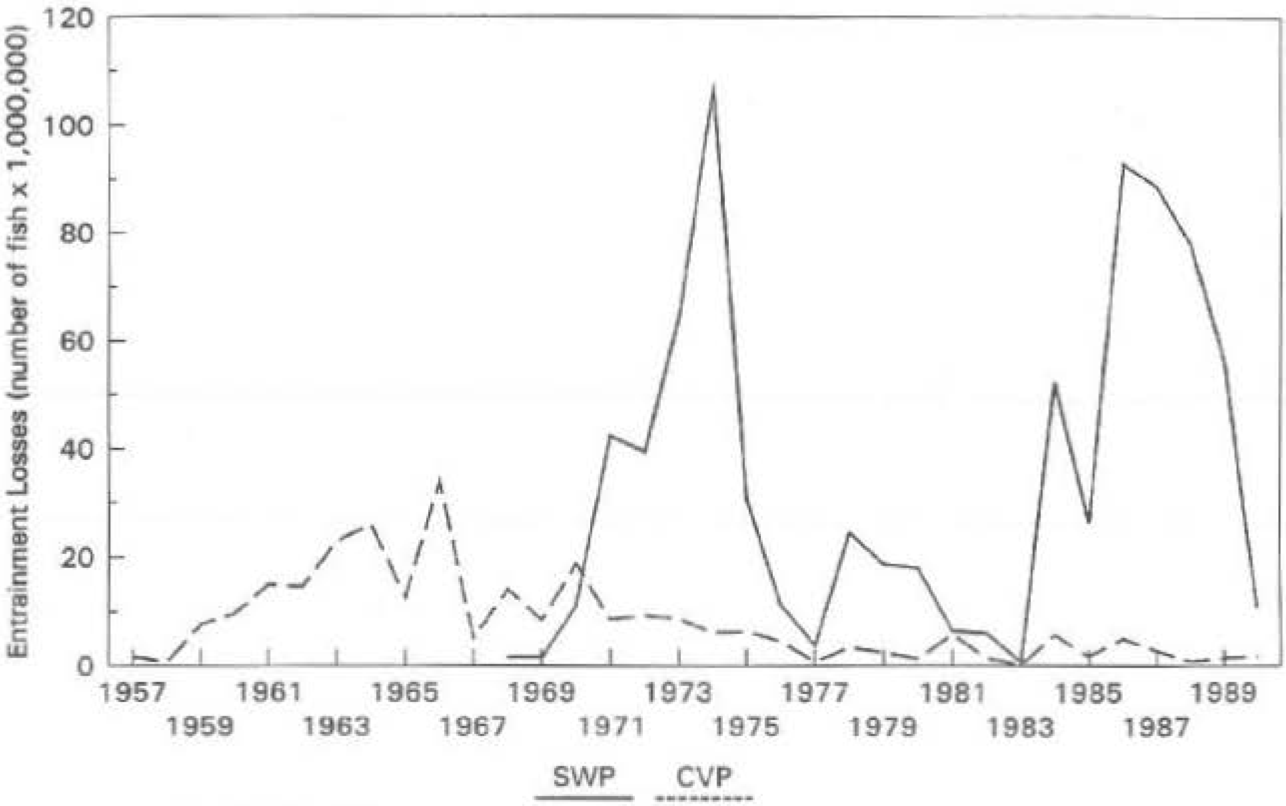
FIGURE 2-VII-27



Source: Hergesell (1993).

YEARLING EQUIVALENTS FOR STRIPED BASS EGGS AND LARVAE LOST IN DIVERSIONS BY THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT DELTA PUMPING FACILITIES (1985-1991)

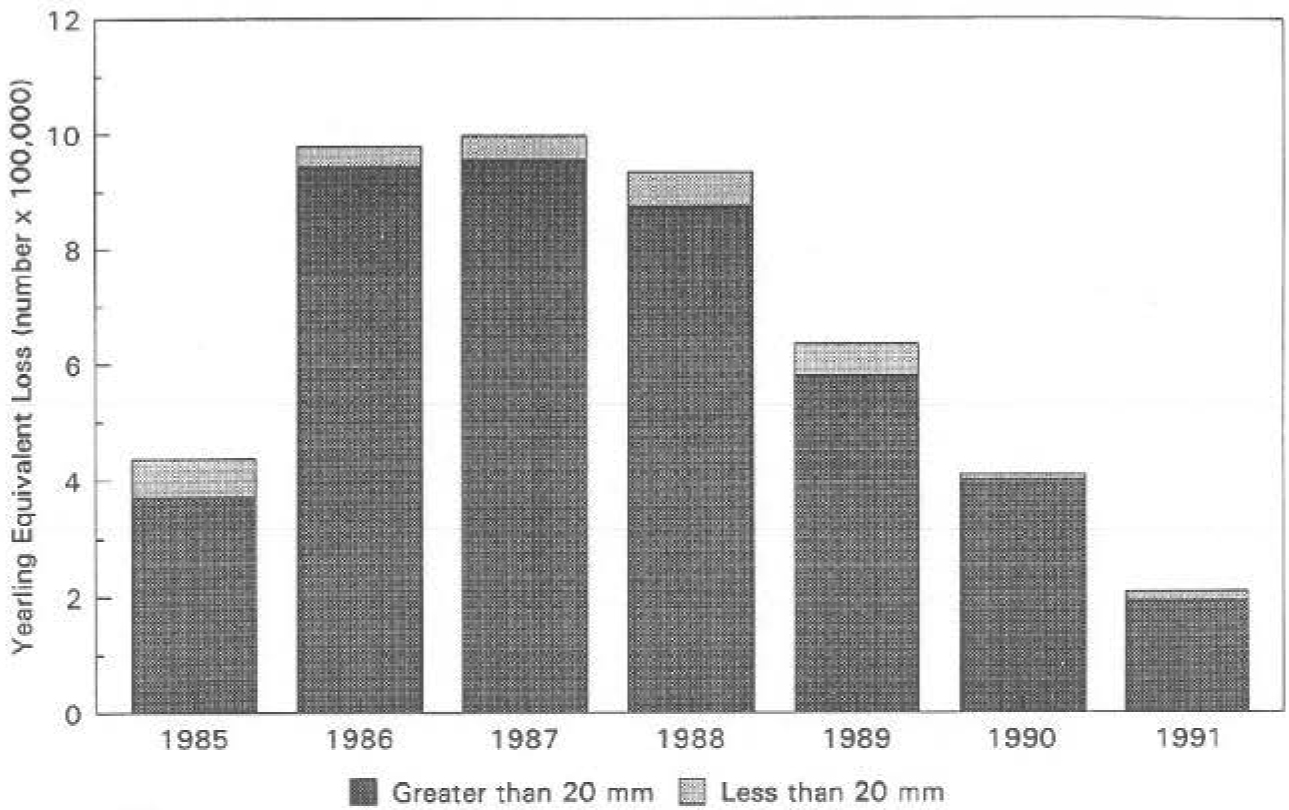
FIGURE 2-VII-28



Source: California Department of Fish and Game (1992b).

ENTRAINMENT LOSS OF JUVENILE STRIPED BASS IN DIVERSIONS BY THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT DELTA PUMPING FACILITIES (1957-1990)

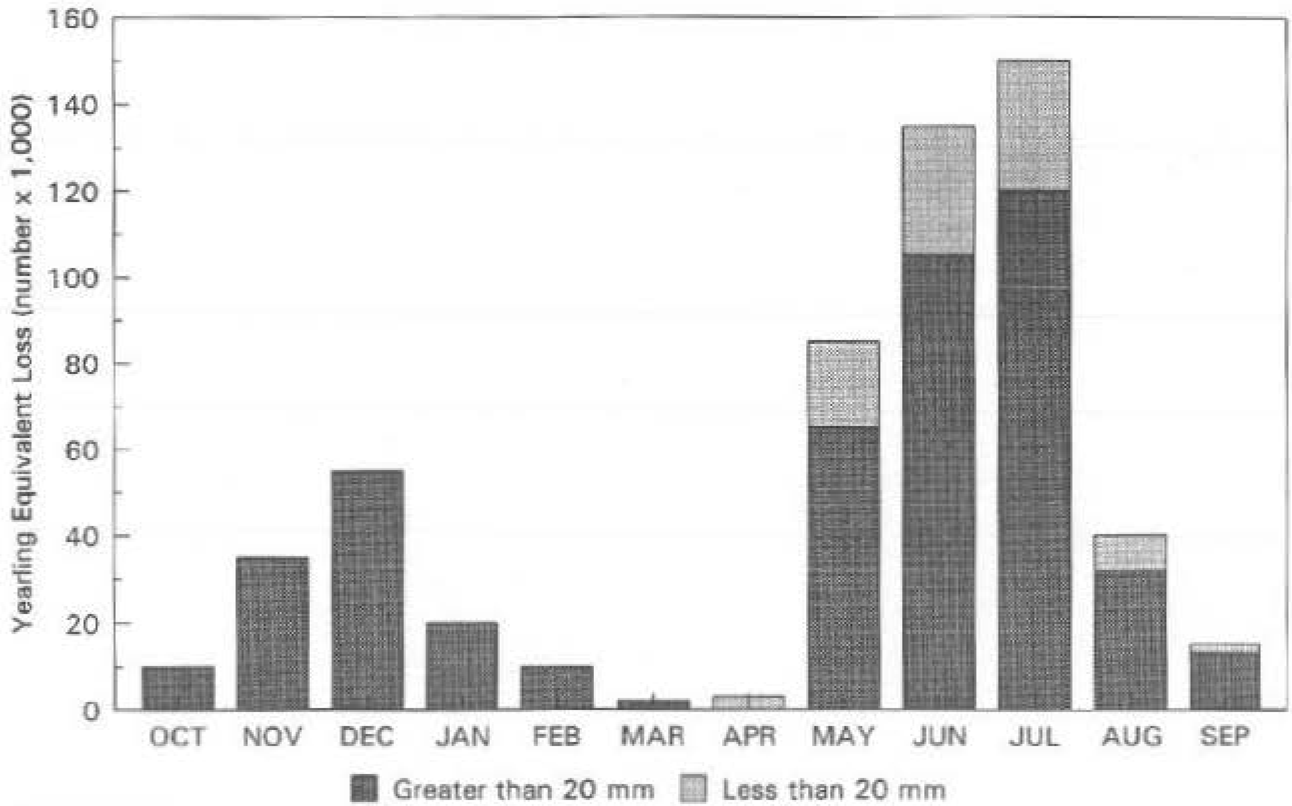
FIGURE 2-VII-29



Source: Brown (1992).

YEARLING EQUIVALENT ENTRAINMENT LOSS OF STRIPED BASS AT THE STATE WATER PROJECT FACILITY (1985-1991)

FIGURE 2-VII-30



Source: Brown (1992)

ANNUAL ENTRAINMENT PATTERN FOR STRIPED BASS AT THE STATE WATER PROJECT FACILITY (1986-1991)

FIGURE 2-VII-31

fish size, predation rates, and handling and trucking mortality. These factors are different for the CVP and SWP pumping facilities.

Entrainment loss of larger bass has a more adverse effect on the population than the loss of the same number of smaller bass. Conversion to yearling equivalents shows the relative annual loss for all sizes combined, including eggs and larvae (Figure 2-VII-30). The bulk of entrainment loss is composed of early juvenile life stages (prior to 1.52 inches) and occurs during May-August (Figure 2-VII-31). Substantial losses of young-of-the-year bass have also occurred during November-January and may be a function of young bass distribution (i.e., relative to the location of X2).

Agricultural diversions - Losses of striped bass to agricultural diversions are believed to be considerable (Odenweller 1981) and have been estimated to be in the millions, possibly equivalent to entrainment loss to SWP and CVP diversions (Stevens et al. 1985, Brown 1992). Actual loss estimates are currently unavailable (Brown n.d.). Losses to agricultural diversions depend on the timing, size, and location (geographically and position in the channel) of individual diversions relative to the seasonal distribution and abundance of striped bass. Losses of egg and larval striped bass could be most effectively minimized by curtailing diversions in May and June.

Juvenile striped bass may have the swimming ability to avoid entrainment in small intakes, but losses have been documented. The magnitude of entrainment losses of juvenile bass to agricultural diversions is currently unknown. Entrainment of juvenile bass in agricultural diversions is a function of diversion location (including location in the channel relative to distance from shore and depth); diversion volume and design; and distribution, size, and behavior of young striped bass. Most agricultural diversion occurs in the interior Delta, where there are generally fewer bass; therefore, the effect may be less than for other diversions (Cannon 1982).

Power generation facility diversions - Two of the largest nonconsumptive diversions in the Delta are PG&E's Contra Costa and Pittsburg Power Plants. Considering the location of the facilities' intakes in the striped bass rearing area (near Antioch and Pittsburg) and the size of the diversions (nearly 1,500 cfs at each power plant, depending on power generation needs), substantial numbers of egg and larval striped bass could be entrained and lost in the diversions (PG&E 1985). From 1984 to 1989, 10,000-61,000 striped bass yearling equivalents were killed at the two power plants (PG&E 1990).

Losses of striped bass, however, have been reduced from previous operations. Annual variability in water temperature (a factor controlling bass mortality) and variability in the availability of alternative power supplies have prevented the power plants from additional reductions in striped bass losses. PG&E has participated in the juvenile striped bass stocking program to mitigate losses.

PG&E's Contra Costa and Pittsburg power plants have fish salvage facilities, but the efficiency of the salvage facilities and the loss of juvenile bass could not be determined with available data. As discussed previously for eggs and larvae, losses to the power plant diversions are likely substantial because of the location of the intakes in proximity to striped bass rearing areas (Cannon 1982).

Other diversions - Other diversions also entrain and kill striped bass eggs and juveniles. The largest diversions not previously discussed are the North Bay Aqueduct diversion and CCWD's Rock Slough diversion. Losses of eggs and juveniles to diversions other than those described in previous sections are currently unquantified.

Egg and larval sampling in the sloughs leading to the North Bay Aqueduct indicate that striped bass abundance has increased (Herrgesell 1993). Diversion during the striped bass spawning and early rearing period may draw water and the associated eggs and larvae off the Sacramento River. Other diversions would likely have similar effects.

The fish screen at the North Bay Aqueduct diversion prevents entrainment of juvenile striped bass into the diversion. Indirect losses (i.e., predation and other factors associated with the screen) have not been determined. Relative to other diversions, the effect on juvenile bass is probably minimal because of the location relative to the main striped bass rearing areas.

Annual entrainment losses of eggs and larvae to CCWD's Rock Slough diversion are unknown. The diversion is not located near the main striped bass spawning area; however, high entrainment losses of striped bass eggs and larvae occur at the SWP and CVP Delta pumping facilities. Old River transports water and striped bass eggs and larvae to the SWP and CVP Delta pumping facilities. Diversion during the striped bass egg and larval period draws water and the associated eggs and larvae off of Old River and to the Rock Slough diversion.

Annual entrainment losses to CCWD's Rock Slough diversion may have historically exceeded 1 million juvenile striped bass (Odenweller 1992). Sampling of striped bass entrainment, however, has not been consistent, and actual entrainment losses are unknown. The diversion is not located near the main striped bass rearing areas, but striped bass juveniles are abundant in some years in Old and Middle rivers, which transport water to the SWP and CVP Delta pumping facilities (as supported by high entrainment losses of juveniles at those facilities). The Rock Slough diversion draws water off the Old River channel.

Toxic substances - Survival of adult striped bass may be affected by toxic materials entering the Sacramento-San Joaquin estuary from agricultural runoff, discharge of industrial and municipal waste, and runoff from non-point sources (i.e., stormwater runoff). Adult striped bass tissues contain concentrations of toxics exceeding levels recommended for human consumption; however, data prior to the striped bass decline after 1970 are unavailable for comparison (Herbold et al. 1992). Relative to striped bass on the Atlantic Coast and in other estuaries, striped bass from the Sacramento-San Joaquin estuary appear to be in poor health and often have open lesions (reactions to parasite infection) (Brown 1987).

Every year, during May and June, hundreds to thousands of adult striped bass die and wash up along the shoreline of the estuary (Brown 1992). The highest density of dead adults is found in Carquinez Strait. Livers from dead striped bass were contaminated with higher concentrations of toxic materials than the livers of healthy fish taken from the Delta. A causative factor for the die-off has not been identified, but the relatively high concentration of toxic materials may contribute to factors resulting in the mortality.

The number of viable eggs is directly affected by contaminant levels in prespawning females, causing resorption of eggs or production of abnormal embryos (Brown 1987, DFG 1987). Analysis has not shown strong relationships between reproductive condition, parasite burdens, and pollutant concentrations. Female striped bass in the Sacramento-San Joaquin estuary, however, are less fecund than female bass from other estuaries. Reduced fecundity appears to be related to the effects of toxic materials, but the extent of reduced fecundity is unknown.

Habitat - As noted previously, nearly half of the available marsh and tidal habitat was filled and leveed off (DFG 1989). In the Delta, less than 3% of the habitat remains in a state similar to Delta habitat 150 years ago (Herbold et al. 1992). Diking and filling restricted striped bass habitat and reduced tidal mixing and overall estuary productivity. However, most diking and filling in the estuary preceded the recent precipitous 20-year decline in the population. Since 1970, only relatively small habitat areas have been lost to levee riprapping and additional filling. Although habitat loss does not account for the population decline, restoration of diked and filled wetlands, with subsequent reconnection to the estuary, could provide additional habitat for adult striped bass and increase overall productivity of the estuary.

AMERICAN SHAD

General Problems

Since the early 1900s, the shad population is believed to have experienced a gradual decline in abundance. Evidence suggests that this decline has occurred primarily from anthropogenic factors, such as water development, that likely continue to affect abundance. The rapid increase in American shad abundance and distribution shortly after their introduction indicates that habitat and environmental conditions historically were ideal for shad. Although the rivers and Delta were largely leveed and many of the wetlands were diked and filled soon after the introduction of shad, the Delta environment and river flow patterns were relatively unmodified compared to current conditions.

Undoubtedly, many factors have combined to decrease California's American shad populations, and historical conditions for successful shad spawning, growth and development, and emigration have been impaired. Although knowledge of American shad ecology and specific factors limiting shad abundance in California has been primarily limited to DFG's American shad studies in the mid 1970s, additional information being developed in the context of other studies could assist in understanding factors affecting shad abundance in the future.

Many of the factors affecting the abundance of eggs and larvae equally apply to the juvenile stage. Although year class strength of the shad population may be set early in the life cycle of American shad, probably occurring before the juvenile stage, survival of juvenile shad ultimately determines the number of shad recruited to the adult population. Therefore, factors affecting juvenile shad may be important in determining adult shad abundance.

In general, overall shad production depends on both freshwater conditions (factors affecting adult migration, spawning, egg incubation, rearing, and emigration) and oceanic conditions (factors affecting ocean shad growth, survival, and migration back to fresh water). More is known about the freshwater life history, biology, and environmental requirements of shad. The oceanic ecology of shad in the Pacific Ocean has been generally neglected. Oceanic conditions should not be entirely dismissed as a factor affecting abundance, however, because DFG viewed the 1982-1983 El Niño conditions in the ocean as having detrimental impacts on shad populations (Messersmith pers. comm.), and oceanic conditions are being found to have greater effects on salmon populations than once thought.

Flow and water temperature - River flows are important in determining the spawning locations of virgin American shad, while water temperature appears to be the most important mechanism triggering the onset of spawning. Water temperatures outside the optimum range for migrating and spawning adult shad may affect shad abundance by reducing reproductive success or by increasing mortality in post-spawning adults.

Operation of large upstream reservoirs has altered historical water temperature regimes in tributary rivers. The survival of shad eggs and larvae are closely related to water temperatures. Exceedingly low water temperatures (less than 52^{o}F) can reduce hatching success of shad eggs (Stier and Crance 1985). Similarly, exceedingly high water temperatures (greater than 80^{o}F) can be unsuitable for hatching of eggs and eventual development of larvae (Stier and Crance 1985). Less than optimal water temperatures may cause developing larvae to sustain poor development, reduced growth rates, and increased mortality.

Diversions - American shad eggs, larvae, and juveniles are susceptible to unscreened and sometimes screened diversions that occur throughout the distributional range of shad in the Sacramento-San Joaquin River system. Direct losses to these diversions are, for the most part, largely unknown.

Habitat - Habitat modifications have had the greatest effect on shallow-water habitats particularly important to developing larvae. Important shallow-water habitats provide optimal water temperatures necessary for growth and proper development and excellent conditions for food production. As noted previously, levee construction, river channelization, dredging, and the diking and filling of historical flood basins have drastically reduced the amount of shallow-water habitats available to young shad both in the major river systems and the Delta.

Toxic materials - All life stages of American shad may be affected by toxic materials entering the Sacramento-San Joaquin River system from agricultural runoff, discharge of industrial and municipal waste, and runoff from non-point sources (e.g., urban stormwater runoff). In the Delta, pollutants of particular concern are trace elements (e.g., selenium, copper, cadmium, and chromium) and agricultural chemicals and their derivatives, which are used extensively in the Central Valley.

Although no specific information is available on how toxic materials are affecting shad populations in the rivers or Delta, the effects of toxics on adult shad may be similar to known effects on other Delta fish species. For instance, toxics exceeding levels considered safe for human consumption have been found in tissue samples of adult striped bass and appear to reduce fecundity in female striped bass. Although toxic materials likely have an adverse affect on adult shad, no evidence exists to suggest that these materials are causing a decline in shad abundance. Toxic materials may affect adults either directly or indirectly, thereby reducing reproductive success and survival.

One of the complicating factors in understanding the effects of toxics on ecological processes in the estuary is the complex distribution of "hot spots" (i.e., areas with high concentrations of toxics), both spatially and temporally (Herbold et al. 1992). These hot spots may cause adults to avoid biologically important habitat or alter movements.

Although shad spawn when flows are typically high and pollutant concentrations are probably relatively low (because of the diluting effects of high freshwater flows), localized populations of young shad and eggs may be disproportionately affected by pollutants if developing eggs and larvae encounter discharges containing high pollutant concentrations. Developing eggs and larvae in the vicinity of these discharges may experience poor development, reduced growth rates, and increased mortality, but specific data are unavailable to ascertain the importance of toxic materials in determining shad abundance.

Competition and predation - The effects of increased competition and predation resulting from species introductions are difficult to evaluate in wild populations. Competition-predation effects would be distinguishable if there was a concomitant increase in the abundance of an introduced species with the decline in abundance of shad.

Striped bass are known to prey on young shad; however, it is unlikely that they are responsible for the decline in abundance because shad and striped bass have coexisted since shortly after shad were introduced. Furthermore, historical shad populations were abundant at the same time that healthy striped bass populations occurred. More recently, striped bass populations have been declining along with other Delta species, including shad.

Competition is a more likely source of mortality for larval shad. Numerous accidental species introductions have occurred since shad were introduced to the Sacramento-San Joaquin River system and, in combination with modified habitats, could have adversely affected shad survival in several ways. These mechanisms have been described in detail for striped bass.

Prey availability - Prey availability for larval shad appears to be adversely affected by human-induced factors. Removal of riparian and streamside vegetation in the Sacramento River system upstream of the Delta potentially reduces the recruitment of terrestrial insects. Young shad in these upstream areas rely on terrestrial insects as a food source, which has been decreasing as more river sections are leveed. (DFG 1987.)

Sacramento River

Although shad on the east coast are known to exhibit a tendency to spawn in their natal streams, river flow appears to be largely responsible for affecting the distribution of virgin spawners in the Sacramento River system (Painter et al. 1980). Within the Sacramento River system, the relative magnitude of tributary flow to the mainstem rivers appears to determine the relative percentage of virgin spawners using those tributary rivers (Painter et al. 1980).

Based on 1975-1978 data, flow relationships have been developed that indicate that virgin shad are attracted into the upper Sacramento, Yuba, and American rivers when flows in these rivers relative to the Feather, Feather, and Sacramento rivers, respectively, are relatively large during May and June (Table 2-VII-4) (Painter et al. 1980). A strong relationship does not exist in the Feather River, however, where it is believed that the longer rearing time allows juveniles to become imprinted for homing (DFG 1987). The lack of such a relationship has recently been verified using 1990-1993 shad data from the Sacramento, Feather, and Yuba rivers (Sommer pers. comm.). Equally strong relationships also exist in the 1975-1978 data between the percentage of virgin shad attracted into the upper Sacramento, Yuba, and American rivers and total May-June flows in these rivers, without consideration of the flow percentages between any two rivers (Jones & Stokes Associates file data).

Table 2-VII-4. Percentage flow and virgin shad in the upper Sacramento, Feather, Yuba, and American rivers (1975-1978)

Year/Coefficient	Upper Sacramento		Feather		Yuba		American	
	%Q[a]	%V	%Q[b]	%V	%Q[c]	%V	%Q[d]	%V
1975	65.8	72.7	34.2	62.7	33.8	70.45	19.0	96.8
1976	79.5	90.8	21.5	29.0	10.3	32.61	10.5	71.7
1977	76.8	85.4	23.2	82.2		N/A	5.4	58.8
1978	60.1	63.9	39.9	80.1	38.9	80.06	18.2	91.9
Coefficient of correlation	0.9971		0.5020		0.9997		0.9978	

[a] Percent upper Sacramento of upper Sacramento plus Feather River flow.
[b] Percent Feather River of Feather River plus upper Sacramento.
[c] Percent Yuba River plus Feather River at Yuba City.
[c] Percent American River of Sacramento River at Sacramento.

Notes:

1. Percent virgins each year from Wixom (1981), percent Q based on mean May-June flows, U.S. Geological Service data.

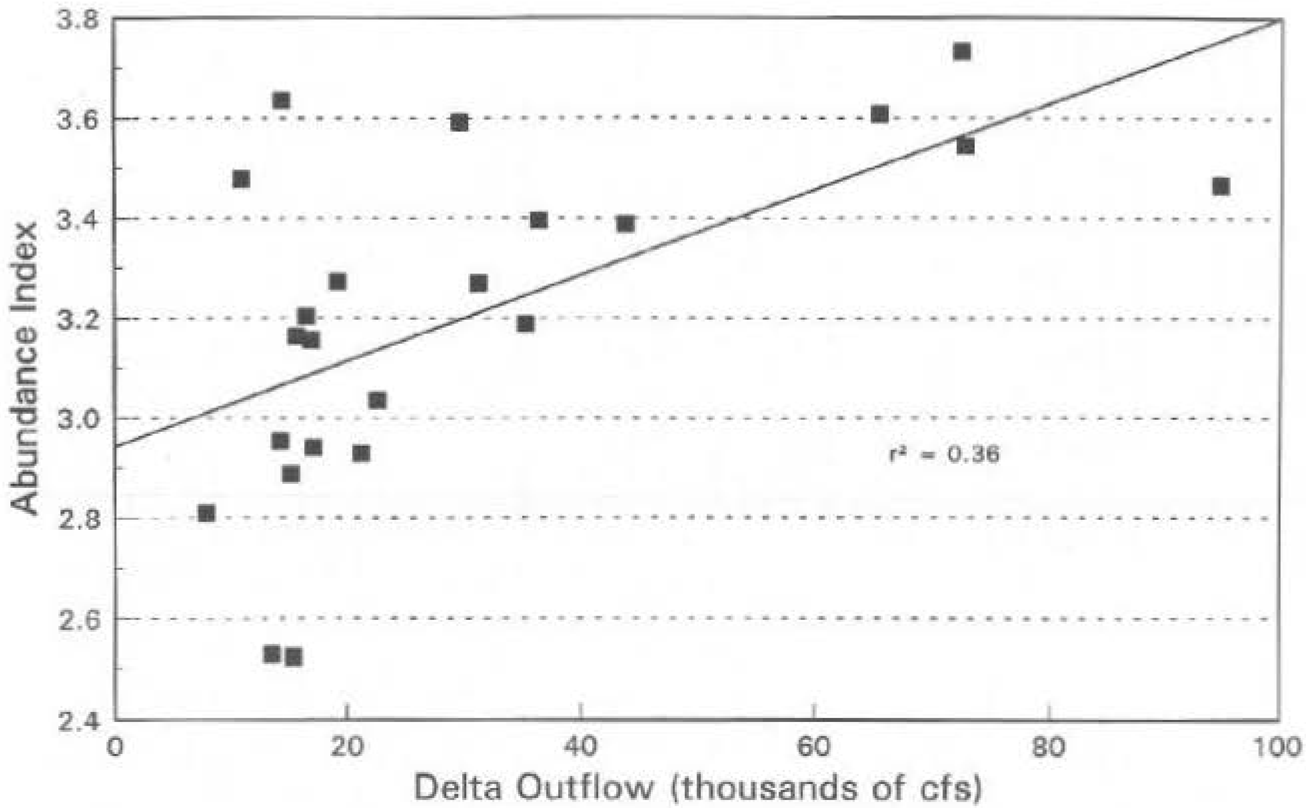
2. Predictive equations (y = percentage flow, x = percentage virgins) are as follows:

Upper Sacramento River	y	=	1.3284 x -15.5171
Feather River	y	=	1.3991 x +21.9482
Yuba River	y	=	1.6440 x +15.5572
American River	y	=	2.7208 x +43.6819

Source: Painter et al. 1980.

Despite these strong relationships, the effect of the relative distribution of virgin spawners on young-of-year (YOY) shad abundance and overall shad populations is unknown. Specifically, it is unclear whether there is increased survival from shad spawning in the major tributaries rather than spawning in the Sacramento River. It is unknown whether YOY abundance is a function of the distribution of flows (and therefore spawners) or increased flows in general. For instance, fall midwater trawl survey data suggest that YOY abundance is greater during years with high freshwater Delta inflow. However, during years of high Delta inflow, relatively more YOY shad may be washed downstream into the Delta compared to years with lower Delta inflows, causing the abundance index to be higher than it actually is.

Adult passage into tributary streams is also an important factor in determining the distribution of spawning adults. Relatively low flows during spring may reduce or restrict adult access to spawning areas in tributary rivers at critical riffle habitats. Critical riffle habitats occur when decreasing flows cause water depths to be too low to pass migrating adult shad. Reduced or restricted access to spawning areas may cause adult shad to spawn where habitat or environmental conditions are less favorable, thereby reducing reproductive success.



AMERICAN SHAD ABUNDANCE VERSUS AVERAGE APRIL-JUNE DELTA OUTFLOW

FIGURE 2-VII-32

San Joaquin River

All of the factors described above for the Sacramento River, and for American shad in general, have worked in concert to limit shad runs in the San Joaquin River basin. Of particular importance, however, is the lack of adequate spring instream flows and corresponding poor water quality.

Delta/Bay

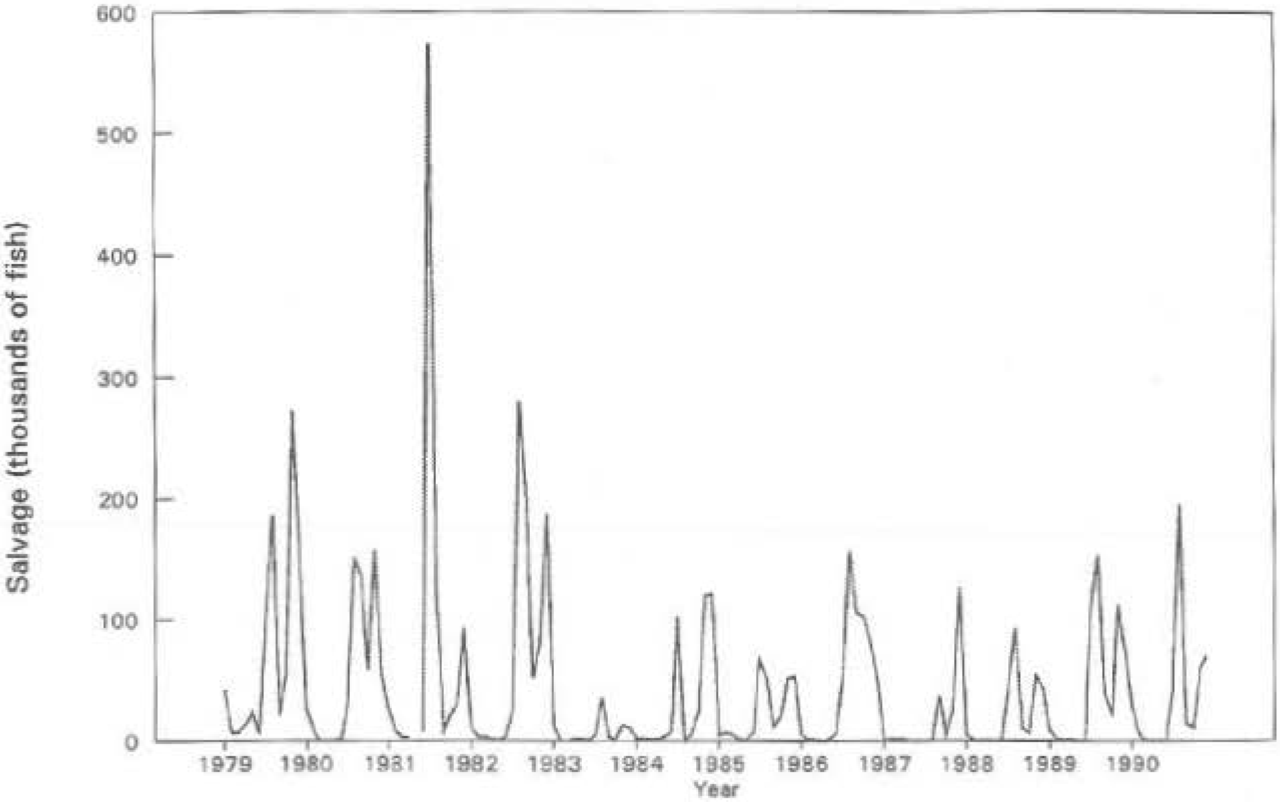
Flow - YOY shad abundance appears to be positively correlated with flow during the primary spawning months (April-June) (Painter 1979). Analysis of the 1967-1991 midwater trawl abundance indices indicates that YOY shad abundance is greater in years when April-June Delta outflows are greater (Figure 2-VII-32). Seining surveys conducted during the 1975-1978 period collected a greater number of juvenile shad in 1975 and 1978, compared to the 1976-1977 drought years (Painter et al. 1980).

The precise environmental mechanism responsible for increasing YOY shad abundance during years with increased April-June flows is unknown. However, the following mechanisms may explain reduced abundance at lower Delta outflows:

- Eggs and larvae are more likely to settle to the river bottom and die because water velocities, which are necessary to suspend eggs off the bottom, are reduced.
- Egg and larval survival is reduced because of warmer water temperatures associated with reduced river flows.
- Eggs and larvae are more susceptible to exposure of toxic substances in the rivers and Delta.
- A lower proportion of larvae are carried to the Delta where feeding efficiency and survival rates may be increased.
- A higher proportion of larvae are drawn into the central and south Delta where vulnerability to entrainment in diversions is greater.

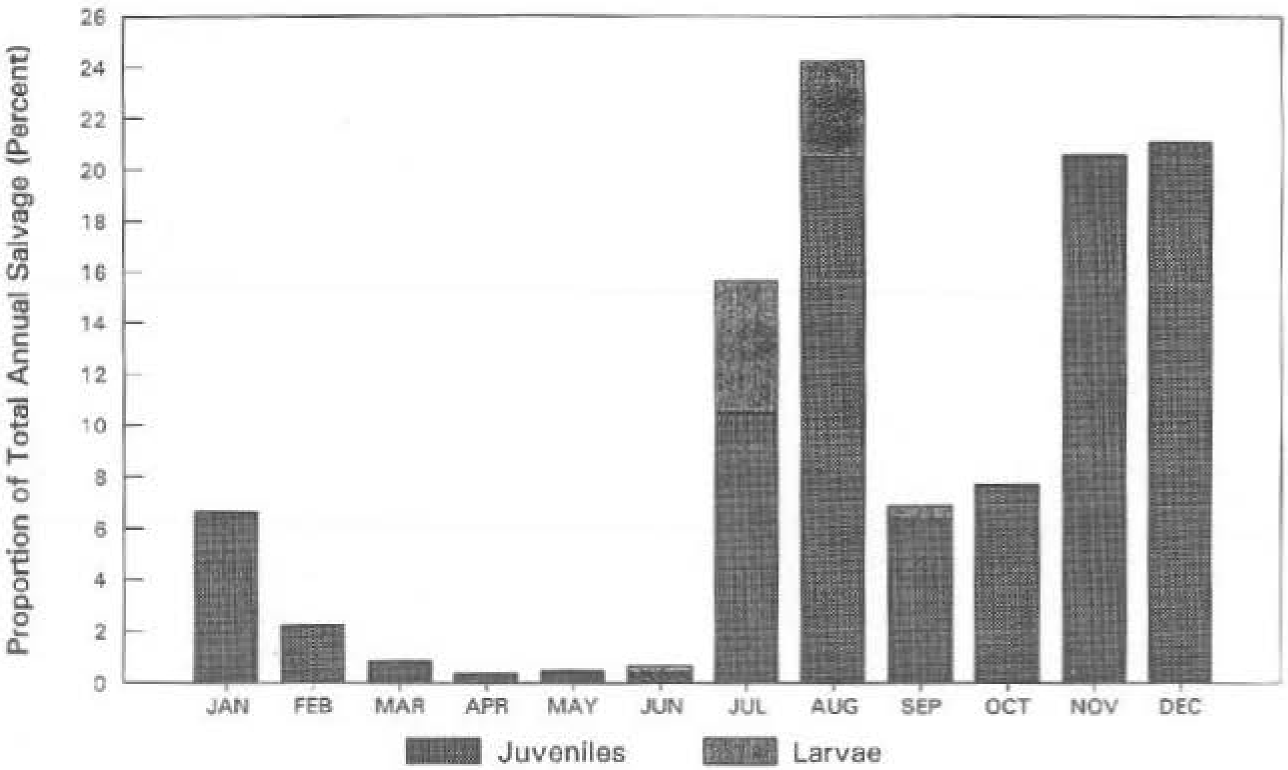
However, the precise environmental mechanism that determines shad abundance is unknown. Mechanisms that may contribute to reduced abundance of egg and larval stages likely apply to juvenile shad as well.

Salinity - As stated earlier, upstream water storage projects, diversions, and Delta export pumping have reduced Delta outflow and periodically increased salinity in Suisun Marsh, Suisun Bay, and the lower Delta. Because larval shad appear to be highly tolerant of salinity and salinity changes (Stier and Crance 1985), increased salinity in the estuary does not appear to directly affect young shad. However, increased salinity in the estuary may influence other environmental and biological factors such as prey availability, thereby indirectly affecting shad abundance.



TOTAL SALVAGE OF AMERICAN SHAD AT THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT FISH PROTECTION FACILITIES (1979-1990)

FIGURE 2-VII-33



AVERAGE MONTHLY PROPORTION OF ANNUAL AMERICAN SHAD SALVAGE AT THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT FISH PROTECTION FACILITIES (1979-1990)

FIGURE 2-VII-34

Entrainment - Entrainment losses depend on the timing, size, and location of individual diversions relative to the seasonal distribution and abundance of American shad. Losses of larval shad could be most effectively minimized by reducing diversions in July and August.

CVP and SWP Delta pumping facilities - CVP and SWP Delta Pumping Facilities are the largest diversions in the Delta, and young shad are vulnerable to diversion by these and other facilities. Thousands of American shad are salvaged annually by CVP and SWP fish protection facilities (Figure 2-VII-33), and thousands more are lost to the diversions. American shad are the third most common fish salvaged at the SWP screens (DFG 1987).

Thousands of juvenile shad (2.8-30 centimeters long) are entrained in diversions at the CVP and SWP Delta Pumping Facilities each year and account for most entrained shad. Although the bulk of juveniles are entrained from July through December, salvage records indicate that the juvenile shad are entrained year round (Figure 2-VII-34).

The relative proportion of entrained juveniles that are salvaged and returned to the Delta alive has not been quantified. Evaluations of screening efficiency comparable to studies for striped bass and salmon have not been conducted for American shad; however, it is believed that larger fish in fall are screened more efficiently than those in late spring and early summer (DFG 1987).

Entrainment losses occur from predation near the screening facilities and stress associated with handling and trucking. Salvaged American shad suffer mortality rates in excess of 50% during summer, with slightly lower mortality rates during the cooler fall (DFG 1987). Because of the high handling losses that occur at the CVP and SWP fish protection facilities, the only practical means of reducing these losses would be pumping restrictions during July through December.

Young shad spawned in the south Delta and Mokelumne River channels are drawn into the pumps as larvae and small juveniles; Sacramento River system juveniles tend to be drawn through the DCC and across the Delta during their downstream migration (DFG 1987). Salvage data from the CVP and SWP pumping facilities indicate that larval shad (less than 1.12 inches long) are entrained from May through September (Figure 2-VII-34). Most of the entrained larvae are lost in the diversions. Entrainment losses, including predation, handling, and trucking mortality, have not been quantified.

Agricultural diversions - Losses of larval shad to agricultural diversions are probably considerable because these diversions account for approximately one-third of the volume of water diverted from the Delta. Losses to agricultural diversions depend on the timing, size, and location (geographically and position within the channel) of individual diversions relative to the seasonal distribution and abundance of larvae. Entrainment losses to agricultural diversions have not been quantified.

Entrainment of juvenile shad to agricultural diversions is a function of fish size, location of the diversions (geographically and position within the channel), and the volume and design of the diversions. Although juvenile shad may be capable of avoiding smaller intakes, entrainment is likely. The magnitude of entrainment losses of juveniles to these diversions is currently unknown and depends on juvenile abundance and distribution in addition to the factors mentioned above.

Power generation facility diversions - PG&E's Contra Costa and Pittsburg Power Plants have fish salvage facilities, but entrainment rates, salvage efficiency, and associated losses of larval shad are not available. Shad larvae are known to occur in the Delta and Suisun Bay and are probably susceptible to entrainment as they pass near the intakes to these power plants.

PG&E's Contra Costa and Pittsburg Power Plants have fish salvage facilities, but entrainment rates, salvage efficiency, and associated losses of juvenile shad are not available. Juvenile entrainment may be substantial because of the proximity of the intakes to juvenile rearing areas.

Other diversions - The magnitude of larval entrainment losses at the North Bay Aqueduct and CCWD's Rock Slough diversions is unknown. Losses at upstream diversions in rivers where shad spawn, rear, and emigrate undoubtedly occur but are not quantified. It would generally be expected that as the proportion of river flow diverted is increased, American shad egg, larvae, and juvenile survival would decrease if these life stages resided in the area of the river where the diversions were occurring.

The efficiency of the salvage facilities and the entrainment losses of juvenile shad at the North Bay Aqueduct and losses to CCWD's Rock Slough diversions are unknown. Diversions in known juvenile rearing areas in the rivers would have an adverse effect similar to that described for eggs and larvae but substantially diminished because of the swimming capabilities of the larger juvenile fish.

Habitat - Land reclamation, flood control facilities, and agricultural development have eliminated or drastically altered much of the aquatic habitat within the Central Valley. Dams may have restricted access to upstream spawning and rearing habitats and modified or reduced freshwater flows that provide the necessary conditions for optimal shad migration, spawning, egg incubation, and rearing. Diking and dredging have eliminated an estimated 96% of the wetland habitats in the lowland areas (50 CFR Part 17). Diking and filling of wetlands in the Delta have restricted shad habitat and, in combination with reductions in freshwater flows, have reduced tidal mixing and overall estuary productivity. Although many of these modifications occurred before the initial introduction of shad in California, more recent anthropogenic factors may exacerbate the effects of wetland filling and diking, thereby contributing to the decline in shad abundance.

Prey availability - Water development has affected zooplankton abundance in the Delta, primarily because the use of Delta channels to convey Sacramento River water to the south Delta has reduced water residence times in the Delta and increased the volume of zooplankton-deficient Sacramento River water that is transported to the central and south Delta (DFG 1987).

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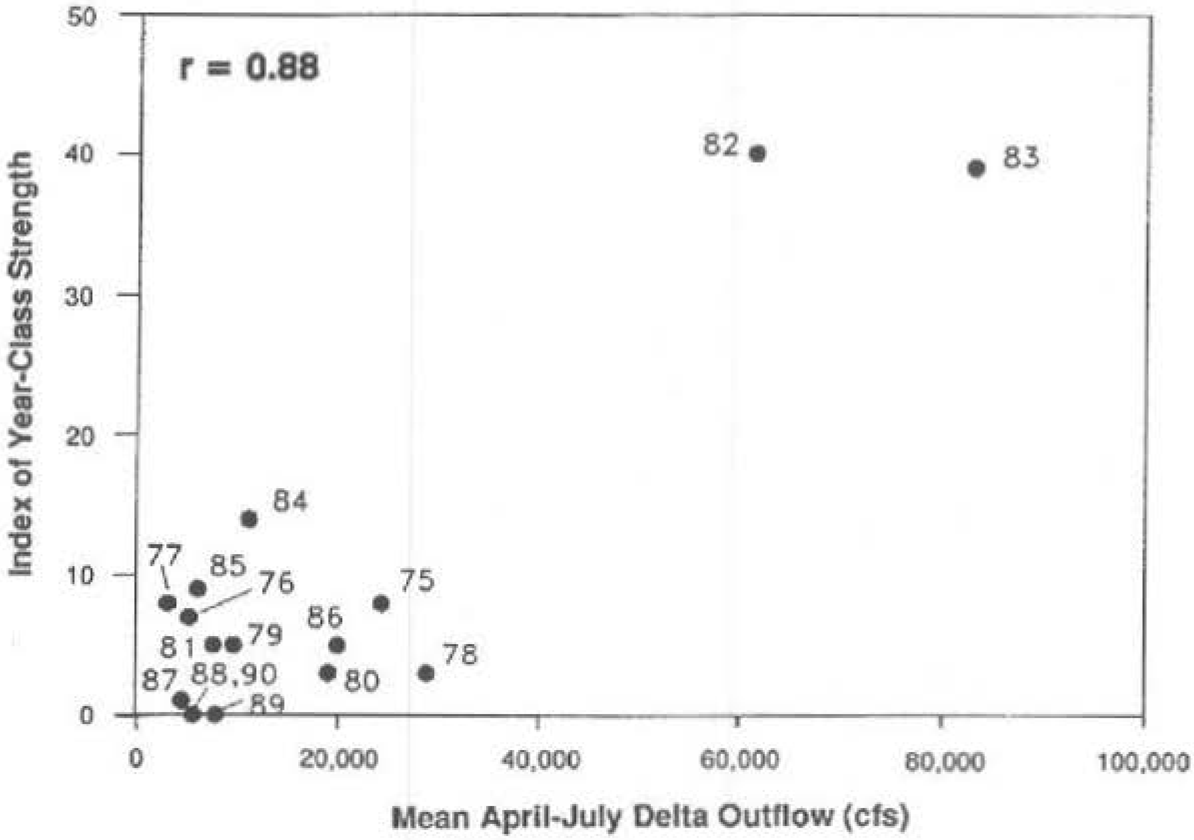
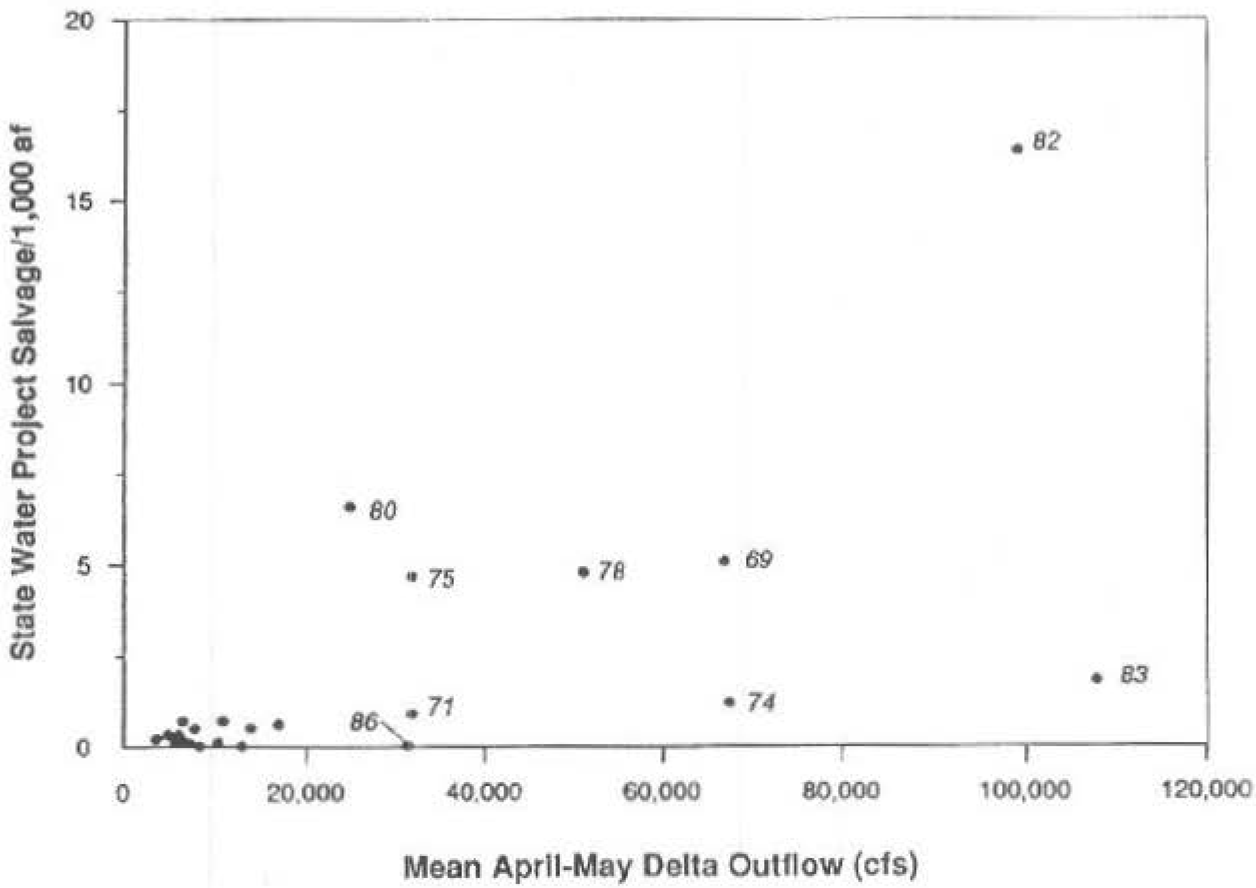


Source: Kohlhorst et al. 1991.

Note: Year-class index determined from trawl catches.

WHITE STURGEON YEAR-CLASS INDEX VERSUS MEAN DELTA OUTFLOW FOR APRIL THROUGH JULY (1975-1990)

FIGURE 2-VII-35



Source: California Department of Water Resources 1990.

Note: Year-class index determined from salvage at State Water Project Skinner Fish Facilities.

WHITE STURGEON YEAR-CLASS INDEX VERSUS MEAN DELTA OUTFLOW FOR APRIL THROUGH MAY (1968-1987)

FIGURE 2-VII-36

The introduced Asiatic clam (*Potamocorbula* sp.) may affect young shad abundance because the clam has become extremely abundant in Suisun Bay where it may compete with opossum shrimp, a prey item of American shad. Introduced species of copepods and cladocerans may have similar effects on young shad abundance.

WHITE STURGEON

Flows

Kohlhorst et al. (1991) found a significant positive correlation between a year-class strength index and Sacramento River outflow from April to July. During years with high April to July flows (1982 and 1983), white sturgeon year-class strength was greater than years between 1975 and 1985 with lower outflows (Figure 2-VII-35). SWP data from 1968 to 1987 also indicate that sturgeon production (as determined by the number of young sturgeon salvaged per acre-foot of water exported) was related to April-May Delta outflows (DWR 1990) (Figure 2-VII-36).

Mechanisms responsible for increased recruitment are not well defined. Likely contributing factors include increased spawning activity cued by high flows, larval dispersion by the currents to more productive or less utilized habitats, reduced entrainment, and increased nutrient loading to the nursery environment due to increased flows.

Diversions

Larval and juvenile sturgeon are weak swimmers that are transported downstream primarily by the currents. Consequently, larval and juvenile sturgeon are susceptible to entrainment and impingement on fish screens associated with water diversion projects in the Sacramento River and Delta. Magnitude of losses and effects on population abundance are unknown. Fish screen designs at diversions are important to successfully pass juvenile sturgeon at diversions and prevent impingement of sturgeon on the screens. Based on the work of Reading (1982), Ward (pers. comm.) suggested that required maximum approach velocities would need to be approximately 0.06 foot per second to protect juvenile sturgeon at diversions.

Water Quality

The influence of water pollution on sturgeon is not well documented. Sturgeon tissue has been found to contain polychlorinated biphenyls (PCBs), organochlorides, mercury, selenium, and dioxins (Pacific States Marine Fisheries Commission 1992). Egg tissues can also contain toxins, which could reduce reproductive potential (Doroshov 1990). Turbidity can affect the adhesiveness of eggs, which could displace eggs to less-than-optimum habitats during incubation.

Predation

There are no published data on the effects of predators on juvenile sturgeon in the Sacramento River. Mass nocturnal hatching, hiding behavior during yolk absorption, and avoidance of light are all adaptations to minimize predation. As sturgeon grow, they become less likely to be killed by predators. Adult sturgeon are not known to have any predators except humans. Benthic-feeding fish are most likely to consume sturgeon eggs and larvae. Dramatic increases in these predators could adversely affect sturgeon recruitment.

Migration Barriers

Though not well documented, low flows and physical obstructions can impede sturgeon migration. For example, blasting was required to remove an in-river obstacle on the Klamath River that was determined to impede sturgeon migration (USFWS 1982). Major physical barriers to adult sturgeon migration on the mainstem Sacramento River are RBDD and the ACID's diversion dam. Unimpeded migration past RBDD occurs during gates-raised operation roughly between mid-September through early May (as mandated by NMFS); while passage past the ACID's diversion dam occurs from November through March when dam flashboards are removed. Both RBDD and the ACID's diversion dam have fish ladders primarily designed to facilitate salmonid passage. Potential physical barriers to upstream migration in the Feather River are a rock dam at Sutter Extension Water District's sunrise pumps, Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to Thermalito Afterbay outlet. Ted Sommer (pers. comm.) thought each of the above-listed physical barriers could impede adult upstream migration during low flows. Finally, on the San Joaquin River anglers describe sturgeon migrating through shallow water and believe that low water slows migration (Russell pers. comm.).

Low dissolved oxygen levels commonly occur near Stockton each fall due to dredging activities in the Stockton Ship Channel and turning basin, flow reversals due to high Delta exports, and effluent discharge from the Stockton Municipal Sewage Plant, and other sources. Low dissolved oxygen levels have been shown to inhibit adult salmon migration near Stockton. The quality and quantity of agricultural drainwater may also inhibit adult sturgeon migration. Whether or not low dissolved oxygen levels of other water quality conditions inhibit passage of adult sturgeon is unknown and needs to be investigated.

GREEN STURGEON

Problems affecting green sturgeon production are likely to be similar to those affecting white sturgeon.

SECTION VIII. MANAGEMENT FACTORS

AUTHORITIES AND AGENCY RESPONSIBILITIES

The management of Central Valley anadromous fish populations and their migration, holding, spawning, and rearing habitats is achieved through a broad diversity of state and federal laws and regulations. Significant responsibilities are vested through the Public Trust Doctrine, the state and federal Endangered Species Acts, the federal Clean Water Act, the State Porter-Cologne Water Quality Control Act, the U.S. Fish and Wildlife Coordination Act, the Magnuson Fishery Conservation and Management Act, the federal Water Pollution Control Act, the federal Rivers and Harbors Act, the federal Power Act, the National Environmental Policy Act, the California Environmental Quality Act, and numerous provisions of the California Fish and Game Code.

The following is a discussion of agencies, policies, and programs that affect management of Central Valley anadromous fisheries, riparian, and wetland resources.

Federal Role

The National Environmental Policy Act (NEPA) requires federal agencies to prepare detailed environmental impact statements when considering major federal actions that could significantly affect the quality of the human environment.

The Fish and Wildlife Coordination Act (FWCA) establishes a national policy of protection and enhancement of fish and wildlife that may be affected by federally constructed projects. The FWCA provides that "wildlife conservation shall receive equal consideration and be coordinated with other features of water development programs". Equal consideration is achieved primarily through the required consultation process. Federal agencies must consult with the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and state fish and wildlife agencies on proposed projects and must adopt reasonable mitigation and enhancement measures.

The federal Endangered Species Act (ESA) limits the take of federally listed threatened or endangered species and their habitats. Federal agencies are required under ESA to consult with the appropriate federal fish and wildlife agency when proposing a project with the potential to affect a listed fish or wildlife species. Several federally listed species depend on Central Valley streams, wetlands, or riparian areas for their survival.

The U.S. Natural Resources Conservation Service (NRCS) (formerly the U.S. Soil Conservation Service [SCS]), U.S. Department of Agriculture, provides technical assistance in the conservation, development, and productive use of the nation's soil, water, and related resources. NRCS is staff to the Local Resource Conservation Districts in California. NRCS administers a Water Bank Program, with assistance from the Agricultural Stabilization and Conservation Service and other agencies. The objectives of the program are to preserve, restore, and improve habitat in important migratory waterfowl nesting and breeding areas and to benefit other wildlife. Landowners with eligible wetlands may enter into agreements to receive annual payments for conserving land as wetlands.

The mission of the NMFS, U.S. Department of Commerce, is to conserve, manage, and develop living marine resources and to promote the continued use of these resources for the nation's benefit. The NMFS administers the ESA for federally listed threatened or endangered anadromous fish species and marine species. In the Central Valley, NMFS has responsibility for the federally listed threatened Sacramento River winter-run chinook salmon.

The Federal Energy Regulatory Commission (FERC) is authorized by the federal Power Act to issue licenses for the development of hydropower projects. This authority is tempered by its obligations under environmental protection statutes. Conditions are placed on power licenses for the protection of fish, wildlife, and vegetation. For many streams in the Central Valley with hydroelectric power plants, the streamflows and fish passage facilities to maintain anadromous fisheries are required by conditions placed upon the FERC project licenses.

The mission of the U.S. Army Corps of Engineers (Corps), U.S. Department of Defense, is to develop, control, maintain, and conserve the nation's waterways and wetlands. The Corps plays a significant role in flood control. The Corps is the principal federal agency involved in the regulation of wetlands and shares a lead role with the U.S. Environmental Protection Agency (EPA) in preventing degradation and destruction of "waters of the U.S." (most freshwater, wetlands, estuaries, and coastal waters within the territorial limits). The Corps has authority under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, which prohibit the discharge of dredged or fill material into waters of the United States, or the obstruction or alteration of navigable waters of the United States, without a permit.

The U.S. Bureau of Reclamation (USBR), U.S. Department of the Interior, constructs and maintains federal water development (reclamation) projects for irrigation water services, municipal and industrial water supply, hydroelectric power generation, water quality improvement, fish and wildlife enhancement, outdoor recreation, and river regulation and control. USBR operates the Central Valley Project (CVP), which consists of several large water storage reservoirs and export facilities in the Trinity River basin, the Sacramento Valley, the San Joaquin Valley, and the Sacramento-San Joaquin Delta.

The U.S. Geological Survey (USGS), U.S. Department of the Interior, provides geologic, topographic, and hydrologic information that contributes to the management of resources. USGS collects data on a routine basis to determine quantity, quality, and use of surface water and groundwater, conducts water resources appraisals describing the consequences of alternative plans for developing land and water resources, researches hydraulics and hydrology, and coordinates all federal water data acquisition.

The USFWS, U.S. Department of the Interior, is responsible for protecting and conserving fishes, wildlife (birds and most mammals), and their habitats for the benefit of the public. USFWS is the natural resource trustee for migratory birds, certain anadromous fish, endangered species, and certain federally managed water resources. Under the FWCA, USFWS reviews Corps Section 10 and 404 permit applications, FERC license applications, and federally permitted or constructed projects in or affecting waters of the United States with the goal of protecting and restoring the fish and wildlife values. The North American Waterfowl Management Plan seeks to restore and maintain the diversity, distribution, and abundance of waterfowl that occurred from 1970 to 1979 by solving habitat problems. The plan focuses on seven priority habitat areas; the Central Valley is one of these areas. The Central Valley Habitat Joint Venture is a group of private organizations and public agencies that have agreed to pool their resources to solve habitat problems in the Central Valley. The Migratory Bird Conservation Act of 1929 authorizes the USFWS to acquire lands for conservation of migratory waterfowl and the Fish and Wildlife Act of 1956 authorizes the acquisition of lands for wildlife refuges. The Emergency Wetland Resources Act of 1986 authorizes the Secretary of the Interior to acquire wetlands, and the North American Wetland Conservation Act of 1989 authorizes acquisition of wetlands to implement the North American Waterfowl Management Plan.

The EPA, Executive Branch, was established to protect, maintain, restore, and enhance environmental quality and human health through the regulation of activities that have potentially harmful effects on air, water, and land resources. EPA exercises authority through the National Pollution Discharge Elimination System (NPDES), National Pretreatment Program, Ocean Dumping/Dredging and Fill, and has delegated to the states the authority to certify that permitted actions are consistent with the state's water quality objectives under the Clean Water Act.

The Pacific Fishery Management Council (Council) and seven other regional councils were created by the Magnuson Fishery Conservation and Management Act in 1976 with the primary role of developing, monitoring, and revising management plans for fisheries conducted within 3 to 200 miles of the United States coast. The Council develops plans for ocean fisheries off California, Oregon, and Washington. The Council is not a federal agency but is a regional body funded through the U.S. Department of Commerce. The Council employs a professional staff headquartered in Portland, Oregon; a Scientific and Statistical Committee; several fishery management plan technical teams; and a citizen advisory panel.

The Council meets in various locations throughout its area of jurisdiction and discusses salmon management issues in March and April. The Council has 13 voting members, including the regional director of the NMFS; chief fishery officials of Oregon, Washington, California, and Idaho; and eight private citizens appointed by the Secretary of Commerce from lists submitted by each state governor.

The ocean salmon fisheries off Washington, Oregon, and California have been managed by the Council since 1977. Annual amendments to the Fishery Management Plan were used to provide required management flexibility each season until a framework concept was adopted. Beginning with the 1985 season, the ocean salmon fishery has been managed by a framework amendment that allows flexibility to adjust annual management regulations in response to varying stock abundance.

The harvest management objectives of the Council are to:

1. Establish ocean harvest rates for commercial and recreational fisheries that are consistent with requirements for optimum spawning escapements, treaty obligations, and continuance of established recreational and commercial fisheries within the constraints of meeting conservation and allocation objectives. Achievement of this objective requires that:

   a. Escapements of viable natural spawning stocks of salmon shall be sufficient to maintain or restore the production of such stocks at optimal levels.

   b. Escapement of hatchery stocks shall be sufficient to achieve production goals established by the management entity or entities with responsibility for establishing goals.

   c. In managing mixed stock salmon fishing, the level of exploitation that can be sustained by the weakest natural spawning stocks for which specific management objectives have been defined will be used by the Council to establish maximum fishing rates.

   d. Harvest allocation of salmon stocks between ocean and inside recreational and commercial fisheries shall be fair and equitable and fishing interests shall equitably share the obligations of fulfilling any treaty or other legal requirements for harvest opportunities.

2. Minimize fishery mortalities for those fish not landed from all ocean salmon fisheries as consistent with optimum yield.

3. Manage and regulate the fisheries so the optimum yield encompasses the quantity and value of food produced, the recreational value, and the social and economic values of the fisheries.

4. Develop fair and creative approaches to managing fishing effort and evaluate and apply effort management systems as appropriate to achieve these management objectives.

5. Achieve long-term coordination with the member states of the Council and other management entities which are responsible for salmon habitat or production in the development of a coastwide salmon management plan.

6. Manage consistent with any United States-Canadian salmon treaty.

7. Support the enhancement of salmon stock abundance in fishing effort management programs to facilitate a return to economically viable and socially acceptable commercial, recreational, and tribal seasons.

State Role

The California Environmental Quality Act (CEQA) requires the preparation of environmental impact reports for projects proposed or permitted by state or local agencies with the potential to significantly affect the environment. Its regulations include specific protection for species designated as threatened or endangered. The Sacramento-San Joaquin Delta is listed as having regional and statewide significance; wetlands and riparian lands are defined as significant. Impacts must be mitigated to a level of insignificance (or a finding of overriding consideration), and a mitigation monitoring plan must ensure the effectiveness of mitigation measures.

The California Endangered Species Act (CESA) controls take of state-listed threatened or endangered species. CESA requires state agencies to consult with the California Department of Fish and Game (DFG) on projects with the potential to affect state-listed species and to implement measures to minimize project effects on the listed species.

The California Department of Transportation (Caltrans) plans, designs, and builds the state highway system. Under the Assembly Bill 471 grant program, Caltrans provides $10 million per year for the enhancement of fish and wildlife in the state beyond the requirements of NEPA and CEQA.

The California State Water Resources Control Board (SWRCB) administers California's system of water rights and controls water quality. The SWRCB reviews applications for the diversion of water from the Delta or its tributaries to determine the effect of the proposal on the quantity and quality of water and the resultant effect on other uses of water in the Delta. The SWRCB is also chiefly responsible for implementing Section 208 of the Clean Water Act, the mandate to control "non-point" pollution. The SWRCB and regional water quality control boards review all proposed activities in the Delta that require federal grants, licenses, or permits to determine the effect of the proposed action on water quality. Several sections in the State Water Code refer to the protection of fish and wildlife. The SWRCB is charged with establishing water quality standards for the CVP and the State Water Project (SWP).

The Regional Water Quality Control Boards (RWQCBs) act as agents of the SWRCB and the EPA by issuing waste discharge permits under provisions of the Clean Water Act and Porter-Cologne Act. The San Francisco RWQCB jurisdiction includes the watershed of San Francisco Bay downstream of Chipps Island in the Delta. The Central Valley RWQCB jurisdiction includes the Delta from Chipps Island east and the Central Valley. DFG has legislative authority to preserve, protect, and manage the state's fish, wildlife, and vegetation. DFG administers provisions of the CESA. DFG is responsible for wildlife management, collection and management of data for waterfowl and nongame wildlife, disease research, wetland enhancement, habitat development and management on 76 designated state-owned wildlife areas, ecological reserves, and other public lands. DFG derives its duties and responsibilities from the California State Constitution, the Legislature, and the Fish and Game Code. Essentially, it is the policy of the Legislature that California's fish and wildlife resources are property of the people of the state, are of utmost public interest and concern, and should be protected, conserved, and managed for the benefit of the public today and in the future.

Several provisions in the Fish and Game Code provide an important basis for the protection of fish and wildlife. Sections 1600-1607 require a Streambed Alteration Agreement with DFG for projects that affect the flow, bed, channel or bank of any river, stream, or lake. Protective measures for fish, wildlife, and water quality are included in these agreements. Section 2760 et seq. provides policy relative to protection and restoration of the state's fisheries and makes significant findings relative to the impacts caused by water development. The Keene-Nielsen Fisheries Restoration Act of 1985 states that "California intends to make reasonable efforts to prevent further declines in fish and wildlife, intends to restore fish and wildlife to historic levels where possible, and intends to enhance fish and wildlife resources where possible." Sections 5900 et seq. deal with dams, conduits, and screens as they relate to protection of fishery resources. Section 5937 requires that the owner of any dam allow sufficient water at all times to pass downstream to keep in good condition any fish that may be planted or exist below the dam. Section 5650 prohibits the placement into waters of the state any substance or material deleterious to fish, plant, or bird life. Section 1505 of the code gives DFG the authority to manage, control, and protect the portions of designated salmon spawning reaches which occupy state-owned lands to the extent necessary to protect fish life in these areas. All of the major salmon spawning reaches of Central Valley streams are designated for protection in this code section.

The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 has been incorporated into Fish and Game Code Sections 6900-6924. The California Legislature declared as follows:

> a) It is the policy of the State to significantly increase the natural production of salmon and steelhead trout by the end of this century. The DFG shall develop a plan and a program that strives to double the current natural production of salmon and steelhead trout resources. b) It is the policy of the State to recognize and encourage the participation of the public in privately and publicly funded mitigation, restoration, and enhancement programs in order to protect and increase naturally spawning salmon and steelhead trout resources. c) It is the policy of the State that existing natural salmon and steelhead trout habitat shall not be diminished further without offsetting the impacts of the lost habitat.

Several California Fish and Game Commission policies, adopted pursuant to Section 703 of the Fish and Game Code, have widespread importance for the protection of fish and wildlife species in the Central Valley. The Commission's Water Policy describes specific actions that DFG shall take to provide maximum protection and enhancement of fish and wildlife and their habitat. The Commission's policy on wetlands is to provide for the protection, preservation, restoration, enhancement, and expansion of wetland habitat in California. Further, it is the policy of the Commission to strongly discourage development in or conversion of wetlands. It opposes, consistent with its legal authority, any development or conversion that would result in a reduction of wetland acreage or wetland habitat values. The Commission opposes wetland development proposals unless, at a minimum, project mitigation assures there will be "no net loss" of either wetland habitat values or acreage.

The Wildlife Conservation Board (WCB) acquires land, develops recreational facilities and public access to natural sites, and investigates areas to determine suitability for wildlife production, preservation, and recreation.

The mission of the California Department of Water Resources (DWR) is to evaluate present and projected needs for water and development programs and ensure the best use of the resource; to protect the public through water quality improvement, flood control, and dam safety programs; and to assist local water agencies with funds, expertise, and technical support to improve their water delivery systems. DWR administers the Davis-Grunsky Act grant program, which provides grants to local water districts for the construction of dams and reservoirs and provides for measures to enhance fishery and recreational resources. On several Central Valley streams, Davis-Grunsky Act contracts have provided important streamflow augmentations and other measures that benefit salmon. DWR also issues permits for activities involving dams or reservoirs. DWR is responsible for the SWP with major storage reservoirs and pumping facilities in the Delta near Byron. DWR is involved in a levee improvement program for flood protection that overlaps the North Delta Water Management Plans for widening channels.

DWR administers the legislatively mandated San Joaquin River Management Program (SJRMP) in the San Joaquin River basin. The mission of this interagency program is to develop consensus solutions to fishery, water supply, water quality, flood control, wildlife, and recreation problems in the basin. All federal, state, and local agencies with jurisdiction over the basin's resources participate in this process.

The Reclamation Board (RB), administratively part of DWR, exercises responsibilities for flood management on the Sacramento and San Joaquin rivers and their tributaries and participates with the federal government in the completion of federal levee and channel flood control projects.

The State Lands Commission (SLC) administers policies established by the Legislature and the SLC for the management and protection of lands that the state received from the federal government upon its entry into the Union. Such lands include the beds of all naturally navigable waterways such as major rivers, streams and lakes, tidelands and submerged lands that extend from the mean high tide line seaward to the 3-mile limit, swamp and overflow lands, vacant school lands, and granted lands. The state holds its sovereign lands in trust and they can no longer be sold. The SLC manages the resources in a manner consistent with the public trust values for fisheries, navigation, public access, recreation and wildlife habitat, and open space. The SLC requires a Land Use Permit or Lease for activities on its lands.

The Office of the Secretary for Resources (OSR) directs the State Resources Agency, which functions as an "umbrella" agency, setting major resource policy for the state and overseeing programs of agency departments, including DWR and DFG. The agency evaluates CEQA documents for consideration of existing state policy, programs, and plans and coordinates all state agency comments regarding permit applications administered by Corps for compliance with the Federal Clean Water Act.

The California Department of Parks and Recreation (DPR) administers the California Wildlife Protection Act of 1990; one provision provides $2 million in annual funding for grants to acquire, restore, or enhance aquatic habitat for spawning and rearing of anadromous salmonids and trout.

Local Agency Role

Resource Conservation Districts are authorized to assist the state in conserving soil and water on farm, range, urban, and timber lands. The districts provide assistance to landowners and government agencies to prevent soil erosion, control runoff, stabilize soils, and protect water quality.

Local water districts serve the water supply needs of users within specific geographic areas. Many are responsible for making instream flow releases or maintaining habitat or fish- and wildlife-related facilities on Central Valley streams used by anadromous fish.

Reclamation Districts are responsible for levee maintenance. These special districts are formed and supported by the landowners of the area protected by the levees.

Local governments are required to have a general plan with mandated elements including open space/conservation, safety, land use, and circulation. The conservation element addresses the conservation, development, and utilization of natural resources, including water, forests, soils, rivers and other waters, harbors, fisheries, wildlife, minerals, and other natural resources.

Federal Agencies and Statutes

The major federal agencies that have legal mandates and responsibilities for maintaining and restoring either populations of anadromous fish within the Central Valley or the aquatic and associated habitats on which those populations depend are presented below.

Federal agency	Legal mandate
U.S. Fish and Wildlife Service	Central Valley Project Improvement Act Endangered Species Act Listing Critical Habitat Designation Recovery Planning Consultations Biological Opinions Fish and Wildlife Coordination Act
U.S Environmental Protection Agency	Clean Water Act Water Quality Standards National Pollution Discharge Elimination System permits Effluent Standards State Certification Performance Standards Toxic Pollutants Non-point source Decisions Information and Investigatory Activities Wetland Decisions Technical Assistance Contaminant Standards
National Marine Fisheries Service	Endangered Species Act Listing Critical Habitat Designation Recovery Planning Consultations Biological Opinions Magnuson Fishery Conservation Act Fish and Wildlife Coordination Act
U.S. Bureau of Reclamation	Central Valley Project Improvement Act Reclamation Act of 1902 Reclamation Reform Act on 1982 Clean Water Act Agreement Between the U.S. and California for the Coordinated Operation of the CVP and the SWP
U.S. Army Corps of Engineers	Clean Water Act

Federal agency	Legal mandate
	Section 404 Permits Federal Rivers and Harbors Act of 1899 Water Resources Development Act
U.S. Forest Service	Forest and Rangeland Renewable Resources Planning Act Forest Plans Resource Assessment Program Research Program Federal Land Policy and Management Act of 1976
Natural Resource Conservation Service	Soil and Water Resources Conservation Act of 1977 Soil and Water Conservation Program Data Collection and Technical Assistance Public Law 566
Bureau of Land Management	Federal Land Policy and Management Act of 1976 Public Land Inventory Land Use Plans Management of Public Lands
Federal Energy Regulatory Commission	Federal Power Act
All federal agencies	National Environmental Policy Act Endangered Species Act U.S. Fish and Wildlife Coordination Act U.S. Wild and Scenic Rivers Act

State Agencies and Statutes

The major state agencies that have legal mandates and responsibilities for maintaining and restoring either populations of anadromous fish within the Central Valley or the aquatic and associated habitats on which those populations depend are presented below.

State agency	Legal mandate
California Department of Water Resources	California Water Code State Water Project Fish and Wildlife

State agency	Legal mandate
	Water Appropriations Agreement Between the U.S. and California for the Coordinated Operation of the CVP and the SWP Reasonable Use Doctrine California Water Plan Water Conservation Projects Act of 1985 Water Transfer Act of 1986 San Joaquin Drainage Relief Act Flood Plain Management Act Agricultural Water Suppliers Efficient Water Management Act U.S. Fish and Wildlife Coordination Act
California State Water Resources Control Board and Regional Water Quality Control Boards	Reasonable Use Doctrine Public Trust Doctrine Water Appropriation Fish and Wildlife Public Trust Water Quality Water Conservation Water Rights Determinations Perter-Cologne Water Quality Control Act Water Quality Policy Water Quality Plans Waste Discharge Requirements/NPDES Permits Clean Water Act Water Quality Standards State Certification Toxic Pollutants Non-Point Source Decisions Research and Investigatory Decisions Water Reclamation Law California Water Code
California Department of Fish and Game	California Endangered Species Act Listing Consultations Take Natural Community Conservation Planning Act

State agency	Legal mandate
	California Native Plant Protection Act Salmon, Steelhead Trout and Anadromous fisheries Program Act Fisheries Restoration Act of 1985 Fish and Wildlife and Recreation in Connection with State Water Project Trout and Steelhead Conservation and Management Planning Act of 1978 Commercial Fisheries Investigation Law Enhancement and Management of Fish and Wildlife Riparian Habitat Conservation Act
The Resources Agency	California Wild and Scenic Rivers Act
California Fish and Game Commission	California Endangered Species Act California Native Plant Protection Act Angling Regulations
State Lands Commission	State Lands Act
State Board of Forestry	Z/berg-Nejedly Forest Practices Act of 1973
Delta Commission	Delta Protection Act of 1992
All state agencies	California Environmental Quality Act Porter-Cologne Water Quality Control Act Federal Endangered Species Act California Endangered Species Act

DFG is the primary state trustee agency empowered to manage, enhance, restore, and protect the wide diversity of fish, wildlife, and plant species within the Central Valley. DFG meets its mandated goals regarding fish and wildlife through coordination with other regulatory agencies.

PUBLIC TRUST DOCTRINE

DFG has a public trust responsibility and acts as a steward for the fish and wildlife resources of California. Successful stewardship requires protection of all of California's biological diversity through such programs as law enforcement, management of lands and wildlife, and compensation of loss of wildlife habitat.

The U.S. Declaration of Independence, the Constitution, the legislative process using statute law, and the courts using case law, in conjunction with the principles of the public trust doctrine, can provide the foundation for the people to conserve and protect their common heritage of rivers, streams, lakes, marshlands, and tidelands and their associated resources, uses, and values (Smith 1989).

The California Constitution (Article 1, Section 25) clarifies the public fishing right:

> The people shall have the right to fish upon and from the public lands of the State and in the water thereof and no land owned by the State shall ever be sold or transferred without reserving in the people the absolute right to fish there upon . . . .

One can reasonably conclude that the right to fish cannot be enjoyed unless fish are in sufficient abundance to be harvested, provide healthful food and products, or just simply enjoyed (Smith 1989).

The California Supreme Court in its monumental 1983 Mono Lake Decision emphasized the state's overall duties and responsibilities to protect the people's common heritage of streams, lakes, marshlands, and tidelands for their many uses and values covered by the public trust.

In its 1983 ruling, the California Supreme Court also stated:

- Parties acquiring rights in trust property hold those rights subject to the trust, and can assert no vested right to use those rights in a manner harmful to the trust.

- The public trust is more than an affirmation of the State power to use public property for public purposes, it is the duty to take public trust properties (i.e., salmon and steelhead) into account in the planning and allocation of water and to avoid or minimize any harm to these properties, interests, or associated uses whenever feasible.

- The State, under its public trust responsibilities, has the affirmative duty and continuing authority to vigorously protect the public trust uses and to avoid or minimize any harmful impacts to such uses.

- The Public Trust is more than affirmation of State's power to use public property for public purposes. It is an affirmation of the duty of the State to protect the people's common heritage of streams, lakes, marshlands, and tidelands surrendering that right of protection and, in rare cases when the abandonment of that right is consistent with the purposes of the trust.

- The Public Trust includes the protection of ecological and biological values of water and waterways.

The California Fish and Game Commission has established a variety of policies that provide directions for DFG in regard to anadromous fish management and restoration, aquatic and riparian habitat management, and other issues of aquatic habitat management and the species that depend on those habitats.

It is the policy of the California Fish and Game Commission:

I. To maintain an adequate breeding stock, suitable spawning areas, and provide for the natural rearing of the young to migratory size. Hatchery production shall be limited to areas where it is necessary to supplement natural production in coastal streams.

II. That resident fish will not be planted or developed in coastal steelhead and salmon streams, except after prior Commission approval (a) where the stream is no longer adaptable to anadromous runs, or (b) during the mid-summer period in those individual streams considered on a water-by-water basis where there is a high demand for angling recreation and such planting or development has been determined by the Department not to be detrimental to the anadromous species.

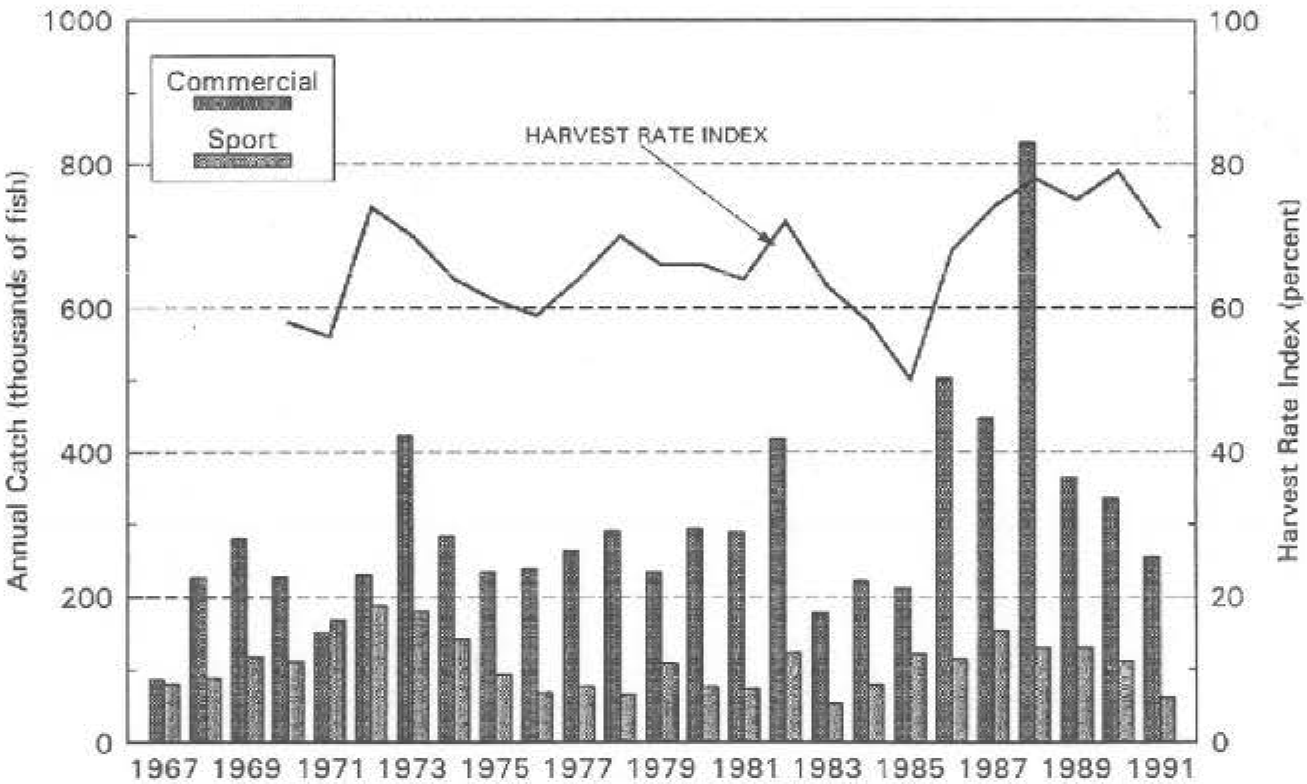
III. That salmon and steelhead may be rescued whenever the water supply is a stream is inadequate to maintain fish life.

CHINOOK SALMON

Harvest

Total commercial and sport annual landings from 1967 to 1991 ranged from 358,000 pounds in 1983 to 1,489,000 pounds in 1988 and averaged 707,000 pounds (Council 1993) (Figure 2-VIII-1). Since 1988, total landings have steadily decreased to levels near the historical minimum for the entire period of record. Catch-per-unit effort, roughly approximated by the number of fish landed per number of days fishing, was computed for commercial landings (1978-1990) and for sports landings (1962-1990) (Figure 2-VIII-2). Catch-per-unit effort for the sport fishery remained relatively constant during this period, while the commercial fishery exhibited a general upward trend over the last 13 years. From 1986 to 1989, catch-per-unit effort for commercial landings more than doubled, reflecting a large increase in ocean salmon abundance during these years.

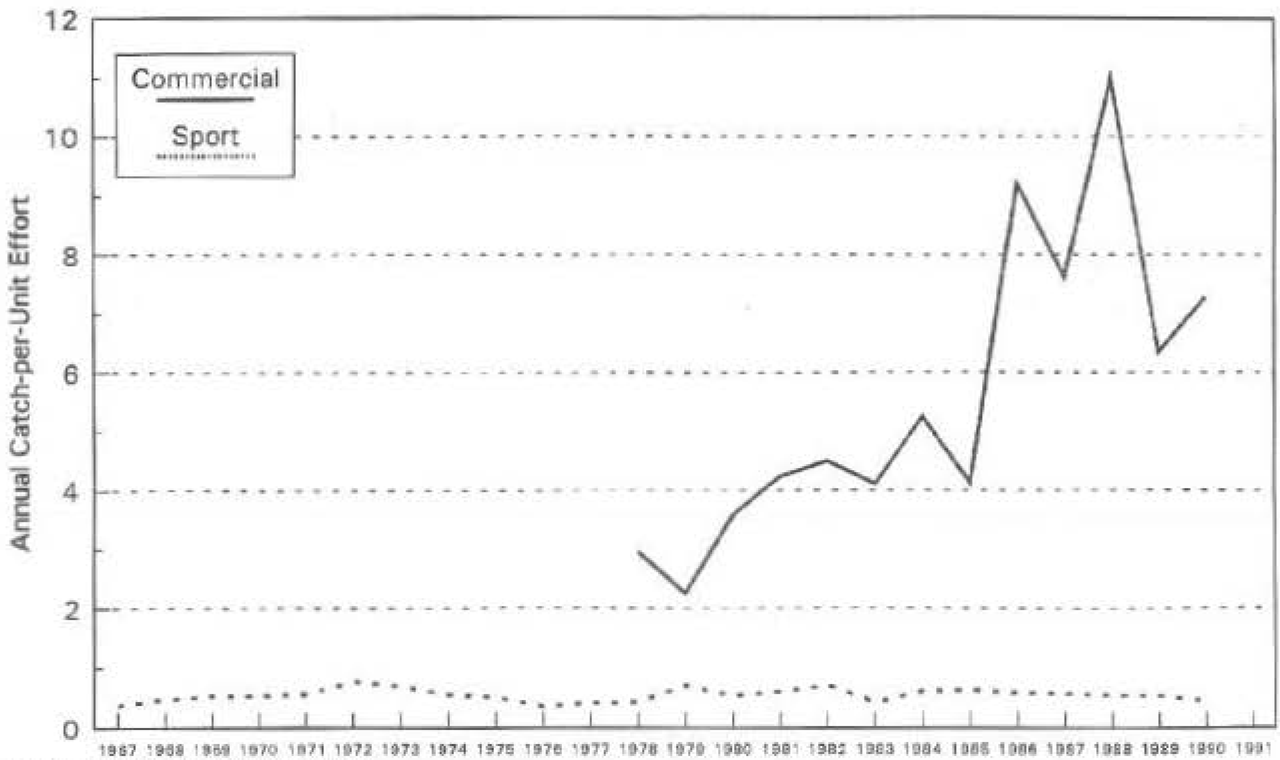
Intensive harvest of natural chinook salmon stocks for many years has resulted in a shift in age composition toward smaller, earlier maturing individuals. Historically, adult spawning populations in California appear to have been dominated by 4- and 5-year-old fish with smaller proportions of 2-, 3-, and 6-year-old fish. Today, spawning runs typically consist largely of 2- and 3-year-old fish with smaller numbers of 4-year-old



SOURCE: Pacific Fishery Management Council (1993).

ANNUAL HARVEST RATE INDEX AND LANDINGS FOR CALIFORNIA COMMERCIAL AND SPORT OCEAN FISHERIES (1967-1991)

FIGURE 2-VIII-1



SOURCE: Pacific Fishery Management Council (1993).

NOTE: No effort data are available for commercial fishery from 1967-1977.

ANNUAL CATCH-PER-UNIT EFFORT FOR CALIFORNIA COMMERCIAL AND SPORT OCEAN SALMON FISHERIES (1967-1991)

FIGURE 2-VIII-2

fish and very few 5-year-old fish (Dettman et al. 1987). Changes in age composition have been accompanied by a decrease in average size of fish landed in the California troll fishery since 1950 (Reisenbichler 1986). Major reasons for declining age and size of chinook salmon stocks include the selective harvest of larger or faster growing individuals; higher fishing mortality of later maturing fish that are exposed to ocean harvest for more years than earlier maturing fish; and the resulting long-term genetic selection for smaller, younger fish (Ricker 1980).

From 1977 to 1981, the average sport catch of fall-run chinook salmon in the Sacramento River was 1.8% of the total estimated run (Allen and Hassler 1986).

DFG initiated a 4-year program in 1990 to estimate annual angler effort and catch of salmon and steelhead in seven river reaches covering 420 miles of the Sacramento basin, including the reach from the Carquinez Bridge to Sacramento. Table 2-VIII-1 shows estimated annual catch of chinook salmon (excluding fish released) for each survey reach and period.

Table 2-VIII-1. Estimated chinook salmon sport landings for six Sacramento basin reaches from July 1, 1990 to June 30, 1993.

Period	Carquinez Bridge to Sacramento	Sacramento to Colusa	Colusa to Red Bluff	Red Bluff to Redding	Feather River	American River
July 1, 1990- June 30, 1991	34	276	724	2,174	1,547	12,155
July 1, 1991- June 30, 1992	1,834	2,122	2,436	5,909	9,207	13,035
July 1, 1992- June 30, 1993	2,730	1,644	2,463	3,503	5,187	6,526

Note: Numbers of fish landed exclude fish released.

Source: Wixom pers. comm.

Poaching, particularly during low flows, is another source of mortality for upstream migrating chinook salmon.

Fish Resource Agency Policy/Goals

It is the policy of DFG to maintain the genetic integrity of all identifiable stocks of salmon and steelhead in California. To protect the genetic integrity of California salmon and steelhead stocks, each salmon or steelhead stream shall be evaluated by the DFG and the stocks classified according to their probable genetic source and degree of integrity. Management and restoration efforts will be guided by this classification system, and policies relating to artificial production must also be compatible with this classification system (Reynolds et al. 1990).

Classification and management system - The classification system shall be employed to define the appropriate stocks and the role of artificial production for management of each salmon and steelhead stream in California. This classification may be applied to drainages, individual streams, or segments of streams as necessary to protect discrete stocks of salmon or steelhead. Only designated appropriate stocks may be placed or artificially produced in any stream within the guidelines specified under this classification system. Exceptions to these management constraints may be allowed only under emergency conditions that substantially threaten the long-term welfare of the fishery. Exceptions may be granted only on submission of a written request, which details the emergency conditions, by a region or an Inland Fisheries Division Assistant Chief to the Chief of Inland Fisheries Division. The Chief of Inland Fisheries Division will review the request and make recommendations for approval or denial to the Deputy Director of Fisheries who will then approve or deny the request.

Salmon and steelhead stream classification system terms - The salmon or steelhead stocks stream management goal shall manage streams for the following appropriate stock and only those stocks may be placed in the stream (each term is progressively inclusive of the preceding terms):

a. **Endemic** - Only historic naturally reproducing fish originating from the same stream or tributary.

b. **Naturally reproducing stocks within drainage** - Naturally reproducing stocks from streams basin of which the stream is part.

c. **Hatchery stocks within basin** - Stocks which may include hatchery produced fish from streams within the drainage.

d. **Naturally reproducing stocks from out of basin** - Naturally produced fish from streams outside the basin.

e. **Hatchery stocks out of basin** - Stocks which may include hatchery produced fish from streams outside the basin.

f. **Any stock** - Any stock which appears to exhibit characteristics suitable for the stream system.

Section 1505 of the California Fish and Game Code grants DFG the power to manage, control, and protect spawning areas on state-owned lands to the extent necessary. The identified areas are:

1) The Sacramento River between Keswick and Squaw Hill Bridge near Vina

2) The Yuba River between Englebright Dam and a point approximately 4 miles east of Marysville

3) The American River between Nimbus Dam and a point 1 mile downstream from Arden Way

4) The Mokelumne River between Pardee Dam and Lockeford

5) The Stanislaus River between Goodwin Dam and Riverbank

6) The Tuolumne River between La Grange Dam and the Geer Road (J14) Bridge

7) The Merced River between Crocker-Huffman Dam and Cressy
8) Battle Creek from its mouth to Coleman powerhouse

9) The Cosumnes River from Meiss Road Bridge to Latrobe Road Bridge

The Central Valley Salmon and Steelhead Restoration and Enhancement Plan (Reynolds et al. 1990) was the first step in developing a series of basin plans for all anadromous fish waters in California. It was prepared in response to California's Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988.

DFG has subsequently prepared a plan titled "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993). This plan reviews anadromous fish resources of the Central Valley, discusses statutes and funding sources for restoration activities, and presents individual stream action plans for streams in the Central Valley basin, including the Sacramento River and all of its major, and most of its minor, tributaries.

DFG's Lower Mokelumne River Fisheries Management Plan (DFG 1991) identifies problems and recommends flows and other improvements for anadromous fish in that river. The draft Central Valley Anadromous Fisheries and Associated Riparian and Wetland Areas Protection and Restoration Action Plan (Reynolds et al. 1993) presents individual stream action plans for the San Joaquin River and its tributaries.

Hatchery/Production Facility Practices

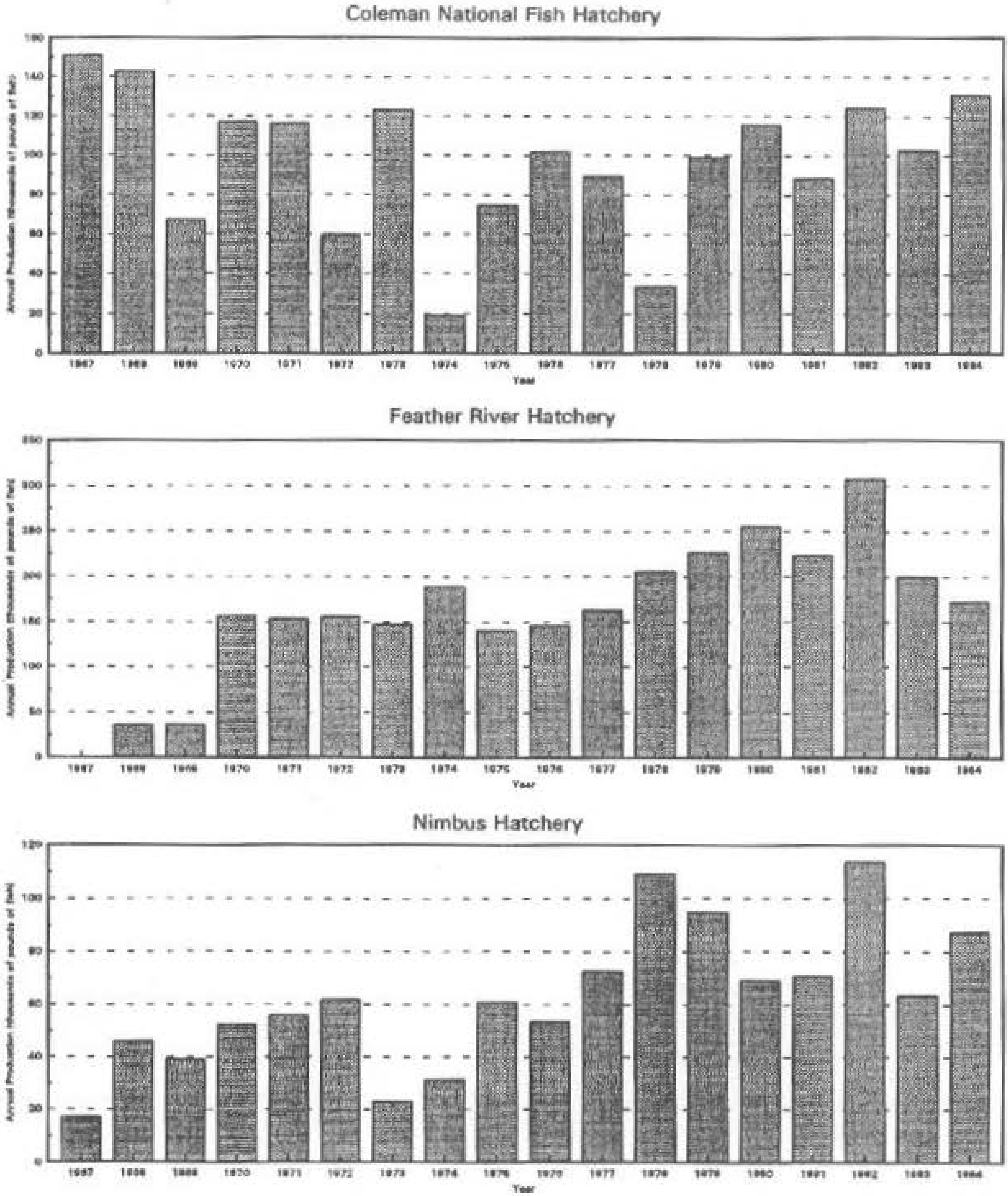
Hatchery production - Baird Hatchery was constructed on the McCloud River in 1872, marking the beginning of artificial propagation of chinook salmon in the Central Valley (Skinner 1962). Five hatcheries currently produce chinook salmon in the Central Valley (Table 2-VIII-2). The three largest hatcheries (Coleman, Feather River, and Nimbus) are located in the Sacramento River basin. Smaller hatcheries exist on the Mokelumne and Merced rivers in the San Joaquin River basin. DFG operates six other salmon hatcheries in northern California outside the Central Valley, including Trinity River Hatchery. Most of these salmon hatcheries were constructed between 1940 and 1970 as mitigation for specific dams or water projects. Only Nimbus and Coleman Hatcheries had significant production before 1967. The salmon hatcheries are funded by hatchery-specific mitigation agreements with state, federal, and public agencies and monies collected from commercial salmon fishers.

Table 2-VIII-2. Central Valley chinook salmon hatcheries.

Hatchery	Location	First Year of Operation	Operator	Primary Funding Source	1984-85 Salmon Production (lb/year)
Coleman National Fish Hatchery	Battle Creek near Cottonwood, CA	1942	USFWS	USFWS	130,958
Feather River Fish Hatchery	Feather River at Oroville, CA	1967	DFG	DWR	203,388
Merced River Fish Hatchery	Merced River near Snelling, CA	1974	DFG	DFG	49,188
Nimbus Fish Hatchery	American River below Nimbus Dam	1955	DFG	USBR	146,176

DFG hatchery production data were obtained from annual DFG reports (California Trout, Salmon, and Warmwater Fish Production and Costs [1959-1985]). Production data were last published in 1984-1985. The release numbers reported by Cramer (1990) for Coleman National Fish Hatchery were converted to weights using the average weight of each release type (e.g., fingerling). From 1967 to 1991, annual production of chinook salmon from Feather, Nimbus, Mokelumne, and Merced River Hatcheries exhibited a general increase, while Coleman showed no clear trend (Figures 2-VIII-3 and 2-VII-14). Total Central Valley salmon production nearly doubled during this period (Figure 2-VIII-4).

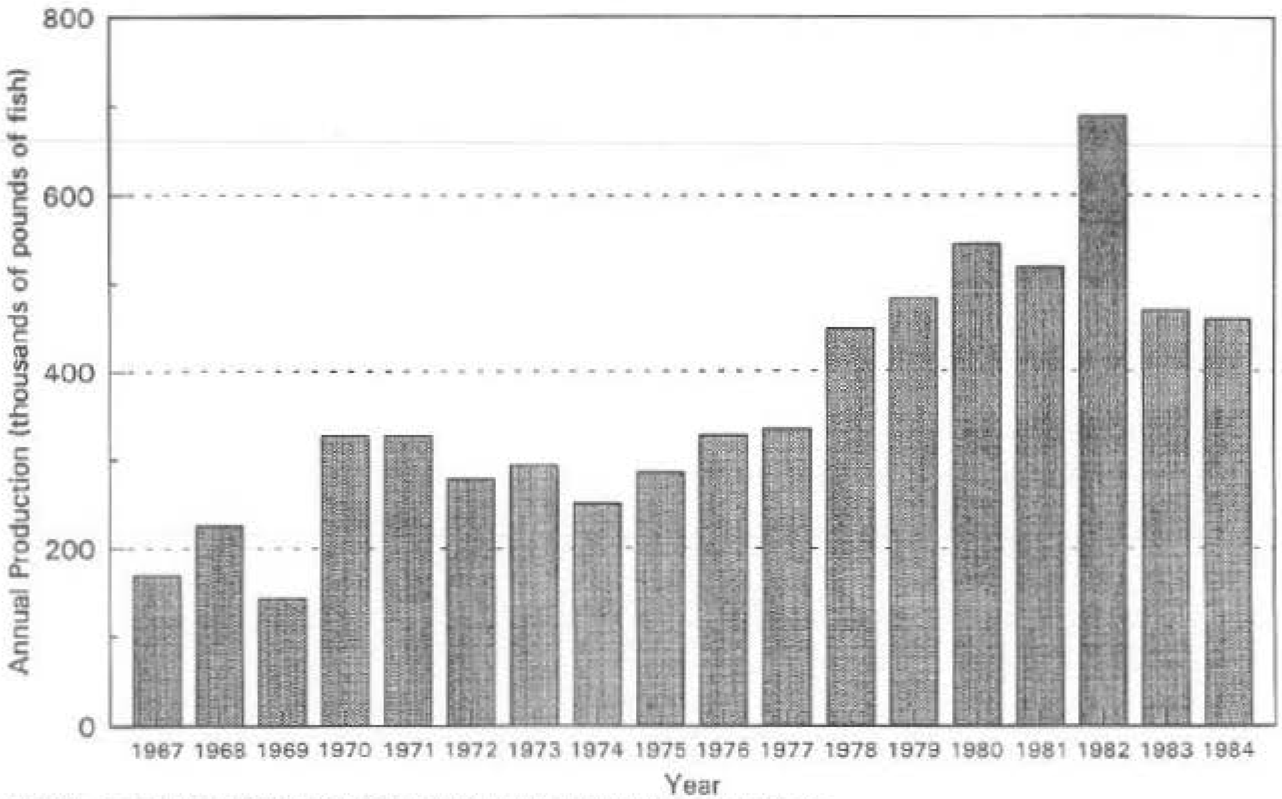
Release practices - Traditionally, Central Valley hatcheries have released fish directly into the river. To reduce downstream mortality, some of the hatcheries have trucked fish to locations nearer the ocean. At



SOURCES: Cramer (1990) and California Trout, Salmon, and Warmwater Fish Production and Costs (1967-85).

ANNUAL PRODUCTION OF CHINOOK SALMON AT COLEMAN NATIONAL FISH HATCHERY, FEATHER RIVER HATCHERY, AND NIMBUS HATCHERY (1967-1991)

FIGURE 2-VIII-3



SOURCES: Cramer (1990) and California Trout, Salmon, and Warmwater Fish Production and Costs (1967-85).

TOTAL ANNUAL HATCHERY PRODUCTION OF CHINOOK SALMON IN THE CENTRAL VALLEY (1967-1991)

FIGURE 2-VIII-4

Nimbus Hatchery, fish were predominantly released at the hatchery during the early 1970s, at Rio Vista during the late 1970s, and in the estuary during the 1980s. At Feather River Hatchery, most chinook salmon were released in the estuary after 1983. Survival was observed to be significantly greater for fish released farther downstream.

For paired releases from Feather River Hatchery in 1980, fish released at Port Chicago were four times more likely to survive than those released at the hatchery and two times more likely to survive than those released at Discovery Park (Cramer 1990). The increase in survival depended on the time of release, river temperature, oceanic conditions, and size of fish. Fish released off station have a higher tendency to stray on return than fish released on station.

Offsite releases, however, do have their drawbacks. Hatchery juveniles that have been transported and released at sites other than the hatchery or stream of origin may fail to imprint properly and may exhibit high straying rates on their return as adults. These adults tend to migrate where streamflows are greatest. Cramer (1990) estimated mean straying rates of 7% to 86% for Feather River and Coleman National Fish Hatchery adults, depending on release location.

Increased survival of hatchery fish has also been achieved by releasing juveniles at larger sizes. Survival significantly increases for fingerlings (1-5 grams) and smolts (5-10 grams) compared to fry (less than 1 gram) (Cramer 1990).

Increased production and survival of hatchery chinook salmon has resulted in increasing contributions of hatchery fish to adult spawning escapements since 1967. Annual contributions of hatchery fish to runs in the American and Feather rivers in recent years range from 33% to 80% (Dettman and Kelley 1987, Cramer 1990).

Hatchery contribution to ocean fishery - Accurate estimates of the Central Valley hatchery contribution to ocean chinook salmon landing have not been developed because of the lack of a consistent hatchery marking program in California. Kjelson and Brandes (1988) estimated that 21% of the smolts passing Chipps Island in 1988 were of hatchery origin. Cramer (1990) estimated that hatchery fish composed about one-third of the spawning escapement to the American and Feather rivers. This fraction is significantly lower than previous estimates developed by Dettman and Kelley (1987).

Because of increased survival from eggs to smolts under hatchery conditions, fewer adults are needed to maintain a hatchery run. Consequently, a harvest rate based on hatchery fish will tend to eliminate wild fish in a mixed fishery comprising wild and hatchery stocks (Hilborn 1992). Current harvest rates of Central Valley chinook salmon are high enough to adversely affect the natural production in some rivers.

Effects of hatchery production on natural production - There are growing concerns that the release of large numbers of hatchery fish can pose a threat to wild fish populations. Potential impacts include direct competition for food and other resources between wild and hatchery fish, predation of hatchery fish on wild fish, genetic dilution of wild fish stocks by hatchery fish allowed to spawn in rivers, and increased fishing pressure on wild stocks due to hatchery production. Because of increased survival from eggs to smolts under hatchery conditions, fewer adults are needed to maintain a hatchery run. In a mixed fishery of hatchery and wild fish, a harvest rate based on the hatchery fish will tend to eliminate the wild fish (Hilborn 1992).

STEELHEAD

Harvest

Sport fishing and illegal poaching affect migrating adult steelhead in the Sacramento River system in ways similar to how they affect chinook salmon. Poaching of steelhead is incidental compared to poaching of chinook salmon, however, because steelhead are smaller, more difficult to catch, and generally less accessible to poachers. Unlike salmon, steelhead do not generally die after spawning and are exposed to sport fishing on their return to the ocean.

Although the estimated annual sport catch of steelhead in the upper Sacramento River system above Big Chico Creek ranged as high as 11,000 fish in the 1950s and as high as 7,000 fish in the late 1960s, the present actual total population counts at Red Bluff Diversion Dam averaging 1,714 fish during 1987-1991 extrapolate to estimated catches of less than 1,100 fish (Reynolds et al. 1990). In the lower Sacramento River system from Big Chico Creek downstream, about 8,000 steelhead are harvested in the Feather River during about 30,000 angler days per year, and an additional 1,000-2,000 Feather River fish are harvested downstream in the Sacramento River system and in the American River. An estimated 20,000 angler days each year result in an estimated catch of 5,000 to 8,000 steelhead on the American River. Hundreds of American River fish, along with steelhead from other sources, are also estimated to be caught incidentally downstream in the Delta and Carquinez Strait sport fisheries for other species. No estimates of steelhead harvests in the Yuba River and other Sacramento River system tributaries are available for the present period (Reynolds et al. 1990).

Juvenile steelhead are indistinguishable from resident rainbow trout in appearance, feeding, and other activities, and many are caught by sport anglers fishing for resident trout. On a statewide basis in 1965, DFG estimated that the fishing pressure on juvenile steelhead exceeded that for adult steelhead (Barnhart 1986).

Fish Resource Agency Policy/Goals

Fish resource agency policies are discussed previously in the section on chinook salmon.

The 1990 Central Valley Salmon and Steelhead Restoration and Enhancement Plan inventories and identifies restoration needs for salmon and steelhead in the Sacramento-San Joaquin River system and states that, among other goals, the DFG has a goal of developing an annual steelhead run of 100,000 fish in the Sacramento River system; 50,000 in the upper Sacramento River and its tributaries; and 50,000 in the lower Sacramento River tributaries. In response to the 1988 act and other actions, DFG prepared a Steelhead Restoration Plan for the American River (McEwan and Nelson 1991).

The Central Valley Salmon and Steelhead Restoration and Enhancement Plan inventories and identifies restoration needs for steelhead in the Sacramento-San Joaquin River basin and identifies DFG's goal of attaining an annual steelhead run in the San Joaquin River system of 20,000 fish, equally divided between natural and hatchery production (Reynolds et al. 1990).

DFG is also developed a statewide steelhead management plan that identifies impacts on the state's steelhead resources and focuses mostly on habitat restoration and stock recovery, including stocks in the San Joaquin Drainage (McEwan and Jackson 1994).

Hatchery/Production Facility Practices

More than 90% of the adult steelhead (greater than 15 inches in length) in the Central Valley are produced from hatcheries (Reynolds et al. 1990). Therefore, the number and survival to adulthood of hatchery-released steelhead presently has far more bearing on steelhead run sizes than natural production. The sizes, timing, and points of release of hatchery-reared juvenile steelhead, as well as the same factors affecting naturally produced fish in the same physical environments, affect their survival rates. A major difference is that survival of eggs, fry, and juveniles prior to release is much higher for hatchery-produced fish. Because high survival rates of hatchery releases are desired, hatchery fish will be released during periods and at sites most conducive to survival, whereas natural fish cannot be controlled in such a manner. Consequently, the survival of juvenile hatchery fish may be higher than naturally produced juveniles, at least on entering the ocean.

In operation since 1943, Coleman National Fish Hatchery on Battle Creek has a capacity to raise about 1,000,000 yearling steelhead, which are raised to reach sizes of about seven fish per pound before being released to the upper Sacramento River near the mouth of Battle Creek, or in Battle Creek itself, in December and January (The Resources Agency 1989, Reynolds et al. 1990). Feather River Hatchery, in operation since 1967, and Nimbus Fish Hatchery on the American River, in operation since 1955, each have a capacity to raise about 400,000 yearling steelhead to a size of three to four fish per pound. The

Feather River Hatchery fish are planted in the Feather River below Yuba City, most by the end of March, and the Nimbus Fish Hatchery fish are trucked and released in the Carquinez Strait (Reynolds et al. 1990).

In the Delta and San Joaquin River tributaries, consistent hatchery-maintained steelhead runs now take place only in the Mokelumne River, with sporadic runs occurring up the Stanislaus and Merced rivers (Reynolds et al. 1993).

Steelhead migrate 64 miles up the Mokelumne River to the Mokelumne River Fish Hatchery (in operation since 1965) at Camanche Dam (completed in 1963). During 1967-1991, hatchery returns have been from 0 to 134 fish, with an average of only 40 fish. Efforts to create a naturally producing steelhead run have been unsuccessful to date (Reynolds et al. 1993), and there is no known recent natural spawning of steelhead in the Mokelumne River (Richardson 1993). Steelhead fry and juveniles have been known to rear only in the upper river reaches below Camanche Dam where temperatures are coolest (DFG 1991).

The present program for the Mokelumne River calls for about 30,000 yearlings or older steelhead to be planted on a weekly basis in the river during the recreation season (April-September). The program has provided a fishery for 12- to 20-inch trout that is popular with anglers; a few of these planted fish survive to return to the Mokelumne River as adults. (Reynolds et al. 1990.)

DFG has a goal of 2,000 adult steelhead spawners to return annually to the Mokelumne River Fish Hatchery. The hatchery, which has the capacity to raise 100,000 yearling steelhead, presently has a goal to annually raise 40,000 yearling steelhead for release into the Mokelumne River. Since the target number of adult spawners do not currently reach the hatchery, eggs are supplied primarily from surplus Feather River Hatchery and Nimbus Fish Hatchery eggs (Reynolds et al. 1993). Plants of steelhead raised at the Mokelumne River Fish Hatchery typically return as adults to the American River (Reynolds et al. 1990).

STRIPED BASS

Harvest

The annual sport catch in the late 1980s was less than 150,000 fish, compared to more than 300,000 fish landed by anglers in the early 1970s. After 1967, harvest rates have ranged from 10% to 24% of the adult striped bass population. (DFG 1992a.)

The existing annual catch of striped bass is 100,000-200,000 fish (i.e., approximately 15-30% of the adult population) (DFG 1992a). Incidental take of striped bass in legal commercial fisheries increases the annual harvest rate by an undetermined amount. Considering that fish populations can sustain high levels of fishing mortality and that striped bass populations on the Atlantic Coast have sustained harvest rates greater than 40%, the existing harvest rate, including illegal fishing, would likely have minimal effects on a healthy striped bass population. The precipitous decline in adult striped bass abundance over the past 20 years, however, indicates that the population is unhealthy (Figure 2-VI-31).

Illegal fishing may kill thousands of juvenile striped bass, possibly equivalent to the deaths of least 125,000 legal-sized bass each year (Brown 1987). This level of illegal fishing could equal or exceed the annual legal sport catch of 100,000-200,000 adult striped bass (DFG 1992a). As discussed previously, healthy fish populations can sustain high levels of fishing mortality, but the precipitous decline in adult striped bass abundance over the past 20 years indicates that the population is unhealthy (Figure 2-VI-31).

The declining status of the adult population has resulted in more stringent angling regulations, including an 18-inch minimum length and two-fish-daily bag limits (DFG 1992a). Before 1982, the minimum legal length was 16 inches and the daily bag limit was three fish. More stringent sport fishing regulations and stricter enforcement could reduce adult mortality and increase egg production.

Fish Resource Agency Policy/Goals

Because of the popularity of the sport fishery, DFG has focused considerable attention on monitoring striped bass and developing a management plan. Ongoing monitoring, enhancement, and habitat improvement actions for striped bass in the Sacramento-San Joaquin estuary are included in the Striped Bass Management Program (DFG 1991). The purpose of the Striped Bass Management Program guidelines is to describe ongoing and proposed actions designed to restore and improve the striped bass population. The guidelines require DFG to review the Striped Bass Management Program annually, receive public review and comment every 2 years, and revise the program every 2 years.

The specific striped bass resource goals are to stabilize, restore, and improve the striped bass fishery of the Sacramento-San Joaquin estuary. Specific objectives are to:

- restore a self-sustaining Bay-Delta striped bass population to levels of more than 3 million adult fish by 2000;

- provide Bay-Delta striped bass which, if consumed, will not endanger human health due to contamination from chemicals or trace-metals; and

- provide striped bass angling, aesthetic, and educational use opportunities.

Major aspects of the Striped Bass Management Program are listed below (Table 2-VIII-3).

Table 2-VIII-3. Summary table of the striped bass management program

Program element	Status	Agency
I. Develop public participation in plan preparation and implementation		
A. Submit draft of the plan to public, private, and government entities	U	S
B. Develop recommendations for tasks to be conducted by public, private, and government entities	U	S
C. Prepare information to increase public awareness	U	S
II. Resolve problems detrimental to striped bass		
A. Minimize entrainment losses of bass eggs, larvae, and young in Delta water diversions, including diversions by:		
1. SWP Delta pumping facilities: two-agency fish protective agreement	P, U	S
2. CVP Delta pumping facilities: agreement between U.S. Bureau of Reclamation and the DFG to reduce and offset direct fish losses	P, U	S, F
3. Contra Costa Water District	P, U	S, F
4. Pacific Gas and Electric Company (PG&E): operating permit for PG&E from the Central Valley Regional Water Quality Control Board (Contra Costa Power Plant) and the San Francisco Bay Regional Water Quality Control Board (Pittsburg Power Plant)	P, U	S, P
5. Agriculture	P, U	S, F, P
B. Eliminate reverse flows in the Delta east of Antioch when bass eggs and larvae are present (same participants as in "A" above)	P	S, F
C. Increase Delta outflow in spring and early summer (same participants as in "A" above)	P, U	S, F
D. Increase residence time in secondary Delta channels (i.e., not including the Sacramento and San Joaquin rivers) (same participants as in "A" above)	P	S
E. Reduce quantities of toxic materials contained in municipal, industrial, and agricultural discharges		
1. DFG Aquatic Toxicology Laboratory	P, U	S

Program element	Status	Agency
2. DFG Regions 2 and 3 are to continue monitoring and evaluating waste discharges	P, U	S
F. Reduce bass losses during fish screen salvage, handling, and fish release operations at SWP and CVP facilities		
1. DFG assumes operations of the fish protection facilities	P, U	S, F
2. Upgrade fish holding facilities	P, U	S, F
G. Install fish screens on larger Delta agricultural diversions		
1. Roaring River diversion in Suisun Marsh	P	S
2. Other	P	S, F, P
H. Improve existing fish screens	P	S, F
I. Consolidate and relocate Delta agricultural diversions to areas of lower bass abundance	P	S
J. Reduce predation at major water intake structures		
1. SWP Delta pumping and fish facilities and Clifton Court Forebay	U	S
2. CVP Delta pumping and fish facilities	U	S, F
K. Curtail channel dredging and prohibit dredge spoil disposal in Delta channels		
1. DFG review of U.S. Army Corps of Engineers (Corps) dredging permits	U	S, F
2. DFG review of Corps dredging spoils disposal permits	U	S, F
L. Eliminate future Bay-fill projects	U	S
M. Reduce illegal take and poaching		
1. Resolve illegal commercialization	P	S
2. Increase law enforcement activities	U	S
N. Reduce bass diseases and parasitic infestations	N	
O. Reduce the annual summer bass die-off near Carquinez Strait	P	S
P. Minimize kill of small bass by the commercial bay shrimp fishery	P	S
Q. Halt introductions of exotic aquatic organisms from maritime		

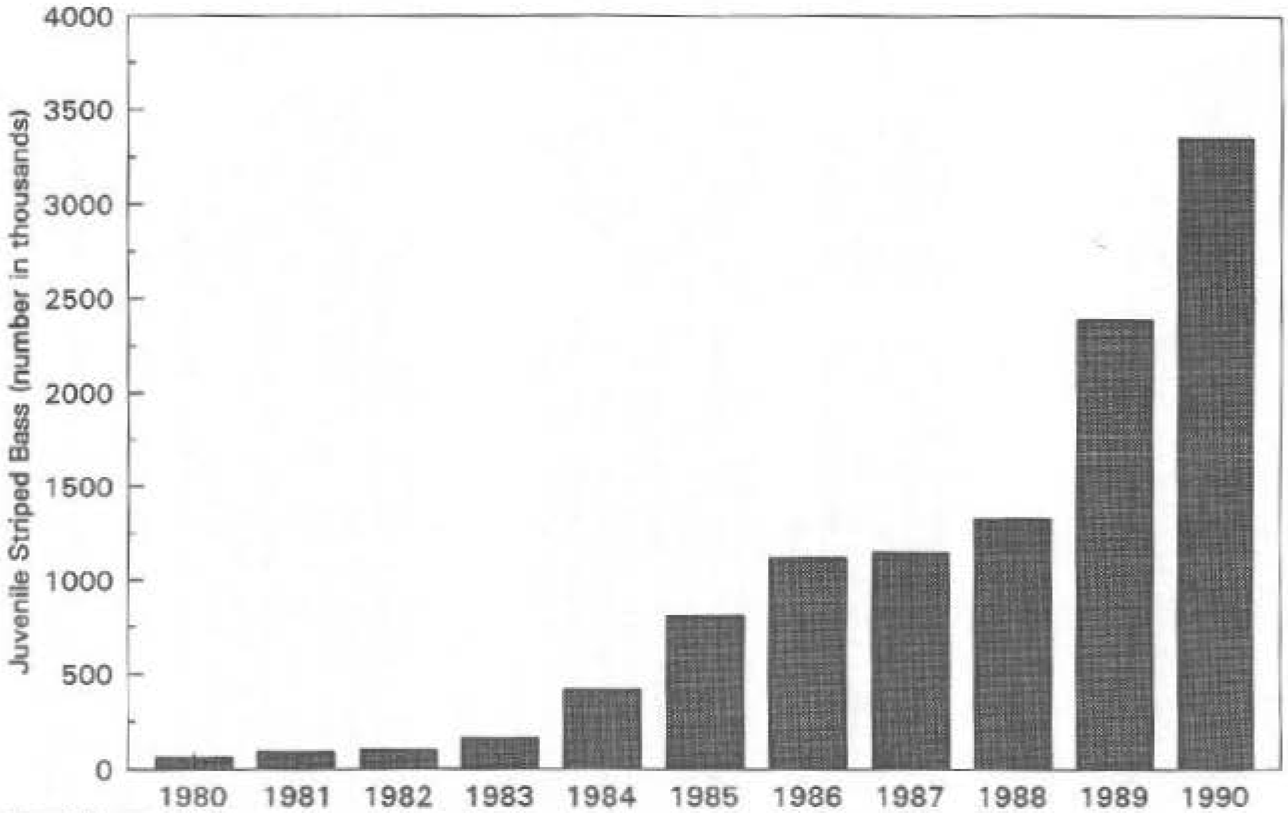
Program element	Status	Agency
shipping		
1. Federal regulations and legislation to restrict discharge of ship ballast	P	S, F
2. High seas exchange of ballast	P, U	S, F
III. Resolve problems of human use of striped bass		
A. Continue hatchery-reared striped bass stocking program	U	S, P
B. Improve pond production at state hatchery	N	
C. Maintain sport fishing and commercial regulations to protect the resource and allow angling opportunities	P, U	S
D. Reduce methyl mercury contamination of adult bass	U	F
E. Reduce diseases and parasitic infestations	N	
F. Reduce tainting of bass flesh	N	
IV. Conduct fishery and environmental studies		
A. Develop techniques to better detect large masses of bass eggs and larvae as they drift downstream		
1. U.S. Bureau of Reclamation	U	F
2. DFG egg and larval survey	U	S
B. Continue survey of annual production of bass eggs, larvae, juveniles, and adults	U	S, F, P
C. Improve annual larval bass growth and mortality estimates	U	S
D. Survey waste discharges to locate sources of toxic materials in the estuary		
1. Rice herbicides and insecticides	U	S
2. Colusa Basin Drain studies	U	S
3. Toxics and trace metals studies	U	S
E. Continue testing impacts of toxic materials on young bass and their food organisms	U	S
F. Develop a striped bass population model to evaluate factors	U, P	S, F, P

Program element	Status	Agency
affecting the bass population abundance		
G. Analyze bass food production in spring and determine if food is limited	U	S, F
H. Extend toxicology testing	U	S, F
I. Improve DFG ability to estimate striped bass egg and larval entrainment losses	U	S, F
J. Compare prey suitability of introduced and native copepods	N	S
K. Determine the effect of toxic materials on egg viability	N	P, S
L. Continue monitoring abundance of fish, invertebrates, and aquatic plants as indicators of adverse conditions for striped bass	U	S
M. Evaluate merits of adding Atlantic Coast bass stocks for improved growth and Sacramento-San Joaquin stock condition	N	
N. Develop improved model of striped bass mortality	N	S
O. Evaluate bass predation	U	S, F
P. Determine results of stocking hatchery-reared striped bass		
1. Stocking of tagged bass	U	S
2. Creel census	U	S
Q. Evaluate new stocking locations for tagged bass	N	
R. Evaluate potential of bass "grow-out" facilities	U	S

Notes:

Status
U = construction/operation underway
P = planning underway
N = no activity

Agency
S = state
F = federal
P = private
C = county



Source: Delisle pers. comm.

RELEASES OF HATCHERY-REARED JUVENILE STRIPED BASS TO THE SACRAMENTO-SAN JOAQUIN ESTUARY (1980-1990)

FIGURE 2-VIII-5

Source: California Department of Fish and Game 1991.

The EPA has proposed water quality standards for surface waters of the Sacramento River, San Joaquin River, San Francisco Bay, and Delta that would directly improve the habitat of striped bass (EPA 1994). The standards include:

- salinity criteria to protect the estuarine habitat and other designated fish and wildlife uses,
- salinity criteria to protect striped bass spawning habitat in the lower San Joaquin River, and
- salmon smolt survival index criteria to protect fish migration and cold fresh water habitat uses in the estuary (i.e., additional spring Delta inflow and reduced diversions).

Hatchery/Production Facility Practices

From 1981 to 1990, more than 10 million juvenile striped bass were raised in hatcheries and released in the Delta and Bay to supplement the wild population (Delisle pers. comm.). The hatchery contribution to the total adult striped bass population increased from less than 1% in 1984 to more than 12% in 1991. The greater percentage contribution to the wild population is attributable to increased annual stocking of hatchery fish and to the declining population of wild fish.

More than 3 million juvenile striped bass were released into the estuary in 1990 (Figure 2-VIII-5). If habitat and food availability are limiting juvenile survival, release of hatchery juveniles could have a detrimental effect on the wild juvenile population. Available data do not indicate any detrimental effects of hatchery releases on wild striped bass survival. The release of hatchery-produced juvenile striped bass was discontinued by DFG after 1991 as part of the effort to avoid the risk of adverse effects on winter-run chinook salmon (Ford pers. comm.). Low numbers (32,000) of juvenile striped bass were released to the Sacramento-San Joaquin estuary in 1992 as part of the pen-rearing project.

Prior to continuation of the striped bass stocking program, DFG has been asked by the NMFS to initiate Section 10 consultation under the federal ESA, specifically with regard to the potential effect on the endangered winter-run chinook salmon (Ford pers. comm.). DFG anticipates a similar request from the USFWS to initiate Section 10 consultation on the threatened Delta smelt. The results of the consultation will determine the immediate future of the striped bass stocking program.

AMERICAN SHAD

Harvest

Sport fishing for shad continues to be popular in the Sacramento, American, Feather, and Yuba rivers, with a smaller, less consistent fishery in the San Joaquin River and its tributaries (Painter et al. 1980). Evidence suggests that the shad catch and angler effort have both declined; however, it is unclear whether this is a reflection of a change in shad abundance or angler interest. During 1976-1978, the mean annual sport catch ranged from 86,200 to 152,000 adult shad, and angling effort ranged from 35,000 to 55,000 angler-days (Meinz 1981).

Commercial harvesting of American shad in the Delta has not occurred since 1957. Presently, shad are harvested only as food by sport anglers. Although the present sport harvest limit is 25 shad per day, most sport anglers typically release all or most of their catch (DFG 1987). Although it is unknown if caught-and-released fish have significantly higher prespawning mortality, shad are delicate fish and the slightest physical injury usually results in death (Skinner 1962). More recently, it appears that more shad caught in the Feather River are being kept, and many anglers catch and keep their limits on consecutive days during the peak of the spawning runs. If the number of spawned eggs significantly affects overall adult abundance, further increases in the number of fish caught and kept may affect population levels.

Fish Resource Agency Policy/Goals

Because of the popularity of the sport fishery, DFG originally had plans to focus on monitoring American shad and developing a detailed management plan for this species in the late 1970s, with the principal goal of maintaining and enhancing the adult shad population present at that time. Funding for further research on American shad and development of the detailed management plan was substantially reduced, ending the program and resulting in a management plan being developed (Painter et al. 1980) based on the available data. Little progress has been made since that time on basic shad research and management; however, many of the programs described for other anadromous species will provide benefits to American shad. For completeness, the original goals and recommendations for managing American shad are described below (Painter et al. 1980).

Specific objectives of the management plan included the following:

- identify factors affecting the survival of juvenile shad during their rearing and out-migration periods,
- determine the role and relative importance of the lower Delta and Bay in the growth of juvenile shad and the maintenance of adult shad populations,
- develop and implement methods to reduce entrainment losses at water diversions, and
- plan and implement studies to periodically monitor shad population abundance and sport harvest rates.

Recommendations proposed in the management plan focused on maintaining suitable habitat conditions (i.e., water temperature and instream flows). Specific recommendations included the following:

- maintain the highest practicable level of activities and studies to preserve and maintain shad habitat and implement program objectives;

- maintain a normal distribution of adult shad in tributary rivers by maintaining instream flows during May and June so that the Feather River flow is at least 34% of the Sacramento River flow, the Yuba River flow is at least 33% of the Feather River flow, and the American River flow is at least 10% of the Sacramento River flow at Sacramento; and

- maintain water temperatures between 60°F and 70°F in the upper Sacramento, Feather, Yuba, and American rivers during May and June.

Hatchery/Production Facility Practices

There are currently no hatchery or other production facilities for American shad in California.

In the late 1800s, shad hatcheries were built along the Atlantic Coast with the expectation of maintaining and increasing production. The hatching and stocking of young shad that was practiced from 1880 until 1950, however, did not significantly increase shad abundance. (Cheek 1968.)

WHITE STURGEON

Harvest

Annual exploitation rates (e.g., sport harvest rate) of white sturgeon in the Sacramento-San Joaquin River system have increased dramatically between the 1960s and 1970s and the mid-1980s due to increased popularity of the fishery, more effective bait, and more sophisticated means of locating and landing sturgeon. By the mid-1980s, exploitation rates increased by 40% (Kohlhorst et al. 1991). Increased exploitation rates decreased recruitment of fish to harvestable size (Pacific States Marine Fisheries Commission 1992).

As a means of decreasing mortality and increasing recruitment, stricter size limitations have recently been imposed on sport anglers. In 1990, the minimum size limit increased from 40 inches, and, for the first time, a 72-inch maximum size limit was imposed. The minimum size limit was increased in 2-inch increments from 42 inches in 1990 to 46 inches in 1992. As a result of these restrictions, harvest rate has been reduced approximately 70% from the high levels of the mid-1980s.

Fish Resource Agency Policy/Goals

New sport fishing regulations were designed to meet the following management goals for the white sturgeon in the Sacramento-San Joaquin River system. The regulations require:

- reduction in sturgeon harvest to 50% of that observed during the 1980s by March 1993,
- protection of large fecund females from sport harvest,
- maximization of sport angling opportunities consistent with the management plan, and
- maintenance of equal access to the resource for all sport anglers.

Ongoing monitoring of white sturgeon populations are being conducted by DFG (Pacific States Marine Fisheries Commission 1992). Current projects include:

- tag recapture programs to estimate abundance, mortality rates, and movement patterns;
- trapping of juvenile sturgeon to determine abundance and year-class strength on a monthly basis; and
- identification of spawning habitats, spawning migrations, and specific spawning sites in the Sacramento-San Joaquin River system.

Hatchery/Production Facility Practices

Stocking of hatchery fish in the Sacramento River and estuary has been prohibited because of iridovirus (Kohlhorst pers. comm.). However, regional DFG biologists are attempting to re-establish white sturgeon in Lake Shasta through stocking.

Several white sturgeon aquaculture programs are in progress at the University of California, Davis, to study:

- nutrition;
- reproductive endocrinology;
- domestic broodstock development and spawning;
- hatchery technology;
- population genetics;

- pathology and virology;
- molecular biology;
- environmental physiology; and
- age, size, and population structure (Pacific States Marine Fisheries Commission 1992).

At least two commercial aquaculture ventures are currently in operation.

GREEN STURGEON

Harvest

Relatively little is known about harvest of green sturgeon in the Central Valley. Trends in harvest are assumed to be similar to trends in harvest of white sturgeon.

Fish Resource Agency Policy/Goals

There is presently no active management of green sturgeon in the Central Valley, beyond what is deemed necessary to protect white sturgeon. Moyle et al. (1994) included green sturgeon as a Species of Special Concern in California and recommended it for threatened species status. USFWS (1994) listed recovery objectives and criteria for green sturgeon.

SECTION IX. KEY AFRP DOCUMENTS

PROCESS OF DEVELOPMENT FOR THE AFRP

A source document for guidelines used to develop the Working Paper was the May 1994 Anadromous Fish Restoration Program (AFRP) Plan of Action (POA), which is summarized below. The POA outlines the process that the Core Group originally envisioned would be followed in developing a Restoration Program by October 1995. Deviations from the POA have occurred as a result of delays in development of restoration actions and evolution of the public involvement concept. While the POA called for release of a Draft Restoration Program, the U.S. Fish and Wildlife Service (USFWS) and the Core Group have since endorsed the concept of first releasing a working paper that identifies restoration needs on the basis of the best available technical information. The working paper will remain open for revision to provide opportunities for input from groups with additional technical information; the final AFRP Plan will be developed based on the technical recommendations in the working paper as modified to reflect public and interest group concepts of reasonableness.

Introduction and Purpose of the Central Valley Anadromous Fish Restoration Program, Plan of Action, May 1994

The CVPIA requires the Secretary of the Interior (Secretary) to develop and implement a program, "which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991" (Section 3406[b][1]). The Secretary is also authorized and directed to provide flows of suitable quality, quantity, and timing to protect all life stages of anadromous fish on all CVP-controlled streams.

The plan of action to develop the AFRP involves the following tasks:

- identify the steps necessary to develop the AFRP,
- generally identify the responsibilities of the agencies involved in the development of the AFRP,
- provide all participating entities with guidance needed for its development,
- communicate to the public the overall intent of the effort and the activities to be undertaken, and
- describe a mechanism to solicit and incorporate public input into the process.

Participants

USFWS has the administrative lead for development of the AFRP, which includes the direct participation of the U.S. Bureau of Reclamation (USBR), National Marine Fisheries Service (NMFS), U.S. Environmental Protection Agency (EPA), California Department of Fish and Game (DFG), and California Department of Water Resources (DWR). AFRP development will be directed by a Core Group composed of representatives from these six agencies.

Other agencies with expertise and statutory or proprietary interest may include the U.S. Army Corps of Engineers (Corps), the U.S. Bureau of Land Management, the U.S. Natural Resources Conservation Service, the U.S. Forest Service (USFS), and the California State Water Resources Control Board (SWRCB). The public will also be invited to participate.

General Approach to Development of the AFRP

In general, the Core Group is responsible for directing the technical teams and developing a draft AFRP Plan; technical teams are responsible for providing specific recommendations to the Core Group; and USFWS is responsible for overseeing all aspects of the process, providing policy guidance and support to the Core Group and technical teams, and developing the final AFRP Plan.

The Core Group directing AFRP development depends on technical teams to provide written products and advice in developing the AFRP. Five of these teams are addressing chinook salmon and steelhead in mainstem Sacramento River, upper Sacramento tributaries, lower Sacramento and Delta tributaries, Sacramento-San Joaquin Delta, and San Joaquin River and tributaries. Three additional teams are addressing striped bass, American shad, and white and green sturgeon. The remaining team is addressing measurement of success. The Core Group and technical teams will also carefully consider all public input.

Each technical team will compile and review data presented in a draft document prepared by the DFG titled "Central Valley Anadromous Sport Fish Annual Run-Size, Harvest, and Population Estimates, 1967-1991" (Mills and Fisher 1994). The technical teams will use the data in the document to assist in:

- determining levels of natural production (or numeric restoration goals) for each species by geographic area,
- identifying factors potentially limiting natural production and developing an array of potential solutions to overcome those limiting factors,
- developing actions to ensure that natural production for the species will be sustainable, and
- identifying areas needing further study.

After each team has developed and analyzed a list of actions for each species, the Core Group will compare lists, identify conflicts between actions and species, and develop or ask the teams to develop alternative programs that meet the needs of all anadromous fish species.

With products from the technical teams, public input, and other information, the Core Group will develop a draft AFRP Plan. After developing the draft AFRP Plan, the Core Group will circulate it for interagency and public review and comment. Following receipt and analysis of comments, USFWS will finalize, adopt, and publicly release the AFRP Plan.

Restoration Goal and Program Evaluation

The CVPIA identifies an AFRP goal of natural production of anadromous fish at twice the average attained during 1967-1991 in Central Valley rivers and streams. In 1967-1991, data collection efforts varied and generally did not focus on estimating natural production; estimating levels of natural production for 1967-1991 will be challenging for most species and drainages because of incomplete data. The technical teams will work individually and together with the Core Group to develop estimates of natural production and to document estimation procedures, rationale for adoption of those procedures, and justification for final estimates.

The Core Group and technical teams will set numeric goals for each species and race by individual streams. If doubling the natural production of a species or race within a specific stream proves infeasible, the unmet production increment will be transferred to other individual streams.

A monitoring program to evaluate the effectiveness of the AFRP will focus on determining yearly levels of natural production and the effectiveness of restoration measures for each of the species and races of anadromous fish in each drainage identified in the AFRP. The AFRP will be considered successful when natural production of target species is doubled in the long term. Long term, in this context, must encompass at least several generations of fish (not less than five) over a variety of hydrologic conditions (to allow for natural variation in production) and will continue indefinitely. The Core Group and technical teams will document criteria and methods selected and the rationale used to determine these criteria and methods in the position paper or in the AFRP Plan itself.

Relationship to Other CVPIA Investigations, the Programmatic EIS, and Other Ongoing Activities

Because the AFRP Plan must be developed and implemented by October 30, 1995, this effort will be based largely on existing data. Efforts to develop additional data and information (required by the CVPIA or initiated to fill data gaps) will be undertaken concurrently with the development of the AFRP and will include the following investigations:

- a plan to address the fish, wildlife, and habitat concerns on the mainstem San Joaquin River;
- existing and future water supply, water quality, and fish and wildlife water needs of the Stanislaus River Basin;
- measures to maintain suitable temperatures for anadromous fish survival in Central Valley streams and the Delta;
- the need and opportunities for additional hatchery production while avoiding adverse effects on remaining wild stocks;
- ways to eliminate barriers to salmon and steelhead migration in Central Valley streams;
- the feasibility of temperature control devices at Trinity Reservoir to conserve cold water;
- the need to modify operations or construct new or improved facilities at the Delta Cross Channel (DCC) and Georgiana Slough to assist migration of anadromous fish;
- other measures to protect, restore, and enhance natural production of salmon and steelhead in tributary streams;
- ecologic and hydrologic models to support our understanding of the Central Valley ecosystem; and
- in consultation with the DFG, recommendations for instream flows for anadromous fish on all CVP-controlled streams.

Concurrent with the development of the AFRP and pursuant to Section 3409 of the CVPIA, USBR is preparing a programmatic environmental impact statement (PEIS) to generally cover the direct and indirect impacts and benefits of implementing Title 34, including the AFRP.

Numerous other activities in the Central Valley will either contribute to or be affected by the CVPIA implementation and the AFRP. Several projects being considered for implementation would, if implemented, also affect anadromous fishes. In the course of developing the AFRP, extensive coordination with the agencies involved and consideration of the potential impact of their actions will be required. Many ongoing federal, state, and private activities have the capability to contribute to anadromous fish restoration and could be incorporated into the AFRP.

Compliance with the National Environmental Policy Act and the Endangered Species Act

The options and alternatives that will be considered for the AFRP will be incorporated into and addressed in the PEIS that will cover the effects of implementing the CVPIA and will satisfy the requirements of the National Environmental Policy Act for development of the AFRP. The needs of threatened and endangered species will be taken into account and incorporated into the AFRP Plan. Consequently, formal and informal consultation under provisions of Section 7 of the Endangered Species Act will be initiated to ensure compliance with the law and protection of listed species.

Public Involvement

Throughout development of the AFRP, the public will be encouraged to provide input. All input received in writing or at public meetings and workshops will be fully considered and incorporated, if appropriate, into the AFRP. Core Group and technical team meetings will be open to observation by the public, and members of the public will be able to submit written comments to be considered by the group. Representatives of interested parties and members of the public with expertise in technical areas may be asked by the Core Group to serve on technical teams, although the Core Group will not include members of the public. Public meetings and workshops will be held periodically in various locations during the process of developing the AFRP. In addition to open meetings of the Core Group, a series of three workshops will be held at multiple locations.

GUIDING PRINCIPLES AND ASSUMPTIONS

One of the source documents for guidelines used to develop this working paper was described above for the "Central Valley Anadromous Fish Restoration Program, Plan of Action, May 1994". Presented in its entirety below is another source document titled "Position Paper for Development of the Central Valley Anadromous Fish Restoration Program".

POSITION PAPER FOR DEVELOPMENT OF THE CENTRAL VALLEY ANADROMOUS FISH RESTORATION PROGRAM

INTRODUCTION

The Plan of Action (POA) for the Central Valley Anadromous Fish Restoration Program (Program) identifies the steps necessary to develop the Program (USFWS 1994). One of the steps included the preparation of a Position Paper to be developed by the Core Group. This document is a draft of the Position Paper described in the POA.

This Position Paper is a reference document for use by the Core Group and the technical teams to guide Program development. Because it was impossible to anticipate all issues prior to drafting the Position Paper, this paper will be amended and supplements added as needed. To determine if your copy is current and to request copies of the Position Paper, contact the Public Information Officer, Central Valley Fish and Wildlife Restoration Program, 2800 Cottage Way, Sacramento, California 95825, (916) 978-4460.

The paper is divided into three sections: (1) Program goal and definitions, (2) Intent of Title 34, and (3) Implementation criteria. The first section states the Program goal and develops general definitions for each of the terms used in the Program goal. The second section presents and interprets the intent of Title 34 and reexamines some of the definitions presented in the first section. These first two sections lay the foundation for the last section.

In the last section, implementation criteria are discussed for the 1967-1991 (baseline) period and for the future. Discussions of implementation criteria are separated because the two periods require different criteria. As discussed later in this paper, limitations are imposed by the type or quantity of data collected during the baseline period. Future monitoring programs may be designed to avoid these limitations.

PURPOSE OF POSITION PAPER

The purposes of the Position Paper are two-fold: (1) to explain or clarify the Core Group's position on issues related to developing the Program and (2) to document reasons used to develop these positions.

PROGRAM GOAL AND RELATED DEFINITIONS

Title 34 requires that "...natural production of anadromous fish in Central Valley rivers and streams be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991..." (Section 3406[b][1]). Several terms need to be clearly defined before the program can be designed to meet this requirement: natural production, anadromous fish, Central Valley rivers and streams, sustainable, long-term basis, and average levels.

Natural Production

Title 34 defines natural production as: "... fish produced to adulthood without direct human intervention in the spawning, rearing, or migration processes" (Section 3403[h]). To apply this definition, we must develop an understanding of the meaning of each of the components of the definition. Important components that have been identified to date are the following: production, adulthood, and direct human intervention.

Production

Ricker (1958) defined production as "the total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time." Although Ricker's definition includes changes in mass as well as numbers of fish, Title 34 specifies "... fish produced to adulthood..." and therefore production will refer to numbers of fish produced.

Because a fish can only be "...produced to adulthood..." once in its lifetime, an individual fish should not be counted twice. In addition, production should be measured over a discrete time interval. Because all stocks under consideration are seasonal spawners, **a direct and simple approach will be to count the first-time spawners each spawning season**.

Ricker's definition also states that a fish is counted toward production for the time period over which production is being measured "...irrespective of whether or not it survives to the end of that time". Using Ricker's definition, juvenile fish that did not survive to adulthood would be counted. The definition of natural production in Title 34 specifies "... fish produced to adulthood..." and therefore does not count juvenile fish. On the other hand, Title 34 does not discriminate between adult fish that return to spawn and those taken in recreational and commercial fisheries. Because Ricker's definition includes fish that do not survive to the end of the time period, and because the definition of natural production in Title 34 specifies fish produced to adulthood, **all naturally produced, adult fish shall be counted, including those that are harvested prior to spawning**.

Including harvested fish is consistent with the definition of production in the California Salmon, Steelhead Trout and Anadromous Fisheries Program Act. The California Act defines production as "the survival of fish to adulthood as measured by abundance of the recreational and commercial catch together with the return of fish to the states spawning streams." Because both the Federal and State acts have similar purposes and goals, and because implementation of both acts should be coordinated, it is convenient that the definitions of production being implemented for both acts are similar.

Whether or not a fish attains adulthood is key to determining whether or not to count that fish toward the production goal. Adulthood is defined below.

Adulthood

Section 3403(h) includes the phrase "...fish produced to adulthood..." as part of the definition of natural production. Adulthood is not defined within Title 34. Adulthood is generally defined as the state, condition or quality of being fully developed and mature. Applying this definition to fish is complicated by the fact that most fish continue to grow throughout life (i.e., cessation of growth can't be used to indicate full development) and may become sexually mature several times during their lifetime (i.e., although developed gonads can be used to indicate maturity, lack of developed gonads cannot be used to indicate immaturity). Because the presence or absence of external characters can't always be used to identify adult fish, and because sexual maturity (i.e., developed gonads) is a transitory state, fishery managers often use size or age criteria to indicate maturity.

An adult fish will be defined as one that is capable of reproduction. Ability to reproduce should be based on some external characteristic, such as size. Because Title 34 requires that production be compared between baseline and goal periods, the same criteria for determination of adulthood will be applied to both periods.

Direct Human Intervention

The definition of natural production precludes "...direct human intervention..." in the spawning, rearing, or migration processes of an individual, naturally produced fish. A definition of direct human intervention is key to understanding the definition of natural production. Humans have pervasively intervened in the structure and function of the Sacramento-San Joaquin system. All anadromous fish that spawn in the system have been impacted by this intervention. Indeed, Title 34 has as one of its purposes "...to address impacts of the Central Valley Project on fish, wildlife, and associated habitats..." (Section 3402[b]). But not all human intervention is direct. The word direct is an important component of the phrase "...direct human intervention...".

Direct human intervention is any action taken in the absence of intervening elements. Any form of intervention that requires handling of fish is direct intervention due to a lack of intervening elements. Any action that includes one or more intervening elements would be considered indirect intervention.

Hatchery and artificial propagation, including supplementation and out-planting of eggs or any other life-stage, requires handling of fish by humans during the spawning and rearing processes and therefore are forms of direct intervention. Transporting fish, including truck and barge transport, and fish salvage require capture and handling of fish during the rearing or migration process and therefore are forms of direct intervention. Hatchery and artificial propagation, transport and salvage of fish, or any process that requires handling of any life-stage of fish will be considered direct human intervention.

Title 34 clearly states that fish produced with direct human intervention should not be included in counts of natural production. In developing the Program, we will avoid counting hatchery-produced fish or fish produced with any other form of direct human intervention in counts of natural production. The Core Group has determined that there will be one exception to this rule: the progeny of naturally spawning fish salvaged at the John E. Skinner Delta Fish Protective Facility and the Tracy Fish Protective Facility, if they reach adulthood, will be counted as naturally produced.

An example of a form of intervention that does not fit the definition of direct intervention is flow manipulation. When we manipulate flow to benefit fish, flow acts as the intervening element. Humans directly alter flows and flows alter fish spawning, rearing, or migration processes. Therefore, flow manipulation is not a direct but an indirect form of intervention. Construction of fish ladders, screens and barriers are forms of indirect intervention because each of these structures act as the intervening element. Reservoir or flow manipulations (including Delta flows and flows to maintain desired stream temperatures), ladders, screens, barriers, and other forms of habitat alteration and enhancement activities will not be considered direct human intervention because each of these is or has an intervening element and does not require handling of fish.

Because the definition of natural production in Title 34 includes the phrase "...produced to adulthood...", fish that are not subject to direct human intervention until after they reach adulthood would still be considered naturally produced. For example, a naturally produced fish that returned to a hatchery and was spawned in the hatchery would be considered naturally produced. Obviously, its progeny would not be considered naturally produced because they were produced in a hatchery. Similarly, naturally produced adult fish whose migration was subject to direct human intervention would still be considered naturally produced, although their progeny would not be considered naturally produced.

Anadromous Fish

Title 34 defines anadromous fish as "...those stocks of salmon (including steelhead), striped bass, sturgeon, and American shad that ascend the Sacramento and San Joaquin rivers and their tributaries and the Sacramento-San Joaquin Delta to reproduce after maturing in San Francisco Bay or the Pacific Ocean" (Section 3403[a]). This definition identifies five groups or species of fish: salmon, steelhead, striped bass, sturgeon, and American shad. The American Fisheries Society recognizes steelhead as the common name for the anadromous form of *Oncorhynchus mykiss* and striped bass and American shad as the common names for *Morone saxatilis* and *Alosa sapidissima* (AFS 1991). Clearly, Title 34 includes these species in the definition of anadromous fish. The names salmon and sturgeon both include multiple species of fish and the meaning of these terms in relation to Program development needs clarification. The term "stocks" in the definition of anadromous fish also needs clarification.

Salmon - Salmon is a common name for at least six species of fish. Five species of salmon have been observed in the Sacramento River: chinook (*O. tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon (Moyle 1976, Fry 1973). Chinook salmon are common in the Sacramento-San Joaquin system, the other four species are rare. Based on observations of adults during 1949 through 1958, Hallock and Fry (1967) concluded that sockeye, pink, and chum salmon entered the Sacramento River regularly enough to be regarded as very small runs, but that coho salmon were so scarce and irregular that they should be regarded as strays. Juvenile coho salmon were planted in Mill Creek in 1956, 1957, and 1958, but by 1963 coho salmon were almost as scarce as they had been before the introductions (Hallock and Fry 1967). During the baseline period, there is no evidence that coho, sockeye, pink, or chum salmon maintained self-sustaining spawning runs in the Central Valley (Fisher pers. comm.). Because the definition of anadromous fish specifies "...salmon... that ascend the Sacramento and San Joaquin rivers...to reproduce..." and because chinook salmon is the only salmon known to reproduce in the system on a regular basis during the baseline period, the use of the word salmon in the definition will be interpreted to mean chinook salmon.

Sturgeon - Two species of sturgeon are found in the Sacramento-San Joaquin system: white sturgeon (*Acipenser transmontanus*) and green sturgeon (*A. medirostris*) (Moyle 1976). Because both species of sturgeon reproduce in the Sacramento-San Joaquin system, the word sturgeon will be interpreted to include white and green sturgeon.

In summary, **the species of anadromous fish identified by Title 34 that reproduce in the Sacramento-San Joaquin system include chinook salmon, steelhead, striped bass, white sturgeon, green sturgeon, and American shad**. The Program will be designed to double the natural production of the anadromous forms of these six species.

Other anadromous fish - Title 34 does not identify several species of anadromous fish that spawn in Central Valley rivers and streams. These include threespine stickleback, brown trout, and two species of lamprey and smelt (Fry 1973). The Program will not establish restoration goals specific to these species.

Stocks

For purposes of the Program, **a stock is defined as a group of individuals which are more likely to mate with each other than with individuals not included in the group**. The term stock describes a fish population that spawns in a particular stream, or stream reach, at a particular season and that do not interbreed to a substantial degree with any group spawning in a different place, or in the same place at a different time. This definition does not rely upon absolute reproductive barriers. In fisheries management, stocks are recognized to maintain and improve the genetic basis for management.

Several stocks which meet this definition are already recognized. For example, chinook salmon are divided into several races based on the season during which they enter the rivers to begin their upstream spawning migrations as follows: fall, late-fall, winter, and spring runs. Others stocks which might be recognized in the future will likely become stocks of special concern.

Good evidence exists for salmon and steelhead that these species return to their natal streams to spawn. There is some evidence and little reason not to expect that the same relationship holds for some of the other anadromous species. As stated in the POA for the Program, the objective of the Program will be to double the natural production of all species and races within specific individual streams, and to preserve genetic stocks. If it proves unfeasible to double the natural production of a species or race within a specific stream, the unmet production increment will be transferred to other individual streams in the following order of priority: (1) another stream within the same drainage system, (2) another stream within the larger basin, such as the Sacramento River Basin, and (3) any stream within the Central Valley.

Central Valley Rivers and Streams

For the purposes of the Program, **Central Valley rivers and streams are defined as all rivers, streams, creeks, sloughs and other watercourses, regardless of volume and frequency of flow, that drain into the Sacramento River basin, the San Joaquin River basin downstream of Mendota Pool, or the Sacramento-San Joaquin Delta upstream of Chipps Island**.

Sustainable

Sustainable means capable of being maintained or kept in existence. In Title 34, sustainable refers to natural production, which is defined as "... fish produced to adulthood without direct human intervention...." Elimination of direct human intervention as a legitimate alternative requires reliance on restoration and maintenance of habitat conditions that allow anadromous fish populations to sustain themselves at levels consistent with numeric restoration goals. Therefore, in the context of Title 34, **sustainable is defined as capable of being maintained at target levels without direct human intervention in the spawning, rearing or migration processes**. Production levels specified by numeric goals will be considered sustainable when they are maintained under the entire range of conditions resulting from legal human activities, as superimposed on natural variability inherent in the system. Human activities shall include, but not be limited to, agricultural diversion and discharge, exports, flow manipulation, water pollution, dredge and fill, channel modification and damming.

There is an element of time implicit in sustainability. Therefore, if natural production is to be sustainable, modifications to system operations as well as improved physical habitat and water quality must be provided into the future. Title 34 requires that "...natural production...be sustainable, on a long-term basis" and provides for annual funding without a specified expiration date. The intent of Title 34 is that numeric restoration goals continue to be realized or exceeded in perpetuity.

Long-Term Basis

Long-term will encompass at least several generations of fish (not less than 5) over a variety of hydrologic conditions (to allow for natural variation in production) and will continue indefinitely.

Average Levels

As stated in Title 34, the goal is to sustain natural production "...at levels not less than twice the average levels attained during the period of 1967-1991..." To attach numeric values to this goal, we need to estimate average levels of production. One problem is that average is not a precise statistical term. In statistics, the term average can apply to several measures of central tendency (Langley 1971). The most commonly used measure of central tendency is the arithmetic mean (Lapin 1975). Consequently, the public generally understands average to mean arithmetic mean and it is reasonable to assume that this was the intent of the authors of Title 34. Therefore, **the definition of average will be the arithmetic mean**.

INTENT OF TITLE 34

Habitat Restoration

Of the six purposes of Title 34, three are particularly germane to discussion of the intent of Title 34 as it relates to the Program. These three purposes are listed below:

(1) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California (3402[a]);

(2) to address impacts of the Central Valley Project on fish, wildlife and associated habitats (3402[b]);

(3) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (3402[e]);

In addition, Section 3406(b)(1)(A) states that the Program "...shall give first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations, and implementation of the supporting measures mandated by this subsection..." Because Title 34 directs that the Program shall emphasize habitat restoration, **emphasis will be placed on restoring habitat**.

Natural versus Hatchery Production

Title 34 requires that "...natural production of anadromous fish in Central Valley rivers and streams be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991..." (Section 3406[b][1]). The requirement that natural production be sustainable on a long-term basis suggests that the intent of Title 34 is for the definition of natural production to extend between generations of fish. Natural production should be self-sustaining. **The Program should not depend on hatchery-produced fish to sustain populations of naturally spawning fish**.

In addition, Title 34 requires investigations of "...opportunities for additional hatchery production to mitigate the impacts of water development and operations on, or enhance efforts to increase Central Valley fisheries; Provided, That additional hatchery production shall only be used to supplement or to re-establish natural production while avoiding adverse effects on remaining wild stocks" (Section 3406[e][2]). This section provides insight into the intent of Title 34 as it relates to the roles of natural and hatchery production and emphasizes avoiding adverse effects of hatchery production on wild (naturally produced) stocks. Under Title 34, **hatchery production should only be used as a last resort to supplement or to re-establish natural production, and then only after investigations on the desirability of developing and implementing additional hatchery production**.

Adverse effects of hatchery production on natural stocks can include reductions in population size caused by competition, predation, disease or other factors (Sholes and Hallock 1979, Waples 1991). A large potential for negative interaction exists when these stocks interbreed (Hindar et al. 1991, Taylor 1991, Waples 1991). The adverse effects of interbreeding increase as hatchery-produced fish become more prevalent in the naturally spawning population. Interbreeding reduces interpopulation diversity and may lead to a reduction in overall productivity and a greater vulnerability to environmental change (Waples 1991). Outbreeding depression may also result from interbreeding. In addition, large populations of hatchery-produced fish that are indistinguishable from naturally produced fish may intensify effects of harvest on naturally produced fish (Wright 1993). The simplest way to avoid adverse effects on naturally produced stocks is to minimize the opportunities for interaction between naturally and hatchery-produced fish. **The Program should be designed to avoid adverse effects of hatchery production on natural stocks**.

Harvest

Title 34 does not directly address harvest. Title 34 defines natural production as: "... fish produced to adulthood..." (Section 3403[h]) and requires that natural production be increased. Inclusion of the term production, and especially production to adulthood, suggests that **Title 34 does not intend for restriction of harvest to be used as a means of achieving Program goals**. As stated in the definition of production, harvested fish should be included in counts of production. Sound harvest management is designed to harvest only excess production, allowing for enough fish to escape harvest to maintain production at the highest level the habitat can support.

Title 34 requires that natural production be increased. There are two mechanisms by which natural production can be increased: (1) increasing the productivity of the existing habitat, and (2) increasing the amount of habitat. These mechanisms are consistent with the emphasis Title 34 places on habitat restoration. Doubling productivity of existing habitat would provide more offspring from the same number of spawners. If existing spawning habitat is being fully utilized, then increasing the number of spawners by reducing harvest would not increase production. If production of naturally produced fish is doubled and escapement is held to present levels, then harvest of naturally produced fish could more than double.

The second mechanism, doubling the amount of habitat, would accommodate twice the number of spawners. This would also provide twice the number of offspring. Under this scenario, harvest of naturally produced fish could double. Under either mechanism, barring other harvest restrictions, we would expect at least a doubling of harvest of naturally produced fish. To meet the Intent of Title 34, **harvest should be maintained at levels that allow sufficient numbers of naturally produced fish to spawn to meet goals for at least doubling natural production**.

IMPLEMENTATION CRITERIA

As stated earlier, criteria for determination of natural production will conform to the definition of natural production and intent of Title 34, including definitions and interpretations of intent discussed and refined in this Position Paper. Because determination of natural production in the past will require different criteria than in the future, criteria for these time periods will be discussed separately.

Criteria for the baseline period - In the past, data collection efforts have not focused on estimating natural production and existing data may not provide direct estimates of natural production. In order to establish numerical goals for the Program, average levels of natural production must be estimated for the baseline period. Estimates will require assessing existing data and developing criteria to determine which data are germane. Criteria may not strictly conform to the definitions in and intent of Title 34 but are a compromise necessitated by a lack of data on natural production.

As explained in the POA, the Core Group and technical teams are responsible for developing these criteria. Technical teams are asked to develop initial criteria and estimates of average levels of natural production for the baseline period.

Where data are lacking, technical teams will make assumptions to expand existing data, or put existing data in perspective. For example, run-size estimates for American shad exist for only two years. In addition, young American shad abundance has been sampled during the fall emigration each year since 1967, except for 1974 and 1979 (Mills and Fisher, in preparation). The American shad technical team could look at young American shad abundance data to determine if run-size estimates for adults are representative of the abundance of shad for the baseline period. This approach has assumptions (chief among these is that abundance of young American shad can tell us something about average adult run-sizes) which are probably violated to some degree and is only presented as an example of what might be considered. Technical teams will document options considered for estimating natural production in issue papers that will be appended to the Program Plan if not in the text. Data quantity and applicability toward estimating natural production varies between species and drainage. Each technical team will need to address these issues for each species and drainage separately. Criteria for determining natural production during the baseline period will be applicable to existing data.

Because there is a relative wealth of data for chinook salmon and because several Teams deal with chinook salmon, specific criteria are proposed for them. Most of the data necessary to estimate production of each stock of chinook salmon for the baseline period are compiled in Mills and Fisher (1994). The proposed procedure for estimating yearly production of each race of chinook salmon for each stream during the baseline period follows.

In the following explanations and formulas, P is for production, E is for escapement, H is for harvest, and *h* is for the portion of total production not produced naturally. Subscripted letters following the normal letters and prior to the first comma represent different races of chinook salmon as follows: F for fall, L for late-fall, W for winter, S for spring, and C for all races combined. Subscripted letters following the first comma represent the following: O for ocean, D for downstream, I for instream, N for natural, H for hatchery, and T for total. Subscripted letters following the second comma represent the following: CV for Central Valley, SF for San Francisco, M for Monterey, and other letter combinations correspond to specific streams (e.g., AM for American River). Subscripted letters following a third comma refer only to ocean harvest and are C for commercial and R for recreational. In all cases, a subscripted X acts as a "wildcard" place holder for an unspecified subscript.

1. A portion of production returns to spawn in each stream, both naturally and in the hatchery. Some of these fish are captured before spawning. These fish are counted toward production for the stream in which they spawned or were harvested according to the following:

   a. To determine the total spawning escapement ($E_{X,T,XX}$) for each race in each individual stream, sum the estimated number of each race of chinook salmon returning to spawn naturally ($E_{X,N,XX}$) and in hatcheries ($E_{X,H,XX}$) for each individual stream.

   $$E_{X,T,XX} = E_{X,N,XX} + E_{X,H,XX}$$

   b. To determine the portion of production for each race returning to each stream (in-river run-size, $P_{X,I,XX}$), add $E_{X,T,XX}$ to the estimated number of each race of chinook salmon harvested in each stream ($H_{X,I,XX}$). Estimates of $H_{X,I,XX}$ do not exist for all streams and all years. Where estimates are not available or are inadequate, best professional judgement must be used. Technical Teams should document options considered for estimation of $H_{X,I,XX}$ in the Program Plan or in issue papers that will be appended to the Program Plan.

$$P_{X,I,XX} = E_{X,T,XX} + H_{X,I,XX}$$

c. To determine the total number of each race of chinook salmon returning to the Central Valley ($P_{X,I,CV}$), sum $P_{X,I,XX}$ for all streams in the Central Valley ($\Sigma P_{X,I,XX}$) .

$$P_{X,I,CV} = \Sigma P_{X,I,XX}$$

d. To determine the total number of chinook salmon (all races combined) returning to the Central Valley ($P_{C,I,CV}$), sum $P_{X,I,CV}$ for all races of chinook salmon ($\Sigma P_{X,I,CV}$) .

$$P_{C,I,CV} = \Sigma P_{X,I,CV}$$

2. A portion of production is harvested in the ocean and downstream of areas in rivers where the stream responsible for this production is not easily identified. To assign these harvested salmon to individual streams, the total number of salmon falling into this category is summed and subdivided to race and stream, proportional to the portion of production attributed to each race and returning to each stream, according to the following:

   a. To determine the Central Valley component of ocean harvest ($H_{C,O,CV}$), sum commercial catch at San Francisco ($H_{C,O,SF,C}$) and Monterey ($H_{C,O,M,C}$), sum recreational catch at these same ports ($H_{C,O,SF,R} + H_{C,O,M,R}$), and add these together. This estimate of $H_{C,O,CV}$ is based on the Central Valley Index (CVI), where harvest of Central Valley stocks equals landings at major ports south of Point Arena (San Francisco and Monterey). Use of CVI to estimate the Central Valley component of ocean harvest assumes that the number of Central Valley chinook salmon harvested from ports north of San Francisco is balanced by the number of chinook salmon from drainages north of the Central Valley harvested from San Francisco and Monterey. To carry $H_{C,O,CV}$ forward in subsequent calculations, assume that each chinook salmon harvested in the ocean fishery is equivalent to an adult salmon returning to spawn.

$$H_{C,O,CV} = H_{C,O,SF,C} + H_{C,O,M,C} + H_{C,O,SF,R} + H_{C,O,M,R}$$

   b. To account for that portion of inland harvest that occurs downstream of streams for which production is being estimated, estimate portion of inland recreational harvest captured downstream of spawning streams ($H_{C,D,CV}$). Information necessary to estimate $H_{C,D,CV}$ may not be available. If an estimate exists, use it. If an estimate of inland harvest for the entire Central Valley exists ($H_{X,I,CV}$), then sum all assignable inland harvest ($\Sigma H_{X,I,XX}$) and subtract it from $H_{X,I,CV}$ to determine $H_{C,D,CV}$. If other options exist, these should be explored. $H_{C,D,CV}$ could be assumed to be small and therefore left out of the calculations or could be included in $H_{X,I,XX}$, in which case it would already to assigned to an individual stream.

c. To determine ocean and downstream inland harvest for the Central Valley ($H_{C,O+D,CV}$), sum $H_{C,O,CV}$ and $H_{C,D,CV}$.

$$H_{C,O+D,CV} = H_{C,O,CV} + H_{C,D,CV}$$

d. To assign portions of $H_{C,O+D,CV}$ to specific races, subdivide $H_{C,O+D,CV}$ to each race, proportional to the portion of production for each race returning to the entire Central Valley ($P_{X,I,CV}$) to the portion of production for all races combined returning to the entire Central Valley ($P_{X,I,CV}$).

$$H_{X,O+D,CV} = H_{C,O+D,CV} \bullet (P_{X,I,CV}/P_{C,I,CV})$$

e. To assign portions of $H_{X,O+D,CV}$ to specific streams, subdivide $H_{X,O+D,CV}$ to each stream, proportional to the portion of production for that race returning to each stream ($P_{X,I,XX}$) to the portion of production for that race returning to the entire Central Valley ($P_{X,I,CV}$).

$$H_{X,O+D,XX} = H_{X,O+D,CV} \bullet (P_{X,I,XX}/P_{X,I,CV})$$

3. To determine total production for each race and stream ($P_{X,T,XX}$), sum $P_{X,I,XX}$ and $H_{X,O+D,XX}$.

$$P_{X,T,XX} = P_{X,I,XX} + H_{X,O+D,XX}$$

4. A portion of the total production was not produced naturally (h). For the baseline period, only hatchery-produced salmon will be considered to be produced by other than natural means. To determine the natural production for each individual stream ($P_{X,N,XX}$), multiply $P_{X,T,XX}$ by (1-h). Technical Teams should document options considered and chosen for estimation of h in issue papers that will be appended to the Program Plan or in the text for the Program Plan.

$$P_{X,N,XX} = P_{X,T,XX} \bullet (1-h)$$

Numeric restoration goals for chinook salmon in each stream will be calculated as at least double the average of $P_{X,N,XX}$ for each of the years during the baseline period.

Criteria for the future - In the future, opportunities exist to improve estimates of natural production. These range from augmenting historic data collection activities with efforts to estimate the proportion of fish that are naturally produced, to designing new data collection to better account for natural production. The Core Group and technical teams are responsible for designing future monitoring programs.

The Core Group and technical teams have and will identify deficiencies in the baseline data. Future monitoring activities will be designed to address and avoid deficiencies. For example, monitoring programs should focus on estimating production, including harvest, on a consistent and regular basis, preferably yearly, in all of the streams in the Central Valley.

Monitoring programs should also estimate natural production, requiring some means of separating naturally produced fish from fish produced by other than natural means. At the very least, natural production must be discernable from hatchery production. Several methods can be used to separate naturally produced fish from hatchery-produced fish, including use of scale (Scarnecchia and Wagner 1980) or otolith (Paragamian et al. 1992) characteristics and constant fractional (Hankin 1982) or complete marking of hatchery-produced fish (Wright 1993), including incorporation of genetic markers (Waples 1991), inducement of otolith banding patterns (Volk et al. 1990), and more standard methods such as clipping fins. In addition, recommendations for the future should include managing naturally and hatchery-produced fish separately.

In addition, better estimates of harvest of Central Valley salmon in the ocean and of all anadromous fish in the Bay, Delta, and in each individual river and stream in the Central Valley should be developed. Harvest should be monitored continually.

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Working Paper on Restoration Needs

Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California

Volume 3

WORKING PAPER ON RESTORATION NEEDS

HABITAT RESTORATION ACTIONS TO DOUBLE NATURAL PRODUCTION OF ANADROMOUS FISH IN THE CENTRAL VALLEY OF CALIFORNIA

Volume 3

Prepared for the U.S. Fish and Wildlife Service
under the direction of the
Anadromous Fish Restoration Program Core Group

May 9, 1995

ORGANIZATION OF THIS WORKING PAPER

This is Volume 3 of three volumes that comprise the Anadromous Fish Restoration Program (AFRP) Working Paper on Restoration Needs. The contents of the three volumes are as follows:

Volume 1 describes how the WORKING PAPER was developed, explains the process envisioned for completing a final Restoration Plan, and summarizes the production goals, limiting factors, and restoration actions sections developed by the AFRP technical teams. Interested parties should read the letter from Dale Hall and Wayne White that appears at the beginning of Volume 1.

Volume 2 provides descriptions of Central Valley rivers and streams, summarizes information on historic and existing conditions for anadromous fish, identifies the problems that have led to the decline of anadromous fish populations, and identifies roles and responsibilities of state and federal agencies in managing anadromous fish. It also includes two key documents that were used by the AFRP Core Group and technical teams to develop the WORKING PAPER.

Volume 3 includes the complete production goals, limiting factors, and restoration actions sections as submitted by the AFRP technical teams and edited by USFWS staff. Volume 3 also includes citations for all three volumes of the WORKING PAPER.

To request copies of this Working Paper, call the AFRP=s information line at (800) 742-9474 or (916) 979-2330 and dial extension 542 after the recorded message begins. You may also obtain copies by calling Roger Dunn, CVPIA Public Outreach, at (916) 979-2760 or by sending e-mail requests to roger_dunn@fws.gov. The Working Paper is available to be viewed and downloaded on the Internet at http://darkstar.dfg.ca.gov/usfws/fws_home.html.

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SECTION X. REPORTS FROM THE TECHNICAL TEAMS

INTRODUCTION

This section consists of the reports from the eight technical teams. Five of these teams addressed chinook salmon and steelhead in each of the following areas: (1) mainstem upper Sacramento River, (2) upper Sacramento River tributaries, (3) lower Sacramento River and Delta tributaries, (4) San Joaquin basin, and (5) Sacramento-San Joaquin Delta. Three additional teams addressed (6) striped bass, (7) American shad, and (8) white and green sturgeon. The teams that addressed chinook salmon and steelhead, American shad, and white and green sturgeon organized their reports according to river systems.

Each report is presented in at least two sections, "Limiting factors and potential solutions" and "Restoration actions". The first of these sections describes factors potentially limiting the production of the species and gives an overview of potential solutions for each factor; the second section lists specific actions and describes the objective, location, and predicted benefits and provides details of implementation for each action.

A. CHINOOK SALMON AND STEELHEAD

Baseline Natural Production and Goals

Chinook salmon - The procedures described in Volume 2, Section IX, AGuiding Principles and Assumptions,@ were used to estimate restoration goals for chinook salmon (Table 3-Xa-1). The Core Group defined the restoration goal to be equal to, at least, twice the mean estimated natural production for the baseline period (1967-1991). It defined natural production during the baseline period to be that portion of production not produced in hatcheries and defined total production to be the sum of harvest and escapement. Only rough estimates of hatchery production and ocean and inland harvest exist for the baseline period, and then only for some Central Valley rivers and streams. Where estimates were not available or where they were known to be inaccurate, values for these parameters were assigned. The proportion of production produced in hatcheries was assigned based on available estimates (Dettman and Kelley 1985, 1986; Cramer 1990) and on the opinion of fishery biologists. Ocean harvest of Central Valley chinook salmon was assumed to be equal to the Central Valley Index. Inland harvest values were assigned as a proportion of escapement based on available harvest data (Mills and Fisher 1994, draft summaries of California Department of Fish and Game [DFG] 1991-1993 angler survey data) and the opinion of fishery biologists. In general, escapement estimates were taken from Mills and Fisher (1994). More specific sources of information considered for each river are listed as notes associated with production spreadsheets in Appendix A at the end of this subsection.

Opportunities exist to improve estimates of most of the parameters used to estimate the restoration goal, especially estimates of the proportion of production produced in hatcheries and ocean and inland harvest. The goals listed in Table 3-Xa-1 should be considered preliminary estimates.

Table 3-Xa-1. Escapement, harvest, and production data and preliminary estimated restoration goals for chinook salmon based on doubling of natural production.

		Harvest		Production		
Race and river[a]	Escapement	Instream	Ocean	Total	Natural	Goal[b]
All races combined	280,000	53,000	410,000	740,000	500,000	990,000
Fall run	220,000	40,000	340,000	610,000	370,000	750,000
Late fall run	15,000	5,500	24,000	34,000	22,000	68,000
Winter run	23,000	4,600	26,000	54,000	54,000	110,000
Spring run	13,000	2,400	19,000	34,000	34,000	68,000
Sacramento River						
Fall run	77,000	7,700	110,000	190,000	120,000	230,000
Late fall run	14,000	2,800	20,000	37,000	22,000	44,000
Winter run	23,000	24,000	26,000	54,000	54,000	110,000
Spring run	11,000	2,200	16,000	29,000	29,000	59,000
Clear Creek	1,600	160	2,700	4,500	3,600	7,100
Cow Creek	1,400	140	1,400	2,900	2,300	4,600
Cottonwood Creek	1,600	160	1,900	3,700	3,000	5,900
Battle Creek						
Fall run	18,000	1,800	31,000	50,000	5,000	10,000
Late fall run	1,000	200	1,500	2,700	270	550
Paynes Creek	90	10	110	200	160	330
Antelope Creek	190	20	240	450	360	720
Mill Creek						
Fall run	1,100	110	1,400	2,600	2,100	4,200
Spring run	800	80	1,300	2,200	2,200	4,400
Deer Creek						
Fall run	410	40	510	950	760	1,500
Spring run	1,300	130	1,800	3,300	3,300	6,500
Miscellaneous creeks	300	30	350	680	550	1,100
Butte Creek						
Fall run	420	40	490	951	760	1,500
Spring run	360	40	620	1,000	1,000	2,000
Big Chico Creek	240	20	230	500	400	800
Feather River	49,000	9,700	80,000	140,000	86,000	170,000
Yuba River	13,000	1,300	19,000	33,000	33,000	66,000
Bear River	100	10	110	220	220	450
American River	41,000	18,000	75,000	130,000	81,000	160,000
Mokelumne River	3,300	300	4,100	7,800	4,700	9,300
Cosumnes River	760	80	800	1,600	1,600	3,300
Calaveras River						
Winter run	410	480	590	1,100	1,100	2,200
Stanislaus River	4,800	240	5,800	11,000	11,000	22,000
Tuolumne River	8,900	450	9,500	19,000	19,000	38,000
Merced River	4,500	230	5,100	9,900	9,000	18,000

[a] Data for rivers without a race designation are for fall-run chinook salmon.

[b] Because of rounding errors, goal category numbers do not add up to twice the natural production category numbers.

Steelhead - Insufficient data are available to estimate natural production of steelhead in the Central Valley other than upstream of Red Bluff Diversion Dam (RBDD). The restoration goal for steelhead spawning upstream of RBDD is 13,000 steelhead per year (refer to Appendix B at the end of this subsection).

Upper Mainstem Sacramento River

Limiting factors and potential solutions - Population levels of chinook salmon and steelhead in the upper Sacramento River are at historically low levels. The winter-run salmon is listed as endangered; spring-run populations in the mainstem are less abundant than winter-run populations, but occur in tributaries to the upper Sacramento River at low levels. The commercial fisheries that depend on Sacramento River stocks have been curtailed to a considerable degree.

Actions that are needed include seasonal opening of dam gates at RBDD, releases of cold water from Shasta and Trinity dams from levels below the powerhouse intakes, removal of acid and metal from the worst portion of the discharge from Iron Mountain Mine Superfund Site, and avoidance of entrainment of juveniles at Glen-Colusa pumps and other diversions.

There is historical evidence that the salmon fishery was compatible with the basic components of the water projects during the 1940s, 1950s, and 1960s. During the 1950s, the combined population of all salmon runs on the upper Sacramento River probably exceeded one-half million salmon. Over the last two decades salmon escapements and harvests have declined. As water demands increased, the CVP grew, becoming less operationally flexible in providing water-related benefits to fish, wildlife, and associated habitats, especially during dry periods. This trend continued even with increased regulation.

By restoring operational flexibility to water projects, a reasonable balance can be achieved among competing demands for use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors. The Central Valley Project Improvement Act (CVPIA) calls for several fish and wildlife restoration activities, some of which are structural changes to the existing facilities. These changes (e.g., addition of a structural temperature control device at Shasta Dam) are especially valuable because they provide structural operational flexibility, allowing more needs to be met with the same amount of water.

With limited water supplies and high demand requirements for fish and wildlife, agriculture, municipal and industrial, and power production, complex water management solutions are needed. For fish and wildlife and associated habitat protection, the Central Valley Project (CVP) should attain operational flexibility to protect the salmon and steelhead populations. In drought situations, the salmon and steelhead runs should be protected at least 2 out of 3 successive years, thus ensuring the populations' maintenance, recovery, and resiliency and avoiding the decade-long recovery periods from cumulative mortality rates produced by the present water management operations.

Existing habitat conditions - The Sacramento River is the largest river system in California. The river's water resources yield 35% of the state's supply and the river's salmon and steelhead resource supplies the largest portion of the state's catch. The upper Sacramento River supports one of the largest contiguous riverine and wetland ecosystems left in the Central Valley even though the remaining riparian habitat is only 5% of the historical amount. The river ecosystem supports several federal- and state-listed endangered and threatened species and several species of special concern.

The flow of the Sacramento River is regulated by Shasta Dam where as much as 4.5 maf of water are stored during the wet season. River flow is augmented in average years by up to 1 maf of Trinity River water transferred by tunnel to Keswick Reservoir. The U.S. Bureau of Reclamation (USBR) owns and operates the Shasta and Trinity divisions of the CVP, which also includes Spring Creek Debris Dam, which is used for metering out toxic wastes from the Iron Mountain Mine, and RBDD, which diverts into the Tehama-Colusa Canal and the Corning Canal.

The upper Sacramento River extends from Keswick Dam to the confluence of the Feather River, a distance of 215 river miles. Other alterations of the river affecting this reach include: the Glen-Colusa Irrigation District's (GCID's) pumps, which divert approximately 1 maf of water per year; the Anderson Cottonwood Irrigation District's (ACID's) seasonal dam, which diverts approximately 150,000 af, May to October; hundreds of small riparian diversions; and displaced riparian forests along selected sections of the bank that have major flood-control and bank protection works from Red Bluff to the Feather River.

Habitat needs - The upper Sacramento River supports four races of chinook salmon and steelhead. Other native anadromous fish include white sturgeon (*Acipenser transmontanus*), green sturgeon (*A. medirostris*), Pacific lamprey (*Lampetra tridentata*), and river lamprey (*L. ayresi*). Nonnative anadromous fish include striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*).

This subsection addresses six primary limiting factors affecting salmon and steelhead in the upper mainstem Sacramento River: 1) changes in the natural frequency, magnitude, and timing of flows; 2) water temperature changes; 3) passage at artificial migration barriers; 4) toxic discharges; 5) effects of hatchery stocks on natural stocks; and 6) loss of riparian forests and associated rearing habitat and water temperature moderation capacity. Specific issues for achieving restoration follow:

Changes in the natural frequency, magnitude, and timing of flows - Reservoirs have changed the natural flow regimes of the Sacramento River by changing frequency, magnitude, and timing of flow. Flows need to be established that support the life history needs of all four races of salmon and steelhead: spawning flows, stable flows for early life stages, outmigration flows, and flushing flows for sediment transport.

The Sacramento River functions as a water delivery canal for the CVP. Flows are regulated in large part by CVP water delivery operations. During the irrigation season, flows released to satisfy project purposes generally exceed flows needed to satisfy spawning and temperature control requirements. Critical periods for coordinating flows between fishery needs and water delivery needs include fall and early winter months to ensure that incubation conditions are adequate, late winter when there may be a need to reduce flows and increase storage for temperature control later in the year, and spring when temperature control plans and water contracting decisions are made for the next season.

The runoff and storage conditions in the project vary widely, requiring different types of operation. USBR generally operates the project in accord with a CVP Operations Criteria and Plan (USBR 1992) and the Biological Opinion for winter-run chinook salmon (National Marine Fisheries Service [NMFS] 1993).

The flow allocation process is now coordinated with the CVPIA (CVPIA; P.L. 102-575). Each year there is coordination among the fishery trustees (DFG, U.S. Fish and Wildlife Service [USFWS], and NMFS) and the CVP operators to select the flow regimes and flow changes meeting habitat requirements within the available water supply. Habitat considerations include prevention of stranding and isolation of redds and juveniles due to flow fluctuations, attainment of temperature objectives, and provision of experimental spring-time releases for facilitating outmigration. Consideration is given to balancing reservoir carryover storage needs for temperature control with flow needs for habitat. The project operators provide monthly forecasts to the fishery trustees and further coordination occurs throughout the year as hydrologic conditions change.

The benefits of pulsed flows need to be accurately determined to facilitate juvenile outmigration. This flow requirement can consume enormous quantities of water from supplies dedicated to fish and wildlife. Because of the high water cost, it is necessary to define the benefits through carefully designed studies of experimental spring-time outmigration flows. There may be a need for flushing flows for channel maintenance (e.g., to remove the harmful effects of sedimentation or growths of nuisance algae and oligochaetes that destroy salmon eggs). Presently, there is insufficient information to determine the timing and amount of the flushing flow. Until the recent drought, carryover storage was sufficient to produce spills from Shasta Dam at adequate intervals.

Water temperature changes - Reservoirs have changed the natural cycle of water temperature and blocked access to historical spawning areas. The temperature regulation is important to the restoration of winter-run, spring-run and, to a lesser degree, fall-run salmon. Late fall-run salmon, steelhead, and other anadromous fish are not threatened by temperature problems. Past instances of temperature-induced mortality caused major year class failures and losses, especially when poor runoff conditions were combined with heavy reservoir drawdowns.

The California State Water Resources Control Board (SWRCB), on behalf of the fishery trustees, requires CVP operations to provide the best temperature control attainable for all races of salmon and steelhead. In addition, it requires eventual installation of temperature control devices at Shasta Dam and at Whiskeytown Reservoir. The NMFS, under the Endangered Species Act, prescribes measures for temperature control for winter-run salmon.

Permanent remedies are needed to resolve the temperature problem through the installation of structural devices on all reservoirs releasing to the river, in combination with prudent reservoir management practices that leave sufficient carryover storage to maintain cold water reserves the following year. In the interim, the reservoir operations are reviewed by a temperature task force and recommendations are made to avoid possible losses of salmon and steelhead by the optimum budgeting and delivery of cold water reserves via the coldest available reservoir outlets. These actions are consistent with the intent of the Clean Water Act (Water Rights Order 90-5), Federal Endangered Species Act, and the CVPIA. Uncontrollable factors, such as extreme drought, will limit the ability to control temperatures even with temperature control devices.

The temperature regime of the middle Sacramento River below Tehama County is not significantly influenced by reservoir operations due to its distance downstream from the dam. The objectives of restoration activities that affect the temperature regime in the middle river include rerouting major agricultural drainwater discharges from the river into flood bypass channels and reestablishing large-tract riparian forests that increase humidity and moderate air temperatures. Further study and analyses are needed to quantify the benefits of these two actions. However, it may not be necessary to precisely quantify these benefits if these actions are taken for the overriding benefits of restoring riparian forest for wildlife and directing large pesticide and herbicide discharges away from the river.

Passage at artificial migration barriers -

Red Bluff Diversion Dam - Opening the RBDD gates eliminates delay in passage and blockage of adult salmon and steelhead, which can result in reproductive failure if the fish are unable to reach additional spawning habitat and the coldest available water. The open gates also eliminate concentrations of piscivorous fish (their upstream movement is blocked by the dam), which prey on juvenile salmonids disoriented by passage under the dam gates. A needed partial remedy to fish passage problems is installation of USBR's proposed research pumping plant, which will allow the diversion dam gates to be open from mid-September through mid-May. A final remedy will depend on results of pilot studies, evaluations of the research pumping plant, and further feasibility studies focusing on different sizes of pumping stations and/or ladder-type passage facilities.

Anderson-Cottonwood Irrigation District - The ACID's 75-year-old seasonal dam needs an updated fish passage facility and a water control device that adjusts the head on the canal without flash-board removal and related drastic stream flow reductions. The ACID's dam has several effects on salmon and steelhead: (a) adjustments to the flashboard dam according to stipulations in a USBR contract allow the district to order rapid and drastic changes in the river flow, thus causing fish stranding and redd dewatering; (b) high volume water releases from canal waste gates can attract and strand spawning adult salmon and steelhead; (c) there are occasional discharges of toxic herbicides to tributaries crossing the canal; and (d) inadequate fish ladders at the dam impair upstream fish passage.

Fishery restoration remedies are proceeding on a cooperative basis. The ACID is developing the necessary information to better operate and improve the facilities necessary to exercise its water right with minimum biological impacts, consistent with various litigation settlement agreements. A setting for the flashboards and canal drum gates was recently and successfully tested at river flows of 4,000-14,000 cubic feet per second (cfs). The setting can deliver the full water demand in the canal without requiring mid-season adjustment of the flashboards and not exceeding the safety of dam water surface elevation in the diversion pool at the main dam.

The canal system operating procedures have been revised to prevent major biological problems. Once the ACID has determined the level of remediation possible from operational changes and structural modifications, appropriate agreements need to be completed.

Keswick Dam - Keswick Dam routinely spills during powerhouse problems and floods. The spill attracts all races of salmon and steelhead into a stilling basin, isolating them from the river when spills cease. A more effective escape passage can be provided by installing a small stream channel through the bedrock at the outside corners of the basin. The spills occur intermittently with turbine load rejections, required safety checks of the gates, and rare flood releases. The basin also receives oil-laden discharges from the internal dam works.

Unscreened diversions - There are more than 300 separate irrigation, industrial, and municipal water supply diversions along the Sacramento River between Redding and Sacramento, diverting nearly 1.2 maf of water annually from April through October. These unscreened diversions may cause significant losses of juvenile salmon and steelhead rearing in these sections of the river during the irrigation and nonirrigation seasons. Flooding of rice fields during the nonirrigation season is presently under consideration, which would expose more rearing salmon and steelhead to unscreened pumps. According to The Resources Agency of California (1989), 10 million juvenile salmon and steelhead are lost to unscreened diversions annually.

Glen-Colusa Irrigation District - The GCID was organized in 1920 to take over the Central Irrigation District's diversion project, which had operated since 1905. Significant hydraulic changes have occurred in the river since installation of the existing fish screens in 1972. The entrance to the diversion has dropped about 3 feet in elevation, lowering water depths in the oxbow and decreasing the effective surface area of the screens. Decreasing surface area increases water velocity through the screens, killing juvenile salmon, steelhead, and other small fishes by impingement.

Bypass flows needed to allow juvenile fish to return to the river are insufficient, and reverse flows occur when drawdown in the intake channel exceeds the natural flow of the main channel of the river. Most fish entering the diversion during these periods are believed to be lost to predation.

Original screen design criteria did not call for screening out salmonid fry (less than 1.75 inches in total length). It is now recognized that these screens were never completely effective. DFG estimates an average annual loss of 7 million downstream migrating salmonids at this diversion.

Restoration of anadromous salmonid populations above Keswick Reservoir - The amount of chinook salmon and steelhead habitat lost upstream from Keswick and Shasta dams was enormous. Hanson et al. (1940) determined from extensive gravel surveys that more than 2.4 million square feet of spawning habitat in 187 miles of accessible rivers and streams capable of supporting a maximum run of 188,000 salmon were blocked to anadromous fish by the project. This area once provided substrate for natural spawning for approximately one-half of the total Sacramento River salmon run (Calkins et al. 1940, Van Cleve 1945, Azevedo and Parkhurst 1958). Restoration of fish access to historical spawning and rearing habitat currently blocked by Keswick and Shasta dams would provide an opportunity to augment natural production of anadromous salmonids and could extend the current reduced geographical ranges for chinook salmon and steelhead. If restoration is successful, anadromous salmonids would have access to historical spawning ranges above Keswick and Shasta dams, providing additional restoration opportunities.

Restoration of habitat above the dams would be a secondary objective explored if it proves unfeasible to double the natural production in Central Valley streams below Keswick and Shasta dams. Elements of a feasibility study to determine the potential for restoration would include, but not be limited to, a survey for suitable or restorable habitat above Shasta Dam; a survey for suitable or restorable habitat between Keswick and Shasta dams; examination of Keswick Dam fish trap to move adults above Keswick Dam; survivorship of juveniles through Keswick Dam turbines; and analysis of volitional fish passage, including fish bypass systems and trucking of fish to facilitate adult and juvenile migration past Keswick and Shasta dams.

Toxic discharges - The Sacramento River receives a variety of discharges that have created contamination and increased toxicity to fish and other aquatic life.

Metals - Due to waste from the Iron Mountain Mine, the Sacramento River has impaired water quality according to standards for metals established under the Clean Water Act (SWRCB 1992). The Iron Mountain Mine discharges a complex mixture of toxic metals from abandoned mine workings. The discharge enters the Sacramento River approximately 1 mile above Keswick Dam, polluting the river with dissolved metals and forming large deposits of chemical sediments.

Historically, fish toxicity is managed to the extent possible by metering waste from the Spring Creek waste reservoir and diluting it with releases from Whiskeytown and Shasta reservoirs. Dilution does not solve the problem. Normally, dilution capability is large in what is the largest reservoir and river complex in the state; however, during drought or operations at Shasta Dam to prevent downstream flooding, little or no dilution water exists. High concentrations of toxic metals have caused more than 40 documented kills of salmon and steelhead and more undocumented damage. Lower concentrations of metals that are fairly common in the river can result in reduced growth, disease resistance, and physiological problems.

During the last decade, the Iron Mountain Mine site has been on the U.S. Environmental Protection Agency's (EPA's) Superfund program. The main objectives of EPA and the fishery trustees in the Iron Mountain Mine clean-up include: (a) eliminate the water demand that the dilution of the toxic discharge places on the Shasta-Trinity Project of the CVP and (b) attain water quality objectives for toxic metals and contaminated sediments to protect the fishery resources of the Sacramento River from acute and chronic toxicity.

Protection of the Sacramento River fishery has been greatly improved by the actions completed to date under the EPA program, including diverting uncontaminated waters away from contaminated areas, capping an open pit mine, disposing of numerous large tailings piles, and piping the drainage from the portals to the major underground workings to a lime treatment plant that removes 98% of the metals and acid. The remaining necessary remedial actions still in the planning process include controlling pollution from the diffuse sources of copper still in the watershed, which causes pollution during large rainfall events, and cleaning up the chemical sediments in Keswick Reservoir (EPA 1994). Fifty years of discharging the metal-laden waste, which has a pH of 3, into Keswick Reservoir produced a deposit estimated to be 109,000 cubic meters in size and to contain metal levels exceeding those designated for hazardous waste and toxic to salmon fry and invertebrates in small amounts (DFG 1995). The location of a large portion of the deposits near the Spring Creek Powerhouse can mobilize deposits into the river under certain types of operations.

Bioaccumulative substances - Monitoring of dibenzofuran and dioxin concentrations in resident fish and pulp mill effluent should ensure compliance with the Central Valley Regional Water Control Board's (CVRWQCB's) basin plan (CVRWQCB 1990) and suitability of different fish species for sport and commercial uses.

Biostimulatory substances - Monitoring of nuisance algae growths and *Hydrilla*, with the possible use of infrared technology, is needed to determine when the river has reached its capacity to assimilate nutrients. Large sources of biostimulatory substances include nitrogen from municipal waste, pulp mill effluent, and trace elements such as iron from Iron Mountain Mine.

Effects of hatchery stocks on natural stocks - Effects of hatchery stocks on natural spawning stocks is unknown. There is a potential for competition to occur between hatchery-released and wild/natural juveniles in the Sacramento River. Biological interactions of hatchery-released fish with wild fish may include direct competition for food and space during the freshwater rearing phase (Steward and Bjornn 1990).

The extent of transmission of diseases or parasites from hatchery-released salmonids to wild stocks is largely unknown. Although disease outbreaks and epizootics are fairly common in hatcheries, direct transfer of these diseases to wild fish has not been clearly demonstrated. Steward and Bjornn (1990) state that there is little evidence of transmittance of diseases or parasites from hatchery to wild salmonids, although research on this subject is limited and the full impact of disease on supplemented stocks is probably underestimated.

Loss of riparian forests and associated rearing habitat and water temperature moderation capacity - Riparian forests have been removed because of bank stabilization projects that reduce rearing habitats and increase heat gain along the river.

Riparian forests - The continuing fragmentation of the remaining riparian ecosystem has been implicated in the decline of salmon and steelhead populations in the upper mainstem of the Sacramento River. The riparian habitat along the river is an integral part of this system, affecting erosion, deposition, and channel morphology.

The riparian ecosystem along the Sacramento River consists of a mosaic of habitat types of different age, species composition, and vegetative structure. From grasses, forbs, and willows sprouting on newly deposited point bars to thick stands of cottonwood, sycamore, and black walnut to high terrace valley oak woodland, the system is inextricable from the geomorphological processes of erosion and deposition. The vegetation structure in turn affects river morphology by promoting sedimentation during floodflows and influencing erosion rates and channel cutoffs. The resulting channel and floodplain configuration has a diverse array of instream habitat conditions that benefit salmon and steelhead populations.

Loss of riparian forest has many deleterious effects on salmonid populations. These include the loss of configurations suitable for creating spawning riffles; gravel from eroding banks for the creation of spawning riffles; wood debris that provides habitat for juvenile fish; and organic material for aquatic invertebrates, - cover, and shade.

Many factors have resulted in considerable reduction in the amount of riparian habitat along the Sacramento River. Conversion of riparian forests to agriculture is the principal reason for the decline. Completion of Shasta Dam fostered further conversions of habitat to agriculture as decreasing flood risks allowed the planting of orchards and row crops in the historical floodplain. Bank protection also fostered conversion of forests by reducing bank erosion and meandering. The CVP altered the river's natural flow regime and sediment transport characteristics, changing patterns of forest regeneration. Operation of flood control projects, primarily south of Chico, with their associated systems of weirs, levees, bypasses, and bank protection precludes the reestablishment of a dynamic riparian ecosystem. Other current and historical factors contributing to the degradation of the riparian system include timber and fuel harvesting and urban and residential development.

For most of the length of the river, many of these factors currently preclude the reestablishment of an active meander zone. North of Cottonwood Creek, for example, lack of flooding has disrupted the historical pattern of vegetative succession, resulting in a reduction in early successional stages of riparian forest. The

Sacramento River Flood Control Project directs floodflows away from the leveed main channel, leaving only small remnants of riparian habitat south of Colusa.

Between Chico Landing and Red Bluff, conditions still exist that could eventually support the reestablishment of a relatively continuous and viable riparian system. Unregulated tributary flows contribute to a hydrology that still bears some resemblance to the natural system. Active erosion and deposition is still occurring in many places, and remnants of the vegetation mosaic remain. Both USFWS and The Nature Conservancy have targeted this reach for riparian habitat acquisitions.

The riparian forest moderates temperature in shallows along the water's edge and in the sloughs and side channels that are preferred rearing habitat because of lower water velocities.

Another contribution of the riparian system to the health of fisheries is the spatial heterogeneity created by woody debris and overhanging vegetation (Schlosser 1991). Such habitat components may provide escape cover for salmon and steelhead fry.

Cut banks, regardless of the presence of overhanging vegetation, may be preferred by salmon and steelhead fry. A DFG study compared three pairs of natural cut bank and artificial rock revetment sites, finding about three times as many salmon and steelhead fry near the cut banks (DFG 1982). The survey also found a higher diversity of fish species not characteristic of salmon and steelhead streams at the rock revetment sites, suggesting increased salmon smolt predation and competition for food.

Spawning substrate - Gravel recruitment to salmon and steelhead spawning beds has been halted by Shasta Dam. The problem is most acute in the uppermost 15 miles of the river where there is an absence of tributary streams capable of providing gravel to the river. Many tributaries have been mined for decades, reducing bedload replenishment to the river.

To date, two basic types of gravel restoration projects have been conducted: direct engineered placement of gravel in the river bed by heavy equipment and stockpiling gravel on the banks where it can replenish the bedload under high flows. The gravel placement projects have demonstrated the following problems: (a) engineered riffles are placed during lower flow conditions, making them unstable at high flows and potentially causing mortality to the early life stages in the shifting gravel; (b) placements contain large depressions and unnatural irregularities that isolate and strand juveniles when the flows are ramped down to elevations below the constructed gravel deposit; and (c) the operation of heavy equipment in the river, while placing gravel, discharges sediment above protection standards of downstream municipal water supplies and natural spawning areas.

Placing gravel in areas where it will be distributed naturally by floodflows costs less and does not create biological and water quality problems. Because the gravel is replenished at high flow, the river has the capacity to dilute fine sediment and prevent it from depositing on downstream spawning riffles or exceeding water quality criteria. The gravel used for bedload replenishment at high flow does not have to be washed.

Tracer rock placed into stockpiles indicates significant distribution with flows of 20,000 cfs and complete distribution when the 1993 flows ranged between 30,000 cfs and 40,000 cfs.

To ensure sufficient gravel supplies for the river, aggregate management plans should be in the counties that have streams that are mined for gravel (California Department of Water Resources [DWR] 1994). Gravel mining operations have to be modified to prevent formation of migration barriers, destruction of spawning habitat, and removal of spawning sized-gravel that would otherwise recruit to the river. Mitigation measures include stopping all instream gravel mining or requiring the spawning-sized gravel to be reserved for fishery projects. Streams that need aggregate management plans include Clear, Cow, Cottonwood, Thomes, and Stony creeks.

Gravel surveys have been conducted near Keswick Dam to estimate the available gravel from the ACID's dam to Keswick Dam (Vogel and Taylor 1987, Bigelow 1994). Good spawning substrate is predominately composed of gravel and cobble (90-100%), 1-6 inches in diameter, with most 2-4 inches with scarce boulders or fines (Vogel and Taylor 1987). Bigelow's estimate of good gravel between Keswick and Jelly's Ferry was 1,149,000 ft^2 and Vogel and Taylor's was 1,170,000 ft^2. This suggests that at the current salmon and steelhead population levels, spawning habitat probably is not limiting.

Table 3-Xa-2. Limiting factors and potential solutions.

Limiting factors	Potential solutions
Instream flows	1. Regulate CVP flow releases to provide adequate spawning and rearing habitat 2. Avoid flow fluctuations to avert dewatering redds or stranding or isolating adults and juveniles 3. Consider all effects of flow on ecosystem
Water temperatures	Maintain water temperatures at or below 56°F to at least Bend Bridge to Keswick Dam except in extreme water years
Passage at artificial impairments is inadequate	1. Correct migration problems at RBDD 2. Correct fish passage and other problems at the ACID's diversion dam 3. Avoid entrapment of adults at Keswick Dam stilling basin

Limiting factors	Potential solutions
	4. Correct unscreened pump diversions 5. Correct problems at the GCID water diversions
Contaminants	Remedy water quality problems associated with Iron Mountain Mine and other toxic discharges
Effects of hatchery stocks on natural spawning stocks is unknown	1. Evaluate competitive displacement between hatchery and natural stocks 2. Evaluate displacement of natural stocks by hatchery stocks 3. Maintain genetic diversity in hatchery stocks 4. Evaluate disease relationships between hatchery and natural stocks
Loss of riparian forests	Restore and preserve riparian forests

Restoration Actions -

Action 1: Develop and implement a river regulation plan that balances carryover storage needs with instream flow needs based on runoff and storage conditions.

Objective: Actively regulate river flows and reservoir storage in the upper mainstem Sacramento River system to provide necessary habitat for the production of all races of chinook salmon, steelhead, and other anadromous fish, consistent with sound ecological management principles.

Location: Shasta-Trinity Unit of the CVP.

Narrative description: These flow recommendations balance instream flow needs for habitat with carryover storage needs for temperature control. They are also intended to stabilize flows during important winter-run chinook rearing and spring-run and fall-run chinook spawning periods immediately after the irrigation season. Recommendations are listed in Table 3-Xa-3[1].

[1] The algorithm described here does not account for the ramping down of flows at the end of the irrigation

The algorithm for flow is built on the minimum flow and carryover requirements established in the Biological Opinion (BO) for CVP and State Water Project (SWP) effects on Sacramento River winter-run chinook salmon (NMFS 1993) and Water Rights Order 90-5 stipulating minimum instream flows. The BO also requires a minimum instream flow of 3,250 cfs from October 1 to April 30 and temperature control operation from May 1 to September 30 (NMFS 1993).

The recommended flows are based on runoff from a critically dry year and on maintaining a stable release throughout the period. However, water project operations will require flow increases under wet runoff conditions to control downstream flooding, and flow decreases if the runoff is less than critically dry to produce conservation storage. The recommended time to address concerns with runoff drier than critically dry is January 15 when approximately 40% of the wet season runoff has occurred. The recommended flow reduction is 275 cfs to make up for the increment of lost runoff between a critically dry and extreme critically dry water year (driest 5% of record), thereby producing reservoir storage sufficient to reach the 3.0 to 3.2 maf target by April 30. Reducing the flow during the wet season can cause reductions in the wetted perimeter of the spawning grounds and result in stranding and dewatering of the salmon in immobile early life stages that cannot follow the receding water. Managing flow reduction at mid-January produces the least amount of stranding risk during the wet season; but there are still 10% of the late fall-run salmon and 40% to 60% of the fall-run salmon at immobile early life stages (Vogel and Marine 1991).

season in early October or the ramping up at the beginning of the irrigation season in late April.

Table 3 Xa 3. Minimum recommended Sacramento River flows (cfs) at Keswick Dam for October 1 to April 30 based on October 1 carryover storage in Shasta Reservoir and critically dry runoff conditions (driest decile runoff of 2.5 maf) to produce a target April 30 Shasta Reservoir storage of 3.0-3.2 maf for temperature control [2]

Carryover storage (maf)	Keswick release (cfs)
1.9	3,250
2	3,250
2.1	3,250
2.2	3,500
2.3	3,750
2.4	4,000
2.5	4,250
2.6	4,500
2.7	4,750
2.8	5,000
2.9	5,250
3	5,500

The flow recommendations are based on historical operations of the water project. Future changes in water project operations could become an obstacle to implementing flow recommendations, especially changes that increase in the transfer of storage from Shasta Reservoir to off-stream reservoirs (e.g., San Luis Reservoir and other proposed projects). The transfer of storage during the early part of the wet season would reduce the probability of attaining the Shasta Reservoir storage target in April needed to provide temperature control. Even without changes in operations, the actual implementation of the flow regime is expected to vary from that proposed due to uncontrollable factors such as the quantity and timing of runoff. However, by basing the flow recommendations on critically dry runoff conditions, the proposed operation

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$$Flow = \frac{\dfrac{carryover - 3.2\ maf\ (target) + 2.5\ maf\ (inflow)}{211\ days}}{1.98x10^{-6}\ maf/day},$$

should be able to maintain the balance between instream habitat and reservoir storage for temperature control.

Discussion: The river regulation program for Keswick and Red Bluff dams, during the May through September irrigation season, generally does not need to be integrated with any of the habitat requirements other than temperature and outmigration flows. The seasonal irrigation releases from the Shasta Trinity Unit of the CVP provide the flows needed for temperature control for winter-run chinook salmon, as described below for Action 5, upper mainstem Sacramento River.

The source of the flows on an annual basis includes Shasta and Trinity reservoirs and, to a smaller extent, Whiskeytown Reservoir. During the wet season, Shasta Reservoir supplies approximately 80% of the water (with the exception of Trinity Reservoir flood control releases) because most of the Trinity basin water export is concentrated in the dry season when the needs and financial returns are greater. During drought cycles, Trinity River water exports are reduced during the wet season such that it generally approximates 10% of the Sacramento River flow. During the dry season, the Shasta Reservoir still contributes an average of 75% of the Sacramento River flow with the balance coming from Trinity and Whiskeytown Reservoirs.

No algorithm exists that combines water year type, previous year carryover, and other variables such as weather and project operations to provide an end of water year carryover target. The decision-making process for allocating the water supply available to CVP contractors involves comparing the forecasted conditions resulting from drawing on storage during the existing water year with the risks of potential impacts in the following water year or years (USBR 1992). No current set rule curve or formal risk analysis has been established to make that comparison and decision. However, the current process, which has evolved through 6 years of continuous drought, forms a basis for the allocation decision.

An algorithm to provide reservoir storage targets is not recommended. Rather, as suggested in the BO, 1.9 maf should be the minimum carryover in critical operational conditions (NMFS 1993). The methodology used for determination of minimum carryover storage needs was an empirical, exploratory seasonal irrigation release from the Shasta Trinity Unit of the CVP to provide the flow needed for temperature control for winter-run chinook salmon, as described below for Action 5, upper mainstem Sacramento River.

It may be impossible to maintain a minimum carryover storage of 1.9 maf in the driest 10% of water years. If the 90% probability of exceedance runoff forecast projects critical or extremely critical hydrological conditions and the CVP operations forecast projects carryover storage levels in Shasta Reservoir below 1.9 maf at the end of the water year, USBR must reinitiate consultation with NMFS prior to the first water allocations announcement.

The river flow should be actively regulated to meet the ecological requirements of all the anadromous fish that coexist in the Sacramento River, especially species that have suffered the greatest declines. In addition, there is a goal of managing the river system at an ecosystem level, which includes all organisms that interact in those environments located throughout the Central Valley that are influenced by the Sacramento River and its reservoir system.

Minimum flow requirements should allow salmon and steelhead to successfully interact with the overall river environment. Justifications for the recommended minimum flows are described below.

Releases of 5,500 cfs would provide a stable river environment throughout the wet season when restricted to water years having high runoff and storage conditions. As poorer runoff and storage conditions occur, flows are reduced toward a minimum of 3,250 cfs (Table 3-Xa-3) to increase conservation storage for future temperature control.

Compared to lower flows, 5,500 cfs provides good spawning conditions in the reach directly below Keswick Dam, reduces the risk of redd superimposition, and increases the length of river with suitable spawning temperature. This flow also generally wets the width of the river channel, providing extensive rearing habitat to the riparian growth bordering the river and optimum cover for juvenile fish and increasing aquatic insect production.

A flow of 5,000 cfs is the lowest release that produces comparatively little change in wetted perimeter with increasing flows, which tends to reduce the risk of stranding juveniles and dewatering redds if flows are temporarily raised and then reduced.

At 5,000 cfs, salmon and steelhead are generally discouraged from placing redds in the thalweg because water velocities are too high. Locating the sensitive embryos in the thalweg can expose them to flood control releases that could scour them out of the redds or crush them in the bedload.

The downstream migrant salmon include fry and larger juveniles. Outmigration cues may include turbidity, flow, and smoltification. During dry low flow years, there is an observed tendency for juveniles to delay downstream movement in the river above Red Bluff (USFWS 1988).

The effects of flow on outmigration is uncertain. Experiments are needed to empirically develop the most effective pattern of springtime flows. One possible practice is to artificially augment and intensify turbid river flows produced by small to moderate natural runoff events that occur between January 15 and May 15. The river would be regulated in a pattern that produced by the storm to yield augmented test flows ranging between 20,000-40,000 cfs as measured at Bend Bridge for a duration of 3-4 days. The total volume of water allocated for these flow experiments would vary between 60-120 thousand acre-feet (taf) depending on water supply. The natural flow recession curve should be mimicked to avoid stranding; however, if it is prolonged, the river flow should be ramped down as specified in Water Rights Order 90-5 (SWRCB 1990).

Flood control operations are another feature of river regulation that may be altered to meet ecological requirements of the river if they do not interfere with the protection of life or property. To the extent possible, flood control operations should attempt to produce this range of flows to facilitate transportation of stockpiled gravel for spawning gravel replenishment. For example, operational flexibility may allow higher releases for shorter time periods to produce flows in the target range. These stockpiles should be replaced so they can wash into the river during high flows.

The loss of late fall-run chinook redds during certain types of flood control operations may be minimized by shortening flood release periods. When flood control releases extend for weeks beyond a storm period, late fall-run chinook begin to spawn on river flood terraces above the normal river channel where their redds become stranded when flood control operations cease. Flood control operations may, in some cases, be able to use a higher release for a shorter period of time that tracks closer to natural storm events, if it is the operational equivalent to lower releases for a longer period. However, this recommended approach recognizes the potential for increased orchard seepage throughout the lower Sacramento River (drowning of tree roots), which is normally controlled with lower releases for longer time periods.

Predicted benefits: The proposed plan provides the most productive and stable environment that can be attained under the reservoir storage, runoff, and project operation conditions during the water year.

Action 2: Develop a flow regime that imitates natural flow changes and avoids dewatering redds or isolating or stranding juveniles on monthly and daily rates of change.

Objective: Avoid flow fluctuations to avert dewatering redds or stranding or isolating adults and juveniles.

Location: Keswick Dam (river mile [RM] 307) to Princeton (RM 164).

Narrative description: Reducing the flows rapidly or during months when a large portion of any race is incubating can result in significant fish losses due to stranding and isolation. Small juvenile fish have limited ability to follow receding waters back to the river and the early life stages are completely immobile. The types of channel morphology that produce the largest losses are large flat terraces, shallow side channels, and shallow nearshore areas, all preferred rearing habitat for fry. Repeated flow fluctuations in these shallow habitats can cause significant cumulative mortality.

Water project operations require two basic types of flow reductions throughout the year: 1) short-term adjustments to accommodate changes in water demands and 2) seasonal adjustments that reduce the flows at the end of the irrigation season to begin storing wet season runoff (USBR 1992). There is a special problem associated with operation of the ACID's dam when flow reductions are made at Keswick Dam to accommodate adjustments of the flashboards (see action item for the ACID). To control damages to the fishery, different operational measures must be taken for the different types of flow reductions.

The short-term flow adjustments are limited to 15% in a 12-hour period (2.5% per hour) under the water rights for Shasta Dam (Water Rights Order 90-5) and the BP (NMFS 1993). In the years following the 1977 drought, low fluctuating flows between 3,000 and 6,000 cfs became a common occurrence during the wet season for the first time in the history of the project. Monitoring of these flow fluctuations revealed serious reductions in wetted perimeter of the spawning and shallow nearshore areas requiring slower ramping rates. The recommended ramping rates are 200 cfs per night when river flows are between 6,000 and 4,000 cfs and not more than 100 cfs per night at flows below 4,000 cfs where the largest rate of wetted perimeter reduction occurs (DFG 1992 and stipulations of NMFS BO). Salmon fry have been shown to be less susceptible to loss if the waters are receding during the night (Olsen and Metzgar, *Draft*) when there is reduced predator efficiency.

The seasonal flow adjustments are generally characterized by a flow reduction in fall at the end of the irrigation season when the weather cools and also during the time when temperature control releases are no longer needed. The best management practice to avoid significant reductions in the wetted perimeter of the spawning area during fall and winter is to maintain a flow above 5,000 cfs without any fluctuations (other than flood control). When limited reservoir water supply requires lower flows (Table 3-Xa-3 flow section) the best management practice is to establish as early as possible a flow that is the minimum that can be maintained throughout the incubation period without any fluctuation. This is similar to the Agreement concerning the Operation of the Oroville Division of the SWP (1963). Because the recommended flow schedule for the wet season is based on critically dry runoff, it ensures that the selected flow can be maintained throughout the incubation period in 90% of the water years.

Scheduling seasonal flow reductions to occur in the first week of October ensures that approximately 90% of the fall-run spawning activity occurs at a stable flow. Spring-run salmon are the only race consistently incubated at flows much less than they are spawned at because they all spawn during high irrigation releases and incubate at lower post-irrigation season flows, making their redds susceptible to dewatering at flows less than 5,000 cfs. After the irrigation season resumes in spring, the flows steadily increase to levels three to four times that during the normal wet season releases, eliminating risks to early life stages of late- fall-run, winter-run, and steelhead present at that time.

<u>Predicted benefits</u>: By integrating measures into the water project operation, losses due to stranding and isolation can be avoided for all of the races of salmon and steelhead except for spring-run chinook. Avoiding flow reductions during incubation prevents reductions in the interchange of surface flow to the intergravel environment of the redd, yielding larger healthier fry from the spawning effort (Reiser and White 1990). Stabilizing flows in the nearshore areas and side channels maintains the best rearing habitat available in the river.

Action 3: Complete an integrated instream flow incremental methodology study (IFIM) to refine a river regulation program that actively balances fishery habitat with the flow regime, including needs for adequate

temperature, flushing flows, outmigration, channel maintenance, attraction flows, and maintenance of a riparian corridor.

Objective: Regulate CVP releases to provide adequate spawning and rearing habitat for salmon and steelhead and to minimize flow fluctuations to avoid dewatering redds and stranding or isolating adult and juvenile fish.

Location: Upper Sacramento River from Keswick Dam to Hamilton City.

Narrative description: Between 1985 and 1990, DWR and DFG carried out a cooperative study (Phase I report) to collect the hydrologic and physical data for an IFIM study of the upper Sacramento River between Keswick Dam and Hamilton City (DWR 1993). This study, together with other evaluations, represented the first phase of a process that should ultimately lead to a multiagency recommendation for modified flow releases from CVP projects to the upper Sacramento River.

The primary objective of the Phase I report was to present an estimate of the amount of habitat for fall-run chinook salmon available at various streamflows.

The fish habitat versus streamflow relationships developed in the Phase I report provide only part of the information needed to make flow decisions. Further work should integrate the following additional topics with the habitat model in order to make appropriate flow decisions: (1) habitat models for late fall-run, winter-run, and spring-run chinook salmon; (2) timing of chinook salmon life stages; (3) spawning and rearing locations; (4) water temperature; (5) tributary inflow; (6) water quality; (7) agricultural diversions; (8) redd dewatering; (9) adult and juvenile stranding; (10) changes in substrate due to recent gravel restoration work; (11) potential changes in cover due to riparian vegetation restoration plans; and (12) outmigration. Flow needs for other, sometimes competing purposes, such as for other wildlife species, water supply, power generation, and maintenance of Delta water quality, should also be considered in this process.

Predicted benefits: Defining and implementing the "optimum flow" for anadromous fish in the upper Sacramento River would be a major step in maximizing the river's capacity for natural fish production.

Action 4: Manage flow to restore riparian vegetation.

Objective: Consider all features of how flow influences ecosystem.

Location: Red Bluff at RM 242 to Chico Landing at RM 204.

Narrative description: With control of the Sacramento River, flow patterns no longer resemble the hydrology that helped to establish and maintain riparian forests. Because our knowledge of the dynamics of Sacramento River riparian forests is limited, we suggest the following actions:

- # Experimental springtime pulse flows to assist juvenile salmonid outmigration should also attempt to mimic historical patterns of flooding followed by decreasing spring flows; they also establish and maintain riparian vegetation. The present patterns increase rather than decrease flows in spring, but the succession of riparian plant communities is better facilitated by decreasing flows. Flushing flows are needed to manage sedimentation and are therefore beneficial to both fish and riparian communities.

- # A hydrologic model should be developed for a meander belt from Red Bluff to Chico Landing.

Discussion: Many factors have resulted in considerable reduction in the amount of riparian habitat along the Sacramento River. Agricultural conversion is the principal reason for the decline. Completion of Shasta Dam as part of the CVP fostered further conversions of habitat to agriculture as decreasing flood risks allowed the planting of orchards and row crops in the historical floodplain. Bank protection also fostered conversion of forests by reducing bank erosion and meandering. The CVP altered the river's natural flow regime and sediment transport characteristics, changing patterns of forest regeneration. Operation of flood control projects, primarily south of Chico, with their associated systems of weirs, levees, bypasses, and bank protection, precludes the reestablishment of a dynamic riparian ecosystem. Other current and historical factors contributing to the degradation of the riparian system include timber and fuel harvesting and urban and residential development.

For most of the length of the river below Colusa, many of these factors currently preclude the reestablishment of an active meander zone. The Sacramento River Flood Control Project directs floodflows away from the leveed main channel, leaving only small remnants of riparian habitat south of Colusa. Although the river is not meandering in these reaches, valuable habitat remains, providing benefits to salmon and other wildlife species and opportunities for improvement.

Predicted benefits: The reestablishment of a healthy riparian system along the Sacramento River would have several positive impacts on salmonid populations. These include: 1) maintaining channel configurations suitable for creating spawning riffles; 2) supplying gravel from eroding banks for the creation of spawning riffles; 3) supplying woody debris that provides habitat for juvenile fish and a source of organic material for aquatic invertebrates; 4) supplying a renewable source of shaded riverine aquatic habitat; 5) supplying terrestrial invertebrate food for juvenile fish; and 6) moderating the temperature regime of the river, particularly the near shore and backwater areas.

Action 5: Maintain water temperatures at or below 56^{o} F from Bend Bridge to Keswick Dam except in extreme low water years.

Objective: Develop a water management plan that will ensure USBR=s ability to provide cold water during critical months and budget cold water reserves in reservoirs to maximize survival during critical months.

Location: Keswick Dam at RM 302 to RBDD at RM 242.

Narrative description: Water temperatures in the Sacramento River are a major limiting factor to the maintenance of winter-run chinook salmon, spring-run chinook salmon, and, to a lesser extent, fall-run chinook salmon (NMFS 1993, USBR 1992, USFWS 1987, DFG 1992). By providing temperature control at Shasta Dam, it is possible to compensate for the spawning grounds now blocked by the dam that historically maintained winter-run and spring-run chinook salmon during summer. In addition, temperature control actions maintain fall-run chinook salmon by overcoming the delayed cooling of the river that the reservoirs cause in fall. The historical water project operations and temperature modeling demonstrate that the Shasta-Trinity Unit of the CVP has the capability of controlling water temperatures in the 60 miles of river between Keswick Dam and RBDD under typical runoff and storage conditions (USBR 1992).

Over the last 20 years, various scientific studies and regulatory actions have established that 56^{o}F is needed for successful incubation (Seymour 1956 as cited by DWR 1988, USFWS 1987, Water Rights Order 90-5, NMFS 1993). Controlling temperatures to a "daily" average of 56^{o}F on the longest length of spawning grounds that the storage and runoff conditions will allow requires the following actions:

- Attain optimal management of the cold water supply available in the reservoir system by installing and properly operating the Shasta Temperature Control Device and the temperature control curtains in Lewiston and Whiskeytown Reservoirs pursuant to Water Rights Order 90-5). Prior to installation of the device, operate the low level outlets that bypass the powerhouse bypass.

- For each race of salmon, establish a temperature compliance point that will attain 56^{o}F throughout the incubation period of each race as determined by available storage as shown in Table 3-Xa-4 pursuant to the BO (NMFS 1993).

- Conserve sufficient Shasta Reservoir storage by the end of the water year so that in the next water year at least 90% of the recorded runoff conditions will refill the reservoir to the point the cold water supply will yield a temperature of 56^{o}F in the river reach where 90% of winter-run incubation activity occurs (above Jelly's Ferry). Specifically, Shasta Reservoir should be operated to attain a minimum October 1 carryover storage of 1.9 maf under all runoff conditions except the driest 10% of the water years.

Table 3-Xa-4. Water temperature control points for winter chinook salmon in the upper Sacramento River as a function of operational environment (carryover + Shasta inflow from October 1-February 1 and on April 1) related to Bend Bridge (RM 258) and Jelly's Ferry (RM 267).

Operational Environment (maf) February 1	Operational environment (maf) April 1	Control point	Inclusive dates	Temperature (°F)
≥3.03	4.33≥	Bend Bridge	April 15 - September 30	≤56
≥3.03	4.33≥	Bend Bridge	October 1 - October 31	60
2.54≥ ≤3.03	3.17≥ ≤4.33	Bend Bridge	April 15 - August 31	56
2.54≥ ≤3.03	3.17≥ ≤4.33	Jelly's Ferry	September 1 - September 30	56
2.54≥ ≤3.03	3.17≥ ≤4.33	Jelly's Ferry	October 1 - October 31	60
2.38≥ ≤2.54	2.82≥ ≤3.17	Jelly's Ferry	April 15 - September 30	56
2.38≥ ≤2.54	2.82≥ ≤3.17	Jelly's Ferry	October 1 - October 31	60
<2.38	<2.82	Meet Delta water quality standard		

Water allocations in spring should be based on a 90% exceedance forecast to reduce the risk of over allocating water supplies and missing the carryover storage target (NMFS 1993).

Attain optimal operations and planning of the annual cold water budget by using a temperature model on a daily time step model, monitoring temperature (Clean Water Act, Water Rights Order 90-5), and scheduling the Trinity River diversion to the Sacramento River to provide a temperature benefit.

All existing and future discharges of municipal and industrial waste that could add heat to the river, as well as water projects that could reduce the flow of the river and increase its heat gain, must attain temperature objectives established in accordance with the Clean Water Act. Specifically the Basin Plan for the Central Valley Regional Water Quality Control Board provides that "temperature shall not be elevated above 56° F in the reach between Keswick Dam to Hamilton City and 68°F in the reach between Hamilton City and the I Street Bridge" (Sacramento). The reach below Hamilton City is a migration corridor and rearing area for salmon.

Discussion: Fisheries experts have identified water temperature in the upper Sacramento River as a critical factor in the decline of winter-run chinook salmon. During most years, winter-run chinook salmon are unable to spawn successfully below RBDD because of lethal temperatures (Hallock and Fisher 1985). In recent years, drought conditions have resulted in lethal temperatures above the dam as well.

Coombs and Burrows (1957) found that water temperatures between 43°F and 57.5°F are optimal for chinook egg development although a literature review conducted by DWR indicated that the optimum range of temperature for development through the emerged fry stage may be bound by 56°F on the upper end (Seymour 1956 as cited by DWR 1988). Water temperature of 62°F is believed to produce 100% mortality.

Water temperature in the upper Sacramento River varies with location and distance downstream of Keswick Dam, depending on hydrologic conditions and operation of the Shasta and Trinity Divisions of the CVP. Water temperatures between Keswick Dam and RBDD are influenced by meteorological conditions, tributary inflows, volume of water released from Keswick Dam, temperature distribution in the reservoir, the ratio of Spring Creek Power Plant release to Shasta Dam release, and depth of release from both Shasta and Trinity dams. Water released from Keswick Dam generally warms as it travels downstream during summer and early fall months.

The reservoir system provides large reserves of cold water that can be tapped in a planned fashion. During most years, cold lake water and large irrigation flows provide sufficient thermal mass and rapid travel time to prevent excessive heat gain in the first 40-60 miles below Keswick Dam. Thus, the project can maintain a temperature regime suitable for the spawning and incubation of salmon over an area that is roughly equivalent to that found in the mountainous reaches of the river system now blocked by the dam.

During the past 5 years, USBR, in coordination with the multiagency Sacramento River Temperature Task Group, has developed temperature operational plans for the Shasta and Trinity Divisions of the CVP. From 1987 to 1994 USBR has implemented plans to provide for temperature protection for winter-run chinook salmon while still meeting other project purposes (USBR 1992; pages 33-36). The task group meets annually to discuss operational alternatives, new objectives, biological information, and status of water temperatures. Once the task group has recommended an operation plan for temperature control, USBR then submits a report on the operation plan to the SWRCB generally on or before June 1 each year. Operational plans have included releases of water from upper and lower outlets at Shasta Dam, releases from the lower outlet on Trinity Dam, and manipulation of the timing of Trinity River diversions and Whiskeytown Reservoir flood control drawdown. The lower outlets on Shasta and Trinity dams have the ability to gain access to deep, cold water in the reservoirs. However, water released through the lower outlets is unavailable for hydropower generation, and power generation is not possible from upper level outlet releases on Shasta Dam. Warmwater releases from the upper level outlets have been made to conserve cold water in Shasta Lake for temperature control operations during late summer months and to induce winter-run chinook salmon to spawn as far upstream as possible.

Action 6: Raise RBDD gates during primary chinook adult and juvenile migration periods.

Objective: Provide unimpeded adult and juvenile passage past RBDD and decrease juvenile mortality associated with predation.

Location: RBDD, RM 243, Red Bluff, California.

Narrative description: This action requires raising the dam gates at minimum from September 15 to May 15 each year to benefit all chinook salmon runs and steelhead by providing unimpeded passage (Table 3-Xa-5). Raising the dam gates at RBDD is a proven, attainable technology that allows unimpeded fish passage in the Sacramento River at Red Bluff. The river returns to a natural configuration that avoids mortality of adult and juvenile salmon, provided protective measures are incorporated into the alternate water pumping system(s). The seasonal removal of the dam at Red Bluff allows fall-run and spring-run chinook salmon access to an additional 3 miles of habitat.

Table 3-Xa-5. Percent of adult and juvenile chinook salmon runs and steelhead passing RBDD from September 15 to May 15 (DFG 1991).

Life stage	Chinook salmon run				Steelhead
	Fall[a]	Late fall	Winter	Spring	
Adults	75%	100%	89%	19%	84%
Juveniles	89-64%[b]	74%	74%	100%	--[c]

[a] Juveniles includes only those emerging above the dam.

[b] Values represent wet and dry years.

[c] No estimate of juvenile steelhead passage has been made because of difficulty in differentiating from resident trout.

Discussion: Fish ladders at RBDD are inefficient at passing migrating adult salmon (Hallock et al. 1982; Vogel and Smith 1984; USFWS 1987, 1989, 1990; Vogel et al. 1988). This results in significant delays and blockage of upstream migrating chinook salmon and steelhead, causing increased spawning downstream in waters previously too warm for successful egg incubation. Delay at the dam can produce elevated stress conditions in the adult salmon, especially when water temperatures along their migration passageways approach the upper limits of their temperature tolerance. Radio telemetry studies to evaluate passage of adult salmon reported up to 40% of radio-tagged winter chinook and 33% of late fall-run chinook salmon were blocked by the dam (Hallock et al. 1982, Vogel et al. 1988).

Since 1987, USBR has raised the RBDD gates for a variable and significant portion (80%) of the nonirrigation season, allowing free passage of adults during that period. Upstream progress of late fall-run and winter chinook salmon as they approach and pass RBDD was monitored yearly from 1986 through 1991 by USFWS. Analysis of the data have shown that raising the RBDD gates during the nonirrigation season dramatically improves upstream fish passage (Northern Central Valley Fishery Resource Office, USFWS, Red Bluff, California, unpublished data).

Problems in passage of juvenile salmonids has also been reported (Vogel and Smith 1984; Hallock 1989; USFWS 1987, 1989, 1990; Vogel et al. 1988). A cause of mortality in juvenile chinook salmon is the dysfunctional predator-prey relation created by RBDD, largely from the Sacramento squawfish (*Ptychocheilus grandis*) (Vondracek and Moyle 1983, Vogel et al. 1988). The piscivorous nature of Sacramento squawfish, as well as its preference for salmonids, is well documented (Vondracek and Moyle 1982, 1983); however, it has not been systematically studied immediately below RBDD (Garcia 1989). The Sacramento squawfish is a native species that co-evolved in the river with chinook salmon and steelhead. In the natural free-flowing river setting, the predator-prey relationship between the Sacramento squawfish and the native salmonids is intact and has no significant effect on salmonid populations (Brown and Moyle 1981). Artificial structures, however, can provide increased feeding and ambush settings, creating an unnatural advantage for predators. Other piscivors present below RBDD include striped bass (*Morone saxatilis*), rainbow trout and steelhead (*Oncorhynchus mykiss*), and American shad (*Alosa sapidissima*), as well as numerous other fish and bird species.

The juvenile passage problem at RBDD is twofold: upstream movement of piscivorous fishes is obstructed by the dam, causing fish to accumulate downstream, and juvenile salmon are disoriented from passing under the dam gates or through the bypass system, making them vulnerable to predation or injury. Vogel et al. (1988) found that mortality attributable to physical injury from passage under the dam gates was negligible (at or near 0) and mortality due to passage through the Tehama-Colusa headworks fish bypass system was measurable (1.6-4.1%). To estimate total mortality during dam passage, Vogel simultaneously released known numbers of juvenile hatchery salmon immediately above and below RBDD. Fish released above RBDD were recaptured 16% to 55% less than those released below the dam in this experiment. Some releases of hatchery fish above RBDD have contributed 51% less to the commercial and sport harvest than releases below the dam (Northern Central Valley Fishery Resource Office, USFWS, unpublished data, 1991). Vondracek et al. (1991) estimated an annual loss of 1-6% to juvenile downstream migrants during passage at RBDD due to Sacramento squawfish predation; however, peak estimates of mortality in April and May were as high as 80%.

The installation of the new fish screening system may reduce entrainment and predation of those fish that are diverted into the Tehama-Colusa Canal forebay although the effectiveness of this new fish bypass system has only been partially evaluated (Big Eagle et al. 1993). More symptomatic of the extent of the predation are surface and *in situ* observations by USFWS's scuba divers of concentrations of Sacramento squawfish feeding immediately below the dam. This suggests a significant predation problem on juvenile migrants passing under the dam gates. New information suggests that more significant mortality may be associated with juvenile passage under the dam gates. Rotary-screw traps operated below RBDD during August and September 1994 experienced high levels of juvenile salmonid mortality (resulting from passage under the dam gates) in their catch. After the RBDD gates were raised in September, mortality became negligible (USFWS 1994). These preliminary findings are under further investigation but do suggest that juvenile mortality during passage may have other causes, or that predators are benefiting from prey already dead or injured. Predation also occurs in the Red Bluff Reservoir where there are populations of black bass and other predators, not typical of a riverine habitat.

It was recommended by Vogel et al. (1988) that measures to control predation by Sacramento squawfish should be developed at RBDD. Some of the suggested measures were to trap and remove Sacramento squawfish from the fish ladders, use physical methods to disperse Sacramento squawfish below the dam, develop a commercial or sport fishery for Sacramento squawfish, or reduce Sacramento squawfish holding areas below RBDD. The goal of trapping and developing commercial or sport fisheries for Sacramento squawfish would be to remove a portion of the accumulated squawfish below RBDD, which theoretically would increase juvenile salmon survival, thereby increasing the number of adult salmon returning to the river. Trapping Sacramento squawfish in the fish ladders would have little impact on numbers immediately below the dam as it removes Sacramento squawfish that have already left that area. New fishways, designed to improve salmon passage, might also improve Sacramento squawfish passage; however, this is speculative as the biological criteria for Sacramento squawfish passage have not been developed.

Commercial fishing was evaluated in 1989 (Leveen 1990). Leveen used traps and hook and line methods to capture Sacramento squawfish. He caught 620 Sacramento squawfish immediately below RBDD in an undetermined amount of time using hook and line methods, he also caught 20 salmon. In 660 trap-days, 3,423 fish (mostly hardheads) were captured, including Sacramento suckers (31), tule perch (16), and carp (2). Contamination of Sacramento squawfish flesh by high levels of dioxin from upstream pulp mills terminated the project. The levels are now reduced to the point they may not interfere with a commercial fishery, but the California Department of Health Services has not determined if the fishery is suitable for commercialization.

It is unlikely a sport fishery could remove enough Sacramento squawfish to make a measurable impact on juvenile salmon survival. Sacramento squawfish are more abundant at RBDD in spring (Vogel et al. 1988) but spring removal may only temporarily decrease their abundance. This is because Sacramento squawfish are highly migratory and would repopulate the area below RBDD. Hence Sacramento squawfish removal would be a continuous process. Additionally, a spring fishery would likely incur an unacceptable incidental catch of threatened winter-run salmon. Sacramento squawfish are most abundant in the tailrace area immediately below the dam gates where disoriented prey are available. Boats are unsafe in the swift tailrace water immediately below the dam precluding entry by sport anglers.

The best long-term solution for improving or eliminating the dysfunctional predator-prey relationship would be the removal of feeding habitat in Red Bluff Reservoir and below the dam by seasonally or permanently raising the dam gates during the nonirrigation season. This allows free passage of juvenile salmon and Sacramento squawfish in near natural river conditions where the native predator-prey relationship has sustained itself for thousands of years. This is a known technology with easily understood benefits.

Predicted benefits: Upper Sacramento River salmon populations declined an estimated 114,000 fish (57,000 fall-run, 17,000 late fall-run, and 40,000 winter-run chinook) between 1969 and 1982 because of passage problems at RBDD (Hallock 1987). These losses have reduced the sport and commercial fisheries by about 228,000 salmon a year. Raising the dam gates for 8 months per year benefits all adult and juvenile chinook salmon runs and steelhead because negligible mortality is incurred at the dam. Supplemental pumping that occurs during the gates-raised period can have an impact on salmon located along the bank unless managed properly. Allowing spring-run and fall-run salmon to spawn by not inundating the spawning bed should remove a mitigation obligation for the Red Bluff project specific to the Tehama-Colusa Fish Facility.

Action 7: Complete the process to find final solutions to passage problems at RBDD and improve passage conditions beyond opening the dam gates longer than 8 months.

Objective: Correct problems at RBDD.

Location: RBDD, RM 243, Red Bluff, California.

Narrative description: This action calls for finding solutions to passage problems that will benefit the fishery resource beyond opening the gates 8 months per year. During the 8 months of the year the gates are open, there are no fishery problems associated with the RBDD. The following is a recommendation summary, based on current literature findings, for actions needed to monitor and evaluate existing fish protection facilities and to provide additional data required to make defensible decisions regarding solutions to passage problems at RBDD:

- USBR should continue to monitor entrainment past the rotary drum screens to evaluate long-term screening effectiveness.

- USBR should continue to inspect the screens *in situ* (SCUBA) to evaluate the durability of the seals and accumulation of silt in front of screens.

- USBR should measure screening efficiency by exposing a known number of fish to the screens and then measuring the number bypassed to the river or entrained in the canal.

USBR should make inspections of the screens during high flows with the release of a known number of juvenile salmonids into the forebay to determine the likelihood of impingement.

USBR should evaluate predation on juvenile salmonids in the forebay and at the bypass of the rotary drum screens.

USBR should evaluate trash deflectors in front of Tehama-Colusa Canal headworks to determine fish deflector qualities.

USBR needs to develop the ability to make real-time observations of screen seating during screen replacement.

USBR should evaluate the effectiveness of screens on the centrifugal pumps located in the right bank fishway.

USBR should evaluate piscine predation in Red Bluff Reservoir.

USBR should continue to turn off RBDD high-intensity lights to reduce predation.

USBR should evaluate bird predation at RBDD.

USBR should develop, with the cooperation of USFWS, NMFS, and DFG, standard operating procedures for monitoring, maintenance, and operation of fish protection facilities.

USBR should continue to use gate 6 fish ladder as an interim measure until final resolution of RBDD's fish passage problem.

USBR should evaluate entrance modification to the west fish ladder entrance to optimize hydraulics.

USBR should develop delay versus percent fish ladder discharge models by run. Include any new data in model development.

USBR should explore feasibility of an experiment to increase supplemental flows in the fish ladders and, if feasible, conduct this experiment.

USBR should evaluate mortality of juvenile salmonids through the fishway civil works.

USBR and the fisheries trustees should give proper consideration to the concerns of the community and their desire to keep Red Bluff Reservoir intact as long as a viable fishery can be assured.

- # USBR should develop delay versus percent fish ladder discharge models for upstream migrating steelhead.

- # USBR and the fisheries trustees should give proper consideration to the temporary remedy of the gates-out modification from September 1 to May 30, along with modification to fish ladders to improve adult passage.

Discussion: Fish passage studies have been conducted at RBDD since the early 1980s (Hallock 1981; Hallock et al. 1982; Vondracek and Moyle 1982, 1983; Vogel and Smith 1984, 1985; Vogel et al. 1988; USFWS 1987, 1989, 1990). These studies identified numerous problems associated with fish passage at RBDD. Raising the dam gates is a completely effective remedy that solves all fishery problems relating to the dam for all species of anadromous fish at all life stages. The fish entrainment problem associated with diverting water at RBDD through the ineffective louver and bypass system was essentially solved by installing a state-of-the-art rotary drum fish screen in 1990. This screen system has, so far, proven to reduce canal entrainment and mortality of downstream migrating juveniles to near zero when water is being diverted and the system is properly operated and maintained (Johnson 1991, 1993; Big Eagle et al. 1993; Johnson and Croci 1994). Though remarkable progress has been made, additional studies are required to satisfy decision makers as to the permanent approach for alleviating passage problems. With anadromous salmonid runs in serious decline, the studies must be started as quickly as possible to minimize their population recovery times and lost use of these valuable resources.

The Red Bluff Fish Passage Program was undertaken to solve identified causes of declines in anadromous fish populations attributed to RBDD. This was a 5-year study initiated in October 1983 to develop methods to improve upstream and downstream anadromous fish passage at RBDD. The program is a coordinated effort between USBR, USFWS, NMFS, and Department. USBR is the lead agency for the program and the other agencies are participants. The purpose was to identify specific problems and implement corrective measures. A final report was produced for downstream migrant and adult upstream passage (Vogel et al. 1988). The results of this report form the major basis for the recommendations under this action.

Predicted benefits: Upper Sacramento River salmon populations declined an estimated 114,000 fish (57,000 fall-run, 17,000 late fall-run, and 40,000 winter-run chinook) between 1969 and 1982 because of passage problems at RBDD (Hallock 1987). These losses have reduced the sport and commercial fisheries by about 228,000 salmon a year. During the 8 months of the year the gates are open, there are no fishery problems associated with the RBDD. Raising the dam gates is a completely effective remedy that solves all fishery problems relating to the dam for all species of anadromous fish and all life stages. However, current gates-up operation is a transient fix and final resolution of passage problems at RBDD that will fulfill water needs for domestic, agriculture, and wildlife are pending. The process must be expedited and brought smoothly to closure so that benefits can be realized by still-viable fish populations. As new questions arise, USBR and fisheries trustees must collaborate with the interested publics to answer their questions and concerns. Acting in good faith to share information and concerns will facilitate understanding and hasten the realization of restoration goals.

Action 8: Implement structural and operational modifications to eliminate stranding, toxic discharges, and passage problems for chinook salmon and steelhead and improve screens.

Objective: Correct problems at the ACID's diversion dam.
Location: Keswick Dam, RM 302, and the ACID's diversion dam, RM 299.

Narrative description: The ACID's diversion dam is a flashboard dam located on the upper Sacramento River near Redding, at RM 298.5. This was the first dam on the Sacramento River, completed in 1917. Approximately 175,000 af of water can be diverted annually to the ACID's main canal.

The dam is installed only during the irrigation season. Typical operations involve the installation of flashboards in the dam in early April and their removal in late October or early November. Installation, removal, and mid-season adjustment of the flashboards are coordinated with flow reductions in the Sacramento River provided by USBR at Keswick Dam.

High flows make it physically difficult to install and remove the flashboards in the dam using hand-powered methods that date to 1917. ACID has historically indicated that 5,000 cfs is the maximum flow at which personnel can safely remove or install the dam flashboards. On several occasion, however, the flashboards have been removed or installed at flows above 5,000 cfs.

Past flow reductions to accommodate mid-season adjustments can cut the river flow in half. Reductions have occurred in a matter of hours, dewatering redds and producing large losses of juvenile salmonids through stranding and predation in isolated pools. The flow reductions for the ACID have not been consistent with the water right permit conditions for operation of Shasta Dam.

Operational modifications have successfully avoided the need to adjust the dam last year at flows between 4,000 and 14,000 cfs. Adjustment of the dam for flows less than 4,000 cfs can be accomplished without changing the Keswick Dam release.

The canal system needs several standard operating procedures to prevent documented problems. These include limiting waste gate flows to levels that do not attract salmon and steelhead from the river and containing canal waters when toxic herbicides are present to prevent fish kills. The canal intakes at Bonnyview Pumps and the main dam require maintenance and routine inspection.

Further empirical work is needed before any operational remedy is shown to be effective under all types of water years and water delivery demands. Once the ACID has determined the level of remediation it can provide through operational changes, structural measures can be designed to achieve complete remediation.

The following actions are proposed or have been enacted to reduce impacts of the ACID's dam on the aquatic environment.

- Modify the dam so it is unnecessary to reduce Keswick Reservoir releases to accommodate flashboard adjustment. Once modifications are shown to be successful, an agreement can be reached clarifying the water rights settlement contract between USBR and the ACID.

- If changes in structure and operations produce only a transitory remedy for river flows less than 14,000 cfs, other more costly alternatives need to be evaluated, including installing large automatic drum gates on the dam, installing a large Archimedes screw pump station, or supplementing canal flows with water pumped from other sources.

- Modify catwalks at the ACID's dam to include a new and safer work platform on the dam.

- Modernize the removal method for the topmost flashboard.

- Investigate solutions to excessive releases from the canal to waste gates that attract adults into the wasteways where they are stranded when the gates are shut off.

- Modify fish screen at the headworks of the district's canal to improve structural strength.

- Reduce or eliminate toxic discharges to the river and tributaries after application of herbicides.

- Reduce or eliminate stranding of adult chinook and steelhead attributable to cross connections of the canal with tributaries.

- Improve fish ladders at the dam to allow adult fish passage.

Discussion:

Stranding - A safe catwalk and easier flashboard removal is required to allow flashboard extraction and replacement without changing Keswick Dam releases. The current catwalk is a safety hazard because of its slippery surface; footing could be improved by covering the surface with nonskid material. Flashboards are currently removed by stabbing them with a pike-pole and prying them loose, an inefficient procedure made more so by high flows. The uppermost flashboards could be modified to make their removal easier at high flows by pegs attached to the upstream face. Additionally, if the ACID's operations can be accommodated with fewer flashboards in place, creating a lower head, the dam would not be as sensitive to higher river flows.

Cross connection of the canal with tributary streams during the nonirrigation season allows adult fish to enter the canal when it carries storm water. Physical improvements will be necessary to eliminate this cause of stranding.

Toxic discharges - Improper application of herbicides to the canal waters results in toxic chemical concentrations in river tributaries. Procedures have been initiated to contain toxic chemicals in the canal.

Fish screens - The canal screen has limited structural strength that need reinforcement. When it becomes clogged with aquatic vegetation or when there are rapid changes in flows, there is a danger of failure. To avoid catastrophic failure of the screen, trip panels are present that break away before the structure fails, leaving the diversion temporarily unscreened.

Adult passage - The ACID's dam was a complete barrier to the upstream migration of salmon until a ladder was installed in 1927. Since completion of Shasta and Keswick dams in 1942 cut off all but 3.5 miles of the Sacramento River upriver of the ACID's dam, the need for fish passage has been to provide access to spawning habitat between the dams and allow passage to a fish trap at Keswick Dam that serves as a collection facility for Coleman National Fish Hatchery.

There are no passage problems for most adult fall- and late fall-run chinook salmon and most steelhead trout because dam flashboards are removed during the nonirrigation season when these fish are migrating. There are no known juvenile salmonid passage problems associated with the dam. The seasonal presence of the small dam has not created any congregations of predators or good predator ambush habitat similar to larger dams.

During the 6 months of the year the dam is present, it is a partial barrier to adult anadromous fish, including winter-run chinook. There are small fish ladders located on each bank of the river that are ineffective because they carry only 1-4% of river flow. Construction of modern effective ladders is possible.

At this time, progress on the needed fishery remedies is proceeding on a cooperative basis. The ACID is developing the necessary information to better operate and improve the facilities necessary to exercise its water right while minimizing impacts on the aquatic environment, consistent with settlement agreements resulting from previous litigation.

Predicted benefits: This project will avoid the unnecessary destruction of valuable salmon and steelhead in the Sacramento River. This includes avoiding loss of winter-run chinook salmon, a species that is listed as endangered by both the federal and state Endangered Species Acts.

Action 9: Construct escape channel from stilling basin to the Sacramento River at Keswick Dam.

Objective: Avoid entrapment of adults at Keswick Dam stilling basin.

Location: Keswick Dam, RM 302.

Narrative description: Keswick Dam is located at RM 302 on the Sacramento River approximately 9 miles downstream from Shasta Dam. The dam has no fish ladders and completely blocks further upstream passage of migrating adult salmon and steelhead.

Keswick Dam was designed as a flow control structure for the Sacramento River to stabilize uneven water releases from Shasta Dam. Its construction, with a spillway, fishtrap, and power plant (75,000-kilowatt capacity), began in 1941 and was completed in 1951. It is a concrete gravity structure 157 feet high with a crest length of 1,046 feet creating a 23,800-af reservoir.

Aside from receiving Sacramento River water released from Shasta Dam, the reservoir created by Keswick Dam also receives interbasin flows from the Trinity River. Water from the Trinity River Basin is diverted via the Clear Creek Tunnel through the Judge Francis Carr Powerhouse into Whiskeytown Reservoir. From here, Trinity River water can be diverted into Keswick Reservoir via the Spring Creek power conduit to the Spring Creek Power Plant.

The spillway located on the east side of Keswick Dam is used for flood releases and during power plant outages. During normal power plant operations, there is no flow through the spillway and the stilling basin below the spillway is elevated above the tailwater river channel by the spillway end sill and a rock bench. During normal power plant operation, the tailwater is lower in the river channel than the spillway end sill, isolating the stilling basin from the river channel.

During a spill, the spillway end sill and rock bench become inundated, connecting the stilling basin to the main river channel. In past decades, the spills attracted migratory fish into the stilling basin where they became trapped when the spills ended. Documentation of this phenomenon dates back to 1972. More recent occurrences include December 1990, February 1992, and September 1994. Although fyke weirs in the shared stilling basin wall are intended to allow free passage of stranded fish into the fish ladder, testing conducted in December of 1993 demonstrated that fish were also attracted into the stilling basin through these fyke weirs.

The incidental take statement in the BO (NMFS 1993) addressing the effects of the CVP on winter-run chinook salmon requires USBR to structurally modify the stilling basin at Keswick Dam to allow free passage of adult salmonids back to the Sacramento River. The proposed solution to this problem, agreed to by the NMFS, DFG, USFWS, and USBR, involves excavating a channel from the spillway stilling basin through the spillway end sill and rock bench. This modification eliminates fish entrapment in the stilling basin. The agencies also agreed USBR should develop an interim fish salvage plan to immediately remove trapped fish from the basin following spills until the escape channel is constructed.

Predicted benefits: Adult salmonids would have access back to the main river and would not be lost to the spawning population resulting from poor water quality within the basin or losses associated with handling during rescue attempts.

Action 10: Implement structural and operational modifications to eliminate entrainment at water diversions.

Objective: Increase survival of outmigrating anadromous salmonid stocks by correcting unscreened or inadequately screened water diversions.

Location: Numerous irrigation diversions on the Sacramento River from Redding to its confluence of the Feather River.

Narrative description: Numerous unscreened water diversions from the Sacramento River and Delta adversely affect outmigrating juvenile salmonids, including the endangered winter-run chinook salmon. An estimated 10 million juvenile salmonids are lost to unscreened diversions annually (The Resources Agency 1989). There are more than 300 separate irrigation, industrial, and municipal diversions along the Sacramento River between Redding and its confluence with the Feather River, diverting nearly 1.2 maf of water annually from April through October (The Resources Agency 1989). There are an additional 1,800 smaller diversions in the Sacramento-San Joaquin Delta, diverting approximately 1.6 maf annually (DWR unpublished report 1983).

Diversions cause losses of fish in three ways: 1) direct entrainment of fish into irrigation systems, 2) physical damage of fish through contact with poorly screened diversions or bypass structures (impingement), and 3) increased predation on juvenile salmon due to hydraulic conditions near the diversion. These types of losses can occur at inadequately designed or poorly installed screens as well as unscreened diversions.

The CVPIA authorizes USBR and USFWS to "assist the State of California in efforts to develop and implement measures to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions on the Sacramento and San Joaquin rivers, their tributaries, the Sacramento-San Joaquin Delta, and the Suisun Marsh". The CVPIA Unscreened Diversions Program (UDP) provides this assistance by administering funding and providing technical assistance for fish screen projects. The state's ongoing program and priorities have guided most of the site-selection processes. A UDP technical team composed of representatives from USFWS, USBR, DWR, NMFS, and DFG provides technical advice and ensures that the program meets the goals and intentions of the CVPIA.

Fish screen technologies have been proposed that use sound or electricity to guide fish away from pumps. Although these alternatives have not been fully developed or tested, they have not provided necessary levels of fish guidance. Alternative technology for fish screen projects will be funded under an Experimental

Unscreened Diversion Research Program funded in fiscal year 1995 by USBR's Miscellaneous Project Program Construction Appropriations.

The UDP includes an accelerated program designed to immediately fund screening projects during the development of a long-term fish screen program. The accelerated screening program moved ahead in fiscal year 1994 to spend $600,000 from the restoration fund on three fish screen projects and program administration.

Predicted benefits: These fish screen programs have a high probability of reducing the 10 million juvenile salmon lost annually to unscreened diversions. These programs will probably have similar benefits for other anadromous species.

Action 11: Implement structural and operational modifications to eliminate impingement and entrainment of juvenile salmon at the GCID's water diversions.

Objective: Correct problems at the GCID's water diversions.

Location: GCID diversion, RM 206, Sacramento River, near Hamilton City, California.

Narrative description: This action calls for implementation of the on-going program to modify fish screens and bypass channel to mitigate fully for the fishery impacts associated with operations of the GCID's Hamilton City Pumping Plant. On August 19, 1990, a three-party agreement between the DWR Reclamation Board, GCID, and DFG was signed to fund environmental documentation and supporting preliminary engineering for gradient restoration and fish screen replacement. A contract was signed with HDR Engineering to complete the environmental documentation and engineering analysis, with a preliminary draft of the engineering Feasibility Report completed during 1994. In addition, a draft environmental impact statement (EIS) and environmental impact report (EIR) are currently under review with final completion scheduled for early 1995. Six alternatives, in addition to a no-action alternative, are considered feasible. The recommended environmentally superior alternative, in the draft EIS/EIR, is the construction of a multiple "V" screen near the mouth of the oxbow with a pumped bypass to return fish to the river (Alternative B). The basis for selecting Alternative B was the project purpose of fish protection and the overriding importance of fish protection when considered in combination with other environmental impacts. The report concluded that Alternative B "would most likely offer the greatest protection to endangered winter-run chinook salmon and other fish species that use the Sacramento River near the GCID's Hamilton City Pumping Plant".

The draft EIR/EIS concludes that prior to construction of the preferred alternative, an alternative that may or may not be the "environmentally superior alternative", future lead and responsible agencies must weigh environmental considerations against other factors such as construction costs, socioeconomic costs, legal considerations, technical modifications and feasibility, and political considerations. It also concludes that several areas of controversy exist that would bear on selection of the ultimate preferred alternative. The following are recommended actions needed to resolve those controversies:

- USBR should determine the degree of predation as a cause of mortality in the intake channel and the relative impact of predation on downstream migrants, compared to other sources of mortality, such as impingement, entrainment, and sedimentation.

- DFG should evaluate the importance of strict adherence (versus slight deviations) to existing fish screening velocity criteria as a means of protecting fish.

- USBR should determine the number of juvenile fish actually entering the GCID's intake channel under a range of flow conditions.

- USBR should determine the frequency and severity of predation at slow-flow holding areas near the existing fish screens and in the existing bypass channel.

- USBR should determine whether predation in the GCID's oxbow exceeds natural predation rates in other parts of the Sacramento River.

- USBR should determine whether the Sacramento River has the eventual capability to meander in such a manner as to leave the GCID's oxbow stranded.

- USBR should determine the degree to which sedimentation would occur and extend upstream of any new fish screens built.

- USBR should determine the degree to which sedimentation would occur and extend upstream of a Gradient Restoration Facility (GRF).

- USBR should determine the probability of success that can be expected from bypassing fish through pumps.

- USBR should determine the amount of time that should be devoted to future study before committing to a long-term solution.

The draft EIR/EIS also concludes that prior to construction of the Preferred Alternative "some studies can be conducted that would provide additional, valuable information" including the following:

- USBR should develop two-dimensional mathematical models and physical models of the GRF in combination with new fish screens. The models should be designed to accurately depict existing and post-project instream conditions, including approach and sweeping velocities at the screens, water depths and velocities throughout the entire affected reach of the river, and areas of turbulence. Modeling should be accomplished over a reasonable range of flow conditions expected after construction.

USBR should determine the swimming abilities of all fish species and important live stages occurring in the project area when such information is lacking. It is imperative that the screens and either pumps or GRF be designed to protect the most sensitive of the species in the area.

USBR should correlate post-project water surface elevations with elevations of various habitats in the area. This must be accomplished so that hydrologic impacts on vegetation communities can be more accurately determined.

USBR should determine whether the GRF, if selected, could cause a change in river course resulting in flow to another channel.

USBR should evaluate screw pumps at the RBDD and at GCID, if selected, to determine their feasibility at screened diversions.

Discussion: Fishery impacts at the GCID site were identified in the 1920s by researchers from the then California Division of Fish and Game. Court action required GCID to install fish screens in 1935, which were almost immediately rendered ineffective by undermining from flood events. No subsequent attempts were made to alleviate the problem until DFG built the existing screen structure in 1972 with funding from the Anadromous Fish Conservation Act of 1965.

The screen facility built in 1972 consists of 40 rotary drums, 17 feet in diameter and approximately 8 feet wide. The drums, housed in a 450-foot-long concrete headworks, are located midway down the oxbow, immediately in front of GCID's pumping facility. Within the headworks are 10 fish bypass orifices that converge in a 60-inch pipe that empties into the lower oxbow. The bypass was designed to transport fish around a seasonal earthen dam installed by GCID to decrease pumping lift. The original contract signed by GCID and DFG required that 90 cfs be allowed to go through the bypass to facilitate fish passage.

Studies conducted by DFG during the mid-1970s revealed that the screening structure was not operating effectively and suggested that large losses of juvenile salmon were continuing to occur at the site. Specific deficiencies identified included ineffective bypasses, screen leakage, high screen face velocities, and high potential for predation. Several modifications were made to rectify the situation, including screen seals on the rotary drums and placement of culverts through the seasonal dam. Even with the modifications, however, fish losses were still high.

Beginning in 1970, river gradient changes began to adversely affect flows and water surface elevations at the fish screens. Gradual lowering of the river surface profile occurred from 1971 until 1983 when high waters caused significant changes. During this period, scouring of the main river channel resulted in an average surface elevation that was 3-3.5 feet lower than that existing before 1971. The result was to lower the water surface elevation at the face of the fish screens and increase the through-screen velocity. In addition, gradient profile changes resulted in bypass flows ceasing and often flowing in reverse direction. The inability to provide positive bypass flows of 90 cfs placed GCID in direct violation of its contractual obligations with DFG.

Discussions between GCID and DFG were begun in the early 1980s to investigate potential remedies to the lack of bypass flows. Deteriorating hydraulic conditions finally resulted in DFG installing a fyke trap in place of one of the rotary screens. The trap was first operated in spring 1985 as a salvage facility with minimal effectiveness. During 1986, GCID widened and deepened its intake channel, which served to restore bypass flows. Continued high screen velocities, coupled with screen deficiencies identified by the DFG studies in the mid-1970s, resulted in continued discussion between GCID and DFG about fishery impacts. GCID's application for renewal of its dredge permit in 1986 resulted in a number of conditions being imposed by the U.S. Army Corps of Engineers (Corps), among which was implementation of a study to define a state-of-the-art solution to the fishery problems. Paralleling the requirements of the Corps permit was a memorandum of understanding (MOU) between GCID and DFG to conduct studies to define solutions to fish passage and water supply problems at the diversion site.

The result of the joint GCID/DFG study was a feasibility report published in 1989 that recommended building an entirely new screening structure at the head of the existing intake channel. The recommendation was based on extensive review of alternative solutions that would provide protection to fishery resources while allowing water deliveries by GCID.

During 1989, winter-run chinook salmon were listed under the California and federal Endangered Species Acts as endangered and threatened, respectively. Federal status was upgraded to endangered in 1994. Historical record had demonstrated that fry and juvenile winter-run salmon were exposed at the GCID pumping site as early as mid-July, with a peak fry exposure during late August to early September. During 1991, the NMFS brought suit against GCID to prevent it from causing further losses of winter-run salmon. The BO issued by NMFS indicated that operation of the GCID facility was likely to jeopardize the continued existence of winter-run salmon. The lawsuit resulted in a federal court injunction preventing the GCID from pumping during periods of peak downstream migration of winter-run salmon. As the result of the injunction, a joint stipulation between GCID, DFG, and NMFS provided conditions under which GCID could continue to pump. The joint stipulation initially required that GCID submit a completed and adequate application for an incidental take permit pursuant to Section 10 of the federal Endangered Species Act. Subsequent submittals were deemed inadequate by NMFS on February 4, 1993. With passage of the CVPIA (P.L. 102-575), USBR has been given responsibility for screening at GCID. The original joint stipulations were amended in 1993 to reflect the new status of USBR. GCID was required to fulfill certain conditions under the direction of NMFS. GCID was required to ensure the full funding of environmental analysis, selection, design, and construction of acceptable measures to provide long-term protection to winter-run salmon. During the interim period, GCID was required to reduce pumping during the critical period of August 1 through November 30 to meet screen velocity criteria of 0.33 foot per second (fps) required by DFG. In addition, among other conditions, minimum bypass flows were required to provide adequate passage for juveniles back to the river.

Various fishery studies were conducted by consultants hired by GCID during 1990-1993. The results failed to clearly identify solutions to rectify the problem. However, during 1993 GCID modified the portion of the oxbow channel in front and downstream of the fish screens to provide positive flows and reduce predator habitat. During 1993-1994, GCID refitted, as a stated "interim solution", the existing screen structure with new fixed plate screens meeting the screen opening criteria required by DFG/NMFS. These modifications are currently undergoing evaluation.

Predicted benefits: Fish losses at GCID are potentially very large. At times, the GCID diverts up to 20% of the total Sacramento River flow at RM 206 (Hallock 1987). If we assume that juvenile salmonids are distributed proportionally to flow, then up to 20% of the juvenile salmonids passing RM 206 could come in contact with the fish protection facilities at GCID. Correcting problems associated with the fish protection facilities at GCID can improve the probability of survival of those juvenile salmonids that contact it.

Action 12: EPA will complete Superfund cleanup of Iron Mountain Mine by 1996.

Objective: Remedy water quality problems associated with Iron Mountain Mine and other toxic discharges.

Location: Iron Mountain Mine, Spring Creek Drainage

Narrative description: Fish will be protected from chronic and acute toxicity caused by the discharge of heavy metals in acid mine drainage. The discharge can and has produced major kills of salmon and steelhead, as well as sublethal exposures that cause injury to anadromous fish by reducing growth and interfering with migratory behavior (EPA 1992a, Sorensen 1991). Completion of studies and subsequent implementation of EPA remedies for the Iron Mountain Mine Superfund site are needed to attain the safe metal concentrations identified in the CVRWQCB's Basin Plan. Pollution control remedies are required at the Iron Mountain Mine portal discharges from remaining sulfide ore deposits inside the mountain, the discharges from tailing piles, other sources, and the metal sludge in Keswick Reservoir. Attaining the objectives requires close coordination with the state and federal agencies, fishery trustees, legal council, consultants, and the responsible party.

We endorse the ongoing process to remedy problems associated with mine drainage entering the Sacramento River. Specifically, the main objectives of EPA and the fishery trustees in the Iron Mountain Mine clean up include:

- Eliminate the water demand that the dilution of the toxic discharge places on the Shasta-Trinity Project of the CVP. The water demand can be several hundred thousand af of storage that is needed for all the other beneficial uses of the project, including fish and wildlife conservation and temperature control.

- Attain the water quality objectives for toxic metals and contaminated sediments in the basin plan to protect the fishery resources of the Sacramento River from acute and chronic toxicity.

Until the site is fully remediated, there are a series of interim operations needed to achieve proper dilution of Iron Mountain Mine effluents:

- USBR will operate the CVP according to the 1980 MOU signed by USBR, DFG, and SWRCB. Under the provisions of the Spring Creek MOU, USBR agrees to operate according to criteria and schedules to minimize the probability of an uncontrolled spill and catastrophic fish loss, provided that such operation will not cause flood control parameters on the Sacramento River to be exceeded or interfere unreasonably with other CVP requirements as determined by USBR. The water quality criteria established in the MOU exceeds the metal concentration levels specified by the basin plan and causes chronic toxicity because operating to such standards would increase the frequency of acute toxicity that could affect a large portion of the salmon and steelhead populations.

- Operate by the stipulations in the BO (NMFS 1993).

Discussion: Site Location (EPA 1992b) - The Iron Mountain Mine site includes approximately 4,400 acres of land that includes the mining property situated around the 3,000-foot-high mountain. The site consists of several inactive underground and open pit mines, numerous waste piles, abandoned mining facilities, and mine drainage treatment facilities. The drainage from inactive mines on Iron Mountain Mine represents the largest pollutant discharge to the Sacramento River. This discharge is at least equal to all the combined industrial and municipal discharges to the San Francisco Bay and Estuary System (EPA 1992b). The toxic discharge is created by the mine characteristics, together with the natural occurrence of nearly pure sulfide deposits, producing a unique chemical reaction that is nearly optimal for the production of acid mine waters. This mine water contains extremely elevated concentrations of copper, zinc, cadmium, and other metals known to be toxic to fish and wildlife. On occasion, fish kills (including salmon) have been documented in the upper Sacramento River due to Iron Mountain Mine wastes. More frequently, there are documented instances of metal concentrations that exceed chronic toxic levels considered "safe" to early life stages of salmon.

The wastes from Iron Mountain Mine are collected in the Spring Creek Reservoir, then metered out into the releases of clean water from Shasta and Whiskeytown Reservoirs to achieve the best water quality possible. However, due to the extremely large waste load (averaging over 1 ton of copper and zinc per day), it is not possible to attain water quality objectives for heavy metals and a less protective target has been established. In the past and occasionally during intense, winter storms, the dam spills introduces toxins into the river at uncontrolled rates that sometimes result in fish kills. These highly toxic conditions are exacerbated when flows from Shasta and Whiskeytown Reservoirs are not available for dilution due to other CVP constraints.

Operating the Sacramento County Diversion Dam (SCDD) during major flood events is complicated because releases from Keswick Dam may be reduced to meet downstream flood control objectives while Spring Creek is spilling. Water released for diluting spills may be in excess of any other CVP requirements, representing a loss of beneficial use of the water for other purposes.

Predicted benefits: Source control and water management actions will significantly reduce copper and zinc in the Sacramento River below Keswick Dam. Such reduction would result in metal concentrations that consistently meet water quality objectives and that have been determined to be safe for fisheries. The control actions are being designed to protect fisheries from chronic and acute toxicity during all but a one in 100-year flow. Successful completion of the superfund program will (1) protect all fish from acute and chronic toxicity, including physiologic problems and slow growth; (2) protect salmonid reproduction between Keswick Dam and Cottonwood Creek from toxicity; (3) restore salmon and steelhead production to compensate for losses caused by the discharge; and (4) make available the water supply in the Shasta-Trinity unit of the CVP for all the beneficial uses.

Action 13: Avoid potential competitive displacement of wild, naturally produced juveniles with hatchery-released juveniles by stabilizing hatchery production levels and implementing release strategies designed to minimize detrimental interactions.

Objective: Evaluate competitive displacement between hatchery and natural stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: There is a potential for competition to occur between hatchery-released and wild/natural juveniles in the Sacramento River. Biological interactions of hatchery-released fish with wild fish may include direct competition for food and space during the freshwater rearing phase (Steward and Bjornn 1990). The extent of competition is, however, dependent on the degree of spatial and temporal overlap and the basic concept of supply and demand (Steward and Bjornn 1990).

The precise level of competitive interactions between hatchery-produced and wild/ naturally produced juveniles in the Sacramento River is unknown due to the absence of detailed studies. However, when comparing current population levels to apparent historical carrying capacities, the degree of competition as they rear and migrate through the 200-mile reach of river is assumed to be minimal (USFWS 1993).

Management practices exist that will avoid the risk of excessive competitive interaction both now and in the future. The practices can be implemented now and include: 1) stabilizing the total amount of hatchery production basinwide at established production goals and 2) releasing hatchery fish in a manner that avoids competitive displacement of wild/natural fish to the greatest extent possible.

Production goals should be quantified for all hatcheries in the basin and held or "capped" at current established levels. An allowable overage (e.g., 15%) can be built into these caps to accommodate fluctuations in spawning population numbers. Capping of production in this manner at USFWS's Coleman National Fish Hatchery has been implemented to avoid potential competitive impacts on endangered winter-run chinook salmon (NMFS 1994). As river carrying capacity and hatchery-wild interactions become more fully understood, production goals will be modified to benefit survival of both hatchery-produced and wild/naturally produced fish.

All current release strategies throughout the Sacramento River should be evaluated at a greater level of detail to identify the potential occurrence of competitive displacement of wild/natural juveniles with hatchery-released juveniles. USFWS's 1993 *Biological Assessment on the Effects of Coleman National Fish Hatchery Operations on Winter-Run Chinook Salmon* cites Steward and Bjornn (1990) and McMichael et al. (1992) in recognizing that hatchery-produced salmonids could lower production of wild/natural salmonids through competition if 1) the carrying capacity of the river is exceeded, 2) hatchery fish are larger than wild fish, 3) hatchery fish are in place before wild fish emerge, 4) large numbers of hatchery fish are released, or 5) released fish fail to disperse.

Carrying capacity is not believed to be a factor due to the 200-mile length of rearing area and the fact that this reach historically supported at least two to four times the current number of salmon and steelhead. An assessment of current release strategies should focus on competitive interaction questions, including:

a) Are hatchery fish larger than their wild/natural counter-parts at time of release?

b) Are hatchery fish allowed to take up residency prior to the emergence of wild/natural fish?

c) Are large numbers of hatchery pre-smolts released in a short time-frame?

d) Do hatchery fish fail to disperse after release?

Releases from all hatcheries within the basin should be evaluated in terms of these questions. Release strategies should be implemented to avoid identified competitive interactions. Established monitoring programs for wild/natural juveniles should be continued to evaluate potential competitive interactions due to size or timing of releases (questions a and b). Additional in-river monitoring will be needed if there is evidence that the number of hatchery fish or a failure to disperse produces undesirable levels of competition with wild/natural fish (questions c and d). Monitoring program objectives include relative abundance estimates of natural/wild juveniles near hatchery release sites, pre- and post-release, and average weights or preferably length-weight relationships (i.e., condition factors) of natural/wild juveniles near hatchery release sites, pre- and post-release. Relative abundance estimates of wild/natural juveniles pre- and post-release may assist in determining the extent to which hatchery released juveniles displace wild/natural juveniles, while estimates of condition factors may give insight into levels of competition for available food supplies.

Although carrying capacities are currently not presumed to be limiting, they will be considered in establishing long-term release strategies. Also, release strategies involving pre-smolts and fry should always consider the estimated densities of wild/natural fish and attempt to utilize underseeded habitats (Hard et al. 1992).

Predicted benefits: The precise nature of competitive displacement of wild/naturally produced juveniles by hatchery-produced juveniles is currently not defined. However, the current low population levels of wild/natural fish lead us to believe existing impacts of competitive displacement are minimal. Implementation of the above-stated recommendations may further reduce the potential for any negative impacts and therefore may result in higher survivability of wild/naturally produced juveniles and smolts.

Action 14: Implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and wild stocks.

Objective: Maintain genetic diversity in hatchery stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: Steward and Bjornn (1990) and Hard et al. (1992) provide in-depth discussions of the potential genetic impacts or risks hatchery programs may pose on wild populations. These genetic risks include 1) extinction, 2) loss of within-population genetic variability, 3) loss of between-population genetic variability, and 4) genetic differences between hatchery and wild stocks resulting from differential selection pressures in the hatchery environment.

Implementing specific spawning guidelines and maximizing the survival of the resultant progeny will limit founder effects, genetic drift, and inbreeding in the hatchery population.

It is extremely important, however, that genetic variance between the groups is initially low (Reisenbichler et al. 1992, Hindar et al. 1991) and survival of hatchery adults and resultant eggs and fry in the hatchery is maximized. If survival of eggs and progeny in the hatchery program is maximized, genotypes will not be lost due to low survival rates and maladaptive selection in the hatchery environment.

One of the main parameters used to assess the viability of a population is its effective population size (Bartley et al. 1992). Therefore, to minimize inbreeding and genetic drift, a mating scheme should be developed to maximize the effective population size for all fish collected as hatchery brood stock.

Genetic differences between hatchery and wild stocks can be held to a minimum by employing specific breeding guidelines to minimize allele-frequency differences between hatchery and wild fish (e.g., Meffe 1986, Reisenbichler et al. 1992, Hynes et al. 1981, Hindar et al. 1991, Simon 1991, Simon et al. 1986, Tave 1986, Bonneville Power Administration [BPA] 1994). Guidelines to maximize the effective population size, conserve genetic diversity, and minimize genetic differences between hatchery and wild stocks (as described by the above authors) should be implemented as follows:

- Use adults that are genetically similar to the corresponding wild/natural stocks.

- Incorporate large numbers of adults into the spawning program to more adequately represent all genomes present in the wild. Although a reduction in the genetic variability in hatchery stocks of Pacific salmon due to inbreeding is not well documented (Steward and Bjornn 1990), small population sizes in hatchery programs may lead to losses of within-population genetic variability through inbreeding depression and genetic drift (Waples 1991).

- Implement a "no selection" protocol. Consider <u>all</u> returning or collected fish as part of the population (i.e., avoid selection based on phenotypic characteristics or other criteria).

- Use jacks to ensure genes associated with all age classes are incorporated in the population at appropriate levels.

- Implement a 1:1 male-to-female spawning ratio (i.e., one time use of each adult, single pair spawning, unpooled gametes).

- To ensure full fertilization when the egg supply is severely limited or male gamete viability is known to be low, successively use two males for each egg lot (1 and 2; 2 and 3; 3 and 4, etc). This procedure utilizes the first of the pair (with mixing), followed by interval of 30 seconds, and then the immediate use of the second male.

- Use pairing schemes to avoid discarding of excess spawners on spawning days where one sex is more numerous than the other. This can be used on all populations, except those that are critically small.

- For critically small populations (i.e., winter-run chinook salmon) apply a splitting scheme. Divide eggs from each female into two lots and fertilize with gametes from two different males. Also, use each male twice, once with two separate females. This practice safeguards against the loss of genetic contribution from an individual producing viable gametes mated with an individual that produced nonviable gametes (USFWS 1993).

- Develop improved gamete cryopreservation techniques to permit later crossing of lines from different generations.

Additionally, programs should be developed to obtain baseline information on the genetic diversity of current hatchery and wild/natural stocks and evaluation programs should be developed to monitor changes in these diversity levels over time.

Predicted benefits: Implementation of specific spawning protocol will serve to minimize the potential genetic effects of hatchery programs on wild/natural stocks. Development of genetic evaluation programs will aid in assessing the success of the spawning strategies to maintain existing genetic diversity.

Action 15: Evaluate transfer of disease between hatchery and natural stocks.

Objective: Evaluate disease relations between hatchery and natural stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: Develop and implement strategies to minimize the risk of disease outbreaks in hatcheries, determine degree of prevalence of pathogens/disease in wild/natural stocks, and evaluate potential for disease transmission from hatchery fish or hatchery water supplies to wild/naturally produced fish.

The actual extent of horizontal transmission of diseases or parasites from hatchery-released salmonids to wild stocks is largely unknown. Although disease outbreaks and epizootics are fairly common in hatcheries, direct transfer of these diseases to wild fish has not been clearly demonstrated. Steward and Bjornn (1990) state there is little evidence of transmittance of diseases or parasites from hatchery to wild salmonids. Their literature review describes a number of studies suggesting diseases such as bacterial kidney disease (BKD) and infectious pancreatic necrosis (IPN) were not transmitted from infected hatchery fish to wild fish. However, they go on to state that research on this subject is limited and conclude the full impact of disease on supplemented stocks is probably underestimated.

Infectious disease is considered to be a normal component in the life history of hatchery-reared and wild/naturally produced salmonids in the Sacramento River due to their similar parental stock (free-ranging brood stock of mixed origin) and exposure to similar water supplies. Some incipient level of pathogens are natural and also probably essential for the development of proper immunological response to actual disease outbreaks (Hard et al. 1992). Unfortunately, hatchery-rearing conditions often render hatchery fish more susceptible to contracting and spreading disease and parasites in the confined, high-density rearing environment.

Most pathogens endemic to Sacramento River salmonids evolved with their salmonid hosts and are not recent introductions. Endemic pathogens that have caused significant health problems in Central Valley salmon hatcheries include infectious hematopoietic necrosis virus (IHNV), BKD, *Yersinia ruckeri, Flexibacter columnaris, Ceratomyxa shasta, Ichthyophthirius multifiliis,* and *Nanophyetus salmincola* (Cox 1993). Numerous other bacterial, parasitic, and fungal species have also been identified as being pathogenic to hatchery populations under appropriate conditions.

Exposing wild stocks to infected hatchery fish may result in mortality or disability or may have no effect. This ultimate result depends on several ecological parameters (e.g., proximity and exposure time) that influence the spread and pathology of diseases and the immune status of the fish. The reduced probability of contact between individuals outside the confines of the hatchery may reduce the potential for wild salmonids being infected by the hatchery fish (Steward and Bornn 1990).

Reducing the risk of disease outbreaks within a hatchery consequently can reduce potential transfer of disease to wild/natural stocks. To minimize the risk of disease outbreaks in hatcheries within the Sacramento River basin, management practices as modified from BPA (1992) should be implemented as follows:

- All phases of propagation, transfers, and distribution will follow recommendations similar to those of USFWS's Fish Health Policy (1995).

- All hatcheries relying on surface water where anadromous fish are in the headwaters above the hatchery should be equipped with state-of-the-art water sterilization systems (e.g., utilizing ozone, ultra-violet).

- Bird exclusion devices should be installed at all rearing facilities to avoid disease introduction and pond-to-pond transfer by predators.

- During hatchery operations, strict sanitation and disinfection procedures should be employed.

- Isolation, segregation, and quarantine practices should be employed when necessary.

Additionally, state and federal fish health centers and the National Biological Survey should devise programs to 1) ascertain the disease implications of hatchery effluent waters on wild/natural juveniles, 2) perform laboratory and *in situ* exposures of infected hatchery fish to uninfected wild/natural fish to gain an understanding of the kinetics of horizontal disease transmission, and 3) gather baseline information on the degree of prevalence of pathogens/disease in wild/naturally produced juvenile salmonid populations.

<u>Predicted benefits</u>: Implementing strict fish health policies and practices in Sacramento River basin hatcheries will reduce disease outbreaks within hatcheries and consequently reduce the potential for pathogen/disease transfer from hatchery-reared fish to wild/naturally produced fish.

Action 16: Create a 50,000-acre meander belt from Red Bluff to Chico Landing to provide gravel recruitment, large woody debris, moderate air temperatures, and nutrient input to the lotic system.

Objective: Restore and preserve riparian forests.

Location: Red Bluff at RM 242 to Chico Landing at RM 204.

Narrative description: Recreate an active meander belt and restore a continuous riparian corridor between Chico Landing and Red Bluff. The meander belt and corridor would encompass approximately 50,000 acres.

Protect and restore the Sacramento River riparian corridor and, by doing so, preserve important instream values. The riparian and associated meander zone affect the aquatic ecosystem by providing the majority of spawning gravel; creating a variety of preferred spawning areas (e.g., point bar riffles, chute cutoffs, multiple channel areas, and areas near islands); maintaining and improving the hydrologic diversity of the river channel; reestablishing and maintaining a diversity of substrates; supplying a continually renewable source of shaded riverine aquatic habitat, including large woody debris; and providing an important terrestrial food source.

The most feasible location for reestablishing a functional Sacramento River riparian ecosystem is in the reach between Chico Landing and Red Bluff. Along this stretch of the river, riparian vegetation influences erosion and deposition within the floodplain. In turn, these fluvial processes create the diversity of streamside vegetation and maintain its overall condition.

Riparian vegetation creates a buffer to decrease local flood velocities. This increases the deposition of suspended materials derived upstream from eroding banks. It is this erosion-deposition process that builds the middle terrace and eventually the high terrace lands that support high-terrace climax forest and agriculture. Overbank flooding is essential for the continued health of the riparian system. As silt and seeds are deposited during these overbank waterflow events, the native vegetation is rejuvenated.

The interplay between biological succession and hydrologic and geomorphic factors results in a mosaic of habitat types in the riparian zone. These types follow a chronological and topographic continuum from a bare sandbar, to young forests of cottonwoods and willows, to mature forests of older cottonwoods and other deciduous species, to a climax forest of valley oak. Mature riparian forests are typically 40-90 years old. A meander zone along the Sacramento River should include an unbroken band of the full continuum of these river-created habitats that are maintained by the river over time. By definition, young to mature forest exists where the river channel has been in the last 100 years. The movement of the river within this 100-year meander belt creates and maintains the rich mosaic of habitats. It is estimated that this 100-year zone encompasses approximately 13,000 acres between Chico Landing and Red Bluff.

The hydrologic regime is an integral part of the riparian corridor. A healthy and sustainable riparian corridor depends on both seasonal flow fluctuations and periodic flood events. Receding spring flows are required to ensure a moist alluvial substrate for the establishment of willows and cottonwoods at the edge of sandbars. During winter and early spring, higher flood flows are necessary both to ensure deposition on high terraces and to erode banks to provide sediment downstream. The overbank deposition of sediments is necessary to offset the bank erosion and maintain the equilibrium of erosion and deposition in the floodplain. Sustained releases from Shasta Reservoir at a level just below bankfull discharge (such as occurred in spring 1993) may cause considerable erosion of saturated banks; however, allowing the river to utilize the floodplain can reduce flow velocities and allow for sediment deposition.

Ongoing DWR studies indicate that while floodplain deposition in the Sacramento River riparian zone has decreased since the construction of Shasta Dam, the rate of bank erosion has decreased as well. This suggests the possibility of an overall balance between erosion and deposition.

Research needs associated with meander-belt establishment include:

- Ongoing erosion and deposition measurements, particularly during wet years (most available data have been collected in the dry years since 1986). Further data collection and analysis is necessary to adequately assess erosion and deposition rates along the Sacramento River.

- Modeling the dynamics of the geomorphic system and biological succession. Data on geology, erosion, sedimentation, hydrology, and channel morphology can be used in combination with vegetation studies to determine the proportion of plant communities that will be established over time in the riparian zone. This information will also be valuable in assessing the impact of different flow regimes on the dynamics of the riparian ecosystem.

Under Senate Bill (SB) 1086, a group of landowners, government agencies, and environmental interests have been developing plans for the institution of a meander zone along the Sacramento River. Their ongoing dialogue resulted in the blueprint for limited meander zone found in the *Upper Sacramento River Fisheries and Riparian Habitat Management Plan* (The Resources Agency 1989). Parallel with these efforts, The Nature Conservancy has purchased several tracts along the river, and USFWS includes the Sacramento River riparian corridor as part of the Sacramento River National Wildlife Refuge. Through the SB 1086 process, plans are currently being laid for the establishment of a legislated, locally based district to implement the establishment of a meander belt.

<u>Predicted benefits</u>: Creation of a 50,000-acre meander belt from Red Bluff to Chico Landing will restore natural processes to the river ecosystem, providing gravel replenishment for spawning habitat enhancement; large woody debris for fish cover; moderate air temperatures that should contribute to a lower, more stable river temperature regime; and nutrient and food input to the lotic system.

B. UPPER SACRAMENTO RIVER TRIBUTARIES

Clear Creek -

Limiting factors and potential solutions - Table 3-Xb-1 lists key limiting factors for salmon and steelhead in Clear Creek and potential solutions.

Instream flow - Clear Creek as a regulated stream system receives very little stream flow. Therefore, restoring habitat and achieving doubling of the salmon and steelhead populations in the stream will require higher flows. The increased flow regime must provide sufficient spawning, incubation, rearing habitats, and outmigration flows for salmon and steelhead, together with suitable temperatures and channel maintenance (prevention of riparian encroachment).

Water temperature - High water temperatures can be lethal to adult spring-run chinook and yearling steelhead that live in the creek during the dry season (U.S. Geological Survey [USGS] Water Quality Records, DWR 1986, USFWS 1991). Warmer temperature regimes favor development of warmwater fish populations (e.g., black bass and squawfish) that will prey on juvenile salmon and steelhead.

Whiskeytown Dam has several outlets that release water from different elevations and temperatures within the reservoir water column. Integrated management of water temperatures and flow rates of reservoir releases is necessary to attain the proper creek habitat requirements for spring-run chinook salmon and juvenile steelhead.

Gravel recruitment and extraction - Suitable spawning gravel is being reduced in Clear Creek as a result of blockage by Whiskeytown Dam and gravel mining in the lower stream sections below the dam. For the past decade, about 12% of the stream below Whiskeytown Dam was mined for gravel. Another 10% of the streambed is targeted for mining. The channel configuration in mined areas is braided and pitted. The braided sections are shallow and split the flow, causing adult passage problems. The excavation pits entrain and trap juvenile outmigrants when the water level goes up and down during spring storm periods that subject them to predation by bass and squawfish. During periods of high runoff, the excavation pits also trap new gravel, making it unavailable for fish spawning (DWR 1986, 1994).

Fish passage - McCormack-Saeltzer Dam, constructed in 1903 for gold mining and later agriculture, is located about 10 miles downstream from Whiskeytown Dam. Water (about 10 cfs) is diverted into the Townsend Flat water ditch under pre-1914 water rights and an additional water rights settlement contract with the USBR. The use of the water right has changed; most of the water right service area is subdivided for housing or mined for gravel, leaving little for agricultural or fishery use. Saeltzer Dam is a partial barrier to fish passage that is compounded by difficult passage areas in the bedrock stream channel immediately below the dam. Improving fish passage and implementing a recommended flow regime will open up spring-run chinook salmon and steelhead habitat and restore additional spawning capacity to the creek.

Land use - Approximately half the creek's watershed below the dam is composed of decomposed granite soils (DWR 1986). The steep slopes and erosive soils below Whiskeytown Dam add sedimentation problems to downstream spawning and rearing areas. These problems are exacerbated by reduced flushing flows and blocked gravel recruitment below Whiskeytown Dam.

Table 3-Xb-1. Key limiting factors for chinook salmon and steelhead in Clear Creek and potential solutions.

Limiting factors	Potential solutions
Instream flow	Implement integrated flow schedule providing for T° and riparian channel maintenance
Water temperature	Operate Whiskeytown Dam to provide temperature control
Gravel extraction	Restrict instream gravel mining and restore mined-out channel sections
Fish passage	Remove McCormick-Saeltzer Dam and find alternate water supply
Land use	Make land use practices compatible with salmon restoration by acquiring land in the watershed and implementing erosion control practices, a stream corridor protection plan, and other appropriate land use planning developed in a comprehensive resource management plan for the watershed
Whiskeytown Dam	Restore spawning gravel recruitment halted by the dam and stream channel sections disturbed by dam construction and compensate for the blockage and inundation of 12 miles of spawning habitat above the dam

Restoration actions -

Action 1: Implement an integrated instream flow schedule.

Objectives:

1. Provide adequate instream flows and channel maintenance flows for all life stages of salmon and steelhead.

2. Provide suitable temperatures for all life stages.

3. Provide channel maintenance flows.

Location: Whiskeytown Dam.

Narrative description: The recommended releases from Whiskeytown Dam to Clear Creek are 200 cfs from October to April and 150 cfs for the remainder of the year with variable spring-time releases depending on water year type. Annually, this flow regime represents an amount of water that is equaled or exceeded by the natural runoff of the creek at the dam site during 25-30% of the water years. During drought conditions, these recommended releases are reduced by 25%. These recommendations (DFG correspondence report 1993) are based on attainable temperature objectives and habitat requirements that were determined by an instream flow study (DWR 1986) and the Clear Creek hydrologic data at Whiskeytown Dam for 1923 to 1994 (USBR Central Valley Project Operations Hydrologic Data).

The recommended flows provide habitat and temperature requirements for fall-run and late fall-run chinook salmon and steelhead and, to a lesser extent, for spring-run salmon, which are presently extirpated from the stream. If the spring-run chinook salmon population becomes successfully reintroduced, it may require an even lower summer water temperature regime, necessitating increased flows. The releases are measured at Whiskeytown Dam to provide more precise temperature regulation and prevent harmful flow fluctuations.

A springtime flushing flow recommendation will be developed empirically to accomplish sediment removal, prevent riparian vegetation encroachment, maintain the proper channel configuration, distribute new spawning gravel, facilitate timely juvenile outmigration, and attract adult spring-run salmon and steelhead into the stream. The schedule and amount of flow would be determined by a series of experiments designed to intensify and augment a storm flow at strategic times. The flushing flow releases would not exceed the natural inflow into Whiskeytown Reservoir during the storm.

Implementing the recommended flows can be accomplished via a reoperation of the Keswick and Whiskeytown dams in a manner that does not affect the water supply of the Shasta-Trinity unit of the CVP. Because Clear Creek enters the Sacramento River a short distance below Keswick Dam, it can be used to convey a small portion of the large irrigation water supply needed in the river.

Clear Creek flows recommended during the wet season approximate the annual amount of natural runoff that is present or exceeded in 90% of the years of record (1923-1994 in USBR Central Valley Project

Operations Hydrologic Data). Drought years within the 10% of the driest years on record require flow reductions that approximate the natural runoff. During the dry season, the Clear Creek releases will be subtracted from the Keswick Dam releases, requiring no net change in release from storage, only a change in delivery route. The flow reductions at Keswick Dam during May through September are minor relative to the average river flow (approximately 1%) and will not affect the habitat or temperature regime of the Sacramento River. Specifically, the Keswick Dam releases would be reduced to approximately 85 cfs (the flow increment above the water right requirements).

The recommended flow schedule should be implemented as soon as possible because a significant amount of usable habitat, presently taken out of service, that can significantly contribute to the doubling goals.

Related actions that may impede or augment the action: The water rights permit for the project allows implementation of a new release schedule for Whiskeytown Dam at any time on mutual consent between the USBR and DFG (CVPIA does not affect water right permits). The reoperation of Whiskeytown Dam may require preparation of a Fish and Wildlife Coordination Act Report; however, it may not be needed prior to operational changes based on past practice.

Agency and organization roles and responsibilities: The U.S. Department of the Interior is responsible for providing the stream flows that ensure preservation of fish and wildlife and compensate for lost spawning areas above Whiskeytown Dam. DFG should recommend flow releases, and the fishery agencies must monitor the habitat restoration effort. The USBR and DFG must update the water right for the project by submitting a revised MOU to SWRCB.

A detailed operational plan describing the recommended flow regime, consisting of natural runoff from Clear Creek into Whiskeytown Reservoir, should be prepared by DFG, the USBR, and USFWS. It should include flow release adjustment procedures at Keswick and Whiskeytown dams and dry year flow regimes to ensure that Clear Creek flows do not exceed its annual natural unimpaired runoff.

Potential obstacles to implementation: A consequence of providing additional releases down Clear Creek is the translocation of power production from Spring Creek and Keswick power plants to the city of Redding power plant located at Whiskeytown Dam where there is less power potential (head). A timely resolution of this power production loss may not be possible.

Predicted benefits: By increasing the flows below Whiskeytown Dam, it is possible to add back approximately 5 miles of spring-run habitat and 10 miles of steelhead habitat and to reintroduce spring-run chinook salmon. If successful, another distinct and genetically viable population of spring-run chinook salmon and steelhead could become established in the Central Valley, which would reduce the probability of these species going extinct. In addition, the recommended flow releases can nearly double available fall-run and late fall-run chinook salmon habitat over that provided by the present releases. Clear Creek is one of two tributaries in the upper Sacramento River that can provide habitat for three races of salmon and steelhead.

Clear Creek's estimated production is 6,190 salmon and 13,052 steelhead (USFWS 1986, DWR 1985).

Action 2: Provide temperature control.

Objective: Operate Whiskeytown Dam to control temperatures primarily for steelhead or spring-run chinook salmon if reestablishment is successful.

Location: The reach of stream above the valley floor near McCormick-Saeltzer Dam.

Narrative description: Whiskeytown Dam has several outlets at different elevations that allow lower temperature water releases. The installation of the Oak Bottom temperature control curtain further assists in regulating temperature for Clear Creek. A remote-sensing temperature monitoring device is needed at the USGS gauge station at Placer Road Bridge to help project operators to actively control creek temperatures.

Temperature monitoring during several experimental flow releases demonstrated that temperature objectives for juvenile rearing (65° F), holding of prespawning adults (60° F), and egg incubation (56° F) are attainable (DWR 1986, DFG temperature data, USGS temperature data).

Related actions that may impede or augment the action: In a related action, DFG has proposed an amendment to the Water Quality Control Plan for the Central Valley Basin that establishes temperatures suitable for spring-run chinook salmon and steelhead in the foothill reaches of Clear Creek (DFG correspondence 1994). The CVRWQCB's staff is considering the recommended amendment pending further analysis.

Agency and organization roles and responsibilities: Roles and responsibilities are the same as those described for Action 1. In addition, the CVRWQCB will continue to analyze the temperature objectives for Clear Creek proposed by DFG.

Potential obstacles to implementation: Potential obstacles are the same as those as described for Action 1.

Predicted benefits: Temperature control makes the habitat usable for salmon and steelhead and recreates habitat similar to what is now blocked by Whiskeytown Dam. The expected temperature regime provided by the recommended flows will ensure that: 1) the first 10 miles of stream below the dam will be suitable for steelhead spawning and incubation and oversummering rearing of juveniles; 2) any reintroduced spring-run chinook salmon would be provided with suitable habitat for adult summer holdover, spawning, and incubation within the first 5 miles below the dam; and 3) suitable habitat would be provided for spawning, incubation, and juvenile rearing of fall-run and late fall-run chinook salmon within the first 8 miles of the stream above its confluence with the Sacramento River.

Action 3: Restrict gravel mining and restore degraded channel.

Objective: Eliminate the severe adverse effects of gravel mining.

Location: North State Aggregate and Sunrise Excavation Pits.

Narrative description: The adverse effects of instream gravel mining are documented (DWR 1994). Specific problems on Clear Creek include formation of a highly unstable braided and pitted channel that affects upstream passage and lacks sufficient gravel recruitment (DWR 1986). Purchase of the mined stream channel, along with that proposed for mining, would eliminate this problem.

Currently the U.S. Bureau of Land Management (BLM) is in the process of exchanging some of its lands for 900 acres of land bordering Clear Creek between McCormack-Saeltzer Dam and the confluence with the Sacramento River (Schmidt Estate and BLM February 1995 pers. comm.), which is consistent with the Record of Decision for the Redding Resource Areas Land (BLM 1993). Completion of the land exchange will place approximately 96% of the lands along the valley reach of the stream in public ownership, while in the foothill reach of the stream, all the adjoining lands are in public ownership.

After mined areas are transferred to public ownership, channel restoration projects such as the placement of a berm to deflect water from the pits, consolidation of braided channels, and installation of spawning riffles can begin. Plans and environmental documentation are completed for some of the initial channel restoration work.

Related actions that may impede or augment the action: The approved Surface Mine Reclamation Plan for the mined section of the creek is compatible with projects that restore the site for fish and wildlife uses. Restoration activities may be augmented by the Federal Forest Plan Option 9 program that includes Clear Creek watershed. Restoration proposals for labor-intensive projects have been submitted to this program for funding.

Agency and organization roles and responsibilities: BLM is implementing the land exchange with the assistance of DFG. Shasta County and the City of Redding are administering the Surface Mine Reclamation Plans that have requirements consistent with restoration of fish and wildlife habitat. Plans for public recreation in the watershed are the responsibility of the City of Redding, National Park Service, and BLM. The County of Shasta and the Corps are responsible for establishing conditions for any future proposed gravel mining activity in the lands near Clear Creek.

Potential obstacles to implementation: None, if the land exchange process proceeds as planned.

Predicted benefits: Approximately 12% of the anadromous fish habitat has been heavily mined for gravel but can be restored for spawning and rearing. An additional 10% of the stream can be exempted from gravel mining.

Action 4: Provide fish passage.

Objective: Provide access to stream habitat above McCormick-Saeltzer Dam.

Location: McCormick-Saeltzer Dam.

Narrative description: DFG has made a number of attempts to provide effective fish passage over McCormack-Saeltzer Dam (Saeltzer Dam) that have been largely unsuccessful to date. This is compounded by a difficult passage situation in the bedrock channel below the dam that could be improved by blasting a wider channel (project scheduled for 1995).

The most effective method of passing fish would be removal of the dam. The land at the dam site is now under the ownership of DFG. Although the dam can be used to segregate fall-run from spring-run salmon, that service is not relevant and can be provided by alternate means if necessary. To protect water quality and substrate, dredging of sediment behind the dam is needed. A project design and environmental documentation is already completed for this action.

The dam and diversion appear to be greatly oversized for the current water use serviced by the canal (i.e., much of the irrigation district lands serviced by this diversion have been urbanized and mined for gravel). There are alternate methods of supplying water, including groundwater pumping, contracting water from the ACID's canal, or piping water from Clear Creek using a smaller diversion. The proposal to exchange the dam for an alternate water supply was discussed with the owner-operators and in public meetings; the evaluation process is continuing.

Related actions that may impede or augment the action: The program could be augmented by the CVPIA water purchasing program by offering to purchase its pre-1914 water right and the USBR water contract. The landowners in the district may request the Natural Resources Conservation Service (NRCS) (formerly the U.S. Soil Conservation Service) to develop a water conservation plan for farm use and this program could identify alternate water supplies.

Agency and organization roles and responsibilities: DFG is responsible for documenting the fish passage problem. The SWRCB is responsible for responding to any complaints that the water right is not being exercised according to the rules for reasonable use and/or preventing environmental damage.

Potential obstacles to implementation: The water district serviced by the dam may choose not to enter into a water conservation program or not accept any alternate water supply.

Predicted benefits: Fish passage provides access to the only reach of the stream where water temperatures can be controlled by releases from Whiskeytown Dam during the dry season. Without access to this reach there would not be suitable habitat available for yearling steelhead or spring-run chinook salmon. There are educational benefits to allowing salmon and steelhead access to the upper reach where they could be observed at the Whiskeytown Environmental Camp. This facility is operated by the Shasta County Department of Education and the National Park Service to accommodate thousands of elementary school students annually with programs that include fishery issues.

Action 5: Prevent habitat degradation due to sedimentation and urbanization.

Objective: Develop an erosion control and stream corridor protection program for the creek.

Location: Entire stream.

Narrative description: The soils in the upper portion of the watershed consist of highly erodible decomposed granite that can degrade water quality and spawning substrate. A review of land management practices in the Clear Creek watershed is being conducted through the coordinated resource management process. The Western Shasta Resource Conservation District (RCD) formed a group of interested parties from private and government sectors and held several public meetings discussing fishery restoration plans. This collaborative process is directed at developing the land use practices for timber harvest, residential development, agriculture, mining, and road building that prevent sedimentation of the stream. The RCD will be initiating a watershed analysis in spring 1995 that will identify the scope and scale of watershed problems. The NRCS could, if funded, inventory and prioritize problem sites and design and implement treatment measures.

As urbanization of the land continues in the Clear Creek watershed, there is a need to preserve a wide, unfragmented corridor of riparian vegetation for fish and wildlife. The land exchange process being completed by BLM will produce a greenbelt along 98% of the stream. The stream corridor along the remaining private land should be protected under the Stream Corridor Protection Program (DFG 1993) adopted as an interim policy by both the city and the county. Part of the documentation for this program includes a complete mapping of Clear Creek with its riparian habitat and wetlands in a geographic information system format.

Related actions that may impede or augment the action: Almost all the land adjacent to the creek will be owned by public agencies that presently have land management objectives consistent with fishery restoration, wildlife conservation and public recreation. The land use activities on the remaining private lands should be consistent with the recently revised Shasta County General Plan (Shasta County 1993) that specifies special development and erosion control practices in the erodible Clear Creek watershed and protection of salmon spawning gravel in the creek.

Agency and organization roles and responsibilities: The land use activities on public lands must be managed in a manner that prevents degradation of the quality of either the water or the spawning substrate consistent with state and federal water quality laws. The land use activities on private land are conditioned in permits issued by Shasta County consistent with the provisions of the general plan. DFG, CVRWQCB, and the Western Shasta RCD review the proposed land use activities and advise the county on appropriate measures to conserve natural resources through the California Environmental Quality Act (CEQA) process.

Potential obstacles to implementation: None anticipated if all land management agencies follow current plans.

Predicted benefits: By establishing land use practices that decrease rather than increase the discharge of sediment to the stream, the restored sections of habitat will not be degraded by future land use practices. Effective source control of sediment discharge will also eliminate the need to operate sediment basins that interfere with fish passage and water quality protection. The decreased sediment loads will also increase the effectiveness of spring-time flushing flow releases from Whiskeytown Dam. Fish and wildlife values associated with the stream and its riparian vegetation will be preserved with the implementation of the Stream Corridor Protection Program.

Action 6: Restore lost gravel recruitment and spawning habitat.

Objective: Compensate for spawning gravel recruitment and spawning areas blocked by Whiskeytown Dam.

Location: Below Whiskeytown Dam, below McCormick-Saeltzer Dam.

Narrative description: The recruitment of spawning gravel to the creek is halted by Whiskeytown Dam, resulting in a 90% reduction in spawning habitat in the first 10 miles below the dam as indicated by a comparison of preproject and postproject spawning gravel surveys (DWR 1986, DFG 1971). This loss can be compensated for by artificially introducing quantities of spawning-sized gravel on a continuous basis.

During construction of Whiskeytown Dam, the stream below the dam site was mined for dam building materials, including boulders and rubble, reducing the quality of the habitat in this reach. Boulders can be placed in this section to restore habitat diversity.

The construction of Whiskeytown Dam also resulted in the blockage and inundation of approximately 12 miles of stream suitable for salmon spawning (U.S. Bureau of Fisheries 1940). The early surveys of the stream reach above Whiskeytown Dam indicated that less than 1% of the streambed was suitable for spawning, yielding an estimated capacity to support a run of approximately 700 salmon (U.S. Bureau of Fisheries 1940). These surveys did note that the stream was affected by mining wastes. There are historical records of a salmon run above the town of Whiskeytown prior to blockage by Saeltzer Dam at the turn of the century (DFG correspondence 1956).

Related actions that may impede or augment the action: Reintroduction of salmon and steelhead above Whiskeytown Dam is impossible because of insolvable fish passage issues for adults and juveniles. The preferred mitigation method when mitigation cannot be accomplished onsite, according to DFG and USFWS policies, is to compensate for those lost resources by creating new ecologically equivalent habitat as close to the site as possible. Mitigation could be achieved on the remaining 16 miles of stream below Whiskeytown Dam by managing flows, temperature, and spawning gravel so that the stream has the habitat with the capacity to support the same type and population size of anadromous fish as the historical habitat prior to blockage by dams.

Agency and organization roles and responsibilities: DWR, DFG, and USFWS need to formulate and implement a habitat restoration plan for Clear Creek below Whiskeytown Dam.

Potential obstacles to implementation: None are anticipated if all land management agencies follow current plans.

Predicted benefits: The replacement of a portion of the spawning gravel will restore and increase available habitat. Attainable increases in habitat using many years of gravel addition could range between 25% and 50%. This restoration action, along with the other actions proposed for Clear Creek, are expected to nearly double existing populations of salmon and steelhead.

Cow Creek -

Limiting factors and potential solutions - Primary land and water use activities in the Cow Creek drainage include timber harvest, livestock grazing, and hydropower production. Loss of habitat and water diversions are largely due to activities associated with livestock production. The Cow Creek watershed is in relatively good condition and measures to protect existing habitat from water diversion, cattle grazing, creekside development, and gravel extraction should maintain and preserve habitat conditions. Primary limiting factors for chinook salmon and steelhead are low fall and summer flows affecting attraction, migration, spawning, and rearing, caused in part by irrigation diversions. Irrigation diversions also affect steelhead by delaying or blocking adult upstream migration and the entrainment of juvenile migrants. Table 3-Xb-2 lists key limiting factors to salmon and steelhead in Cow Creek and potential solutions.

Water diversions - The only laddered dams and screened diversions are part of hydropower facilities. Agricultural diversions are unscreened, and ditches are unlined and poorly maintained. Nearly all the larger irrigation diversions occur within the tributary streams above the valley floor and generally do not limit chinook salmon migration to potential upstream spawning habitat (Harvey pers. comm.). The one possible exception to this is the concrete based flashboard diversion on North Cow Creek near Bella Vista (1.3 miles below Indian Oak Road) that presents a potential barrier. Irrigation diversions typically operate from April through October and can negatively affect stream flows important for fall-run attraction, migration, and spawning. Habitat surveys conducted by DFG in 1992 identified several permanent and temporary irrigation diversions in the various tributary streams, including 13 diversions in South Cow Creek, 10 diversions on Old Cow Creek, one on Clover Creek, and two on North Cow Creek. No surveys were conducted on Oak Run Creek. According to DFG, no summary data readily exist for information on diversion rights (i.e., ownership, magnitude, and duration).

Steelhead are directly affected by water diversion because they impede upstream migration of adults and entrain downstream migrating juveniles. Agricultural diversions and Pacific Gas and Electric Company's (PG&E's) hydropower diversions on South Cow Creek also reduce summer flows important for juvenile steelhead rearing. Colleen Harvey identified potential migration barriers to adult steelhead. All agricultural diversions are unscreened.

Livestock grazing - Livestock grazing has reduced riparian vegetation and eroded streambanks in the various tributary streams and in the mainstem Cow Creek. Sedimentation will continue to degrade the quality of spawning gravel in Cow Creek. Habitat surveys conducted by DFG in 1992 identified stream sections within the various tributaries where excessive erosion has occurred. Fencing these stream sections to protect the riparian corridor has been recommended for approximately 42,600 feet of stream on South Cow Creek, 45,600 feet on Old Cow Creek, 39,120 feet on Clover Creek, and 19,500 feet on North Cow Creek (Harvey pers. comm.).

Urbanization - Population growth in the towns of Palo Cedro, Bella Vista, Oak Run, and Millville is resulting in increased demand for domestic water and is affecting riparian habitat within the Cow Creek watershed (Reynolds et al. 1993). Creekside development projects will continue to threaten existing habitat conditions unless appropriate measures are taken to ensure that riparian corridors are protected. DFG has worked with Shasta County to address riparian concerns in its recently revised Shasta County General Plan (Shasta County 1993). The plan currently includes provisions to protect the riparian corridor within the watershed.

Gravel mining - Gravel mining occurred in North Cow Creek between Bella Vista and Palo Cedro near the confluence of Dry Creek. Gravel extraction has destroyed the riparian area and removed in-channel gravel. Chinook salmon spawning and rearing habitat have been adversely affected in this area. Currently, gravel mining in Cow Creek has ceased but its effects still remain. The recently revised Shasta County General Plan includes specific ordinances that currently prohibit gravel mining operations within the watershed.

Table 3-Xb-2 . Key limiting factors for chinook salmon and steelhead in Cow Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Instream flow	Work with water right holders to obtain agreement for additional flows
Adult passage	Work with water right holders to obtain agreement for improved passage at diversions
Entrainment	Screen diversions
Livestock grazing	Fence riparian corridors to exclude livestock
Urbanization and creekside development	Work with county and private land owners to develop a riparian corridor protection zone
Gravel mining	Eliminate instream gravel extraction operations

Restoration actions -

Action 1: Work with water right holders to obtain an agreement for adequate flows for fall-run chinook salmon migrations and spawning and juvenile steelhead rearing.

Objective: Provide suitable passage and early spawning flows for fall-run chinook salmon adults (particularly in dry water years) and adequate flows for juvenile steelhead rearing.

Location: South Cow, Old Cow, Clover, and North Cow Creeks and possibly Oak Run Creek.

Narrative description: Agricultural diversions on various tributaries and streams have reduced streamflows important for migration and early spawning of fall-run chinook salmon (primarily during dry years in mainstem Cow Creek and in South Cow Creek. Irrigation diversions and PG&E hydroelectric diversions on South Cow Creek have also reduced juvenile steelhead rearing habitat in the tributary streams, particularly during summer. DFG habitat surveys conducted in 1992 have documented the number and location of agricultural diversions on most of the main tributary streams that generally operate from April through October of each year. Thirteen agricultural diversion exist on South Cow Creek, ten on Old Cow Creek, one on Clover Creek, and two on North Cow Creek. No surveys were conducted on Oak Run Creek.

Related actions that may impede or augment the action: Some solutions depend on additional investigations. Although no IFIM studies have been conducted on Cow Creek, DFG has suggested that 50 cfs (measured at the Millville gauge) be maintained during October. This should provide adequate migration and spawning flows for fall-run chinook salmon until DFG has completed the instream flow studies to evaluate overall needs for migration, spawning, and rearing of anadromous fish.

Agency and organization roles and responsibilities: Additional investigations need to be carried out on all of the tributaries to examine current ownership and the specifics of the water rights. Specific canal maintenance programs need to be identified to minimize water losses. DFG should have primary responsibility for developing an agreement with water users to obtain the necessary flows for fall-run salmon and steelhead. DFG should also have lead responsibility for identifying specific canal maintenance programs. SWRCB should assist DFG in these efforts.

Potential obstacles to implementation: Diverters may oppose the suggested improvements or accepting liability or operation and maintenance costs. A reasonable plan will have to be negotiated between private diverters and responsible agencies to balance legitimate needs of agriculture, power generation, and fishery resources. Efforts to sort out water rights, gage and monitor stream flows, determine instream flow needs, and possibly purchase supplemental water will require funding and agency involvement. Adequate funding and staff must be available to DFG and SWRCB to cover these costs.

Predicted benefits: Obtaining additional fall flows from current water users will significantly enhance attraction, migration, and spawning habitat for fall-run chinook salmon, particularly in dry years. Additional summer flows will enhance steelhead rearing habitat, particularly with other actions taken to improve passage and reduce entrainment (see Actions 5 and 6). Projected benefits would be best addressed after an instream flow study is conducted to determine migration, spawning and rearing needs for all anadromous salmonids.

Action 2: Effectively screen agricultural diversions.

Objective: Prevent loss of juvenile steelhead due to entrainment.

Location: Various agricultural diversions in the tributary watersheds.

Narrative description: Agricultural diversions on Cow Creek are unscreened. The extent to which these diversions entrain juvenile steelhead is currently unknown; however, DFG conducted surveys on various Cow Creek tributaries in 1992 and found that diversions took nearly 50-100% of the available stream flow (Harvey pers. comm.). If the existing steelhead spawning and rearing habitat is enhanced through increased flows and passage improvements, then screening will be necessary.

Related actions that may impede or augment the action: Additional studies will be needed to identify diversions that significantly affect the fishery. Screening should be accomplished where instream flow and passage issues are resolved.

Agency and organization roles and responsibilities: DFG should have primary responsibility for conducting studies to identify diversions that require screening. DFG should also be responsible for identifying screening alternatives to reduce steelhead mortality. USFWS and the NMFS should support DFG.

Potential obstacles to implementation: The cost to screen private diversions will be objectionable to individual owners. This effort would have to find funding for screen installation and maintenance. Adequate funding would also be needed for fish screen design studies and agency involvement.

Predicted benefits: Effectively screening diversions will prevent the loss of juvenile steelhead and subsequently increase production.

Action 3: Improve passage at agricultural diversion dams.

Objective: Improve passage for adult steelhead and increase steelhead spawning and rearing habitat.

Location: Various agricultural diversions from Cow Creek above the valley floor.

Narrative description: DFG has identified several natural structures and agricultural diversions that may be potential migration barriers to adult steelhead (Harvey pers. comm.). Most water diversions in Cow Creek operate from April through October. Some diversions are temporary and may not be migration barriers; however, several diversion structures remain in place throughout the year and limit or impede migrating adults.

Related actions that may impede or augment the actions: Agency efforts have been successful in requiring PG&E to build a ladder at its hydroelectric diversion on South Cow Creek. The Olsen Hydroelectric Project on Old Cow Creek has also constructed a fish ladder.

Agency and organization roles and responsibilities: DFG, acting as the lead agency, should contact all water right holders to determine operating procedures and identify actions to rectify passage problems. Potential solutions include replacing dams with pumps, installing ladders, consolidating diversions, and temporarily removing dams. USFWS should support DFG.

Potential obstacles to implementation: Diverters may oppose suggested solutions for fish passage improvements or operation and maintenance costs. Cost for passage improvements may be prohibitive for private diverters. Alternative funding sources may be necessary for passage improvements. Adequate funding and staff must be available to DFG and USFWS to cover these costs.

Predicted benefits: Improving or providing passage at diversion dams will increase the usable holding, spawning, and rearing habitat for steelhead. Increased production will likely result from improved passage.

Bear Creek -

Limiting factors and potential solutions - Unscreened diversions in the valley reach are thought to be the major limiting factors. Natural flows are often less than the combined rights of the diverters, resulting in a total dewatering of the creek in the valley reach during critical periods for salmon. Table 3-Xb-3 lists limiting factors to salmon and steelhead in Bear Creek and potential solutions.

Table 3-Xb-3. Limiting factors for chinook salmon and steelhead
in Bear Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Flows	1. Provide an alternate source of water 2. Purchase existing water rights from diverters 3. Initiate legal action to provide instream flows
Entrainment	Build and operate fish screens on all diversions

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide adequate instream flows to permit safe passage of juvenile and adult salmon and steelhead at key times of the year.

Location: Bear Creek from the Sacramento River to Bear Creek Falls.

Narrative description: In most years, and particularly dry years, flows in Bear Creek are insufficient and do not allow passage during spring and early fall mostly due to agricultural diversions. Precise volumes necessary for passage have not yet been defined.

Related actions that may impede or augment the action: Cooperative agreements have been implemented on Deer and Mill Creeks to exchange instream flows for groundwater during key times of the year with the intent of refining volumes and timing in future years. Such agreements that provide pumped groundwater in place of diverted stream flows could also be negotiated with the Bear Creek water right holders. Two additional avenues exist to achieve required flows: (1) purchase of an existing water right or (2) legal action.

Agency and organization roles and responsibilities: USFWS, DFG, DWR and water rights holders need to collaborate on solutions for this action to work. DFG should take the lead role to initiate negotiations with the water right holders.

Potential obstacles to implementation: None.

Predicted benefits: Recovery of the fall-run salmon on a sustainable basis requires a consistent guaranteed flow during the key migration periods, late summer and early fall. It is thus anticipated that achieving the specified flows is essential to meeting the specified recovery goals.

Action 2: Build and operate fish screens on all unscreened diversions.

Objective: Prevent losses of migrating juvenile fall-run salmon and steelhead into agricultural diversions.

Location: Sacramento River to Bear Creek Falls.

Narrative description: None of the agricultural diversions on Bear Creek are screened. If adequate flows are acquired, it will then be necessary to screen all remaining diversions during spring.

Related actions that may impede or augment the action: The success of this action depends on acquiring the necessary flows described in Action 1.

Agency and organization roles and responsibilities: DFG, with assistance from USFWS and DWR, should contact the diverters and begin implementing screening.

Potential obstacles to implementation: None.

Predicted benefits: Actions 1 and 2 must be accomplished with the anticipated benefit that salmon runs will return to, or exceed, DFG-estimated production and restoration goals.

Cottonwood Creek -

Limiting factors and potential solutions - Gravel mining on the valley floor has significantly reduced or eliminated available spawning area. In addition, poor land use practices are thought to have resulted in increased water temperatures and siltation and contributed to armoring of previously utilized spawning areas. Table 3-Xb-4 lists key limiting factors for salmon and steelhead in Cottonwood Creek and potential solutions.

Table 3-Xb-4. Key limiting factors for chinook salmon and steelhead in Cottonwood Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Gravel	1. Restrict or eliminate gravel mining in important spawning areas through county zoning or state legislation 2. Rip and clean or reconstruct salmon spawning riffles on the south Fork Cottonwood Creek below Dippings at dam site and on lower Cottonwood Creek below the South Fork
Straying	1. Construct barrier to prevent fall-run chinook salmon from entering Crowley Gulch as the result of attracting flows caused by releases from the ACID
Water temperatures and siltation	1. Establish land use management practices in the watershed to restore and protect riparian vegetation and control erosion 2. Implement revegetation and erosion control program to restore lost riparian areas

Restoration actions -

Action 1: Protect and enhance spawning gravel.

<u>Objective</u>: Increase spawning opportunity.

<u>Location</u>: Valley sections of Cottonwood Creek.

<u>Narrative description</u>: Spawning gravel in the Sacramento River system is a limited resource, and Cottonwood Creek is one of the most important sources. Gravel has been mined in Cottonwood Creek for

many years and has damaged spawning areas and significantly reduced gravel recruitment into the Sacramento River. Two major gravel mines operate on the creek near Interstate 5. Potential regulations to improve stream habitat include confining gravel extraction to off-stream terrace areas and mining only gravel of a size not used by spawners. Because some spawning gravels have become armored or compacted with sediment and unfit for spawning, a program is needed to rip and clean affected spawning riffles and to reconstruct additional riffles where possible.

Related actions that may impede or augment the action: Shasta and Tehama counties have enacted gravel mining ordinances that serve to protect critical spawning areas.

Agency and organization roles and responsibilities: DFG should continue to work with both counties in an effort to stop any new gravel extraction permits from being issued for streams supporting anadromous fish and to improve existing gravel extraction practices. DFG should also take the lead role in implementing spawning gravel rehabilitation where necessary.

Potential obstacles to implementation: None.

Predicted benefits: Reduction of instream gravel mining and rehabilitation of existing spawning riffles will produce long-term benefits to salmon in Cottonwood Creek and protect a valuable gravel source for the Sacramento River.

Action 2: Eliminate attraction flows in Crowley Gulch.

Objective: Eliminate mortalities from stranding.

Location: The ACID's waste gate at Crowley Gulch.

Narrative description: The ACID currently releases excess water into Crowley Gulch through a waste gate. Such releases have attracted adult fall-run salmon into a channel with no spawning habitat, which results in stranding.

Related actions that may impede or augment the action: Construction of a barrier at the mouth of Crowley Gulch will prevent adult entries and stranding.

Agency and organization roles and responsibilities: With support from USFWS and DWR, DFG should take the lead role in working with the ACID on this action.

Potential obstacles to implementation:

Predicted benefits: Eliminating adult mortalities at this site will provide additional fall-run spawners to the system.

Action 3: Improve land use practices.

Objective: Reduce water temperatures to improve holding, spawning, and rearing habitat and reduce siltation and sedimentation of existing spawning gravel.

Location: Mouth to upper end of watershed.

Narrative description: Incompatible land use practices such as overgrazing, road building, timber harvest, and development have resulted in watershed degradation. This degradation is believed to have resulted in increased water temperatures, siltation, and reduced spawning habitat. Regulatory actions need to be taken to control timber harvest, grazing, and road building need to eliminate additional damage to the watershed. In addition, active programs need to be implemented to restore riparian vegetation where necessary.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should investigate and work with responsible agencies and stakeholders to facilitate watershed protection and restoration.

Potential obstacles to implementation: None.

Predicted benefits: Increased salmon productivity will result from decreased water temperatures and improved spawning areas.

Battle Creek -

Limiting factors and potential solutions - Table 3-Xb-5 lists key limiting factors for chinook salmon and steelhead in Battle Creek and potential solutions.

Hydrogeneration development - The primary factor that limits the potential production of anadromous fish above Coleman Powerhouse is stream flow. Bypass flows required by the Federal Energy Regulatory Commission (FERC) project license at PG&E's diversions are only 3 cfs on North Fork and 5 cfs on South Fork (Federal Power Commission 1976). Substantially greater flows will be required for salmon to reproduce successfully. All PG&E's diversions are unscreened and the effectiveness of the fish ladders is unknown. Additionally, the outflow from power generation facilities is generally greater than the creek flow. This causes some fish to stray toward the higher flow, and the fish may become stranded in the event of a powerhouse shutdown.

There is biological justification to implement restoration of Battle Creek on a long-term plan that can be phased in over 20 years. Because the residual populations of spring-run salmon and steelhead are so small, there is no need to immediately increase flows throughout the entire 41-mile stream system. The first phase of the project would confine the anadromous fish to a reach of stream that is large enough to meet habitat requirements of a growing population, yet small enough to increase spawning success by confining the mating pairs to a small enough area where they can find each other. Action 3 describes this initial restoration phase and recommended interim flows.

Agricultural diversions - There are two significant agricultural diversions on the mainstem of Battle Creek: the Orwick and Gover diversions. Only the latter is screened. However, the Gover diversion fish screen is located part way down the ditch and prevents only juvenile entrainment. Adults are often seen spawning in the canal and are presumed to gain access to the area below the screen by jumping over the screen (visual observation, DFG-Redding and USFWS-Coleman National Fish Hatchery (CNFH) and Northern Central Valley Fishery Resource Office).

Barriers to migration - Since the construction of CNFH, natural salmon and steelhead fall-run and late fall-run spawning in Battle Creek has for the most part been limited to the 5.7 miles from the mouth to the hatchery weir. CNFH personnel have expressed concern that substantial spawning of anadromous fish upstream from the hatchery water supply intake could result in disease organisms affecting hatchery production. During 1985-1989, as many as 10,000 fall-run spawners surplus to CNFH's egg-taking needs were released into Battle Creek above the hatchery weir to spawn naturally. Because of concerns for potential disease problems related to decomposing carcasses in the hatchery water supply, which is taken from the Coleman Powerhouse tailrace before the flow returns to Battle Creek, the fish ladders on PG&E's two lowermost diversions (Wildcat on the North Fork and Coleman on the South Fork) were purposely closed precluding migrations into the middle reaches of those streams.

Large boulders in the Eagle Canyon reach of North Fork Battle Creek create a probable barrier to upstream migration of salmon (Payne & Associates 1991a).

Disease control - An additional management consideration with introducing anadromous fish into upper Battle Creek is the increased risk of disease in CNFH. It is also possible to reduce disease risk to the hatchery by sterilizing the effluent from the large number of aquaculture facilities that discharge fish pathogens into upper Battle Creek with a proposed multimillion dollar ozone water treatment system. This system will ultimately facilitate reintroduction of anadromous fish into 41 miles of stream. Until then, hatchery disease risk can be managed by separating the hatchery water supply from the first 17 miles of upper Battle Creek using existing power canals along with some minor modification of the water delivery system for the hatchery. This action provides a low-cost interim action, opening up a 17-mile reach of stream that can support anadromous fish above the hatchery.

Table 3-Xb-5. Key limiting factors for chinook salmon and steelhead in Battle Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Water flow	Increase bypass flows at PG&E diversions to quantities needed to provide near-optimum transportation, spawning, and rearing of anadromous fish
Upstream passage of adults	1. Allow passage at the CNFH weir 2. Modify the barrier in Eagle Canyon 3. Examine fish ladders at PG&E dams for effectiveness particularly during increased flows; modify as necessary
Entrainment	1. Effectively screen Orwick diversion 2. Effectively screen all PG&E diversions within the reach of potential anadromous fish distribution
Straying of adults	1. Effectively screen Gover diversion to prevent adult salmon from entering the ditch 2. Effectively screen tailrace at Coleman Powerhouse
Potential disease problems at Coleman National Fish Hatchery	Install water treatment facilities capable of completely removing disease organisms from the hatchery water supply. As interim solution, install bypass pipe from Coleman Powerhouse Forebay to Coleman Powerhouse tailrace channel

Restoration actions -

Action 1: Treatment of CNFH water supply.

Objective: Eliminate the potential for waterborne disease to adversely affect hatchery production.

Location: CNFH.

Narrative description: Personnel from CNFH have expressed concern that decaying carcasses of spawned-out chinook salmon upstream from the hatchery water supply intake could release disease organisms that might adversely affect hatchery operation. The hatchery water supply treatment should be improved so that it will completely remove disease organisms. Funds for sterilization of the hatchery water supply are currently appropriated through the USBR. Due to the enormous cost of the project, the construction is being accomplished in phases and the project is presently capable of treating only about 25% of the hatchery water supply. The final completion date is uncertain. Achieving the benefits of most other actions are contingent on complete treatment of the water supply. A lower cost interim solution is to deliver disease-free Coleman Canal water to the hatchery by installing a bypass pipe from the Coleman Powerhouse Forebay to the Coleman Powerhouse Tailrace channel that feeds the hatchery (Rectenwald pers. comm., CH2M Hill 1994). This bypass will be used only when the powerhouse is shut down during load rejection.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: USFWS and the USBR should seek budget augmentations or redirection so that the project will be completed in a timely manner.

Potential obstacles to implementation: Funding of the project depends on Congressional appropriations. Attempts to reduce federal budget deficits could delay necessary funding.

Predicted benefits: Providing a disease-free source of water to CNFH will likely increase hatchery survival. Additionally and probably most importantly, implementation of this action will support the endeavor for providing fish passage above the CNFH weir. Providing passage at this point will enable fish to gain access to approximately 41 miles of stream. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 2: Allow passage above CNFH weir.

Objective: Increase available habitat for all salmonid runs and life stages.

Location: CNFH weir.

Narrative description: CNFH operates a weir at RM 5.7 that prevents passage upstream and directs fish into the hatchery. Currently, the weir is in operation from July through March. This prevents passage of nearly all fall-run and late fall-run chinook salmon and steelhead. Substantial superimposition of fall-run redds occurs in years when large numbers of fish return. During extreme high flows, salmon and steelhead are able to swim over the weir to spawn upstream (Coots and Healey 1966). In the late 1980s, fall-run fish were allowed passage above the CNFH weir when production goals were met. Currently, spring- or winter-run chinook salmon that reach the weir from April through June are allowed to pass upstream.

One of the main reasons for denying passage at the weir is to prevent spawned-out carcasses from introducing disease organisms into the hatchery water supply. CNFH diverts water from Battle Creek above the hatchery weir. Currently CNFH is developing facilities for treating its water supply.

Because CNFH is operated to compensate for blocking spawning grounds upstream from Shasta Dam, any partial or seasonal blockage at the CNFH weir for accommodating hatchery operations is an impact of the CVP and as such may require mitigation in accordance with Section 3406(b)(I) under "other impacts" of the CVP. Avoiding any blockage that interferes with the natural production of Battle Creek will reduce the mitigation obligations of the CVP.

Hankin (1991) determined that it is feasible to maintain both natural production and hatchery production in Battle Creek. Once the water treatment facilities are completed, fish should be allowed access to the creek above the weir. All spring-run and winter-run fish should be allowed passage. Passage of fall-run and late fall-run chinook salmon and steelhead should be evenly distributed throughout the run. The time and number of fish to place over the weir should be based on the estimated size of the run returning to the hatchery and hatchery production goals.

Related actions that may impede or augment the action: This action depends on completion of Action 1.

Agency and organization roles and responsibilities: The action will be implemented by USFWS once Action 1 is complete. Action 1 depends on funding to be obtained by the USBR.

Potential obstacles to implementation: Requires funding to complete Action 1.

Predicted benefits: Passage above the weir will provide approximately 41 miles of spawning and rearing habitat for chinook salmon and steelhead. Providing access to additional spawning habitat for fall-run will likely increase production for Battle Creek because it is believed that available spawning habitat below CNFH is utilized at capacity.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species and races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 3: Increase bypass flows at PG&E's hydropower diversions.

Objective: Provide streamflow of sufficient quality and quantity to provide adequate holding, spawning, and rearing habitat.

Location: All hydropower diversions on North Fork and South Fork Battle Creek.

Narrative description: Many different factors are considered when determining instream flow requirements at hydropower diversions, including hydrology, stream temperature, run timing, the relationship between streamflow and physical habitat available to fish, and the impact on power generation. Thomas R. Payne and Associates (1991a) evaluated the relationship between streamflow and physical habitat available to various anadromous fish life-history stages for several reaches of Battle Creek. While the following instream flows are subject to revision based on additional analyses, they are offered as an indication of the magnitude of flows needed to optimize anadromous fish production:

Diversion	Months	Flow (cfs)
Keswick	All year	30
North Battle Creek feeder	September-November	40
	January-April	40
	May-August	30
Eagle Canyon	May-November	30
	December-April	50
Wildcat	May-November	30
	December-April	50
South	May-November	20
	December-April	30
Inskip	May-November	30
	December-April	40
Coleman	September-April	50
	May-August	30

The restoration of anadromous fish in Battle Creek will be implemented in a phased approach. The optimum flows listed above will not be required until the population grows to a size sufficient to utilize all the available habitat. The initial restoration phase in the 17-mile reach between the Coleman fish barrier and Eagle Canyon Dam on the North Fork and Coleman Diversion on the South Fork will require the following interim actions:

1) Eagle Canyon Dam - Release 40 cfs from Eagle Canyon Dam from September 1 to April 1 and 30 cfs the remainder of the year. The source for the release would be all the springs diverted into the canal, plus a small amount of surface flow. Close the fish ladder all year.

2) Coleman Diversion - Release 50 cfs from Coleman Diversion from October 1 to February 1 and 30 cfs for the remainder of the year and close the fish ladder all year.

3) Wildcat Diversion - Close Wildcat Diversion to allow all the spring water to remain in the creek and avoid entraining juvenile outmigrants in the power canal.

4) Coleman Forebay - Deliver canal water to the hatchery through a bypass pipe from the Coleman Power Plant forebay to the plant's outlet (tailrace) channel.

The preliminary engineering cost estimate for the pipeline and work on the hatchery delivery system is $1,000,000. This interim effort would delay the need to install and operate an expensive ozone water treatment plant. This bypass represents a loss of power production with an estimated value ranging from $220,000 to $640,000 per year (including the recommended fish water release), depending on the runoff and power prices. The value of the fall-run salmon production exceeds $700,000 per year based on the commonly accepted median value of $100 dollars per salmon. The spring-run chinook salmon and steelhead production would increase the value of this production 3-10 times, based on existing values and the value of avoiding future listings under the Endangered Species Act.

This action item and actions 6, 7, and 8 are mostly reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. They will, however, be costly in terms of capital construction costs and lost power generation, and PG&E would be expected to resist being saddled with these costs. The Battle Creek Project is licensed by FERC (the present license expires July 31, 2026), which has the legal authority to order that the needed changes be implemented (Article 44 of the license).

Related actions that may impede or augment the action: All of the other actions are required to gain maximum benefit from this action.

Agency and organization roles and responsibilities: DFG, CVRWQCB, USFWS should seek PG&E cooperation in providing improved flows and temperatures below project diversions. If such an attempt should fail, the agencies should petition FERC to reopen the project license and direct the licensee to release the necessary flows.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Inadequate DFG and/or USFWS staff available to pursue and complete the needed regulatory actions.

Predicted benefits: Increased water releases, in combination with Actions 2 and 9, will make available approximately 41 miles of spawning and rearing habitat. The recommended flows will provide sufficient habitat for achievement of the identified restoration goals. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists. Phasing anadromous fish production into the first 17 miles of upper Battle Creek could produce 6,000 fall-run chinook salmon immediately, 1,000 spring-run chinook salmon by 2015, 1,000 steelhead by 2015, and reintroduction of a small population of winter-run salmon by 2015 (Rutter 1901, DFG 1966).

Action 4: Construct rack to prevent adult salmon from entering Gover Diversion.

Objective: Prevent loss of spawning adult fall-run chinook salmon.

Location: Head of Gover Diversion Canal.

Narrative description: The Gover Diversion, creek mile 5.3, is effectively screened part way down the ditch to prevent juvenile salmonid entrainment. However, in some years adult fall-run chinook salmon are observed in the ditch both above and below the fish screen (DFG, USFWS-CNFH, and Northern Central Valley Fishery Resource Office observations). It is believed these fish are able to jump over the fish screen or swim up the channels that convey excessive water back to Battle Creek. Fry produced in the ditch are presumed lost to diversion. A bar rack with openings not greater than 2 inches located at the head of the diversion has been suggested, along with some sort of barrier at the terminus of the waste gates.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG needs to cooperate with the ditch owner to develop an effective means to prevent adult salmon from spawning in the channel. DFG's screen shop in Red Bluff should investigate the site and develop suitable screening. If screening is not feasible, then DFG should discuss other options with the ditch owner such as implementing conservation measures to reduce the ditch flow during the spawning period.

Potential obstacles to implementation: Requires the ditch owner's cooperation.

Predicted benefits: Effectively screening this diversion from adult entry to the canal will prevent adult salmon from spawning in a location where reproduction will not contribute to population maintenance.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 5: Screen Orwick Diversion.

Objective: Prevent straying of spawning adult fall-run chinook salmon and prevent entrainment of juvenile salmonids.

Location: Head of Orwick diversion ditch.

Narrative description: The Orwick diversion, creek mile 7.3, is unscreened and would entrain adult and juvenile salmon if passage is afforded at the CNFH weir. DFG has constructed a screen, and it is ready for placement. However, it has not been installed because of a lack of cooperation by the land owner. Section 6021 of the Fish and Game Code requires the owner of a conduit to grant access for the installation and maintenance of the required screen.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should pursue compliance with the law and complete installation of this screen.

Potential obstacles to implementation: Requires-cooperation by the landowner.

Predicted benefits: Effective screening will prevent adult fish from entering the diversion ditch where any spawning would not be productive and will ensure that juvenile salmonids are not lost to entrainment. This will increase escapement in future years.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 6: Screen tailrace of Coleman Powerhouse.

Objective: Prevent straying of spawning adult chinook salmon and steelhead.

Location: Outfall of Coleman Powerhouse.

Narrative description: Flows released from Coleman Powerhouse are generally greater than flows in the main creek channel above the powerhouse. The tailrace flow attracts upstream-migrating adult salmon where there is limited spawning habit and where the fish or the resulting spawn could be dewatered in the event of a powerhouse shutdown. This occurs only when fish are allowed to pass the CNFH weir.

DFG has constructed an effective barrier on the outfall of a lateral from Gover ditch (near the Riverview Restaurant) that could be used as a model.

This action item, as well as Actions 3, 7, and 8, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. These action will, however, be costly in terms of capital construction costs and lost power generation, and PG&E would be expected to resist being saddled with these costs. The Battle Creek Project is licensed by FERC (the present license expires July 31, 2026), which has the legal authority to order that the needed changes be implemented (Article 44 of the license).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should actively pursue development of the needed barrier through administrative or legal action.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Unavailable DFG and/or USFWS staff to pursue and complete the needed regulatory actions.

Predicted benefits: Implementing this action will prevent the loss of adults due to straying and increase the production in Battle Creek. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979]), and the professional judgment of DFG biologists.

Action 7: Construct fish screens at the PG&E diversions.

Objective: Minimize loss of both adult and juvenile salmonids.

Location: All diversions except those upstream from North Battle Creek Feeder Diversion.

Narrative description: PG&E operates six diversions on Battle Creek within the reach of potential anadromous fish distribution, none of which are screened. Anadromous fish spawning could be expected to occur as far upstream as above North Battle Creek Feeder Diversion (to the Cross Country Canal) on North Fork Battle Creek and South Diversion on South Fork Battle Creek. Contingent on obtaining necessary flows and providing passage at the CNFH weir, these diversions should be screened to prevent the loss of adult and outmigrant salmon and steelhead.

Specific diversions that should be screened are prioritized as follows: 1) Wildcat Diversion, 2) Eagle Canyon Diversion (only if barrier described in Action 9 is modified), 3) Coleman Diversion, 4) Inskip Diversion, 5) South Diversion, and 6) North Battle Creek Feeder Diversion.

This action item, as well as Actions 3, 6, and 8, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. (See the narrative description for Action 6.)

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Screening is the responsibility of PG&E pursuant to Section 5980 et seq. of the Fish and Game Code and Section 18 of the Federal Power Act. DFG and USFWS should actively pursue construction of the needed screens.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Unavailable DFG and/or USFWS staff to pursue and complete the needed regulatory actions.

Predicted benefits: Effective screening will prevent loss of juvenile and adult fish to hydropower diversions. This in turn will increase production on Battle Creek.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 8: Evaluate the effectiveness of fish ladders at PG&E diversions.

Objective: Ensure that fish passage is occurring.

Location: PG&E dams.

Narrative description: All PG&E hydropower diversion dams have fish ladders that are assumed to work. However, the effectiveness of these ladders has not been tested. The current ladders were constructed to operate with the current bypass flows of 3 cfs (North Fork) and 5 cfs (South Fork). The increased flows (Action 3) required to restore anadromous fish production may affect their ability to pass or attract fish under the new flow conditions and their effectiveness will need to be assessed. Ladders that are determined to have poor or no passage should be modified or replaced. PG&E is responsible for the maintenance and operation of the ladders. DFG should monitor passage at the ladders. Ladders needing improvements should be fixed based on priority; those with no passage should be fixed first, beginning downstream and working upstream.

This action item, as well as Actions 3, 6 and 7, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. (See the narrative description for Action 6).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, USFWS, NMFS, and PG&E should jointly inspect and evaluate the effectiveness of the ladders.

Potential obstacles to implementation: None.

Predicted benefits: Assessing the effectiveness of the fish ladders under the new flow regime will aid in determining passage problems. Doing this will enable real time action to resolve such problems. Alleviating passage problems will ensure utilization of holding, spawning, and rearing habitat for steelhead and for fall-, late fall-, winter-, and spring-run chinook salmon. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 9: Improve fish passage in Eagle Canyon.

Objective: Facilitate movement of adult salmon and steelhead to habitat in north Battle Creek in and above upper Eagle Canyon.

Location: Eagle Canyon.

Narrative description: A bedrock ledge and boulders that have fallen from the canyon wall have created a probable barrier to upstream migration of anadromous fish through the Eagle Canyon reach of North Fork Battle Creek (Payne & Associates 1991a).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG stream improvement personnel are planning to modify this barrier.

Potential obstacles to implementation: None.

Predicted benefits: Modification of the barrier will allow access to approximately 8.3 miles of holding, spawning, and rearing habitat.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 10: Examine the feasibility of establishing a spawning population of winter-run chinook salmon.

Objective: Increase the genetic diversity and current habitat of the endangered Sacramento River winter-run chinook salmon.

Location: Above CNFH Weir.

Narrative description: While winter-run are assumed to be extirpated in Battle Creek, an additional population that spawns in this stream would increase the possibility of recovery of the species and reduce the probability of the race becoming extinct. Presently, the entire spawning population depends on habitat conditions in the Sacramento River below Shasta and Keswick dams. During critically dry or consecutively dry years, it is unlikely that Shasta Reservoir will be capable of maintaining or providing the necessary cold water in the river to support winter-run chinook salmon (about 1 in 10 years). This race of salmon will continue to be imperiled by such situations and years of low rainfall and low water storage may delay their recovery. Reintroduction of winter-run chinook salmon into the Battle Creek drainage following implementation of this plan would allow them access to substantial flows in the upper creek. This source of water is capable of protecting incubating winter-run chinook salmon eggs and fry during severe drought years because of the cool water provided by springs in the drainage.

Related actions that may impede or augment the action: All of the other actions are required for this action to succeed at the earliest time possible.

Agency and organization roles and responsibilities: NMFS, USFWS, and DFG, through the winter-run recovery team, would direct such an effort. Implementation would be carried out by USFWS.

Potential obstacles to implementation: None.

Predicted benefits: A successful reintroduction of winter-run chinook salmon into Battle Creek will likely shorten their recovery period and allow delisting earlier than would occur by recovering a single population in the Sacramento River. This action, in concert with the other proposed actions, would increase the winter-run by an estimated 2,500 fish. This estimate is based on the amount of potential spawning substrate in reaches where winter-run salmon would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Paynes Creek -

Limiting factors and potential solutions - Table 3-Xb-6 lists key limiting factors for chinook salmon and steelhead in Paynes Creek and potential solutions. Paynes Creek is primarily limited by instream flow that is directly related to precipitation. Sixteen seasonal diversions also have some impact on flows. Lack of adequate spawning gravel is also a limiting factor, although there are no known gravel extraction projects that would have altered natural recruitment.

Table 3-Xb-6. Key limiting factors for chinook salmon and steelhead in Paynes Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Instream flows	1. Negotiate with diverters to release additional flows at key times 2. Purchase water rights or provide alternate source of water 3. Initiate legal action to provide instream flows
Spawning gravel	Construct spawning riffles and periodically maintain

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide minimum instream flows to improve spawning, rearing, and migration opportunities.

Location: Mouth to upper end of watershed.

Narrative description: In general, flows in Paynes Creek are most affected by the lack of adequate rainfall. Benefits could be achieved by acquiring additional instream water from the seasonal diverters because these are minimal diversions; however, this action, by itself, probably would not significantly improve survival conditions. Paynes Creek is thus likely only an opportunistic resource dependent on natural rainfall conditions.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should seek sources of additional water from diverters particularly in years with moderately low precipitation.

Potential obstacles to implementation: In years with low precipitation, it is likely that fish would not utilize the stream and any additional water supplied by diverters would be insufficient.

Predicted benefits: Consistent and adequate instream flow levels during the early fall and winter should provide the necessary conditions for fall-run salmon production increases. Fish population monitoring will provide data necessary to define IFIM study requirements and other studies deemed necessary to double the populations.

Action 2: Restore spawning gravel.

Objective: Increase spawning potential.

Location: Valley section.

Narrative description: No known gravel extraction projects or major dams have affected the volume or availability of natural spawning gravel. Thus, the addition of gravel and creation of riffles would potentially increase the productive capability of the creek over historical levels.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should assume the role of coordinating the location and placement of additional spawning gravel to enhance the productivity of Paynes Creek.

Potential obstacles to implementation: None.

Predicted benefits: Improve spawning habitat and theoretically increase production.

Antelope Creek -

Limiting factors and potential solutions - Table 3-Xb-7 lists key limiting factors for chinook salmon and steelhead in Antelope Creek and potential solutions. Two diverters, the Edwards Ranch and the Los Molinos Water Company, have water rights for 50 and 70 cfs, respectively. Natural flows are often less than the combined rights of the two diverters, resulting in a total dewatering of the creek below the canyon mouth during critical periods for salmon. The average annual natural flow for 1940-1980, April through October, was 92 cfs.

Flows in Antelope Creek at the valley floor often split into three channels. The result of this split during spring is often insufficient water to support passage for adult and juvenile migration. No clearly defined channel has been identified, although human intervention (water diversions) may partially be the cause of the split (Harvey pers. comm.).

Table 3-Xb-7. Key limiting factors for chinook salmon and steelhead in Antelope Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Agricultural diversions	1. Provide an alternate source of water to Edwards Ranch and Los Molinos Mutual Water Company 2. Purchase existing water rights from diverters 3. Initiate legal action to provide instream flows
Flow split	Define desired channel and construct flow control structure

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide adequate instream flows to permit safe passage of juvenile and adult salmon at key times of the year.

Location: Edwards Ranch and Los Molinos Mutual Water Company diversion dam at the canyon mouth.

Narrative description: During most years, and particularly dry years, flows in Antelope Creek are insufficient to allow passage due, in part, to agricultural diversions. More precise volumes necessary for passage will be defined in future IFIM studies; however, until then, an estimated interim flow of 50 cfs seems reasonable to provide passage (Fisher and Harvey pers. comms.).

Related actions that may impede or augment the action: Cooperative agreements have been implemented on Deer and Mill Creeks to exchange instream flows for groundwater during key times of the year. Such agreements could be negotiated with the Antelope Creek water right holders. Required flows can also be achieved with: 1) purchase of an existing water right or 2) legal action.

Agency and organization roles and responsibilities: DFG should develop cooperative agreements with water right holders to gain access to alternative groundwater for the necessary flows during the critical times of the year. USFWS and DWR should support DFG's efforts.

Potential obstacles to implementation: Funding for wells and cooperation from water right holders are important to the success of this action.

Predicted benefits: Recovery of the spring-run, fall-run, and late fall-run salmon on a sustainable basis requires a consistent minimum guaranteed flow during the key migration periods. It is thus anticipated that achieving the specified flows is essential to meeting the specified recovery goals.

Action 2: Create defined stream channel.

Objective: Reduce infiltration losses and maintain flows to the Sacramento River.

Location: Antelope Creek at the canyon mouth.

Narrative description: Passage problems occur at the point where Antelope Creek splits into three different channels near the canyon mouth. Because of these split channels, much water is lost to infiltration, particularly at key times of the year. Restructuring the streambed for agricultural diversions is thought to have caused and is continuing to contribute to the flow splits. If additional flows are gained as the result of Action 1, it is important that any increases are not lost to infiltration. Two options are channel reconfiguration or construction of a permanent flow distribution structure.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should cooperate with property owners and DWR to develop a solution. Actions that brought about this problem need to be identified and then remedied.

Potential obstacles to implementation: None.

Predicted benefits: Actions 1 and 2 must both be accomplished with the anticipated benefit that salmon runs will return to, or exceed, the baseline production and restoration goals.

Elder Creek -

Limiting factors and potential solutions - Table 3-Xb-8 lists key limiting factors for chinook salmon and steelhead in Elder Creek and potential solutions. The Corning Canal siphon, which crosses Elder Creek just west of Interstate 5, approximately 4 miles from its mouth, creates a barrier to migrating chinook salmon during low to moderate flow conditions. Blocking of adult fall-run chinook salmon by the siphon has been observed on several occasions since 1970. Spawning habitat is limited in the lower reaches of Elder Creek. Fall flows are inconsistent and the available spawning gravel is heavily silted.

The stream channel has been extensively manipulated with flood control levees and bank erosion control projects. The lower stream channel is a Corps flood control project maintained by DWR and Tehama County.

Table 3-Xb-8. Key limiting factors for chinook salmon and steelhead in Elder Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Poor fish passage over Corning Canal siphon	Construct a fish passage structure over the Corning Canal siphon
Limited and heavily silted spawning habitat in lower Elder Creek	Adopt an erosion control ordinance to minimize sediment input and carefully plan and coordinate flood management activities to integrate fish habitat improvements whenever possible

Restoration actions -

Action 1: Construct a fish passage structure over the Corning Canal siphon.

Objective: Improve fish passage for chinook salmon and steelhead.

Location: Corning Canal siphon about 4 miles above the mouth of Elder Creek.

Narrative description: The Corning Canal siphon creates a barrier to migrating chinook salmon and steelhead under low to moderate flow conditions (DFG 1993). Because spawning habitat is limited in the lower reaches of Elder Creek and spawning gravel available there is heavily silted, this barrier probably has a significant impact on chinook salmon production. Construction of a fish passage structure over the siphon is estimated to cost about $250,000 (DFG 1993).

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: DFG, with USFWS support and in cooperation with the water districts that use the Corning Canal, will take the lead in designing and implementing this project.

Potential obstacles to implementation: Before this project can be constructed, an engineering feasibility report and environmental documentation are needed to evaluate this proposal and identify any alternatives. This work requires funding.

Predicted benefits: Improved fish passage in lower Elder Creek is needed to achieve any significant increase in anadromous fish production. No specific estimates of fish numbers are available.

Action 2: Adopt an erosion control ordinance to minimize sediment input into Elder Creek.

Objective: Reduce sediment input into Elder Creek.

Location: Elder Creek.

Narrative description: The stream channel of lower Elder Creek is confined within Corps flood control levees and there has been extensive bank erosion. The channel has been extensively manipulated by flood and erosion control activities in order to maintain channel capacity. Tehama County should adopt an erosion control ordinance to reduce erosion-causing activities and to minimize sediment input. Flood management activities should be carefully planned and coordinated with appropriate agencies (DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control) to improve the existing fish habitat. Specific fisheries habitat restoration projects can usually be included in flood maintenance operations at little additional cost. Because USFWS has recently purchased property near the mouth of Elder Creek, it may be possible to undertake fishery habitat restoration work in conjunction with development of the Middle Sacramento River Wildlife Refuge.

Related actions that may impede or augment the action: With anticipated reductions in state and federal funding it is likely that local government and land owners may play a bigger role in flood management work, such as removal of invasive vegetation or protection of eroding banks. This could make inclusion of fish habitat improvements more difficult.

Agency and organization roles and responsibilities: DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control should work together to make the flood management activities in Elder Creek more fish friendly.

Potential obstacles to implementation: Future agency personnel, local government, and land owners must be willing to work together to minimize fishery impacts of flood management activities.

Predicted benefits: There is significant potential that improved fishery habitat in lower Elder Creek will provide benefits for migrating juvenile salmonids. Maslin and McKinney (1994) found that many minor tributaries of the Sacramento River, like Elder Creek, are used as temporary rearing habitat by juvenile salmonids, which may or may not have been spawned there. Elder Creek is one of those tributaries for which there is anecdotal evidence of historical runs of chinook salmon and steelhead. Elder Creek has few fish today but may have high potential for restoration.

Mill Creek -

Limiting factors and potential solutions - Table 3-Xb-9 lists key limiting factors for chinook salmon and steelhead in Mill Creek and potential solutions. The most immediate restoration objective is to provide unimpaired passage for migrating adults and juveniles in the valley floor reach (DFG 1993). Blockage or delays in fish passage are attributed to insufficient flows in April, May, June, and October of dry years due to naturally occurring low flows and agricultural diversions. Inadequate fish passage conditions occur during high runoff events at Clough Dam and the middle of the three agricultural diversion dams on Mill Creek (DFG 1993).

Spawning habitat for fall-run in lower Mill Creek is limited due to a shortage of high-quality gravel. Additionally, total spawning habitat is reduced by the three dams.

Although poaching has been identified as a potential problem in the spring-run holding areas, there are no specific data as to its impact on Mill Creek. Potential poaching in the upper watershed is being addressed by DFG through a focused law-enforcement and education effort.

Residential development near Los Molinos is encroaching on Mill Creek's riparian corridor and has the potential, through cumulative impact, to significantly degrade the habitat of the lower creek.

Although the quantity and quality of upstream habitat does not appear to be limiting for the restoration of anadromous fish populations at this time, degradation of upstream habitat is evident in some areas. Siltation is primarily a problem in upstream spawning and nursery areas between State Highway 36 and Big Bend (The Resources Agency 1989). In addition to the erosion of naturally occurring land forms in Lassen Volcanic National Park, timber harvesting, grazing, and roads have at times been identified as primary sources of stream siltation (The Resources Agency 1989).

Mill Creek is presently closed to fishing on the valley floor. In the anadromous fish sections above the canyon mouth, it is open to a catch-and-release trout fishery from April through the middle of November.

During 1993, DFG amended its policy of managing a catchable trout fishery within the anadromous sections of Mill Creek to its present policy of excluding catchable trout from anadromous sections of the stream.

Table 3-Xb-9. Key limiting factors for chinook salmon and steelhead in Mill Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Inadequate transportation flows on valley floor	Complete agreements presently under negotiation with water right holders to leave natural flow in stream in exchange for groundwater
Improve passage at Clough Dam	Remove Clough Dam and provide owners with an alternate means of obtaining irrigation water
Land use impacts in upper watershed	1. Preserve the largely pristine character of the upper reaches of Mill Creek through managing the watershed, limiting development, and discouraging public access to spring-run and steelhead holding and spawning areas 2. Complete a comprehensive watershed analysis to assess present land use management practices and identify needed changes
Armored spawning gravel on valley floor	1. Mechanically rip compacted gravel to improve spawning habitat and food producing areas 2. Engineer and construct spawning gravel beds
Degraded habitat on valley floor	1. Work with local government to ensure protective zoning or ordinances for the Mill Creek riparian corridor 2. Restore riparian vegetation along lower Mill Creek

Restoration actions -

Action 1: Improve transportation flows in the valley reach of Mill Creek.

Objective: Ensure that upstream migrating spring-run chinook salmon and downstream migrating juvenile spring-run and late fall-run chinook salmon and steelhead can migrate safely through the lower portion of Mill Creek.

Location: Mill Creek below Ward Dam.

Narrative description: Inadequate transportation flows during critical migration periods (April, May, June, and after October 15) have largely been alleviated due to negotiated agreements between the Los Molinos Mutual Water Company, The Nature Conservancy, water right holders on Mill Creek, and state agencies. Central to these agreements are minimum base flow requirements (approximately 25 cfs) and the flexibility necessary to adapt management of instream flows to fishery needs as identified by on-the-ground personnel. For example, DFG personnel can request flow pulses or higher base flows (up to the entire creek flow) if conditions warrant. The only limitation on providing the additional instream flow is the state's ability to replace the fish bypass flows during the irrigation season with groundwater.

Related actions that may impede or augment the action: Although the existing agreements have been successful in meeting critical flow needs, additional flow provided on a voluntary basis through private water rights would make the existing program more cost effective and efficient. A study to refine flow needs for fish passage is presently being conducted by DFG.

Agency and organization roles and responsibilities: The DWR monitors flow in the creek and operates the project wells. DFG monitors fish populations and passage conditions. Continued cooperation and flexibility in the Los Molinos Mutual Water Company operations is essential to the success of the exchange program.

Potential obstacles to implementation: Participation by agencies and water right holders in contractual arrangements for additional instream flows is voluntary and therefore not guaranteed.

Predicted benefits: This project guarantees spring-run chinook salmon access to upper Mill Creek in dry to critically dry years when instream flows might otherwise be limiting. Unimpeded upstream passage of spring-run will maintain the genetic integrity of this species in Mill Creek. Although the supplemental flows are focused on the restoration of the spring-run chinook salmon population, fall-run adults and downstream migrant late fall-run chinook salmon and steelhead also benefit.

Action 2: Remove Clough Dam.

Objective: Provide unimpaired passage where an existing structure presently obstructs migrating adults under certain flow conditions.

Location: Clough Dam, lower Mill Creek.

Narrative description: At higher flows, the fish ladder on Clough Dam is inadequate and causes significant delays for upstream migrants. The Los Molinos Mutual Water Company could provide an alternate source of water to replace water diverted at the Clough Dam. Delivery of water from the company's system would, however, require the construction of a siphon under Mill Creek. Replacing the dam with a siphon would require the cooperation and approval of the dam's owners.

Related actions that may impede or augment the action: Although a second ladder would help alleviate the problem, the preferred alternative is to eliminate Clough Dam altogether. Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: DFG and DWR should work through the newly formed Mill Creek conservancy to initiate this project.

Potential obstacles to implementation: Until issues related to the removal of Clough Dam are resolved, a second fish ladder on Clough Dam would provide improved passage over a greater range of flows than presently exists.

Predicted benefits: Removal of Clough Dam would provide improved passage conditions for all anadromous salmonids in Mill Creek. Additionally, removal of the dam could result in the restoration of approximately 0.5 mile of fall-run spawning habitat.

Action 3: Protect and restore anadromous salmonid fisheries habitat and preserve the long-term productivity of the upper Mill Creek aquatic ecosystem through cooperative watershed management.

Objective: Identification of restoration priorities and protection of Mill Creek's aquatic ecosystem through cooperative land use management in the upper watershed.

Location: Mill Creek watershed above the Sacramento Valley floor.

Narrative description: Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. For Mill Creek, a comprehensive watershed analysis should first be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices. This information could then be used to assist in setting priorities for improving current habitat conditions and developing alternatives to present land use practices that are detrimental to the long-term productivity of Mill Creek's anadromous fish populations. Measures must be taken to improve management practices on state, federal, and private lands. Ecosystem management from a watershed perspective is the most promising approach to guiding restoration in the watershed and maintaining viable anadromous fishery habitat in upper Mill Creek.

Related actions that may impede or augment the action: Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: To be successful, implementation of ecosystem management will require participation of all major landowners in the watershed and all federal and state agencies involved with managing resources in the watershed. A Mill Creek Conservancy is being formed that could play a large role in this process if it is successful.

Potential obstacles to implementation: Watershed management within the Mill Creek drainage is essentially voluntary and therefore will require the cooperation of all major stakeholders. Agreement on a common goal to protect anadromous fishery habitat is essential before the process can begin in earnest.

Predicted benefits: A coordinated resource management planning process focused on the protection of anadromous fish habitat in the upper watershed will assist in the protection of existing habitat and preserve the long-term productivity of the upper Mill Creek aquatic ecosystem.

Action 4: Improve salmon spawning areas in lower Mill Creek.

Objective: Increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall-run and late fall-run chinook salmon.

Location: Lower 8 miles of Mill Creek.

Narrative description: Some spawning areas in lower Mill Creek are armored with rocks or boulders too large for salmon to move. Often these are locked together by sediment. This project would rip compacted gravel areas on certain riffles to improve spawning conditions and increase food production. In a few selected areas, spawning areas would be engineered and constructed with graded gravel. In some cases, it may be desirable to engineer and construct hydraulic controls to decrease velocities so that suitable-sized gravel can accumulate.

Related actions that may impede or augment the action: Continued operation of the water exchange program identified in Action 1 will enhance the benefit of this proposed action.

Agency and organization roles and responsibilities: DFG and DWR have cooperated in constructing similar projects in Mill Creek in the past and should continue to do so in the future.

Potential obstacles to implementation: Because Lower Mill Creek is entirely located on private property, the cooperation of local landowners will be required for implementation of this project.

Predicted benefits: This project would provide additional spawning habitat for about 1,500 fall-run or late fall-run chinook salmon.

Action 5: Maintain and restore riparian habitat along the lower reaches of Mill Creek.

Objective: Maintain and restore riparian habitat along the lower reaches of Mill Creek to help maintain cool water temperatures.

Location: Lower 8 miles of Mill Creek, Tehama County.

Narrative description: The riparian corridor is integral to maintaining the ecological integrity of the lower creek system. Local land use planning and regulations need to create a buffer zone between the creek and new development. Additionally, state and federal agencies could work with local land owners and land owner groups to restore riparian vegetation.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: A cooperative effort between the USBR, DFG, DWR, and local government has already been instituted that shows promise in defining and implementing a riparian buffer zone for lower Mill Creek. The first step, mapping of existing resources, was initiated by California State University (CSU), Chico, in spring 1994.

Potential obstacles to implementation: Protection of the lower Mill Creek corridor is largely a question of local land use planning, laws, and regulation and therefore is subject to the willingness of local government to address this issue.

Predicted benefits: It is impossible to predict specific increases in fishery habitat or fish numbers due to this project; however, fish survival should increase to the extent water temperatures are decreased in lower Mill Creek and insect drop from streamside vegetation is increased during late spring when downstream migrant salmon and steelhead are passing through the area.

Thomes Creek -

Limiting factors and potential solutions - Table 3-Xb-10 lists key limiting factors for chinook salmon in Thomes Creek and potential solutions.

Land use - Timber harvest, overgrazing, and road building cause excessive erosion and compaction of the soil. Poor land use practices worsened the effects of the 1964 flood that conveyed hundreds of tons of gravel from the head waters to the valley floor (DWR 1982). The flood raised the stream bed in the valley and now much of the water below Paskenta flows subsurface, reducing the amount available for salmon.

In some areas, gravel mining has caused incision of the stream channel (Gard 1994). The stream channel has been incised so greatly as to cause passage problems at the Corning Canal siphon. A similar situation may be occurring at the Tehama-Colusa Canal (TCC) siphon and bridge crossings.

Migration barriers (diversions) - Excessive streambed erosion has exposed the Corning Canal siphon creating a migration barrier under most flow conditions (Gard 1994). Gravel mining adjacent to the siphon is the likely cause.

No major dams exist, but two minor seasonal gravel diversion dams may act as migration barriers; one is located in Paskenta and the other near Henleyville. Several small pumps draw water from the creek. These may also cause predation problems.

Instream flows - As is typical of westside streams, suitable flows for salmon reproduction are occasional at best. Historical records of flows in Thomes Creek reveal that in only 18 of 36 years are flows adequate to support salmon spawning (DFG 1961). Today, this probably occurs less due to the flood of 1964.

Water diverted from the TCC into Thomes Creek has attracted salmon to the creek to spawn, only to have the redds dewatered when diversions ceased (Villa pers. comm.). The TCC was designed with a turnout structure to provide water to Thomes Creek for mitigation of the RBDD. Water was delivered to Thomes Creek via the TCC but not for fishery purposes.

Water quality - Paskenta township has had concerns over the quality of its drinking water and recommends no consumption.

Table 3-Xb-10. Key limiting factors for chinook salmon and steelhead in Thomes Creek and proposed corrective actions.

Limiting factors	Potential solutions
Land use	1. Modify gravel extraction methods 2. Modify timber harvest practices 3. Modify grazing practices 4. Stabilize areas of high erosion

Limiting factors	Potential solutions
Migration barriers	1. Replace Corning Canal siphon 2. Solicit assistance from water diverters
Instream flow	Develop release strategy for the TCC
Water quality	Conduct regular water quality monitoring

Restoration actions -

Action 1: Modify gravel mining methods.

Objective: Improve land use practices.

Location: Gravel mining areas.

Narrative description: As a result of gravel mining operations in Thomes Creek, particularly the Red Bluff/Valley Rock operation located 500 feet downstream of the Corning Canal siphon and the Thomes Creek Rock/Wolf Pit operation located a short distance upstream of Highway 99, the channels have incised 8-13 feet. Today, the top of the existing Corning canal siphon is 3 feet above the streambed elevation (Gard 1994). The exposed culvert is a migration barrier under most flow conditions. Similar effects have been noted at other portions of Thomes Creek, with 10 feet of incision at the TCC siphon, and concerns by California Department of Transportation about channel incision at bridge crossings. Other problems associated with gravel mining include increasing suspended solids, causing passage problems and stranding of fish into extraction pits.

Related actions that may impede or augment the action: If gravel mining persists in the current manner, more structural fixes will be needed in the near future. Therefore, eliminating the causes is essential for correcting the fish passage barriers. The Tehama County Planning Commission is currently in the process of reviewing and modifying gravel extraction permits in Tehama County. More favorable conditions for salmon could be obtained with modified permit regulations.

Agency and organization roles and responsibilities: USFWS and DFG should contact the Tehama County Planning Commission and the DWR.

Potential obstacles to implementation: New regulations will likely incur resistance from the gravel mining companies.

Predicted benefits: Reform in gravel mining practices will prevent future passage problems, reduce entrainment, decrease suspended solids, and keep existing habitat from becoming degraded or lost.

Action 2: Modify timber harvest practices.

Objective: Improve land use practices.

Location: Entire stream.

Narrative description: Erosion caused by timber harvest has caused much damage to the upper watershed (DWR 1982). Logging roads are also of concern.

Related actions that may impede or augment the action: More favorable timber extraction techniques need to be employed to reduce these impacts.

Agency and organization roles and responsibilities: The Mendocino National Forest needs to employ the most ecologically sound timber extraction practices and require private timber harvesters to employ such methods and to remediate any incurred damages.

Potential obstacles to implementation: Cooperation of timber harvesters and enforcement by the U.S. Forest Service (USFS) and the California Department of Forestry (CDF) are necessary for this action to succeed.

Predicted benefits: Reform in timber harvest practices will improve salmon habitat by controlling erosion, increasing riparian habitat, and providing food and shelter.

Action 3: Modify grazing practices.

Objective: Improve land use practices.

Location: Entire stream.

Narrative description: The effects of cattle grazing on salmon are well known (Armour et al. 1994).

Related actions that may impede or augment the action: Cooperative efforts with the Mendocino National Forest would prove beneficial for the improvement of grazing practices on public lands.

Agency and organization roles and responsibilities: Private ranchers in the area should be encouraged to utilize the best environmentally sound grazing practices. DFG, with support from USFWS, should start discussions with local ranchers and provide necessary budgets to fence out cattle and begin restoration actions. Riparian restoration plans may have to be developed for specific ranchers.

Potential obstacles to implementation: The success of this action depends on the cooperation of private ranchers.

Predicted benefits: Improved cattle grazing practices will reduce erosion, improve water quality, and increase riparian habitat.

Action 4: Stabilize areas of high erosion.

Objective: Reduce impacts of previous land use practices and improve habitat.

Location: Entire stream.

Narrative description: Incompatible land and water use practices (overgrazing, deforestation, road building, and gravel mining) in the past have caused serious erosion problems.

Related actions that may impede or augment the action: Success of this action depends on permanent correction and reform of past forest practices described in Actions 1, 2, and 3.

Agency and organization roles and responsibilities: The NRCS, USFS, and CDF should provide the expertise to identify and prioritize specific areas that require rehabilitation.

Potential obstacles to implementation: Appropriate funding is required to accomplish this task.

Predicted benefits: Stabilization of areas having high erosion will reduce siltation and sedimentation of spawning habitat and holding pools. It will also help maintain the riparian corridor, which moderates water temperature and provides food and cover for juveniles.

Action 5: Replace Corning Canal siphon.

Objective: Improve fish passage.

Location: Corning canal crossing (RM 7).

Narrative description: The Corning Canal crossing has been identified as a fish passage problem (Gard 1994). Incision of the stream channel as a result of gravel mining has exposed the once-buried culverts.

Related actions that may impede or augment the action: USFWS's Ecological Services in Sacramento recently completed a Fish and Wildlife Coordination Act Report and supports replacing the siphon. The USBR is responsible for the funding. The project to replace the siphon is currently underway.

Agency and organization roles and responsibilities: Successful implementation of Action 1 is required to stabilize the streambed after the siphon is replaced.

Potential obstacles to implementation: If gravel mining practices are not improved, similar passage problems may evolve.

Predicted benefits: Replacing the Corning Canal siphon will permit fish passage at this point.

Action 6: Minimize diversion barrier usage.

Objective: Improve fish passage.

Location: Henleyville Diversion, Paskenta Diversion.

Narrative description: Two diversions, one in Paskenta and one in Henleyville, were noted in DFG's Anadromous Fish Restoration Program (1993) and may be migration barriers to spring-run chinook salmon and steelhead. It is suspected that these are migration barriers and that spring-run chinook salmon utilize the stream.

Related actions that may impede or augment the action: Spring-run and steelhead probably ascend the creek only in years with high precipitation, and it is unlikely these dams operate during this time.

Agency and organization roles and responsibilities: DFG and USFWS should encourage diversion operators to keep barriers out as long as possible or to allow some method of fish passage and to notify DFG if spring-run chinook salmon are observed. Additionally, DFG should monitor the stream for spring-run salmon.

Potential obstacles to implementation: It should be noted that these are probably problems only in years when adequate precipitation allows spring-run salmon to ascend the creek up to these diversions.

Predicted benefits: Providing passage at these points will aid spring-run and steelhead migration to historical spawning grounds.

Action 7: Develop release strategy for the TCC into Thomes Creek.

Objective: Improve instream flows.

Location: Tehama-Colusa Canal crossing.

Narrative description: The TCC has the potential to supply water to Thomes Creek for spawning salmon but has not been utilized for this purpose.

Related actions that may impede or augment the action: At times water has been supplied to Thomes Creek via TCC and has attracted salmon to spawn in the creek (Villa pers. comm.), but this water has been turned off in the past and redds were left dewatered and fish stranded.

Agency and organization roles and responsibilities: The USFWS, USBR, and DFG should contact the Tehama-Colusa Canal Authority to coordinate development of a water release strategy for the TCC into Thomes Creek. If water is supplied, a minimum flow should be maintained from October through May to ensure survival for all life stages. Until a minimum flow can be determined, 50 cfs should be released. This flow is a professional opinion (Ward pers. comm.).

Potential obstacles to implementation: If it is not possible to maintain a minimum flow, no water should be released during this time period.

Predicted benefits: Developing a water release strategy at TCC will: 1) provide for water needs of salmon and 2) ensure that salmon are not inadvertently drawn upstream to spawn, resulting in stranded juveniles.

Action 8: Conduct regular water quality monitoring.

Objective: Provide suitable water quality.

Location: Entire stream.

Narrative description: Recently, Paskenta township's drinking water source, Thomes Creek, has been declared unsafe, suggesting that water quality may not be favorable for salmon.

Related actions that may impede or augment the action:

Agency and organization roles and responsibilities: DWR or EPA should be contacted to monitor the water quality.

Potential obstacles to implementation: Funding for any water quality improvement projects could be a limiting factor for success of this action.

Predicted benefits: Monitoring water quality will assist in determining point sources of pollution so that remedial actions can be accomplished.

Deer Creek -

Limiting factors and potential solutions - Table 3-Xb-11 lists key limiting factors for chinook salmon and steelhead in Deer Creek and potential solutions. Habitat in the upper watershed is relatively intact, with numerous holding areas and an abundance of spawning gravel. Some spawning areas in lower Deer Creek are lightly armored but could be improved for use by fall-run chinook salmon.

Except for the lack of streamflows on the valley floor below the agricultural diversions, fish habitat throughout the drainage is generally of good quality. Water right holders on Deer Creek have recently expressed interest in cooperating with DFG to develop alternative water sources and to provide flows to meet fishery needs. Water users are concerned about the depleted status of the spring-run chinook salmon and are willing to work toward mutually acceptable solutions to restore the fishery. Flows necessary to provide unimpaired migration for adult salmon and steelhead are not accurately known but are estimated to be about 50 cfs for planning purposes (Harvey pers. comm.). A flow study by DFG is underway to better define these needs.

Inadequate flows for upstream passage is the most significant problem on Deer Creek. During low-flow periods, flows in Deer Creek below the lower diversion dam are, at times, inadequate for fish to pass upstream from the Sacramento River.

Spawning gravel in lower Deer Creek is adequate for present population levels of fall-run salmon. However, gravel rehabilitation at selected sites could increase available spawning habitat and would be needed in order to double spawning populations.

Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. Participants in a cooperative watershed management effort would include state, federal, and county agencies; private land owners; and land owner organizations. A comprehensive watershed analysis should be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices in the Deer Creek watershed. Such information could be used to help set priorities for improving current habitat conditions and to develop alternatives to present land use practices that are detrimental to the long-term productivity of Deer Creek's anadromous fisheries.

Juvenile spring-run chinook salmon and steelhead need protection from possible predation and competition from catchable-sized hatchery rainbow trout stocked in the headwater rearing areas. DFG no longer allows stocking of rainbow trout in the upper 3 miles of rearing habitat. Eliminating this planting location and shifting the trout allotment to above Upper Deer Creek Falls has alleviated any possible conflict between anadromous salmonids and the catchable trout stocking program.

Table 3-Xb-11. Key limiting factors for chinook salmon and steelhead in Deer Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Inadequate transportation flows	Negotiate agreements with water districts and water right holders to pump groundwater at state expense in exchange for leaving up to 50 cfs of natural flow in stream for fish migration
Potential land use impacts in upper watershed	1. Preserve the largely pristine character of Deer Creek through cooperative managing the watershed, limiting development, and discouraging public access to spring-run and steelhead holding and spawning areas 2. Complete a comprehensive watershed analysis to assess present land use management practices and identity needed changes
Armored spawning gravel	1. Mechanically rip compacted gravel to improve spawning habitat and food-producing areas 2. Engineer and construct spawning areas with graded gravel
High temperatures	Negotiate land use agreements with Deer Creek Conservancy to protect existing riparian vegetation along lower Deer Creek and develop programs to restore riparian vegetation
Flood management activity	Plan and coordinate flood management activities carefully with appropriate agencies to integrate fish habitat

Limiting factors	Potential solutions
	improvements whenever possible

Restoration actions -

Action 1: Improve transportation flows in the valley reach of Deer Creek.

Objective: Provide improved flows in the lower 10 mines of Deer Creek to ensure that upstream and downstream migrating juvenile spring-run and fall-run chinook salmon and steelhead can pass over three diversion dams.

Location: Valley reach of Deer Creek.

Narrative description: In dry years, water right holders may divert nearly the entire flow of Deer Creek during the critical migration period of May to early June. As a result, upstream migration of adult spring-run chinook salmon and downstream migration of juvenile salmon and steelhead can be impeded or entirely blocked. If low flows persist in the creek, water temperatures quickly exceed the tolerance range for these species. Supplemental flows will help restore the population of wild spring-run chinook salmon by allowing migrating adults to reach their spawning habitat and by providing transportation flows for the juvenile salmon and steelhead migrating to the Sacramento River.

An agreement, or agreements, will be completed between Deer Creek Irrigation District (DCID), Stanford-Vina Irrigation Company (SVIC), DFG, and DWR. Under the agreements, natural flow that would otherwise be diverted for irrigation would be left in the creek when requested by DFG to aid fish passage during critical migration periods. The DCID diversions would be replaced by groundwater. SVIC would replace diversions partially with groundwater and partially with improvements to its distribution facilities. Up to five wells would be built or refurbished in DCID, and SVIC would build an unspecified number of wells and line some of its canals. Stream hydrology suggests that supplemental flows would be needed about every 3 years.

Agreements to operate this project would be formalized under a long-term (minimum 15-year) contract. The agreements would guarantee the state certain stream flows, on request, but would not modify the water rights of the individuals or agencies. Pumping payment rates and other contract conditions could be renegotiated at the end of the contract, which could extend the agreements indefinitely.

Related actions that may impede or augment the action: Although the existing agreements have been successful in meeting critical flow needs, additional flow provided on a voluntary basis through private water rights would make the existing program more effective. A study to refine flow needs for fish passage is presently being conducted by DFG.

Agency and organization roles and responsibilities: The DWR monitors flow in the creek. DFG monitors fish populations and fish passage conditions. Continued cooperation and flexibility in the operations of DCID and SVIC is essential to the success of the diversions-to-wells exchange program.

Potential obstacles to implementation: Participation by agencies and water right holders in contractual arrangements for additional instream flows is voluntary and therefore not guaranteed.

Predicted benefits: By ensuring access during dry and critically dry years, this action would guarantee spring-run chinook salmon access to about 38 miles of suitable holding, spawning, and rearing habitat every year. Spawning populations of spring-run chinook salmon have declined 90% over the past three decades. Although it is recognized that transportation flows in dry years is only one of many factors that have reduced this population, this action will remove a major uncertainty in the restoration of spring-run salmon in Deer Creek.

Providing adequate transportation flows during spring of dry years would primarily benefit upstream migrating adult spring-run salmon; however, downstream migrant spring- and fall-run chinook salmon and steelhead would also benefit from these flows. The juvenile salmon and trout must be out of Deer Creek by late April or May during dry years to avoid elevated temperatures resulting from low flows.

Although this project is primarily focused on spring-run salmon, flow augmentation in fall of dry years to benefit out-migrating salmon and steelhead smolts would also benefit adult fall-run salmon. Thus, this project provides the potential to improve migration and spawning flows for fall-run adults after October 1 and to increase survival of downstream migrant yearling spring-run salmon and steelhead.

Action 2: Protect and restore chinook salmon and steelhead habitat and preserve the long-term productivity of the upper Deer Creek aquatic ecosystem through cooperative watershed management.

Objective: Reduce the effects of land use practices.

Location: Deer Creek watershed above the Sacramento Valley floor.

Narrative description: Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. For Deer Creek, a comprehensive watershed analysis should first be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices. This information could then be used to assist in setting priorities for improving current habitat conditions and developing alternatives to present land use practices that are detrimental to the long-term productivity of Deer Creek's anadromous fisheries. Measures must be taken to improve management practices on state, federal, and private lands. Ecosystem management taken from a watershed perspective is the most promising approach to guiding restoration in the watershed and maintaining viable anadromous fishery habitat in upper Deer Creek. To be successful, implementation of ecosystem management will require participation of all major land owners in the watershed and all federal and state agencies involved with managing resources in the watershed.

Related actions that may impede or augment the action: Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: To be successful, implementation of ecosystem management will require participation of all major land owners in the watershed and all federal and state agencies involved with managing resources in the watershed. A Deer Creek Conservancy is being formed that could play a large role in this process if it is successful

Potential obstacles to implementation: Watershed management within the Deer Creek drainage is essentially voluntary and therefore will require the cooperation of all major stakeholders. Agreement on a common goal to protect anadromous fishery habitat is essential before the process can begin in earnest.

Predicted benefits: A coordinated resource management planning process focused on the protection of anadromous fishery habitat in the upper watershed will assist in the protection of existing habitat and preserve the long-term productivity of the upper Deer Creek aquatic ecosystem.

Action 3: Improve salmon spawning areas in lower Deer Creek.

Objective: To increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall-run and possibly late fall-run chinook salmon.

Location: Lower 10 miles of Deer Creek.

Narrative description: Some spawning areas in lower Deer Creek are armored with rocks or boulders too large for salmon to move. Often these have become locked together by sediment. This action proposes to rip compacted gravel areas on certain riffles to improve spawning conditions and increase food production. In a few selected areas, spawning areas would be engineered and constructed with graded gravel. In some cases, it may be desirable to engineer and construct hydraulic controls to decrease velocities so that suitable-sized gravel can accumulate.

Related actions that may impede or augment the action: Continued operation of the water exchange program identified in Action 1 will enhance the benefit of this proposed action.

Agency and organization roles and responsibilities: DFG and DWR have cooperated in constructing similar projects in Mill Creek and should be able to continue to do so on Deer Creek projects.

Potential obstacles to implementation: Lower Deer Creek is almost entirely located on private property, and therefore the cooperation of local land owners will be required for implementation of this project.

Predicted benefits: This project would provide additional spawning habitat for about 1,500 fall-run chinook salmon.

Action 4: Maintain and restore riparian habitat along lower reaches of Deer Creek.

Objective: To maintain and restore riparian habitat along lower reaches of Deer Creek to help maintain low water temperatures.

Location: Lower 10 miles of Deer Creek, Tehama County.

Narrative description: Negotiate long-term agreements with the Deer Creek Conservancy and other land owners to protect existing riparian vegetation along lower Deer Creek and develop programs to restore riparian vegetation.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: A cooperative effort between the USBR, DFG, DWR, and local government has already been instituted that shows promise in defining and implementing a riparian buffer zone for lower Deer Creek. The first step, mapping of existing resources, was initiated by CSU, Chico in spring 1994.

Potential obstacles to implementation: Protection of the lower Deer Creek corridor is largely a question of local land use planning, laws, and regulation and therefore is subject to the willingness of local government to address this issue.

Predicted benefits: It is difficult to predict quantifiable increases in fishery habitat or fish numbers due to this project. However, fish survival should increase if water temperatures are decreased in lower Deer Creek and insect drop from streamside vegetation is increased during fall and late spring when downstream migrant salmon and steelhead are passing through the area.

Action 5: Conduct flood management activities.

Objective: Carry out required flood management activities with minimal damage to the fishery resources and riparian habitat of lower Deer Creek.

Location: Lower 5 miles of Deer Creek, Tehama County.

Narrative description: The objective of this action is to plan and coordinate flood management activities carefully with appropriate agencies (DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control) to protect existing fish habitat and to integrate fish habitat improvements whenever possible. DWR is responsible for maintaining flood channel capacity in the valley portion of Deer Creek, which is a leveed flood control project of the Corps. Salmon spawning areas in the lower 5 miles of Deer Creek have been damaged by flood control maintenance activities, when spawning gravel was removed from the stream channel to increase capacity and when spawning riffles were compacted by heavy equipment or simply covered by soil, sand, or silt. In some cases, the stream channel was leveled during this process so that no low-flow channel remained. This made upstream migration by adult salmon difficult or impossible.

More recent DWR flood management activities on lower Deer Creek have successfully increased channel capacity and repaired levee damage, while maintaining a low-flow channel to permit fish passage. Large boulders and stumps were placed to create scour holes and provide resting habitat. Compacted gravel areas on spawning riffles were ripped to improve spawning habitat. A boulder weir was placed across the channel immediately downstream of the Stanford-Vina Dam to restrict flow and raise the water surface about 2 feet. This caused a more favorable water surface elevation at the entrance to the two fish ladders. Specific fisheries habitat restoration or enhancement projects can usually be completed during flood maintenance operations at little additional cost.

Related actions that may impede or augment the action: With anticipated reductions in state and federal budgets, local government and land owners may plan a larger role in future flood management activities, such as limited removal of invasive vegetation or protection of eroding banks on private property. This could make inclusion of fish habitat improvements more difficult. DFG and other agencies should work with local land owners to exclude cattle from the creek channel, especially in important spawning and rearing areas. This will help to maintain the integrity of stream banks as well as protect fish habitat.

Agency and organization roles and responsibilities: DWR, DFG, the Corps, the Reclamation Board, and Tehama County should continue to work together to make flood management projects more fish friendly.

Potential obstacles to implementation: Future agency personnel, local government, and land owners must be willing to work together to minimize fishery impacts of flood management activities.

Predicted benefits: It is impossible to predict specific increases in fisheries habitat or increased numbers of fish due to this project; however, if we can reduce damages due to flood maintenance activities, and perhaps actually increase fishery habitat by these activities, this will contribute measurably to the overall goal of doubling anadromous fish populations in Deer Creek.

Stony Creek -

Limiting factors and potential solutions - Table 3-Xb-12 lists key limiting factors for chinook salmon in Stony Creek and potential solutions.

Table 3-Xb-12. Key limiting factors for chinook salmon in Stony Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Stream channel blocked at the GCID's canal intersection	Install siphon under Stony Creek at intersection
Insufficient water flow for all life stages	1. Adjust management of Black Butte Reservoir 2. Positive operation of the constant head orifice at TCC 3. Reduce diversions 4. Conduct IFIM
Poor spawning habitat	1. Modify gravel extraction permits 2. Add spawning sized gravel 3. Excavate distinct stream channel
High water temperatures for all life stages	1. Excavate discrete stream channel 2. Develop riparian canopy
Entrainment of fish and reduction of instream flow at the constant head orifice	1. Terminate reverse operation 2. Develop replacement sources of water
Insufficient riparian habitat	Develop a plan to establish riparian corridor

Limiting factors	Potential solutions
Potential passage and entrainment at North Diversion Dam	Correct problems associated with fish passage and entrainment
Questionable water quality	Conduct water quality monitoring

Migration barriers

Glenn-Colusa Irrigation District (RM 3) - Major challenges for Stony Creek restoration are fish passage and water flow enhancement at its intersection with the Glenn-Colusa Canal. During the irrigation season, the GCID constructs a gravel levee across Stony Creek at RM 3 as part of the eastern sidewall of the canal. The barrier is usually in place from April through November. It is removed during winter to allow potential high flows to pass down Stony Creek to the Sacramento River. In past years, the barrier has been in place year round, preventing flow to the Sacramento River and hence precluding the movement of salmon into the creek. After the levee is constructed, juvenile salmon that have moved from the Sacramento River into Stony Creek for rearing become stranded in residual pools below the levee or are entrained into the canal above the levee. In spring 1994, the temporary levee was erected in late February and an estimated 5,000 to 10,000 juvenile salmon were left stranded in the creek (Maslin and McKinney 1994). Adult chinook salmon were observed spawning in Stony Creek only once, in 1982, since the GCID's levee has been in place (Reavis 1983). That was in a year with early and above-normal precipitation, when passage at the levee was possible.

Tehama-Colusa Canal (RM 12) - Temporary passage problems may be occurring when water is diverted from Stony Creek to the TCC. During 1992 and 1993, a temporary gravel training dike and diversion dam were created across Stony Creek so that water could be diverted into the TCC (Brown 1994). This causes fish passage problems and reduces flow downstream. Brown (1994) documented resident and outmigrating fish were entrained by this diversion.

The TCC is equipped with a siphon under Stony Creek. Stony Creek water is diverted into the TCC via reverse operation of a constant head orifice. The original purpose of this diversion was to provide water from the TCC to Stony Creek to enhance salmon production as partial mitigation for operation of the RBDD. It is ironic that the constant head orifice is now used to divert Stony Creek water into the TCC. TCC demand for Stony Creek water occurs in spring and fall and is a result of the recent change in operation of the RBDD to facilitate fish passage on the Sacramento River. The gates-closed period for the RBDD has been shortened to 4 months, leaving unmet irrigation demand both before and after.

The USBR has applied for a permanent diversion permit for this site. California Sport Fishing Alliance (CalSPA) filed a protest to this application. As a result of negotiations, CalSPA agreed to withdraw its protest if the USBR met certain conditions. Among these the USBR commitments is the formation of a task force, technical team, and work plan for development of a long-term fish, wildlife, and water use management plan for Stony Creek. The creation of the task force could be a pivotal event in the restoration of Stony Creek.

North Diversion Dam (RM 18) - Potential fish passage problems may occur at the Orland Unit Water Users Association's North Diversion Dam. No fish passage facilities exist at this structure. In a study conducted in 1981-1982, 30+ salmon and redds were observed downstream of the dam, suggesting passage problems (Reavis 1983). Nick Villa (pers. comm.) reports that the North Diversion Dam is a migration barrier under most flow conditions.

Black Butte Dam (RM 24) - Built for flood control in 1967, Black Butte Dam has no provision for fish passage. Secondary uses of Black Butte Reservoir include recreation and water storage for the Orland Unit Water Users Association and the CVP.

Stony Gorge Dam (RM 45) - Stony Gorge Dam, located 45 miles upstream from the Sacramento River confluence, was built with no fish passage facilities. The dam supports irrigation needs of the Orland Unit Water Users Association. Prior to the closing of Stony Gorge Dam, Stony Creek supported "very good" populations of chinook salmon (Clark 1929). Subsequently, the native runs have become extinct. Most of Stony Creek's historical salmon spawning most likely occurred upstream of RM 45.

East Park Dam (RM 63) - East Park Dam is located on Little Stony Creek, 18 miles upstream of Stony Gorge Dam, and has no fish passage structures. Investigations by Kondolf and Swanson (1993) indicate that much of the gravel recruitment to Stony Creek originated from Little Stony Creek.

Instream flow - Ideally, all diversions would be eliminated, allowing the stream to return to a natural state. However, this scenario would be difficult to achieve both politically and economically. It is felt that Stony Creek could contribute to doubling salmon in the Sacramento River system without removal of all dams or diversions. Contributions can be achieved below Black Butte Dam. Regulating water releases from Black Butte Dam and the Tehama-Colusa Canal will aid in ascertaining escapement goals. Considering the artificial nature of the stream below Black Butte Dam, utilization of this structure to enhance the remaining habitat is of utmost importance. A need exists to develop a water release schedule for Black Butte Dam to benefit salmonids, while not infringing on flood control capabilities. Stony Creek would also benefit from supplemental releases from the TCC, and a water release delivery schedule would need to be developed for that structure. Releases need to provide suitable flows for attraction, migration, spawning, incubation, rearing, and outmigration, while ensuring that fish or redds are not left stranded. An IFIM study should be conducted to determine the best flows.

Spawning habitat - Limited usable spawning gravel exists in Stony Creek. The Black Butte Dam precludes the recruitment of gravel to lower Stony Creek, and what remains is being removed or embedded by gravel mining operations. Based on surveys of Stony Creek in the past (Puckett 1969) and more recent informal ones by the USFWS, gravel for spawning is considered very poor but still usable. Additions of spawning-sized gravel to Stony Creek and improvement of gravel mining operations would benefit salmon production.

The creation of a discrete channel below Black Butte Dam would provide the best use of the available water. Historically, the portion of Stony Creek below RM 24 was broad, shallow, and braided (Kondolf and Swanson 1993) and probably did not support salmon spawning consistently. Black Butte Dam now blocks passage to the higher elevations, but it can also provide cooler water and damping of flow extremes to the downstream portion of Stony Creek and thus provide some salmonid habitat. Given time, the proper flow regime will, by itself, create and maintain an appropriate channel; however, this process can be greatly accelerated by the design and excavation of a creek channel.

A single creek channel would alleviate passage problems at various flows; increase water velocity as needed for attraction, spawning, incubation, rearing and emigration; reduce water temperatures; and aid in establishing a riparian corridor.

Diversions

Glenn-Colusa Irrigation District - Potential entrainment of juvenile salmon behind the GCID's levee exists, particularly in wet years. When sufficient creek flows exist, salmonids move up from the Sacramento River to rear in Stony Creek and can be found up to the GCID's canal crossing. Juvenile salmonids become entrained when closing of the levee occurs before they emigrate.

Tehama-Colusa Canal - Resident and outmigrating fish are entrained into the TCC when flows are diverted (Brown 1994). Potential for entrainment exists if salmon spawning were to occur above this point.

North Diversion Dam - Salmon have not been observed above the North Diversion Dam in recent years, so entrainment is unlikely at this time. However, if passage issues are resolved, the potential for entrainment then becomes an issue because this diversion is not screened.

Riparian habitat - Many areas are nearly devoid of riparian vegetation, especially near gravel mining operations. This is apparent at the Highway 32 bridge. In some areas, orchards grow up to the stream margins and cows graze at the stream bank. Some eroded banks have been riprapped. A riparian canopy and streamside vegetation would reduce water temperatures, lower sedimentation, and provide terrestrial insects as an additional food source for juveniles.

Water temperature - High water temperature is a potential limiting factor in Stony Creek for all life stages. Human influence on water temperature should be controlled or minimized to benefit anadromous fish. Human-related activities have reduced the riparian canopy and its associated thermal benefits. Additionally, impoundment of water behind reservoirs elevates water temperature. Reestablishment of a riparian corridor and lower level releases of water from reservoirs will assist in moderating water temperatures.

Water quality - Other factors that limit salmonid spawning and survival include high turbidity, agricultural chemicals run-off, low oxygen levels, and otherwise poor water quality. These issues need further investigation.

Restoration actions -

Action 1: Install siphon under Stony Creek for GCID's canal.

Objective: Provide all life stages of fish passage, and prevent entrainment of juvenile salmonids.

Location: GCID's canal (RM 3).

Narrative description: A major challenge for the restoration of Stony Creek is passage of fish and water flow through the Glenn-Colusa Canal. During the irrigation season, the GCID constructs a gravel levee across Stony Creek at RM 3 as the eastern sidewall of the canal. The barrier is usually in place from April through November. It is removed during the month. In past years, the barrier has been in place year round, preventing flow to the Sacramento River and hence precluding the movement of salmon into the creek. After the levee is constructed, non-natal juvenile salmon that move from the Sacramento River into Stony Creek for rearing become stranded if caught below the levee or entrained to the GCID's canal if above the levee. In spring 1994, the gravel levee was erected in late February and an estimated 5,000 to 10,000 juvenile salmon were left stranded in the creek (Maslin and McKinney 1994). Since the GCID's levee has been in place, adult chinook salmon were observed spawning in Stony Creek only once, in 1982. That was in a year with early and above-normal precipitation, making passage at the levee possible.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should work with GCID to construct a siphon under Stony Creek. The construction of a siphon, including associated structures, is estimated to cost $3.4 million (CH2M Hill 1994). GCID is supportive and desires to pursue this option (Clark pers. comm.).

Potential obstacles to implementation: If funding is not provided, this action may not be possible.

Predicted benefits: Restoration of Stony Creek will not occur without resolution of fish passage and necessary flow releases at the GCID's canal. The success of all other recommendations depends on resolving these two major issues. If they are not resolved, a salmon run cannot be re-established in Stony Creek. In 1982, when fish and water had passage at GCID, 393 adult salmon were estimated to spawn in Stony Creek (Reavis 1983). Potentially 24 miles of salmonid habitat would become available if passage is allowed at this structure.

Action 2: Develop water management release strategy for Black Butte Dam.

Objective: Provide adequate water flows.

Location: Black Butte Dam (RM 24).

Narrative description: Built for flood control in 1967, Black Butte Dam does not include provision for fish passage. Secondary uses of Black Butte Reservoir include recreation and water storage for the Orland Unit Water Users Association. Black Butte Dam blocks access to historical spawning habitat for chinook salmon and steelhead in Stony Creek. Consequently, the only potential anadromous fish habitat is now below the dam. The Corps manages Black Butte Reservoir for flood control. Flood peaks have been reduced to a fraction of pre-dam values (from 70% for Q2 to 25% for Q50) (Kondolf and Swanson 1993).

Related actions that may impede or augment the action: Even though there has been a reduction in peak flow and the duration of flow has increased, releases could potentially have a negative effect on salmon. Prolonged flows at sufficient discharge could attract salmon to migrate up Stony Creek, only to be left stranded when the water is "turned off". Similar situations could occur at any life stage. An IFIM study should be initiated after implementation of provisional salmon restoration flows.

Agency and organization roles and responsibilities: DFG and USFWS must work with the Corps to better manage water releases from Black Butte Dam for salmonids. Historically, an average of approximately 50,000 af is released from Black Butte Reservoir from October to May of each year (Yaworsky pers. comm.). These releases could provide an average daily release of, at least, 150 cfs with higher spikes serving as migration cues. Professional opinions of the staff at the USFWS's Northern Central Valley Fishery Resource Office recommend a daily average of 150 cfs as sufficient flow for attraction, migration, spawning, incubation, rearing, and outmigration. The October to May dates coincide with fall-run and late fall-run salmon spawning and rearing.

Water releases from Black Butte Dam need to be coordinated with those from Stony Gorge and East Park Reservoir.

Potential obstacles to implementation: There should be no major obstacles to implementing this action.

Predicted benefits: A sufficient and timely flow of water in Stony Creek should encourage salmon to utilize the stream for spawning through outmigration. Up to 24 miles of spawning and rearing habitat could be made available.

Action 3: Develop water management strategy for TCC releases.

Objective: Provide adequate water flows.

Location: Tehama-Colusa Canal (RM 12).

Narrative description: Water for Stony Creek could be supplied via the TCC. The TCC was built with a turnout to provide water to Stony Creek for mitigation of fish loss caused by the RBDD (USFWS 1967).

Related actions that may impede or augment the action: Mitigation for the RBDD was to provide water to Stony Creek via TCC, at a minimum of 100 cfs per day and up to 500 cfs per day (USFWS 1967); this mitigation commitment has not been met. On occasion, water has been supplied to Stony Creek via the TCC (Kelly pers. comm.), but it was never intended to benefit anadromous fish in Stony Creek. The amount and timing of release would depend on those releases from Black Butte Dam.

Agency and organization roles and responsibilities: DFG should work with the USBR to develop trades or transfers of TCC water that could be made in an effort to obtain water higher up in the system (i.e., Black Butte Dam).

Potential obstacles to implementation: There should be no major obstacles to implementing this action.

Predicted benefits: Twelve miles of potential spawning habitat could be made available, providing habitat for many additional spawners.

Action 4: Modify gravel extraction permits.

Objective: Provide suitable spawning habitat.

Location: Entire stream.

Narrative description: Gravel mining should cease in Stony Creek. Black Butte Dam precludes the recruitment of new gravel, and mining is removing residual gravel.

Related actions that may impede or augment the action: Mining within the creek should be restricted to May through October, a time when salmon are less likely to be present in the stream. Access would be limited to only a few sites in order to protect the riparian habitat. Permits could be modified with provisions that ensure that gravel from 1 to 6 inches in diameter is left in the stream.

Agency and organization roles and responsibilities: Other sources of gravel for the current mining operations should be sought. Kondolf and Swanson (1993) identified gravel sources in the immediate area. Other potential gravel sources include the heads of reservoirs on Stony Creek or mining laterally to the creek channel. Mining permits could be purchased from extraction companies, or companies could be assisted in relocating operations. Discharge of fine sediments should be regulated with assistance from the Corps.

Potential obstacles to implementation: DFG should work with the permitting agency for gravel removal, the Glenn County Planning Commission, to complete preparation of a management plan for gravel mining aimed at reducing impacts on fish.

Predicted benefits: Reformed gravel mining activities will help to ensure that spawning-sized gravel remains in the stream, sedimentation of existing gravel is reduced, riparian habitat is protected, and moderate water temperatures are attained.

Action 5: Add spawning gravel to the Stony Creek.

Objective: Provide suitable spawning habitat.

Location: Below North Diversion Dam (RM 18), below TCC (RM 12), or other.

Narrative description: Suitable spawning habitat for salmon is lacking in Stony Creek. Black Butte Dam prevents recruitment of new gravel, and mining companies are removing or embedding the existing spawning gravel. Because of this, spawning-sized gravel needs to be placed in the creek. Placement of gravel below the North Diversion Dam is selected because passage at this dam is questionable and any gravel placed above the North Diversion Dam could eventually settle into the reservoir. The last evidence of spawning salmon in the creek was just below the diversion dam, suggesting potential for successful spawning (Reavis 1983). Another option for the placement of gravel is below the TCC. This site is selected because in years that Black Butte Reservoir is unable to supply a sufficient amount of water, diversions could be made from the TCC.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should work with the Glenn County Planning Commission. Permits could be modified to require mines located on the creek to leave gravel of 1-6 inches in the river or provide gravel for reintroduction to the streambeds.

Potential obstacles to implementation: The success of this action depends on the success of Action 4, modifying or eliminating gravel mining in the streambed.

Predicted benefits: Providing spawning-size gravel should increase the usable spawning area and increase the survival of eggs produced in this stream.

Action 6: Develop a distinct creek channel.

Objective: Provide suitable spawning habitat.

Location: From Black Butte Dam downstream.

Narrative description: The creation of a distinct creek channel below Black Butte Dam would provide the best use of the available water for spawning chinook salmon. Historically, the portion of Stony Creek below Black Butte Dam was fanlike, shallow, and braided (Kondolf and Swanson 1993) and probably did not support spawning salmon. With appropriate management of the reservoirs now extant on Stony Creek, this reach could provide spawning and rearing habitat for fall-run and perhaps late fall-run chinook salmon.

Related actions that may impede or augment the action: A distinct creek channel would alleviate passage problems at various flows. Increased water velocities are needed for attraction, migration, incubation, rearing, and outmigration; regulated lower water temperatures are necessary; and the establishment of a riparian corridor is required. Well-defined creek channels exist below Black Butte Dam and in the area of the Highway 32 bridge resulting from the effects of the dam and gravel mining, respectively (Kondolf and Swanson 1993). Nonnatal rearing habitat occurs in the lower 3 miles of the creek (Maslin and McKinney 1994, Brown 1994), and care should be taken to avoid negatively affecting this function.

Agency and organization roles and responsibilities: DFG and USFWS and other appropriate agencies need to coordinate and fund channel restoration. It is an established technology (Rosgen 1991). It would require substantial excavation and revegetation activity within the existing streambed.

Potential obstacles to implementation: Funding, coordination, and cooperation between key organizations and land owners are important to the success of this action.

Predicted benefits: Some of the benefits in developing a distinct creek channel include alleviating some passage problems, moderating water temperatures, enhancing the riparian corridor, sorting substrate, and cleaning gravels.

Action 7: Develop plan to establish riparian corridor.

Objective: Provide suitable water temperature.

Location: From Black Butte Dam to mouth.

Narrative description: A riparian corridor of native vegetation needs to be established. Because of gravel mining operations, many areas along the stream are nearly devoid of riparian vegetation. This is apparent at the Highway 32 bridge. Exotic plant species such as false bamboo have taken over many disturbed areas. In other areas, orchards grow up to the stream margins and cows graze at the stream bank. Eroded banks have been stabilized with riprap. A riparian canopy would help moderate water temperature, control erosion, and increase terrestrial insects for juvenile salmonids. A healthy riparian corridor will also provide diverse habitat and help maintain lower water temperatures. A plan needs to be developed for the establishment of a riparian corridor. Included in the plan should be provisions for protecting existing riparian habitat, planting native species, removing exotic species, developing a distinct creek channel, and modifying Black Butte Dam releases.

Related actions that may impede or augment the action: All of these provisions should be considered for the creek below Black Butte Dam, and some may be worthwhile to consider above the reservoir. The Nature Conservancy has an office near the mouth of Stony Creek and may have an interest in becoming involved. Additionally, land owners need to be educated on the benefits of riparian corridors and how to establish and maintain them.

Agency and organization roles and responsibilities: DFG and USFWS need to develop a comprehensive technical plan to establish riparian corridors and coordinate riparian corridor rehabilitation and acquisition with private land owners.

Potential obstacles to implementation: Funding and available agency staff could be limiting factors in successfully completing this action.

Predicted benefits: Developing a plan to establish a riparian corridor will help moderate water temperatures and enhance and preserve the existing salmonid habitat. The increase of riparian habitat will also benefit other fish and wildlife.

Action 8: Discontinue diversions into the TCC.

Objective: Alleviate passage problems, ensure adequate flows, and prevent entrainment.

Location: Tehama-Colusa Canal (RM 12).

Narrative description: Temporary passage problems occur when water is diverted from Stony Creek to the TCC. During 1992 and 1993, a dam was created across Stony Creek so water could be diverted into the TCC via reverse operation of the constant head orifice. This affects fish passage and reduces downstream flows. Brown (1994) documented entrainment of resident and outmigrating fish by this diversion. This diversion was temporarily permitted for 1992 and 1993. The USBR has applied for a permanent diversion permit. CalSPA protested this application. As a result of negotiations, CalSPA agreed to withdraw its protest if the USBR met certain conditions. Passage problems are likely, and water for attraction, migration, spawning, and rearing of salmonids in Stony Creek is lost. Diverting water into the TCC entrains resident and outmigrating fish and would undoubtedly entrain juvenile salmon.

Related actions that may impede or augment the action: Among USBR=s commitments is the formation of a task force and technical team, as well as a work plan for development of a long-term fish, wildlife, and water use management plan for Stony Creek.

Agency and organization roles and responsibilities: DFG should coordinate the formation of a task force to manage the restoration of Stony Creek. Unmet demand for this seasonal water should be met through other means, otherwise alleviated, or left unmet.

Potential obstacles to implementation: None.

Predicted benefits: Cessation of this diversion would make more water available for fish in Stony Creek, alleviate potential passage problems, and eliminate salmonid entrainment at this site.

Action 9: Correct problems associated with North Diversion Dam.

Objective: Provide fish passage for all life stages, provide adequate flows past dam, and prevent entrainment.

Location: North Diversion Dam (RM 18).

Narrative description: The North Diversion Dam is considered to be a migration barrier under most flows (Nick Villa, DFG, Rancho Cordova, CA, per. comm.). The magnitude of the passage problem needs to be evaluated. A possible mechanism to allow fish passage at the North Diversion Dam would be to raise the gates as early as possible, preferably at the beginning of October. Flow is most critical from October to May, and diversions should be kept to a minimum. Raising the gates would allow fish easier access to additional spawning habitat. If passage problems persist, a fish ladder could then be constructed. If fish do spawn above the North Diversion Dam, the potential for entrainment would exist.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Entrainment could be reduced if diversions were kept to a minimum. DFG should initiate discussions with the USBR to minimize diversions from December until February, the time at which most fry would hatch and then emigrate from this section of the stream. Screening the diversion is also an option that must be evaluated.

Potential obstacles to implementation: None.

Predicted benefits: Potentially, 6 miles of stream will become available for spawning if passage is ensured.

Action 10: Develop plan to assess water quality.

Objective: Ensure adequate water quality for all life stages.

Location: Entire creek.

Narrative description: The water quality of Stony Creek is poor. Toxicants from agricultural runoff, elevated turbidities from gravel mining, and rubbish are just some of the problems.

Related actions that may impede or augment the action: Water quality may be a larger limiting factor than expected.

Agency and organization roles and responsibilities: A plan should be developed to assess water quality and develop solutions. DWR or EPA should conduct an assessment of Stony Creek.

Potential obstacles to implementation: None.

Predicted benefits: Assessing water quality will provide an indication of creek health, identify problems, and define cleanup solutions.

Action 11: Conduct an IFIM study.

Objective: Determine preferred water flows for all life stages.

Location: From Black Butte Dam to mouth.

Narrative description: Management of minimum flow releases from Black Butte Dam are necessary for anadromous fish production.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should conduct an IFIM study to determine the proper amount and timing of water released by Black Butte Dam and the TCC.

Potential obstacles to implementation: None.

Predicted benefits: An IFIM study will estimate the required flows necessary to sustain anadromous fish production.

Big Chico Creek -

Limiting factors and potential solutions -

Loss to flood and agricultural diversion - A significant problem affecting the Big Chico Creek anadromous fishery results from diversions at the M&T Ranch pumps located at the end of a forebay just downstream of the Chico-Mud Creek confluence (Paul Ward, DFG, Red Bluff, and Paul Maslin, CSU, Chico, pers. comms.). The five unscreened pumps at this diversion have a combined pumping capacity of approximately 135 cfs, which often exceeds the creek flow. The resultant reversal of flow in the lower 0.75 mile of creek would be expected to divert outmigrant juveniles and make it unlikely that upstream migrating adults will find the creek. (See discussion under "Upstream passage of adults".) Even when the creek is not reversed, these unscreened pumps are believed to take many juvenile salmon, both from Big Chico Creek and from the Sacramento River, because many juveniles move into the lower ends of Chico, Mud, and Rock Creeks for rearing (Maslin and McKinney 1994). The M&T Ranch has been cooperating in trying to find alternative water and leave the pumps off at critical times (Herringer pers. comm.). However, data obtained by Julie Brown (pers. comm.) and Maslin and McKinney (1994) show that critical times are more extensive than originally thought and vary from year to year.

At the Five-Mile Recreation Area (Bidwell Park), a 1963 Corps flood control project splits Big Chico floodflows into three channels. This project provides flood protection for the city of Chico. Box culverts were designed to limit the maximum flow that can pass down Big Chico Creek and Lindo Channel to 1,500 cfs and 6,000 cfs, respectively. Flow in excess of 7,500 cfs spills over an open weir through the Sycamore Diversion into Mud Creek. DWR is currently investigating whether the high-flow split still meets design capacity. A base flow split was also designed into the 1963 flood control project. The combined width of the box culverts in the Big Chico channel is 20 feet. A low concrete weir, with a 12-foot-wide notch at the same elevation as the bottom of the Chico box culverts, was constructed across the channel leading to the

Lindo Channel box culvert and Sycamore weir. This design was intended to split 12/32 of base flow down Lindo Channel, leaving 20/32 in Big Chico Creek. Unfortunately, design of the flow control structures creates an upstream stilling basin during flood events. This causes gravel to fall out above the diversion, creating a gravel bar that blocks subsequent low flow to Lindo Channel unless gravel is mechanically removed following each high water event. Because of variability in size and shape of the gravel bar, the minimum total flow that still has some spillage down Lindo Channel varies. Lindo Channel has often ceased to flow while total flow was still in excess of 200 cfs, sometimes trapping adults and downstream migrants several times during a single season.

Upstream passage of adults - When flow is reversed in the lower 0.75 mile of Big Chico Creek by The M&T Ranch pumps, upstream migrating adults are unlikely to find the creek. (See discussion under "Loss to Agricultural diversion".)

At about Stream Mile 13, in Upper Bidwell Park, Big Chico Creek has cut through the Lovejoy Basalt into softer marine sandstone, causing jumbles of house-size boulders to tumble into the channel, making upstream passage of salmonids difficult. The Iron Canyon fish ladder, built in the late 1950s to facilitate fish passage through this zone, has been severely damaged (Ward pers. comm.), delaying or preventing upstream migration in low-flow years and thereby forcing the adult spring-run salmon to hold or even oversummer downstream of the ladder where temperatures, human harassment, and poaching are serious problems.

The Five-Mile Recreation Area flood control project also delays or impedes upstream movement of adults. Downcutting (approximately 8 ft) immediately below the Lindo culvert has resulted in fracturing of the concrete apron, making fish passage difficult in situations other than high flows.

Poor spawning habitat in lower creek - The Five-Mile Recreation Area flood control project also impedes gravel movement downstream. Only reduced amounts of relatively small gravel pass the Big Chico box culverts, very little gravel passes through the Lindo box culverts, and no gravel passes over the Sycamore weir. Poor gravel recruitment and absence of flushing flows have resulted in armoring, compaction, and siltation of spawning gravel throughout the Chico channel. Cleaning of One-Mile Pool (a swimming pool in the Chico Channel) during summer low flows creates turbidity and silt build-up downstream, causing further deterioration of gravels. Present downstream siltation levels during pool cleaning exceed standards set up by the CVRWQCB. Lindo Channel is scoured to bedrock from the weir to the Longfellow Bridge, but still has good spawning gravel further downstream. The high flow volume of diverted Chico Creek floodwater has scoured essentially all gravel from Mud Creek downstream of the Sycamore Flood Diversion Channel.

Marginal summer holding temperatures - There is some evidence that temperatures in the summer holding reach for spring-run salmon adults, from Iron Canyon to Higgin's Hole, may approach critical levels in late summer, particularly in low-flow years (Ward pers. comm.). It is not known if summer temperatures currently average higher than existed historically when salmonids were more abundant in the creek. Possibly human-induced changes in the upper watershed (such as logging, development, grazing, and road building) may have altered base flow and summer temperatures. Because holding temperatures are marginal, any human harassment of the adults would be especially detrimental. Currently prime holding areas are in private ownership, with limited access. Future development of the land, resulting in greater public access, could have serious consequences for spring-run chinook salmon in Chico Creek.

Degraded rearing habitat in Mud and Rock Creeks - The principal anadromous fisheries reach of Mud Creek, from Highway 99E downstream, has been straightened, levied, and kept free of riparian vegetation by annual controlled burns or herbicide applications to facilitate its function as a flood diversion channel. Consequently, shade and cover are scarce, contributing to critically warm temperatures in late afternoons from mid-April through early May in most years. The high volume of diverted Chico Creek floodwater has also scoured this reach of Mud Creek to bedrock or clay, prohibiting salmonid spawning and further reducing diversity for rearing. To add to the problem for fish, existing regulations pertaining to riparian protection and waste disposal are poorly enforced with respect to Mud and Rock Creeks. Hazardous materials are often clandestinely dumped from bridges, particularly in Mud Creek, and some land owners along Rock Creek have damaged or eliminated riparian vegetation by bulldozing, burning, or spraying (Maslin pers. comm.).

Rock Creek has not been modified as a flood channel, but in several reaches has been straightened and levied to maximize agricultural land. These straight, canal-like reaches provide far less habitat for rearing salmonids than do unmodified reaches. Rock Creek receives sporadic inputs of agricultural overflow water between Highway 32 and West Sacramento Avenue. Under certain conditions, this may facilitate outmigration of juveniles.

Both creeks dry to intermittent pools as summer approaches. In years with adequate late-season precipitation, this occurs in May, by which time most juvenile salmon have outmigrated. In low precipitation years, the creeks dry down earlier and many young salmon, particularly fall-run juveniles, are trapped in isolated pools and ultimately devoured by avian predators.

Table 3-Xb-13. Key limiting factors for chinook salmon and steelhead in Big Chico Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Loss to flood and agricultural diversion	1. Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps or move the pumps to the river and screen them 2. Split low flows between Big Chico Creek and

Limiting factors	Potential solutions
	Lindo Channel
Upstream passage of adults	1. Repair the Iron Canyon Fish ladder 2. Repair the Lindo Channel weir and fishway 3. Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps or move the pumps to the river and screen them
Marginal summer holding temperatures	Preserve from development and disturbance the primary summer holding area for spring-run chinook salmon to minimize additional stress
Poor spawning habitat in lower creek	1. Replace spawning gravel in the channels modified for flood control 2. Improve cleaning procedure at One-Mile Pool
Degraded rearing habitat in Mud and Rock Creeks	1. Revegetate denuded stream reaches 2. Restore a protected riparian strip

Restoration actions -

Action 1: Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps.

Objective: Prevent loss of juvenile salmonids and permit sufficient attraction flows for adults.

Location: Just downstream of the Chico-Mud Creek confluence.

Narrative description: Four options exist: 1) the pumps could be moved to the river, set up to have bypass flow, and screened; 2) a siphon could be installed to carry Feather River water across Butte Creek and the pumps eliminated; 3) the irrigation water could be replaced with groundwater and the pumps eliminated; and 4) effluent from the Chico Municipal Sewage Treatment Plant, although inadequate for total needs, could be discharged into irrigation canals to supply water needs during low demand periods and to supplement other sources at high demand periods. Because versatility in water delivery systems permits water from the M&T Ranch pumps, Butte Creek, the Feather River, or the Chico Municipal Sewage Treatment Plant to be delivered to a range of users, and because all sources except the sewage plant have their own share of problems with anadromous fisheries, the problem should be approached on a regional basis, rather than a watershed basis. A combination of options 1, 2, and 4 would probably provide the best long-range management for anadromous fisheries in Big Chico Creek, Butte Creek, and the Sacramento River. DFG is currently negotiating with water users to determine the best overall solution. Active pursuit of this negotiation should be continued by DFG, DWR, USFWS, the USBR, the M&T Ranch, and Western Canal Water District (WCWD).

Related actions that may impede or augment the action: Improvement of the pumping situation at the mouth of Big Chico Creek would positively affect all actions that concern Big Chico Creek and its tributaries; therefore, it should be a priority.

Agency and organization roles and responsibilities: DFG is currently negotiating with water users to determine the best overall solution. Active pursuit of this matter should be continued by DFG, DWR, USFWS, the USBR, the M&T Ranch, and the WCWD.

Potential obstacles to implementation: Costs of building a siphon, pumping groundwater, or moving and screening pumps could be an obstacle.

Predicted benefits: The present loss to these pumps of juvenile chinook salmon from both the Big Chico Creek fishery and the Sacramento River fishery would be prevented or at least reduced; Chico Creek adults would have an increased chance of finding the creek. Recent estimates of the numbers of adult salmon entering Chico Creek do not exist, but 26 adults were observed during a spring-run survey conducted in 1993. This number could reasonably be expected to at least double, as Chico Creek historically supported thousands of spring-run, fall-run, and late fall-run chinook salmon (Yoshioka pers. comm.).

Action 2: Repair the Iron Canyon Fish ladder.

Objective: Facilitate movement of adult spring-run chinook salmon and steelhead to favorable summer holding habitat.

Location: Iron Canyon upstream of Salmon Hole (Upper Bidwell Park).

Narrative description: The severely damaged Iron Canyon fish ladder should be repaired. The responsible agency is DFG, which plans to complete this project in summer 1995.

Related actions that may impede or augment the action: This action would be augmented by Action 5 (constructing a fishway at the Lindo Channel box culvert at the Five-Mile Diversion).

Agency and organization roles and responsibilities: DFG plans to complete this project in summer 1995.

Potential obstacles to implementation: Cost of the project may be an obstacle.

Predicted benefits: More rapid movement through this area, particularly in years of low flows, will reduce stress and increase survival of spring-run salmon and steelhead adults.

Action 3: Split low flow between Big Chico Creek and Lindo Channel.

Objective: Minimize trapping and subsequent loss of both adult and juvenile salmonids from periodic dewatering of Lindo Channel.

Location: At the divergence of Big Chico Creek and Lindo Channel.

Narrative description: Two options exist for maintaining a minimum flow down Lindo Channel: 1) existing gates in the Big Chico box culverts at Five-Mile Diversion could be modified to permit operation under hydraulic head and adjusted as needed by city personnel to keep a suitable flow split and 2) city personnel could mechanically remove gravel deposits after each storm event. Because of infiltration losses in both channels at times when groundwater is low, a minimum of 75 cfs should be maintained in Big Chico Creek during March through May to facilitate upstream passage of adults. In critical low-flow years, sufficient water would not be available to maintain flow in Lindo Channel and fish would be lost. Unfortunately, flood control considerations preclude simply cutting off one channel or the other.

Related actions that may impede or augment the action: This action would be augmented by Action 8. If DWR determines the amount of riparian vegetation compatible with flood passage and salmon survival in Mud Creek, this information might be used or modified for Lindo Channel.

Agency and organization roles and responsibilities: The responsible agencies are the City of Chico and California DWR.

Potential obstacles to implementation: The need for gravel removal after storm events may be an obstacle.

Predicted benefits: Because many spring-run chinook salmon and steelhead juveniles and some adults travel by way of Lindo Channel, their survival would be enhanced. Survival of fall-run and late fall-run salmon redds and rearing fry in Lindo Channel would also be improved.

Action 4: Replace spawning gravel in the channels modified for flood control.

Objective: Improve spawning habitat for fall-run and late fall-run chinook salmon.

Location: In both Big Chico and Lindo Channels from the Five-Mile Diversion downstream through the city of Chico.

Narrative description: Gravel trapped at the Five-Mile Diversion stilling basin should be sorted and cleaned if necessary and moved to strategic locations downstream. This action should be executed by the Chico Parks Department and overseen by DFG.

Related actions that may impede or augment the action: This action could be augmented by Action 6 (improving of the cleaning procedure of One-Mile Pool) if gravel from Five-Mile Diversion was added downstream of One-Mile Pool

Agency and organization roles and responsibilities: This action should be executed by the Chico Parks Department and overseen by DFG.

Potential obstacles to implementation: Costs of personnel and equipment required to sort, clean, and move the gravel could be obstacles.

Predicted benefits: Spawning success will be improved for fall-run and late fall-run chinook salmon.

Action 5: Repair the Lindo Channel weir and fishway.

Objective: Facilitate upstream passage of spring-chinook salmon and steelhead from Lindo Channel.

Location: At the Lindo Channel box culvert at the Five-Mile Diversion.

Narrative description: The downstream apron should be regrouted and a fishway constructed.

Related actions that may impede or augment the action: This action would be augmented by Action 3 (splitting flow between Big Chico Creek and Lindo Channel).

Agency and organization roles and responsibilities: Planning and execution of this action should involve a collaboration between DFG, DWR, and the Corps.

Potential obstacles to implementation: Cost of building the fishway could be an obstacle.

Predicted benefits: Fewer adult spring-run chinook salmon and steelhead will be lost in Lindo Channel.

Action 6: Improve cleaning procedure at One-Mile Pool.

Objective: Reduce siltation of downstream spawning and rearing habitat.
Location: One-Mile Dam in Chico.

Narrative description: The following alternative approaches have been presented to the city (Swanson 1994): 1) remove the swimming pool and dam and restore the natural stream and 2) modify the dam and divert stream flow during pool cleaning.

Related actions that may impede or augment the action: None known.

Agency and organization roles and responsibilities: The responsible group for this action is the city of Chico.

Potential obstacles to implementation: Costs of modifying the dam for diversion during cleaning and public protest over removing the pool are potential obstacles to implementation.

Predicted benefits: Spawning success of fall-run and late fall-run chinook salmon would be enhanced because many spawn downstream of One-Mile Dam. Slight improvements in rearing habitat would also be expected.

Action 7: Preservation from development and disturbance of the primary summer holding area for spring-run chinook salmon.

Objective: Obtain title or conservation easement on land adjacent to primary summer holding pools for spring-run chinook salmon. This is especially important considering the marginal summer temperatures and possibility of residential development in those areas. Additional disturbance would cause significant mortality.

Location: Higgin's Hole downstream to the upper end of Bidwell Park.

Narrative description: Preservation can be accomplished by purchase of a conservation easement or purchase of the land.

Related actions that may impede or augment the action: None known.

Agency and organization roles and responsibilities: The USFWS and DFG should collaborate with local land owners and private conservation groups such as The Nature Conservancy in achieving this goal.

Potential obstacles to implementation: Costs of acquiring the land and the landowners's unwillingness to sell are potential obstacles to implementation.

Predicted benefits: This action would have minimum benefit in the immediate future, but is essential for continued long-term production of spring-run chinook salmon and steelhead in Big Chico Creek.

Action 8: Revegetate denuded stream reaches and restore and maintain a protected riparian strip.

Objective: Expand the usable habitat, provide habitat diversity and cover from predators, and shade to keep the water cooler in late spring.

Location: All Central Valley reaches of Rock and Mud Creeks, with special attention given to the reach of Mud Creek from the confluence of Sycamore Creek to the junction of Mud and Big Chico Creeks and the reach of Rock Creek from the Nord-Cana Highway to the Nord-Gianella Road.

Narrative description: Restore and maintain a natural riparian corridor. An educational campaign to dispense knowledge about the value of small tributaries as salmon habitat, coupled with more stringent enforcement of existing prohibitions on dumping and riparian destruction, should help significantly to preserve and restore tributary habitat. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration. Critical stream reaches might be preserved by purchase of conservation easements.

Related actions that may impede or augment the action: This action would be augmented by Action 9 (replacing gravel in the flood-diversion reach of Mud Creek), which would help to increase the overall habitat quality and diversity.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential. DWR will have to determine the amount of riparian vegetation compatible with flood passage and salmon survival in Mud Creek. Butte County must cooperate to allow that amount to remain while maintaining the channel.

Potential obstacles to implementation: Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: Trees, roots, and stumps at the stream edge create eddy currents during flood. The eddies scour out the deep holes the young salmon need for survival in dry years. The trees also shade the stream, contributing to lower stream temperatures, while the roots and fallen branches provide cover for juveniles to escape from predators. Resultant habitat diversity supports many forms of aquatic foods, while terrestrial insects, falling into the water from overhanging vegetation, also contribute to the food base. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration.

Action 9: Replace gravel in the flood-diversion reach of Mud Creek.

Objective: Expand the usable habitat and provide habitat diversity for rearing salmon and their prey.

Location: The reach of Mud Creek from the confluence of Sycamore Creek to the junction of Mud and Big Chico Creeks.

Narrative description: Continual additions of gravel are required to compensate for scouring by the diverted Chico Creek floodwater. Gravel replacement would be necessary after each 10-year or larger flood event.

Related actions that may impede or augment the action: This action could be augmented by Action 4 (removing gravel trapped in the Five-Mile Diversion stilling basin and moving it to strategic locations downstream) if some gravel is placed in the flood-diversion reach of Mud Creek. This action would also be augmented by Action 8 (revegetate denuded stream reaches and restore and maintain a protected riparian strip).

Agency and organization roles and responsibilities: Responsible agencies are Butte County and DFG with supervision from DWR to ensure that flood transport capacity is not compromised.

Potential obstacles to implementation: Costs of continuous maintenance may be an obstacle to implementation.

Predicted benefits: Gravel replacement in Mud Creek would increase habitat diversity for rearing and permit adults straying into the creek to spawn successfully.

Future research needs - Further study is needed to determine if human-induced changes (such as logging, development, grazing, and road building) in the Big Chico Creek upper watershed may have altered base flow and summer temperatures, thereby making it hazardous for oversummering adult spring chinook salmon.

Thermographs have been installed by DFG at strategic points in Big Chico Creek to evaluate holding habitat for spring-run adults. Temperature data needs to be gathered over a number of years, preferably spanning both wet and dry periods.

Considering the paucity of available data for Big Chico salmonids, installation and monitoring of an adult counting device and a trap for outmigrants are needed.

Both Big Chico Creek and Lindo Channel receive storm drain runoff from the City of Chico, with its associated load of litter and pollutants. While this has not been implicated as a problem to the fishery, it should be monitored to ensure that no problem arises.

An investigation of the relationship of foothill diversions to downstream flow volume and water temperature in Mud and Rock Creeks would help with management decisions for those tributaries.

Butte Creek -

Limiting factors and potential solutions - Habitat needs within the Butte Creek system are complex and vary by area and time of year. Passage at dams and diversions, instream flows, and water temperature are the factors of most concern. Water rights in all of Butte Creek above the Western Canal Dam were adjudicated in 1942 (Butte Creek Judgment and Decree No. 18917). Additional issues that are more site specific include poaching, land development, and recreation (Table 3-Xb-14).

Table 3-Xb-14. Limiting factors for chinook salmon in Butte Creek
and potential solutions to those problems.

Limiting factor	Potential solutions
Instream flows	1. Negotiate with PG&E to provide a minimum of 40 cfs below Centerville Diversion Dam at all times 2. Negotiate with water rights holders at Parrott-Phelan diversion (Diversion 50) to purchase or trade for right to water diverted from West Branch of Feather River (approximately 105 cfs), possibly as part of trade for relocation of M&T pumps on Big Chico Creek 3. Purchase existing water rights from diverters 4. Acquire water rights by replacement with Feather River water delivered through the Western Canal system as part of

Limiting factor	Potential solutions
	removal of up to five dams resulting from the proposed Western Canal siphon project 5. Adjudicate water rights and provide state Watermaster Service for the entire reach of Butte Creek on a year-round basis in conjunction with the existing adjudication 6. Initiate legal action to ensure adequate instream flows
Adult passage	
Centerville Diversion Dam	1. Remove Centerville Diversion Dam, Forks of the Butte Dam, and Butte Creek Head Dam 2. Build and maintain ladders over the Centerville Diversion Dam, Forks of the Butte Dam, and the Butte Creek Head Dam
Natural barrier 0.5 mile below Centerville Diversion Dam	1. Build and maintain fish ladder 2. Physically modify barrier to facilitate passage
Durham Mutual Dam	Build new high-volume fish ladder to replace existing ladders
Western Canal Dam	Remove dam and install siphon
Adams, Gorrill, McGowan, and McPherrin dams	1. Remove dam and provide alternate sources of water as part of Western Canal siphon project 2. Build new high-volume fish ladders if dam cannot be removed
Sanborn Slough bifurcation	Establish operational criteria for flow split either through existing legally binding agreements or as part of overall Butte Creek water

Limiting factor	Potential solutions
	right adjudication
White Mallard Dam	Replace existing fish ladder with new high-volume fish ladder
White Mallard Duck Club outflow	Install culvert and riser at the point that the outflow meets Butte Creek to eliminate straying
Drumheller Slough outfall	Rebuild and maintain existing culvert and riser at the point Drumheller Slough meets Butte Creek to eliminate straying
Butte Slough outfall	1. Develop operational criteria to provide continuous passage at outfall gates from February through June and October through December 2. Modify flap gates to allow upstream passage of adult salmon
East-West Diversion Weir Sutter Bypass Weir #2	1. Establish operational criteria for timing and volume of flow splits between East and West Barrows 2. Install high-volume fish ladder 1. Establish operational criteria to specify dates of installation and removal of weir 2. Install high-volume fish ladder
Nelson Slough	Establish operational criteria to specify time and volume of flows through Nelson Slough
Sutter Bypass Weir #5	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder

Limiting factor	Potential solutions
Sutter Bypass Weir #3	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder
Sutter Bypass Weir #1	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder
Juvenile Passage	
Durham Mutual Dam	Install fish screens on both diversions
Western Canal Dam Adams, Gorrill, McGowan, and McPherrin dams	Remove dam and install siphon 1. Remove dams and provide alternate sources of water as part of Western Canal siphon project 2. Install fish screens on gravity and pumped diversions if dams cannot be removed
Little Dry Creek pumps	Install fish screens
Sanborn Slough bifurcation	Install fish screen
White Mallard Dam	Install fish screen
Butte Slough outfall gates	Maintain positive flow into Sacramento River from October through December and January through June

Limiting factor	Potential solutions
Sutter Bypass, Butte Slough to Sacramento River	Investigate and screen diversions as necessary
Poaching	Increase enforcement effort throughout portion of Butte Creek accessible to anadromous salmonids
Land Use	1. Develop and enforce land use plans that create buffer zones between the creek and development 2. Develop watershed management plan

Restoration actions - The following action items are generally prioritized relative to their overall value for restoring habitat and enhancing anadromous fish production. Those actions having the same primary number configurations are considered of equal priority (e.g., ***1***[a] vs. ***1***[b]). Those actions having the same primary numbers and subletters (e.g., ***3[a]***[1] and ***3[a]***[2]) are also of equal priority. The subnumerals (e.g., 3[a]***[1]*** and 3[a]***[2]***) are meant to act only as action identifiers, not indicators of priority. However, differences in primary numbers and/or subletters are indicative of differences in relative priority (e.g., ***1***[a] vs. ***2***[a] or 3***[a]***[1] vs. 3***[b]***[1]). Many action items are interdependent and could therefore change in priority, depending on completion of other actions or additional information.

Action 1(a): Obtain rights to approximately 105 cfs of water from Parrott-Phelan Diversion.

<u>Objective</u>: Provide adequate instream flows for all life stages of salmonids.

<u>Location</u>: Parrott-Phelan Diversion.

<u>Narrative description</u>: Flow requirements within the Butte Creek system are a generic problem; however, they must be considered relative to site-specific requirements within the overall system and also by changing conditions during the year. There are generally no baseline studies to define fishery flow requirements within Butte Creek. The value of any additional water is increased by its location in the system. Additional water to increase instream flows includes a possible trade of rights to waters diverted by PG&E from the West Branch of the Feather River for power generation. The rights are currently owned by M&T and Parrott Ranches near Chico; however, alternate sources of water may be available as the result of a possible relocation of the M&T pumps, currently located on Chico Creek. Relocation of the M&T pumps, coupled with an increased capacity, would allow about 105 cfs of West Branch Feather River water to remain in Butte Creek. Rights acquired at the top of the anadromous portion of Butte Creek, such as the rights to

water diverted from the West Branch, are more valuable in resolving the overall issue than those that enter further down in the system.

Related actions that may impede or augment the action: DFG currently has an application before the SWRCB's Division of Water Rights to convey some recently acquired water rights from above the Western Canal to the Sacramento River. The water rights in priority, time, and volume generally are not available during the period most important for fishery needs. However, an important issue could be resolved relative to changing the point of use to the Sacramento River.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS should plan and carry out baseline studies to define fishery flow requirements within Butte Creek. They should define base fishery flows by location and time of year and acquire rights to the defined amounts. Passage of the required amounts of water through the system to the Sacramento River must be guaranteed.

Potential obstacles to implementation: Success of this action depends on obtaining the necessary funding and staffing resources and cooperation of the many water right holders.

Predicted benefits: Providing additional water will increase the amount of available habitat for all life stages of salmonids, thus increasing the productivity of the creek.

Action 1(b): Maintain a minimum 40 cfs instream flow below Centerville Diversion Dam.

Objective: Provide suitable holding, spawning, and rearing habitat.

Location: Centerville Diversion Dam.

Narrative description: Temperature modeling and IFIM studies have been completed by PG&E to define flow requirements for summer holding and spawning for spring-run salmon in the reach between the Centerville Diversion Dam and the Centerville Powerhouse. These studies indicated a need for a minimum of 40 cfs for summer temperature control and a minimum of 40 and 30 cfs for spawning and egg incubation, respectively (Steitz pers. comm.). As a result of these studies and additional negotiations with the resource agencies, FERC adopted in January 1992 a 40-cfs minimum flow between December 15 and October 31 and a 30-cfs minimum flow between November 1 and December 14 during normal water years.

During dry years, however, the FERC license adequately addresses only summer flows (40 cfs minimum between June 1 and September 15) with a low 10-cfs minimum required the rest of the year. This 10-cfs minimum is considered inadequate for adult spawning and juvenile rearing. Therefore, a flow regime similar to that required for normal water years should also be required for dry years.

Related actions that may impede or augment the action: In several recent dry years, PG&E has accommodated resource agency requests to provide additional flows (up to 30 cfs) for salmon spawning and egg incubation. These actions suggest that PG&E recognizes the need for additional minimum flows during dry years and may be open to further negotiations on this issue.

Agency and organization roles and responsibilities: DFG and USFWS should open negotiations with PG&E and FERC to obtain the necessary minimum flows needed to sustain adult spawning and juvenile rearing below the Centerville Diversion Dam during dry years.

Potential obstacles to implementation: PG&E is already providing nonmandated flows (30 cfs during dry years after September 15) and may be reluctant to provide these flows on a permanent legally binding basis.

Predicted benefits: Providing suggested water releases will ensure better holding and spawning conditions for spring-run chinook salmon. Additional benefits will also be afforded to rearing juvenile salmon and steelhead.

Action 1(c): Purchase existing water rights from diverters.

Objective: Ensure adequate instream flows.

Location: Any or all points of diversion.

Narrative description: Additional instream flow could come from purchasing water rights from willing sellers. Several water rights holders have expressed interest in selling. Additional water might be available through the Western Canal system and could potentially be acquired as a trade for other waters delivered through the SWP and Oroville Reservoir. When purchasing water, consideration should be given to site-specific requirements within the overall system and changing conditions during the year.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should initiate negotiations with water rights holders to purchase their water.

Potential obstacles to implementation: Success of this action depends on necessary funding and the cooperation of water rights holders.

Predicted benefits: Any additional water obtained will benefit the system by increasing the available salmon and steelhead habitat. Obtaining water higher up in the system will have greater benefits to the entire system.

Action 2(a): Build a new high-volume fish ladder at Durham Mutual Dam.

Objective: Provide adequate passage for adult salmonids.

Location: Durham Mutual Dam.

Narrative description: Durham Mutual Dam is a concrete-base, seasonally installed flashboard structure. Erosion below the dam now makes passage a problem under other than the highest flows. There are presently two existing fish ladders, only one of which is capable of passing fish under all flows. Diversions at this site occur throughout the entire year.

Related actions that may impede or augment the action: Potential for Western Canal siphon project to increase diversion amount at this site.

Agency and organization roles and responsibilities: DFG should assist the Durham Mutual Dam operators in developing means for better fish passage.

Potential obstacles to implementation: Improving fish passage could be too costly.

Predicted benefits: Recovery of salmon and steelhead on a sustainable basis requires adequate spawning and rearing habitat. Expedited passage at this site will reduce delays and injury and provide a significant benefit.

Action 2(b): Install fish screens on both diversions at Durham Mutual Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Durham Mutual Dam.

Narrative description: Durham Mutual Dam is a concrete-base, seasonally installed flashboard structure. Diversions at this site occur throughout the entire year. Neither of the diversions at this site is screened.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should coordinate design and placement of necessary screens at this diversion.

Potential obstacles to implementation: Cooperation of dam owners is necessary for this action to be successful.

Predicted benefits: Screening this diversion will prevent loss of juvenile salmon and steelhead from entrainment and will likely increase production from the creek.

Action 3(a)(1): Develop and construct Western Canal siphon.

Objective: Eliminate adult passage and juvenile entrainment problems associated with five dams and obtain additional instream flows.

Location: Western Canal Dam.

Narrative description: WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season of April-August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal. WCWD has proposed to remove its dam and install a siphon under Butte Creek. The WCWD completed a conceptual design study in 1992 and is currently proceeding with an additional feasibility level investigation of the potential to include removal of Adams, Gorrill, McGowan, and McPherrin dams as part of the project.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, the USBR, and DWR should be involved with this activity and provide any assistance the WCWD needs to complete its feasibility study and project approval. Interaction by the agencies at this stage may be critical to the proposal's successful implementation.

Potential obstacles to implementation: Without agency support, it is possible that the proposal would not be feasible based on costs or future water needs.

Predicted benefits: Construction of this siphon and removal of the four additional dams will eliminate several passage and entrainment problems.

Action 3(a)(2): Investigate the possibility of consolidation or replacement of additional diversions below the Western Canal siphon project.

Objective: Eliminate adult passage and juvenile entrainment problems and potentially obtain additional instream flows.

Location: Entire stream.

Narrative description: There are numerous diversions below the proposed Western Canal siphon project that could potentially be consolidated or removed.

Related actions that may impede or augment the action: The approval of WCWD's feasibility study (previously described for Action 3[a][1]) to remove its Western Canal Dam may provide the opportunity and impetus to develop alternative water sources or to remove additional downstream diversion dams.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, together with dam owners, should initiate an investigation to identify the possibility of developing alternate water sources or conveyance methods. Potential alternatives might include consolidation of diversions, transfers from other watersheds, utilization of groundwater or installation of screened pumps.

Potential obstacles to implementation: The success of this action depends on cooperative efforts with the dam owners.

Predicted benefits: Elimination of diversions will immediately benefit adult and juvenile passage and may potentially provide additional instream flows.

Action 3(a)(3): Acquire water rights as a part of the Western Canal siphon project.

Objective: Obtain adequate instream flows.

Location: Western Canal Dam.

Narrative description: There should be an investigation of the possibility of acquiring additional water rights as a part of the Western Canal siphon project supplement to Actions 1(a) and 1(c). Previously, DFG acquired right to 60 cfs of excess Butte Creek flows below the Western Canal Dam. The 60-cfs DFG fish flows are available only after 462 cfs are supplied to priority right holders. Generally, during most critical periods for salmon passage of both adults and juveniles, far less than 462 cfs of the natural flow of Butte Creek remains, thus making DFG's water right of little practical value.

Related actions that may impede or augment the action: This action is supplementary to Action 1(b).

Agency and organization roles and responsibilities: DFG, the USBR, DWR, and USFWS should initiate this study in cooperation with water right holders. This activity should be closely integrated with ongoing feasibility studies looking at removal of Western Canal Dam.

Potential obstacles to implementation: Lack of dedicated staff and funding could limit the success of this action.

Predicted benefits: Additional instream flows will provide immediate benefits by increasing available habitat for all life stages of salmonids.

Action 3(b)(1): Adjudicate water rights and provide watermaster service or equivalent for entire creek.

Objective: Ensure adequate instream flows.

Location: Entire creek.

Narrative description: Adjudication of the creek below the Western Canal would be beneficial in maintaining adequate instream flow.

Related actions that may impede or augment the action: Butte Creek is currently adjudicated in the reach above the Western Canal (Butte Creek Judgment and Decree No. 18917). Watermaster service is currently provided from April through September from the headwaters to the Western Canal under the original adjudication.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS should initiate actions to provide watermaster service or the equivalent, such as a water supervisor, in the entirety of Butte Creek to cover the entire year.

Potential obstacles to implementation: This action would probably involve much negotiation among water users and possible litigation and would be very costly.

Predicted benefits: Watermaster service resulting from adjudication, or its equivalent, such as a water supervisor, would serve to protect instream flows for the rest of the creek and for the rest of the year. Maintenance of defined instream flows throughout the entire creek will significantly benefit migratory salmonids.

Action 3(b)(2): Remove Western Canal Dam and replace with siphon.

Objective: Expedite adult passage, eliminate straying of adults, and prevent entrainment of juveniles.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. Passage over the foundation with the dam not installed is somewhat restrictive, although large rocks have been used to stabilize downstream erosion. A single fish ladder is operational, although it is thought to be marginally effective as the result of size and volume of flow. The diversion is also unscreened. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal.

Related actions that may impede or augment the action: This action is related to the success of Action 3(a)(1), which is a higher priority action. If Action 3(a)(1) does not evolve, then this action takes precedence.

Agency and organization roles and responsibilities: The success of this action depends on cooperative efforts with WCWD.

Potential obstacles to implementation: Costs and staff resources could be the major limiting factors.

Predicted benefits: Recovery of salmonids on a sustainable basis requires access to adequate spawning and rearing habitat. Expedited adult salmon passage at this site will reduce delays and injury and provide a significant benefit salmonid production. Additionally, prevention of juvenile entrainment will also benefit production.

Action 3(b)(3): Establish operational criteria for Sanborn Slough Bifurcation.

Objective: Provide better passage for adult salmonids and prevent entrainment of juveniles.

Location: Sanborn Slough dam.

Narrative description: Flow splits at the Sanborn Slough Bifurcation Structure may cause delay and or stranding of juvenile and adult salmonids. The existing Sanborn Slough structure is an earthen cobble dam with two large gated culverts installed across the main channel of Butte Creek. Operational responsibility for the structure is unclear, although there is a loose arrangement between the duck clubs and agricultural users to provide diversions to meet the respective needs by time of year. In addition, Reclamation District 1004 has an open application to appropriate additional Butte Creek waters that specifies operational criteria at this site. Depending on time and flows, this site may be a major barrier to adult migration and could divert significant numbers of juveniles into the Butte Sink.

Related actions that may impede or augment the action: If Actions 3(a)(1-3) are successful, the flow issues would be resolved. However, fish passage issues must still be addressed.

Agency and organization roles and responsibilities: DFG, with USFWS support, should lead an effort to bring together involved parties and develop operational criteria for flow splits, either through legally binding agreements, or as a part of an overall Butte Creek water right adjudication (Action 3[b][1]).

Potential obstacles to implementation: Cost and complexity of water right issues can slow this action.

Predicted benefits: Developing operational objectives will reduce or prevent entrainment and expedite passage of juvenile and adult salmon and steelhead.

Action 3(c): Develop operational criteria for, and potential modification to, Butte Slough outfall.

Objective: Provide sufficient attraction and passage flows for adults and outmigration flows for juveniles.

Location: Butte Slough outfall and Sutter Bypass.

Narrative description: The Butte Slough Outfall gates and the effects of the flow split into the Sutter Bypass may be causing passage problems due to insufficient attraction flows and due to the gates acting as a physical barrier. Potentially, a regulated flow split will be required to provide passage through both systems during the period when anadromous fish might be present.

Butte Slough outfall gates are controlled by DWR and Reclamation District 70 based on flood and agricultural needs. Flood needs are generally met by balancing flows between the Sacramento River and Butte Creek utilizing the gated culverts at the end of Butte Slough. Agricultural needs generally are met by completely closing these gates and routing all Butte Creek flows through the Sutter Bypass. The change in operation frequently occurs in the early spring at a time when adult spring chinook salmon would be migrating past the mouth of the Feather River, with the net result that attractant flows into Butte Creek would be changing in volume and point of entry between Butte Slough outfall and Sacramento Slough. Fish that would be attracted up the Sacramento River to attempt to enter Butte Creek via the Butte Slough outfall gates have an obstacle of unknown magnitude in the form of the flap gates on the Sacramento River side of Butte Slough culverts. In addition, changing flow regimens through the Sutter Bypass could serve to delay or prevent migration into upper Butte Creek. Operational objectives should be developed that provide continuous passage at the outfall gates from January to June and October through December.

Related actions that may impede or augment the action: Upstream adult fish passage issues must still be addressed.

Agency and organization roles and responsibilities: DFG should take the lead in supporting Action 3(c) and incorporating appropriate flow passage needs either at the Butte Slough outfall gates or the Sacramento Slough. If flows are designed for fish upstream entry at the Butte Slough outfall, DFG, with USFWS support, should design and construct adult upstream passage facilities in conjunction with the gates that would be operational at high- and low-flow levels.

Potential obstacles to implementation: Necessary flows for fish passage at the Sacramento Slough entry and costs for a fish passage facility at this location can be high.

Predicted benefits: Developing and implementing operational criteria and potential modifications to the flap gates will facilitate movement of adult and juvenile salmon and steelhead and potentially significantly improve production.

Action 4(a)(1): Build new high-volume fish ladder at Adams Dam.

Objective: Improve adult fish passage.

Location: Adams Dam.

Narrative description: Adams Dam is a concrete-base, seasonally installed flashboard type structure. Severe erosion below the dam has resulted in significant passage problems for adults at low flows with the dam removed. The existing fish ladder is operational only with the dam installed and is extremely inefficient due to the size of the ladder, volume of water, and ineffective ladder entrance. If the Western Canal siphon project is not completed or Adams Dam is not included, Adams Dam should be modified.

Related actions that may impede or augment the action: Adams Dam has been identified for possible removal if the Western Canal siphon project is completed and an alternate conveyance system for a source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: None.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 4(a)(2): Install fish screens on both diversions at Adams Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Adams Dam.

Narrative description: Adams Dam is a concrete-base, seasonally installed flashboard type structure. Neither of the diversions at Adams Dam is screened, which would be a necessity only if dam was not removed as part of the Western Canal siphon project (Action 3[a][1]).

Related actions that may impede or augment the action: Adams Dam has been identified for possible removal if the Western Canal siphon project is completed and an alternate source of water and conveyance system can be identified.

Agency and organization roles and responsibilities: If the Adams Dam remains, DFG should develop contingency plans to design screens and upstream passage facilities in conjunction with the dam operators.

Potential obstacles to implementation: None are anticipated at this time.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(a)(3): Build new high-volume fish ladder at Gorrill Dam.

Objective: Improve adult fish passage.

Location: Gorrill Dam.

Narrative description: Flows below Gorrill Dam are a significant passage issue during late spring and early fall. Late-arriving spring-run and early arriving fall-run chinook salmon are affected by ineffective passage at this site. Gorrill Dam is a concrete-base, seasonally installed flashboard structure. As with all the other diversion dams, erosion below the structure has caused significant passage problems for adult salmon. The existing structure has a low-flow center ladder that is marginally passable with the dam out. When the dam is installed, a second ladder is operational, although it is probably marginally effective as the result of size, volume of flow, and ineffective entrance characteristics.

Related actions that may impede or augment the action: Gorrill Dam has been identified for possible removal as part of the Western Canal siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a fish ladder would probably be delayed until a decision has been made regarding the removal of Gorrill Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 4(a)(4): Install fish screens on diversions at McGowan Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: McGowan Dam.

Narrative description: McGowan Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Basin Wildlife Area. Past operation of the diversion was generally restricted to March-September. With the change of usage to wildlife, the diversion will potentially be operated on a year-round basis depending on flow conditions in Butte Creek. McGowan Dam is a concrete-base, seasonally installed flashboard type structure. Diversions from this site are unscreened and include one large gravity diversion and two or more small pumped diversions.

Related actions that may impede or augment the action: McGowan Dam has been identified for possible removal as part of the Western Canal siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of McGowan Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(a)(5): Install fish screens on three diversions at McPherrin Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: McPherrin Dam.

Narrative description: McPherrin Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Sink Wildlife Area and others. As with the McGowan Dam, past operation was generally restricted to March-September. Acquisition of the wildlife area has resulted in a year-round operation dependent on flow conditions in Butte Creek. The dam is a concrete-base, seasonally installed flashboard structure. Three major gravity diversions and several pumped diversions are unscreened.

Related actions that may impede or augment the action: McPherrin Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the gravity and pumped diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made regarding the removal of McPherrin Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(b)(1): Install fish screens on both diversions at Western Canal Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. The diversion is also unscreened. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January.

Related actions that may impede or augment the action: Western Canal Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of Western Canal Dam.

Predicted benefits: Prevention of juvenile entrainment will benefit production.

Action 4(b)(2): Build new high-volume fish ladder at Western Canal Dam.

Objective: Provide better adult fish passage.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. Passage over the foundation with the dam not installed is somewhat restrictive, although large rocks have been used to stabilize downstream erosion. A single fish ladder is operational, although it is thought to be marginally effective as the result of size and volume of flow. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October-January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal.

Related actions that may impede or augment the action: Western Canal Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made about the removal of Western Canal Dam.

Predicted benefits: Recovery of salmonids on a sustainable basis requires access to adequate spawning and rearing habitat. Expedited adult salmon passage at this site will reduce delays and injury and provide a significant benefit salmonid production.

Action 4(b)(3): Install fish screens on both diversions at Gorrill Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Gorrill Dam.

Narrative description: Gorrill Dam is a concrete-base, seasonally installed flashboard structure with two unscreened diversions.

Related actions that may impede or augment the action: Gorrill Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the gravity and pumped diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of Gorrill Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(b)(4): Build new high-volume fish ladder at McPherrin Dam.

Objective: Improve adult fish passage.

Location: McPherrin Dam.

Narrative description: The dam is a concrete-base, seasonally installed flashboard structure. Adult passage with the dam removed is not a problem. The existing structure has an operational fish ladder that is believed to provide marginal passage resulting from fish not rapidly finding and traversing the ladder. McPherrin Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Sink Wildlife Area. As with the McGowan Dam, past operation was generally restricted to March-September. Acquisition of the Wildlife Area has resulted in a year-round operation dependent on flow conditions in Butte Creek.

Related actions that may impede or augment the action: McPherrin Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made regarding the removal of McPherrin Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmonids.

Action 4(c)(1): Build a new high-volume fish ladder at McGowan Dam.

Objective: Improve adult fish passage.

Location: McGowan Dam.

Narrative description: McGowan Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Basin Wildlife Area. Past operation of the diversion was generally restricted to March-September. With the change of usage to wildlife, the diversion will potentially be operated on a year-round basis, depending on flow conditions in Butte Creek. McGowan Dam is a concrete-base, seasonally installed flashboard type structure. There are no known adult passage problems with the dam removed. Adult passage with the dam installed is generally a problem as the result of fish not rapidly finding and traversing the existing ladder. A high-volume fish ladder should be installed at the dam if it is not removed.

Related actions that may impede or augment the action: McGowan Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made about the removal of McGowan Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 5(a)(1): Build new high-volume fish ladder at East-West Diversion Weir.

Objective: Provide passage for adult salmonids.

Location: East-West Diversion Weir.

Narrative description: Flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure referred to as the East-West Diversion Weir. This weir is operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. Flow manipulations at this site may therefore be significantly affecting passage of adults and juveniles of both races of chinook salmon. This weir does not contain a fish ladder and under some flows is a barrier. Construction of a high-volume fish ladder will alleviate most passage problems associated with this dam.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: Cooperation by the dam owner, Meridian Farms Water Company, and funding are unknown factors at this time.

Predicted benefits: Installing a fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 5(a)(2): Establish operational criteria for the East and West Barrows.

Objective: Improve adult fish passage.

Location: East-West Diversion Weir.

Narrative description: Diversions and their impacts in this reach are unknown; however, flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. Flow manipulations at this site are affecting outmigration of juvenile salmonids.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and DWR, in cooperation with the Meridian Farms Water Company operators, need to develop operational criteria for timing and volume of flow splits between the East and West Barrows.

Potential obstacles to implementation: Cooperation by dam owner, Meridian Farms Water Company, and funding are unknown factors at this time.

Predicted benefits: Developing operational criteria will provide better passage flows for adult salmon and steelhead.

Action 5(a)(3): Establish operational criteria for Sutter Bypass Weir #2.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #2.

Narrative description: Flow splits between the East and West Barrows and the impacts on anadromous fish are not well understood, particularly with the recent changes in water usage resulting from rice straw decomposition and waterfowl needs in fall and winter. In general, the East Barrow has been identified as the most desirable migration route. Drainage flows enter the East Barrow at the Wadsworth Canal and are a mixture of various diversions from the Feather River. Adult salmon are periodically reported to have migrated up the Wadsworth Canal, presumably to have died without spawning. Weir #2, a concrete, seasonally installed flashboard structure, is located approximately 1 mile south of the Wadsworth Canal. A fish ladder installed on the west side of the weir is generally passable. Weir #2 is operated and maintained by DWR and is generally in place from March through early November. There is, however, a concern for delay and also for regulation of flows within the fish ladder, which are often found to be impassable. With the recent advent of waterfowl needs for the Sutter National Wildlife Refuge, and potential rice straw decomposition needs, Weir #2 is operated over a longer period and, as demonstrated in 1993-1994, was never removed. Thus, Weir #2 can be a major obstacle to anadromous fish migration.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and DWR, in cooperation with dam operators, need to develop operational criteria relative to installation date and removal of the weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will serve to identify and facilitate passage flows for adult and juvenile salmon and steelhead, while maintaining agricultural and wildlife needs.

Action 5(a)(4): Establish operational criteria for Nelson Slough.

Objective: Improve adult fish passage.

Location: Nelson Slough.

Narrative description: Flows from the East Barrow, other than floodflows, historically have rejoined the West Barrow at several locations, including Gilsizer, Willow, and Nelson Sloughs. Problems in regulating flows through the three sloughs often resulted in stranded adult salmon. The result was a decision to route all flows during most of the year through Willow Slough, which was modified with a concrete denile fish ladder. Currently, Nelson Slough is the lowermost interconnection with the West Barrow and Sacramento Slough and generally flows only during flood events. During 1994, DWR installed a control structure that will allow regulation of flows into Nelson Slough during nonflood periods to facilitate better regulation of flows and elevations at the lower end of the East Barrow.

Related actions that may impede or augment the action: Even with the single route through Willow Slough and an improved fish ladder, delay and injury are probably still a factor at this site. Also, the newly installed control structure that will allow regulation of flows into Nelson Slough during nonflood periods has the potential to cause stranding of salmon and steelhead.

Agency and organization roles and responsibilities: DFG and DWR need to develop operational criteria relative to installation date and removal of the weir.

Potential obstacles to implementation: Funding is unknown at this time.

Predicted benefits: Developing operational criteria will serve to enhance passage and reduce stranding of salmon and steelhead.

Action 5(a)(5): Establish operational criteria for Sutter Bypass Weir #1.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #1.

Narrative description: Weir #1, the lowermost of the West Barrow dams, is located immediately upstream of the Tisdale Bypass and is owned and operated by the USFWS for the Sutter National Wildlife Refuge. This weir is primarily utilized for the management needs of the refuge; however, it also provides for agricultural users. As with the other dams in the Sutter Bypass, changing conditions are resulting in year-round operations in some years, creating potentially significant impacts on migrating salmon and steelhead.

Weir #1 is a seasonally installed concrete flashboard structure, with an existing operational fish ladder. As with all of the other weirs and dams, Weir #1 creates a major blockage that, even with its operational fish ladder, contributes to delay and injury of migrating salmon.

Related actions that may impede or augment the action: Alternative sources of water for the Sutter Refuge are currently being developed. If an alternative is developed, the weir could potentially be eliminated or the time of use reduced.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS need to develop operational criteria relative to installation date and removal of the weir and to explore alternative water sources to allow dam removal.

Potential obstacles to implementation: None.

Predicted benefits: The development of sound operational criteria or weir removal will benefit salmon and steelhead as well as wildlife.

Action 5(a)(6): Install fish screens at Sanborn Slough Bifurcation Structure.

Objective: Prevent entrainment of juvenile salmonids.

Location: Sanborn Slough Bifurcation Structure.

Narrative description: Flow splits at the Sanborn Slough Bifurcation Structure may cause delay and or stranding for juvenile salmon and steelhead. The existing structure is an earthen cobble dam with two large gated culverts installed across the main channel of Butte Creek. The potential for installation of a fish screen at this site needs to be investigated. Operational responsibility for the structure is unclear, although there is a loose arrangement between the duck clubs and agricultural users to provide diversions to meet the respective needs by time of year. In addition, Reclamation District 1004 has an open application to appropriate additional Butte Creek waters that specifies operational criteria at this site. Depending on time and flows, this site may be a major migrational barrier and could divert significant numbers of juveniles into the Butte Sink.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should coordinate screen design and installation.

Potential obstacles to implementation: None.

Predicted benefits: A fish screen at this site could prevent the loss of significant numbers of salmon and steelhead resulting from straying into the Butte Sink.

Action 5(a)(7): Install fish screens at White Mallard Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: White Mallard Dam.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season, and White Mallard Duck Club diverts water at this site during the fall waterfowl season. The dam is an earthfilled, seasonally installed flashboard structure. There is an existing fish ladder that, in conjunction with the dam, is of questionable durability.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, in conjunction with the USBR and USFWS, should design and install a new fish screen.

Potential obstacles to implementation: None.

Predicted benefits: Installation of a fish screen will prevent the loss of juvenile salmon and steelhead at this dam.

Action 5(a)(8): Screen diversions within Sutter Bypass where necessary.

Objective: Prevent entrainment of juvenile salmonids.

Location: Sutter Bypass, Butte Slough to Sacramento River.

Narrative description: Diversions and their impacts in this reach are largely unknown; however, flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. None of the diversions within the Sutter Bypass are screened, and thus they potentially entrain significant numbers of juvenile salmon and steelhead.

Related actions that may impede or augment the action: Development of alternative water source for Sutter Refuge could eliminate need for one or more screens.

Agency and organization roles and responsibilities: DFG, with support from the USFWS, should investigate the need for fish screens and facilitate installation where necessary.

Potential obstacles to implementation: None.

Predicted benefits: Fish screen installation has the potential to prevent the loss of juvenile salmon and steelhead.

Action 5(b)(1): Install culvert and riser at White Mallard Duck Club outfall.

Objective: Prevent straying of adult salmonids.

Location: White Mallard Duck Club outfall.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season, and White Mallard Duck Club diverts water at this site during the fall waterfowl season. Tailwater from the diversion at the White Mallard Dam often results in stranding of adult salmon at the base of the White Mallard Duck Club bottom weir. Adult salmon, primarily fall-run salmon, are attracted out of Butte Creek approximately 0.5 mile to the base of the bottom weir.

Related actions that may impede or augment the action: None

Agency and organization roles and responsibilities: DFG, USFWS, and White Mallard Duck Club need to provide corrections to the system to avoid attracting and stranding salmon below the White Mallard Duck Club's bottom weir.

Potential obstacles to implementation: None.

Predicted benefits: Elimination of stranding at this site will increase production in the creek.

Action 5(b)(2): Rebuild and maintain existing culvert and riser at Drumheller Slough outfall.

Objective: Prevent straying of adult salmonids.

Location: Drumheller Slough outfall.

Narrative description: Tailwater from Drumheller Slough at the point it enters Butte Creek, under current operating conditions, is known to attract adult fall-run chinook salmon, stranding them in the upper portion of the slough. Changing water needs for wildlife and rice straw decomposition may eventually cause impacts on late fall-run and spring-run chinook salmon and steelhead. The existing structure needs to be rebuilt and maintained.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Reclamation District 1004, with support from DFG and USFWS, needs to design, build, and maintain the existing culvert and riser at Drumheller Slough outfall to avoid attracting and stranding salmon and steelhead.

Potential obstacles to implementation: None.

Predicted benefits: Rehabilitation of the existing culvert and riser at the outfall will prevent the loss of adult salmon due to straying and increase production in the creek.

Action 5(b)(3): Establish operational criteria for Sutter Bypass Weir #5.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #5.

Narrative description: Anadromous fish migration is generally encouraged through the East Barrow; however, flows in the West Barrow are generally present and sufficient to attract anadromous fish. Three weirs (dams) are located within the West Barrow below the East West Diversion Structure. The uppermost dam, Weir #5, is a seasonally operated concrete flashboard structure located approximately 1 mile south of the Highway 20 bridge crossing. It is operated primarily for agricultural needs in spring, although it may have some use in fall flooding for waterfowl and rice straw decomposition. Fish passage at the site is not well understood and has the potential, under some flow conditions, to present a significant blockage to migrating adults.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, in cooperation with dam operators, need to develop operational criteria for this weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will facilitate passage for adult salmon and steelhead.

Action 5(b)(4): Establish operational criteria for Sutter Bypass Weir #3.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #3.

Narrative description: Weir #3, the second of the West Barrow dams, is located across from the mouth of the Wadsworth Canal. It is operated primarily for agricultural needs and, as with the other weirs, will potentially have increasing usage in fall and winter for waterfowl and rice straw decomposition. Fish passage at this site is not well understood; however, it is thought to be a problem under some flow conditions. Operational criteria need to be developed.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, in cooperation with dam operators, need to develop operational criteria for this weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will provide better passage flows for adult salmonids.

Action 6(a)(1): Initiate legal actions on diverters who are violating water right allocations.

Objective: Ensure sufficient instream flows.

Location: Entire creek.

Narrative description: In general, during most periods when impacts on anadromous fish would be of concern, adequate flows exist below the Western Canal. Cursory review has revealed however, that some users in this reach appear to be diverting water outside of their right or entitlement.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, with USFWS support, needs to investigate this problem and consider legal action only after other actions have failed (see Action 3[a][1]).

Potential obstacles to implementation: Cost and cooperation are important to the success of this action.

Predicted benefits: Legally defined instream flows will provide significant benefit to migrating salmon and steelhead.

Action 6(a)(2): Install high-volume fish ladder on Sutter Bypass Weir #2.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #2.

Narrative description: Flow splits between the East and West Barrows and the impacts on anadromous fish are not well understood, particularly with the recent changes in water usage resulting from rice straw decomposition and waterfowl needs in fall and winter. In general, the East Barrow has been identified as the most desirable migration route. Drainage flows enter the East Barrow at the Wadsworth Canal and are a mixture of various diversions from the Feather River. Adult salmon are periodically reported to migrate up the Wadsworth Canal and, presumably, to die without spawning. Weir #2, a concrete, seasonally installed flashboard structure, is located approximately 1 mile south of the Wadsworth Canal. A fish ladder is installed on the west side of the weir and is generally passable. There is a concern for delay and regulation of flows within the fish ladder, which is often impassable. Weir #2 is operated and maintained by DWR and is generally in place from March through early November. With the recent advent of waterfowl needs for the Sutter National Wildlife Refuge, and potential rice straw decomposition needs, Weir #2 is operated over a longer period and, as demonstrated in 1993-94, was never removed. Thus, Weir #2 can be a major obstacle to anadromous fish migration.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, in cooperation with DWR, needs to design and install a high-volume fish ladder.

Potential obstacles to implementation: None.

Predicted benefits: Installation of a high-volume fish ladder will improve fish passage at this site.

Action 6(a)(3): Install high-volume fish ladder on Sutter Bypass Weir #1.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #1.

Narrative description: Weir #1, the lowermost of the West Barrow dams, is located immediately upstream of the Tisdale Bypass and is owned and operated by the USFWS for the Sutter National Wildlife Refuge.

This weir is primarily utilized for the management needs of the refuge; however, it also provides for agricultural users. As with the other dams in the Sutter Bypass, changing conditions are resulting in year-round operations in some years, thus potentially having significant impacts on salmon and steelhead. Weir #1 is a seasonally installed concrete flashboard structure, with an existing operational fish ladder. As with all of the other weirs and dams, Weir #1 creates a major blockage, even with its operational fish ladder, that contributes to delay and injury of migrating salmon.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: If an alternative source of water for Sutter Refuge is developed, the weir might be removed or the time of operation reduced.

Predicted benefits: Installation of a high-volume fish ladder will improve fish passage at this site.

Action 6(a)(4): Install fish screens on Little Dry Creek pumps.

Objective: Prevent entrainment or impingement of juvenile salmonids.

Location: Little Dry Creek pumps, approximately 1 mile below Afton Road.

Narrative description: The reach between McPherrin Dam and Sanborn Slough borders the Little Dry Creek Unit of the Upper Butte Basin Wildlife Area. Two unscreened pumps supply water to the Little Dry Creek Unit, while an unknown number of additional pumps exist in this reach. None of the pumps are screened.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to coordinate screening of all pumps on Butte Creek.

Potential obstacles to implementation: None.

Predicted benefits: Screening will prevent loss of juvenile salmon and steelhead.

Action 6(a)(5): Increase law enforcement of fishing regulations.

Objective: Eliminate or reduce poaching.

Location: Entire creek.

Narrative description: Poaching is considered to be a significant problem along the entire length of Butte Creek. One additional warden position was added by DFG during 1994 to patrol spring-run salmon streams. However, the one additional position is responsible for providing patrol on five or six tributaries. Additional intensive enforcement might be achieved by providing funding overtime to existing wardens in the key areas.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to provide the resources to accomplish this action.

Potential obstacles to implementation: None.

Predicted benefits: Increased enforcement of fishing regulations will prevent loss of adult salmon and steelhead due to poaching.

Action 6(b)(1): Install high-volume fish ladder on Sutter Bypass Weir #5.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #5.

Narrative description: See the narrative description for Action 5(b)(3).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 6(b)(2): Install high-volume fish ladder on Sutter Bypass Weir #3.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #3.

Narrative description: See the narrative description for Action 5(b)(4).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 7(a)(1): Install high-volume fish ladder at White Mallard Dam.

Objective: Improve adult fish passage.

Location: White Mallard Dam.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season and White Mallard Duck Club diverts water at this site during the fall waterfowl season. The dam is an earthfilled, seasonally installed flashboard structure. There is an existing fish ladder that, in conjunction with the dam, is of questionable durability.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this dam.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 7(a)(2): Develop and enforce land use plans that create buffer zones between the creek and development.

Objective: Protect existing salmonid habitat from further human development.

Location: Entire stream.

Narrative description: Local land use plans and regulations need to be implemented or modified to create buffer zones between the creek and any new development. An ecosystem approach needs to be developed to integrate any anadromous fishery management plans into an overall watershed management plan that will require participation of all federal, state, and local entities, including land owners and private groups. Formation of local advocacy groups should be encouraged to ensure that the legitimate needs of all stakeholders are considered and addressed. One such group, the Butte Creek Spring Run Restoration Committee, is currently addressing and reviewing spring-run restoration activities. DFG is in the process of developing a plan that would protect riparian habitats. Local groups should be encouraged to participate in such an effort.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: All agencies need to continue their interactions with local conservation groups to facilitate development and outside support of anadromous fish restoration plans.

Potential obstacles to implementation: None.

Predicted benefits: A healthy riparian corridor is important to the maintenance of the watershed.

Action 7(a)(3): Develop a watershed management program.

Objective: Protect existing salmonid habitat while providing for human use of the resources.

Location: Entire stream.

Narrative description: See the narrative description for Action 7(a)(2).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: All agencies need to continue interagency and local conservation group interactions to facilitate collaborative development and outside support of anadromous fish restoration plans.

Potential obstacles to implementation: None.

Predicted benefits: Preserving and protecting the existing watershed is very important to the restoration and continued existence of salmon and steelhead in Butte Creek.

Action 7(b): Enhance fish passage at natural barrier below Centerville Diversion Dam.

Objective: Increase the amount of available salmonid habitat.

Location: 0.5 mile downstream of the Centerville Diversion Dam.

Narrative description: A natural barrier exists approximately 0.5 mile below the Centerville Diversion Dam which, under most flow conditions, would preclude spring-run chinook salmon and steelhead from ascending. Some additional spawning and rearing habitat is available above this barrier. Potential solutions include construction of a fish ladder or physical modification of the barrier.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should investigate the feasibility of removing or modifying this barrier for upstream movement of spring-run chinook salmon and steelhead.

Potential obstacles to implementation: None.

Predicted benefits: Some additional spring-run and steelhead habitat would be provided.

Action 8: Enhance fish passage at PG&E diversion dams.

Objective: Increase the amount of available salmonid habitat.

Location: Centerville Diversion Dam and above.

Narrative description: Within the upper watershed area above the Centerville Diversion Dam, flows are regulated by PG&E. Flows from Butte Creek are commingled with diversions from the West Branch of the North Fork of the Feather River for power generation at the PG&E Desabla and Centerville Powerhouses. West Branch flows are augmented by storage in Round Valley and Philbrook Reservoirs. Currently, releases from the two reservoirs are based primarily on power generation needs, with some consideration given to recreation in Philbrook Reservoir and flow and temperature considerations below the Centerville Diversion Dam, a prime spring-run chinook salmon holding area. Salmon are currently blocked under almost all flow conditions from further upstream movement by the Centerville Diversion Dam.

If PG&E diversion dams in the Butte Creek system are to be considered permanent structures, the potential to enhance anadromous fish habitat above the dams can be achieved only by installation of fish ladders. This consideration would, of necessity, be incremental in nature due to the three-dam sequence blocking the original natural route to the extreme upper watershed area. The second of these, the Forks of Butte diversion, is a recent installation owned and operated by Energy Growth Partnership. In addition, natural barriers that existed prior to the dams or that formed after dam installation, would need to be evaluated for passage.

Related actions that may impede or augment the action: PG&E is currently reevaluating the efficacy of maintaining and operating the DeSabla-Centerville Project. The FERC license (FERC 803), which expires in 2009, may significantly alter considerations relative to the continued existence of the dams and their operation.

Agency and organization roles and responsibilities: DFG, in conjunction with USFWS, should begin negotiating with PG&E and Energy Growth Partnership to facilitate fish passage. The success of this action is also depends on the completion of Action 7(b).

Potential obstacles to implementation: None.

Predicted benefits: Unimpeded passage, either through installation of fish ladders or removal of dams, would provide additional habitat that is thought to have been historically utilized by salmon and steelhead.

Colusa Basin drain -

Limiting factors and potential solutions -

Migration barriers - Access to westside tributaries is currently blocked by the levee system along the Sacramento River. In addition, migration from the Colusa Basin Drain into the individual tributaries is often blocked by various dams and checks installed by irrigation and reclamation districts. To facilitate movement of salmon and steelhead, defined migrational corridors would have to be identified, constructed, and maintained.

Migrational flows - Most of the flow of the major westside tributaries is captured by the various irrigation and reclamation districts. Thus, it is virtually impossible for adults to consistently enter the system and for juveniles to consistently exit the system. To facilitate adult entrance and juvenile exit, defined instream flows have to be provided for each of the specified tributaries.

Water temperatures - Temperature is probably limiting for juveniles and adults entering or exiting the system during April through October. Drain flows often exceed 2,000 cfs and water temperatures exceed 80°F. Drainage flows entering the Sacramento River at Knights Landing during April through June probably significantly affect Sacramento River temperatures below Knights Landing.

Restoration actions -

Action 1: Develop defined migrational routes.

Objective: Provide direct access to Westside Tributaries.

Location: Westside Tributaries entering Colusa Basin.

Narrative description: Before water development, westside tributaries that currently enter the Colusa Basin Drain probably entered the Sacramento River through various sloughs between the towns of Glenn and Knights Landing. Reclamation efforts have since blocked this access other than through the outfall gates at Knights Landing. In addition, within the basin, most tributaries are blocked or diverted by various irrigation and reclamation districts.

Related actions that may impede or augment the action: Migrational corridors have to be identified that would either provide river access similar to that existing historically or, alternatively, provide a defined route through the Colusa Basin Drain outfall into the tributaries. Either alternative would require significant structural work such as levees, fish screens, fish ladders, siphons, and bridges.

Agency and organization roles and responsibilities: It is necessary for DFG, USFWS, and DWR to reach consensus as to the feasibility of developing anadromous fish production potential in the Colusa Basin Drain, given the low potential for developing migration corridors and the necessary infrastructure to ensure successful passage and reproduction (small reservoirs, levees, fish screens, fish ladders, siphons, and bridges).

Potential obstacles to implementation: The cost to make necessary structural fixes to a complex irrigation drainage system to gain a potentially small anadromous fish production contribution and the high temperature input during May to June suggest that greater salmon production benefits could accrue from investing similar costs into major diversion screens located on the mainstem of the Sacramento River or enhancing higher production potential streams.

Predicted benefits: Potential benefits are unknown although defined access routes might allow sporadic opportunistic runs of fall-run salmon based on historical knowledge of the drainage. Alternatively, some unknown benefit to upper Sacramento River salmon stocks might result from excluding entry to the Colusa Basin Drain at the Knights Landing outfall gates. A greater benefit to salmon stocks, particularly fall-run, may be preventing entrance into the Colusa Basin Drain. Currently, it is believed that any fish entering the drain and respective tributaries are straying from the Sacramento River as the result of high return flows at the Knights Landing outfall gates.

Action 2: Develop defined migrational flows.

Objective: Provide direct access to Westside Tributaries.

Location: Westside Tributaries entering Colusa Basin.

Narrative description: Before water development, westside tributaries that currently enter the Colusa Basin Drain probably entered the Sacramento River through various sloughs between the towns of Glenn and Knights Landing. Most likely, historical flows were sporadic and confined to October through March.

Related actions that may impede or augment the action: Currently, during most of the year, flows are diverted by various irrigation and reclamation districts. Some potential might exist to enhance flows through implementation of a foothill reservoir project identified by DWR (1964) as a possible flood control alternative. In addition, significant structural work such as levees, fish screens, fish ladders, siphons, and bridges would be required.

Agency and organization roles and responsibilities: See roles and responsibilities discussed for Action 1.

Potential obstacles to implementation: As stated for Action 1, general benefits to salmon stocks, particularly fall-run stocks, might be improved by preventing entrance into the Colusa Drain. Again, it is believed that any fish entering the drain and respective tributaries are straying from the Sacramento River as the result of high return flows at the Knights Landing outfall gates. See potential obstacles discussed for Action 1.

Predicted benefits: Benefits are the same as stated for Action 1.

Action 3: Reduce water temperatures.

Objective: Enhance survival in Colusa Drain and westside tributaries.

Location: Westside tributaries entering Colusa Basin.

Narrative description: Historically, water temperatures were probably a limiting factor that, in conjunction with inconsistent flows, served to limit salmon populations in the Colusa Basin Drain tributaries. Isolating flows through defined channels, in conjunction with enhanced flows from a foothill reservoir project, might provide some marginally lower water temperatures.

Related actions that may impede or augment the action: Temperature impacts on the Sacramento River from drain return flows are believed to be significant during the late spring and early fall periods. Enlargement of the Knights Landing Ridge Cut might facilitate allowing such flows to be routed into the Yolo Bypass, thereby eliminating impacts on the river at Knights Landing and below.

Agency and organization roles and responsibilities: See roles and responsibilities discussed for Action 1.

Potential obstacles to implementation: See potential obstacles discussed for Action 1.

Predicted benefits: Potential benefits are unknown although reduced temperatures facilitate sporadic opportunistic runs of fall-run salmon. Alternatively, some unknown benefit to upper Sacramento River salmon stocks might result by routing excess bypass flows during spring and fall into the Yolo Bypass. As stated for Action 1, general benefits to salmon stocks, particularly fall-run, might be improved by preventing entrance into the Colusa Drain. See predicted benefits discussed for Action 1.

Miscellaneous small tributaries -

Limiting factors and potential solutions - Table 3-Xb-15 lists key limiting factors for chinook salmon and steelhead in small tributaries and potential solutions. Small tributaries have been degraded in many ways. Some have been diverted into irrigation canals such as the Glenn-Colusa Canal and are no longer direct tributaries to the river. Others have been channeled for drainage or flood control and burned or sprayed with herbicides to keep channels free of plant obstructions. Irrigation diversions, usually in upstream areas where the stream is perennial, contribute to early dewatering of downstream reaches used for rearing by juvenile chinook salmon. Sometimes tributaries are damaged simply because local people fail to recognize their value and place burn piles where they destroy riparian vegetation or carelessly overspray the streams with herbicide or pesticide. Most small tributaries have been used as dumps for all sorts of waste, including car batteries, engine blocks, oil filters, animal carcasses, refrigerators, TVs, and household garbage, all of which may leach toxic substances into the water. In some cases, fish are lost to irrigation diversions that pull river water upstream near the mouth of the tributary. While chinook salmon rearing in most small tributaries is limited by one or more of the above problems, the smaller streams have not been studied enough to detail which reach of which stream needs particular restoration.

Table 3-Xb-15. Key limiting factors for chinook salmon and steelhead in small tributaries and potential solutions to those problems.

Limiting factors	Potential solutions
Degraded rearing habitat	Revegetate denuded stream reaches; restore a protected riparian strip
Loss to agricultural diversion	Move pumps to the river where sufficient bypass flow exists to avoid entrainment of juvenile salmonids and avoid screen intakes
Presence of toxic materials in streams	Remove existing hazardous materials; educate public about importance of small streams; enforce ordinances prohibiting dumping in streams
Early dewatering of streams	Find alternative sources of water for upstream diversions
Blocked upstream passage for rearing juvenile chinook salmon	Replace bridge/ford combinations with bridges or enlarged culverts
Loss of rearing habitat due to interception of tributaries by canals	Provide siphons to get "beheaded" tributary streams past irrigation canals

Restoration actions -

Action 1: Revegetate denuded stream reaches and restore and maintain a protected riparian strip in all tributaries.

Objective: Expand the usable rearing habitat and provide habitat diversity, cover from predators, and shade to retain lower water temperatures in late spring.

Location: All Central Valley reaches of rearing tributaries.

Narrative description: Restore and maintain a natural riparian corridor that is not sprayed, mowed, burned, channeled, or used as a garbage dump. Educational campaigns to dispense knowledge about the value of small tributaries as salmon habitat should help significantly to preserve and restore tributary habitat. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration. Critical stream reaches might be preserved by purchase of conservation easements.

Related actions that may impede or augment the action: All of the actions in this report augment one another because they all improve rearing habitat for juvenile chinook salmon.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential.

Potential obstacles to implementation: Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: Trees, roots, and stumps at the stream edge create eddy currents during flood. The eddies scour out the deep holes that young salmon need for survival in dry years. The trees also shade the stream, keeping temperatures safe for juvenile salmon, while the roots and fallen branches provide cover for escape from predators. Resultant habitat diversity supports many forms of aquatic foods, while terrestrial insects, falling into the water from overhanging vegetation, also contribute to the food base. Improved habitat from riparian revegetation would result in greater survival of juvenile chinook salmon rearing in tributaries. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration.

Action 2: Move pumps to the river where sufficient bypass flow exists to avoid entrainment of juvenile salmonids. (Screen pumps.)

Objective: Reduce loss of juveniles to agricultural diversion.

Location: All Central Valley reaches of rearing tributaries where diversion pumps are located but designed to take water from both tributary and river.

Narrative description: Pumps are frequently located on a tributary just off the river to reduce damage and displacement from the meandering river. When functioning, they reverse the natural flow between them and the river. While convenient and cheaper for the water user, pumps are disastrous to anadromous fish. During winter or early spring, juvenile chinook salmon move up the tributaries for rearing (Maslin and McKinney 1994). If the pumps located in the tributaries are turned on before the salmon leave, most salmon will be lost. Such diversions should be relocated, moved to the river, and re-installed with screening and bypass flows. Federal and state funds should be made available to avoid excess hardship to small operators.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: This action should be accomplished by a collaboration between DWR, DFG, the USBR, USFWS, and local water users.

Potential obstacles to implementation: The cost of moving and screening pumps could be an obstacle.

Predicted benefits: Thousands of juvenile chinook salmon would be saved annually (Maslin and McKinney 1994).

Action 3: Find alternative sources of water for upstream diversions.

Objective: Prevent early dewatering of stream reaches used for rearing.

Location: All rearing tributaries with upstream diversion.

Narrative description: Small irrigation diversions exist in almost all of these streams, usually in the foothill region where streams are perennial. They cause reduced flow in downstream reaches, often resulting in early dewatering and associated loss of juvenile salmonids that would have successfully emigrated in a few weeks. Timing and quantity of agricultural diversion need to be changed to prevent early dry down in downstream reaches. Substitution of groundwater sources from mid-April to mid-May would improve survival, particularly of fall-run juveniles.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: This action should be accomplished by collaboration between DWR, the USBR, and local water districts.

Potential obstacles to implementation: Lack of understanding of the importance of small tributaries may affect the cooperation of water users.

Predicted benefits: Fall-run juvenile chinook salmon that are almost to the smolt stage are often trapped as intermittent streams dry down in late April and early May. Leaving additional water in small tributaries at these critical times could permit survival of thousands of juvenile salmon (Maslin and McKinney 1994).

Action 4 Survey tributaries for toxic materials, follow with cleanup projects as needed; expand enforcement of dumping ordinances.

Objective: Remove hazards and potential hazards such as car batteries, oil filters, and animal carcasses from streams. Prevent further use of streams for dumps.

Location: All Central Valley reaches of rearing tributaries.

Narrative description: The value of intermittent streams is often unrecognized, and, consequently, the streams are used as convenient waste receptacles. All sorts of waste, including car batteries, engine blocks, oil filters, animal carcasses, refrigerators, TVs, and household garbage, can be observed in these tributary streams. This problem can be addressed by a combination of cleanup, education, and enforcement of existing prohibitions on dumping.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential.

Potential obstacles to implementation: Lack of understanding of the importance of small tributaries may limit public cooperation. Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: While it is impossible to estimate loss of juvenile salmonids due to toxic and oxygen-demanding materials in streams, rampant illegal dumping is substantially degrading habitat.

Action 5: Replace bridge/ford combinations with bridges or larger culverts.

Objective: Expand the usable habitat in some tributaries.

Location: Central Valley reaches of rearing tributaries that have bridge/ford crossings.

Narrative description: Some rearing tributaries have low road crossings, usually constructed of concrete with small culverts so that low flows pass through the culverts at high velocity and higher flows spill over the road bed (e.g., Elder Creek by TCC, Dye Creek at Shasta Boulevard.) The high velocity and turbulence of water passing through these culverts prevent juvenile chinook salmon from migrating further upstream, sometimes blocking access to miles of channel suitable for rearing.

Related actions that may impede or augment the action: See related actions discussed for Action 1 above.

Agency and organization roles and responsibilities: Resolution of this problem should be accomplished by a collaboration between the California Department of Transportation, DFG, and private land owners.

Potential obstacles to implementation: Costs of improving road crossings could be an obstacle.

Projected benefits: Additional rearing habitat would become accessible to juvenile salmon. The absolute benefit would vary with the proximity to the river of the crossing and the amount of potential rearing habitat upstream. Within a few miles of the river, a reasonable projection would be about 1,500 juveniles per stream mile.

Action 6: Provide siphons to get "beheaded" tributary streams past irrigation canals.

Objective: Expand the usable habitat.

Location: Central Valley streams that formerly were tributary to the Sacramento River but now emptying into an irrigation canal, especially on the west side of the Sacramento River in Glenn and Colusa counties.

Narrative description: Many tributaries now flow directly into canals. (e.g., Willow, Hunter's, Corral, Lurline, Freshwater, Sand, Oat Creeks.) Because water in these streams no longer reaches the river, their habitat is no longer available to anadromous fish. Some of these "beheaded" streams formerly supported minor spawning populations of fall-run chinook salmon; most provided rearing habitat.

Related actions that may impede or augment the action: See related actions discussed for Action 1 above.

Agency and organization roles and responsibilities: Local water districts, DWR, DFG, and the USBR should cooperate to solve this problem.

Potential obstacles to implementation: The cost of providing siphons could be an obstacle.

Predicted benefits: Each tributary could provide rearing habitat for between 5,000 and 20,000 juvenile chinook salmon annually. Small spawning populations (50 to 100 adults) could be supported by some (Paul Maslin, professional opinion pers. comm.).

C. LOWER SACRAMENTO RIVER AND DELTA TRIBUTARIES

Approach -

The Lower Sacramento River and Delta Tributaries Salmon and Steelhead Technical Team's approach to developing recommendations for the anadromous fisheries restoration program was to assign drainages to individual team members (Table 3-Xc-1). Team members were each responsible for taking a lead role in developing recommendations for their assigned drainages. Individual team members enlisted the help of additional authors to help them write their sections, or additional authors were enlisted by the team leader.

Table 3-Xc-1. List of team members and additional authors assigned to writing sections for each of the lower Sacramento River and Delta tributaries.

Drainage	Assigned member	Additional authors[a]
Feather	Ted Sommer, DWR	Dan Castleberry, USFWS
Yuba	Paul Bratovich, Beak Consultants	Mike Bryan, Beak Consultants
Bear	Nick Villa, DFG	John Nelson, DFG Steve Croci, USFWS
American	Paul Bratovich, Beak Consultants	Mike Bryan, Beak Consultants
Cosumnes	Nick Villa, DFG	Dawne Becker, DFG Steve Croci, USFWS
Mokelumne	Joe Miyamoto, EBMUD	Gary Rensink, USFWS
Calaveras	Kate Puckett, USBR	

[a] In addition to the listed authors, formatting and editorial changes were made by the USFWS, primarily at the request of the Core Group.

To develop this report, the team first developed a comprehensive list of potential limiting factors. This list is not included in the report. Each team member selected only those factors that were potentially limiting in their drainage and included those factors under the header "Limiting factors and potential solutions". Team members then selected only those factors that they considered to be of primary importance and described restoration actions for these factors under the header "Restoration actions".

Throughout this process, team members agreed to confine their lists of limiting factors and restoration actions to those factors and actions that take place within the drainage to which they were assigned.

Two factors that affect production outside the assigned drainages and that all team members agreed must be addressed are that (1) substantial progress toward restoration must be achieved within the Sacramento-San Joaquin Delta if natural production of salmonids that spawn in the lower Sacramento River and Delta tributaries was expected to double and (2) ocean harvest of naturally produced chinook salmon must not be allowed to occur at higher levels than natural production on small rivers can support. Because the authors believed these factors would be discussed elsewhere in the report, the sections on individual drainages that follow rarely mention these factors.

Feather River -

Limiting factors and potential solutions - - Following is a list of factors that may limit chinook salmon and steelhead production within the Feather River basin (ranked in approximate order of importance).

Instream flows - Low flows during the baseline period may have limited spawning habitat, rearing habitat, and juvenile outmigration.

Spawning gravel - The quantity and quality of spawning gravels are reduced by armoring, gravel mining, lack of gravel recruitment, and encroachment of vegetation.

Water temperature - Warm temperatures below Thermalito outlet possibly could negatively affect the reproductive success of adult spring-run chinook salmon. However, temperatures in the low-flow channel remain relatively cool because of dam releases. Field observations during 1992 indicated that temperatures below Thermalito outlet in the springtime reach levels considered unsuitable for young salmon.

Angling - Recent studies indicate that Feather River fishery in-river and Bay/Delta anglers may harvest 20-21% of the spawning escapement (Brown and Green in press). In addition to reducing the numbers of spawners, anglers also trample redds, potentially reducing the survival of pre-emergent salmonids in the redd.

Hatcheries - The viability of spring-run salmon in this system is questionable because of possible interbreeding with fall-run salmon, resulting in genetic dilution. Studies are needed to determine if pure stocks of spring-run salmon remain. In addition, Cramer (1990) estimated that a large percentage of hatchery-produced salmon stray to other rivers in the Sacramento Basin. While these fish contribute to the overall escapement in the Central Valley, production in the Feather River could be increased by reducing straying rates.

Bank and streambed modification - Channelization is aggravated by levees and embankments that restrict lateral channel movement, increasing flow velocities and deepening the channel. Channelization and riprapping may also reduce habitat diversity, instream cover, and food availability for fry and juveniles.

Diversions - Several unscreened agricultural diversions and pumps exist along the lower Feather River. The degree to which these diversions affect salmonids is unknown; however, it is possible that some entrainment occurs.

Water quality - The effects of wastewater discharge into the river are unknown; however, Dick Painter (DFG retired pers. comm.) expressed concern that water quality problems were possible. This issue should be investigated.

Predation - Large schools of striped bass congregate near the mouth of the Yuba River during the months of peak outmigration of smolts. Predation rates have not been measured, but are expected to be significant.

Table 3-Xc-2. Key limiting factors for chinook salmon production in the Feather River and potential solutions.

Limiting factor	Potential solutions
Instream flows	1. Compete instream flow study 2. If initial instream flow results are accurate, increase discharge into the low-flow channel 3. Increase flows in reach below Thermalito Dam to 2,500 cfs 4. Gravel restoration to increase spawning habitat, particularly near the hatchery 5. Experimental pulse flow events in spring to promote outmigration 6. Test the effectiveness of increasing turbidity in the river as an alternative to pulse flows

Limiting factor	Potential solutions
Spawning gravel	1. Gravel restoration to reduce armoring in spawning habitat, particularly near the hatchery 2. Gravel replacement at the head of one or more low-flow channel riffles 3. Increase instream flows to reduce encroachment 4. Consider occasional flushing flows to clean channel margins 5. Gravel restoration at the margins of problem riffles, including removal of encroaching riparian vegetation
Water temperature	1. Complete temperature model for the river as a tool to examine this issue 2. Develop alternatives to reduce temperatures during critical periods. Increasing flow through the low-flow channel in summer is one possible alternative
Angling	1. The extent of this problem requires further study 2. Restrict sport fishing in the Feather River 3. Educate sport fishers on risks of redd trampling 4. Promote catch-and-release fishing
Hatcheries	1. Conduct studies to determine if pure stocks of spring-run chinook salmon remain 2. If spring-run salmon are shown to be genetically distinct, modify hatchery practices to maintain their viability 3. Continue tagging studies to determine the extent of the straying problem

Limiting factor	Potential solutions
Bank and streambed modification	Actions related to channelization remain to be determined. Further studies are needed to assess possible impacts.

Restoration actions -

Action 1: Increase flows in low-flow channel.

Objective: Enhance and maintain spawning and rearing habitat.

Location: Low-flow channel.

Narrative description: Under this action, instream flows in the low-flow channel would be increased for at least part of the year. Under the present configuration of the system, most flow in the lower Feather River is generally diverted through Thermalito Diversion Dam, leaving a constant flow level of 600 cfs in the "natural" watercourse, the low-flow channel. Extra flow through the low-flow channel during at least September through May may enhance spawning habitat without an adverse effect on rearing. Two alternate flow schedules are discussed below. Schedule A flows would be as follows:

Schedule A. Adopt for 1 year and evaluate.

Months	Flow (cfs) for three year types	
	Wet and normal	Dry
September-May	2,500	1,700
June-August	1,100	800

Adoption of Schedule B would depend on the results of evaluation of Schedule A. Under Schedule B, flows would be set at 800 cfs year round in all year types.

The rationale for this action is that initial results from a DWR/DFG instream flow study suggest that spawning habitat in the low-flow channel would be maximized at higher flows than the present level of 600 cfs (Sommer 1994). DWR (1982) studies also indicate that excessive spawning densities in the low-flow channel result in superimposition of redds, reducing egg survival by as much as 40%. Recent field observations confirm the presence of extensive superimposition.

The two schedules are based on two different modeling scenarios presented in a draft IFIM report (Sommer 1994). The modeling scenarios differed in assumptions about depths preferred by spawning chinook salmon. Recommendations may be modified after completion and final release of the IFIM report.

Schedule A is based on the assumption that chinook salmon prefer to spawn at depths greater than or equal to 1.5 feet, provided that velocity and substrate requirements are met. Evidence for this assumption comes from observations of chinook salmon spawning in the American and Sacramento rivers. Although most salmon have been observed to spawn at a depth of 1.5 feet in the Feather River, it is possible that flows have not been sufficiently high during the period of observation to create the right habitat conditions.

Schedule B is based on the assumption that chinook salmon in the Feather River prefer to spawn at a depth of 1.5 feet. Evidence for this assumption comes from observations of chinook salmon spawning in the low-flow channel of the Feather River (Sommer 1994).

Whether Schedule A or B provides optimal spawning habitat depends on which assumption is most realistic. Flows similar to those recommended in Schedule A did not occur during the period of observation, but flows similar to those in Schedule B did occur. Without observations at flows similar to Schedule A flows, it is difficult to compare the validity of the two assumptions.

Based on this uncertainty, the effects of Schedule A flows on spawning habitat (especially depth preferences) should be tested. The test should consist of at least 1 year of Schedule A flows in the low-flow channel and should include observations of spawning habitat and preferences. Because the potential exists for Schedule A flows to result in substantially less spawning habitat than is present at existing flows (as is predicted by the modeling scenario on which Schedule B flows are based), the effects of Schedule A flows should be evaluated yearly. If Schedule A flows result in a reduction in spawning habitat, Schedule B flows (or flows derived from subsequent analyses) should be adopted.

Potential obstacles to implementation: Instream flows in the low-flow channel have been set through an agreement between DWR and DFG. FERC also has regulatory authority over Oroville Dam operations. Any changes in flow would require approval from these parties. In addition, the action would have costs to the SWP as a result of the water that would no longer be diverted through Thermalito Power Plant.

Predicted benefits: This action is probably one of the best ways to improve salmonid production in the lower Feather River. Benefits include increased spawning habitat, egg survival, and outmigration flows. However, the projected benefits of this action are difficult to specify because of the preliminary nature of the instream flow model questions about whether "deep spawning" is realistic. Given the severity of the superimposition problem in this reach, an increase in salmon production by 10-50% may be expected, depending on which alternative is most realistic.

Action 2: Consider providing experimental pulse flows

Objective: To stimulate outmigration of juvenile chinook salmon.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Experimental pulse flows could be considered as an approach to promote outmigration. Outmigration is a particular concern in the low-flow channel, where flows are constant unless surface runoff or floodflows enter the river. Moreover, temperatures are cooler in the low-flow channel; fish who delay their migration because of insufficient migration cues may face dangerously high temperatures in the lower reach (Sommer 1993). Pulse flows might provide important cues to enhance the migration. Possible experimental release schedules remain to be developed.

Potential obstacles to implementation: Changes to instream flow will require approval from DFG, DWR, and FERC. Flood control is also a potential concern.

Predicted benefits: A possible benefit of this action is enhanced survival of smolts. However, the potential effects on salmonid production in the system cannot be identified until field trials are conducted.

Action 3: Consider providing experimental high-turbidity pulses.

Objective: To stimulate outmigration of juvenile chinook salmon.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Turbidity pulses could be considered as an approach to promote outmigration. Outmigration is a particular concern in the low-flow channel, where flows are constant unless surface runoff or floodflows enter the river. Moreover, temperatures are cooler in the low-flow channel; fish that delay their migration because of insufficient migration cues may face dangerously high temperatures in the lower reach. However, initial observations from the Feather River suggest that turbidity or flow pulses might provide important cues for outmigration (Sommer 1993). Moreover, studies by Ligon et al. (in prep.) suggest that increased turbidity reduces predation losses during outmigration.

Potential obstacles to implementation: This option is *highly* experimental; techniques have not yet been developed. Moreover, clearance would be needed from the CVRWQCB and perhaps other agencies.

Predicted benefits: A possible benefit of this action is enhanced survival of smolts. However, the potential effects on salmonid production in the system cannot be identified until new studies are completed.

Action 4: Restore gravel and create spawning habitat in the low-flow channel.

Objective: Reduce armoring; increase spawning habitat.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Problems with limited spawning habitat were described previously under the instream flow option. Additional problems are that: 1) the existing spawning habitat is undergoing significant armoring, particularly near the high density spawning area near the Feather River Fish Hatchery (DWR 1982); and 2) low, stable flows appear to have promoted vegetation encroachment at the edge of spawning riffles. Maintenance of relatively stable flows in the low-flow channel through much of the past decade may have promoted vegetation encroachment at the margins of spawning riffles. Flood events in 1986 and 1993 are the major exception to this comment. Although flows have been much more variable below Thermalito outlet, reduced flow during many months of the recent 6-year drought may have promoted vegetation encroachment in this reach of the river.

Restoration activities should be undertaken to reduce armoring and increase spawning habitat. A total of approximately 2-3 river miles are considered high priority for restoration.

Potential obstacles to implementation: Extensive engineering studies are needed before this option can be implemented. Permits would probably be required from the Corps, DFG, CVRWQCB, and perhaps other agencies.

Predicted benefits: Redd superimposition could be reduced if the quality of spawning habitat was improved and if new riffles were created. Possible benefits cannot yet be identified until engineering studies identify the potential areas and design constraints for restoration and riffle creation.

Action 5: Replenish gravel.

Objective: Reduce the degradation of spawning gravel.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Clear water releases from Lake Oroville are eroding streambanks and the channel bottom without replenishment. Gravel studies indicate that channel degradation is expected to continue throughout the river below Oroville Dam (DWR 1982). Placement of gravel in upstream areas and allowing it to migrate downstream may help to alleviate this problem.

Potential obstacles to implementation: Extensive engineering studies are needed before this option can be implemented. Permits would probably be required from the Corps, DFG, CVRWQCB, and perhaps other agencies.

Predicted benefits: This option would help arrest channel degradation caused by the construction of Oroville Dam. However, it is unclear if this option would significantly increase the quality and quantity of spawning habitat. At the very least, it would help to reduce long-term reduction in fish production.

Action 6: Complete temperature model.

Objective: Develop a temperature model as a tool for river management.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: A temperature model is needed to help address issues for adult holding, egg incubation, and rearing of young, summarized below. The University of California, Davis, is presently completing this model under contract with DWR.

Adult holding: Warm temperatures below Thermalito outlet may negatively affect spring-run salmon. The extent of this problem has not yet been documented. However, temperatures in the low-flow channel remain relatively cool because of dam releases. Temperatures are considered less of a problem for fall-run salmon because they appear to remain in downstream areas until suitable temperatures are present in the river for spawning.

Incubation: It is unknown if water temperatures result in egg mortality in this system. Impacts are most likely to occur in October on spring-run salmon and early spawning fall-run salmon.

Rearing: Field observations during 1992 indicated that spring temperatures below Thermalito outlet reach levels considered unsuitable for young salmon in relation to the available information on temperature tolerance (Sommer 1993). If high temperatures are a problem for any of these life stages, a likely action would be to increase flows through the low-flow channel.

Predicted benefits: The possible benefits of a temperature model remain to be determined, but the model is expected to be a key tool for the management of salmonids in the system.

Action 7: Conduct studies on the hatchery program.

Objective: 1) Determine distribution of Feather River Fish Hatchery chinook salmon in Central Valley stocks, and 2) determine genetic integrity of Feather River spring-run chinook salmon.

Location: Feather River Fish Hatchery.

Narrative description: The viability of spring-run salmon in this system is questionable because of possible interbreeding with fall-run salmon. Studies are needed to determine if pure stocks of spring-run salmon remain. Also unclear is the degree to which Feather River salmon stray to other basins in the system. Cramer (1990) estimated that a large percentage of hatchery-produced salmon stray to other Sacramento Basin tributaries. A better understanding of the effect of hatchery practices on salmon survival and distribution may help to improve salmon production and maintain genetic integrity in the system.

Based on these observations, two studies are proposed:

1) **Genetic testing on Feather River spring-run chinook salmon.** The initial part of this study would focus on electrophoretic or DNA studies to determine if viable pure stocks of spring-run salmon exist. If viable stocks can be demonstrated, the second phase of the study would develop hatchery practices to maintain genetic integrity.

2) **Tagging of hatchery fish.** During the past year, DWR initiated an extensive program of tagging hatchery fish. The goal is to mark approximately 1 million salmon each year for at least 5 years. The fate of these tagged salmon would be determined through creel census, spawning, and hatchery surveys. Survival rates would ultimately be compared to the hatchery practices and environmental conditions during the release of smolts.

Predicted benefits: Preservation of a viable spring-run salmon stock would be a major benefit to the gene pool of Central Valley salmon stocks. Moreover, hatcheries have a major, but poorly understood, effect on salmon production. Tagging studies would allow better management of salmon in the system. However, projected improvements in production cannot be specified at this time.

Action 8: Increase flows below Thermalito outlet.

Objective: Enhancement of rearing habitat, maintenance of spawning habitat.

Location: Reach below Thermalito outlet.

Narrative description: Under the proposed action, flows would be increased according to the schedule shown below for salmon and steelhead.

Months	Flow (cfs) for year types		
	Wet	Normal	Dry
October-March	2,500	2,500	1,700
April-May	3,000	3,000	2,100
June-August	1,000	1,000	1,000
September	2,500	2,500	1,400

A draft instream flow report (Sommer 1994) forms the basis of this recommended action for salmon and steelhead. However, implementation of these flows should include completion of the IFIM study to confirm the initial recommendations. The March-June flows apply to salmon and steelhead only.

Preliminary IFIM results indicate that spawning habitat during October through December would be maximized in the 750- to 2,750-cfs range (Sommer 1994). There is no evidence that the recommended normal and wet year flows of 2,500 cfs for October through December would increase spawning habitat, but this higher level may be a safer level for maintenance of habitat. For example, vegetation encroachment at the margins of some riffles may be reduced.

The main purpose of the January-May flows is to increase rearing habitat for fry and juveniles and to promote outmigration. IFIM results show that increasing January-May flows would create additional rearing habitat, although it remains to be demonstrated that rearing habitat is a limiting factor in the system (Sommer 1994). Nonetheless, increased flows would probably have temperature and outmigration benefits for rearing, particularly in late winter and early spring.

The June-August flows remain unchanged from the present instream flow requirement (DWR/DFG 1983). However, recommended flows for these months are contingent on the completion of a temperature model for the system. Additional changes are possible to benefit spring-run salmon adults, which migrate upstream in spring and hold throughout summer in the low-flow channel.

Potential obstacles to implementation: Instream flows are presently set through an agreement between DWR and DFG. FERC also has regulatory authority over Oroville Dam operations. Any changes in flow would require approval from these parties.

Predicted benefits: The benefits of this proposal cannot be quantified at this time.

Yuba River -

Limiting factors and potential solutions - - Upstream migration of spawning adult salmonids is physically blocked by the Englebright Reservoir; hence, all spawning occurs below this point. The following list of limiting factors (Table 3-Xc-3) is limited to the lower Yuba River as defined by Englebright Reservoir on the upstream end and the Feather River on the downstream end.

Table 3-Xc-3. Factors limiting chinook salmon and steelhead production in the lower Yuba River and potential solutions.

Limiting factor	Potential solutions
Inadequate instream flows	Reoperate New Bullards Bar and Englebright Reservoirs to: 1. Maintain mimimum flows of 600-700 cfs from October 1 to March 31 in all water years 2. Maintain flows ≥1,000 cfs from April 1 to June 30 in all water years 3. Maintain minimum flows of 450 cfs from July 1 to September 30 in all water years 4. Evaluate pulse flows for facilitating juvenile outmigration in dry years 5. Reduce and control flow ramping rates
Unsuitable water temperature	1. Evaluate the efficacy of modifying the physical water release outlet structure at Englebright Dam.
Losses of juveniles at diversions	1. Re-screen the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley diversions 2. Consolidate and screen smaller diversions 3. Modify timing and rate of water diverted 4. Improve efficiency of fish bypasses at diversions 5. Exclude piscivores from areas around diversions

Limiting factor	Potential solutions
Barriers to migration	1. Maintain ≥175 cfs through the critical Simpson Lane reach during spawning seasons of all years 2. Improve fish ladders at Daguerre Point Dam and maintain appropriate flows through ladders 3. Remove Daguerre Point Dam
Bank and streambank modifications	1. Purchase streambank conservation easements 2. Place large woody debris into rearing habitats 3. Terminate current programs that remove woody cover from the stream channel
Overharvest of adults	1. Further limit ocean harvest of naturally produced fish 2. Increase DFG enforcement efforts to stop poaching during the spawning seasons
Losses due to predation and competition	1. Modify Daguerre Dam face to keep outmigrants within the main channel 2. Remove Daguerre Point Dam

Two factors, water quality and gravel extraction, are not included in Table 3-Xc-3 or in the section on restoration actions and are addressed below.

Water quality - The only water quality parameter known to limit salmonid production on the lower Yuba River is water temperature (see "Water Temperature" subsection above). However, a water treatment plant does exist on, and discharge effluent into, Deer Creek, a tributary entering the lower Yuba River just below Englebright Dam (John Nelson, DFG, pers. comm., 1994). No data are currently available concerning the impact (if any) of this point-source discharge on salmonid production in the lower Yuba River and its tributary Deer Creek. However, because the potential for adverse water quality impacts exists at such sites, monitoring of water quality at the confluence of Deer Creek with the Yuba River would be in order.

Gravel extraction - Spawning gravel is not viewed as a limiting factor in the lower Yuba River today. However, wise management must guard against it from becoming one in the future because natural gravel recruitment has been severely limited by the construction and operation of New Bullards Bar and Englebright dams. Along such lines, DFG has made it a priority to regulate gravel extraction to protect salmon and steelhead spawning areas in the lower Yuba River (Reynolds et al. 1993). One option to ensure maintenance of salmonid spawning gravel would be to require mining operators, as a condition of their permits, to occasionally place gravel in the stream to enhance existing salmonid spawning beds.

Restoration actions -

Action 1: Maintain minimum flows of 700 cfs from October 1 through March 31 in all water years.

Objective: Optimize migration, spawning, and incubation conditions in the lower Yuba River.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving lower Yuba River spawning conditions. The Garcia Gravel Pit reach (from just north of Smartville downstream to Daguerre Point Dam) and the Daguerre Point Dam reach (from the dam downstream to the north side of Marysville) provide nearly all of the spawning habitat in the lower Yuba River. A flow of 700 cfs at Marysville maximizes spawning habitat in these reaches, particularly the more heavily utilized Garcia Gravel pit reach.

Current instream flows during the spawning/incubation seasons are often inadequate for optimal production.

Adult spawning migrations: Instream flows may limit adult salmonid migration (via straying) if there is an inadequate quantity of natal stream flows to provide sufficient environmental cues for homing. Furthermore, inadequate instream flows have been known to block upstream spawning migrations of salmon in dry years. For additional information on this factor, see the "Migration Barriers" subsection below.

Spawning habitat: Fall-run chinook salmon spawn during October through January; steelhead begin spawning in January and continue through April. In most years, minimum flow requirements appear adequate for providing suitable spawning habitat. The Garcia Gravel Pit and Daguerre Point Dam reaches provide nearly all of the spawning habitat in the lower Yuba River (DFG 1991). Approximately 60% of fall-run chinook salmon spawn between Daguerre Point Dam and the Highway 20 bridge.

The results of an instream flow study performed by Beak Consultants for DFG on the lower Yuba River indicated that weighted usable area (WUA) is highest for spawning chinook salmon at 600-700 cfs. Thus, when fall flows in the lower Yuba River drop substantially below 600 cfs, spawning habitat becomes limiting. DFG believes that salmonid spawning and rearing habitats are currently limiting in the Yuba River and has therefore assigned an A-1 priority to their improvement (Reynolds et al. 1993).

Rearing habitat: Rearing habitat is of special concern for fall-run chinook salmon from December through March. However, steelhead fry rearing occurs throughout the year and flows must be maintained at a level that permits successful rearing of both species.

Juvenile chinook salmon and steelhead-rearing habitat availability, as determined by IFIM studies (Beak 1989), is maximal at flows of 150-200 and 200-350 cfs, respectively.

Juvenile outmigrations: Juvenile outmigration of both chinook salmon and steelhead occur from April through June. Maintenance of at least 700-cfs flows during this outmigration period would facilitate juvenile downstream movement. Flows of 1,000, 2,000, and 1,500 cfs at the Marysville gage in April, May, and June, respectively, have been recommended for salmon and steelhead emigration (DFG 1991).

Actions for improving instream flows: Maintaining 700-cfs flows at Marysville from October 1 through March 31 would provide good conditions for salmon and steelhead migration and spawning. Furthermore, maintaining 700-cfs flows at Marysville during these months would prevent dewatering of redds and/or stranding of young chinook salmon and steelhead throughout the lower Yuba River. However, because steelhead spawn from January through April, a period when fall-run chinook salmon are in a rearing life stage, a distinct conflict arises regarding target instream flows during these months. Optimal flows for spawning steelhead would be 700 cfs, whereas IFIM studies suggest that rearing salmon would benefit most from flows of about 200 cfs. Because spawning requirements tend to be less elastic than those for rearing of juveniles, and because decreasing flows in January to accommodate those fry that have emerged may result in dewatering of late redds, flow rates should be maintained at 700 cfs from October through March. A compromise flow rate of 600 cfs at Marysville from January through March may be reasonable. Outmigrations of both species occur primarily during April through June, at which time target flows at Marysville should range between 1,000 and 2,000 cfs. However, it should be noted that such flows would reduce the availability of preferred rearing habitat young chinook salmon and steelhead remaining in the river. If flows of 1,000 cfs or greater can not be maintained from April through June during dry and critically dry years, lower base flows punctuated by pulsed flows of approximately 2,000 cfs should be considered. Flow rates at Marysville from July through September should be maintained at 450 cfs for steelhead rearing because, by July, nearly all juvenile salmon have left the river. The upper end of the flow range indicated to be optimal for steelhead rearing was selected because greater thermal protection is afforded by higher flow rates during these warm weather months. For effective management of lower Yuba River salmonids, emphasis should be placed on *consistently* meeting biologically appropriate instream flows throughout the year.

Since the impoundment of the New Bullards Bar Reservoir in 1969, fall chinook salmon and steelhead spawning runs have not increased as anticipated, largely because of consistent failure to meet required instream flows and temperatures during critical periods of the year. Hence, achieving target flows and temperatures in the lower Yuba River will likely involve reoperation of both New Bullards Bar and Englebright Reservoirs. Because instream flows and temperatures are believed to be the two most limiting factors to salmonid production in the lower Yuba River, reservoir reoperation to meet target flows and temperatures must be pursued within the constraints of all other uses of reservoir and river waters. In addition to meeting minimum flow requirements, reoperations should include physical modification of the water release outlets at Englebright Dam, if shown to be effective, in order to control the depth (and thus temperature) at which water is released from the reservoir.

Predicted benefits: Lack of suitable spawning flows is currently a key factor limiting salmonid production on the lower Yuba River, particularly in October. Significant improvements to spawning habitat quantity and quality, made by increased and maintained flow rates, has perhaps the greatest potential for increasing annual salmonid production in the river. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate spawning flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower Yuba River.

Action 2: Maintain minimal flows of 1,000 cfs during April, 2,000 cfs during May, and 1,500 cfs in June in all years.

Objective: Optimize juvenile rearing and outmigration conditions in the lower Yuba River.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Current instream flows during the rearing and outmigration periods are often inadequate, resulting in increased juvenile salmonid mortality from predation, thermal stress, and stranding. Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving lower Yuba River rearing and outmigration conditions.

Predicted benefits: Lack of suitable juvenile rearing and outmigration conditions are factors that currently limit salmonid production on the lower Yuba River. The recommended flows would provide suitable conditions for continued spring-run salmon and fall-run/steelhead smolt emigration. Furthermore, such flows would guard against juvenile fish isolation and stranding and would provide for spring-run chinook salmon attraction and immigration flows. Although IFIM studies indicated that these flows would actually reduce WUA for juvenile rearing, they are necessary to produce the greatest benefit to the greatest number of fish species and stocks.

Maintaining appropriate rearing and outmigration flows will increase annual salmonid production in the river by decreasing juvenile mortality from predation, thermal stress, and stranding. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate rearing and outmigration flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower Yuba River.

Action 3: Maintain minimum flows of 450 cfs from July 1 to September 30 in all years.

Objective: Improve juvenile steelhead rearing conditions.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Current instream flows during the late summer rearing period are often unsuitable for steelhead, resulting in limited physical habitat and stressfully high water temperatures. Such conditions cause increased juvenile mortality from predation and thermal stress. Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving late summer steelhead rearing conditions.

Predicted benefits: Lack of suitable rearing conditions and area currently limit juvenile steelhead survival in the lower Yuba River. Maintaining appropriate rearing flows will increase annual production in the river by decreasing juvenile mortality from predation and thermal stress. However, it should be noted that flows as low as 450 cfs at this time of year could adversely affect spring-run chinook salmon upstream immigration. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate late summer rearing flows will significantly contribute to the goal of increasing steelhead production in the lower Yuba River.

Action 4: Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmonid outmigration.

Objective: Optimize outmigration success when water is in short supply (e.g., dry and critically dry years).

Location: Lower Yuba River.

Narrative description: The faster juveniles can emigrate (within physiological constraints associated with smoltification), the greater their probability of survival. Reduced time in the Lower Yuba, Feather, and Sacramento rivers during outmigration reduces the length of time juveniles are exposed to instream predators and physiologically stressful water temperatures.

Pulse flows should be evaluated as an approach to promote successful salmonid outmigration. Studies are needed for determining how to maximize juvenile outmigration success when water supplies are limited in drier years, and thus instream flows could be reduced during the outmigration period (April-June).

Predicted benefits: Such studies will provide a basis for facilitating juvenile outmigration when water within the system is limited. Rapid outmigration associated with a pulse flow will likely increase juvenile survival rates and thus overall production.

Action 5: Reduce and control instream flow ramping rates.

Objective: Reduce hazards posed to young salmonids when flow rates change quickly.

Location: New Bullards Bar and Englebright dams (points of water discharge).

Narrative description: Fluctuating flows during the base period limited salmonid production by dewatering redds. Redd dewatering continues to be a problem in the lower Yuba River (DFG 1991).

Operations at New Bullards Bar and Englebright dams relating to the release of water downstream should be modified so that adjustments made to instream rates are more gradual than they are currently. Gradual ramping rates will decrease salmonid losses due to redd dewatering and fry and juvenile displacement and stranding, all of which occur when flow rates are changed substantially and quickly. Ramping rates should not exceed 30% of an existing initial flow during any 24-hour period.

Maintaining flows of 700 cfs in the river throughout the spawning and incubation periods of October through April would prevent dewatering of redds and/or stranding of young chinook salmon and steelhead. To further minimize flow reduction impacts on spawning salmonids and fry survival if flows become elevated above target levels between October and February, the following additional flow recommendations are made: 1) If the average flow for a 7-day period is >800 to <1,000 cfs, the minimum flow rate should default to 800 cfs from the date of occurrence through February; 2) if flows for a 7-day period average >1,000 to <1,500 cfs, minimum flows should default to 1,000 cfs; 3) finally, if flows for a 7-day period average ≥1,500 cfs, flows should be maintained at 1,500 cfs through February (DFG 1991). Doing so will help prevent redd dewatering and fry stranding during the October to February period.

Predicted benefits: Establishment of more gradual ramping rates, particularly during spring and midsummer, will reduce losses of young salmonids and contribute to increased production. The exact contribution of this action to increased salmonid production can not be calculated at this time.

Action 6: Maintain adequate instream flows for temperature control.

Objective: Reduce thermal stress to salmonids during the spawning, incubation, rearing, and outmigration periods.

Location: Entire lower Yuba River.

Narrative description: Effects of water temperature on fishery resources in the lower Yuba River have been a concern for many years (DFG 1991). River water temperatures are primarily a function of 1) ambient air temperature and 2) flows and temperatures released from Englebright and New Bullards Bar Reservoirs. Because of its great depth and storage capacity, there is always access to the cold water pool of New Bullards Bar Reservoir, even in late summer of dry years. However, waters released from New Bullards Bar warm substantially within Englebright Reservoir. Furthermore, Englebright Dam currently has no physical mechanism by which the depth (and hence temperature) of water released into the lower Yuba River can be controlled. Thus, a physical modification of the water release outlets of Englebright Dam should be evaluated for improving the control over the temperatures of downstream water releases.

Adult migration, spawning, and incubation: These life stages occur from September to February and October to April for fall-run chinook salmon and steelhead, respectively. Stressful water temperatures that impede spawning can occur during adult upstream migration in October, particularly if low flows combine with high air temperatures. Water temperatures are rarely too high for adults migrating during November. Optimum temperatures for chinook salmon and steelhead migration, spawning, and incubation range from 44°F to 56°F and from 46°F to 52°F, respectively (Beak 1989). Constant exposure of salmonid eggs to temperatures above 56°F result in some egg mortality, while water temperatures above 62°F result in complete egg mortality. Future reservoir releases should target the optimal range of temperatures during the fall spawning period, particularly during October through December. For these life history events, chronic low stress will affect chinook salmon if temperatures are above 56°F and equal to or less than 61°F. Chronic low stress for steelhead during these life stages will occur if water temperatures are above 52°F and equal to or less than 59°F. Thus, water temperature approaching 61°F and 59°F will have significant adverse impacts on the spawning and incubation success of chinook salmon and steelhead, respectively.

DFG (1991) compared thermal preferences of various chinook salmon life stages to Yuba River seasonal water temperatures during the six water years from 1973 to 1978. DFG found in-river temperatures at Marysville to be near or above 57°F until after mid-October and regularly into November as well.

Fry and juvenile rearing: Fry and juvenile rearing of chinook salmon occurs in the Yuba River from December through April, while fry and juvenile rearing of steelhead occurs throughout the year. Optimum instream temperature ranges for rearing young chinook salmon and steelhead are 53°F-56°F and 55°F-60°F, respectively (Beak 1989). Chronic low stress is believed to occur in juvenile chinook salmon if temperatures are above 56°F and equal to or less than 63.5°F. For steelhead, chronic low stress will occur if water temperatures are above 60°F and equal to or less than 68°F. Thus, water temperature approaching 63.5°F and 68°F during critical rearing months will have significant adverse impacts on the rearing success of chinook salmon and steelhead, respectively.

Water temperatures near Marysville may often exceed preferred juvenile chinook salmon rearing temperatures by early April, and, by June, even water that is released from Englebright Dam may exceed the preferred range (DFG 1991).

Juvenile outmigration: Peak juvenile outmigrations occur for both species in April-June. Stressfully high water temperatures frequently occur in June and can also occur in April and May, depending on flow levels and ambient air temperatures. Optimum instream temperature ranges for chinook salmon and steelhead juvenile outmigrations are 46°F-56°F and 44°F-52°F, respectively (Beak 1989). Chronic low stress will occur in chinook salmon outmigrants if temperatures are above 56°F and equal to or less than 63.5°F and in steelhead if temperatures are above 52°F and equal to or less than 60°F. Thus, water temperature approaching 63.5°F and 60°F during these months will have a significant adverse impact on the success of juvenile chinook salmon and steelhead outmigrations, respectively. Elevated water temperatures during this period of the year are particularly a problem below Daguerre Point Dam. Instream flows are substantially reduced below this point, thus allowing high ambient air temperatures to quickly warm instream waters.

Actions for improving water temperature: To facilitate successful salmon and steelhead immigration, spawning, and incubation, river water temperature at Marysville should not exceed 57°F for the months of October through March. Because both species experience peak juvenile outmigration from April through June, river water temperatures at Marysville should not exceed 60°F during April and May and 65°F during June. For the thermal protection of juvenile steelhead, river water temperatures throughout the remainder of the year (July through September) should be maintained at or below 65°F as well.

For effective management of lower Yuba River salmonids, emphasis should be placed on consistently meeting biologically appropriate instream flows and temperatures throughout the year. Adequate uncommitted water currently exists in the Yuba River system (i.e., Englebright and New Bullards Reservoirs) to restore the river's anadromous fishery. Reoperation of New Bullards Bar and Englebright Reservoirs to provide appropriate seasonal instream flows and temperatures for salmonid production in the lower Yuba River should be pursued. Because of the large storage capacity of New Bullards Bar Reservoir (relative to Englebright Dam), reoperation of New Bullards Bar Reservoir should take priority for achieving target instream flows and temperatures. Reoperation of Englebright Reservoir will therefore be heavily influenced by operational changes made upstream at New Bullards Bar. Colder temperatures for chinook salmon spawning in October, for example, could possibly be achieved by: 1) drawing Englebright Reservoir down in August and refilling it with cold water from New Bullards Bar Reservoir, and/or 2) installing a "curtain" into the water release outlets of Englebright Dam so that water can be released from the lower depths of the cold water pool only.

Appropriate outmigration flows and temperatures must be maintained to the Marysville gage to prevent heavy losses of juvenile salmonids below Daguerre Point Dam due to predation and thermal stress.

Related actions that may impede or augment the action: Higher instream flows (Actions 1-3) provide the means for achieving target water temperatures in the lower Yuba River. Better access to the coldwater pool in Englebright Reservoir in fall (see Action 7) could be heavily relied on to meet target spawning temperatures in October and November for fall-run chinook salmon. Drawing Englebright Reservoir down in August or September and refilling with cold water from New Bullards

Bar is likely impractical due to adverse impacts on recreation that would occur at Englebright Reservoir as a result of this action.

Predicted benefits: Lack of suitable in-river rearing and spawning temperatures currently limits both steelhead and salmon production in the lower Yuba River. Maintaining appropriate river temperatures will increase annual salmonid production by decreasing juvenile mortality from predation and thermal stress and increasing early fall reproductive and incubation success. Although quantitative estimates of increased production resulting from incremental changes in river temperatures are not presently available, much is known about how water temperatures affect salmonid survival rates during each life stage (e.g., USFWS 1990). This information clearly shows that lower Yuba River water temperatures are generally higher than that which is optimal for steelhead and chinook salmon and thus every effort should be made to maintain lower river temperatures throughout the early spawning and entire rearing and outmigration periods of the year.

Of all limiting factors and potential solutions, maintaining suitable river temperatures and instream flows will probably do more for increasing salmonid production within the lower Yuba River than all other actions combined.

Action 7: Evaluate and modify (if shown to be effective and appropriate) the water release outlets at Englebright Dam.

Objective: Physically modify (if found to be effective) the water release outlets of Englebright Dam to improve control over the depth at which water is discharged.

Location: Englebright Dam.

Narrative description: Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows needed to achieve target river temperatures. To effectively utilize the cold water pool of Englebright Reservoir, appropriate and effective modifications to the exsting water release outlets may be needed at the dam. The greater the control over the depth at which reservoir waters are released, the better one can control downriver temperatures and manage the reservoirs' coldwater pools throughout summer.

Predicted benefits: See predicted benefits discussed for Action 6.

Actions 8, 9, and 10: Improve efficiency of fish screening devices and fish bypasses at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities. Modify the timing and rate of water diverted from the river annually.

Objective: Reduce losses of juvenile salmonids.

Location: Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities.

Narrative description: The current fish screening devices at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities do not meet existing DFG fish screening criteria. Thus, fish screens at these facilities should be rebuilt to meet the DFG criteria. All water diversions on the lower Yuba River, big or small, should be evaluated for fish losses and screened according to current DFG criteria. Additionally, the efficiency of fish bypasses at these sites should be evaluated and changes made as warranted.

In addition to improving the fish screens and bypasses at these diversions, consideration should be given to the timing and magnitude of water diverted with regard to the timing of juvenile salmonid outmigration, and hence exposure to diversion screens and bypasses. Decreasing diversion flow rates at times of peak salmonid outmigration (e.g., April-June) would decrease fish losses at diversion facilities.

The three most significant diversions along the Yuba River occur at or near Daguerre Point Dam. Water diversions typically occur at this site from late March through October. The Hallwood Irrigation Company, the Cordua Irrigation District, and the Ramirez Water District share one diversion, Brophy and South Yuba Water Districts another, and Browns Valley Irrigation District a third. The combined diversions add up to a maximum of 1,085 cfs.

Juvenile salmonids are lost at all three diversion intake structures due to impingement, entrainment, or predation. While losses at individual diversions may not be great, the cumulative loss from all diversions is an important factor limiting annual salmonid production (Reynolds et al. 1993).

Unscreened diversions: Although a partial gabion structure exists, the Browns Valley Irrigation District's diversion is, for all practical purposes, unscreened, and losses of juvenile salmonids are known to occur there. The Hallwood-Cordua diversion is screened only during peak fall-run chinook salmon outmigrations (i.e., April through June) and remains unscreened during the remainder of the year. In addition, this diversion is not screened for the entire April through June outmigration period in every year and the screen does not meet DFG screen criteria for salmonids smaller than smolt size.

Juvenile salmonid survival is likely limited by pump entrainment at unscreened irrigation diversions. The exact number of unscreened agricultural diversions that exist on the lower Yuba River is not known at this time. However, an estimated six such diversions exist below Daguerre Point Dam (John Nelson, DFG pers. comm. 1994). The degree to which such diversions add to annual juvenile mortality is unknown.

Insufficiently screened diversions: Among the three primary water diversions, the Hallwood-Cordua diversion provides the best fish protection. It uses a V-shape, punched-plate screen that directs fish to a collection tank for removal and transport to a release location downstream. This screen is efficient in preventing the entrainment and impingement of smolt-sized juvenile salmonids (DFG 1991). However, losses do occur near the screen face and in the intake channel due to predation by squawfish. Losses range from 19.0% to 50.2% for test groups examined during 1977 and 1978.

The Brophy-South Yuba gravity diversion is screened by a permeable rock dike that still allows passage of juvenile-fish, even when the diversion is not in operation. This levee separates the diversion pool from a diversion and bypass channel. Studies have shown that fish losses through the levee were proportional to the amount of water diverted. DFG concluded from a survey that the levee is permeable to small fish, even when the diversion is not operational. Approximately 50% of the fish lost were attributed to predation by Sacramento squawfish in the diversion and bypass canal on the upstream side of the rock levee. Additionally, this gabion structure is topped during high flows (e.g., greater than 20,000 cfs), allowing juvenile salmonids to become entrained in the pool behind the structure (John Nelson, DFG, pers. comm. 1994).

The Browns Valley diversion is partially screened by a gabion that stretches across the mouth of the slough where the pump is located. However, a breech was cut through the gabion near the upstream bank to enhance diversion flow after it became clogged. The breech has reduced the effectiveness of the gabion to screen out fry and juvenile fish. Entrainment losses of smolts were calculated for diversion flows ranging from 10 to 75 cfs with 60-day losses estimated to range from 87 to 1,200 fish. At the maximum legal diversion rate of 42 cfs, total loss over a 60-day period was estimated to be 525 fish (DFG 1991).

These losses appear small; however, the overall cumulative effects of losses at all diversion sites make total losses significant. Juvenile salmonids are clearly lost to entrainment and impingement at all of these facilities. Thus, DFG has assigned an A-1 priority to improving these screening devices (Reynolds et al. 1993). In accordance with Fish and Game Code 6100, existing gravel and weir type fish screens have proven unreliable and ineffective and should therefore be replaced and screened with state-of-the-art perforated plate or wedge wire type screens located on the river (DFG 1991).

Inefficient bypass: At the Hallwood-Cordua screen, turbulence in front of the screens prevents juvenile salmonids from being quickly transported into the bypass. As recommended for fish screening devices, all bypasses should be evaluated for their efficiency and actions taken to improve effectiveness where warranted.

Flow reduction: The combined diversions from Hallwood-Cordua, South Yuba-Brophy, and Browns Valley diversions add up to a maximum of 1,085 cfs. When considered with New Bullards Bar Reservoir, the diversions result in increased flows above Daguerre Point Dam and decreased flows below Daguerre Point Dam. Specific effects of the diversions depend on flow levels and months when the diversions are made. Flow reductions from all diversions on the lower Yuba River have undoubtedly limited salmonid production during dry and critically dry water years. The effect of water diversion at Daguerre Point Dam (on in-river water temperatures) is most pronounced when diversions exceed 500 cfs and flows of only 200-300 cfs pass downstream. Low flows allow a more rapid warming of river waters with increasing distance downriver.

Actions for reducing fish losses at diversions: Juvenile salmonids continue to be lost at all diversion intake structures due to impingement, entrainment, and predation. Even if spawning success is high, net annual production of salmonids will remain low if in-river juvenile mortality rates continue to be high. Losses are believed to be highest at the South Yuba-Brophy and Browns Valley diversions. The inefficient rock-gabion structure at the Brophy-South Yuba diversion should be replaced and screened according to current DFG criteria (DFG 1991). Likewise, an effective fish screening devise must be installed at the Browns Valley diversion where no screen currently exists. In addition, all water diversions on the lower Yuba River should be accurately inventoried and effective screens and/or by-passes installed at all diversions identified to protect outmigrating juvenile salmonids. DFG has assigned an A-1 priority to inventorying all water diversions between Englebright Dam and the Feather River and to installing effective screening devises at the Hallwood-Cordua, South Yuba-Brophy, and Browns Valley diversions (Reynolds et al. 1993). Finally, modifications to the timing and duration of water diversions should be considered to reduce the impact of water diversions during critical periods of the year (e.g., juvenile outmigration from April through June).

A routine maintenance program must be established to prevent debris from blocking the entrance to fish bypasses. Similarly, bypass flows must be adequate and pathways from the channel into bypasses direct enough to ensure that fish can find bypass entrances. Finally, structures should be designed and installed near screens and bypass outlets to exclude and thus prevent squawfish and striped bass from selectively preying on juvenile salmonids that become disoriented and hence particularly vulnerable at such sites.

Predicted benefits: Modifications to fish screening devices, bypasses, and the timing of water diverted would reduce annual juvenile salmonid loses at the above-mentioned water diversion facilities. Increased juvenile salmonid survival and thus increased lower Yuba River salmonid production would result.

Action 11: Exclude piscivores from areas around diversions where disoriented juvenile salmonids become easy prey.

Objective: Reduce predation losses of juvenile salmonids.

Location: Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities.

Narrative description: Predation on juvenile salmonids by squawfish and, to a lesser degree, by striped bass is significant at the screening facilities and bypasses of diversions. At the Hallwood-Cordua screens, squawfish and, to a lesser degree, striped bass prey on juvenile salmonids that are concentrated at the screen face. Squawfish and striped bass predation is also potentially significant at the discharge site of the fish bypass system for the Hallwood-Cordua screening facility. Any alterations to existing screens and/or bypass structures that would reduce predatory fish access to disoriented juvenile salmonids would reduce such predation losses. Measures that reduced squawfish access to juvenile salmonids at screening and bypass sites would also reduce predation from adults of other fish species.

Observations by Vogel Environmental suggest that predation losses could be the single greatest source of juvenile salmonid mortality within the Mokelumne River. Although each river within the Central Valley is unique, such findings suggest that juvenile salmonid losses from predation are likely to be significant in other rivers, such as the Yuba River.

Actions for reducing juvenile salmonid losses from predation/competition: Consideration should be given to a squawfish control program in the lower Yuba River. Structures could be designed and installed near screens and bypass outlets to exclude and thus prevent squawfish and striped bass from selectively preying on juvenile salmonids that become disoriented and hence particularly vulnerable at such sites.

The effectiveness of physical and/or electrical devises should be investigated for installation at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities and associated bypasses to prevent piscivores from gaining access to disoriented juvenile salmonids. Doing so would reduce predation losses at these facilities.

Predicted benefits: Exclusion of piscivores from areas where outmigrating juvenile salmonids become particularly vulnerable to predation would increase outmigration survival. Increased juvenile salmonid survival will likely increase overall lower Yuba River salmonid production.

Action 12: Maintain a minimum flow of 175 cfs through the critical Simpson Lane reach during the spawning period in dry and critically dry years.

Objective: Facilitate passage of spawning adults through the critically shallow portions of the Simpson Lane reach.

Location: Simpson Lane reach (from the north side of Marysville downriver to the confluence with the Feather River).

Narrative description: The most severe obstruction to upstream migration is likely to occur at a critical riffle in the Simpson Lane reach. During dry and critically dry years, if instream flow rates are allowed to drop below 150 cfs in the Simpson Lane reach, physical blockage of upstream spawning migrations can occur, preventing adults from reaching preferred spawning habitat upstream (i.e., Garcia Gravel Pit and Daguerre Point Dam reaches). (See Action 1 for boundary definitions of these reaches.)

The recommended minimum clearance depth for upstream migration of adult chinook salmon varies in the literature. DFG (1991) indicated that a minimum of approximately 175 cfs is required to meet fish passage criteria for this reach. This was determined using a minimum depth criteria of 0.8 foot to continuously cover a minimum of 10% of the stream cross-section.

Actions 1 through 6 specify additional flows needed to provide spawning, incubation, rearing, and outmigration habitat for chinook salmon and steelhead. Flows for passage through the Simpson Lane reach should not be construed to suggest that flows below those specified in Action 1 through 6 are adequate to achieve the goals of the AFRP.

Predicted benefits: If spawning migrations become physically blocked by inadequate flows through the Simpson Lane reach of the lower Yuba River, spawning success will likely be significantly reduced. Thus, by maintaining appropriate flows here, spawning will be allowed to occur in the best habitat available even in dry and critically dry years. The result will be greater egg production and survival to the fry stage than would occur if fish were not allowed to pass beyond this point in the river.

Actions 13 and 14: Modify fish ladders at Daguerre Point Dam and maintain appropriate flows through these ladders to improve adult passage efficiency during the spawning seasons.

Objective: Maximize the number of spawning adults that reach preferred spawning habitat upstream of Daguerre Point Dam.

Location: Daguerre Point Dam.

Narrative description: There are two pool and weir type fish ladders (one on either side of the river channel) at Daguerre Point Dam. The ladders are effective as long as flows exceed 70 cfs over the ladders and are not in excess of approximately 4,000 cfs. Several problems can be stated for the existing set of ladders. First, ladder outlets are arranged at a 90° angle to the main channel's flow pattern. Secondly, attraction flows at the entrance to the ladders are not constant and often inadequate to effectively attract migrating adults. This is particularly a problem at higher flows (John Nelson pers. comm.).

Modifications of Daguerre Point Dam and its fish ladders are recommended to improve the upstream passage of spawning adults and the downstream passage of juvenile outmigrants. Structural modifications to existing fish ladders are needed to: 1) increase and continuously maintain attraction flows at the entrance to the fish ladders, 2) realign the entrance of ladders so they are not at a 90° angle to the main channel flow, and 3) eliminate sharp turns in the ladders to reduce the difficulty of fish passage. In addition, the 70-cfs flow that is currently recommended as the minimum flow through the ladders at Daguerre Point Dam should be reevaluated after ladder reconfiguration and maintained at the optimal flow for successful adult passage during peak spawning periods. Finally, construction of a third fish ladder up the middle of the dam, in line with the main flow pattern, should also be considered, because such a ladder may be most effective in routing fish over the dam.

Removal of Daguerre Point Dam would solve passage problems for both adults and juveniles and should therefore also be considered.

Predicted benefits: Allowing greater numbers of adult salmonids to reach preferred spawning habitat above Daguerre Point Dam while they are in sound physiological condition will improve their spawning success. A greater number of viable eggs and fry produced annually is likely to be the net result of this necessary action.

Action 15: Purchase of streambank conservation easements.

Objective: Improve riparian habitat and instream cover.

Location: Lower Yuba River.

Narrative description: Historically, riparian forests were likely extensive along the lower Yuba River. Riparian vegetation is important to the maintenance of anadromous salmonid populations by virtue of: 1) stabilization of streambanks, thereby reducing sediment load in the river; 2) provision of shade; 3) enhancement of stream nutrients due to decay of plant debris; 4) provision of streamside habitat for terrestrial and aquatic insects that are preyed on by fish; and 5) provision of instream cover. Mine tailings left from previous hydraulic mining activities, however, do not support the rich loam soil required by most native riparian species for reproduction and growth. The lack of native riparian habitat on the lower Yuba River is limiting to its salmonid populations (DFG 1991, Reynolds et al. 1993).

Water temperature: The riparian vegetation along the lower Yuba River is somewhat sparsely distributed and provides limited cover and shading of the stream channel. Lack of riparian cover to provide shading causes river temperatures to be higher than they would be if such cover were present.

Insect availability: Reduction in riparian communities along the lower Yuba River has likely reduced the abundance of aquatic and terrestrial insects. Re-establishment of native riparian cover would increase invertebrate food available to fish by providing additional invertebrate habitat and by increasing river nutrient levels and, hence, productivity.

Habitat diversity and instream cover: Riparian communities remain depauperate with poor habitat diversity. Instream cover and diversity is likely restricted by the riparian vegetation. Riparian vegetation along the river has yet to develop to the point that it significantly contributes to the improvement of rearing habitat that is believed to limit juvenile salmonid survival in the river. The river levees restrict the range of suitable water depths and velocities for salmonid spawning and rearing, particularly at high flows. Additionally, suction gold dredging in areas where salmon reside during summer is a concern of DFG.

Actions for improving streambank and channel habitat: Efforts should be made to protect and enhance existing riparian vegetation along the lower Yuba River. As needed, purchase of stream bank conservation easements would facilitate widening and improving the existing riparian corridor. A management plan would then be needed to determine best possible approaches to improve and maintain the riparian habitat. Local conservation organizations should be contacted to determine their interest in developing and implementing such a riparian enhancement and management plan. Private land owners should be given incentives to enhance riparian vegetation on their lands.

In addition to maintaining appropriate instream flows, improvements in juvenile salmonid rearing habitat can be made by: 1) increasing food availability and 2) increasing instream cover, both of which are results of enhancing riparian habitat. Additional streamside shading provided by enhanced riparian vegetation will also aid in keeping instream temperatures appropriately cool during spring, summer, and fall.

Periodic high flows are necessary for natural channel maintenance and thus should be allowed to occur annually in spring. In addition, no additional riverbanks should be riprapped; rather, natural riparian vegetation should be established and managed to stabilize banks.

Predicted benefits: Enhancement of riparian habitats will increase the abundance of both terrestrial and aquatic insects and therefore their availability to juvenile salmonids. This increased prey base will likely facilitate more rapid growth and earlier outmigration. Riparian cover will also shade river waters, thereby helping to keep water temperatures low enough to prevent thermally stressing outmigrating juveniles and immigrating adults.

Actions 16 and 17: Placement of large woody debris into the stream channel. Terminate current programs that remove woody debris from the stream channel.

Objective: Provide instream cover for juvenile salmonids.

Location: Lower Yuba River.

Narrative description: Trees and logs could be added to selected rearing habitats on the river, particularly upstream of Daguerre Point Dam, to enhance instream cover for juvenile salmonids. In addition, the current practice of clearing trees and other objects from the river to eliminate hazards to recreationists should be terminated. This practice has clearly reduced the availability of instream cover needed by juvenile salmon and steelhead.

Predicted benefits: Establishment and maintenance of instream woody cover will provide needed cover for juvenile salmonids, resulting in increased survival from reduced predation losses. Such instream cover will also provide a substrate for aquatic invertebrates to colonize, ultimately increasing food availability for juvenile salmonids.

Action 18: Impose stricter harvest regulations on commercial fishers.

Objective: Increase spawning escapement.

Location: Pacific Ocean.

Narrative description: Commercial harvest regulations could be modified to reduce current exploitation rates. Oceanic harvests significantly influence escapement and are not stock selective. Thus, reductions in oceanic harvests will likely increase spawning escapement in most Central Valley streams, including the lower Yuba River.

At higher flows (as recommended by Actions 1-3), the lower Yuba River can accommodate a larger number of spawning adults because of increased acreage of suitable spawning habitat.

Predicted benefits: Reducing commercial harvest will likely translate effectively into increased lower Yuba River escapement. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions proposed above, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower Yuba River.

Action 19: Conduct weekly on-river patrols in areas where poaching is a concern.

Objective: Increase spawning escapement.

Location: Lower Yuba River.

Narrative description: No accurate estimates of illegal harvest of adult salmonids at the Daguerre Point fish ladders and elsewhere on the lower Yuba River are currently available. Thus, it is difficult to say if this is a significant limiting factor. Because such losses can be largely prevented, necessary actions in the form of patrolling and increasing fines would be appropriate.

DFG could establish a greater enforcement presence at areas along the lower Yuba River where poaching is a concern (e.g., fish ladders at Daguerre Point Dam). Information regarding the status of the salmon migratory season could be used by the wardens to optimize the time and manpower allocated to patrolling the locations selected for particular days or weeks.

Predicted benefits: At higher flows, the lower Yuba River can accommodate a large number of spawning adults. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions proposed above, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower Yuba River.

Action 20: Modify the dam face of the Daguerre Point Dam.

Objective: Reduce juvenile mortality from predation as outmigrants pass over the dam.

Location: Daguerre Point Dam.

Narrative description: Outmigrating juvenile salmonids pass over the face of the Daguerre Point Dam and become disoriented in waters below, where waiting piscivores (e.g., squawfish and striped bass) prey heavily on them. This is a particular problem because juveniles can pass over the dam face at any point and thus often fall into calmer waters adjacent to the main channel flows where piscivores are particularly successful in capturing them. Losses at the base of Daguerre Point Dam are of greatest concern during dry years.

Notches or other structures directing flow through particular points on the dam face should be considered in order to route outmigrating smolts into the main channel of the river below the dam. Doing so would allow higher velocity main-channel flows to more quickly carry disoriented smolts beyond waiting predators.

Removal of Daguerre Point Dam would solve passage problems for both adults and juveniles and should therefore also be considered.

As a related action, physical/electrical barriers could be designed and installed below the dam, which would deny piscivores access to disoriented smolts immediately below the dam. This would reduce predation losses from squawfish and other piscivores at Daguerre Point Dam.

Predicted benefits: By reducing the opportunity for squawfish and other piscivores to feed on disoriented smolts following their passage over Daguerre Point Dam, juvenile survival through the outmigration stage will be increased. Increased juvenile survival during outmigration may result in an increase in future escapement of that year-class.

Bear River -

Limiting factors and potential solutions - - Following is a list of factors that may limit chinook salmon and steelhead production within the Bear River basin (Table 3-Xc-4).

Table 3-Xc-4. Limiting factors for chinook salmon and steelhead in the Bear River and potential solutions.

Limiting factors	Potential solutions
Instream flow	1. Increase instream flows 2. Determine instream flow requirements for chinook salmon and steelhead
Water temperature	Increase instream flows
Water diversions	Screen diversions
Water quality	Monitor water quality particularly at agricultural return outfalls
Migration barriers	Negotiate for removal or modification of the culvert crossing at Patterson Sand and Gravel

Restoration actions -

Action 1: Establish and protect adequate instream flows.

Objective: Provide a sufficient amount water at the appropriate temperatures for salmonid migration, holding, spawning, incubation, rearing, and outmigration.

Location: South Sutter Water District's (SSWD's) diversion dam.

Narrative description: Lack of flows limit anadromous fish production in the lower Bear River. Presently, flows in the Bear River below SSWD's diversion dam are not adequate for salmonid production. In past years, high escapement estimates corresponded to high fall flows (Table 3-Xc-5).

Table 3-Xc-5. Estimates of numbers of chinook salmon that spawned in the lower Bear River for selected years.[a]

Year	Number of adult spawners	Flow range (cfs) in October [b]	Flow range (cfs) in November [c]
1978	0	1.6 - 8.7	0.45 - 14
1980	0	2.1 - 9.2	4.9 - 29
1982	<100	6.8 - 37	28 - 7,170
1983	>200	37 - 55	484 - 4,360
1984	300	19 - 47	24 - 1,430
1985	0	4.4 - 33	10 - 28
1986	1	9.5 - 20	15 - 34

[a] Source: DFG Region 2, Rancho Cordova, file data for Bear River-Placer, Sutter, and Yuba counties.

[b] Source: USGS Water Resources Data, California, Volume 4, various years, gage 11424000, Bear River near Wheatland.

[c] Estimate of angler catch from Dry Creek.

Table 3-Xc-6 lists the minimum stream flow and maximum temperature regimes that should be maintained in the lower Bear River during wet and normal water years for the protection and maintenance of chinook salmon. These recommendations are based on information provided by the SSWD for its proposed Garden Bar Project (Nelson pers. comm.). According to SSWD (1988), the microhabitat variables describing depth, velocity, and substrate for the juvenile and spawning life stages of fall-run chinook salmon were taken from Bovee (1978) for use in the simulation model. However, comparison of the criteria used with that presented by Bovee (1978) indicates that criteria for juvenile substrate and spawning substrate and depth were not taken from Bovee (1978).

Table 3-Xc-6 was developed in the absence of PHABSIM analyses of the physical habitat WUA/river discharge relationships for steelhead. Information for fall-run chinook salmon indicate that the preferred physical living space requirements are optimized by the flow regime presented in Table 3-Xc-6.

Table 3-Xc-6. Minimum instream flow and maximum temperature regimes for wet and normal water-year types to facilitate doubling production of chinook salmon and steelhead in the Bear River.

Month	Flows (cfs)	Temperature (°F)[a] at:	
		Wheatland[d]	Highway 70
October 1-14	100[b]	60	60
October 15-December 15	250[b]	58	57
January-March	250[b,c]	56	57
April-June	250[c]	60	60
July-September	10[d]	65	65

[a] Recommended mean daily temperatures to be maintained during normal and wet water years for protection of chinook salmon.

[b] Flows needed for spawning and incubation of chinook salmon and steelhead.

[c] Flows needed for rearing and outmigration of chinook salmon and steelhead. Physical habitat needs alone (depth, velocity, and substrate in PHABSIM analyses) suggest that chinook salmon require flows of at least 190 cfs from January to March and 100 cfs from April to June.

[d] Flows for July to September will need to be higher to address temperature requirements of steelhead.

Evaluating existing river temperatures and flows indicates that it may be possible to achieve favorable water temperatures for chinook salmon under these flows. The flow regime during the July through September period, however, will not achieve the temperature requirements necessary for steelhead because temperatures at existing flows since 1963 have been consistently recorded above 75°F at Wheatland during July and August. Once additional studies of the temperature and flow relationship downstream of Camp Far West Reservoir and of the physical habitat WUA/river discharge relationship for steelhead are completed, changes in this flow regime will be necessary to meet the above temperature requirements for steelhead during the July through September period and possibly during other times of the year for chinook salmon as well.

Analysis of the annual flow at Wheatland indicates that the recommended flow regime at Wheatland (95,249 af) represents only 29.5% of the unimpaired flow (Table 3-Xc-7). Comparing the lower Bear River's proposed flows at Wheatland with the river's annual unimpaired flow for the 63-year period indicates that the total annual flow recommended for fishery purposes is exceeded about 94% of the years (Table 3-Xc-6). Hence, on the average, there is insufficient water in the Bear River to meet fishery needs in only 6 out of every 100 years.

Comparing the monthly unimpaired flow with the recommended monthly flow indicates that recommended October flow exceeds the unimpaired requiring a flow augmentation of 6,207 af (Table 3-Xc-7).

Table 3-Xc-7. Estimated Bear River mean monthly unimpaired flow at Wheatland for the 63-year period 1921-1983, actual flow at Wheatland gage for the 1964-1990 period, and proposed minimum flow regime at Wheatland.

Month	Unimpaired flow, 1921-1983[a]	Actual flow, 1964-1990[b]	Proposed minimum flow
October 1-14	2,250 (81)	461 (17)	2,777 (100)
October 15-31	2,750 (81)	561 (17)	8,430 (250)
November	16,000 (269)	9,458 (159)	14,876 (250)
December	43,000 (699)	30,757 (500)	15,372 (250)
January	61,000 (992)	58,579 (953)	15,372 (250)
February	68,000 (1,224)	64,772 (1,158)	13,884 (250)
March	61,000 (992)	67,176 (1,092)	15,372 (250)
April	42,000 (706)	43,537 (732)	14,876 (250)
May	17,000 (276)	11,726 (191)	15,372 (250)
June	6,000 (101)	2,690 (45)	14,876 (250)
July	2,000 (33)	1,061 (17)	615 (10)
August	1,000 (16)	934 (15)	615 (10)
September	1,000 (16)	823 (14)	595 (10)
Total	323,000	292,535	133,032

Note: Flows are in af with cfs in parenthesis.

[a] Source: DWR (1987).

[b] Source: USGS, Water resource data - California, water years 1964 through 1990.

Because flow in the lower Bear River is impaired by water project operations and diversions, comparison of the actual and recommended flows at Wheatland provides a more representative evaluation than one using unimpaired flows. Compared to the total annual impaired flow, the recommended flow regime represents only 32.6% of the impaired flow at the Wheatland gage. However, comparing the monthly recommended flow with the monthly impaired indicates that on the average to achieve the recommended minimum flow, the recommended flow exceeds the average monthly impaired during June, October, and November requiring flow augmentation of 18,864 af.

Potentially, water can be acquired by: (1) evaluating the existing water rights throughout the watershed and petitioning SWRCB for a change to obtain increased streamflow and (2) purchasing water from willing sellers (potentially SSWD and PG&E).

Water temperatures in the lower Bear River are affected by the operations of Camp Far West Reservoir, other reservoirs upstream, and diversions downstream of Camp Far West Reservoir. Operations of the Camp Far West project and diversions have resulted in low flows and elevated temperatures downstream during critical life stages of chinook salmon and steelhead. Evaluation of existing temperatures indicated that river temperatures are often at or above preferred ranges for salmon and steelhead life stages. Maintenance of ideal temperatures can be achieved by developing operational criteria for Camp Far West Reservoir and other reservoirs upstream and incorporating them into the prescribed flow schedule.

Predicted benefits: Providing adequate instream flows will encourage spawning in Bear River. Based on past records, this action should, independently, double escapement.

Action 2: Conduct an IFIM to determine instream flow and temperature requirements for all life stages of salmon and steelhead.

Objective: Ensure that the available water is utilized to its fullest potential to benefit all life stages of salmon and steelhead.

Location: Entire stream below SSID's diversion dam.

Narrative description: Previous IFIM studies proved inconclusive due to the methodology employed (see Action 1) and did not consider steelhead (temperature) or biological criteria. DFG, with aid from the SSID, should conduct an IFIM on the entire river. The study should evaluate the needed flows for all life stages of salmon and steelhead using biological and physical parameters.

Predicted benefits: An IFIM study will ensure the available water is used wisely for all life stages of salmon and steelhead. Ensuring ideal or adequate flows will directly benefit salmonid restoration.

Action 3: Effectively screen all diversions.

Objective: Reduce loss of production to entrainment.

Location: Entire stream below SSID's diversion dam.

Narrative description: Loss of juvenile salmon due to unscreened water diversions is a generic problem in the Central Valley. DFG should identify what diversions need screening on Bear River. Under the authority of standing Fish and Game Codes (6100), all diversions should then be screened.

Predicted benefits: Screening will directly prevent the loss of juveniles and likely increase production.

Action 4: Monitor water quality particularly at agricultural return outfalls.

Objective: Ensure that suitable water quality exists for all life stages of salmon.

Location: Entire stream, particularly below agricultural drains.

Narrative description: Excess water from agricultural diversions return to the river. This water may be contaminated with herbicides, pesticides, and agricultural wastes that may affect water quality. The EPA or CVRWQCB should conduct water quality testing, particularly at the outfalls of agricultural drains. Additionally, water quality may be affected by past heavy metal mining.

Predicted benefits: Monitoring the water quality will help identify potential sources of pollution. Eliminating these sources will improve the overall quality of the river and potentially increase production.

Action 5: Negotiate for removal or modification of the culvert crossing at Patterson Sand and Gravel.

Objective: Provide uninhibited passage for all life stages of salmonids.

Location: Patterson Sand and Gravel culvert.

Narrative description: DFG or USFWS should contact Patterson Sand and Gravel and assist it in modifying the culvert to ensure adequate passage of all life stages of salmonids. The culvert is likely a migration barrier under most flow conditions.

Predicted benefits: This action will enable better passage at this point and increase the available habitat.

American River -

Limiting factors and potential solutions - The following information (Table 3-Xc-8) was compiled to identify potentially limiting factors to fall-run chinook salmon and steelhead production in the lower American River. Although some factors are clearly more limiting, fish production is ultimately limited by the cumulative effects of all limiting factors. Thus, actions that reduce or eliminate any of these limiting factors will increase salmonid production. Nevertheless, efforts should center on those factors that are generally most limiting from year to year.

This list concentrates on factors pertaining to the lower American River as defined by Nimbus Dam on the upstream end and the confluence of the American River with the Sacramento River on the downstream end. Obviously, a major factor limiting production of salmon and steelhead in the American River is the presence of Nimbus and Folsom dams, which have eliminated access for salmonids to their historical spawning and rearing areas above Nimbus Dam. Because removal of these dams or facilitation of movement of salmonids past Nimbus Dam and especially Folsom Dam seems impractical, this list is limited to those factors potentially limiting populations of salmon and steelhead in the American River below Nimbus Dam.

The limiting factors addressed in this section of the report are organized under major section headings taken from the original matrix of limiting factors developed by the Lower Sacramento River and Delta Tributaries Chinook Salmon and Steelhead Technical Team.

Table 3-Xc-8. Limiting factors for chinook salmon and steelhead production in the lower American River and potential solutions.

Limiting factors	Potential solutions
Inadequate instream flows	1. Modify existing instream flow requirements 2. Develop water allocation guidelines 3. Evaluate pulse flows for facilitating juvenile outmigration in dry years 4. Reduce and control flow ramping rates
Unsuitable water temperatures	Reconfigure water release shutters at Folsom Dam

Limiting factors	Potential solutions
Inadequate spawning substrate	Implement a spawning gravel management program
Water diversion operations	1. Evaluate the effectiveness of the fish screen at the Fairbairn Water Treatment Plant and improve if necessary 2. Evaluate the efficacy and modify the timing and rate of water diverted annually, if appropriate
Bank and streambank modifications	1. Implement a riparian corridor management plan 2. Terminate current programs that remove woody cover from the stream channel
Overharvest of adult brood stock	1. Further limit sport and commercial harvests of naturally produced fish 2. Increase DFG enforcement efforts to stop poaching during the spawning seasons
Hatchery practices	1. Reduce reliance on stocking programs for meeting angler demands 2. Use all available spawning stock, not just those fish over a minimum length or arriving at a given time (to increase genetic diversity) 3. Discontinue stocking fish produced from adults taken from other rivers if those fish are genetically distinct from the native stock

The degree to which these and other factors may have limited production in the lower American River is unclear and is therefore subject to further study. Information is currently being complied to more completely assess this issue and to estimate current and past salmon and steelhead run sizes annually entering the lower American River.

Because of the interrelatedness among the various limiting factors, assigning a rank of relative importance to each factor is difficult. Furthermore, relative importance among limiting factors varies across years. Nevertheless, with adequate historical data, conditions in the lower American River, Sacramento River, and Delta could be related to annual spawning run sizes and numbers of juvenile outmigrants using multiple regression procedures. Such a statistical approach would allow limiting factors to be ranked in terms of their relative impacts on spawning run size and numbers of juvenile outmigrations passing defined points in the lower American River. This approach would also shed light on the relative importance of in-river versus down-river conditions as they pertain to salmonid production in the lower American River.

Several potential limiting factors were not addressed by restoration actions. These factors were not considered to be key factors currently limiting the production of salmonids in the lower American River. Nevertheless, they are briefly discussed below.

Migration barriers - Nimbus Dam, located about 23 miles upstream of the confluence, is the upstream terminus of anadromous fish migration in the lower American River. Approximately 73% of salmon and 100% of steelhead in the American River historically spawned upstream of Nimbus Dam (Hallock 1987). No significant migration barriers exist in the lower American River between Nimbus Dam and the confluence. Nimbus Hatchery weir prevents upstream migration and diverts spawners to the hatchery egg-take facility.

As no significant migration barriers exist on the lower American River, no action options are needed. Relative to the Nimbus Hatchery, however, one might suggest that time periods that the weir is in place be managed to balance benefits to the hatchery and natural production.

Water quality - The major water quality parameter known to be adversely affecting salmonid production in the lower American River is water temperature (see Actions 1 and 5).

Urban runoff - Urban development within the lower American River watershed contributes substantial urban runoff. Inadequate treatment of runoff results in contaminants reaching the American River. The extent to which urban runoff affects salmonid production is not currently known and therefore warrants additional study and monitoring.

Other point sources - Various industries along the American River, such as Aerojet and others, may be introducing contaminants into the river. Aerojet does not appear to be an issue at this time; however, it has the potential to contaminate groundwater, and thus both groundwater and surface water quality monitoring programs for the lower American River basin are needed.

Options to improve water quality - Improvements in the capture and treatment of urban runoff would undoubtedly improve water quality in the river. Public education to reduce the amount of contaminants introduced into urban drainage system would also benefit water quality. Water quality monitoring programs are necessary for identifying water quality problems when they arise, determining their source(s), and identifying corrective actions.

Predation/competition - Important predators of juvenile salmonids, including squawfish and striped bass, are common in the lower American River. Predation by these species is generally considered to be serious near instream obstructions and diversions where unusual flow patterns disorient or concentrate smolts. Because of the general absence of these conditions in the river, it is believed that although predation losses of juvenile salmonids from piscivores are probably lower in the American River than in many other rivers, it should still be considered a limiting factor.

Squawfish and other piscivores - Squawfish and various centrarchids are believed to be responsible for most piscivorous predation on outmigrating salmonids in the lower American River. Squawfish are present in the river year-round and are known to prey heavily on salmon and steelhead here and elsewhere in Central Valley streams. Juvenile salmonids isolated by reduced flows in side channels and backwater areas that support higher densities of squawfish and centrarchids often experience high predation losses.

Striped bass - Striped bass are known to prey on juvenile salmon and steelhead in the lower American River. A year-round sport fishery exists for striped bass, suggesting adult-sized striped bass are in the river year-round. Juvenile striped bass are also common in the lower sections of the river and may compete with juvenile salmon and steelhead. Lack of vegetative and woody cover, especially in the lower sections of the river, limits salmon and steelhead refuge from predators.

Hatchery fish - Hatchery fish, when released into the river, may prey on or compete with naturally produced fish.

Avian predators - Mergansers, egrets, herons, kingfishers, terns, and other fish-eating birds are common on the lower American River. Mergansers are particularly common during the early spring when salmon fry are most abundant. Fluctuating flows during spring may contribute to increased predation on juvenile salmonids. Fish temporarily stranded by reduced flows in pools and ponds along the river channel (a circumstance not necessarily lethal) have been observed to be the focus of heron and other avian predators.

Options for reducing juvenile salmonid losses from predation/competition - Restoration of instream vegetative and woody cover may partially alleviate fish and avian predation problems. Higher flows and cooler water would also favor salmon and steelhead over striped bass and other warmwater species that often prey on juvenile salmonids (e.g., various centrarchids). Continuing the policy of not releasing hatchery-produced fish to river (but rather downstream) would be effective in reducing predation on naturally produced salmonids by hatchery fish. However, this practice exacerbates the straying problem. Hence, simply decreasing reliance on hatchery-produced fish is the best policy for restoring native stocks. To effectively do so, we must act on the other limiting factors discussed in this paper.

Restoration actions -

Action 1: Maintain flows recommended in Table 3-Xc-9.

Objective: Optimize conditions in the lower American River for all salmonid life stages.

Location: Throughout the lower American River.

Narrative description: In 1972, the Environmental Defense Fund (EDF) filed suit against the East Bay Municipal Utility District (EBMUD) challenging the proposed diversion of water from Nimbus Dam through the Folsom South Canal, bypassing the lower American River. A 1990 court decision resulting from this case (known as the Hodge decision) ordered the following flows for the protection of salmonid resources in the lower American River: 2,000 cfs between October 15 and February 28; 3,000 cfs between March 1 and June 30; and 1,750 cfs between July 1 and October 14. These flows were established after extensive review of available scientific data concerning the relationship between lower American River flows and salmonid production.

It should be noted that Hodge decision flows were selected to protect aquatic public trust resources in the lower American River, not to double production of anadromous fish in the river. Hence, use of Hodge decision flows will not necessarily facilitate doubling production. Additional information addressing optimal instream flows for salmonid spawning and incubation, rearing, outmigration, and temperature control has been developed subsequent to the Hodge decision. Much of this information has been developed as part of the retained jurisdiction associated with the *EDF et al. vs. EBMUD* litigation, and was used to develop the instream flow recommendations for the lower American River that appear below.

Adult migration: Instream flows in the lower American River are typically not limiting to upstream passage. However, in recent years it has been observed that relatively high flow releases during the summer months have attracted adult chinook salmon upstream as far as the basin below Nimbus Dam. The origin of these fish is uncertain, although it is speculated that their origin may be from the Feather River or Coleman National Fish Hatchery. Conversely, the typical pattern of flow reduction to about 1,500 cfs during late September through October or November has occurred concurrently with elevated water temperatures released from Nimbus Dam. These elevated temperatures may cause prespawning mortality, reduce embryo viability, and/or delay timing of spawning. Thus, instream flows may adversely affect adult upstream migration primarily through elevated water temperatures.

Spawning habitat: Chinook salmon spawning is concentrated in several well-documented areas in the river between RMs 14 and 22 (Snider et al. 1993). During low flow conditions, the areal extent of available spawning habitat is further restricted. Recent redd surveys conducted by DFG have shown that the incidence of redd superimposition increases at lower flow levels (e.g., 42% in 1992 vs. 8% in 1991) (Snider et al. 1993).

Redd dewatering: Flow releases from Folsom and Nimbus dams are made to augment Sacramento River flows to: 1) meet Delta water quality standards, 2) generate hydroelectric power, 3) make deliveries to downstream users, and 4) provide fish protection. These demands result in considerable flow fluctuations in the river. DFG aerial redd surveys conducted for 1991-1993 (Snider and McEwan 1992, Snider et al. 1993, Snider and Vyverberg 1995) have provided evidence that chinook salmon redds are dewatered as a result of flow reductions during the fall and winter months. The potential for significant losses is greatest in years when flows are low and redds are concentrated.

Redd or fry stranding: Fluctuating flows are believed to result in considerable stranding and loss of chinook salmon and steelhead fry. Observations of stranded fish have been recorded in the river. For example, on May 31, 1990, a reduction of flow in the American River resulted in the stranding of several thousand juvenile chinook salmon and steelhead in the vicinity of Fair Oaks below Nimbus Dam. Mortality of young salmonids that become stranded outside of the main channel as a result of rapid instream flow reductions is near 100%. Sources of mortality in such cases include predation by fish and avian predators, as well as death resulting from thermal stress.

Rearing habitat: Low flows reduce the availability of appropriate rearing habitat. In addition, rapid ramping rates may affect diversity, productivity, and availability of insects (an important food source for salmon and steelhead) in the lower American River. The flows (high and low) at which the availability of rearing habitat for juvenile salmonids becomes limiting, from the standpoint of physical space or suitable depth and velocity distributions, is not well documented. At low-flow levels, however, these considerations are probably overridden by water temperature issues.

Juvenile outmigration: Inadequate flows during April through June decrease the success of juvenile salmon and steelhead outmigrations. When flows drop below 1,500 cfs, extensive juvenile isolation and stranding occurs (Bill Snider, DFG, pers. comm. 1994).

Table 3-Xc-9. Instream flow regimes[a] recommended to facilitate doubling of chinook salmon and steelhead production in the lower American River[b] under four year types[c]

Month	Flow (cfs) for each of four year types			
	Wet	Normal	Dry/ critical[d]	Critical relaxation[e]
October	2,500	2,000	1,750	800
November-February	2,500	2,000	1,750	1,200
March-May	4,500	3,000	2,000	1,500
June	4,500	3,000	2,000	500
July	2,500	2,500	1,500	500
August	2,500	2,000	1,000	500
September	2,500	1,500	500	500

[a] These flow regimes were developed in consideration of water availability (i.e., unimpaired runoff at Fair Oaks) associated with each of the hydrologic conditions (wet, normal, dry/critical, critical relaxation). One objective associated with these flow regimes is that Folsom Reservoir achieves a target storage of about 610 taf by September 30 to provide a sufficient volume of water (and coldwater pool) to maintain spawning and incubation (fall and winter) flows; however, hydrologic modeling was not conducted as part of this review. These flow recommendations likely will be modified based on additional hydrologic evaluations. In addition, these flow regimes likely will be modified based on the results of monitoring programs intended to evaluate the effectiveness of these flows, as well as additional restoration actions.

[b] Lower American River flows (cfs) measured at the H Street Bridge.

[c] These flow regimes should be viewed as "minimum" flows under each hydrologic condition. Therefore, it is important to note that higher flows are likely to occur during a given month depending on precipitation and runoff patterns, particularly during the "wetter" hydrologic conditions.

[d] The dry/critical flow regime can accommodate a relatively wide range of hydrologic conditions, including all but the most severe drought conditions.

[e] The "critical relaxation" flow regime is intended for application to hydrologic conditions characterized by the most severe drought years.

Options for improving instream flows (instream flow recommendations) -

Wet year type: Even in a wet year, the amount of water that can be released from Folsom Reservoir during the chinook salmon spawning and incubation period (October through February) is limited by the storage in the reservoir on October 1. The 2,500-cfs flow recommendation for October through February in a wet year approaches the maximum release rate that can be sustained throughout this and subsequent months. Releases during this fall period are conducted prior to knowledge of the water-year type that is being entered in the following year. Thus, excessive drawdown resulting from fall releases in excess of 2,500 cfs are not recommended, because this may create severe water availability problems. Because the reservoir will be filling throughout the late fall and winter months, flows may be increased to 4,500 cfs from March through June to provide: 1) appropriate juvenile rearing habitat availability and outmigration flows and 2) temperature control during May and June (i.e., maintain mean monthly river temperatures below 65°F at H Street). Flows are reduced to 2,500 cfs during July through September to provide some thermal protection (i.e., maintain mean monthly river temperatures at or below 70°F) for resident steelhead juveniles, while remaining within a realistic water budget for the year.

Normal: A flow rate of 2,000 cfs is recommended for October through February in a normal water-year type (Table 3-Xc-9). This flow is believed to provide appropriate spawning conditions for fall-run chinook salmon and steelhead in the lower American River during a normal water year.

Flow rates are increased to 3,000 cfs for March through June to provide 1) appropriate juvenile rearing habitat availability and outmigration flows and 2) temperature control during May and June (i.e., below 65°F). Flow recommendations of 2,500, 2,000, and 1,500 cfs for July, August, and September, respectively, are to provide some thermal protection (i.e., maintain mean monthly river temperatures at or below 70°F) for resident juvenile steelhead while not exceeding projected water availability for this water year type. Lesser flows during July and August (e.g., 1,000 cfs) produce mean monthly temperatures near or exceeding 72°F. Chronic exposure of juvenile steelhead to such temperatures would likely result in high mortality during these months. These summer flow recommendations are intended to reduce such losses.

Dry/critical: During a dry/critical year type, prioritization should be given to producing a good spawn, and facilitating successful juvenile outmigration. The recommended flow rate of 1,750 cfs for October through February is believed to provide reasonable spawning/incubation flows under the dry/critical regime. Flows are recommended to be increased to 2,000 cfs for March through June to provide adequate rearing habitat and outmigration flows. Temperatures will often exceed 65°F, particularly during June, at this flow rate. Because July is the month of greatest concern for river water temperatures, 1,500 cfs is recommended for July to provide minimal temperature protection for resident juvenile steelhead. The mean monthly temperature achieved in July at 1,500 cfs (about 71-71.5°F) can be achieved in August at the lower flow rate of 1,000 cfs. Finally, temperature control is of much lesser concern during September, so flows may be dropped to 500 cfs. Doing so aids in achieving adequate carryover for the upcoming fall spawning season.

Critical relaxation: In such water year types, insufficient water exists within the system to meet even minimal requirements of fish throughout the year. Thus, substantial trade-off decisions must be made. A flow rate of 800 cfs is recommended for October to save water for subsequent spawning months. A flow rate of 1,200 cfs is recommended for November through February to achieve reduced, but successful spawning. The recommended flow rate is increased to 1,500 cfs for March through May to facilitate successful rearing and outmigration for a substantial portion of the juveniles produced. Because little water remains available by this point in the year, flow rates are dropped to 500 cfs in June, out of necessity, and remain there through September.

To achieve the recommended seasonal instream flows discussed above, operations of Folsom Reservoir will require modification. Clearly, annual management for appropriate instream flows must be flexible, because the amount of water available to meet target flows will vary with water year type. During wet years, instream flows likely will exceed Hodge decision flows and facilitate natural channel maintenance, reduce the likelihood of spawning gravel becoming embedded, and provide optimal flows for fish. Redistributing the timing of flows will also be important to meeting fish flow needs. For example, in 1988 to 1992, the highest measured streamflow occurred during months of the year with the lowest estimated fish flow needs. Finally, additional attention must be given to storage carryover in Folsom Reservoir. Extensive drawdown of the reservoir from various water uses (including Delta water quality flows) can lead to insufficient water supplies for meeting in-river fall-run chinook salmon spawning needs, particularly during October.

Related actions that may impede or augment the action: Water allocation guidelines developed as a result of Action 2 may affect possible flow levels, especially in dry and critical relaxation water years as proposed in Table 3-Xc-9. In fact, regional water planning efforts are underway that build on the regimes presented in Table 3-Xc-9 via a more thorough hydrologic evaluation, because flows presented in Table 3-Xc-9 may not be consistently achievable or sustainable. These ongoing efforts are focusing on alternative assessments of water availability (i.e., storage in Folsom Reservoir) and subsequent allocation of available water to provide maximum instream beneficial use. It is presently assumed that resultant flow regimes will be dynamic and responsive to water availability on an annual basis.

Agency and organization roles and responsibilities: USBR is responsible for managing Folsom Dam and Reservoir.

Potential obstacles to implementation: The various water-user groups will likely have a difficult time agreeing to recommended flows that will alter present or future operations.

Predicted benefits: Although quantitative estimates of increased production resulting from incremental increases in flows are unavailable, the recommended instream flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower American River.

Action 2: Develop water allocation guidelines.

Objective: Provide, through planning, a reasonable way to allocate limited water resources among beneficial uses, including maintenance of aquatic resources (fish and aquatic habitat).

Location: The American River watershed (within the context of inflow to Folsom Reservoir), Folsom Reservoir, and throughout the lower American River.

Narrative description: There is a pressing need to develop a resource management plan that maximizes the public trust resources of the lower American River. Setting minimum flow requirements as shown above (Table 3-Xc-9) is productive in satisfying fish needs. However, history shows that target fish flows are often violated when water within the system becomes insufficient to meet them. The reason this occurs so frequently is that clear guidelines for where water allocation cuts will be made when water becomes limited have not been established to date for the American River system.

The focus of studies on the lower American River must be redirected toward establishing a resource management plan that will provide specific guidance on how best to manage the water supply from the American River from year to year and month to month. Thus, initial operational studies are needed to determine: 1) the frequency that Hodge decision flows can be maintained with existing CVP operational constraints and 2) the optimum flow regimes for those years when insufficient water is available to fully meet Hodge decision or other recommended flows for fisheries. These studies will also be used to evaluate CVP constraints (physical, institutional, or legal) that reduce the CVP's ability to optimize flow and temperature conditions for the fisheries. Each identified institutional or legal constraint could then be evaluated to determine the benefit on flows and temperatures of removing that constraint. The impact, if any, of removing each constraint on other CVP project purposes could also be determined. The goal of this effort would be to identify operations of Folsom Dam and Reservoir and the impacts of the operations that would optimize flow and temperature conditions for the lower American River fisheries, within the context of other environmental operation constraints on the CVP.

Operation studies could also serve to identify biological data needed to validate or refine existing management approaches. Thus, the operations studies could be used to determine which biological data are necessary to make management decisions and to monitor the results of management actions.

Such a study program could develop balances between the many competing public trust resource needs. An initial protocol that manages given water supplies could result from the development of this lower American River operations and fisheries plan. The information obtained from this effort could improve the ability to make rational decisions regarding the best management of water during times when water availability is not sufficient to serve all purposes.

Related actions that may impede or augment the action: See this section for Action 1.

Agency and organization roles and responsibilities: USBR, DFG, USFWS, and other water-user groups will need to develop together any water allocation guidelines.

Potential obstacles to implementation: The various water-user groups will likely have a difficult time agreeing on what constraints, if any, should be eliminated.

Predicted benefits: Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, the instream flows recommended above (Table 3-Xc-9) and the establishment of fish needs as a priority in an overall resource management plan for the river will significantly contribute to the goal of doubling salmon and steelhead production in the lower American River.

Action 3: Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmonid outmigration.

Objective: Optimize outmigration success when water is in short supply (e.g., dry and critically dry years).

Location: Throughout the lower American River.

Narrative description: The use of pulse flows should be evaluated as an approach to promote outmigration. Studies are needed for determining how to maximize juvenile outmigration success when water supplies are limited in drier years and thus instream flows are reduced during the outmigration period (April-June). The faster juveniles can emigrate (within physiological constraints of the smoltification process), the greater their probability of survival. Reduced time in the Lower American and Sacramento rivers during outmigration reduces the length of time juveniles are exposed to instream predators and physiologically stressful water temperatures. The chances of mortality due to stranding would be reduced when flows are high. However, this may be negated by increased stranding when flows are reduced at the end of each pulse. Anecdotal evidence suggests that increased turbidity may facilitate outmigration of salmonid smolts. Turbidity could be increased artificially, although the injection of clays and other fine materials may adversely affect streambed conditions via sedimentation.

Related actions that may impede or augment the action: Flow reduction/ramping criteria recommended through Action 4 along with flows from Action 1 may make pulses difficult to implement.

Agency and organization roles and responsibilities: USBR would be responsible for controlling flow levels, while DFG and USFWS would take on monitoring and assessment roles.

Potential obstacles to implementation: Various water users may argue as to the benefits of pulse flows to salmonid populations.

Predicted benefits: Such studies will provide a basis for facilitating juvenile outmigration when water within the system is limited. Rapid outmigration associated with a pulse flow will likely increase juvenile survival rates and thus overall production.

Action 4: Reduce and control instream flow ramping rates and flow fluctuations.

Objective: Reduce hazards posed to young salmonids when flow rates change quickly.

Location: Nimbus Dam

Narrative description: Ramping rates of flows across time must be addressed. Stabilization of instream flows to prevent rapid flow rate reductions (i.e., rapid ramping rates) from October through April would reduce the likelihood of stranding redds and fry. Similarly, prevention of rapid flow increases during this period would reduce the frequency of fry displacement. Finally, rapid ramping rates may be associated with gas supersaturation problems that occasionally occur below Folsom Dam. McEwan and Nelson (1991) recommended that USBR adjust overall CVP operations and procedures so that ramping problems can be eliminated, without sacrificing Delta water quality or habitat conditions in the upper Sacramento River for winter-run chinook salmon.

Operations at Folsom Dam relating to the release of water downstream should be modified so that adjustments made to instream rates are more gradual than they are currently. Ramping rates should not exceed 30% of an existing initial flow during any 24-hour period. If flow rates become significantly elevated above target levels for a week or more during the spawning period, flows should be maintained at or near this new level through February to prevent redd dewatering and fry stranding.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: USBR would be responsible for flow release levels, while DFG and/or USFWS would monitor and assess the effects on redd de-watering and juvenile stranding.

Potential obstacles to implementation: USBR may resist implementing ramping restrictions due to their possible effects on flood control and hydroelectric generation operations.

Predicted benefits: Establishment of more gradual ramping rates, particularly in spring and fall, will reduce losses of eggs and young salmonids and contribute to increased production. The exact contribution of this action to increased salmonid production can not be calculated at this time.

Action 5: Reconfigure Folsom Dam (penstock inlet ports) shutters.

Objective: Enhance control over temperature of water released downstream and management of Folsom Reservoir's coldwater pool.

Location: Folsom Dam and Reservoir.

Narrative description: The primary purpose of reconfiguring shutters on Folsom Dam is to provide increased ability to control the temperature of water in the lower American River. Water temperature in the American River is important to multiple life stages of salmonids.

Adult migration: Lower American River water temperatures in late summer and early fall (sometimes extending well into October) are often above 15°C (59°F). Optimum temperatures for adult salmon and steelhead migration are believed to be about 6.5-13°C (44-56°F) and 8-11°C (46-52°F), respectively (Beak 1989). Water temperatures above 15°C (59°F) will likely delay adult spawning migrations and thus may impede reproductive success. Exposure of pre-spawning adult salmonids to water temperatures above 15°C (59°F) can result in reduced gamete production, infertility, and increased embryonic developmental abnormalities.

Spawning: Spawning chinook salmon and steelhead begin to experience chronic stress at water temperatures of 13-16°C (56-61°F) and 11-15°C (52-59°F), respectively (Beak 1989). Salmonids often delay spawning when water temperatures reach the upper end of this range (see "Adult Migration" subsection above). Redds do not appear in the lower American River until water temperatures drop to approximately 15.5°C (60°F) (Snider et al. 1993). However, if spawning does occur at temperatures >15°C, impaired egg maturation and decreased performance and survival of progeny results. In addition, high water temperatures may alter behavior of spawning salmonids, resulting in reduced egg fertilization success and reduced egg survival. It is difficult to separate effects of exposing pre-spawning and spawning adults to high temperatures because the two almost always co-occur. Under such conditions, adult fish may spawn predominately in upper portions of the river to avoid warmer temperatures downstream, possibly increasing superimposition of redds.

Incubation: Constant exposure of salmonid eggs to temperatures above 13°C (56°F) will result in some egg mortality, while incubation at water temperatures above 17°C (62°F) is believed to result in complete egg mortality. Temperatures above 13°C can occur when eggs and larvae are incubating in the lower American River. This problem is most likely to occur for chinook salmon in October and early November.

Rearing: Optimum instream temperatures for rearing of young chinook salmon and steelhead are 11.5-13°C (53-56°F) and 13-15.5°C (55-60°F), respectively (Beak 1989). Juvenile salmon and steelhead in the lower American River can be exposed to temperatures greater than 14°C as early as March and to temperatures greater than 20°C during May. Surveys (seine and snorkel) conducted over the past several years have indicated that juvenile salmon and steelhead congregate in upstream reaches of the river as temperatures in the lower river warm. In addition to direct thermal stress, elevated rearing temperatures result in multiple indirect effects, including increased risk of predation, decreased growth rates, starvation, and susceptibility to disease, all of which contribute to reduced juvenile survival. Thermal stress to juvenile salmonids (primarily steelhead) is a particular problem during July through October, when water temperatures at the Nimbus Hatchery are generally greater than 18.3°C (65°F). In fact, lower American River water temperatures are commonly 65-75°F from July through October and are thus not conducive to high juvenile steelhead survival. Steelhead would not survive such extended warmwater periods in many years and often move prematurely out of the American River in search of cooler water (McEwan and Nelson 1991). High water temperatures during June through October have severely limited natural steelhead production in the lower American River.

Juvenile outmigration: Juvenile outmigration for both species primarily occurs from March through June. Optimal instream temperatures for outmigrating juvenile chinook salmon and steelhead are about 8-13°C (46-56°F) and 7-11°C (44-52°F), respectively (Beak 1989). Stressfully high water temperatures (i.e., >15.5°C [60°F]) frequently occur in June in the lower American River and may also occur in April and May, depending on instream flows and ambient air temperatures. Warm downstream temperatures may cause juveniles to extend their residence in upstream areas (as evidenced by DFG and USFWS surveys). In addition to direct thermal stress, elevated outmigration temperatures result in multiple indirect effects, including increased risk of predation, decreased growth rates, starvation, and susceptibility to disease, all of which contribute to reduced juvenile survival.

Options for improving water temperatures: The most promising near-term option for improving water temperatures in the lower American River is directed toward adult chinook salmon spawning. The pending reoperation of Folsom Reservoir will likely facilitate the preservation of a larger coldwater pool throughout summer so that it may be relied on to meet target chinook salmon adult upstream migration and spawning temperatures of <13°C (56°F) in the river during part of October and all of November.

Folsom Dam currently has nine water release shutters that are arranged in what is referred to as a "1-1-7" configuration. This means that the top shutter can be opened independently of the others, as can the second shutter. The bottom seven shutters, however, must be opened as one unit. With such a shutter configuration, the coldwater pool can be rapidly depleted when the bottom seven shutters must be opened to release water from the reservoir. This currently occurs whenever the reservoir elevation drops below 402 feet. Hence, in low water years, loss of the coldwater pool has been a concern for chinook salmon spawning during October and November.

Beak Consultants (unpublished) modeled temperatures of reservoir release waters and has predicted daily temperatures to assess the temperature control benefits of three alternative shutter configurations (2-1-6, 2-2-5, 3-2-4, 3-3-3, 2-3-4, 4-2-3, and 3-4-2). Shutter configurations were evaluated using the Corps' lake/reservoir temperature model CE-THERM-R1. Shutter configurations were evaluated by specifying a downstream temperature objective and allowing reservoir withdrawals at levels determined by the model that would best meet the downstream objective. Average daily outflow temperatures for October and November were the primary products of these simulations.

Modeling results indicated that the 3-2-4 configuration would provide the greatest temperature control benefit and therefore the configuration will be physically constructed in 1995. The 3-2-4 configuration under reservoir reoperation will significantly increase control over the temperature of water released throughout the year, thereby providing additional control over the rate of coldwater pool depletion. Water temperature simulations indicated that by reoperating the reservoir with a 3-2-4 shutter configuration, waters released into the lower American River during October would be 1-9°F colder than the temperature attained under current protocol and shutter configuration (1-1-7). Similar but smaller reductions in water temperature would typically occur throughout November as well. Current reservoir operations produce fall water temperatures in the lower American River that exceed the preferred thermal threshold of 56°F for successful chinook salmon spawning and incubation greater than 91% and 41% of the time in October and November, respectively (Beak Consultants unpublished data). Thus, any decrease in river water temperature during these critical spawning months would be significantly beneficial. A decrease in fall river water temperature of 5°F or more (as indicated by simulation model output) could mean the difference between successful and unsuccessful spawning for a large portion of the chinook salmon population in such years.

The multitude of uses of Folsom Reservoir waters must be reevaluated within the context of reservoir operations so that adequate coldwater storage exists to meet these and other target water temperatures throughout the year. Temperatures should be maintained at or below 13°C (56°F) from November through February to provide adequate incubation temperatures for both salmon and steelhead and should not exceed 15.5°C (60°F) for March through June to provide adequate rearing and outmigration temperatures. Increasing flow rates may increase the length of river thermally suitable for rearing, as well as making the early summer months more suitable for rearing.

Related actions that may impede or augment the action: Increased flow rates described in Action 1 will contribute to temperature control. Conversely, flow rates described in Action 1 may be modified to provide the greatest possible benefits to anadromous fish after the shutters are reconfigured (see this section for Action 1).

Agency and organization roles and responsibilities: The Corps and USBR would be responsible for Folsom Dam facility modifications and operations. DFG and/or USFWS would monitor and assess water temperatures and their effects on salmonid survival rates.

Potential obstacles to implementation: Alterations to Folsom Dam shutters may be costly and construction difficult.

Predicted benefits: Lack of suitable spawning temperatures currently limits chinook salmon production in the lower American River. Maintaining appropriate river temperatures will increase annual salmonid production by increasing early fall reproductive and incubation success. Although quantitative estimates of increased production resulting from incremental changes in river temperatures are not presently available, much is known about how water temperatures affect salmonid survival rates during each life stage (e.g., USFWS 1990). Such information clearly shows that lower American River water temperatures are generally higher than optimal for steelhead and chinook salmon, and thus every effort should be made to maintain lower river temperatures throughout the early spawning and entire rearing and outmigration periods of the year.

Enhanced control over the depth of water discharge from Folsom Reservoir would also translate into an increased ability to manage the coldwater pool throughout summer. A larger coldwater pool in fall could then be heavily relied on to meet target spawning temperatures in October and November for fall-run chinook salmon. Of all limiting factors and potential corrective actions, maintaining suitable river temperatures and instream flows will probably do more for increasing salmonid production within the lower American River than all other actions combined.

Action 6: Replenish and/or restore spawning gravel in existing spawning grounds.

Objective: Enhancement of spawning habitat.

Location: Selected areas between RMs 14 and 22.

Narrative description: Several characteristics of spawning gravel may limit production of salmonids spawning in the lower American River. These characteristics are described below.

Gravel size: Observations of lower American River spawning gravel suggest that substrate particle sizes are relatively large by comparison to those typically used by chinook salmon and steelhead in other streams. This condition is related to the lack of recruitment of smaller-sized gravel from areas upstream of Nimbus and Folsom dams. The low availability of suitable-sized spawning gravel may, in part, limit spawning success of salmon and, to a greater degree, steelhead (Snider pers. comm.).

Armoring: Areas of substrate in the upper reaches of the lower American River have become armored. Fine gravel has been washed away during high flow events, leaving mostly large cobble type substrates. Little gravel recruitment occurs to replenish smaller gravels. Armoring may, in part, limit spawning success of salmon and, to a greater degree, steelhead (Snider pers. comm.).

Embeddedness: Some potential spawning grounds within the lower American River have become embedded with fines, thereby removing these areas from the total acreage of suitable spawning habitat. However, this is believed to be of lesser concern than the armoring of spawning beds (Snider pers. comm.).

Gravel recruitment: Folsom and Nimbus dams prevent recruitment of gravel from upstream areas. Even if spawning gravel is not a key limiting factor today, it may become one if production increases and gravel naturally moves downstream without replacement.

Options for improving the quality of spawning gravel: Survey salmonid spawning habitat between RMs 14 and 22 (where nearly all current salmonid spawning occurs) (Snider and McEwan 1992, Snider et al. 1993, Snider and Vyverberg 1995), and identify those areas where gravel of appropriate size is lacking. Physically add gravel measuring approximately 0.6-2.4 inches in diameter to these areas to enhance spawning conditions for salmon and steelhead. Develop and implement a continuing program for restoring and replenishing, as needed, spawning gravel of the appropriate size, and/or develop a program to mechanically loosen and clean existing streambed areas, particularly in areas where subsurface flow is less than optimal. For example, a prototype gravel cleaning machine is being tested on the Tuolumne River by EA Engineering, and a gravel cleaning machine has been used on the single/dual purpose channels at RBDD.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would identify sites where gravel is to be added or cleaned and implement this action.

Potential obstacles to implementation: Cost and logistics of gravel addition need to be determined.

Predicted benefits: This action is a simple way to increase the reproductive success of lower American River salmonids. Overall production would be increased significantly through: 1) increasing the availability of high-quality spawning substrate, 2) decreasing the frequency and magnitude of redd superimposition, 3) increasing the percent hatchability of eggs, and 4) decreasing mortality rates for yolk-sac fry.

Action 7: Improve fish screen at the Fairbairn Water Treatment Plant.

Objective: Reduce loss of juvenile salmonids at the Fairbairn Water Treatment Plant.

Location: Fairbairn Water Treatment Plant.

Narrative description: The city of Sacramento's Fairbairn Water Treatment Plant, located about 7 miles upstream from the confluence, is the only large diversion (capacity of about 105 million gallons per day) on the lower American River. This pumping facility is screened but does not meet DFG screening criteria. Impingement, entrainment, and predation losses of salmonid fry may occur here but have not been evaluated or documented.

The Fairbairn Water Treatment Plant screen should be modified, as necessary, to meet current DFG salmonid screening criteria.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would determine what screening is necessary and would install the screen. The city of Sacramento would monitor and maintain the screen.

Potential obstacles to implementation: The city of Sacramento may object to any decrease in the efficiency of operations due to the installation of a screen.

Predicted benefits: Increased juvenile salmonid survival and thus increased lower American River salmonid production.

Action 8: Modify the timing and rate of water diverted from the river annually.

Objective: Reduce loss of juvenile salmonids at American River diversions.

Location: American River watershed.

Narrative description: Water diverted at Folsom-South Canal, at Fairbairn Water Treatment Plant, and by other diverters on the lower American River reduces flow within the river. In addition, water diverted upstream of Folsom Dam reduces water flowing into the reservoir, thereby reducing water available to be released downstream into the lower river. The city of Sacramento's diversion currently withdraws a maximum of about 140 cfs. In all but extremely low-flow years, the reduction in flow downstream of this facility probably does not significantly affect habitat availability or river water temperatures. Nevertheless, the total of all diversions clearly reduces instream flows within the river. Lower flows allow more rapid warming of river waters with increasing distance downstream, reduce habitat availability, and may lead to stranding of young salmonids.

By modifying the timing and duration of water diversions according to critical salmonid life stages, adverse impacts on salmonid production can be minimized. Also, the volume of water diverted should be minimized to maintain the greatest instream flows possible, particularly during dry and critically dry years. Additional limitations on the volume and timing of water diverted may need to be imposed on water users.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: The City of Sacramento would identify any opportunities to change the timing and magnitude of water diversions.

Potential obstacles to implementation: Such alterations to existing water diversion schedules may not be practical.

Predicted benefits: Increased juvenile salmonid survival and thus increased lower American River salmonid production.

Action 9: Develop a riparian corridor management plan.

Objective: Improve riparian habitat and instream cover.

Location: Lower American River, particularly downstream from Howe Avenue.

Narrative description: Riparian habitat along the lower American River is in relatively good condition from Nimbus Dam downstream to Howe Avenue. Downstream from Howe Avenue, however, riveted banks become common and natural riparian cover becomes limited. Riparian vegetation is important to the maintenance of anadromous salmonid populations by virtue of: 1) stabilization of streambanks, thereby reducing sediment load in the river, 2) provision of shade, 3) enhancement of stream nutrients due to decay of plant debris, 4) provision of streamside habitat for terrestrial and aquatic insects that are preyed on by fish and 5) provision of instream cover.

Riprapping: Riprapping exists primarily where development restricts natural channel migration and is particularly common on downstream sections (e.g., below Howe Avenue). For example, streambanks are heavily riprapped from the Fairbairn Water Treatment Plant to Paradise Beach. Because riprapping prohibits vegetation from colonizing river banks, it clearly reduces shading of river waters and decreases insect production and availability to instream fishes.

Gravel recruitment: (See "Gravel recruitment" under the "Spawning Gravel" subsection above).

A management plan would then be needed to determine best possible approaches to improve and maintain the riparian habitat. Local conservation organizations should be contacted to determine their interest in developing and implementing such a riparian enhancement and management plan. Private land owners should be given incentives to enhance riparian vegetation on their lands. Further development and encroachment on the American River floodplain should be prohibited. Efforts should be made to protect and enhance existing riparian vegetation along the lower American River. As needed, purchase of stream bank conservation easements would facilitate widening and improving the existing riparian corridor. No additional riverbanks should be riprapped; rather, natural riparian vegetation should be established and managed to stabilize banks. Periodic high flows are necessary for natural channel maintenance and thus should be allowed to occur annually in spring.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would likely take a lead role in developing such a riparian corridor management plan for the lower American River.

Potential obstacles to implementation: Current ownership and use of the riparian corridor as well as needs for immediate bank stabilization may be obstacles to this action.

Predicted benefits: Enhancement of riparian habitats will increase both terrestrial and aquatic insect abundance and therefore their availability to juvenile salmonids. This increased prey base will likely facilitate more rapid growth and earlier outmigration. Riparian cover will shade river waters, thereby helping to maintain more suitable localized water temperatures and reducing thermal stress on outmigrating juveniles.

Action 10: Terminate current programs that remove woody debris from the river channel.

Objective: Provide instream cover for juvenile salmonids.

Location: Lower American River, particularly below RM 14.

Narrative description: Habitat diversity in the lower American River is limited in downstream sections (e.g., in the vicinity of the H Street or Fair Oaks Boulevard Bridge) and below. Most large woody debris has been (and continues to be) removed from the river to eliminate hazards to recreationists (especially swimmers and rafters). Lack of vegetative and woody cover reduces habitat diversity, and is limiting to juvenile salmonid survival. Juvenile outmigrants and young steelhead rearing in the river need instream cover to escape fish and avian predators. Lack of instream cover is believed to be particularly limiting to juvenile steelhead survival in the lower American River (Snider pers. comm.). Finally, in addition to protective cover, instream structure provides a substrate for aquatic invertebrates to colonize, thereby increasing prey availability for juvenile salmonids.

Trees and logs could be added to selected rearing habitats on the river to enhance instream cover for juvenile salmonids. In addition, the current practice of clearing trees and other objects from the river to eliminate hazards to recreationists should be terminated. This practice has clearly reduced instream cover for juvenile salmon and steelhead.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: The agency now charged with removing this woody debris would simply terminate this practice.

Potential obstacles to implementation: Instream woody debris providing cover for juvenile salmonids may interfere with rafting activities.

Predicted benefits: Establishment and maintenance of instream woody cover will provide needed cover for juvenile salmonids, resulting in increased survival from reduced predation losses. Such instream cover will also provide a substrate for aquatic invertebrates to colonize, ultimately increasing food availability for juvenile salmonids.

Action 11: Impose stricter harvest regulations on both sport and commercial harvesters.

Objective: Increase spawning escapement of naturally produced fish.

Location: Lower American River and Ocean.

Narrative description: Angling pressure in the lower American River is high. In the past 3 years, estimates of between 28% and 52% of the chinook salmon returning to spawn in the American River were harvested by anglers. In addition, angling pressure is typically heavy near redds, resulting in redd trampling and reduced egg and fry survival.

Options for reducing angler impacts on salmonid production: Because angler harvest of spawning adults is very high in the lower American River, angling/take restrictions may be appropriate if production from this river is to be doubled. It currently remains unclear whether increasing the spawning escapement will result in increased smolt production. As future studies provide additional insight into this issue, decisions regarding further restrictions to in-river angling harvest to increase spawning escapement can better be made. To prevent redd trampling, public education and/or closing areas with high concentrations of redds to the public, for an appropriate period of time, should be considered.

Oceanic harvests are greater than sport harvests and are not stock selective. Thus, reductions in oceanic harvests will likely increase spawning escapement of most Central Valley streams.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and NMFS will likely be involved in changes made to river and ocean harvest regulations.

Potential obstacles to implementation: It currently remains unclear whether increasing the spawning escapement will result in increased smolt production.

Predicted benefits: Reducing commercial harvest will likely translate effectively into increased lower American River escapement. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower American River.

Action 12: Conduct weekly on-river patrols in areas where poaching is a concern.

Objective: Increase spawning escapement.

Location: Lower American River.

Narrative description: Illegal harvest may be significant in the upper reaches of the river, just below the dams. The take by poachers contributes to overall harvest of spawning adults and should therefore be viewed as significant within this context.

DFG could establish a greater enforcement presence at areas along the lower American River where poaching is a concern. Information on the status of the salmon migratory season could be used by the wardens to optimize the time and manpower allocated to patrolling and the locations selected for particular days or weeks. Preventing losses from poaching will ease the burden on restricting the legal catch. Every effort available should be used to prevent poaching losses.

Related actions that may impede or augment the action: Changes in harvest regulations either in the ocean or the rivers would likely augment this action.

Agency and organization roles and responsibilities: DFG wold take the lead role in this action.

Potential obstacles to implementation: Insufficient warden personnel may limit the feasibility of this action.

Predicted benefits: Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production.

Action 13: Change hatchery procedures to benefit native stocks.

Objective: Rebuild native stocks.

Location: Lower American River.

Narrative description: Salmon and possibly steelhead runs on the lower American River were probably eliminated and re-established (replaced) by introduction of non-native stocks during and after construction of Folsom Dam. Potential for naturally spawning fish to adapt to local conditions is hampered by continual infusion of hatchery stocks. Loss of genetic integrity and increased angling and straying will all undoubtedly reduce a given fish stock's productivity. The reduced productivity is then augmented by hatchery stocking, and this cycle of events repeats again and again. The more the genetic integrity of native stocks is diluted, the more we will have to rely on hatchery augmentation to meet target population sizes set largely by public angler demands. When large numbers of hatchery fish are stocked and the proportion of the population made up of hatchery fish increases, so too does the fishing pressure on the remaining wild fish. Adverse impacts on salmonid populations due to straying generally increases as the percentage of the population composed of stocked fish increases. The lower American River is believed to receive a large number of hatchery-propagated strays from the Mokelumne and Feather rivers, as well as smaller contributions from other rivers. The practice of releasing hatchery-produced fish downstream of their natal stream increases straying. Straying has far reaching genetic effects and reduces the ability of constant fractional marking approaches to identify hatchery contribution to overall stocks.

Hatchery efforts focus on a subset of the total time that salmon and steelhead spawn in the American River. Hatchery protocols may influence timing of natural runs through genetic and behavioral interactions between naturally and hatchery-produced fish. Also, the tendency is for Folsom Dam operations and structural changes to focus on improving production of hatchery fish. Prior to the construction of Folsom and Nimbus dams, chinook salmon runs occurred in spring, not in fall. The same may be true of steelhead.

Hatcheries create conditions for the proliferation of fish diseases. Examples include fungus (eggs), columnaris, bacterial gill and kidney disease, and whirling disease. The Nimbus Hatchery has also received fish from outside the American River, creating the potential for introduction of new diseases to native stocks. Furthermore, these non-native hatchery-reared stocks are typically more prone to mortality due to disease factors specific to a river; thus, annual mortality rates of stocked fish are generally higher than that of native fish.

Hatchery fish compete directly for food and cover with native stocks. Likewise, hatchery fish prey on young of native stocks produced in the river. Considered together, these two factors add to the already large pool of factors limiting the productivity and survival of native salmonid stocks. Although hatchery stocking may increase the raw numbers of fish in the river, it is counter-productive to the recovery of native stocks.

Options for rebuilding an American River stock: Reliance on Nimbus Hatchery production and stocking can best be reduced by improving conditions (i.e., habitat) for native stocks. In addition, reducing angling pressure and/or implementing a wild stock catch-and-release program will greatly benefit naturally produced stocks that are currently being over harvested. Future regulations should consider selective harvest of hatchery-produced stocks only. This of course would require that hatchery-produced fish be externally identifiable to anglers.

If hatchery programs are to continue, several issues must be addressed. First, hatchery efforts should focus on propagation of the entire run and/or minimize or eliminate potential for interactions between naturally and hatchery-produced fish. To increase genetic diversity, the hatchery should consider using all available broodstock, including grilse. The practice of discarding broodstock under some minimum length simply reduces the genetic diversity of hatchery-propagated fish and thus should be discontinued. However, broodstock from different rivers should not be shared unless shown electrophoretically to be genetically similar enough to warrant such practices. Doing so with genetically distinct stocks will undermine the "edge" each stock has evolved for its respective river. Fish stocked directly into rivers, rather than downstream, will reduce the incidence of straying. However, doing so will greatly increase losses during the outmigration period; thus, a balance between these two conflicting concerns must be attained. Second, hatcheries must strive to reduce disease problems. Consideration should be given to quality, not quantity. This means improving water quality and reducing densities of fish to create conditions less likely to be conducive to development and proliferation of disease. Finally, the hatchery should consider treating its effluent waters to further guard against the introduction of new diseases that may affect native stocks.

In the attempt to rebuild native salmonid stocks in the lower American River, the Nimbus Fish Hatchery may be able to play an alternative role. The hatchery facility could be used to capture immigrating steelhead, and these fish could be transported and released in traditional headwater spawning grounds above Folsom Reservoir. Outmigrating smolts would likewise need to be captured prior to entering Folsom Reservoir, transported, and released below Nimbus Dam (McEwan and Nelson 1991). Such an approach, however, is not consistent with the definition of "natural production".

Fish are stocked because native populations lack the appropriate habitat and/or numbers to produce sufficient annual numbers themselves. Stocking fish does not act on this problem, but rather treats the symptom (i.e., low numbers of fish). In short, the only way to reduce reliance on hatchery stocked fish is to improve in-river habitat for native stocks.

Changes needed at the Nimbus Hatchery to favor the river's native stock include the following:

- Use of all available broodstock, including grilse to increase genetic diversity of propagated fish. The practice of discarding broodstock under some minimum length simply reduces the genetic diversity of hatchery-propagated fish and thus should be discontinued.

- The emphasis must be placed on the quality, not quantity of hatchery production. This means improving water quality and reducing densities of fish to create conditions less likely to be conducive to development and proliferation of disease.

- Nimbus Fish Hatchery should consider treating its effluent waters to further guard against the introduction of new diseases that may affect native stocks.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG currently operates Nimbus Hatchery.

Potential obstacles to implementation: The measures presented here may conflict with existing goals and objectives of hatchery operation.

Predicted benefits: Changes made to the traditional procedures utilized by Nimbus Fish Hatchery can result in it being a tool to rebuild native stocks rather than one that degrades them. Decreasing the number of hatchery-propagated fish in the lower American River will increase the opportunity for native stock recovery.

Fishery studies needed at this time -

- Salmon redd surveys during different water-year types to describe the response of spawning salmon over a range of flow conditions
- Spawning escapement surveys to provide accurate estimates of escapement
- Juvenile salmon rearing and outmigration studies

An explicit overall conceptual framework must be established to direct these and other studies so that information collected is appropriate for establishing beneficial flow regimes for maximizing salmonid production in the lower American River.

Mokelumne River -

Limiting factors and potential solutions - Following is a list of factors that may limit chinook salmon and steelhead production within the Mokelumne River basin (Table 3-Xc-10).

Table 3-Xc-10. Limiting factors for fall-run chinook salmon on the Mokelumne River and potential solutions.

Limiting factors	Potential solutions
Lack of suitable instream flows	Increase instream flows
Lack of suitable spawning habitat	1. Spawning gravel additions 2. Mechanically loosen and clean the gravel 3. Riparian outfencing 4. Eliminate gravel skimming operations 5. Instream flow increases 6. Provide "cleansing" flows 7. Manage Camanche Reservoir releases to minimize turbidity
Redd de-watering and juvenile stranding	Set flow fluctuation and reduction limits
Predation losses	1. Remove Woodbridge Dam to eliminate predator concentrations at high flows 2. Keep flashboards out at Woodbridge Dam until smolt outmigration ends 3. Pilot predator removal project

Limiting factors	Potential solutions
Loss and delay of juvenile salmonids migrating past Woodbridge Irrigation District (WID) diversion	1. Remove Woodbridge Dam to eliminate barrier 2. Keep flashboards out at Woodbridge Dam until smolt outmigration ends 3. Maintain fish screen and bypass to DFG standards 4. Study WID diversion and Lake Lodi impacts on juvenile survival and migration
Delay of adult salmonids migrating past Woodbridge Dam	1. Remove Woodbridge Dam to eliminate barrier 2. Increase instream flows 3. Convert lower portion of ladder to pool and weir system 4. Replace and modify use of the gate valve at the top of the upper ladder 5. Remove/block Denil fish ladder during high flows 6. Optimize attraction flows to fish ladder
Unscreened diversions	1. Evaluate operation of all riparian diversions 2. Install fish screens at problem diversions 3. Install permanent fish screen at North San Joaquin Conservation District (NSJCD) diversion

Limiting factors	Potential solutions
High water temperatures	1. Maintain a minimum pool in Camanche Reservoir 2. Balance Camanche Reservoir releases with Pardee Reservoir releases 3. Construct multilevel outlet structure at Camanche Dam 4. Increase instream flows 5. Conduct Camanche/Pardee Dam water dynamics study
Loss of riparian habitat	1. Purchase stream bank conservation easements 2. Riparian outfencing projects 3. Convert abandoned dredging and gravel pit mines 4. Provide flooding flows in wet years 5. Implement a riparian management plan 6. Lake Lodi riparian restoration project
Poor water quality	1. Enforce EPA water quality standards 2. Establish a water quality monitoring program 3. Construct multilevel outlet structure at Camanche Dam 4. Maintain a minimum pool in Camanche Reservoir 5. Manage Camanche Dam releases to optimize water quality

Limiting factors	Potential solutions
Poaching and angling of adult salmon	1. Establish DFG enforcement presence at Woodbridge Dam 2. Post "redd trampling" warning signs at Mokelumne Day Use Area 3. Conduct patrols below Woodbridge Dam during the spawning season
Lack of suitable rearing habitat	1. Increase instream flows 2. Utilize abandoned gravel pits as rearing areas

Restoration actions -

Action 1: Provide instream flows beneficial to all salmonid life stages.

Objective: Increase escapement of adults and survival of all salmonid life stages in the lower Mokelumne River.

Location: Mokelumne River from Camanche Dam to confluence with the San Joaquin River.

Narrative description: The flow pattern of the lower Mokelumne River below Camanche Dam has been altered due to projects for storage, diversion, and hydroelectric power generation (DFG 1991). Up to 65% of the unimpaired flow is diverted into the Mokelumne River aqueducts at Pardee Reservoir. Typically, flows at Woodbridge Dam throughout the year are less than those recorded below Camanche Dam due to channel loss and diversions (FERC 1993). Low flows below Woodbridge Dam prevent salmon from reaching the fish ladder as late as the last week in November. Current management of flows released from Camanche Reservoir have resulted in water temperatures detrimental to, and decreased availability of preferred habitat for, all life stages of salmonids at one time or another. Flows adequate for flooding/maintaining the riparian corridor and cleansing spawning gravels are no longer provided except perhaps during extreme storm events.

Chinook salmon spawning habitat is maximized at flows of 300 to 500 cfs (DFG 1991). Comments on the application of IFIM studies to flow recommendations for other than spawning habitat (Chapman 1992, USFWS 1993b) suggest that other criteria be used to determine flows needed to benefit juvenile salmon. Logic suggests that flows that mimic the natural flow regime would be best to ensure optimal survival rates for juvenile/smolt life stages. Tenant (1975) suggests 30% of the average flow, while DFG (1991) recommends 28% of the average annual runoff. The flow schedule to be provided to the San Joaquin River (Table 3-Xc-11) is recommended for implementation:

Table 3-Xc-11. Instream flow regimes[a] recommended to facilitate doubling of chinook salmon and steelhead production in the lower Mokelumne River under three year types.

Month	Flow (cfs) for each of three year types		
	Wet	Normal	Dry
October[b, c]	300	300	200
November-December[b, c]	350	300	200
January[b]	400[d]	300[d]	200[b]
February[b]	450[d]	350[d]	200[b]
March	550[d]	350[d]	250[b]
April	700[d]	600[d]	350[c]
May	1250[d]	900[d]	400[c]
June	950[d]	500[d]	150[c]
July[d]	250	100	60
August-September[e]	60	60	60

[a] Daily flow fluctuations shall not exceed 10% of the average flow within any 24-hour period, and weekly fluctuations shall not exceed 20% of the average flow within any 7-day period. Flows should not be reduced by more than 300 cfs during any 6-day period.

[b] Should flows exceed 400 cfs for any 7-day period during the peak spawning season (October-December), flows shall not be reduced below 400 cfs for the duration of the spawning/incubation period (October-February).

[c] Flows for chinook salmon spawning and incubation.

[d] Flows for spawning, rearing, and migration. Values calculated as approximately 30% of the average monthly unimpaired flows from 1922 to 1991.

[e] Flows for adult passage, based on report of an instream barrier near Thornton that will prevent or impair the upstream migration of adult chinook salmon at flows less than 60 cfs (DFG 1991).

Related actions that may impede or augment the action: The effectiveness of some flows may be impeded by the timing and amount of water diverted to state and federal water projects.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Water supply availability and extended drought conditions may result in water shortages to implement this action. EBMUD will likely oppose flows substantially greater than those released under current management schemes.

Predicted benefits: Available habitat for some or all salmonid life stages will be increased. Wet year flows may help in the cleansing of spawning gravels and maintenance of the riparian corridor. Barrier and timing problems associated with Woodbridge Dam and diversion may be reduced. The water temperature regime in the lower Mokelumne River will improve. Water quality may improve.

Action 2: Provide flows maximizing suitable chinook salmon spawning habitat.

Objective: To improve the quantity of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: Prior to the completion of Camanche Dam in 1964, chinook salmon spawned primarily between Clements (RM 59.2) and the canyon about 3 miles below Pardee Dam (FERC 1993). Most salmon spawning now takes place over the 5-mile reach between Camanche Dam and Mackville Road. The quality and quantity of suitable spawning habitat available in the future will depend to a great degree on the instream flow regime. Although the 1987 IFIM study (Envirosphere 1988) indicates that the maximum potential spawning habitat is available when flow is near 300 cfs, it has been suggested that deep water did not coexist with suitable velocities and substrata at the stream discharges extant in the river when spawning microhabitat was examined, and that DFG recommended flows for spawning in the lower Mokelumne River would be higher if the suitability curves for spawning chinook salmon were to be re-examined at greater river discharges (Chapman 1992).

Flows recommended in Action 1 should be implemented during the spawning season.

Related actions that may impede or augment the action: The effectiveness of these flows may be impeded by the timing and amount of water diverted to state and federal water projects.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Unimpaired runoff available may not be sufficient to implement the proposed flow releases recommended in Action 1. EBMUD will likely disagree with the recommended flow levels proposed in Action 1.

Predicted benefits: Available spawning habitat may be increased. Wet year flows may help in the cleansing of spawning gravels. Barrier and timing problems associated with Woodbridge Dam and diversion may be reduced for adult salmonids. The water temperature regime in the lower Mokelumne River will improve for salmon spawning. Water quality may improve.

Action 3: Replenish gravels suitable for salmonid spawning habitat.

Objective: To improve the quantity and quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: Camanche Dam blocks the movement of gravel from upstream, and immediately below the dam there is no source of replacement gravels. Gravel skimming operations may also contribute to a lack of adequate spawning gravels.

Spawning gravel should be added to portions of the river. On June 8, 1994, biologists from EBMUD and DFG identified four potential sites where gravel could be added to the river: 1) at the DFG pasture site (Envirosphere 1988), 2) upstream of the PG&E gas line crossing, 3) directly below Highway 88, and 4) above Mackville near the old "CC Wood" bridge crossing. DFG is in the process of determining land ownership and potential access. Redd surveys (BioSystems 1992) and habitat usage of previous gravel enhancement projects (Hartwell 1994) in the lower Mokelumne River show that berms that are perpendicular to streamflow are preferred spawning habitat. Gravel should be added to the river so that the above-mentioned berms are formed. Funding for salmon spawning habitat restoration through the State Habitat Conservation Fund (Prop. 117) should continue to be pursued by EBMUD.

Related actions that may impede or augment the action: Instream flows will determine how and to what extent added gravels are distributed downstream from the potential sites listed above.

Agency and organization roles and responsibilities: Categorical exemptions can be obtained for most of the permits required under CEQA for gravel placement work through DFG coordinating with the CVRWQCB and the Corps. EBMUD will need to meet its mitigation responsibilities to replenish and maintain gravels according to agreements signed with DFG. DFG should require gravel permit operators to periodically place gravel in the stream to improve the salmon spawning habitat should they continue to be allowed to operate.

Potential obstacles to implementation: Access to the river for gravel restoration projects will require land owner cooperation.

Predicted benefits: Additional spawning habitat may be created, and spawning habitat quality will improve. Redd superimposition may decrease.

Action 4: Cleanse spawning gravels of fine sediments.

Objective: To improve the quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: The presence of Camanche Dam and the use of Camanche Reservoir for flood control has resulted in the absence of flushing flows necessary to cleanse and prevent sedimentation of spawning gravels in the lower Mokelumne River. BioSystems (1992) reported that over 70% of the substrate samples taken in 1991 and 1992 from chinook salmon redds contained amounts of fine sediment less than 0.48 inch in diameter that are detrimental to egg survival (Chapman 1988). This and the presence of substrate armoring and compaction in the spawning sites (BioSystems 1992) indicate that spawning gravel quality is a limiting factor. Exact sources of these fines are not known, although possible culprits may be turbid flow releases below Camanche Dam, agricultural returns, and poor land use practices.

Flushing flows are needed from Camanche Reservoir to cleanse gravels. A pilot program involving mechanically loosening and cleaning the gravel should be conducted from an upstream to downstream direction to see if such an action would prove effective.

Related actions that may impede or augment the action: Streamflows necessary to move 1/2-inch-diameter gravel may be in excess of 3,000 cfs (Envirosphere 1988). Because some of the substrate is compacted and armored, even higher flows may be required. This would possibly result in some flooding downstream and damage to existing levees (Taylor, USFWS, pers. comm.). A prototype gravel cleaning machine is being tested on the Tuolumne River by EA Engineering. Another gravel cleaning device has been designed and used for 2 years at the Tehama-Colusa Canal and is effective for specific-sized gravel.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir. DFG would be the lead agency for purposes of permitting under CEQA, CVRWQCB, and the Corps. Technical advice and perhaps the loan of a machine may be needed from EA Engineering.

Potential obstacles to implementation: Access to the river for gravel restoration projects will require land owner cooperation. Mechanical gravel cleaning may not prove to be a viable action.

Predicted benefits: Spawning gravel quality may improve substantially.

Action 5: Prevent sedimentation of spawning gravels.

Objective: To improve the quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: The presence of Camanche Dam and the use of Camanche Reservoir for flood control has resulted in the absence of flushing flows necessary to cleanse and prevent sedimentation of spawning gravels in the lower Mokelumne River. BioSystems (1992) reported a significant inverse relationship between mean survival of eggs in wild salmon redds and the percentage of fines in three size categories. They also reported that more than 70% of the substrate samples taken in 1991 and 1992 from chinook salmon redds contained amounts of fine sediment (less than 0.48 inch) in diameter that are detrimental to egg survival (Chapman 1988). This indicates that spawning gravel quality is a limiting factor. Exact sources of these fines are unknown, although possible culprits may be turbid flow releases below Camanche Dam, agricultural returns, and poor land use practices.

Camanche Reservoir should be managed so as to minimize sediment levels in flow releases. A multilevel outlet structure should be constructed at Camanche Dam so that turbid releases can be avoided while adequate water temperatures are maintained. Cattle should be excluded from grazing along the river's edge. Outfencing projects should be promoted with land owners to establish a buffer zone and to allow the re-establishment of riparian vegetation and to prevent bank erosion.

Related actions that may impede or augment the action: Gravel cleaning may affect habitat downstream from the cleaning sites. Bottom releases necessary for maintaining recommended water temperatures may have increased turbidity.

Agency and organization roles and responsibilities: EBMUD manages flow releases from Camanche Reservoir and would play the lead role in any construction taking place at the dam. Cooperation with private land owners would be essential to making any out-fencing program work.

Potential obstacles to implementation: Low-turbidity releases may not be compatible with EBMUD-preferred management practices of Camanche Reservoir. EBMUD will likely resist the installation of a multilevel outlet structure due to construction costs involved. Land owner cooperation will be needed to restore riparian habitat that was destroyed by livestock grazing and protect what remains.

Predicted benefits: Spawning gravel quality may improve substantially.

Action 6: Restrict flow fluctuations and reductions.

Objective: Prevent redd de-watering and stranding of juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Losses of chinook salmon eggs have occurred due to flow reductions in the lower Mokelumne River (Meinz 1985). Additional losses were suspected due to the stranding of juvenile salmon on large gravel bars or in isolated pools or channels. A stranding model (Envirosphere 1988) showed that exposed strandable area increased most with downramping events involving flows at or below 400 cfs. Steady flows during the peak spawning, egg incubation, and juvenile rearing period (October through April) would prevent the desiccation of redds and stranding of juvenile salmonids on gravel bars and in potholes on the lower Mokelumne River (DFG 1991).

Flow fluctuation limits recommended by DFG to avoid loss of aquatic productivity and stranding should be implemented: daily flow fluctuations shall not exceed 10% of the average flow within any 24-hour period and weekly fluctuations shall not exceed 20% of the average flow within any 7-day period. Should flows exceed 400 cfs for any 7-day period during the peak spawning season (October-December), flows shall not be reduced below 400 cfs for the duration of the spawning/incubation period (October-February). Flows should not be reduced by more than 300 cfs during any 6-day period.

Related actions that may impede or augment the action: The maintenance of steady flows throughout the periods mentioned above would make flow ramping unnecessary. Storm events where flows are no longer controlled may make meeting the fluctuation criteria impossible.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Flow ramping schedules may not be compatible with EBMUD management practices of Camanche Reservoir releases. Storm events may make ramping impossible.

Predicted benefits: Instances where redd de-watering and/or the stranding of juvenile salmons occur would be eliminated. Impacts on aquatic productivity due to flow alterations may be lessened.

Action 7: Remove Woodbridge Dam or delay installing the dam flashboards until July.

Objective: Reduce losses of salmon smolts to predation.

Location: Immediately below Woodbridge Dam.

Narrative description: High spring flows can attract striped bass and squawfish to the base of Woodbridge Dam. During Camanche Reservoir flood flow releases in spring 1993, striped bass were attracted to the base of Woodbridge Dam (EBMUD 1994). Based on analysis of striped bass stomach contents, diver surveys, and the time period when striped bass were present, EBMUD biologists estimate that between 11 to 51% of the 1993 salmon smolt production was lost to striped bass predation (Boyd 1994).

In 1994, Camanche Reservoir releases of approximately 150 cfs resulted in spill conditions over the top of Woodbridge Dam. Dave Vogel, conducting experiments to determine the extent of physical injury to salmon smolts passing over the top of Woodbridge Dam, observed heavy predation by squawfish on salmon smolts passing through a pool from the fish ladder entrance discharge (EBMUD 1994). Vogel noted that the predation losses could easily be the highest single mortality to juvenile salmon within the Mokelumne River. A pilot predator removal project for the area just below Woodbridge Dam is presently planned for spring 1995 (Vogel Environmental Services pers. comm.).

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed altogether. If the dam cannot be permanently removed, the flashboards should not be installed until after the smolt outmigration has ended.

<u>Related actions that may impede or augment the action</u>: Increased spring flows may increase the attraction of predators to the tailwaters of Woodbridge Dam.

<u>Agency and organization roles and responsibilities</u>: WID would need to spearhead the process of looking for alternative methods of water withdrawal to meet its needs. Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others. Permission would also have to be obtained from WID to gain access to the river to remove predators that concentrate at the base of the dam. DFG would have to agree to issue permits that would allow for the removal of the fish predators.

<u>Potential obstacles to implementation</u>: WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources during the time that the flashboards would be removed may not be available or adequate. DFG may have a difficult time justifying the removal of fish predators because striped bass are a game fish and squawfish are a native species. Because striped bass are one of the fish species populations to be doubled under the CVPIA, the removal of striped bass predators from the area below Woodbridge Dam may be in conflict with the anadromous fish doubling goal.

<u>Predicted benefits</u>: Removal of Woodbridge Dam would eliminate the problem of concentrating predators and smolts in one small area, thus predation problems may be eliminated entirely. A conservative estimate of the benefits that might accrue from reduced predation on salmon smolts would be an improvement of salmonid smolt survival of 10%.

Action 8: Reduce or eliminate mortality and delays of juvenile salmonids associated with passage past the WID diversion and Woodbridge Dam.

Objective: Improve survival of juvenile salmonids past the WID diversion and Woodbridge Dam.

Location: WID diversion and dam.

Narrative description: WID's diversion and Woodbridge Dam may result in mortality and/or delays of juvenile salmonids migrating downstream past them. Possible causes of the above are: 1) inadequate access and/or attraction flows to the fish bypass, 2) faulty rubber seals on the rotating drum screens, 3) lack of a comprehensive fish facilities monitoring and maintenance program, 4) inadequate fish screen bypass flows, 5) predation and high water temperatures in Lake Lodi, 6) injury to fish when flow over the dam occurs, and 7) inadequate flows released below the dam.

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed altogether. If the dam cannot be removed permanently, the flashboards should not be installed until after the smolt outmigration has ended. If the flashboard installation cannot be delayed, the screening and bypass facilities should be closely monitored and maintained to DFG standards. Flows recommended in Action 1 should be implemented so as to reduce the percentage of the flow diverted by WID. Studies should be conducted looking at: 1) the impact of Lake Lodi on juvenile salmonid survival and its possible use as a rearing area, 2) the efficiency of existing fish screen and bypass facilities, and 3) the extent/causes of delays to the downstream migration of juvenile salmonids that may occur.

Related actions that may impede or augment the action: The amount of flows through Lake Lodi and the percentage of the water diverted by WID may alter the effectiveness of the management actions. Important limiting factors that may negate benefits would be predation losses below Woodbridge Dam, unsuitable water temperatures in the central Delta, and entrainment losses at the water project pumps.

Agency and organization roles and responsibilities: Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others. WID and DFG will need to coordinate facility inspections and maintenance. EBMUD will need to release the flows from Camanche Reservoir to meet recommendations for below Woodbridge. WID, DFG, EBMUD and USFWS should cooperate in conducting any studies concerning Lake Lodi and/or WID facilities.

Potential obstacles to implementation: Cost would be the major obstacle for making the improvements in this section. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources needed during the time when the flashboards would be removed and the filling of Lake Lodi delayed, or made necessary due to the removal of Woodbridge Dam, may be unavailable or inadequate. EBMUD would likely resist any increases in flows required below Woodbridge Dam.

Predicted benefits: Should Woodbridge Dam be removed, or the flashboards be removed during smolt outmigration, juvenile salmonid mortality and delays in their downstream migration may be eliminated entirely in this reach. Increased flows will eliminate the need for trapping juvenile salmonids at Woodbridge Dam and trucking them to the Delta and may result in increased escapement due to improved imprinting by juvenile chinook salmon.

Action 9: Eliminate barriers to efficient and timely migration of adult salmonids.

Objective: Improve passage conditions at Woodbridge Dam for adult salmonid migration.

Location: Woodbridge Dam.

Narrative description: The tailwater elevation below Woodbridge Dam is too low relative to the fishway entrance during low-flow conditions. Access and/or attraction to the fishway entrance may be inadequate, resulting in physical injury to upstream migrating salmon attracted to dam spillage. Under the current design, adult salmon passing up the lower ladder must swim through a series of small rectangular openings (23.6 x 35.5 inches) where there is currently no resting habitat between chambers (EBMUD 1994). The pool and weir system would provide the necessary hydraulic conditions for better fish passage. Spill can place water into the Denil fishway, making it a blind channel for migrants, when Lake Lodi is high (FERC 1993). Flow restriction in the high stage fish ladder occurs due to the gate valve at the top.

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed. If the dam cannot be removed permanently, the flashboards should not be installed until after the smolt outmigration has ended. If the flashboard installation cannot be delayed, the following improvements should be made: 1) attraction flows to the fish access should be optimized, 2) the gate valve at the top of the high stage fish ladder should be removed, 3) access to the Denil fishway should be denied to migrants when Lake Lodi is high, and 4) the lower portion of the ladder should be converted into a pool and weir system. Flows recommended in Action 1 should be implemented to eliminate fish passage problems associated with low flows during adult salmonid migrations.

Related actions that may impede or augment the action: The flows past Woodbridge Dam will affect the ability of the adult salmon to locate and ascend the fish ladders.

Agency and organization roles and responsibilities: Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, Corps, and others. EBMUD will need to release the flows from Camanche Reservoir to meet recommendations for below Woodbridge. Permission will be needed from DFG and WID to modify the fish ladders at Woodbridge Dam.

Potential obstacles to implementation: No funding sources have been identified to modify and improve the fish passage conditions at Woodbridge Dam. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Because this is not a hydropower project, FERC is unlikely to mandate any improvements to this facility. EBMUD will likely oppose any changes in flow requirements below Woodbridge Dam.

Predicted benefits: Although it is difficult to quantify benefits, the natural salmon spawning escapement to the lower Mokelumne River should increase because adult salmon will not be delayed in their upstream migration.

Action 10: Screen all diversions in the lower Mokelumne River to DFG standards.

Objective: Prevent entrainment or loss of juvenile salmonids at lower Mokelumne River diversions.

Location: Mokelumne River from below Camanche Dam to Lake Lodi.

Narrative description: Unscreened or improperly screened diversions can result in the loss or entrainment of juvenile salmonids. From the rearing areas near Camanche Dam downstream to Lake Lodi, over 50 river pumps withdraw water from the river for irrigation, and few, if any, are screened (BioSystems 1992). The NSJCD, operating the second largest diversion below Camanche Dam, had DFG install a temporary fish screen during the 1993 irrigation season.

The operation of riparian pumps should be evaluated because many of the diverters are operating under their own guidelines. Should evaluations show problems at any given diversion, it should be screened to meet DFG standards. The NSJCD diversion should be screened to meet DFG criteria whenever it is operated.

Related actions that may impede or augment the action: The timely outmigration of smolts may have juveniles susceptible to loss or entrainment out of the river before most water diversion occurs.

Agency and organization roles and responsibilities: DFG would investigate and screen up to its standards any diversions that pose problems to juvenile salmonids. Those operating diversions would need to cooperate.

Potential obstacles to implementation: Water diverters may not want to cooperate with any investigation of potential diversion problems and may object to the cost and inconvenience of screening their diversions.

Predicted benefits: Loss and entrainment problems associated with unscreened diversions would be reduced or eliminated.

Action 11: Maintain suitable water temperatures for all salmonid life stages.

Objective: Provide for timely migrations and increased survival of adult and juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Downstream of Camanche Dam, water temperature depends on Camanche Reservoir release water temperature, prevailing meteorological conditions, and flow rate (FERC 1993). From April to mid-October, the closure of Woodbridge Dam and subsequent filling of Lake Lodi effectively slows the water, allowing it to heat. Temperatures downstream of Woodbridge Dam are also affected by a reduction in flow as a consequence of the water withdrawal at the WID diversion. Differences in water temperature between Camanche and Woodbridge dams have been measured up to 16.2°F (9°C) during hot, dry years (Walsh et al. 1992). In 1990, water temperatures at RM 29.5 (Ray Road) regularly exceeded 77°C (25°C) from the end of April to mid-September, and regularly exceeded 86°F (30°C) from early June to early August (Walsh et al. 1992). DFG (1991) describes the preferred range of temperatures for fry and outmigrant juvenile salmon as 7.0-14.6°C (45-58°F), while Raleigh et al. (1986) recommends that from the time fry emerge from the gravel until they migrate out of the river the temperature should not exceed 18°C (64°F).

A minimum pool in Camanche Reservoir of 190 feet from April through September, and a minimum pool of 170 feet from October through March, should be maintained. Instream flows recommended in Action 1 should be implemented. Pardee Reservoir flow releases should be balanced with those from Camanche Reservoir to optimize thermal conditions. Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed and Lake Lodi eliminated. Alternatives that would help provide optimal water temperatures include constructing a pipeline from Pardee Reservoir to the base of Camanche Dam and/or constructing a multilevel outlet structure at Camanche Dam. Further studies are needed on Pardee and Camanche Dam water temperature dynamics so that reservoir management practices can optimize water temperatures downstream.

Related actions that may impede or augment the action: There may be a tradeoff in water temperature benefits from increased springtime flows below Woodbridge Dam and increased losses of smolts from fish predators that are attracted to the base of Woodbridge Dam by the higher flows.

Agency and organization roles and responsibilities: EBMUD is responsible for Pardee and Camanche Dam operations and would bear primary responsibility in construction projects at Pardee and Camanche dams. Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others.

Potential obstacles to implementation: Water shortages resulting from the implementation of this action during dry years and costs involved with proposed construction projects will likely meet with resistance from EBMUD. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources needed due to the removal of Woodbridge Dam may not be available or adequate.

Predicted benefits: Suitable water temperatures provided for all life stages of salmonids will result in timely adult and smolt migrations, increased emergence, and increased survival of fry and smolt stages.

Action 12: Enhance and maintain the riparian corridor.

Objective: Improve streambank and channel rearing habitat for juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: The lower Mokelumne River's riparian vegetation is diminishing over time (USFWS 1993a). In many areas there is no regeneration along the relatively thin riparian corridor (DFG 1991). Riprapping of long lengths of streambank such as above and below Elliot Road has reduced tree growth and therefore fostered increased river temperatures by reducing shading (EBMUD 1994). The reach with the most obvious deficiency in riparian vegetation is at Lake Lodi, which has large areas of shallow water without vegetation (FERC 1993). Bankside erosion has potentially affected salmonid production in several small areas where cattle grazing is permitted along the river corridor (Miyamoto 1994). Sustained flows at or near bankfull discharge, or even overbank flows, during the period of seed set and vegetation growth in spring, would provide for a healthy riparian vegetative community (Chapman 1992).

Sustained flows of at least 3,000 cfs should be provided to flood the lower alluvial surfaces during wet years, and slightly higher surfaces could be inundated periodically with releases from Camanche Reservoir. The response of the riparian community to these flows should be monitored. An active riparian restoration and management plan should be established for the lower Mokelumne River. A riparian restoration project should be conducted at Lake Lodi. Cattle and horses should be fenced out where they now graze down to the river's edge. Stream bank conservation easements could be purchased to widen the riparian corridor.

Related actions that may impede or augment the action: Flushing flows recommended for cleansing spawning gravels may be sufficient to provide benefits to the riparian community as well.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir. DFG would be the lead agency for purposes of monitoring the effects of the above-mentioned flows. Cooperation with private land owners would be an essential element to make an out-fencing program work. Property adjacent to the river might be purchased using State Wildlife Conservation Board funds, or property owners may be given an incentive through a favorable property tax program if they establish a natural riparian corridor with an out-fencing program. The Nature Conservancy could provide technical advise on establishing and implementing an active riparian restoration and management plan.

Potential obstacles to implementation: EBMUD will likely oppose any major changes in its flow management practices. Land owners may be unwilling to participate in any riparian restoration program. Funds needed for the purchase of conservation easements may be unavailable.

Predicted benefits: Riparian regeneration and maintenance may take place. Impacts on spawning gravels due to erosion will be reduced. An improved riparian corridor may lower water temperatures. Rearing habitat availability and quality will probably be increased.

Action 13: Set and enforce water quality standards.

Objective: Provide optimal water quality for all life stages of salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: The management of Camanche Reservoir elevations and Pardee Reservoir inflows have not consistently provided water of suitable quality to the Mokelumne River Fish Facility (MRFF) and the lower Mokelumne River fishery (USFWS 1993a). Occurrences of low dissolved oxygen, elevated hydrogen sulfide, and elevated heavy metal levels at critical times of the year for fisheries and other aquatic resources have been documented, occasionally resulting in fish kills. Camanche Reservoir releases have regularly exceeded EPA criteria for the maintenance and protection of aquatic resources. To gain an accurate and complete account of Mokelumne River water quality conditions and their effects on fishes, and to fully assess the impact of EBMUD's operations on the lower Mokelumne River, a water quality monitoring program that includes a greater number of sampling sites and more frequent sampling of the lower river than presently sampled is needed.

EPA water quality standards for the protection and maintenance of aquatic resources should be met at all times for Camanche Reservoir releases. USFWS guidelines for a water quality monitoring plan, submitted to EBMUD in 1993, should be used to establish a working program. A multilevel outlet structure should be constructed at Camanche Dam so that turbid releases can be avoided while adequate water temperatures are maintained. EBMUD should manage Camanche Reservoir in a way that bottom sediments are not resuspended and subsequently released downstream.

Related actions that may impede or augment the action: The maintenance of a minimum pool in Camanche Reservoir may help prevent the re-suspension of bottom sediments high in heavy metal concentrations.

Agency and organization roles and responsibilities: EBMUD, EPA, and USFWS would work together in implementing a water quality monitoring program. EBMUD would manage releases so that water quality below Camanche Dam would meet EPA standards.

Potential obstacles to implementation: EBMUD will likely resist the installation of a multilevel outlet structure due to construction costs and difficulties involved and resist any changes in current operational procedures regarding releases.

Predicted benefits: Improved water quality would lessen the likelihood of any adverse impacts on incubating salmon eggs and juvenile salmonids and eliminate the potential for fish kills in the future.

Action 14: Eliminate adverse effects of poaching and angling on salmonid production.

Objective: Protect adult salmon and steelhead spawners.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Poaching in the lower Mokelumne River can seriously limit salmonid production with losses up to 50% during low-flow years (BioSystems 1992). Historically, most of the poaching occurs below Woodbridge Dam, but poaching has also occurred in the river adjacent to the MRFF (Estey 1992) and at Highway 88 (Boyd 1992). The Mokelumne River is open to fishing from January 1 through October 16 each year, with a daily bag and possession limit of two salmon and/or steelhead per angler. Hartwell (1994) reported that biologists conducting redd surveys on the lower Mokelumne River routinely observed anglers wading on and around the redds in these areas after the fishing season opens. Roberts and White (1992) have shown that anglers wading on trout redds can significantly affect their hatching success.

A cooperative program established in 1993 between DFG and WID based on wardens knowing the current status of the salmon migration should be continued. Consideration should be given to extending the sport fishing closure from beyond December 31 to March 31, especially during dry years. Consideration might also be given to posting signs warning anglers about trampling on redds during the spawning/incubation period in all public access areas, and at Mokelumne Day Use Area in particular. DFG, with possible assistance from local sports's clubs, could conduct weekly patrols on the river from Woodbridge Dam to Thornton to locate and remove potential fish barriers and discourage poachers.

Related actions that may impede or augment the action: The removal of Woodbridge Dam would reduce the availability of easy prey to potential poachers. Increased flows would reduce the susceptibility of adult salmon to poaching.

Agency and organization roles and responsibilities: WID and DFG will need to continue the information exchange used to alert wardens to any increased potential for poaching to occur due to the presence of migrating salmon. DFG would lead any investigation on possible fishing regulation changes concerning the Mokelumne River and would determine what enforcement presence would be necessary to reduce salmon poaching. EBMUD and/or DFG would post the "redd trampling" warning signs. Local sports's clubs could get involved in river patrols.

Potential obstacles to implementation: DFG has a limited budget to increase its enforcement presence on the lower Mokelumne River. Sport fishers will likely protest changes to restrict fishing on the lower Mokelumne River.

Predicted benefits: Escapement to the spawning grounds would increase due to a reduced take by poachers and/or the sport fishery.

Action 15: Evaluate the feasibility of increasing available rearing habitat.

Objective: Maximize suitable rearing habitat in the lower Mokelumne River.

Location: Mokelumne River approximately 1 mile downstream from McIntire Road to 3 miles downstream of Mackville Road.

Narrative description: To improve salmon rearing habitat, FERC (1993) recommends increasing the number of small pools with velocities greater than 0.49 fps that are interconnected with river channels. Such habitat might be developed by using abandoned gravel dredging and mine sites along the river. The abandoned gravel dredging areas are located approximately 1 mile downstream from McIntire Road to 3 miles downstream of Mackville Road. Similarly, FERC (1993) recommends using abandoned gravel pit mines to provide rearing habitat by connecting them with the Mokelumne River and enhancing them with riparian plantings. The most suitable gravel pits are located between Highway 88 and Mackville Road. FERC (1993) states the ponds would be useful during the March through May rearing period before water temperatures become unsuitable.

Prior to creating new habitat, the use by rearing salmonids of existing habitat similar to that described above should be evaluated. Habitat should be created only if it would provide a net benefit to natural production of salmonids.

Related actions that may impede or augment the action: River flows may affect the interconnection of the new riparian wetland habitat. Many of the gravel pits contain populations of largemouth bass that may pose predation threats to juvenile salmonids (EBMUD 1994).

Agency and organization roles and responsibilities: Cooperation with private land owners will be an essential element to make this program work. Property adjacent to the river might be purchased using State Wildlife Conservation Board funds.

Potential obstacles to implementation: Funding sources for this program may be limited to fully implement this program.

Predicted benefits: The available rearing habitat for juvenile salmonids would be increased.

Cosumnes River -

Limiting factors and potential solutions - Following is a list of factors that may limit chinook salmon production within the Cosumnes River basin (Table 3-Xc-12).

Table 3-Xc-12. Limiting factors for fall-run chinook salmon on the Cosumnes River and potential solutions.

Limiting factor	Potential solutions
Instream flow	1. Set instream flow requirements 2. Restrict diversions during critical migration periods 3. Purchase existing water rights
Migration barriers	1. Evaluate existing barriers for adult and juvenile fish passage and remedy problem ones 2. Remedy passage problems as identified above via dam removal, operational changes, or improved ladders 3. Enforce Fish and Game Codes that prohibit construction of unlicensed dams
Juvenile entrainment	Effectively screen all diversions
Riparian habitat	1. Establish riparian corridor protection zone 2. Rehabilitate damaged areas

Restoration actions -

Action 1: Determine and set instream flow requirements.

Objective: Ensure adequate instream flows for all life stages.

Location: Entire river where salmonids are found (RM 41 downstream).

Narrative description: Low flows in fall appear to be the most critical limiting factor to the run. The lower stretch of river is often dry until fall rains occur, and contiguous flow may not exist until spring. Thus, fall spawning passage of migrating adult salmon is blocked. Young-of-the-year salmon must leave the river by early May to avoid high temperatures and low flows. The current flow and temperature regime, however, prohibits the year-long presence of chinook salmon or steelhead.

The mainstem of the Cosumnes River and its smaller tributaries have 157 registered appropriative water rights. In addition, 58 statements of water diversions and use (pre-1914 and riparian rights), 123 stock ponds, and three small domestic registered diversions are on file with the Division of Water Rights. (The stock ponds are generally less than 10 af and usually are filled from diversions during the first few storms, thus delaying the increased flows that are needed downstream to allow for salmon migration.) There are additional registered water diversions on the three forks of the Cosumnes River. Most water is being diverted from the first rains in fall through early summer. This, of course, coincides with the time that salmon are in the system.

DFG's Region 2 files have no information regarding any minimum instream flow, and no IFIM studies appear to have been conducted on the Cosumnes River. There is documentation, however, that the flow remains discontinuous below the spawning area through fall and early winter in dry years and until heavy rains in normal years. In years when salmon spawn successfully, young-of-the-year salmon must leave the system by early May due to high water temperatures and low flows.

During the baseline period, the current escapement goal was met in 1968, 1969, and 1972 (Table 3-Xc-13). The average monthly flow for October in those years was approximately 1,000 cfs (average daily flow of 32 cfs). Therefore, until better information exists, a minimum instream flow of 32 cfs from October through May, measured at the Michigan Bar flow gage, provides conditions suitable for salmonid production.

Table 3-Xc-13. Escapement estimates and monthly total flow for October and May during the baseline period for the Cosumnes River.

Year	Escapement estimate	October flow	May flow
1967	500	1,467	5,988
1968	1,500	482.7	40,331
1969	4,400	1,654	11,687
1970	600	803	21,296
1971	500	901	10,529
1972	1,600	936	22,096
1973	900	1,533	24,557

Year	Escapement estimate	October flow	May flow
1974	285	NE	NE
1975	725	2,510	3,036
1976	NE	431.9	1,502
1977	NE	0	28,264
1978	100	670	30,457
1979	150	1,332	17,708
1980	200	927	6,013
1981	5	876.9	39,284
1982	NE	6,273	68,770
1983	200	2,468	15,139
1984	1,000	2,131	7,807
1985	220	878	13,160
1986	NE	1,262	2,704
1987	NE	301	3,252
1988	100	11.53	7,082
1989	NE	1,746	4,080
1990	NE	231.7	10,217
1991	NE	513.9	2,364

Note: "NE" indicates no estimate is available.

Predicted benefits: Providing adequate instream flow will ensure salmon utilization in the Cosumnes River on a consistent basis. An IFIM study will aid in determining best utilization of the available flow.

Action 2: Restrict water diversions during critical periods for salmonids.

Objective: Ensure adequate instream flows for all life stages and provide better passage for adults and juveniles.

Location: Water diversions where passage problems are evident.

Narrative description: Refer to Action 1. DFG and DWR should work with diverters to encourage them to reduce or stop diversions during critical times for salmonids (October through May). Diversion dams could be constructed later and disassembled earlier. The stock ponds could be filled in winter, allowing for an initial storm pulse to create contiguous flow for adult migrants in fall.

Predicted benefits: Any action to increase the amount of water in the river will have direct and immediate benefits to fish and likely help attain the restoration goal.

Action 3: Purchase existing water rights.

Objective: Ensure adequate instream flows for all life stages.

Location: Entire river where anadromous salmonids are found (RM 41 downstream).

Narrative description: Refer to Action 1. Purchasing existing water rights for fish is a possible means to maintain adequate flows. DFG should contact all water diverters to identify willing sellers. Water purchased farther upstream will likely provide more habitat if diverters below do not tap into it. Potentially, diverters downstream could be encouraged to request their full right while leaving excess in the stream. Subsequently, no new water appropriations should be allowed.

Predicted benefits: Any and all water that remains in the stream will have immediate benefits to fish. This action will lead to achieving the restoration goal.

Action 4: Evaluate diversion dams and barriers for passage problems.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Diversion within anadromous salmonid habitat (RM 41 downstream).

Narrative description: Small flashboard dams and some illegal dirt and gravel dams exist on the lower Cosumnes River. They do not appear to be major barriers to upstream migration; however, they may cause problems for downstream migration of young of the year. This needs to be examined. DFG should develop a prioritized list of problem barriers. Dams with severe problems should be noted so they can be dealt with immediately.

Predicted benefits: Identifying dams with passage problems will assist in developing means to remedy the situation. This will increase the amount of available spawning habitat and reduce loss of outmigrating juveniles.

Action 5: Remedy passage problems as identified in Action 4.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Dams identified as passage problems in Action 4.

Narrative description: Refer to Action 4. Potential means to resolve passage problems include dam removal, operational changes, and installation or modification of fish ladders. The feasibility of consolidating several smaller diversions into one should be investigated. DFG should work with DWR and water diverters to improve passage at these dams.

Additionally, approximately 41 RMs upstream of the mouth, there is a barrier to upstream migration. However, at extremely high flows, a secondary channel allows for possible upstream access. Attempts to eradicate this barrier have not been successful. According to a DFG report by Robert Reavis, the barrier was removed in 1947 or 1948. Salmon were able to migrate upstream of the old barrier and spawn for only a few years before the barrier re-formed. There is good spawning habitat for about 5 miles above this barrier.

Approximately 11 miles upstream of this barrier exists another barrier, impassible at all flows. The additional distance that would have to be traveled by the downstream migrants and the existence of approximately 15 miles of spawning gravel downstream of the barrier offset the value of removing it.

Predicted benefits: Providing adequate passage at dams and barriers will increase the amount of available salmonid habitat, which will likely increase production.

Action 6: Enforce Fish and Game Codes that prohibit construction of unlicensed dams.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Illegally constructed dams.

Narrative description: It is suspected that several diversion dams are constructed illegally. DFG should identify these dams and take action.

Predicted benefits: Eliminating these diversions will provide better fish passage and potentially keep more water in the river. Accomplishing this action will help attain the restoration goals.

Action 7: Effectively screen all diversions.

Objective: Prevent loss of juveniles to entrainment.

Location: All unscreened diversion in anadromous salmonid habitat (RM 41 downstream).

Narrative description: Most diversion on the Cosumnes River are unscreened and likely entrain juvenile salmonids. DFG should work with water diverters to effectively screen all diversions.

Predicted benefits: Effectively screening diversion will reduce fish loss to entrainment.

Action 8: Establish riparian corridor protection zone.

Objective: Preserve existing salmonid habitat from incompatible land use and moderate water temperature.

Location: Entire river.

Narrative description: DFG is developing a strategy that would establish a stream corridor protection zone. This would prevent incompatible land use from occurring near stream margins. This concept should be supported by all public resource agencies and applied to future developments. The county planning commission should be made aware of this.

Predicted benefits: Establishing a riparian corridor protection zone will prevent incompatible land use from effecting the current salmonid habitat.

Action 9: Rehabilitate damaged areas.

Objective: Remedy incompatible land use practices that have increased sedimentation of the river and elevate water temperature.

Location: Entire river.

Narrative description: The section of the Cosumnes River with the best spawning gravel is also characterized by extensive stretches of willow/cottonwood corridors that provide decent stream bank stabilization and prevent rapid warming of the river. However, some reaches have been denuded of the riparian corridor, causing warming trends and siltation and pollution of the water, in addition to reducing streamside vegetation. Incompatible land use practices have an effect on salmonid habitat and needed to be remedied. Recommendations include fencing and providing off-stream watering for cattle, and either revegetating the denuded sections or leaving them fenced to recover naturally. DFG should pursue rehabilitation efforts.

Predicted benefits: Rehabilitating areas of high erosion will provide better spawning substrate due to reduced sedimentation of the gravel.

Calaveras River -

Limiting factors and potential solutions -

Instream flows - Insufficient instream flow currently limits anadromous fish production in the Calaveras River, especially in dry years. Release schedules are not uniform and the system is over allocated. No dedicated fishery flows or minimum instream flow exists.

Attraction flows at the confluence of the San Joaquin River can be insufficient to move chinook salmon into the Calaveras River (Richardson 1993). Flows in late February and March must be sufficient to allow upstream migrants to swim past Bellota Weir into the spawning areas. Sustained flows between New Hogan Dam and Bellota are required for the spawning grounds. If flows are cut off too early in the season, redds will be dewatered. Incubation is generally from about April through September (for winter-run salmon; Vogel and Marine 1991) and flows in the Calaveras River typically begin to fall off in September. During the recent drought years, flows have been very low even in the spawning ground area that is above most of the diversions. Juveniles are likely moving out of river with the flows in March and April, rather than during the fall. Juveniles may overwinter because of insufficient flow to move them seaward (USFWS 1993).

Water temperature - Water temperature problems are directly linked to New Hogan Dam release schedules (USFWS 1993). Maximum temperatures can climb above the physiological tolerance of chinook salmon during dry years, hot summers, or low flows (S. Schoenberg pers. comm.). Temperatures must also be sufficiently low to attract fish into the Calaveras River; pre-spawning chinook salmon require temperatures between 41°F and 60°F (Vogel and Marine 1991).

Migration barriers - The dam at Bellota discourages passage at certain water levels (DFG 1982). Various check dams that can block migrations exist on both Morman Slough and the Calaveras River (DFG 1993).

Diversions- Most existing diversions are not screened or are inadequately screened (DFG 1993). Nearly all water in the river is diverted, especially during some seasons. The Stockton diverting canal removes water before the river empties into the San Joaquin River. Delta diversions from both the CVP and the SWP affect migrations between the Calaveras River and the Pacific Ocean.

Bank and streambed modification - Reductions in streamflow will have decreased the salmonid food base productivity compared to production with no dewatering of insect habitat (Gislason 1985). Reductions in streamflow tend to alter the streambank by facilitating riparian encroachment. This has occurred on the old channel of the Calaveras River, but this area is downstream of the spawning, incubating, and rearing area.

At the present time, flows are so limiting that bank and streambed modification are considered minor limiting factors and therefore are not further discussed under "Options for Restoration." These factors may become more important once enhanced instream flows encourage increased salmonid production.

Angling - Yearling chinook salmon have been taken by anglers. Chinook salmon poaching has been reported, and at times there has been heavy fishing pressure on rainbow trout (DFG 1984). Most of the spawning ground area is not easily accessible to anglers. Any efforts to enhance chinook salmon production will also enhance rainbow trout production, thereby increasing angler pressure. For these reasons, angling pressure could become a problem once salmonid production is increased.

Table 3-Xc-14. Limiting factors and potential solutions for Calaveras River chinook salmon.

Limiting factors	Potential solutions
Insufficient instream flows	1. Protect and increase instream flows 2. Further refine instream flow needs 3. Monitor fish production as a function of increased flows
Warmwater temperature	1. Protect and increase instream flows 2. Establish a minimum pool size at New Hogan Reservoir
Migration barriers	1. Remove temporary irrigation dams in the Calaveras River, Morman Slough, and Stockton Diverting Canal that block migration 2. Install fish passage facilities at Bellota Weir, Clements Dam, and Cherryland Dam 3. Monitor the effectiveness of fish passage facilities and alter as necessary
Entrainment at diversions	1. Identify screening needs and install screens as needed 2. Restrict further water diversions

Limiting factors	Potential solutions
Angling	1. Monitor rainbow trout fishery and change regulations to protect winter-run chinook salmon if this becomes necessary 2. Monitor for poaching

Restoration actions -

Action 1: Establish and protect adequate instream flows.

Objective: Protect winter-run chinook salmon (all life stages) and other salmonids.

Location: Instream flow protection needed from New Hogan Dam to Bellota for spawning and incubation; attraction and passage flows require protection to tidewater.

Narrative description: Protection of instream flows in the Calaveras River could be accomplished as follows:

- Establish minimum instream flow objectives to protect winter-run chinook salmon (spawning, rearing, and migration) (USFWS 1993).
- Complete a more thorough study to further refine instream flow needs (DFG 1993).
- Monitor fish production as a function of increased flows (Hunter 1991).

USFWS (1993) completed a preliminary instream flow study that clearly outlined the need for more instream flow than currently is allocated to the river. Recommendations based on this work are shown in Table 3-Xc-15. Estimated flow requirements for winter-run chinook salmon vary between 50 and 225 cfs, depending on year type and time of year. Provision of these estimated flow requirements would provide necessary attraction, spawning ground, rearing, and outmigration flows.

Table 3-Xc-15. Instream flow regimes recommended to facilitate doubling production of winter-run chinook salmon in the Calaveras River for each of three water-year types.

Month	Flows (cfs) for three year types[a,b]		
	Wet	Normal	Dry
February 19-29	225[c]	70	50
March 1-20	225[c]	225[c]	225[c]
March 21-30	225[c]	225[c]	120[d]
March 31-September 15	200[d]	160[d]	120[d]
September 16-October 31	100[e]	100[e]	100[e]
November 1-February 18	70[f]	70[f]	50[f]

[a] No current agreement exists to maintain releases for fisheries purposes.

[b] Flow recommendations modified from USFWS (1993). Flows for spawning and incubation, rearing, and temperature control are needed only to Bellota because most fish remain above where most diversions occur. However, 50 to 70 cfs left instream to tidewater would help maintain the overall health of the river system.

[c] Flows of 225 cfs are needed for attraction and passage of adults and smolts. Flows based on past recommendations by DFG. Estimates include yearling outmigration. Flows are required to mouth of San Joaquin River.

[d] Flows needed for spawning and incubation. Flows based on preliminary instream flow measurements (few transects and flows evaluated). Estimates for winter- and fall-run chinook salmon were made using habitat criteria for fall-run chinook salmon on the Stanislaus, Yuba, and American rivers. Spawning, incubation, and rearing flows for wet, normal, and dry years are those flows that yielded 100%, 80%, and 60% of the optimal WUA of physical habitat.

[e] Flows needed for juvenile rearing, including temperature protection.

[f] Flows needed for juvenile rearing.

The Calaveras River system is already over allocated, and therefore retaining water instream for salmonids may reduce water available for offstream uses. For this reason, it may eventually be necessary to more precisely determine instream flow needs by conducting a complete instream flow study. Also, as the instream flow needs are met, other limiting factors may become more important and the study could help identify these.

Finally, it is important to check that actions are working as expected. The number of salmonids passing Bellota Weir could be counted, or spawning surveys could be done, to confirm that instream flow augmentation is benefiting salmonid production. Monitoring should continue for 5-10 years (Hunter 1991).

Related actions that may impede or augment the action: Efforts to manage water temperatures for salmonids (Action 2) will need to be coordinated with this action. Efforts to enhance salmonid production in the Calaveras River should be coordinated with the "Stanislaus River Basin and Calaveras River Water Use Program" (DWR and USBR 1991). Actions as a result of this planning process could affect salmon production within the Calaveras River. Calaveras County and Stockton East Water Districts are investigating various water transfer projects that could (positively or negatively) affect Calaveras River instream flows (S. Schoenberg pers. comm.).

Agency and organization roles and responsibilities: Securing the adequate flows in the Calaveras River will require significant effort on the part of state and federal agencies. New Hogan Dam is operated by the Corps, and USBR contracts water to the state of California. These two agencies have the potential to manage water so that enhanced salmon production in this stream is possible. In addition, stream flow needs could be addressed through the SWRCB. Stockton East Water District would need to be involved in negotiations, as well as the City of Stockton, the Calaveras County Water District, DWR, USFWS, DFG, and other interested parties.

Potential obstacles to implementation: Substantial negotiation efforts would need to take place because the water in the system is already over allocated and, simultaneously, there are significant increases in demand for water because of residential development. Negotiations should stress flexibility in operation of New Hogan Reservoir. For example, operation schedules for New Hogan Dam could incorporate options to enhance salmonid production, including trout. The release schedule now used for agriculture is compatible with winter-run salmon (but not fall-run salmon) and this point should be stressed. Diversions occur mainly downstream of spawning and rearing areas, and thus some of the water requested for fish is still available for other uses downstream. However, attraction flows, which are seasonal, represent increased releases over those now made.

Predicted benefits: Flow protection is critical to chinook salmon for migration, spawning, rearing, aquatic food base production, and maintenance of coldwater temperatures. Chinook salmon production is very low and this measure, in combination with the other measures, will likely increase production at least to levels previously observed (a run size of 400-1,000 chinook salmon). These measures will contribute to the doubling goal, though there are insufficient data to state that the population will be doubled.

These flows have a high probability of increasing winter-run salmon production for the following reasons. First, there were approximately 400 spawning salmon prior to the recent prolonged drought period. In 1993, when flows were higher than during the drought period, some chinook salmon were seen around Morman Slough and the Stockton Diverting Canal (S. Schoenberg pers. comm.), suggesting that when water is present, fish will use the Calaveras River. Second, physical habitat conditions are adequate for salmon spawning and rearing (DFG 1993). For example, there is sufficient gravel of the correct size to support spawning and the existing riparian canopy is adequate (USFWS 1993). Third, the migration distance is short, reducing the number of obstacles that the fish must negotiate. Finally, New Hogan Reservoir is large relative to the size of the Calaveras River and therefore has the potential to provide cold water throughout the year (USFWS 1993). These factors combined suggest that a winter-run salmon population could be supported in the Calaveras River with the provision of sufficient flows. DFG (1993) ranks the Calaveras River as "C1" priority (i.e., restoration action benefits small populations of anadromous species and has significant long-term or permanent benefits).

Action 2: Manage water temperatures for all salmonid life stages, including spawning, incubation, rearing, juvenile outmigration, and adult migration.

Objective: Provide suitable water temperatures for salmonid survival.

Location: New Hogan Dam to Bellota, and to the San Joaquin during fish passage.

Narrative description: Water temperatures in the Calaveras River are closely associated with instream flows, reservoir release schedules, and New Hogan pool size (USFWS 1993). Temperatures climb above the physiological tolerance of chinook salmon, causing stress, migration delays, or death. Temperatures must be sufficiently low to attract fish into the Calaveras River. Required temperatures for chinook salmon are as follows (Vogel and Marine 1991):

- Pre-spawning: 5-15°C (42-60°F)
- Incubation: 5-14°C (41-60°F)
- Rearing: 6-18°C (43-64°F)

Water temperature protection could be achieved through a combination of flow protection and determination of minimum pool size at New Hogan Reservoir (USFWS 1993). Methods to establish flow protection were discussed previously. Initial minimum pool size could be determined according to the USFWS (1993) study, followed by further effort to identify the most appropriate pool size for temperature protection. For example, temperature modeling could be completed as a part of the instream flow study discussed previously.

The best available data suggest that temperatures could be kept cool enough for chinook salmon production with a release schedule as described in Table 3-Xa-1 and a minimum New Hogan pool size of 85,000 af (USFWS 1993).

Related actions that may impede or augment the action: Efforts to establish and protect adequate instream flows (Action 1) should consider and contribute to management of water temperatures.

Agency and organization roles and responsibilities: Representatives from the Corps, USBR, USFWS, DFG, Stockton East Water District, the City of Stockton, the Calaveras County Water District, DWR, and other interested parties may wish to be involved in determining a minimum pool size at New Hogan that will ensure low enough temperatures for chinook salmon production.

Potential obstacles to implementation: See potential obstacles discussed for Action 1.

Predicted benefits: Temperature protection, which is related to flow, will ensure that water temperatures do not exceed physiological tolerances of chinook salmon. In combination with flow and migration protection, this measure will increase chinook salmon production in the Calaveras River as discussed under instream flows.

Action 3: Remove migration barriers affecting salmonids.

Objective: Improve upstream and downstream migration.

Location: Bellota Weir to San Joaquin River (including Morman Slough).

Narrative description: Three specific parts to this action will ensure better upstream passage. First, remove temporary irrigation dams in the Calaveras River, Morman Slough, and Stockton Diverting Canal that partially or totally block migration (DFG 1993). Second, install fish passage facilities at Bellota Weir, Clements Dam, and Cherryland Dam (USFWS 1993, DFG 1993). Third, monitor the effectiveness of any fish passage facilities installed to ensure that the anticipated result was achieved (Hunter 1991).

These barriers definitely block upstream migrants, but may also be influencing downstream migration. Bellota Weir is removed between October 11 and March 30 (USFWS 1993); however, late-arriving fish are still blocked.

Related actions that may impede or augment the action: Provision of adequate instream flows, especially fish passage flows, should contribute to improved upstream and downstream migration.

Agency and organization roles and responsibilities: Stockton East Water District, USFWS, DFG, and other affected parties could be involved in determination of options for solving migration barrier problems at Bellota Weir, Clements Dam, Cherryland Dam, and temporary dams.

Potential obstacles to implementation: Fish passage facilities can be expensive to install and irrigators may object to removing temporary dams for fish passage if this reduces their water supply. These issues will need to be negotiated with affected parties for the best long-term result. Affected parties could seek solutions that allow fish migration and support existing water diversions.

Predicted benefits: Chinook salmon must be able to migrate upstream to the spawning grounds above Bellota; if they are blocked from this area, no production will occur even with adequate flows and water temperatures. Therefore, in combination with flow and temperature protection, this measure will increase chinook salmon production in the Calaveras River as discussed under instream flows.

Action 4: Evaluate screening needs and install screens as needed on existing diversions that may affect juvenile outmigrants (USFWS 1993).

Objective: Protect outmigrants.

Location: New Hogan Dam to San Joaquin River.

Narrative description: Many of the agricultural diversions are not screened or are inadequately screened. Nearly all water in the river is diverted, especially during the crop-growing season. Each of these diversions needs to be evaluated, and those that are likely causing salmonid mortality or delay should be properly screened. Screen effectiveness should be monitored to ensure that the screens are working successfully and as anticipated.

Outmigrants and all salmonid life stages would be better protected by restricting further water diversions for offstream uses. At a minimum, adequate instream flow protection could be required if diversions are from other basins.

Related actions that may impede or augment the action: Efforts to enhance salmonid production in the Calaveras River should increase the need to screen diversions.

Agency and organization roles and responsibilities: Individual irrigators, USFWS, DFG, Stockton East Water District, and other interested parties could be welcomed to negotiations on options for correcting screening problems, potential screening benefits, and cost of implementation.

Potential obstacles to implementation: The determination of screening needs, followed by screen placement, maintenance, and monitoring, will be costly.

Predicted benefits: Compared to the first three restoration actions, this action is less important. However, when production is improved through flow, temperature, and migration protection, loss of juveniles through unscreened diversions could become important. Ensuring that new water developments include instream flow protection or flow enhancements will reduce the chance of further stressing the stream.

Action 5: Monitor sport fishing and regulations.

Objective: Protect chinook salmon and other salmonids.

Location: New Hogan Dam to Bellota.

Narrative description: Before the prolonged drought a rainbow trout fishery existed below New Hogan Dam (DFG 1987). This fishery will need to be monitored closely once efforts are undertaken to enhance chinook salmon production because these efforts will also increase trout production. If angler pressure increases, new regulations may have to be considered to protect winter-run chinook salmon, which could be taken as yearlings.

Related actions that may impede or augment the action: Efforts to enhance salmonid production in the Calaveras River could increase the need to monitor sport fishing.

Agency and organization roles and responsibilities: DFG would probably need to coordinate this action. Local sportfishing groups might want to be involved.

Potential obstacles to implementation: Local fishing groups may protest if not involved initially.

Predicted benefits: Of the recommended options for restoration, this is the least important factor. However, when salmonid production is improved through flow, temperature, and migration protection, losses attributable to angling and poaching could become important.

D. SAN JOAQUIN BASIN

Development of Flow Recommendations

Vernalis flow -

Regression model - The equation relating escapement of chinook salmon to April-June flow and exports during the year of outmigration was derived by Dr. Carl Mesick of Carl Mesick Consultants, using data supplied by DFG, DWR, and USGS (CMC 1994).

DFG has previously presented regression equations describing the relationship between adult escapement into the Stanislaus and Tuolumne rivers and San Joaquin Basin outflow at the time of outmigration (DFG 1992, 1993). Dr. Mesick's analyses differ from DFG's in three important respects: 1) Dr. Mesick's analyses separated 2- and 3-year-old salmon according to the year when they were juveniles outmigrating through the Delta[1]; 2) the data used covered a longer period of time (1951-1993); and 3) in addition to San Joaquin Basin outflow, individual and combined effects of spawning stock numbers, ocean harvest, El Niño, Delta water quality, and total Delta exports were evaluated.

Escapement was best predicted by a model based on the ratio of Vernalis flow (Q_V) to maximum monthly exports at the SWP and CVP pumping facilities ($X_{F,S}$) from April-June (adj-R^2=0.76, p=0.000) and by a model incorporating April-June Vernalis flow and April-June maximum monthly exports as separate terms (adj-R^2=0.68, p_1= 0.000, p_2 = 0.014). Spawning stock numbers, ocean harvest, El Niño conditions, and fall water quality were discarded because their relative contributions to prediction of escapement proved to be insignificant.

Selection of regression model - In developing Vernalis flow recommendations for the purposes of the AFRP, the model relying on the Q_V:$X_{F,S}$ ratio was rejected in favor of the model incorporating Q_V and $X_{F,S}$ as separate terms in the equation. Although the ratio model accounts for a slightly greater portion of

[1]DFG regressed spring flow at Vernalis on escapement 2 years later; for each year escapement estimates were based on 3-year-old salmon, which were juveniles 2 years earlier, and 2-year-old salmon, which were juveniles 1 year earlier. Therefore, in the DFG regression, the portion of escapement composed of 2-year-old fish was not influenced by spring flow at Vernalis 2 years earlier.

the total variance associated with escapement, it has disadvantages associated with its greater potential for selecting flow and export combinations outside the range of observed conditions. For example, while a Q_V:$X_{F,S}$ ratio of 10 could be achieved by setting Q_V=100 and $X_{F,S}$=10 or by setting Q_V=10,000 and $X_{F,S}$=1000, it is unlikely that both scenarios would provide equal benefits for salmon.

Development of April-June Vernalis flow and export recommendations - The initial assumption was that doubling average baseline-period production (as indicated by escapement) of chinook salmon would require conditions that were better than those that occurred during the baseline period. With this in mind, $X_{F,S}$ was set to equal 200 taf/month (3,360 cfs), which is equivalent to about 50% of the mean export rate during the baseline period. Two hundred taf/month is the average value for $X_{F,S}$ over the five San Joaquin Basin water year types. $X_{F,S}$ was adjusted for each year type to reflect by year type distribution of total unimpaired runoff during the period of record (1922-1990) (Table 3-Xd-1). Thus $X_{F,S}$ would exceed 200 taf/mo in above-normal and wet years, but would be lower than 200 taf/mo in below-normal, dry, and critical years.

Table 3-Xd-1. Allocation of total combined Delta exports (CVP and SWP) by percent occurrence of total unimpaired runoff (1922-1990).

Year type	Percent of total unimpaired runoff (1922-1990)	Total monthly exports for 5 years		Maximum monthly exports	
Critical	0.09	x	(200 x 5)	=	90
Dry	0.13	x	(200 x 5)	=	130
Below normal	0.19	x	(200 x 5)	=	190
Above normal	0.23	x	(200 x 5)	=	230
Wet	0.35	x	(200 x 5)	=	350

When $X_{F,S}$ = 200 taf/month, the regression model indicates that a Q_V of 9,000 cfs is required to double escapement of chinook salmon into the Stanislaus and Tuolumne rivers. As with exports, total Q_V was adjusted for year type to reflect percent distribution of total unimpaired runoff between year types during the period of record (1922-1990) (Table 3-Xd-2).

Table 3-Xd-2. Allocation of San Joaquin River flow at Vernalis based on percent occurrence of total unimpaired runoff (1922-1990).

Year type	Percent of total unimpaired runoff (1922-1990)	Total monthly flow for 5 years		Mean monthly flow	
Critical	0.09	x	(9,000 x 5)	=	4,050
Dry	0.13	x	(9,000 x 5)	=	5,850

Year type	Percent of total unimpaired runoff (1922-1990)		Total monthly flow for 5 years		Mean monthly flow
Below normal	0.19	x	(9,000 x 5)	=	8,550
Above normal	0.23	x	(9,000 x 5)	=	10,350
Wet	0.35	x	(9,000 x 5)	=	15,750

Assuming that year types occur with equal frequency, the regression model predicts that implementing these standards would double the average baseline period escapement into the Tuolumne and Stanislaus rivers. Application of weighting factors to account for differences in year type frequency will be considered as a possible future refinement.

Another key assumption is that the unimpaired hydrograph (1922-1990) generally provides the best indication of the optimum timing of flow for chinook salmon. On the basis of this assumption, Vernalis flow was allocated between April, May, and June to reflect the pattern exhibited by unimpaired runoff. For example, on the average, distribution of total April-June unimpaired runoff during wet years was 25%, 39%, and 36% for April, May, and June, respectively. Thus, based on the wet-year flow value in Table 3-Xd-2, recommendations would be (0.25 X [3 X 15,570]) = 11,677 cfs in April, (0.39 X [3 X 15,570]) = 18,217 cfs in May, and (0.36 X [3 X 15,570]) = 16,816 cfs in June.

Tributary flow recommendations -

Tributary flow recommendations were developed using estimated flow needs at Vernalis, unimpaired runoff from 1922 through 1990, and findings of previous IFIM studies. The following assumptions were applied:

1) In a given water year, flow at Vernalis is an index of conditions upstream in the tributaries and upstream in the San Joaquin River.

2) In a given month, unimpaired conditions represent the optimum distribution of total San Joaquin Basin outflow between the tributaries and the mainstem river.

3) Within a given water year, flow during April, May, and June is an index of flow during the other months of the year.

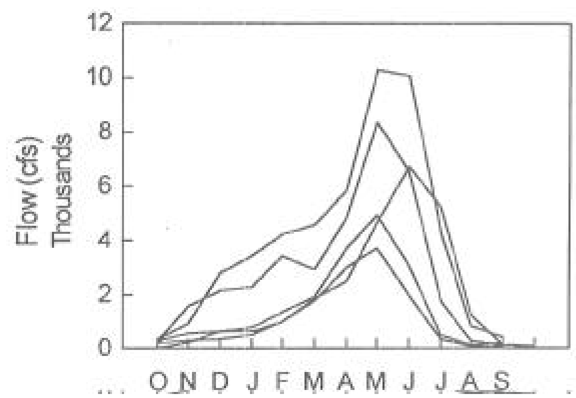
4) In a given water-year type, within each tributary and the mainstem, the unimpaired hydrograph represents optimum distribution of flow between months.

5) An exception to 4 applies to the tributaries during late summer and fall. Unimpaired flows in the reaches that are currently accessible to salmon were often extremely low prior to and

during spawning. Because access to upstream habitat has been prevented by the dams, higher than unimpaired flows are needed in most years to provide suitable conditions for spawning and incubation.

6) Flow should not be reduced between the onset of spawning and peak outmigration. Except during years when flows greater than unimpaired flows are released for spawning, this follows from assumption 3 above.

7) Although the regression model was based on combined escapement into the Stanislaus and Tuolumne rivers, the flows generated by the model were considered to be an index of conditions in the Merced River. Thus, Merced River flows were derived in the same manner as flows for the Stanislaus and Tuolumne rivers.



For April, May, and June, tributary and upper mainstem river flows were developed by allocating total basin outflow (Vernalis flow) on the basis of mean, historic contribution to unimpaired runoff by year. Using the example for a wet year above, percent contributions to flow were 19% for the Stanislaus River, 28% for the Tuolumne River, 16% for the Merced River, and 38% for the mainstem San Joaquin River. Thus, the May flow recommendations would be 3,461 cfs, 5,101 cfs, 2,915 cfs, and 6,922 cfs for the Stanislaus River, the Tuolumne River, the Merced River, and the mainstem San Joaquin River (at Stevinson), respectively.

Within each year type, flows for October-March and July-September were developed using their proportional relationship to April-July flow under mean unimpaired conditions. On the average, for 1922-1990, wet-year flows in the Stanislaus River are distributed as follows: October - 1%, November - 2%, December - 6%, January - 8%, February - 10%, March - 11%, April - 14%, May - 24%, June - 18%, July - 6%, August - 1%, and September - 1%. Returning to the original example, if AFRP \-generated wet-year flows for the Stanislaus River in April, May, and June are 1,985 cfs, 3,461 cfs, and 2,522 cfs, respectively. In an average wet year, 56% of the total annual unimpaired outflow for the Stanislaus River occurs during April-June. Flows for other months were obtained through multiplication of the percentage of the total annual flow occurring in each month by (1,985 + 3,461 + 2,522)/0.56. Flows developed using this approach generally range from 30% to 50% of those that would have occurred under unimpaired conditions.

Under unimpaired conditions, late summer and fall flows in the lower reaches of the Stanislaus, Tuolumne, and Merced rivers were probably insufficient to support chinook salmon spawning and over-summer rearing. Prior to the construction of dams, a large percentage of all spawning and rearing probably occurred upstream of the reaches that are currently accessible. Because flow recommendations developed by allocating Vernalis flow range from 30% to 50% of unimpaired flows, they cannot be expected to provide adequate conditions for spawning and rearing in the lower reaches of the rivers during dryer year types. To compensate for this deficiency, the July-December tributary flows extrapolated from the $Q_V/X_{F,S}$ regression model were replaced with IFIM flows in cases in which the IFIM flows were higher. All values were subsequently adjusted to ensure that no reductions in flow occurred between the onset of spawning in October and peak outflow, which generally occurred in May.

Merced River

Limiting factors and potential solutions -

Table 3-Xd-3. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Merced River.

Limiting factors	Potential solutions
1. Timing and magnitude of low are inadequate to provide conditions required for adult migration, spawning, incubation, rearing, and juvenile outmigration	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed out-migration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Exchequer Dam, McSwain Dam, and Crocker-Huffman Diversion to reduce temperature of water discharged to the Merced River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation
3. Egg mortality, redd dewatering, and juvenile stranding resulting from peaking power operation of hydroelectric facilities and rapid changes in reservoir discharge for other purposes	1. Prevent redd dewatering by prohibiting flow reduction from the completion of spawning through emergence 2. Reduce stranding by establishing suitable ramping rates 3. Evaluate benefits and impacts of redirecting flows released to meet peaking power demands into the canal system 4. Reduce egg mortality resulting from substrate mobilization by reducing the magnitude of peaking

Limiting factors	Potential solutions
	power fluctuations. 5. Re-regulate or stabilize flow fluctuations using Crocker-Huffman Dam.
4. Past and ongoing alteration of stream, riparian, and floodplain habitat	1. Provide funding to increase enforcement of state and federal laws pertaining to stream channel alteration 2. Increase public awareness; provide incentives for reporting violations 3. Provide funding for stream habitat restoration projects
5. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between river channel configuration and flow regime 2. Mechanically clean spawning gravels that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input.
6. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
7. Reduction in overall quantity of accessible spawning and rearing habitat resulting from obstruction of migration by dams	Determine feasibility of modifying major dams to reestablish adult chinook salmon access to upstream habitat and provide safe passage for outmigrating juvenile salmon
8. Entrainment of juvenile chinook salmon at six	1. Provide other water sources and eliminate diversions

Limiting factors	Potential solutions
medium-sized diversions and 68 small pumps	2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
9. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and/or enlist anglers to implement a concerted predator reduction program 2. Eliminate or isolate predator habitat
10. Poor water quality resulting from point and nonpoint discharge of pollutants and toxic compounds	1. Provide funding to increase enforcement of state laws pertaining point- and nonpoint-source pollution 2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Manage reservoirs to provide sufficient flow to dilute existing pollutant and toxic chemical loading
11. Straying of adult chinook salmon into the mainstem San Joaquin River upstream of the Merced River confluence and into Salt and Mud Sloughs	1. Continue to install a fall barrier in the San Joaquin River upstream of the Merced River confluence 2. Provide adequate attraction flows in the Merced River
12. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-4).

Objective: Manage flows to benefit all life stages of chinook salmon.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: New Exchequer Dam impounds Lake McClure, the largest reservoir (1.0-maf capacity) in the Merced River Basin; Crocker-Huffman Diversion is the barrier for upstream migration of salmon (Reynolds et al. 1993).

Existing flow requirements for the lower Merced River are from two sources: a Davis-Grunsky Contract, which requires Merced Irrigation District to maintain a continuous flow of 180-220 cfs from November 1 to April 1 in the reach from Crocker-Huffman Diversion to Shaffer Bridge; and FERC license no. 2179 for flow measured at Shaffer Bridge (Reynolds et al. 1993).

Current reservoir releases are insufficient to accommodate chinook salmon migration, spawning, egg incubation, juvenile rearing, and smolt emigration (Reynolds et al. 1993). Summer flows of 15-25 cfs are usually depleted by riparian diversions before reaching the river mouth, allowing water temperatures to exceed acceptable criteria for salmon (Reynolds et al. 1993). Additionally, water temperatures are often too high during adult migration and spawning in fall and during juvenile rearing and outmigration in spring.

A revised flow schedule for the lower Merced River has been formulated by DFG based on results of the Stanislaus River instream flow study and smolt survival data from the other San Joaquin River tributaries (Reynolds et al. 1993); although this schedule represents an improvement over existing conditions, it is not believed to be optimum or even adequate to meet the needs of all life stages of chinook salmon. Although further revision is planned by DFG following completion of instream flow and outmigration studies and water temperature modeling (Reynolds et al. 1993), the San Joaquin Basin Technical Team has recommended a flow schedule that it believes will achieve the goals of the Anadromous Fish Restoration Program (AFRP).

Table 3-Xd-4. Existing and AFRP-generated flow (cfs) schedules, Merced River, Crocker-Huffman Diversion to San Joaquin River confluence by year type.

Month	Existing [a]		AFRP [b]				
	Wet/ Normal	Dry	Wet	Above Normal	Below Normal	Dry	Critical
October	50	15-60	350[c]	300[c]	300[c]	250[c]	250[c]
November	180-200	180-200	350[c]	350[c]	300[c]	300[c]	250[c]
December	180-200	180-200	600[e]	550[e]	300[c]	300[c]	250[c]

Month	Existing [a]		AFRP[b]				
	Wet/ Normal	Dry	Wet	Above Normal	Below Normal	Dry	Critical
January	180-200	180-200	1,100[e]	600[e]	300[c]	300[d]	250[d]
February	180-200	180-200	1,450[e]	1,050[e]	500[d]	300[d]	250[d]
March	180-200	180-200	1,500[e]	1,050[e]	600[d]	450[d]	400[d]
April	75	60	1,800[f]	1,350[f]	1,150[f]	950[f]	750[f]
May	75	60	2,950[f]	2,300[f]	1,750[f]	1,200[f]	850[f]
June	25	15	2,850[f]	1,450[f]	1,150[f]	650[f]	450[f]
July	25	15	1,150[g]	400[g]	250[h]	200[h]	200[h]
August	25	15	350[h]	300[h]	250[h]	200[h]	200[h]
September	25	15	350[h]	300[h]	250[h]	200[h]	200[h]
Total (taf)	66-80	72-84	894	604	429	321	260
Baseline (taf)	NA	NA	1,449	1,043	647	799	499
Unimpaired (taf)	NA	NA	1,605	1,069	718	512	364

Note: All flows have been rounded to the nearest 50 cfs.

[a] Existing flows stipulated in 1967 Davis-Grunsky Contract (Reynolds et al. 1993) and FERC license agreement.

[b] Water-year type for existing flow schedules based on Lake McClure storage and inflow; water-year type for proposed flow schedules based on San Joaquin Basin 60-20-20 Index.

[c] Flow based on IFIM spawning flow recommendations for similar-size drainages (Reynolds et al. 1993) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[d] Based on IFIM flow recommendations for similar-size drainages and the assumption that, to prevent redd dewatering or stranding of rearing juveniles, flow should not be reduced between spawning and outmigration.

[e] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff for the Merced River Basin and the assumption that, to prevent redd dewatering or stranding of rearing juveniles, flow should not be reduced between spawning and outmigration.

[f] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[g] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[h] Flow based on IFIM flow recommendations for similar-size drainages (Reynolds et al. 1993) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

Related actions: Existing Davis-Grunsky and FERC flow agreements. Vernalis flow recommendations. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: If the proposed flow recommendations were to be implemented, Merced Irrigation District, which operates New Exchequer and McSwain dams, would be responsible for providing flows to meet the AFRP flow schedule. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Flows currently required or recommended are considerably lower than flows believed necessary to double natural production of chinook salmon in the Merced River. Because Lake McClure and Lake McSwain are not CVP impoundments, meeting technical team recommendations would require cooperation with water agencies and water right holders and acquisition of water from willing sellers.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Merced River.

Action 2: Adjust reservoir operations and releases to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Insufficient flows allow water temperatures to exceed acceptable levels for salmon. Other factors contributing to higher water temperatures include a degraded riparian corridor and gravel capture pits. Water temperatures are often too high during adult migration in fall and during juvenile rearing and smolt outmigration in spring. High temperatures are thought to delay migration and spawning (DFG 1992), reduce egg survival, and increase mortality of rearing and outmigrating juveniles (Reynolds et al. 1993). The following water temperatures should be maintained to the downstream boundary of the spawning area during fall and to the mouth of the river during spring.

Dates	Water temperature
October 15 - February 15	56 °F
April 1 - June 31	65 °F

Related actions: Flow recommendations and stream habitat restoration. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: If this action is implemented, Merced Irrigation District would be responsible for operating New Exchequer Dam and Lake McClure to meet temperature standards. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintaining adequate temperatures may require flows higher than those specified under Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Therefore, implementation would require purchase of additional water. Maintaining water temperature of 65°F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting these prescribed temperature standards, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 3: Reduce impacts of rapid flow fluctuations.

Objective: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Location: Merced River from Crocker-Huffman Diversion downstream to the San Joaquin River confluence.

Narrative description: Potential adverse impacts of rapid flow fluctuations resulting from peaking power operation and short-duration reservoir releases for other purposes may disrupt adult salmon migration and spawning, scour or dewater redds, mobilize spawning gravel and kill eggs during incubation, and affect emerging salmon fry by stranding, downstream displacement, and exposure to predation (Reynolds et al. 1993). The potential for adverse impacts is especially great during January and February, when fry are abundant and rely on passive dispersal to reach suitable habitat (Reynolds et al. 1993). Stranding of juvenile salmon following rapid changes in discharge has been documented at several sites along the lower Merced River and may be a principal factor affecting salmon survival in years when power peaking occurs (Reynolds et al. 1993).

The window of vulnerability for adverse impacts of rapid flow fluctuation corresponds to the period when juvenile fish are present in the river, essentially from the onset of spawning in October through outmigration in late May or early June. The team recommends establishing periods when flow fluctuation is prohibited or incorporating standards for ramping rates that will prevent premature downstream transport and stranding. Peaking power operation has the potential to be used as a tool to stimulate outmigration if ramping rates are maintained within a range suitable to prevent stranding. Redirection of flow into canal systems has been proposed by other groups to allow continued peaking power operation while minimizing impacts on anadromous fish (Reynolds et al. 1993). This type of scheme should be evaluated to determine effectiveness and costs in terms of reduced ability to meet needs of fish and other water user groups at other times of the year. Also, the potential of Crocker-Huffman Dam to re-regulate or stabilize flow fluctuations should be investigated.

Dates	Recommendation
October 1 - March 31	Cease peaking power operation or establish a minimum stage to prevent redd dewatering and ramping rates to prevent premature transport and stranding of juvenile fish. Reduce magnitude of fluctuations to prevent sediment mobilization.
April 1 - May 1	Reduce the rate of recession for peaking flows to prevent stranding of juvenile fish.

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: Merced Irrigation District and FERC in cooperation with DFG and USFWS would be responsible for establishing the schedule and standards for ramping rates.

Potential obstacles to implementation: Modifying hydroelectric plant operations to protect juvenile fish could restrict operational flexibility and reduce revenues generated by the sale of electricity during periods of high demand. Redirection of peaking flows into canals could reduce the quantity of water available during other times and for other uses.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 4: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Location: Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

Gold dredging in the early 1900s removed substantial quantities of spawning gravel from the river channel. In many riffles, substantial armoring has occurred, with only large cobble remaining. Dams currently prevent recruitment of additional gravel from upstream in the watershed. Consequent depletion of gravel in reaches downstream of dams has resulted in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature downstream displacement of juvenile salmon.

Gravel mining has also resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). On-channel gravel pits are prevalent downstream of Highway 59. Loss of juvenile salmon to bass predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low. Gravel pits may also act as traps for gravel mobilized during high flows.

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Riparian vegetation has also been removed to facilitate agricultural practices, grazing, urban development, and gravel mining. Reduced coverage by riparian vegetation is probably an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

Description of the proposed action:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, off-channel pools that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable flow regime.

4) Acquisition of floodplain and riparian lands required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature actions.

Agency and organization roles and responsibilities: The action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient for purchasing lands needed for comprehensive restoration. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Merced River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increases in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Merced River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 5: Install and maintain fish protection devices at riparian pumps and diversions; prior to installation, restrict pumping to daylight hours.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Merced River from Crocker-Huffman Diversion downstream to the San Joaquin River confluence.

Narrative description: Substantial numbers of juvenile salmon are potentially vulnerable to entrainment at six medium-sized irrigation diversions within the salmon spawning reach of the Merced River. Although the magnitude of the resulting losses is not known, there are indications it could be substantial (Hallock and Van Woert 1959). Rock screens have been installed at four of these diversions, but these have been only moderately effective at preventing juvenile salmon entrainment. In addition, there are 68 small pump irrigation diversions, none of which are adequately screened to prevent juvenile salmon entrainment.

The available data for chinook salmon is other systems indicate that much of the downstream movement of fry occurs at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping and diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: DFG has already begun an inventory of riparian diversions. USFWS will be administering a screening program as one element of the CVPIA.

Potential obstacles to implementation: Protection devices might reduce the efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installation of effective protection devices, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 6: Provide additional law enforcement.

Objective: Increase spawning success, reduce entrainment, and prevent additional destruction of stream habitat.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Provide additional law enforcement coverage to protect salmon habitat downstream of Crocker-Huffman Diversion through diligent enforcement of screening, water pollution, and streambed alteration Fish and Game Code sections (DFG 1993). If this cannot be accomplished through year-round appointments, at least increase law enforcement efforts during the period of October-December to curb poaching losses (San Joaquin River Management Program Advisory Council 1993).

Related actions: Installation of fish protection devices; habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding and manpower constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: Lake McClure, Lake McSwain, and Crocker-Huffman Diversion.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water users groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from Crocker-Huffman Diversion to the San Joaquin River confluence and reduce costs to other user groups. Providing access to reaches upstream of dams may be essential if restoration efforts are going to have any benefits for steelhead production in the Merced River.

Tuolumne River

Limiting factors and potential solutions -

Table 3-Xd-5. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Tuolumne River.

Limiting factor	Potential solutions
1. Timing and magnitude of flow are inadequate to provide conditions required	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon

Limiting factor	Potential solutions
for adult migration, spawning, incubation, rearing, and juvenile outmigration	
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed outmigration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Don Pedro and LaGrange reservoirs to reduce temperature of water discharged to the Tuolumne River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation
3. Egg mortality, redd dewatering, and juvenile stranding resulting from peaking power operation of hydroelectric facilities and rapid changes in reservoir discharge for other purposes	1. Prevent redd dewatering by prohibiting flow reduction from the completion of spawning through emergence 2. Reduce stranding by establishing suitable ramping rates 3. Evaluate benefits and impacts of redirecting flows released to meet peaking power demands into the canal system 4. Reduce egg mortality due to substrate mobilization by reducing the magnitude of peaking power fluctuations. 5. Re-regulate or stabilize flow fluctuations using LaGrange Dam.
4. Degradation of conditions for chinook salmon resulting from alteration of stream, riparian, and floodplain	1. Provide funding to enforce state and federal laws pertaining to stream channel alteration 2. Increase public awareness; provide incentives for

Limiting factor	Potential solutions
habitat	reporting violations 3. Provide funding for stream habitat restoration
5. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between river channel configuration and flow regime 2. Mechanically clean spawning gavels that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input.
6. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
7. Reduction in overall quantity of accessible spawning and rearing habitat as a result of obstruction of migration by dams	Determine feasibility of modifying major dams to reestablish adult salmon access to upstream habitat and provide safe passage for outmigrating juvenile salmon.
8. Entrainment of juvenile chinook salmon at 36 small, unscreened pump diversions	1. Provide other water sources and eliminate diversions 2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
9. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and enlist anglers to implement a concerted predator reduction/control program 2. Eliminate or isolate predator habitat
10. Poor water quality resulting from point and nonpoint discharge of pollutants and	1. Provide funding to increase enforcement of state laws pertaining point- and nonpoint-source pollution

Limiting factor	Potential solutions
toxic compounds	2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Manage reservoir releases to provide adequate dilution of pollutants and toxic compound loading rates
11. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from LaGrange Dam downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-6).

<u>Objective</u>: Provide adequate flow for all life stages of chinook salmon.

<u>Location</u>: Tuolumne River from LaGrange Dam downstream to the confluence with the San Joaquin River.

<u>Narrative description</u>: New Don Pedro Reservoir is the largest reservoir (2.0 maf) on the Tuolumne River; LaGrange Dam is the downstream barrier to salmon migration. In 1964, FERC issued a license to the Turlock and Modesto Irrigation Districts (TID/MID) to operate the New Don Pedro Project. The license agreement included minimum instream flow requirements. Additionally, Article 39 of the license called for a 20-year fisheries evaluation by cooperating agencies, including TID/MID, DFG, and USFWS, to determine measures needed to ensure continuation and maintenance of the lower Tuolumne River chinook salmon populations. At the end of the evaluation period, all parties were to submit recommendations to FERC. This study began in 1971 and, because of the extended drought conditions, is ongoing. In 1986, the study agreement was amended to include two additional flow schedules for normal water-year conditions.

The 1986 agreement does not provide adequate flow for adult migration, spawning, egg incubation, juvenile rearing, smolt emigration, or oversummering rearing of yearlings (Reynolds et al. 1993). In 1992, the districts reached an agreement with DFG on a revised flow schedule for a 10-year interim period or until issuance of a new FERC license order. The districts filed results of their studies pursuant to Article 39; however, the agreement has not been implemented because of lack of FERC approval. USFWS and the City and County of San Francisco have been unwilling to sign the agreement and have filed their own instream flow recommendations with FERC (TID/MID 1992).

FERC is presently preparing an EIS that will address fisheries issues for the New Don Pedro Project. Various entities with an interest in the FERC process are attempting to reach a negotiated settlement with the assistance of a federal mediator.

There is a positive relationship between smolt survival and spring flow in the Tuolumne River. Under the 1986 agreement, DFG allocates as much flow as possible to the spring smolt migration period, but the total amount of water available is insufficient to meet needs during all times of the year. Instream flow studies by DFG and USFWS indicate that substantially higher flows are needed for salmon spawning and rearing on the lower Tuolumne River than are possible with the present flow allocations. Summer flows are too low to sustain either salmon or steelhead but are sufficient to sustain large populations of predator fish that contribute to losses of young salmon.

Table 3-Xd-6. Existing and AFRP-generated flow schedules for the Tuolumne River from LaGrange Dam to the San Joaquin River confluence (cfs) by year type.

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
October	150-300	750[c]	300[c]	300[c]	200[c]	150[c]
November	200-300	1,250[d]	800[d]	350[c]	300[c]	150[c]
December	150-250	1,400[d]	1,050[d]	350[c]	350[c]	200[d]
January	150-250	1,700[d]	1,150[d]	500[d]	400[c]	250[d]
February	250	2,100[d]	1,700[d]	950[d]	700[d]	500[d]
March	300-250	2,300[d]	1,700[d]	1,300[d]	1,000[d]	900[d]
April	250-500	2,950[e]	2,450[e]	2,350[e]	1,900[e]	1,500[e]
May	100-200	5,150[e]	4,200[e]	3,350[e]	2,500[e]	1,850[e]
June	3	5,000[e]	3,250[e]	2,600[e]	1,550[e]	1,000[e]
July	3	2,150[f]	900[f]	650[f]	250[f]	200[f]
August	3	450[f]	200[f]	100[g]	100[g]	50[g]
September	3	350[g]	150[g]	150[g]	100[g]	50[g]
Total (taf)	128	1,544	1,078	782	564	411

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
Baseline (taf)	NA	1,291	737	355	327	155
Unimpaired (taf)	NA	2,892	2,074	1,499	1,091	805

Note: All flows have been rounded to the nearest 50 cfs.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flows based on FERC license agreement with TID/MID.

[c] Based on USFWS IFIM spawning flow recommendations (USFWS unpublished data) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[d] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff for the Tuolumne River Basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[e] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[f] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff.

[g] Flow based on USFWS IFIM recommendations.

<u>Related actions</u>: Existing flow agreement, recommendations, and FERC negotiation process. Vernalis flow recommendations. Section 3408(h), purchase of land and water from willing sellers.

<u>Agency and organization roles and responsibilities</u>: If the proposed flow recommendations were to be implemented, TID/MID, which jointly operate New Don Pedro Reservoir, would be responsible for meeting the AFRP flow schedule. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Flows currently required or recommended are considerably lower than flows that the San Joaquin Basin Technical Team believes would be required to double production of chinook salmon in the Tuolumne River. Because Don Pedro Reservoir is not a CVP impoundment, meeting technical team recommendations would require acquisition of water from willing sellers.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Tuolumne River.

Action 2: Adjust reservoir operations and releases to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon migration, spawning, incubation, rearing, and outmigration.

Location: Tuolumne River from LaGrange Dam downstream to the confluence with the San Joaquin River.

Narrative description: Elevated water temperature can delay migration and spawning activity in fall, decrease egg survival, and increase mortality of outmigrating smolts in spring (Reynolds et al. 1993).

Water temperatures in October frequently exceed acceptable levels for salmon spawning in at least a portion of the reach of the river used by spawning salmon (Reynolds et al. 1993). This condition contributes to delayed upstream migration and spawning. During the recent drought, the first spawners arrived in the lower Tuolumne River in early November, rather than in October as in previous years.

Elevated water temperatures in the lower Tuolumne River during the spring migration period may be a significant factor affecting smolt survival. Smolts migrating from the Tuolumne River during April and May commonly encounter water temperatures that approach lethal levels (DFG 1992).

Description of the proposed action:

Dates	Water Temperature
October 15 - February 15	56°F
April 1 - June 31	65°F

Related actions: Flow recommendations, restoration of riparian and instream habitat. Riparian and instream habitat restoration and protection measures (Action 4) would facilitate efforts to maintain suitable water temperatures in the Tuolumne River.

Agency and organization roles and responsibilities: If this action is implemented, TID/MID would be responsible for operating New Don Pedro Reservoir to meet the AFRP flow schedule. USFWS and DFG would be responsible for monitoring temperatures and adjusting flow and reservoir operation recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintenance of adequate temperatures may require flows higher than those recommended in Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Implementation would require the purchase of additional water. Maintaining a water temperature of 65°F during June may not be possible

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 3: Reduce impacts of rapid flow fluctuations.

Objective: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Location: Tuolumne River from LaGrange Dam downstream to the San Joaquin River confluence.

Narrative description: Hydroelectric power releases into the lower Tuolumne River from the New Don Pedro Project during the late spawning and rearing period (December through February) can cause fluctuations in downstream flow that commonly range from 200 cfs to 4,500 cfs over a 24-hour period. These releases are typically made in water years when there are no diversions for irrigation and when releases are made in anticipation, or as a direct result, of flood control requirements.

Potential adverse impacts of rapid flow fluctuations resulting from peaking power operation and short-duration reservoir releases for other purposes may disrupt adult salmon migration and spawning, scour or dewater redds, and affect emerging salmon fry by stranding, downstream displacement, and exposure to predation (Reynolds et al. 1993). The potential for adverse impacts is especially great during January and February, when fry are abundant and rely on passive mechanisms of dispersal to reach suitable habitat (Reynolds et al. 1993). Stranding of juvenile salmon following rapid changes in discharge has been documented at several sites along the lower Tuolumne River and may be a principal factor affecting salmon survival in years when power peaking releases occurs (Reynolds et al. 1993).

The window of vulnerability for adverse impacts of rapid flow fluctuations corresponds to the period when juvenile fish are present in the river, essentially from the onset of spawning in October through outmigration in late May or early June. The team recommends establishing periods when flow fluctuation is prohibited or incorporating standards for ramping rates that will prevent premature transport and stranding. If ramping rates were low enough to prevent stranding, peaking flows could be used to stimulate and facilitate juvenile outmigration during April and May. Redirection of flow into canal systems has been proposed by other groups to allow continued peaking power operation while minimizing impacts on anadromous fish (Reynolds et al. 1993).

Dates	Recommendation
October 1 - March 31	Cease peaking power operation or establish minimum stream stage to prevent redd dewatering and ramping rates to prevent premature transport and stranding of juvenile fish. Reduce magnitude of fluctuations to prevent sediment mobilization.
April 1 - May 1	Reduce the rate of recession for peaking flows to prevent stranding of juvenile fish.

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: MID/TID and FERC, in cooperation with DFG and USFWS, would be responsible for establishing the schedule and standards for ramping rates.

Potential obstacles to implementation: Modifying hydroelectric plant operations to protect juvenile fish could result reduced operational flexibility and a reduction in revenues generated by the sale of electricity during period of high demand. Redirection of peaking flows into canals could reduce the quantity of water available during other times and for other uses.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 4: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Location: LaGrange Dam downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

In-channel gravel mining has removed spawning gravel and resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). Loss of juvenile salmon to predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low.

Dams have eliminated the natural process of gravel recruitment from upstream reaches. As a consequence, gravel in reaches downstream of dams has become depleted, resulting in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature down-stream displacement of juvenile chinook salmon.

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Riparian vegetation has also been removed to facilitate agricultural practices, cattle grazing, urban development, and gravel mining. Reduced coverage by riparian vegetation is an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

The proposed action consists of the following:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, off-channel pools that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable flow regime.

4) Acquisition of floodplain and riparian land required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature recommendations.

Agency and organization roles and responsibilities: Action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient for purchasing lands needed for comprehensive restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Tuolumne River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increase in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Tuolumne River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 5: Install fish protection devices at riparian pumps and diversions; prior to installation, restrict pumping to daylight hours.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Tuolumne River from LaGrange Dam downstream to the San Joaquin River confluence.

Narrative description: Thirty-six small pump diversions, none of which are adequately screened to protect juvenile salmon, are located on the lower Tuolumne River (Reynolds et al. 1993). The cumulative loss of young salmon at these diversions resulting from entrainment is not known but is potentially substantial (Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of adequate fish protection devices, interim guidelines restricting pumping and diversion to daylight hours should be adopted.

Related actions: The CVPIA screening program (3406[b][21]) required by Title 34 is a likely source of funding.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. The action would be implemented by USFWS and DFG under 3406(b)(21) and would require cooperation with private land owners and other water right holders.

Potential obstacles to implementation: Protection devices might reduce the efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installing fish protection devices at riparian diversions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 6: Provide additional law enforcement coverage to protect against illegal take of salmon, stream alteration, and water pollution and to ensure adequate protection for juvenile salmon at pumps and diversions.

Objective: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Location: Tuolumne River from LaGrange Dam to the confluence with the San Joaquin River.

Narrative description: Increased enforcement of sections of the Fish and Game Code pertaining to illegal harvest of adult salmon, screening, water pollution, and streambed alteration would provide additional protection for chinook salmon (Reynolds et al. 1993).

Related actions: Continuing prohibition on recreational harvest, screening, and habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that increased enforcement of the specified sections of the California Fish and Game Code, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts of anadromous fish restoration on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: LaGrange and New Don Pedro reservoirs.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water user groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from LaGrange Dam to the San Joaquin River confluence and reduce costs to other user groups. This action may be essential if restoration is going to benefit steelhead production in the Tuolumne River.

Stanislaus River

Limiting factors and potential solutions -

Table 3-Xd-7. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Stanislaus River.

Limiting factors	Potential solutions
1. Timing and magnitude of flow are inadequate to provide conditions required for adult migration, spawning, incubation, rearing, and juvenile outmigration	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed outmigration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Melones, Tulloch, and Goodwin reservoirs to reduce temperature of water discharged to the Stanislaus River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation 4. Modify or remove Old Melones Dam to facilitate fall release from New Melones Reservoir of water within the temperature range suitable for spawning and incubation
3. Degraded instream, riparian, and floodplain habitat	1. Provide funding to increase enforcement of state and federal laws pertaining to stream channel alteration

Limiting factors	Potential solutions
	2. Increase public awareness; provide incentives for reporting violations 3. Provide funding for stream habitat restoration
4. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between flow regime and river channel configuration 2. Mechanically clean spawning gravel that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input
5. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
6. Reduction in overall quantity of accessible spawning and rearing habitat as a result of obstruction by dams	Determine feasibility of modifying major dams to reestablish adult salmon access to upstream habitat and provide safe passage for outmigrating juveniles
7. Entrainment of juvenile chinook salmon at 44 small, unscreened pumps	1. Provide other water sources and eliminate diversions 2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
8. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and enlist anglers to implement a concerted predator reduction program 2. Eliminate or isolate predator habitat

Limiting factors	Potential solutions
9. Poor water quality resulting from point and non-point source discharge of toxic chemicals and other pollutants	1. Provide funding to enforce state laws pertaining to point- and nonpoint- source pollution 2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Provide funding for stream habitat restoration projects
10. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from Goodwin Dam downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase public awareness and incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-8).

Objective: Manage flows to benefit all life stages of chinook salmon.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: While New Melones Reservoir is the largest impoundment (2.4 maf) in the Stanislaus River Basin, Goodwin Dam is the downstream barrier for salmon migration (Reynolds et al. 1993). Existing releases to meet needs of chinook salmon in the lower Stanislaus River are specified in a 1987 study agreement between DFG and USBR (DFG and USBR 1987). This agreement specifies interim annual flow allocations of 98,300 af to 302,100 af, depending on New Melones Reservoir carryover storage and inflow. Since the agreement was signed, water shortages have limited the quantity of water allocated to meeting fish needs to 98,300 af in all years. This quantity has proven to be inadequate for survival of all life stages of chinook salmon (Loudermilk 1994). New Melones Reservoir releases to meet Sacramento-San

Joaquin Delta water quality requirements have provided additional benefits for Stanislaus River chinook salmon in some years.

The DFG/USBR agreement provides for a 7-year study with seven study elements that are in various stages of completion. To date, results of smolt survival studies by DFG and a 1992 instream flow study by USFWS have yielded sufficient data to allow formulation of minimum instream flow schedules with increased allotments for fish. In August 1992, DFG submitted revised flow schedules to USBR and DWR. The revised flows range from 185,280 af to 381,498 af (Reynolds et al. 1993). DFG has indicated that these are minimum flows that are subject to revision upon completion of the remaining studies (Reyno1ds et al. 1993). The purpose of establishing minimum flows is to maintain the current population or prevent further decline as water demands increase (Reynolds et al. 1993); a key assumption of the technical team was that doubling natural production would require flows higher than the specified minimum flows.

Escapement of adult chinook salmon into the Stanislaus River is associated with spring outflow in both the San Joaquin River at Vernalis and the Stanislaus River at Ripon (DFG 1987). Delay of adult migrating and spawning resulting from factors related to low flow in fall is also a concern (DFG 1992). Unfortunately, the existing allocation has proven insufficient to meet both fall and spring flow needs.

The San Joaquin Basin Technical Team has recommended a flow schedule that it believes will achieve the goal of doubling natural production (Table 3-Xd-8).

Table 3-Xd-8. Existing and proposed flow schedules for the Stanislaus River from Goodwin Dam to the San Joaquin River confluence (cfs) by year type.

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
October	--	350[c]	350[c]	300[c]	250[c]	250[c]
November	--	400[c]	350[c]	300[c]	300[c]	250[c]
December	--	850[e]	650[e]	300[c]	300[c]	250[c]
January	--	1,150[e]	800[e]	300[d]	300[d]	250[d]
February	--	1,450[e]	1,150[e]	700[e]	450[d]	300[d]
March	--	1,550[e]	1,150[e]	850[e]	650[e]	550[e]
April	--	2,100[f]	1,800[f]	1,750[f]	1,250[f]	950[f]
May	--	3,500[f]	2,750[f]	2,050[f]	1,400[f]	900[f]
June	--	2,650[f]	1,600[f]	1,300[f]	700[f]	450[f]
July	--	900[g]	400[g]	350[h]	200[h]	250[h]

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
August	--	350[h]	300[h]	250[h]	200[h]	200[h]
September	--	350[h]	300[h]	250[h]	200[h]	200[h]
Total (taf)	98 - 302	943	701	525	375	290
Baseline (taf)		1,015	722	406	242	269
Unimpaired (taf)		1,772	1,291	920	631	449

Note: All flows have been rounded to the nearest 50 cfs.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flows based on agreement between USBR and DFG (DFG and USBR 1987). Actual schedule determined on an annual basis.

[c] Flow based on USFWS IFIM spawning recommendations (Aceituno 1993, Reynolds et al. 1993) and the assumption that flow greater than unimpaired flow is needed at this time of the year to compensate for elimination of access to upstream habitat.

[d] Based on USFWS IFIM spawning flow recommendations and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering and stranding of rearing juveniles.

[e] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River Basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[f] Stanislaus River contribution to Vernalis flow standard. Based on historical monthly contribution of the Stanislaus River to total unimpaired runoff for the San Joaquin River Basin, 1922-1990.

[g] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River Basin.

[h] Based on USFWS IFIM flow and assumption that flow greater than unimpaired flow is needed to compensate for eliminations of access to upstream habitat.

Related actions: Existing flow agreement between USBR and DFG. Vernalis flow recommendations. Section 3406(b)(2) of Title 34, annual dedication of 800,000 af of water for fish, wildlife, and habitat restoration purposes. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of this action will require cooperation and coordination between USFWS, DFG, USBR, and numerous water user groups and irrigation districts.

Potential obstacles to implementation: Neither the existing USBR/DFG agreement nor the 800,000 af of water dedicated to fish and wildlife purposes by 3406(b)(2) of Title 34 are sufficient to meeting flow needs identified by the AFRP. Implementing this flow schedule would reduce water available to meet needs of other user groups and would thus require purchase of additional water.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Stanislaus River.

Action 2: Operate New Melones, Tulloch, and Goodwin reservoirs to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: Water temperature in the lower Stanislaus River is influenced by ambient air temperature, flow, channel width, New Melones Reservoir storage, diversions and thermocline development, and Tulloch Reservoir temperatures and operations (Reynolds et al. 1993). When fall storage in New Melones Reservoir is low, water temperature throughout spawning reaches of the river can exceed 56°F until November (Pisano 1992). During the recent drought, the initial date on which salmon entered the river to spawn was delayed from October until mid-November (DFG 1992). In addition to delaying the onset of spawning, temperatures in excess of 56°F may result in increased mortality of eggs (Pisano 1992).

In spring, elevated water temperatures in the Stanislaus River, the San Joaquin River, and the Delta reduce survival of outmigrating smolts. During May, salmon smolts migrating downstream in the Stanislaus River typically encounter water temperatures that cause physiological stress (DFG 1992). Because their emergence and migration are delayed, the progeny of late-spawning fish are at greater risk of being exposed to stressful or lethal water temperatures (DFG 1992).

Although there is good evidence to support the need for a temperature standard, the understanding of the relationship between temperature and flow in the Stanislaus River is incomplete. Linking an existing USBR temperature model (Rowell 1993) with a USFWS instream flow model (Aceituno 1993) should provide the additional information needed for managing water temperatures by modifying timing and magnitude of reservoir releases.

The proposed action consists of the following:

Dates	Water temperature
October 15-February 15	56°F
April 1-June 31	65°F

Related actions: Flow recommendations, comprehensive restoration of riparian and instream habitat, and modification of Old Melones Dam. Riparian and instream habitat restoration and protection measures (Action 4) would facilitate efforts to maintain suitable water temperatures in the Stanislaus River.

Agency and organization roles and responsibilities: USBR would be responsible for operating New Melones Reservoir to meet temperature standards. USFWS and DFG would be responsible for monitoring and adjusting recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintenance of adequate temperatures may require higher flows than those recommended under Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Therefore, implementation would require purchase of additional water. Maintaining a water temperature of 65°F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting the recommended temperature criteria, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 3: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

In-channel gravel mining has removed spawning gravel and resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). Loss of juvenile salmon to bass predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low.

Upstream of the town of Riverbank, habitat has been lost as of result of relocation and channelization to accommodate construction of Highway 108-120 (Reynolds et al. 1993). In contrast, the river downstream of Riverbank has retained much of its original sinuosity (Reynolds et al. 1993). High sinuosity is associated with greater habitat diversity and relatively good retention of gravel during flood events (Reynolds et al. 1993).

Dams have eliminated the natural process of gravel recruitment from upstream reaches. As a consequence, gravel in reaches downstream of dams has become depleted, resulting in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature downstream displacement of juvenile chinook salmon (Reynolds et al. 1993).

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Reduced coverage by riparian vegetation is an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

The proposed action consists of the following:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, on-channel ponds that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable future flow regime.

4) Acquisition of floodplain and riparian land required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature actions.

Agency and organization roles and responsibilities: This action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient to purchase lands needed for comprehensive restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Stanislaus River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increases in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Stanislaus River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 4: Install and maintain fish protection devices at riparian pumps and diversions.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Stanislaus River from Goodwin Dam downstream to the San Joaquin River confluence.

Narrative description: Forty-four small pump diversions, none of which are adequately screened to protect juvenile salmon, are located on the lower Stanislaus River. The cumulative loss of young salmon at these diversions resulting from entrainment is not known but is potentially substantial (Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. This action would be implemented by USFWS and DFG under 3406(b)(21) and would require cooperation with private land owners and other water right holders.

Potential obstacles to implementation: Protection devices might reduce efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installation of effective protection devices, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 5: Provide additional law enforcement to protect against illegal take of salmon, stream alteration, and water pollution and to ensure adequate screening of pumps and diversions.

Objective: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Location: Stanislaus River from Goodwin Dam to the confluence with the San Joaquin River.

Narrative description: Increased enforcement of sections of the Fish and Game Code pertaining to illegal harvest of adult salmon, screening, water pollution, and streambed alteration would provide additional protection for chinook salmon (Reynolds et al. 1993).

Related actions: Installation of fish protection devices; habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding and manpower constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 6: Remove or modify Old Melones Dam.

Objective: Reduce fall water temperatures in the Stanislaus River.

Location: New Melones Reservoir.

Narrative description: Warm water temperatures during the fall are believed to result in delayed spawning, decreased egg survival, and high juvenile mortality (DFG 1992). Fall water temperatures depend partially on the late summer reservoir storage level, thermocline development, and the depth of diversions from New Melones Reservoir (Reynolds et al. 1993). When fall storage is low, Old Melones Dam, which is located within the reservoir, limits deep circulation and results in the release of water drawn directly from the reservoir surface (Reynolds et al. 1993). When these conditions occur, fall water temperatures may exceed 56°F throughout most of the spawning reaches of the Stanislaus River (Reynolds et al. 1993); this deleterious condition prevails until ambient air temperatures cool the river, usually in November (Hallock and Van Woert 1959).

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: As the agency in charge of operating New Melones Reservoir, USBR would have the primary responsibility for implementing this action.

Potential obstacles to implementation: Cost and feasibility are currently unknown.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts of anadromous fish restoration on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: Goodwin, Tulloch, and New Melones reservoirs.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify dams and operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water user groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from Goodwin Dam to the San Joaquin River confluence and reduce costs to other user groups. This action may be essential if restoration efforts are going to benefit steelhead production in the Stanislaus River.

Mainstem San Joaquin River

Limiting factors and potential solutions -

Table 3-Xd-9. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the San Joaquin River.

Limiting factors	Potential solutions
1. Direct and indirect impacts of exports at Harvey O. Banks (SWP) and Tracy (CVP) pumping plants on juvenile chinook salmon migrating through the lower San Joaquin River and Delta	1. Increase San Joaquin River flow to facilitate migration of juvenile fish through the lower San Joaquin River and Delta 2. Reduce exports when juvenile chinook salmon are migrating through the lower San Joaquin River and Delta 3. Reduce entrainment by installing the head of Old River barrier during juvenile outmigration 4. Improve survival of fish entrained at fish salvage facilities 5. Reduce or eliminate predators in channels leading to pumps 6. Reduce pumping at night
2. Unsuitable temperatures for juvenile chinook salmon in the mainstem San Joaquin River and Delta	1. Restore riparian and bank vegetation along the mainstem and tributaries 2. Operate reservoirs to reduce the temperature of discharged water 3. Evaluate strategies for reducing temperature by increasing tributary and mainstem outflow during outmigration
3. Entrainment of juvenile chinook salmon at the Patterson, El Soyo, West Stanislaus, and Banta-Carbona diversions on the mainstem San Joaquin River	1. Install and maintain effective screens or other fish exclusion devices during the period when juvenile chinook salmon are migrating through the mainstem San Joaquin River 2. Reduce diversion rates when juvenile chinook salmon are migrating through the mainstem San Joaquin River

Limiting factors	Potential solutions
4. Dissolved oxygen and ammonia barrier to adult migration in the San Joaquin River at Stockton	1. Prohibit dredging in the Stockton ship channel during periods when chinook salmon are migrating through the lower San Joaquin River 2. Establish stronger standards for City of Stockton wastewater discharge 3. Increase flows in the San Joaquin River at Stockton when chinook salmon are present (could include installation of the head of Old River barrier) and monitoring indicates that water quality is unsuitable
5. Effects of legal harvest of migrating adult salmon in the Delta reach of the San Joaquin River from Mossdale to Chipps Island	Extend the prohibition on the harvest of adult salmon from Mossdale downstream to Chipps Island
6. Illegal harvest of adult salmon in the San Joaquin River upstream of Mossdale and in the tributaries from their confluences with the San Joaquin River upstream to the dams	1. Increase law enforcement efforts during periods when adult salmon are in the river 2. Increase general public and angler awareness to improve compliance and encourage reporting of poaching
7. Loss of genetic integrity/diversity	1. Reduce risk by implementing habitat restoration measures 2. Investigate feasibility of establishing a gene bank to ensure preservation of genetic material of San Joaquin River fall-run chinook salmon 3. Selectively harvest hatchery fish 4. Use "natural" fish in captive breeding programs

Limiting factors	Potential solutions
	5. Complete genetic differentiation studies for San Joaquin Basin fall-run chinook salmon stocks 6. Establish a genetic advisory committee to review impacts of hatchery operations and release strategies and examine Merced River Hatchery practices and develop strategies to ensure that further increases in hatchery production do not adversely affect wild stocks. 7. If the decline of San Joaquin chinook salmon continues, and extinction appears imminent, consider hatchery spawning and rearing of wild fish as an interim measure
8. Straying of adult chinook salmon into the mainstem San Joaquin River upstream of the Merced River confluence, and into Salt and Mud Sloughs	1. Continue to install a fall barrier in the San Joaquin River upstream of the Merced River confluence 2. Provide adequate fall attraction flows in the Merced River
9. Entrainment of juvenile chinook salmon at four major diversions and numerous smaller diversions on the mainstem San Joaquin River	1. Reduce or prohibit operation of pumps and diversions at times when juvenile salmon are present 2. Install screens or other protective devices to prevent entrainment when pumps or diversions are being operated
10. Limits imposed by over-allocation of existing water supply	1. Evaluate and, if feasible, establish a conjunctive water use program 2. Pursue opportunities for land fallowing and purchase of water from willing sellers 3. Investigate opportunities for water augmentation

Restoration actions -

Action 1: Implement Vernalis flow schedule (Table 3-Xd-10) or measures that provide equivalent protection for San Joaquin fall-run chinook salmon.

Objective: Provide adequate flow for all life stages of chinook salmon.

Location: San Joaquin River at Vernalis.

Narrative description: The timing, amount, and quality of flow affects the migration and survival of both juvenile and adult chinook salmon. Declines in escapement to San Joaquin Basin tributaries have been attributed to inadequate streamflow in the mainstem San Joaquin River and its tributaries (DFG 1987). During spring, low basin outflow and Delta exports result in both direct and indirect mortality of outmigrating smolts and fry (Reynolds et al. 1993); conversely, higher smolt survival has been observed in years when spring flows in the mainstem river and tributaries have been high (CMC 1994, Reynolds et al. 1993). In some years, upstream migration of adult salmon into San Joaquin River tributaries is delayed because of the lack of attraction flow, elevated water temperatures, and low dissolved oxygen concentration (DOC), which commonly occur in the San Joaquin River in fall (SJRMP1993, DFG 1992). Diversion of water through Delta facilities, Port of Stockton operations, City of Stockton waste discharges, channel dredging, tidal action, and San Joaquin River inflow are important factors that are mediated by flow and that affect survival of outmigrating juvenile salmon. There are no specific flow requirements in place in the mainstem San Joaquin River to meet the needs of migrating salmon.

In estimating Vernalis flow needed to meet the goal of doubling natural production of San Joaquin fall-run chinook salmon, maximum export rates from April through June were assumed to be restricted to one half of the average for the baseline period (1967-1991). If combined state and federal exports were further reduced, the regression equation predicts that doubling could be achieved with lower San Joaquin River flow; conversely, higher export rates would necessitate higher flow. Disadvantages of lower spring flow include elevated water temperatures and reduced habitat quality for juveniles in the tributaries.

Table 3-Xd-10. San Joaquin River flow (cfs) at Vernalis.

Month	Existing[b]	AFRP[a]				
		Wet	Above normal	Below normal	Dry	Critical
October	--	1,450[c]	950[c]	900[c]	700[c]	650[c]
November	--	2,000[c]	1,500[c]	950[c]	900[c]	650[c]
December	--	2,850[c]	2,250[c]	950[c]	950[c]	700[c]

Month	Existing[b]	AFRP[a]				
		Wet	Above normal	Below normal	Dry	Critical
January	--	3,950[c]	2,550[c]	1,100[c]	1,000[c]	750[c]
February	--	5,000[c]	3,900[c]	2,150[c]	1,450[c]	1,050[c]
March	--	5,350[c]	3,900[c]	2,750[c]	2,100[c]	1,850[c]
April	--	12,000[d]	8,250[d]	7,300[d]	5,850[d]	4,450[d]
May	--	18,600[d]	13,700[d]	10,200[d]	7,400[d]	5,200[d]
June	--	17,300[d]	9,750[d]	7,650[d]	4,600[d]	2,950[d]
July	--	4,200[c]	1,700[c]	1,250[c]	650[c]	650[c]
August	--	1,150[c]	800[c]	600[c]	500[c]	450[c]
September	--	1,050[c]	750[c]	650[c]	500[c]	450[c]
Total (taf)	--	4,521	3,019	2,200	1,606	1,196
Baseline (taf)		4,691	3,020	1,609	1,617	1,042
Unimpaired (taf)		10,417	6,830	4,648	3,375	2,361

Note: All flows have been rounded to the nearest 50 cfs. Flow schedule would have to be implemented in conjunction with appropriate export restrictions (Table 3-Xd-11).

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flow requirements dictated by December 15, 1994 Delta Accord.

[c] Sum of flow from the Stanislaus, Tuolumne, and Merced rivers.

[d] Flow required to meet salmon production goals based on the following regression relationship:

$$E_{S,T} = (1.820Q_V)-(0.051X_{F,S})-18,417.3 \text{ (CMC 1994)}$$

where, for a given year class, $E_{S,T}$ is the sum of escapement into the Stanislaus and Tuolumne rivers of 2- and 3-year-olds, Q_V is average San Joaquin River flow (cfs) at Vernalis from April 1 through June 30 in the year of outmigration, and $X_{F,S}$ is total combined monthly exports (af) for the federal (CVP) and state (SWP) water projects from April 1 through June 30 in the year of outmigration. Flow is allocated between April, May, and June on the basis of historical occurrence of unimpaired runoff.

Related actions: Existing flow requirements and flow recommendations for San Joaquin River tributaries. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation between multiple government agencies and private entities.

Potential obstacles to implementation: Flows are higher than those that have been recommended in other forums. Implementing these flow standards would reduce the quantity of water available to other user groups.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of the proposed flow schedule, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 2: Implement proposed export restrictions for the state (SWP) and federal (CVP) Delta pumping plants.

Objective: Reduce direct and indirect mortality of outmigrating San Joaquin chinook salmon smolts.

Location: CVP and SWP pumping plants.

Table 3-Xd-11. Combined maximum exports (cfs) at SWP and CVP pumping facilities.

Month	Year type[a]				
	Wet	Above normal	Below normal	Dry	Critical
April	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
May	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
June	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
Total (af)	1,254	713	560	397	280

Notes: All exports have been rounded to the nearest 50 cfs.

Restrictions would have to be implemented in conjunction with AFRP flows (Table 3-Xd-10) to double natural production of San Joaquin basin chinook salmon.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Flow required to meet salmon production goals based on the following regression relationship:

$$E_{S,T} = (1.820Q_V)-(0.051X_{F,S})-18,417.3 \text{ (CMC 1994)}$$

where, for a given year class, $E_{S,T}$ is the sum of escapement into the Stanislaus and Tuolumne rivers of 2- and 3-year-olds, Q_V is average San Joaquin River flow (cfs) at Vernalis from April 1 through June 30 in the year of outmigration, and $X_{F,S}$ is total combined monthly exports (af) for the federal (CVP) and state (SWP) water projects from April 1 through June 30 in the year of outmigration.

Related actions: Related to flow recommendations. Higher export rates require higher flow at Vernalis to meet production goals. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Restricting exports would require cooperation between multiple agencies and private entities.

Potential obstacles to implementation: Export restrictions would reduce the quantity of water available to other user groups. Because state pumping facilities are not under the authority of the CVP, there is little incentive for them to adhere to export restriction for the purposes of the AFRP.

Projected benefits: The San Joaquin Basin Technical Team believes that implementing the recommended export restrictions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in lower San Joaquin Basin tributaries.

Action 3: Establish Stevinson flow standards.

Objective: Manage instream flow to benefit all life stages of chinook salmon.

Location: San Joaquin River at Stevinson (immediately upstream of the confluence with the Merced River).

Table 3-Xd-12. Existing and AFRP-generated flow schedules
for the San Joaquin River at Stevinson (cfs) by year type.

		AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
April	--	5,150[c]	2,650[c]	2,050[c]	1,750[c]	1,250[c]
May	--	7,000[c]	4,450[c]	3,050[c]	2,300[c]	1,600[c]
June	--	6,800[c]	3,450[c]	2,600[c]	1,700[c]	1,050[c]
Total (taf)	--	1,141	637	464	347	235

Note: All flows have been rounded to the nearest 50 cfs.

[a] There are no existing flow requirements at this site.

[b] Year type based on San Joaquin Basin 60-20-20 Index.

[c] San Joaquin River contribution to Vernalis flow standard. Based on Vernalis flow standards and the historical percent contribution of the San Joaquin River to total unimpaired San Joaquin Basin runoff.

Related actions: Existing and proposed flow schedules for all tributaries. Section 3408(h), purchase of land and water from willing sellers. Temperature recommendations.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation between multiple government agencies and private entities.

Potential obstacles to implementation: There are no existing flow requirements for the San Joaquin River above the Merced River confluence. Implementing a Stevinson flow standard would reduce the quantity of water available to other user groups. Although Millerton Reservoir, on the mainstem San Joaquin River, is a CVP impoundment, availability of water for the AFRP is uncertain.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 4: Install and maintain fish protection devices at the Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by the four largest diversions on the San Joaquin River.

Location: Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions on the mainstem San Joaquin River between the Merced River confluence and the Delta.

Narrative description: There are four major unscreened diversions on the mainstem San Joaquin River downstream of the Merced River confluence. The El Soyo diversion has a maximum capacity of 80 cfs, and the Banta-Carbona, Patterson, and West Stanislaus diversions have a maximum capacity of 249 cfs each (Reynolds et al. 1993). Cumulatively, the four diversions are capable of withdrawing a substantial proportion of the total mainstem San Joaquin River flow, particularly during dry water-year types. Although impacts on juvenile chinook salmon are not well documented, there is evidence to suggest they may be substantial (Hallock and Van Woert 1959). Screens installed in the late 1970s were later abandoned; operation of these facilities in the ensuing period is believed to have contributed to low survival of outmigrating juveniles (SJRMP 1993).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. USFWS will be administering a screening program as one element of the CVPIA. Implementation of a San Joaquin Basin screening program would require cooperation between USFWS, DFG, and the Banta-Carbona, West Stanislaus, Patterson, and El Soyo Irrigation Districts.

Potential obstacles to implementation: Screens might reduce efficiency of diversions or require additional maintenance effort on the part of the irrigation districts, although a substantial portion of the costs would probably be covered by funds available under 3406(b)(21).

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 5: Install and maintain fish protection devices at small agricultural diversions.

Objective: Increase survival of juvenile salmon by reducing or eliminating entrainment at small pumps and diversions.

Location: San Joaquin River from the Merced River confluence downstream to the Delta.

Narrative description: Additional small- and medium-sized irrigation diversion on the mainstem San Joaquin River entrain juvenile salmon (Reynolds et al. 1993); cumulative effects are not known but have the potential to be substantial (Reynolds et al. 1993, Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34, install and maintain fish protection devices at major diversions.

Agency and organization roles and responsibilities: USFWS will be administering a screening program as one element of the CVPIA. DFG, which is in the process of conducting an inventory and assessment of San Joaquin Basin diversions, would be the agency likely to implement a screening effort. Cooperation and coordination with USFWS, irrigation districts, and land owners would be necessary.

Potential obstacles to implementation: Fish protection devices might reduce efficiency of diversions or require additional maintenance effort on the part of diverters, although most of the costs should be covered by funds available under 3406(b)(21).

Projected benefits: The San Joaquin Basin Technical Team believes that installing effective fish protection devices at small agricultural diversions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 6: Continue the prohibition on sport harvest of chinook salmon in the San Joaquin Basin upstream of Mossdale; extend closure on the mainstem San Joaquin River downstream to Chipps Island.

Objective: Increase spawning success by preventing the harvest of adult chinook salmon escaping into San Joaquin River tributaries.

Location: San Joaquin River upstream from Mossdale and the San Joaquin River tributaries.

Narrative description: When escapement is low, as it has been during the recent years of drought, legal harvest has the potential to remove a substantial percentage of the total number of spawning adults (SJRMP 1993) and, consequently, reduce juvenile production. Many of the adult salmon harvested in the San Joaquin River between Mossdale and Chipps Island are migrating to spawning grounds in the Stanislaus, Tuolumne, and Merced rivers (SJRMP 1993). Harvest of salmon is currently prohibited in the mainstem San Joaquin River upstream of Mossdale and in the tributaries upstream to the dams. The San Joaquin Basin Technical Team recommends extending the closure in the mainstem river downstream to Chipps

Island and leaving the closure in effect until it has been determined that San Joaquin Basin chinook salmon stocks have recovered.

Related actions: Additional law enforcement to reduce illegal harvest.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although the involvement of local law enforcement authorities would increase chances for success.

Potential obstacles to implementation: Continued prohibition on recreational harvest has the potential to reduce support of anglers' groups for the restoration program.

Projected benefits: The San Joaquin Basin Technical Team believes that maintaining a prohibition on harvest of adult salmon will be necessary for recovery. The team believes that this action, in concert with other actions recommended by the team, would at least double natural production of fall-run chinook salmon in the three lower San Joaquin Basin tributaries.

Action 7: Prohibit the dredging of the Stockton ship channel during critical periods.

Objective: Prevent DOC sag during periods when adult or juvenile salmon are migrating through the lower San Joaquin River and Delta.

Location: San Joaquin River near Rough and Ready Island.

Narrative description: During fall, DOC is commonly low in the San Joaquin River near Stockton (DFG 1993, SJRMP 1993). Adult salmon migration is inhibited by exposure to DOC below 5 parts per million (ppm). Low DOC often results from dredging in the Stockton Ship Channel and turning basin, flow reversals resulting from high Delta exports, and effluent discharge from the Stockton Municipal Sewage Treatment Plant and other sources. DWR installs a rock barrier at the head of Old River in fall to improve DOC levels when the San Joaquin River flow at Vernalis drops below 1,800 cfs. Modifications of sewage treatment plant operation benefitted salmon by improving water quality. However, in fall 1992, a DOC sag occurred in the San Joaquin River near Rough and Ready Island; conditions in the Stockton Deepwater Ship Channel were associated with this oxygen sag.

Related actions: Head of Old River barrier, flow recommendations, and export limits, all of which would improve water quality in the mainstem San Joaquin River.

Agency and organization roles and responsibilities: Preventing future DOC sags in the San Joaquin River near Stockton will require coordination with the Corps regarding restrictions on timing and location of dredging, with DWR for installation of the head of Old River barrier, and with state and local water quality authorities on effects of point- and nonpoint-source discharge.

Potential obstacles to implementation: Lack of funding to adequately address point- and nonpoint-source discharge problems.

Projected benefits: The San Joaquin Basin Technical Team believes that alleviating conditions that lead to development of a dissolved oxygen barrier in the San Joaquin River near Stockton, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 8: Install the head of Old River barrier.

Objective: Improve water quality for migrating adults and reduce entrainment of outmigrating smolts.

Location: San Joaquin River at the head of Old River.

Narrative description: DWR installs a rock barrier at the head of Old River in fall to improve DOC in the lower San Joaquin River when flow at Vernalis drops below 1,800 cfs (Reynolds et al. 1993). Beginning in 1992, the barrier was installed in spring (April 15-21) (DWR 1992) to reduce diversion and probable entrainment at the CVP and SWP pumping plants of chinook salmon smolts migrating down the San Joaquin River. Feasibility and benefits of the barrier are reduced when San Joaquin River flow is high.

Related actions: Flow recommendation, export restrictions, and measures to prevent DOC sag in the San Joaquin River near Stockton.

Agency and organization roles and responsibilities: DWR would be responsible for implementing this action. DFG and USFWS would be responsible for monitoring to determining benefits and impacts on other fish species.

Potential obstacles to implementation: Potential impacts on Delta smelt and other native species may limit the length of time for which the barrier can remain installed in the spring. It is uncertain what level of protection can be obtained by installing the barrier for only a portion of the period when smolts are actually present and vulnerable to entrainment.

Projected benefits: This action has the potential to improve water quality in the San Joaquin River, facilitate adult migration, and provide protection to outmigrating smolts with reduced water costs. Similar or higher levels of protection can be obtained by implementing recommended flow and export schedules.

Action 9: Establish spring and fall water temperature goals for the mainstem San Joaquin River. Goals would be achieved through a combination of changes in reservoir operations, enhanced flows, and riparian restoration.

Objective: In fall, prevent delays in adult migration and resulting increases in egg and juvenile mortality; in spring, increase survival of outmigrating juveniles by reducing stress and mortality associated with high water temperatures.

Location: San Joaquin River from Merced River confluence to the Delta.

Narrative description: Elevated fall water temperatures in the San Joaquin River are believed to delay upstream migration and spawning (DFG 1992). This may lead to delays in emergence and outmigration of juveniles (DFG 1992) and increase the risk of exposure to stressful or lethal water temperatures. Elevated water temperatures during spring result in conditions that have been found to reduce survival of juvenile salmon (DFG 1992, 1987). DFG has determined that when flow at Vernalis is 5,000 cfs or less in May, water temperatures are at levels associated with chronic stress to salmon (DFG 1987). The effects of such stress are cumulative and increase effects of other mortality factors, such as entrainment/impingement at water diversions, predation, and salvage handling at Delta fish facilities.

Following are recommended water temperature standards that should be maintained to the downstream boundary of the spawning area during fall and the mouth of the river during spring.

Dates	Water temperature
October 15-February 15	56°F
April 1-June 31	65°F

Related actions: Mainstem and tributary flow recommendations and sequential habitat restoration, especially recommendations to restore bank and riparian vegetation. Riparian and instream habitat protection and restoration proposals discussed in Action 4 should further reduce water temperatures.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation and coordination of multiple government agencies and private entities and would probably require acquisition of additional water from willing sellers.

Potential obstacles to implementation: It is anticipated that meeting temperature goals may require greater quantities of water than those indicated by flow recommendations. This would result in a substantial reduction in the quantity of water available for other purposes. Restoration of riparian habitat could reduce the quantity of water necessary to meet temperature standards. Maintaining a water temperature of 65° F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting the recommended temperature goals in the San Joaquin River, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 10: Establish a basinwide Conjunctive Water Use Program.

Objective: Obtain adequate water to meet anadromous fish flow requirements while minimizing impacts on other water users.

Location: Entire San Joaquin River Basin.

Narrative description:

1) Evaluate benefits and costs of a conjunctive use program, including potential increases in water supply to meet fish needs.

2) Develop and implement a program, ensuring a net gain in water allocated to meeting anadromous fish requirements.

Related actions: Potential to increase the feasibility and reduce impacts of actions involving flow.

Agency and organization roles and responsibilities: Establishing an effective conjunctive use program would require cooperation and coordination between all government agencies and private entities involved in water use or resource management in the San Joaquin River Basin.

Potential obstacles to implementation: Net benefits for anadromous fish may be great but depend on many factors and have not been evaluated.

Projected benefits: A conjunctive use program has the potential to reduce the adverse impacts on other water users of implementing flow recommendations. Such a program may be an essential tool to obtain water needed to meet fish flow needs.

Action 11: Reduce predator populations.

Objective: Increase survival of juvenile salmon by reducing predator populations.

Location: San Joaquin River and tributaries.

Narrative description: Predatory fish such as largemouth and smallmouth bass are a potential cause of increased mortality of rearing and outmigrating salmon. Abandoned gravel pits on the tributaries provide excellent habitat for these species (Reynolds et al. 1993).

Following are the elements of this action:

1) Increase sport harvest of predators, primarily largemouth bass.

2) Reduce predator habitat, primarily abandoned gravel pits and other pools that are connected to river channels.

Related actions: Sequential habitat restoration on San Joaquin River tributaries; ongoing DWR/DFG habitat restoration efforts (DWR 1994).

Agency and organization roles and responsibilities: Increasing harvest would primarily be the responsibility of DFG. Reducing predator habitat would require cooperation and coordination between various agencies and riparian land owners.

Potential obstacles to implementation: Potential objection from some segments of the angling population. May not be practical or even possible. Magnitude of problems and benefits resulting from implementing this action are poorly documented.

Projected benefits: Impacts of predation on juvenile salmon are not known but are believed to be substantial under some conditions. Predation is generally lower when flow is high.

E. SACRAMENTO-SAN JOAQUIN DELTA

General Approach

The goal of the Delta Salmon and Steelhead Technical Team was to develop a list of actions that would double baseline (1965-1989) salmon smolt survival in the Delta for all races of chinook salmon. It is likely that as smolt survival increases, resulting adult production two and a half years later (1967-1991) will also increase.

Although we know that salmonid fry may rear in the Delta for up to several months (Kjelson et al. 1982), limiting factors for fry are generally not well understood. Relative comparisons between upper river and Delta fry survival have been made, but the relative importance of fry rearing in the Delta compared with that upstream has not been quantified (USFWS 1987).

Additionally, very little information exists on the limiting factors for adult salmon and steelhead migrating upstream through the Delta (Hallock 1970).

Although it is theoretically possible to double adult production by only doubling smolt survival in the Delta, actions that would benefit all life stages of salmonids (including steelhead) in the Delta were preferentially selected. In most cases the limiting factors and potential solutions identified for salmon smolts are likely to be similar for all salmonid juveniles rearing and/or migrating through the Delta. In cases in which the unique needs of the different salmonid life stages were known, they were incorporated into the list of actions, but there may be other areas that have not been adequately explored or addressed.

No action items targeted to improve juvenile salmonid survival were recommended for July-September because very few juveniles are present in the Bay or Delta during those months, presumably because of high water temperatures in the Delta that may be lethal to salmon (USFWS 1987).

Smolt survival between 1965 and 1989 was estimated using Delta salmon survival models that relate habitat conditions in those years to survival. Two separate models have been used, one for smolts emigrating from the Sacramento River (Kjelson et al. 1989, USFWS 1992a) and one for smolts emigrating from the San Joaquin River (Brandes 1994). The models are based on survival indices generated from coded-wire-tagged (CWT) fall-run hatchery smolts released at various locations in the Delta and recovered within a few weeks after release by midwater trawl at Chipps Island. Survival indices were calculated based on the number recovered at Chipps Island corrected for effort in both time and space (USFWS 1987).

Both models split the Delta into various reaches and use backward-stepping multiple-regression analyses to identify environmental variables (exports, flows, and temperature) important to survival in each reach. Professional judgment by the authors was used to some extent in choosing which variables were considered.

Both the Sacramento and San Joaquin models assume that smolts enter the various reaches of the model in the same proportion as flow.

The Delta smolt survival model, developed for fall-run smolts emigrating from the Sacramento River Basin, has been slightly modified to better index survival of Sacramento River juvenile winter-run and late fall-run, and Mokelumne River fall-run chinook salmon in the Delta. The equations used for each reach of the Sacramento and San Joaquin models and the modifications made for the various races are listed in Table 3-Xe-1. Temporal distribution in the Delta for each race of juvenile chinook salmon used to estimate annual Delta survival is listed in Table 3-Xe-2. Although none of the models estimate absolute survival, they are our best tool for obtaining an index of baseline survival, integrating the various action items, and determining what is needed for doubling survival.

Table 3-Xe-1. Formulas used in the models to calculate mortalities

Fall run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(4.34E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)
Late fall run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(5.4E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)
Winter run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(5.4E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)

Fall run, Mokelumne		
Dayflow and Operation Study		
	m1	0.000
	m2	(-0.5916024)+(0.017968*Freeport temp)+(4.34E-05*(CVP+SWP))
	m3	0.000
	m23	(M2*1)+(M3*(1-1))
	m123	(0+M23-(0*M23))
	s123	(1-M123)
Fall run, San Joaquin		
Dayflow and Operation Study		
	m2	(1.01045-3E-05*Upper Old River Flow)
	m3	(0.87634-7.1E-05*Stockton low)
	m4	(-3.65867+0.058492*Jersey Pt temp+5.1E-05*(CVP+SWP))
	m34	(M3+M4)-(M3*M4)
	m234	(P2*M2)+(P3*M34)
	s234	(1-M234)

Table 3-Xe-2. Assumed temporal distributions, by percent, of fall-, late fall-, and winter-run chinook salmon for the Sacramento, Mokelumne, and San Joaquin rivers. Distributions were input to survival models.

Race	River	Month							
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Fall run	Sacramento	0	0	0	0	0	17	65	18
	Mokelumne	0	0	0	0	0	17	65	18
	San Joaquin	0	0	0	0	0	45	55	0
Late fall run	Sacramento	25	50	25	0	0	0	0	0
Winter run	Sacramento	0	0	0	13	57	30	0	0

The models indicate that survival in the Delta cannot be doubled for Sacramento fall-, winter-, and late fall-run and Mokelumne River fall-run stocks of chinook salmon. The team believed that the Sacramento model underestimates the benefits associated with the elimination of CVP and SWP exports because many limiting factors for all juvenile salmonid life stages would cease to exist. Therefore, the team believed that if CVP and SWP exports were eliminated, juvenile salmonid survival in the Delta would likely greatly increase and adult production could potentially double. Although this was the technical team's first recommendation as the most likely to ensure doubled survival in the Delta, the team recognized the need to provide minimal exports to satisfy health and safety concerns. We have assumed that these health and safety concerns would be satisfied with combined CVP and SWP exports of 1,200 cfs.

For the races of juvenile salmon for which we were unable to double survival, we have proposed a combination of action measures that would have the greatest effect toward the doubling goal.

In some cases, restoration actions were not limited to the variables contained in the models. If available evidence indicated that there were other needs of salmonids in the Delta, restoration actions were developed to address these factors. Flow toward the western Delta (QWEST) is an example of this deviation. Many of the parameters selected as action items are similar to recommendations made in past reports by biologists familiar with juvenile salmon data from the Delta (USFWS 1992b).

In an effort to provide relevant information on the value of a specific action, we have summarized data in the narrative description. Although much of these data are included in the models that integrate many of the action items, we believed it was more straightforward to rely solely on the specific experiments and resulting data to justify the specific actions.

The smolt survival model for smolts emigrating from the San Joaquin River indicates that doubling baseline smolt survival in the Delta would be possible, and we have therefore proposed an action to achieve this, based on model simulations.

As noted initially, the Delta fish habitat team has attempted to meet the goal of doubling salmon production using only Delta restoration actions without considering potential benefits of upstream actions. This approach was taken to ensure that the goal of *at least* doubling production would be met. It is possible that a combination of Delta and upstream restoration actions could also achieve the goal of doubling production, but analysis of such a combination of actions has not been completed and is complicated by our inability to quantify the benefits of restoration actions both upstream and in the Delta. Further difficulties arise from other aspects of the population status and the time frame for meeting the restoration goal.

One could argue that, theoretically, if Delta actions provided salmon survival through the Delta at levels of the 1965-1989 baseline period and if upstream actions yielded a doubling of production there, the goal of doubling would be achieved. As additional knowledge is gained on the benefits of restoration actions, we will be better able to define how a combination of Delta and upstream actions can best meet the restoration goals.

There may be potential for compounding benefits resulting from restoration actions in both the Delta and upstream areas: improved salmon production one year could reflect greater production the next year and so on, if more adults return to unsaturated spawning grounds and harvest remains stable. Unfortunately, we do not know what potential there is for a compounding process to be realized, but even if such compounding is possible in part, it could allow the doubling production goal to be met more quickly or with less aggressive actions than if no compounding occurred.

It also should be noted that during a period of decline (as all natural Central Valley anadromous salmonid stocks are experiencing), compounding of negative effects may be occurring. Prompt action is imperative, and the longer declines are allowed to continue, the greater the magnitude of increase in production needed to realize the same benefit.

Limiting factors and potential solutions

Many of the limiting factors observed in the Delta are known or hypothesized to be either directly or indirectly related to exports. Indirect losses are defined as juvenile salmon mortalities attributed to the CVP and SWP export process that occur in the Delta outside the CVP intake and the entrance to the SWP's Clifton Court Forebay. These losses are considered to be of much greater magnitude than the direct losses; thus, they have been identified first in Table 3-Xe-3. These indirect losses are primarily tied to the increased diversion of juvenile salmon off the mainstem rivers and the higher mortality in the central and south Delta. The CVP and the SWP have actually increased the amount of water being diverted into the central and south Delta and are hypothesized to be responsible (at least in part) for the higher mortality observed in the central and southern Delta. The most likely mechanism for the increased mortality is the increase in reverse flows in the central and southern Delta (USFWS 1987, 1992b). In addition to these indirect losses, many direct losses result from CVP and SWP pumping and are listed in the Table 3-Xe-3.

Although some limiting factors cause mortality and lessen production, we have not included them as necessitating key actions critical in gaining the most benefit toward doubling survival. However, when the final restoration program is developed, all actions that are feasible and reasonable, however small their benefits, should be taken to aid in restoration.

Table 3-Xe-3. Key limiting factors in order of importance and potential solutions for chinook salmon and steelhead in the Delta.

Limiting factors	Potential solutions
1. Mortality of juvenile salmonids indirectly resulting from CVP and SWP impacts: (a) Increased diversion of juvenile salmon into the central and south Delta (where mortality is high) as a result of:	1. Prevent or decrease the number of juvenile salmon diverted off the mainstem rivers into the central and south Delta by: - closing the DCC gates (November-June); - increasing Delta inflow;

Limiting factors	Potential solutions
- construction of the Delta Cross Channel (DCC) for water conveyance by USBR in 1951, allowing a greater percentage of flow (and presumably juvenile salmon) to be diverted; - lower spring Delta inflows causing a higher proportion of flow to be diverted into the central and south Delta (Rick Oltman pers. comm.); - exports causing the percentage of flow diverted into upper Old River to increase (DWR pers. comm.); and - increased net flow toward the pumping plants	- reducing or eliminating reverse flows; - installing an acoustical barrier in Georgiana Slough; or - installing a full barrier at the head of upper Old River during the spring migration of San Joaquin smolts through the Delta
(b) Relatively high juvenile mortality in the central and south Delta, presumably resulting from: - inability of juveniles to "find" their way to the ocean as a result of net reverse flows and complex channel configurations; - a longer migration route (increased exposure time to mortality factors, such as predation); and	2. Increase survival in the central Delta by: - severely curtailing or eliminating CVP and SWP exports during the period when salmon are using the Delta (November-June); or - reducing or eliminating reverse flows by increasing San Joaquin River flows

Limiting factors	Potential solutions
- exposure to higher (relative to mainstem) spring water temperatures	
(c) Reduction of shallow-water and riparian habitat as a result of dredging and scouring in water conveyance channels and bank stabilization efforts (removal of riparian vegetation and bank armoring)	3. Increase riparian vegetation and decrease or eliminate bank stabilization efforts
(d) Reduction of spring inflow into and out of the Delta (causes decreases in transport flows for migration and increased temperatures as a result of upstream storage and diversion)	4. Increase Delta inflows
2. Mortality of juvenile salmonids directly resulting from CVP and SWP pumping plant impacts	1. Severely curtail or eliminate CVP and SWP exports during the period when salmon are using the Delta for rearing and migration (November-June) 2. Screen Clifton Court Forebay and combine the CVP and SWP diversion points
3. Substantial losses that occur as a result of the following factors, although the export facilities for both the CVP and the SWP include fish salvage facilities designed to prevent the loss of entrained fish: - Prescreen losses occur at the	3. Implement measures to reduce entrainment, handling, transport, and release losses associated with present facilities

Limiting factors	Potential solutions
trash racks of both fish facilities and in Clifton Court Forebay - The screen (louvers) systems at both facilities are less than 100% efficient in bypassing juvenile fish to the holding facilities - Losses occur with the bypass and holding facilities as a result of predation, debris, and other factors - Some losses occur during handling and trucking - Survival after release may be reduced by enhanced predatory fish densities at release sites	
3. Poor survival of San Joaquin smolts resulting from low San Joaquin River flows in the Delta	Increase flows at Vernalis
4. Poor water quality: (a) Mortality of fall-run smolts resulting from high spring water temperatures (b) Low dissolved oxygen at Stockton inhibiting migration of San Joaquin River fall-run adults	1. Decrease water temperature: - Restore riparian vegetation along Delta channels - Continue to evaluate ways to reduce Delta water temperatures 2. Increase dissolved oxygen levels at Stockton - Increase flows at Vernalis

Limiting factors	Potential solutions
	- Install the barrier at the head of upper Old River between September and December (DFG pers. comm.)
(c) In-Delta agricultural and industrial return flows of poor quality and a source of toxics	3. Reduce toxics - Reduce or eliminate agricultural drain water in or above the Delta - Treat agricultural runoff before it is returned to the river - Increase flows
5. Entrainment at in-Delta agricultural, municipal, and industrial diversions	1. Eliminate in-Delta agricultural and industrial diversions 2. Screen in-Delta diversions 3. Curtail diversions during critical periods
6. Other factors (losses from these other factors are exacerbated when populations are low and stressed as a result of the other limiting factors mentioned above): (a) Competition between natural and hatchery stocks	Keep natural salmonid populations as high and ecosystem as healthy as possible by providing favorable environmental conditions. Also, the following actions could be taken: - Investigate interactions between hatchery and natural stocks to ensure that natural stocks are not being displaced
(b) Interaction with exotic species	- Prevent introduction of exotic species into the system by supporting ballast water legislation, strict enforcement, and other measures
(c) Illegal fishing of races of low	- Continue education and enforcement to

Limiting factors	Potential solutions
abundance	reduce poaching

Restoration actions -

Action 1: Provide protection from direct and indirect impacts of CVP and SWP exports for juvenile salmonids migrating through the Delta from November 1 through June 30, equivalent to protection provided by restricting exports to minimal levels (those needed for health and safety, estimated at 1,200 cfs total).

Objective: Increase in-Delta survival of all juvenile salmonid life stages (and potentially adults) affected by CVP and SWP exports. These include juveniles migrating through the Delta using the mainstem rivers as well as juveniles diverted into the central and southern portions of the Delta and juveniles emigrating from the San Joaquin Basin.

Location: CVP's Tracy and SWP's Harvey O. Banks pumping plants.

Narrative description: Because there are a variety of limiting factors for juvenile salmonids in the Delta related to both the indirect and direct impacts of CVP and SWP pumping, the most comprehensive solution to Delta problems under the present system of using Delta channels for water conveyance would be to eliminate all CVP and SWP exports. As mentioned above, the team realized this was impractical and the final action item has allowed for minimal exports.

The effects of exports are most acute for San Joaquin Basin juveniles migrating through the Delta and for Sacramento Basin juvenile salmon diverted into the central Delta via the DCC, Georgiana Slough, and Threemile Slough.

Fall-run CWT smolts released in the North Fork, South Fork, and lower Mokelumne River show lower survival indices to Chipps Island than are shown by groups released in the mainstem Sacramento River (Ryde). Even lower survival is observed for smolts released into the southern Delta (lower Old River) (Table 3-Xe-4). In general, indices of survival appear to decline the closer the smolts are released to the CVP and SWP pumps. In contrast, salvage rates at the fish facilities tend to be greater the closer the smolts are released to the pumps. Even though smolts released near the pumping plants are salvaged in greater numbers, survival to Chipps Island is lower.

Table 3-Xe-4. Survival indices of CWT fall-run chinook salmon smolts released at several locations in the Delta from 1983 to 1986 and recovered by trawl at Chipps Island.

Release site	1983	1984	1985[a]	1986[a]

Above diversion[b] (Courtland gates open)		0.70	0.32 (0)	0.35 (8)
Above diversion (Courtland gates closed)	1.23			
Below diversion[c] (Ryde gates open)		0.73	0.77 (0)	0.68 (0)
Below diversion (Ryde gates closed)	1.39[d]			
N. Fork Mokelumne River[e]		0.56	0.28 (14)	0.37 (0)
S. Fork Mokelumne River[e]		0.70	0.23 (89)	0.26 (372)
Lower Mokelumne River[f]	1.17			
Lower Old River[g]	0.35	0.16	0.21 (14,774)	0.25 (6,190)

[a] Expanded fish facility (SWP/CVP) recoveries are included in parentheses for 1985 and 1986. No comparable fish facility sampling was conducted in 1983 and 1984.

[b] Release site 3.5 miles above Walnut Grove on the Sacramento River (Courtland site).

[c] Release site 3.0 miles below Walnut Grove on the Sacramento River (Ryde site).

[d] Release site at Isleton.

[e] Release site at Thornton Road.

[f] Release site 2 miles above the junction with the San Joaquin River.

[g] Release site at the southeast corner of Palm Tract.

This difference in survival between fall-run smolts released in the central Delta versus those released in the mainstem Sacramento River has been additionally confirmed by the results of paired CWT groups released at Ryde and in Georgiana Slough in 1992 and 1993. In six sets of experiments using fall-run and late fall-run CWT juvenile salmon, survival of smolts released at Ryde averaged 4.7 times greater than for corresponding groups of smolts released into Georgiana Slough. The difference ranged between 2.9 times and 8.3 times greater for the Ryde groups. Expanded salvage estimates at the CVP and SWP fish facilities are usually greater for smolts released at Georgiana Slough than for those released at Ryde (Table 3-Xe-5).

Table 3-Xe-5. Release dates, mean fork length (FL) of release groups, survival index (S), survival ratios, and expanded numbers of fish counted at federal (CVP) and state (SWP) salvage facilities from studies conducted with CWT fall-run (F) and late-fall-run (LF) chinook salmon smolts, April 6, 1992, through December 2, 1993.

Date	Race	Ryde releases			Georgiana Slough releases			Ryde/ Georgiana survival ratio
		FL (mm)	S	CVP/SWP	FL (mm)	S	CVP/SWP	
4/6/92	F	77	1.36	0/34	74	0.41	10/4	3.30
4/14/92	F	82	2.15	0/0	81	0.71	12/8	3.00
4/27/92	F	81	1.67	0/0	83	0.20	1/4	8.30
4/14/93	F	61	0.41	0/0	63	0.13	0/24	3.15
5/10/93	F	75	0.86	0/0	75	0.29	15/36	2.96
12/2/93	LF	129	1.95	0/9	119	0.28	93/149	7.71
								Avg. = 4.7

In most years, a very low percentage of the smolts released into the central and south Delta can be accounted for by expanded recaptures at Chipps Island and the fish facilities. These data also tend to support our conclusion that indirect losses are greater than the direct losses associated with the projects.

The mechanism behind the lower survival observed for smolts released in the central Delta is not well understood. Greater spring water temperatures in the central Delta relative to those in the mainstem Sacramento River, in combination with increased exposure time to those temperatures, are a problem for fall-run smolts diverted into the central Delta. However, the lower survival in the central Delta was also observed for late fall-run yearlings released in December, when temperatures were low (51^{o}F) and predation would likely be less. Perhaps this indicates that changes in central Delta hydrology (reverse flows, net flows to the pumps, etc.) may be the most important contributor to the high central Delta mortality. The central and southern Delta also are characterized by a complex of channels exposed to tidal hydrology, adding to the diverse flow patterns salmon must face through that part of the Delta, even when flows are not reversed because of export pumping.

Although toxics may contribute to increased mortality in the central Delta, it is not thought to be the a major limiting factor because the CWT smolts used in our experiments were in the Delta for only a short time (average of 2-4 weeks) before recovery. Although reducing toxics via regulation or curtailment of agricultural return flows would be beneficial to salmon, it is unclear whether reducing or eliminating toxics would substantially contribute toward the doubling goal. Thus, no action item for the reduction of toxics is included in our recommended actions.

The longer migration route through the central and southern Delta exposes the smolts to a combination of mortality factors (such as predation and/or entrainment) for a longer time. It is likely that this accounts for at least part of the increased mortality observed for CWT smolts released into the central Delta. However, the route the smolts take once they get into the central Delta may be affected by project exports through reverse flows in the central and southern Delta.

Although the exact mechanisms for the high mortality in the central and southern Delta are unclear, it was the team's belief that eliminating exports would likely result in major benefits to juvenile salmon in the Delta. Reducing exports to 1,200 cfs would result in lesser benefits, which would likely be substantial as well, however.

Smolts migrating through the Delta that originate in the San Joaquin Basin are specifically subjected to diversion towards the pumping plants via upper Old River. Survival of smolts allowed to stay in the main San Joaquin River is about 2 times greater than that of smolts diverted into upper Old River (USFWS 1993). In high-flow years many of the CWT smolts released into upper Old River are observed in the salvage at the fish facilities, but during dry years very few even reach the fish facilities (USFWS 1993). It is unclear why this is the case or if it is related to the export pumps. Salvage numbers in the late 1980s and early 1990s have been much lower than those in the early 1980s. It is possible that the recent continued drought has caused the southern Delta to be more inhospitable to migrating salmon.

It is clear, however, that the export pumps do increase the amount of San Joaquin flow diverted toward the pumping plants at the upper Old River junction (DFG, Exhibit 15, July 1987). Presumably more salmon smolts are also diverted off the San Joaquin River as well, into an area where survival has been shown to be lower.

Related actions that may impede or augment the action: The closure of the DCC gates, combined with increases in net downstream flow from the San Joaquin River (QWEST), would further improve survival. In addition, storing increased amounts of water in upstream reservoirs would likely impede the action, while increasing Delta inflow (up to unimpaired levels) would likely augment the action.

Agency and organization roles and responsibilities: USBR and DWR are responsible for reducing exports.

Potential obstacles to implementation: Exports from the Delta provide water for agricultural and domestic use in the San Joaquin Valley and southern California. There is a reluctance to limit exports to the extent recommended.

Predicted benefits: Restricting exports to minimal levels (1,200 cfs) between November and June would decrease both the direct and indirect losses of juvenile salmon. The benefits are expected to be significant and by itself, this action could potentially double Delta survival for juvenile salmonids. Monthly average SWP and CVP exports have been as great as 11,000 cfs in some months during the baseline period (1965-1989). Future exports may likely be greater in some months.

Other items considered but not recommended: The team did not choose to recommend measures to reduce the loss of entrained fish at the CVP and SWP export facilities. The team believed that measures to reduce entrainment losses would have small population benefits relative to severely reducing exports, closing the DCC gates, and increasing San Joaquin and QWEST flows because the greatest losses are indirect and occur before the fish actually get to the fish facilities or Clifton Court Forebay (P. Coulston, DFG, pers. comm.).

The team also did not choose to identify an isolated Delta facility (DWR 1974) as a potential solution to the indirect and direct impacts of SWP and CVP pumping because benefits from its operation could not be realized for at least a decade. Additionally, with an estimated 15% loss associated with the facility's screens, operation of the facility would not improve Sacramento smolt survival as much as the combination of recommended actions.

The isolated Delta facility may have substantial benefits for smolts emigrating through the Delta that originate in the San Joaquin Basin. Based on past data on fish released at Mossdale, it is believed that benefits would likely depend on the amount of San Joaquin flow entering the Delta at Mossdale and the amount reaching the western Delta (Brandes 1994, DWR 1994). Many biologists believe that operation of an isolated Delta facility with proper flow criteria and operational conditions is likely to have better potential to increase survival of all species in the Delta than the continued present mode and amount of export.

Action 2: Close the DCC gates from November 1 to June 30.

Objective: Increase the survival of smolts migrating down the mainstem Sacramento River by reducing the number diverted into the central and southern Delta.

Location: DCC.

Narrative description: As juvenile salmon migrate through the Delta, they encounter several channels such as the DCC, Georgiana Slough, and Threemile Slough, that divert water off the mainstem Sacramento River. Significant amounts of the downstream flow during dry years is diverted into these channels. For example, when flows at Walnut Grove are approximately 10,000 cfs, the DCC and Georgiana Slough together divert approximately 70% (USFWS 1987). The DCC and Georgiana Slough are used to convey high-quality Sacramento River water to the CVP and SWP pumping plants in the southern Delta. The water diverted through these two major diversion channels moves into the central Delta and is then directed to the southernmost part of the Delta, where the pumping plants are located. Many juveniles are inadvertently diverted with the flow into the central Delta away from their main migration path on the Sacramento River. It should be noted, however, that without project pumping, habitat throughout the central and southern Delta for both migrating smolts and rearing fry likely would be improved and diversion into these areas would be less detrimental (and perhaps even a benefit) to their survival.

Mark-and-recapture studies using fall-run hatchery smolts have found that salmon smolts diverted into the central Delta via the DCC and Georgiana Slough have much lower survival than those migrating down the mainstem Sacramento River. Trawl recovery at Chipps Island of CWT salmon smolts released between 1984 and 1989 above and below the open DCC and Georgiana Slough have shown that, on average, smolt survival is about 3.3 times greater when smolts are released below both diversion channels. Similar experiments with CWT smolts in 1983, 1987, and 1988 revealed that survival of smolts released below the closed DCC and Georgiana Slough was about 1.1 to 2.4 times greater (average of 1.5 times greater) than survival of fish released above the closed DCC and Georgiana Slough (Table 3-Xe-6). We have subsequently found the same trends in survival for fish released above and below the DCC and Georgiana Slough with the gates open and closed (difference of 2.2 times and 1.2 times, respectively) using an index of survival based on recoveries of these marked fish as adults in the ocean fishery (Table 3-Xe-7).

Table 3-Xe-6. Comparisons of the survival indices (S_T) for CWT Chinook smolts released in the Sacramento River above and below the DCC and Georgiana Slough diversion channels between 1983 and 1989.

Channel condition	Year	Above[a]	Below[b]	Below/above
Open	1984	0.70	0.73	1.0

Channel condition	Year	Above[a]	Below[b]	Below/above
	1985	0.32	0.77	2.4
	1986	0.35	0.68	1.9
	1987	0.44	0.88	2.0
	1988	0.73	1.27	1.7
	1988[c]	0.02	0.34	17.0
	1989	0.84	1.20	1.4
	1989	0.35	0.48	1.4
	1989[d]	0.22	0.16	0.7
				Avg. = 3.3
Closed	1983	1.23	1.39	1.1
	1987	0.66	0.80	1.2
	1988	0.68	0.92	1.4
	1988	0.17	0.40	2.4
				Avg. = 1.5

[a] Courtland site (3.5 miles above Walnut Grove).

[b] Ryde site (3.0 miles below Walnut Grove).

[c] Temperatures at release were 76°F and 75°F for Courtland and Ryde, respectively.

[d] The Ryde group survival seemed unusually low compared to Ryde releases in other years.

Table 3-Xe-7. Ocean recovery rates for fall-run CWT chinook salmon smolts released above and below the DCC and Georgiana Slough from 1983 to 1989 and ratios of survival indices for smolts released above and below these channels.

Channel condition	Year	Above	Below	Below/above
Open	1984	.0058	.0042	.72

Channel condition	Year	Above	Below	Below/above
	1985	.0036	.0085	2.36
	1986	.0161	.0194	1.20
	1987	.0142	.0201	1.42
	1988 (May) (June)	.0091 .0007	.0249 .0053	2.74 7.60
	1989	.0049 .0008 .0009	.0082 .0016 .0002	1.67 2.00 .22
				Avg. = 2.21
Closed	1983	.0039	.0038	.97
	1987	.0196	.0312	1.59
	1988 (May) (June)	.0114 .0097	.0202 .0046	1.77 .47
				Avg. = 1.2

The similarity between survival indices of smolts released at Courtland with the DCC gates open and those released in the central Delta (Table 3-Xe-6) indicates that significant numbers of salmon smolts are diverted into the DCC and Georgiana Slough.

As discussed previously under Action 1, the lower survival rate of smolts diverted into the central Delta is evident when survival indices from CWT smolts released in the central Delta are compared with those of smolts released at Ryde on the mainstem Sacramento River downstream of the DCC and Georgiana Slough (Table 3-Xe-6).

Although we are uncertain of the exact percentage of smolts reaching Walnut Grove that are diverted, it appears from all the available data that many smolts are in fact diverted into the central Delta and their survival is lower than survival of smolts in the mainstem Sacramento River.

Related actions that may impede or augment the action: Net western Delta flow (QWEST) cannot be reduced (below the flow during the CWT experiments) or the benefit observed from the DCC gate closure will be reduced.

Agency and organization roles and responsibilities: USBR is responsible for operation of the DCC gates.

Potential obstacles to implementation: The action may cause water quality problems in the central Delta for agriculture and resident fish populations.

Other actions considered but not recommended: Another structural solution was evaluated by the team but was not recommended because implementation and sequential benefits would be at least a decade away; this solution was a new, gated, screened diversion from the Sacramento River to the Mokelumne River with adequate downstream flow and provision for upstream migrants with the permanent closure of the DCC and Georgiana Slough. This is somewhat similar to the isolated facility concept, but the central Delta would continue to be used for water conveyance with its negative impacts on fish present in the central and southern Delta.

One of these structural actions may in the future be determined to be the best long-term solution, but the team acknowledged that significant improvements for juvenile salmon were needed immediately and operational changes could provide immediate benefits. There is also the need to further define these structural solutions so that benefits can more accurately be assessed.

The acoustical (or physical) barrier in Georgiana Slough to prevent diversion of smolts into areas of high mortality was also not selected as a recommended action because of anticipated negative effects on other species and the general experimental nature of this barrier. Benefits resulting from decreases in export and the closure of the DCC gates are more certain and are recommended instead for attaining the desired increases in survival. If study results warrant the use of an acoustical (or physical) barrier in Georgiana Slough and no impacts on other species are expected, then we as a group would support its use, especially in combination with the other recommended actions.

Additionally, the sole use of a barrier at the head of upper Old River during spring was not endorsed by the team because of its apparent negative effects on other species (Delta smelt and winter-run chinook salmon). However, if significant augmentation of Vernalis flow and meaningful export curtailments are instituted simultaneously, likely negative effects on other species would be minimized and salmon smolt survival would likely be improved with the barrier. The barrier does not appear to substantially improve survival through the Delta, even when exports are low, if flows are not significantly augmented simultaneously (DWR 1994).

Predicted benefits: Closing the DCC gates appears to generally increase survival of smolts arriving at Walnut Grove by 36%-200%. The absolute benefits are estimated to be less when temperatures are higher and flows are lower (although the percentage increase is higher) and are estimated to be greater when flows are high and temperatures are lower.

Action 3: Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30.

Objective: Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (October-December).

Location: Flows are presently calculated for QWEST. Measured flows would be preferable.

Narrative description: Upon reaching the mouth of the Mokelumne River on the lower San Joaquin River, juvenile salmon diverted into the central Delta are often exposed to upstream flow (reverse flows) that moves the net flow easterly in the San Joaquin River and toward the south via Old and Middle rivers. These reversals of flow are exacerbated during periods of high pumping. Susceptibility to diversion into Clifton Court Forebay or entrainment at the CVP and SWP pumping plants is also more likely for fish migrating through the central and southern Delta than for those migrating down the mainstem Sacramento River, presumably because of these reverse flows. Reverse flows also make it less likely that smolts originating in the San Joaquin Basin will successfully reach the ocean.

Fall-run CWT fish released in the lower San Joaquin River at Jersey Point between 1989 and 1991 showed that after corrections for temperature at release, reverse flows in the San Joaquin River at Jersey Point appeared to decrease the survival of smolts migrating through the lower San Joaquin River ($r=0.76$, $p<0.10$) (USFWS 1992b).

Also, reverse flows in the western San Joaquin River and diversion into the central Delta through Threemile Slough may be the reason for survival being less for fall-run CWT fish released at Ryde between 1984 and 1992, when flow at Jersey Point (QWEST) was negative. The relationship between smolt survival and flow at Jersey Point (QWEST) is apparent when QWEST flows are between -3,000 to +2,000 cfs ($r = 0.75$, $p<0.01$) (P.Brandes, USFWS, pers. comm.).

Related actions that may impede or augment the action: Export limits and DCC gate closure would result in a survival increase greater than the increase resulting from the improvement of reverse flows alone.

Agency and organization roles and responsibilities: USBR and DWR would be largely responsible for a change in QWEST because it is related to exports and Delta inflow. Water users on the San Joaquin and Sacramento rivers may also be partially responsible for contributing to Delta inflow.

Potential obstacles to implementation: This action may inhibit exports and may require additional flow from the San Joaquin River.

Predicted benefits: Since 1978, only a few CWT smolts released at Ryde have been observed at the CVP and SWP salvage facilities, although up to several hundred from central Delta releases have been observed (USFWS 1987). This suggests that, even though smolts remaining in the Sacramento River are exposed to net reverse flows in the western San Joaquin River through their potential movement through Threemile Slough or around the tip of Sherman Island, they appear to be affected to a much lesser degree than are those smolts diverted into the central Delta via the DCC and Georgiana Slough.

We believe that increasing QWEST flows up to a minimum of 3,000 cfs in wet years will allow the benefits from the other recommended actions to be maximized. All races and stocks of juvenile salmon and steelhead using the Delta for rearing and as a migration corridor could benefit from this action.

Action 4: Increase mean monthly flow at Vernalis to 4,500 cfs, 6,000 cfs, 8,000 cfs, 12,000 cfs, and 21,000 cfs in critical, dry, below-normal, above-normal, and wet year types (60-20-20), respectively, during the smolt migration period.

Objective: Increase the survival of smolts migrating through the Delta that originate in the San Joaquin Basin.

Location: Vernalis.

Narrative description: Survival of CWT hatchery smolts released at Dos Reis between 1982, 1985-1987, and 1988-1991 has shown a strong relationship to flows at Vernalis ($r = 0.89$, $p < 0.01$ with data in 1985 excluded) (USFWS 1992a). Additionally, indices of adult production show a strong relationship to Vernalis flows and exports between 1967 and 1984 ($r = 89$, $p < 0.01$, with data from 1979 not included) (USFWS 1992a). The fact that two independent models essentially respond in the same way lends credibility to our conclusions.

Related actions that may impede or augment the action: Export limits and a barrier at the head of upper Old River would increase survival over that resulting from increasing flows at Vernalis alone.

Agency and organization roles and responsibilities: Various water right holders and USBR.

Potential obstacles to implementation: Water originating in the San Joaquin Basin is in high demand for agricultural and municipal use. Water users are unlikely to contribute water without considerable political necessity.

Predicted benefits: Smolt survival is projected to double over that observed during the baseline period as indexed by the San Joaquin smolt survival model (Brandes 1994), if these Vernalis flows are adopted and total exports are limited to 1,200 cfs, for the entire period of San Joaquin smolt migration through the Delta.

Action 5: Install the head of Old River barrier in September-December.

Objective: Increase dissolved oxygen at Stockton to ensure San Joaquin adult salmon passage through the Delta.

Location: Upper Old River confluence with the San Joaquin River.

Narrative description: Low dissolved oxygen resulting from the high biological oxygen demand (BOD) and high temperatures at Stockton are exacerbated with low flows entering the Delta from the San Joaquin River. These environmental conditions have been shown to delay or block migration of San Joaquin River fall-run adults (Hallock 1970). Increased flows from the San Joaquin River would also serve to increase the oxygen levels at Stockton.

Related actions that may impede or augment the action: Increased flows from the San Joaquin River during September-December would serve to attract adults. Export limits may also augment the action.

Agency and organization roles and responsibilities: DWR has been responsible for the construction of the barrier in past years.

Potential obstacles to implementation: The barrier placement under high exports may increase drafting from central Delta channels and may have an impact on juvenile winter run, spring run, and other central Delta fishes.

Other actions considered but not recommended: Reduction of water temperatures was not selected as an action item because it is uncertain whether water temperature can be significantly reduced using "controllable factors" (SWRCB 1991). However, evaluation of ways to reduce temperature in the Delta should continue because temperature reduction has the potential to significantly increase fall-run survival in the Delta.

The team looked at the impact of in-Delta agricultural diversions on juvenile salmon and steelhead (estimated to be less than a few hundred thousand for each species) (Hayes pers. comm.). The team decided, based on this limited information, that screening appeared to have a relatively small impact on these populations in relation to other limiting factors and that restricting these species from the central Delta or curtailing agricultural diversions during critical time periods would be more effective in minimizing losses. We have chosen to recommend keeping smolts out of the central Delta.

The team also did not recommend any specific action items to deal with "other factors" such as competition, poaching, and exotic species. We believed that if populations are kept healthy through implementation of the recommended actions, the impact of these factors would decline as well. However, the team believes that when positive actions are possible to lessen mortality of fish populations, such actions should be taken.

Additionally, actions were not recommended in Montezuma Slough or in the Bay. Impacts from Montezuma Slough do occur, but changes in operations at that site would have small population benefits toward the doubling goal. This conclusion is based on evidence that only a small fraction of fall-run smolts migrating out of the Delta enter Montezuma Slough. Also, the recovery in the ocean fishery of adults that had been released at Port Chicago and the Golden Gate in 1984, 1985, and 1986 as paired CWT smolts indicated that survival through the Bay was generally high (ranged between 0.78 to 0.85) and did not appear to vary much between years measured (Table 3-Xe-8).

Table 3-Xe-8. Survival indices of smolts migrating through the Bay from Port Chicago to the Golden Gate Bridge.

Year	Port Chicago recovery rate	Golden Gate recovery rate	Survival index
1986	.0282	.0360	.78
1985	.0096	.0113	.85
1984	.0211	.0272	.78

Note: Survival was estimated by dividing the recovery rate in the ocean fishery of the fish released at Port Chicago by the recovery rate of those released at the Golden Gate Bridge (USFWS 1987).

Tables 3-Xe-9 through 3-Xe-13 have been included to show model output for the various races of juvenile salmon with the integration of recommended actions and their effects on the doubling goals. The tables are provided to show comparisons between survival associated with the recommended actions, baseline historical (1965-1989) smolt survival (referred to as DAYFLOW in the tables), and present smolt survival (referred to as OP STUDY in the tables). It is important to view the differences in the indices of survival between alternatives qualitatively, rather than viewing the differences as absolute.

Table 3-Xe-9. Sacramento River fall run (April-June)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.45	.42	.53	.54	.57	.45	.90
AN	.33	.29	.40	.41	.44	.37	.66
BN	.25	.23	.37	.38	.41	.32	.50
D	.19	.17	.29	.31	.32	.27	.38

C	.24	.22	.34	.36	.38	.30	.48
Average for years from 1965-1989	.34	.31	.43	.44	.47	.37	.68

Option A: DCC closed (April-June), 1,200-cfs exports (April-June)

Option B: DCC closed (April-June), 0 exports (April-June).

Option C: DCC closed (April-June) Georgiana Slough closed (April-June).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Migrational distributions = 17% April, 65% May, 18% June.

2. Temperatures based on mean monthly temperatures at Freeport from USGS.

3. Sacramento River fall-run smolt model used to estimate survival.

Table 3-Xe-10. Sacramento River late fall-run and spring-run yearlings (November-January).

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
	.82	.71	.89	.91	.98	.83	W
AN	.73	.60	.89	.91	.98	.83	1.00
BN	.76	.58	.89	.91	.98	.83	1.00
D	.62	.55	.88	.90	.98	.83	1.00
C	.64	.53	.88	.90	.98	.83	1.00
Average for years from 1965-1989	.75	.63	.88	.90	.98	.83	1.00

Option A: Cross Channel gates closed (Nov-Jan), 1200 exports (Nov-Jan).

Option B: Cross channel gates closed (Nov-Jan), 0 exports (Nov-Jan).

Option C: Cross-channel closed (Nov-Jan), Georgiana Slough closed (Nov-Jan).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Temperatures = 53°F November, 47° F December and January.

2. Migrational Distribution = 25% November, 50% December, 25% January.

3. Sacramento Smolt model modified to reflect greater 25 mortality due to exports in reach 2 (coefficient changed from 0.0000434 to 0.000054, based on December 1993 late fall mark/recovery data).

Table 3-Xe-11. Sacramento winter-run salmon (February-April)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.73	.69	.79	.81	.87	.74	1.00
AN	.72	.67	.78	.80	.85	.72	1.00
BN	.64	.61	.76	.78	.84	.71	1.00
D	.51	.48	.71	.72	.78	.66	1.00
C	.42	.42	.72	.74	.81	.68	0.84
Average for years from 1965-1989	.64	.61	.76	.78	.84	.71	1.00

Option A: Cross channel closed (Feb-April), 1200 exports (Feb-April)

Option B: Cross channel closed (Feb-April), 0 exports (Feb-April).

Option C: Cross channel closed (Feb-April), Georgiana Slough closed (Feb-April).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Temperatures: February = 50^{o}F, March = 55^{o}F, April temperatures (X) monthly from USGS.

2. Migrational distributions: Feb = 13%, March = 57% and April = 30%, based on 1993 recoveries at Sacramento.

3. Sacramento fall fun smolt model modified to reflect greater mortality due to exports in reach 2 (coefficient changed from 0.0000434 to 0.000054, based on December 1993 late fall mark/recovery data).

Table 3-Xe-12. San Joaquin fall-run salmon (April-May)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.34	.22	.68	.50	.57	.80	.68
AN	.08	.06	.16	.30	.46	.65	.16
BN	.04	.05	.08	.20	.35	.50	.08
D	.04	.04	.08	.16	.24	.36	.08
C	.04	.03	.08	.14	.15	.24	.08
Average for years from 1965-1989	.16	.12	.32	.32	.40	.57	.32

Option A: No **UOR barrier, 1200 exports (April-May), increased flows (4/1 - 5/31) to (W) 29000, (AN) 5500, (BN) 2000, (D) 2000, (C) 2000.

Option B: No UOR barrier, 1200 exports (April-May), (4/1 - 5/31) flows increased to (W) 21000, (AN) 12000, (BN) 8000, (D) 6000, (C) 4500.

Option C: No UOR barrier, 0 exports (April-May), 2000-10,000 cfs at Stockton (April-May) (may be similar to isolated Delta facility if similar flows were provided).

Option D: UOR barrier (April-May), 0 exports (April-May) 2000-10,000 cfs at Stockton (April-May).

Model Assumptions:

1. Migrational Distribution 45% April, 55% May.

2. Temperature at Jersey point estimated from Neomysis studies.

3. San Joaquin smolt model used to estimate survival.

Table 3-Xe-13. Mokelumne River fall-run salmon (April-June)

Water-year type	Dayflow	Op study	Options A	Options B	Doubling goal
W	.29	.22	.42	.49	.58
AN	.23	.19	.37	.44	.46
BN	.20	.18	.36	.43	.40
D	.14	.15	.33	.39	.28
C	.22	.23	.35	.42	.44
Average for years from 1965-1989	.24	.20	.38	.45	.48

Option A: Reduce exports 1200 (4/1 - 6/30).

Option B: No exports (A-J), or isolated Delta facility.

Model Assumptions:

1. Temperatures are mean monthly from USGS. The same as those used in Sacramento fall run simulations.

2. Migrational distributions: Apr = 17%, May = 65% and Jun = 18%, same as those used in Sacramento fall run simulations.

3. Only reach two from the Sacramento fall fun smolt model was used to estimate survival.

The doubling goal for winter-run and fall-run for all water-year types was truncated at 1.0. This assumes that these indices of survival reflect actual survival and that increases to values of over 1.0 are biologically impossible. Because we could not double the survival index or reach a survival index of 1.0, determining the exact doubling goal for these two races was immaterial.

Although our recommended suite of actions does double average survival of smolts migrating through the Delta that originate in the San Joaquin Basin, it did not match specific water-year-type goals. We believed it was necessary to increase survival to more than doubling in the dry years and decrease it to less than doubling in the wet years. The great discrepancies in survival between wet and all other water-year types made it unlikely that matching such goals would double San Joaquin Basin adult production in the long term.

APPENDIX A

Estimation of Natural Production of Chinook Salmon

This appendix contains output from a three-dimensional spreadsheet used to estimate production of all races of chinook salmon in each of the streams for which escapement data were available. Sources of data considered and specific assumptions made for each stream are noted on the bottom of each worksheet.

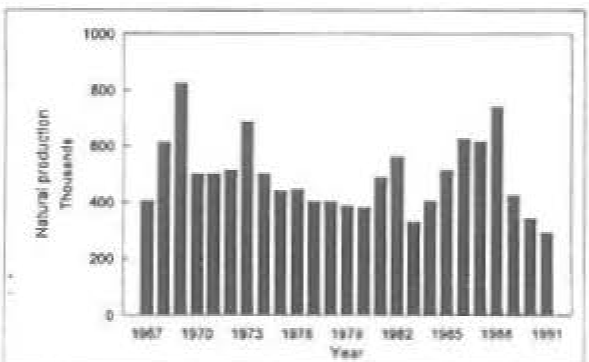
Chinook salmon production summaries for all races and streams.

		Harvest		Production		
	Escapement	Instream	Ocean	Total	Natural	Goal
All races combined	274757	53163	411617	739536	495051	990102
Fall run	223579	40677	342227	606483	372757	745514
Late-fall run	15079	5456	24255	39301	34031	68062
Winter run	23109	4622	26305	54036	54036	108071
Spring run	12990	2408	18829	34227	34227	68454
Sacramento River						
Fall run	76701	7670	107080	191451	114871	229742
Late-fall run	14159	2832	19807	36798	33781	67561
Winter run	23109	23819	26305	54036	54036	108071
Spring run	11089	2218	15983	29290	29290	58580
Clear Creek	1584	158	2708	4451	3561	7121
Cow Creek	1373	137	1384	2895	2316	4632
Cottonwood Creek	1647	165	1872	3684	2947	5895
Battle Creek						
Fall run	17616	1762	30547	49924	4992	9985
Late-fall run	1000	200	1521	2721	272	544
Paynes Creek	90	9	107	206	165	330
Antelope Creek	192	19	241	452	361	723
Mill Creek						
Fall run	1104	110	1423	2638	2110	4220
Spring run	824	82	1285	2191	2191	4382
Deer Creek						
Fall run	406	41	506	952	762	1523
Spring run	1317	132	1812	3260	3260	6520
Misc. creeks	304	30	348	683	546	1092
Butte Creek						
Fall run	418	42	491	951	760	1521
Spring run	360	36	617	1012	1012	2025
Big Chico Creek	242	24	233	499	399	798
Feather River	48512	9702	79711	137926	85726	171452
Yuba River	12868	1287	18975	33130	33130	66261
Bear River	100	10	114	224	224	449
American River	41040	18468	74741	134249	80549	161098
Mokelumne River	3340	334	4098	7772	4663	9326
Cosumnes River	764	76	805	1645	1645	3291
Calaveras River	413	361	588	1083	1083	2167
Stanislaus River	4807	240	5773	10820	10820	21640
Toulumne River	8923	446	9504	18872	18872	37745
Merced River	4512	226	5133	9870	8976	17952

Central Valley: Production totals for all races combined.

Year	E(c.n.cv)	E(c.h.cv)	E(c.t.cv)	H(c.i.cv)	P(c.i.cv)	PFMC H(c.o.sf.c)	PFMC H(c.o.m.c)	PFMC H(c.o.sf.r)	PFMC H(c.o.m.r)	H(c.o.cv)	P(c.t.cv)	P(c.n.cv)
1967	283943	14839	298782	50028	348810	69533	17549	58503	7650	153235	502045	405909
1968	326119	18702	344821	67537	412358	167963	58255	123807	25095	375110	787468	614672
1969	490735	13175	503910	93424	597334	176749	103613	113517	14737	408616	1005950	827233
1970	281525	22643	304168	57764	361932	163097	63732	97300	13838	337967	699899	500121
1971	294244	20419	314663	66346	381009	125755	24944	145879	20448	317026	698035	502194
1972	216274	15176	231450	48057	279507	189558	40238	176503	11089	417388	696895	513856
1973	302990	26943	329933	80199	410132	242412	180283	167017	13886	603598	1013730	688949
1974	252129	20005	272134	62192	334326	222785	59895	130242	11348	424270	758596	503022
1975	242247	19277	261524	52559	314083	160434	73927	84977	7717	327055	641138	441900
1976	258541	14955	273496	53058	326554	138231	99626	63760	4807	306424	632978	446087
1977	203986	22165	226151	50424	276575	185164	78675	72595	4006	340440	617015	404957
1978	183523	17442	200965	37254	238219	158158	132842	64085	1809	356894	595113	405351
1979	217696	24783	242479	47221	289700	180087	54060	102547	5929	342623	632323	388509
1980	163275	30521	193796	42956	236752	211778	82524	73093	4020	371415	608167	382954
1981	259543	47482	307025	62319	369344	199910	89995	70084	3743	363732	733076	490594
1982	218339	44883	263222	52527	315749	281761	136678	116910	5586	540935	856684	562753
1983	193258	34393	227651	39971	267622	75019	103215	49717	3243	231194	498816	333455
1984	228946	48219	277165	47717	324882	167668	53992	73233	5437	300330	625212	405806
1985	353267	34678	387945	67673	455618	175681	36637	112475	9276	334069	789687	512381
1986	290091	31461	321552	61853	383406	302302	200154	86255	28558	617269	1000675	626776
1987	270234	36530	306764	51209	357973	355615	91231	119526	33320	599692	957665	616081
1988	270625	36559	307184	49405	356589	642693	187818	114455	15919	960885	1317474	740693
1989	162253	35426	197679	36323	234002	255817	107955	93659	37248	494679	728681	424390
1990	106603	27232	133835	23151	156986	199147	137072	77562	35053	448834	605820	344513
1991	107833	32792	140625	27908	168533	174831	79798	37274	24830	316733	485266	293116
Mean	247129	170867	274757	53163	327920	208886	91788	96999	13944	411617	739536	495051

Restoration goal: 990102



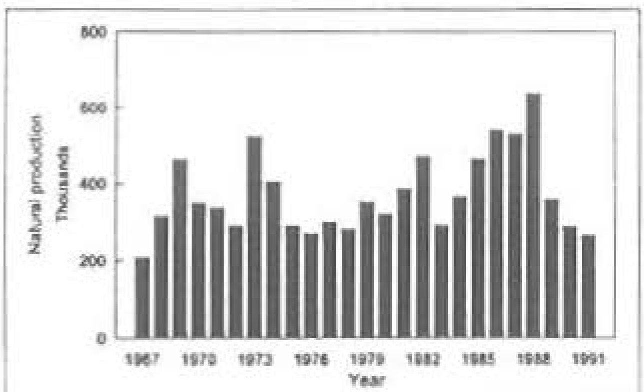
Estimated natural production [P(c,n,cv)] for all races of chinook salmon in the Central Valley for each of the years in the baseline period.

Description of variables named in worksheet:

E(c,n,cv)	Escapement (naturally spawning fish in the Central Valley)
E(c,h,cv)	Escapement (to hatcheries in the Central Valley)
E(c,t,cv)	Escapement naturally and to hatcheries in the Central Valley)
H(c,i,cv)	Harvest (instream harvest in the Central Valley)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(c,o,sf,c)	Harvest (ocean, San Francisco, commercial)
H(c,o,m,c)	Harvest (ocean, Monterey, commercial)
H(c,o,sf,r)	Harvest (ocean, San Francisco, recreational)
H(c,o,m,r)	Harvest (ocean, Monterey, recreational)
H(c,o,cv)	Harvest (ocean harvest of chinook salmon assigned to the Central Valley)
P(c,t,cv)	Production (total Central Valley)
P(c,n,cv)	Production (natural production for the Central Valley)
PFMC	Data taken from Pacific Fishery Management Council reports.

Central Valley: Production totals for fall-run chinook salmon.

Year	E(f,n,cv)	E(f,h,cv)	E(f,t,cv)	H(f,i,cv)	P(f,i,cv)	P(f,t,cv)/ P(c,t,cv)	H(f,o,cv)	P(f,t,cv)	P(f,n,cv)
1967	165735	14839	180574	26405	206979	0.59	90927	297906	207040
1968	191828	18702	210530	33114	243644	0.59	221636	465279	313510
1969	308414	12388	320802	52436	373238	0.62	255319	628557	464926
1970	214489	19583	234072	41017	275089	0.76	256874	531963	348234
1971	218032	19210	237242	44738	281980	0.74	234627	516608	337503
1972	139192	14627	153819	28114	181933	0.65	271681	453614	291069
1973	244945	26540	271485	67479	338964	0.83	498859	837823	523054
1974	215704	19300	235004	51548	286552	0.86	363644	650197	406031
1975	178801	17779	196580	37658	234238	0.75	243912	478149	292048
1976	182092	14346	196438	35686	232124	0.71	217815	449939	271055
1977	163852	21409	185261	40109	225370	0.81	277411	502781	299330
1978	141625	15589	157214	26816	184030	0.77	275708	459738	281939
1979	203682	23954	227636	42531	270167	0.93	319521	589688	353465
1980	142557	29654	172211	38010	210221	0.89	329794	540015	321325
1981	216590	44877	261467	52631	314098	0.85	309326	623424	388039
1982	189784	42997	232781	43866	276647	0.88	473946	750593	470216
1983	173672	33435	207107	34610	241717	0.90	208815	450532	291970
1984	212015	47591	259606	42617	302223	0.93	279383	581606	367721
1985	330222	34290	364512	61554	426066	0.94	312401	738468	465793
1986	262021	30673	292694	53253	345947	0.90	556962	902910	540914
1987	242287	35727	278014	43261	321275	0.90	538214	859489	529988
1988	246195	36102	282297	42464	324761	0.91	875118	1199878	636753
1989	144657	34544	179201	31398	210599	0.90	445205	655804	361936
1990	93917	27040	120957	19354	140311	0.89	401158	541468	288846
1991	99470	32513	131983	26266	158249	0.94	297406	455655	266223
Mean	196871	26708	223579	40677	264257	0.82	342227	606483	372757
							Restoration goal:		745514



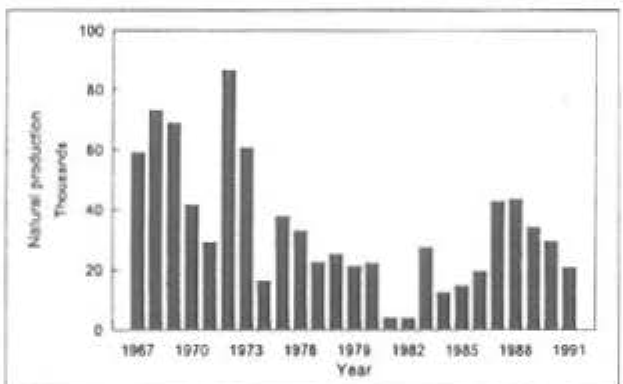
Estimated natural production [P(f,n,cv)] for fall-run in the Central Valley for each of the years in the baseline period.

Description of variables named in worksheet:

E(f,n,cv)	Escapement (naturally spawning fall-run in the Central Valley)
E(f,h,cv)	Escapement (hatchery spawning fall-run in the Central Valley)
E(f,t,cv)	Escapement (naturally and hatchery spawning fall-run in the Central Valley)
H(f,i,cv)	Harvest (instream harvest in the Central Valley)
P(f,i,cv)	Production (total fall-run escapement plus instream harvest)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(f,o,cv)	Harvest (ocean harvest of fall-run chinook salmon assigned to the Central Valley)
P(f,t,cv)	Production (total fall-run in Central Valley)
P(f,n,cv)	Production (natural production of fall-run for the Central Valley)

Central Valley: Production totals for late-fall-run chinook salmon.

Year	E(l,n,cv)	E(l,h,cv)	E(l,t,cv)	H(l,i,cv)	P(l,i,cv)	P(l,t,cv)/ P(c,l,cv)	H(l,o,cv)	P(l,t,cv)	P(l,n,cv)
1967	37208		37208	7442	44650	0.13	19615	64265	58995
1968	34733		34733	14540	49273	0.12	44822	79594	73068
1969	37178	787	37965	12043	50008	0.08	34209	76723	69130
1970	19190	3060	22250	7556	29806	0.08	27833	51632	41590
1971	14323	1209	15532	9527	25059	0.07	20851	34147	29173
1972	31553	549	32102	10942	43044	0.15	64277	96048	86828
1973	22204	403	22607	5951	28558	0.07	42030	67054	60578
1974	6445	705	7150	5062	12212	0.04	15498	19468	16302
1975	16663	1498	18161	6810	24971	0.08	26002	44486	37837
1976	15280	609	15889	5147	21036	0.06	19739	36958	32769
1977	9090	756	9846	4116	13962	0.05	17186	26359	22542
1978	8880	1853	10733	4060	14793	0.06	22163	32175	24993
1979	8740	829	9569	3637	13206	0.05	15618	25063	21232
1980	7747	867	8614	2563	11177	0.05	17535	26553	22190
1981	1597	2605	4202	1446	5648	0.02	5562	10008	4112
1982	1141	1886	3027	3452	6479	0.02	11099	9855	4024
1983	13274	958	14232	4153	18385	0.07	15883	31832	27469
1984	5907	628	6535	2917	9452	0.03	8737	15091	12668
1985	7660	388	8048	3109	11157	0.02	8181	16739	14706
1986	6710	788	7498	4549	12047	0.03	19395	23483	19539
1987	14443	803	15246	5277	20523	0.06	34381	48944	42822
1988	10683	457	11140	4379	15519	0.04	41819	49390	43683
1989	9875	882	10757	3574	14331	0.06	30296	40197	34205
1990	6921	192	7113	2785	9898	0.06	28298	32939	29511
1991	6531	279	6810	1362	8172	0.05	15358	23530	20812
Mean	14159	1000	15079	5456	20535	0.06	24255	39301	34031
							Restoration goal:		68062



Estimated natural production [P(l,n,cv)] for late-fall-run in the Central Valley for each of the years in the baseline period.

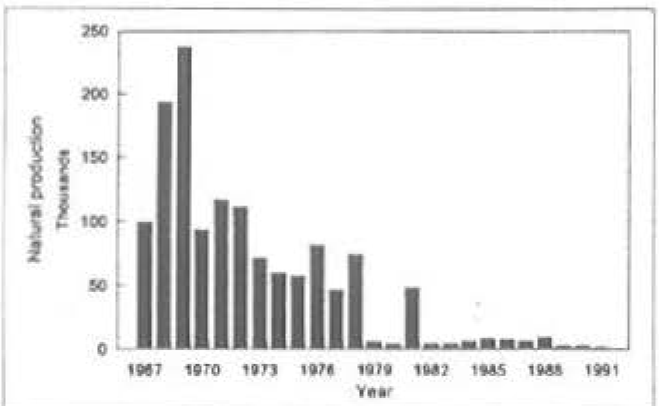
Description of variables named in worksheet:

- E(l,n,cv) Escapement (naturally spawning late-fall-run in the Central Valley)
- E(l,h,cv) Escapement (hatchery spawning late-fall-run in the Central Valley)
- E(l,t,cv) Escapement (naturally and hatchery spawning late-fall-run in the Central Valley)
- H(l,i,cv) Harvest (instream harvest in the Central Valley)
- P(l,i,cv) Production (total late-fall-run escapement plus instream harvest)
- P(c,i,cv) Production (total escapement plus instream harvest)
- H(l,o,cv) Harvest (ocean harvest of late-fall run assigned to the Central Valley)
- P(l,t,cv) Production (total late-fall-run in Central Valley)
- P(l,n,cv) Production (natural production of late-fall-run for the Central Valley)

Central Valley: Production totals for winter-run chinook salmon.

Year	E(w,n,cv)	E(w,h,cv)	E(w,t,cv)	H(w,i,cv)	P(w,i,cv)	P(w,t,cv)/ P(c,t,cv)	H(w,o,cv)	P(w,t,cv)	P(w,n,cv)
1967	57306	0	57306	11461	68767	0.20	30210	98977	98977
1968	84414	0	84414	16883	101297	0.25	92147	193444	193444
1969	117808	0	117808	23562	141370	0.24	96706	238076	238076
1970	40409	0	40409	8082	48491	0.13	45280	93771	93771
1971	53089	0	53089	10618	63707	0.17	53008	116715	116715
1972	37133	0	37133	7427	44560	0.16	66541	111101	111101
1973	24079	0	24079	4816	28895	0.07	42525	71420	71420
1974	21897	0	21897	4379	26276	0.08	33346	59622	59622
1975	23430	0	23430	4686	28116	0.09	29277	57393	57393
1976	35096	0	35096	7019	42115	0.13	39519	81634	81634
1977	17214	0	17214	3443	20657	0.07	25427	46084	46084
1978	24862	0	24862	4972	29834	0.13	44697	74532	74532
1979	2364	0	2364	473	2837	0.01	3355	6192	6192
1980	1156	0	1156	231	1387	0.01	2176	3563	3563
1981	20041	0	20041	4008	24049	0.07	23684	47733	47733
1982	1242	0	1242	248	1490	0.00	2553	4044	4044
1983	1831	0	1831	366	2197	0.01	1898	4095	4095
1984	2663	0	2663	533	3196	0.01	2954	6150	6150
1985	3962	0	3962	792	4754	0.01	3486	8240	8240
1986	2464	0	2464	493	2957	0.01	4760	7717	7717
1987	1997	0	1997	399	2396	0.01	4015	6411	6411
1988	2094	0	2094	419	2513	0.01	6771	9284	9284
1989	533	0	533	107	640	0.00	1352	1992	1992
1990	441	0	441	88	529	0.00	1513	2042	2042
1991	191	0	191	38	229	0.00	431	660	660
Mean	23109	0	23109	4622	27730	0.07	26305	54036	54036

Restoration goal: 108071



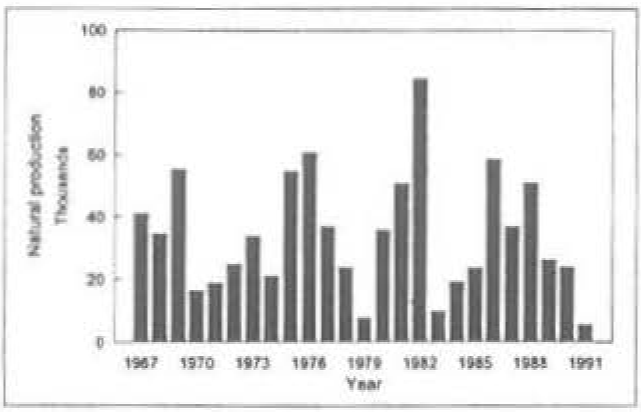
Estimated natural production [P(w,n,cv)] for winter-run in the Central Valley for each of the years in the baseline period.

Description of variables named in worksheet:

E(w,n,cv)	Escapement (naturally spawning winter-run in the Central Valley)
E(w,h,cv)	Escapement (hatchery spawning winter-run in the Central Valley)
E(w,t,cv)	Escapement (naturally and hatchery spawning winter-run in the Central Valley)
H(w,i,cv)	Harvest (in the Central Valley)
P(w,i,cv)	Production (total winter-run escapement plus instream harvest)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(w,o,cv)	Harvest (ocean harvest of winter-run chinook salmon assigned to the Central Valley)
P(w,t,cv)	Production (total winter-run in Central Valley)
P(w,n,cv)	Production (natural production of winter-run for the Central Valley)

Central Valley: Production totals for spring-run chinook salmon

Year	E(s,n,cv)	E(s,h,cv)	E(s,t,cv)	H(s,i,cv)	P(s,i,cv)	P(s,t,cv)/ P(c,t,cv)	H(s,o,cv)	P(s,t,cv)	P(s,n,cv)
1967	23694	0	23694	4721	28415	0.08	12483	40898	40898
1968	15144	0	15144	3001	18145	0.04	16506	34651	34651
1969	27335	0	27335	5384	32719	0.05	22382	55101	55101
1970	7437	0	7437	1109	8546	0.02	7980	16526	16526
1971	8800	0	8800	1463	10263	0.03	8540	18803	18803
1972	8396	0	8396	1574	9970	0.04	14889	24859	24859
1973	11762	0	11762	1952	13714	0.03	20184	33898	33898
1974	8083	0	8083	1202	9285	0.03	11782	21067	21067
1975	23353	0	23353	3406	26759	0.09	27864	54622	54622
1976	26073	0	26073	5206	31279	0.10	29350	60629	60629
1977	13830	0	13830	2756	16586	0.06	20416	37002	37002
1978	8156	0	8156	1406	9562	0.04	14325	23887	23887
1979	2910	0	2910	581	3491	0.01	4129	7620	7620
1980	11815	0	11815	2151	13966	0.06	21910	35876	35876
1981	21315	0	21315	4234	25549	0.07	25161	50710	50710
1982	26172	0	26172	4961	31133	0.10	53336	84469	84469
1983	4481	0	4481	841	5322	0.02	4598	9920	9920
1984	8361	0	8361	1651	10012	0.03	9255	19267	19267
1985	11423	0	11423	2217	13640	0.03	10001	23641	23641
1986	18896	0	18896	3559	22455	0.06	36151	58606	58606
1987	11507	0	11507	2271	13778	0.04	23082	36860	36860
1988	11653	0	11653	2143	13796	0.04	37177	50973	50973
1989	7188	0	7188	1244	8432	0.04	17826	26258	26258
1990	5324	0	5324	925	6249	0.04	17865	24114	24114
1991	1641	0	1641	241	1882	0.01	3538	5420	5420
Mean	12990	0	12990	2408	15398	0.05	18829	34227	34227
							Restoration goal:		68454



Estimated natural production [P(s,n,cv)] for spring-run in the Central Valley for each of the years in the baseline period.

Notes:
Spring-run chinook salmon numbers presented here include spring-run spawning in the Sacramento River and in Mill, Deer, and Butte creeks.

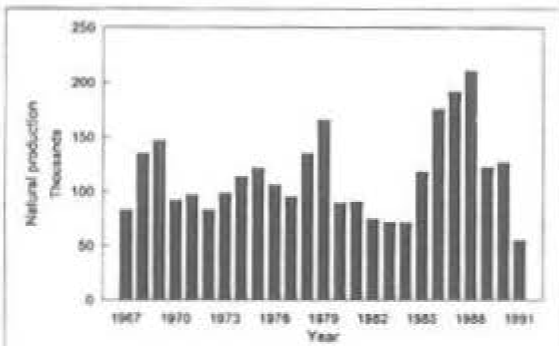
Description of variables named in worksheet:

E(s,n,cv)	Escapement (naturally spawning spring-run in the Central Valley)
E(s,h,cv)	Escapement (hatchery spawning spring-run in the Central Valley)
E(s,t,cv)	Escapement (naturally and hatchery spawning spring-run in the Central Valley)
H(s,i,cv)	Harvest (in the Central Valley)
P(s,i,cv)	Production (total spring-run escapement plus instream harvest)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(s,o,cv)	Harvest (ocean harvest of spring-run chinook salmon assigned to the Central Valley)
P(s,t,cv)	Production (total spring-run in Central Valley)
P(s,n,cv)	Production (natural production of spring-run for the Central Valley)

Sacramento River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,sa)	DFG E(f,h,sa)	E(f,t,sa)	Proportion harvested instream	H(f,i,sa)	P(f,i,sa)	P(f,i,sa)/ P(f,i,cv)	H(f,o,sa)	P(f,t,sa)	h	P(f,n,sa)
1967	87300	0	87300	0.1	8730	96030	0.46	42187	138217	0.4	82930
1968	107400	0	107400	0.1	10740	118140	0.48	107468	225608	0.4	135365
1969	132200	0	132200	0.1	13220	145420	0.39	99477	244897	0.4	146938
1970	71810	0	71810	0.1	7181	78991	0.29	73761	152752	0.4	91651
1971	80203	0	80203	0.1	8020	88223	0.31	73408	161631	0.4	96979
1972	50690	0	50690	0.1	5069	55759	0.31	83265	139024	0.4	83414
1973	60400	0	60400	0.1	6040	66440	0.20	97781	164221	0.4	98533
1974	75794	0	75794	0.1	7579	83373	0.29	105804	189177	0.4	113506
1975	90415	0	90415	0.1	9042	99457	0.42	103564	203021	0.4	121812
1976	83024	0	83024	0.1	8302	91326	0.39	85697	177023	0.4	106214
1977	64673	0	64673	0.1	6467	71140	0.32	87568	158708	0.4	95225
1978	82293	0	82293	0.1	8229	90522	0.49	135618	226140	0.4	135684
1979	115199	0	115199	0.1	11520	126719	0.47	149868	276587	0.4	165952
1980	52414	0	52414	0.1	5241	57655	0.27	90450	148105	0.4	88863
1981	68985	0	68985	0.1	6899	75884	0.24	74730	150614	0.4	90368
1982	41564	0	41564	0.1	4156	45720	0.17	78327	124048	0.4	74429
1983	58244	0	58244	0.1	5824	64068	0.27	55348	119416	0.4	71650
1984	56064	0	56064	0.1	5606	61670	0.20	57010	118680	0.4	71208
1985	103179	0	103179	0.1	10318	113497	0.27	83218	196715	0.4	118029
1986	102330	0	102330	0.1	10233	112563	0.33	181222	293785	0.4	176271
1987	108627	0	108627	0.1	10863	119490	0.37	200175	319664	0.4	191799
1988	86454	0	86454	0.1	8645	95099	0.29	256260	351360	0.4	210816
1989	59568	0	59568	0.1	5957	65525	0.31	138519	204044	0.4	122426
1990	49732	0	49732	0.1	4973	54705	0.39	156406	211111	0.4	126667
1991	28963	0	28963	0.1	2896	31859	0.20	59875	91734	0.4	55041
Mean	76701	0	76701	0.1	7670	84371	0.33	107080	191451	0.4	114871

Restoration goal: 229742



Estimated natural production [P(f,n,sa)] for fall-run in the Sacramento River for each of the years in the baseline period.

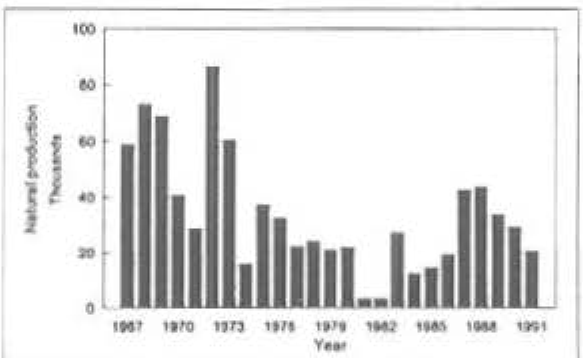
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Description of variables named in worksheet:

E(f,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(f,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(f,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(f,i,sa)	Harvest (in the Sacramento River, estimated as E(f,t,sa)* prop. harvested instream)
P(f,i,sa)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,sa)	Harvest (ocean harvest of fall-run salmon assigned to the Sacramento River)
P(f,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(f,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Sacramento River: Production estimates for late-fall-run chinook salmon.

Year	DFG E(l,n,sa)	DFG E(l,h,sa)	E(l,t,sa)	Proportion harvested instream	H(l,i,sa)	P(l,i,sa)	P(l,i,sa)/ P(l,i,cv)	H(l,o,sa)	P(l,t,sa)	h	P(l,n,sa)
1967	37208	0	37208	0.2	7442	44650	1.00	19615	64265	0.082	58995
1968	34733	0	34733	0.2	6947	41680	0.85	37915	79594	0.082	73068
1969	37178	0	37178	0.2	7436	44614	0.89	30519	75132	0.082	68971
1970	19190	0	19190	0.2	3838	23028	0.77	21503	44531	0.082	40880
1971	14323	0	14323	0.2	2865	17188	0.69	14301	31489	0.082	28907
1972	31553	0	31553	0.2	6311	37864	0.88	56542	94405	0.082	86664
1973	22204	0	22204	0.2	4441	26645	0.93	39214	65858	0.082	60458
1974	6445	0	6445	0.2	1289	7734	0.63	9815	17549	0.082	16110
1975	16663	0	16663	0.2	3333	19996	0.80	20821	40817	0.082	37470
1976	15280	0	15280	0.2	3056	18336	0.87	17206	35542	0.082	32627
1977	9090	0	9090	0.2	1818	10908	0.78	13427	24335	0.082	22339
1978	8880	0	8880	0.2	1776	10656	0.72	15965	26621	0.082	24438
1979	8740	0	8740	0.2	1748	10488	0.79	12404	22892	0.082	21015
1980	7747	0	7747	0.2	1549	9296	0.83	14584	23881	0.082	21922
1981	1597	0	1597	0.2	319	1916	0.34	1887	3804	0.082	3492
1982	1141	0	1141	0.2	228	1369	0.21	2346	3715	0.082	3410
1983	13274	0	13274	0.2	2655	15929	0.87	13761	29689	0.082	27255
1984	5907	0	5907	0.2	1181	7088	0.75	6553	13641	0.082	12523
1985	7660	0	7660	0.2	1532	9192	0.82	6740	15932	0.082	14625
1986	6710	0	6710	0.2	1342	8052	0.67	12963	21015	0.082	19292
1987	14443	0	14443	0.2	2889	17332	0.84	29035	46366	0.082	42564
1988	10683	0	10683	0.2	2137	12820	0.83	34544	47364	0.082	43480
1989	9875	0	9875	0.2	1975	11850	0.83	25051	36901	0.082	33875
1990	6921	0	6921	0.2	1384	8305	0.84	23745	32050	0.082	29422
1991	6531	0	6531	0.2	1306	7837	0.96	14729	22566	0.082	20716
Mean	14159	0	14159	0.2	2832	16991	0.78	19807	36798	0.1	33781
									Restoration goal:		67561



Estimated natural production [P(l,n,sa)] for late-fall-run in the Sacramento River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on the assumption that the number of hatchery-produced late-fall-run chinook salmon that spawned naturally was equal, on average, to the number of late-fall-run chinook salmon that spawned at CNFH.

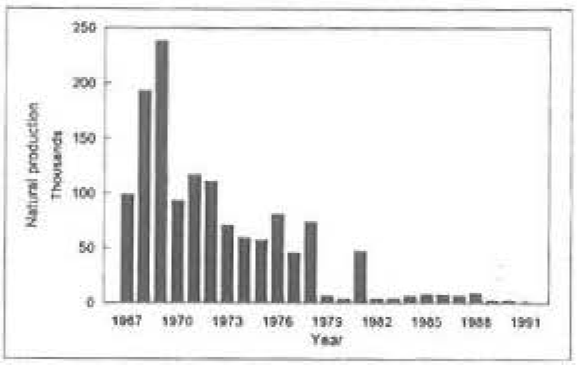
Description of variables named in worksheet:

E(l,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(l,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(l,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(l,i,sa)	Harvest (in the Sacramento River, estimated as E(l,t,sa)* prop. harvested instream)
P(l,i,sa)	Production (total escapement plus instream harvest)
P(l,i,cv)	Production (total Central Valley)
H(l,o,sa)	Harvest (ocean harvest of late-fall-run salmon assigned to the Sacramento River)
P(l,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(l,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994)

Sacramento River: Production estimates for winter-run chinook salmon.

Year	DFG E(w,n,sa)	DFG E(w,h,sa)	E(w,t,sa)	Proportion harvested instream	H(w,i,sa)	P(w,i,sa)	P(w,i,sa)/ P(w,i,cv)	H(w,o,sa)	P(w,t,sa)	*h*	P(w,n,sa)
1967	57306	0	57306	0.2	11461	68767	1.00	30210	98977	0	98977
1968	84414	0	84414	0.2	16883	101297	1.00	92147	193444	0	193444
1969	117808	0	117808	0.2	23562	141370	1.00	96706	238076	0	238076
1970	40409	0	40409	0.2	8082	48491	1.00	45280	93771	0	93771
1971	53089	0	53089	0.2	10618	63707	1.00	53008	116715	0	116715
1972	37133	0	37133	0.2	7427	44560	1.00	66541	111101	0	111101
1973	24079	0	24079	0.2	4816	28895	1.00	42525	71420	0	71420
1974	21897	0	21897	0.2	4379	26276	1.00	33346	59622	0	59622
1975	23430	0	23430	0.2	4686	28116	1.00	29277	57393	0	57393
1976	35096	0	35096	0.2	7019	42115	1.00	39519	81634	0	81634
1977	17214	0	17214	0.2	3443	20657	1.00	25427	46084	0	46084
1978	24862	0	24862	0.2	4972	29834	1.00	44697	74532	0	74532
1979	2364	0	2364	0.2	473	2837	1.00	3355	6192	0	6192
1980	1156	0	1156	0.2	231	1387	1.00	2176	3563	0	3563
1981	20041	0	20041	0.2	4008	24049	1.00	23684	47733	0	47733
1982	1242	0	1242	0.2	248	1490	1.00	2553	4044	0	4044
1983	1831	0	1831	0.2	366	2197	1.00	1898	4095	0	4095
1984	2663	0	2663	0.2	533	3196	1.00	2954	6150	0	6150
1985	3962	0	3962	0.2	792	4754	1.00	3486	8240	0	8240
1986	2464	0	2464	0.2	493	2957	1.00	4760	7717	0	7717
1987	1997	0	1997	0.2	399	2396	1.00	4015	6411	0	6411
1988	2094	0	2094	0.2	419	2513	1.00	6771	9284	0	9284
1989	533	0	533	0.2	107	640	1.00	1352	1992	0	1992
1990	441	0	441	0.2	88	529	1.00	1513	2042	0	2042
1991	191	0	191	0.2	38	229	1.00	431	660	0	660
Mean	23109	0	23109	0.2	23819	27730	1.00	26305	54036	0.0	54036

Restoration goal: 108071



Estimated natural production [P(w,n,sa)] for winter-run in the Sacramento River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

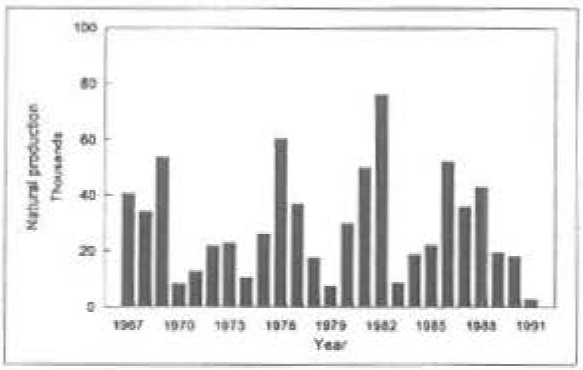
Estimate of h (proportion of production produced in a hatchery) based on absence of hatchery production of winter-run chinook salmon prior to 1991.

Description of variables named in worksheet:

- E(w,n,sa) Escapement (naturally spawning fish in the Sacramento River)
- E(w,h,sa) Escapement (to hatcheries in the Sacramento River)
- E(w,t,sa) Escapement naturally and to hatcheries in the Sacramento River)
- H(w,i,sa) Harvest (in the Sacramento River, estimated as E(w,t,sa)* prop. harvested instream)
- P(w,i,sa) Production (total escapement plus instream harvest)
- P(w,i,cv) Production (total Central Valley)
- H(w,o,sa) Harvest (ocean harvest of fall-run salmon assigned to the Sacramento River)
- P(w,t,sa) Production (total Sacramento River)
- *h* Proportion hatchery
- P(w,n,sa) Production (natural production for the Sacramento River)
- DFG Data taken from Mills and Fisher (1994).

Sacramento River: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,sa)	DFG E(s,h,sa)	E(s,t,sa)	Proportion harvested instream	H(s,i,sa)	P(s,i,sa)	P(s,i,sa)/ P(s,i,cv)	H(s,o,sa)	P(s,t,sa)	h	P(s,n,sa)
1967	23514	0	23514	0.2	4703	28217	0.99	12396	40613	0	40613
1968	14864	0	14864	0.2	2973	17837	0.98	16226	34062	0	34062
1969	26505	0	26505	0.2	5301	31806	0.97	21757	53563	0	53563
1970	3652	0	3652	0.2	730	4382	0.51	4092	8475	0	8475
1971	5830	0	5830	0.2	1166	6996	0.68	5821	12817	0	12817
1972	7346	0	7346	0.2	1469	8815	0.88	13164	21979	0	21979
1973	7762	0	7762	0.2	1552	9314	0.68	13708	23023	0	23023
1974	3933	0	3933	0.2	787	4720	0.51	5989	10709	0	10709
1975	10703	0	10703	0.2	2141	12844	0.48	13374	26218	0	26218
1976	25983	0	25983	0.2	5197	31180	1.00	29258	60437	0	60437
1977	13730	0	13730	0.2	2746	16476	0.99	20281	36757	0	36757
1978	5903	0	5903	0.2	1181	7084	0.74	10612	17696	0	17696
1979	2900	0	2900	0.2	580	3480	1.00	4116	7596	0	7596
1980	9696	0	9696	0.2	1939	11635	0.83	18253	29888	0	29888
1981	21025	0	21025	0.2	4205	25230	0.99	24847	50077	0	50077
1982	23438	0	23438	0.2	4688	28126	0.90	48184	76310	0	76310
1983	3931	0	3931	0.2	786	4717	0.89	4075	8792	0	8792
1984	8147	0	8147	0.2	1629	9776	0.98	9038	18814	0	18814
1985	10747	0	10747	0.2	2149	12896	0.95	9456	22352	0	22352
1986	16691	0	16691	0.2	3338	20029	0.89	32246	52275	0	52275
1987	11204	0	11204	0.2	2241	13445	0.98	22523	35968	0	35968
1988	9781	0	9781	0.2	1956	11737	0.85	31628	43365	0	43365
1989	5255	0	5255	0.2	1051	6306	0.75	13331	19637	0	19637
1990	3922	0	3922	0.2	784	4706	0.75	13456	18162	0	18162
1991	773	0	773	0.2	155	928	0.49	1743	2671	0	2671
Mean	11089	0	11089	0.2	2218	13307	0.83	15983	29290	0.0	29290
									Restoration goal:		58580



Estimated natural production [P(s,n,sa)] for spring-run in the Sacramento River for each of the years in the baseline period.

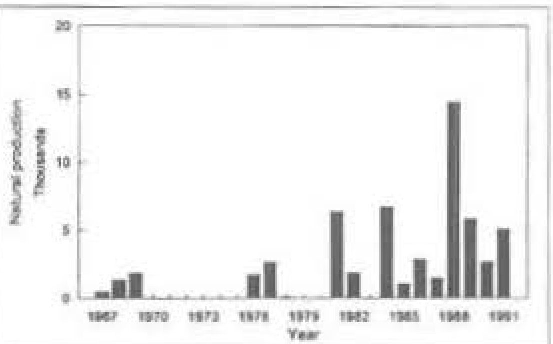
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Description of variables named in worksheet:

E(s,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(s,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(s,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(s,i,sa)	Harvest (in the Sacramento River, estimated as E(s,t,sa)* prop. harvested instream)
P(s,i,sa)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,sa)	Harvest (ocean harvest of spring-run salmon assigned to the Sacramento River)
P(s,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(s,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Clear Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,cl)	DFG E(f,h,cl)	E(f,t,cl)	Proportion harvested instream	H(f,i,cl)	P(f,i,cl)	P(f,i,cl)/ P(f,i,cv)	H(f,o,cl)	P(f,t,cl)	h	P(f,n,cl)
1967	370	0	370	0.1	37	407	0.00	179	586	0.2	469
1968	800	0	800	0.1	80	880	0.00	801	1681	0.2	1344
1969	1240	0	1240	0.1	124	1364	0.00	933	2297	0.2	1838
1970											
1971											
1972											
1973											
1974											
1975											
1976	1013	0	1013	0.1	101	1114	0.00	1046	2160	0.2	1728
1977	1362	0	1362	0.1	136	1498	0.01	1844	3342	0.2	2674
1978	60	0	60	0.1	6	66	0.00	99	165	0.2	132
1979											
1980											
1981	3672	0	3672	0.1	367	4039	0.01	3978	8017	0.2	6414
1982	785	0	785	0.1	79	864	0.00	1479	2343	0.2	1874
1983											
1984	4000	0	4000	0.1	400	4400	0.01	4067	8467	0.2	6774
1985	700	0	700	0.1	70	770	0.00	565	1335	0.2	1068
1986	1260	0	1260	0.1	126	1386	0.00	2231	3617	0.2	2894
1987	650	0	650	0.1	65	715	0.00	1198	1913	0.2	1530
1988	4453	0	4453	0.1	445	4898	0.02	13199	18098	0.2	14478
1989	2154	0	2154	0.1	215	2369	0.01	5009	7378	0.2	5903
1990	799	0	799	0.1	80	879	0.01	2513	3392	0.2	2713
1991	2027	0	2027	0.1	203	2230	0.01	4190	6420	0.2	5136
Mean	1584	0	1584	0.1	158	1742	0.01	2708	4451	0.2	3561
									Restoration goal:		7121



Estimated natural production [P(f,n,cl)] for fall-run in Clear Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

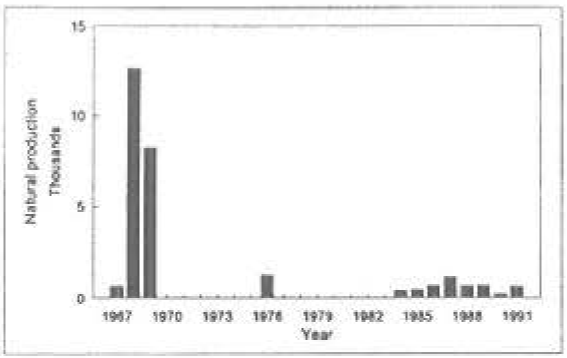
Description of variables named in worksheet:

E(f,n,cl)	Escapement (naturally spawning fish in Clear Creek)
E(f,h,cl)	Escapement (to hatcheries in Clear Creek)
E(f,t,cl)	Escapement naturally and to hatcheries in Clear Creek)
H(f,i,cl)	Harvest (in Clear Creek, estimated as E(f,t,cl)* prop. harvested instream)
P(f,i,cl)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,cl)	Harvest (ocean harvest of fall-run salmon assigned to Clear Creek)
P(f,t,cl)	Production (total Clear Creek)
h	Proportion hatchery
P(f,n,cl)	Production (natural production for Clear Creek)
DFG	Data taken from Mills and Fisher (1994).

Cow Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,cw)	DFG E(f,h,cw)	E(f,t,cw)	Proportion harvested instream	H(f,i,cw)	P(f,i,cw)	P(f,i,cw)/ P(f,i,cv)	H(f,o,cw)	P(f,t,cw)	h	P(f,n,cw)
1967	520	0	520	0.1	52	572	0.00	251	823	0.2	659
1968	7540	0	7540	0.1	754	8294	0.03	7545	15839	0.2	12671
1969	5570	0	5570	0.1	557	6127	0.02	4191	10318	0.2	8255
1970											
1971											
1972											
1973											
1974											
1975											
1976	726	0	726	0.1	73	799	0.00	749	1548	0.2	1238
1977											
1978											
1979											
1980											
1981											
1982											
1983											
1984	250	0	250	0.1	25	275	0.00	254	529	0.2	423
1985	300	0	300	0.1	30	330	0.00	242	572	0.2	458
1986	300	0	300	0.1	30	330	0.00	531	861	0.2	689
1987	500	0	500	0.1	50	550	0.00	921	1471	0.2	1177
1988	200	0	200	0.1	20	220	0.00	593	813	0.2	650
1989	250	0	250	0.1	25	275	0.00	581	856	0.2	685
1990	75	0	75	0.1	8	83	0.00	236	318	0.2	255
1991	250	0	250	0.1	25	275	0.00	517	792	0.2	633
Mean	1373	0	1373	0.1	137	1511	0.01	1384	2895	0.2	2316

Restoration goal: 4632



Estimated natural production [P(f,n,cw)] for fall-run in Cow Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

CDFG spawner surveys have been primarily confined to mainstem Cow Creek, where most chinook spawning occurs. Some additional spawning takes place in Cow Creek's five tributary streams.

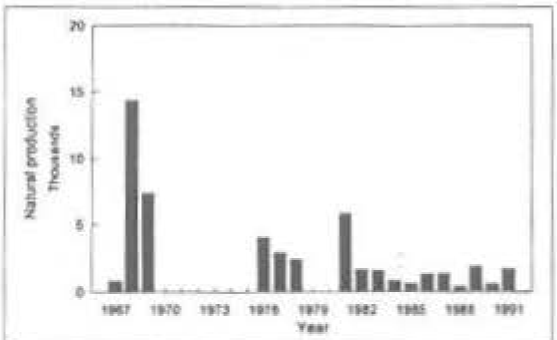
Cow Creek supports a small run of late-fall-run chinook salmon, but there are no abundance estimates due to typically high flows and turbidity during their spawning period.

Description of variables named in worksheet:

E(f,n,cw)	Escapement (naturally spawning fish in Cow Creek)
E(f,h,cw)	Escapement (to hatcheries in Cow Creek)
E(f,t,cw)	Escapement naturally and to hatcheries in Cow Creek)
H(f,i,cw)	Harvest (in Cow Creek, estimated as E(f,t,co)* prop. harvested instream)
P(f,i,cw)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,cw)	Harvest (ocean harvest of fall-run salmon assigned to Cow Creek)
P(f,t,cw)	Production (total Cow Creek)
h	Proportion hatchery
P(f,n,cw)	Production (natural production for Cow Creek)
DFG	Data taken from Mills and Fisher (1994)

Cottonwood Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ct)	DFG E(f,h,ct)	E(f,t,ct)	Proportion harvested instream	H(f,i,ct)	P(f,i,ct)	P(f,i,ct)/ P(f,i,cv)	H(f,o,ct)	P(f,t,ct)	h	P(f,n,ct)
1967	600	0	600	0.1	60	660	0.00	290	950	0.2	760
1968	8540	0	8540	0.1	854	9394	0.04	8545	17939	0.2	14352
1969	4967	0	4967	0.1	497	5464	0.01	3738	9201	0.2	7361
1970											
1971											
1972											
1973											
1974											
1975											
1976	2427	0	2427	0.1	243	2670	0.01	2505	5175	0.2	4140
1977	1512	0	1512	0.1	151	1663	0.01	2047	3710	0.2	2968
1978	1120	0	1120	0.1	112	1232	0.01	1846	3078	0.2	2462
1979											
1980											
1981	3356	0	3356	0.1	336	3692	0.01	3636	7327	0.2	5862
1982	700	0	700	0.1	70	770	0.00	1319	2089	0.2	1671
1983	1000	0	1000	0.1	100	1100	0.00	950	2050	0.2	1640
1984	500	0	500	0.1	50	550	0.00	508	1058	0.2	847
1985	400	0	400	0.1	40	440	0.00	323	763	0.2	610
1986	600	0	600	0.1	60	660	0.00	1063	1723	0.2	1378
1987	600	0	600	0.1	60	660	0.00	1106	1766	0.2	1413
1988	120	0	120	0.1	12	132	0.00	356	488	0.2	390
1989	700	0	700	0.1	70	770	0.00	1628	2398	0.2	1918
1990	175	0	175	0.1	18	193	0.00	550	743	0.2	594
1991	687	0	687	0.1	69	756	0.00	1420	2176	0.2	1741
Mean	1647	0	1647	0.1	165	1812	0.01	1872	3684	0.2	2947
									Restoration goal:		5895



Estimated natural production [P(f,n,ct)] for fall-run in Cottonwood Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

No consistent surveys have been conducted for late-fall and spring-runs of chinook salmon.

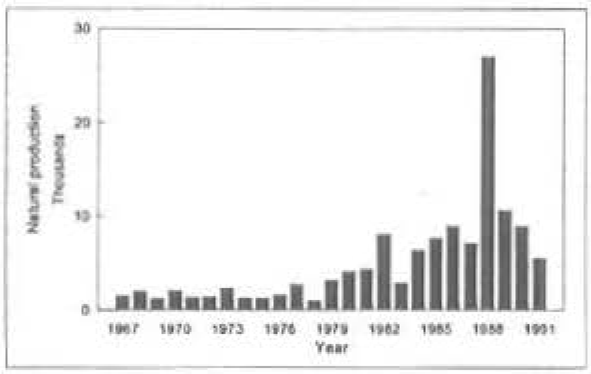
Description of variables named in worksheet:

E(f,n,ct)	Escapement (naturally spawning fish in Cottonwood Creek)
E(f,h,ct)	Escapement (to hatcheries in Cottonwood Creek)
E(f,t,ct)	Escapement naturally and to hatcheries in Cottonwood Creek)
H(f,i,ct)	Harvest (in Cottonwood Creek, estimated as E(f,t,ct)* prop. harvested instream)
P(f,i,ct)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ct)	Harvest (ocean harvest of fall-run salmon assigned to Cottonwood Creek)
P(f,t,ct)	Production (total Cottonwood Creek)
h	Proportion hatchery
P(f,n,ct)	Production (natural production for Cottonwood Creek)
DFG	Data taken from Mills and Fisher (1994).

Battle Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ba)	DFG E(f,h,ba)	E(f,t,ba)	Proportion harvested instream	H(f,i,ba)	P(f,i,ba)	P(f,i,ba)/ P(f,i,cv)	H(f,o,ba)	P(f,t,ba)	h	P(f,n,ba)
1967	2160	7440	9600	0.1	960	10560	0.05	4639	15199	0.9	1520
1968	2950	6355	9305	0.1	931	10236	0.04	9311	19546	0.9	1955
1969	3200	3678	6878	0.1	688	7566	0.02	5176	12741	0.9	1274
1970	3320	6356	9676	0.1	968	10644	0.04	9939	20582	0.9	2058
1971	3285	3645	6930	0.1	693	7623	0.03	6343	13966	0.9	1397
1972	2030	3221	5251	0.1	525	5776	0.03	8625	14402	0.9	1440
1973	4300	4540	8840	0.1	884	9724	0.03	14311	24035	0.9	2403
1974	2294	3036	5330	0.1	533	5863	0.02	7440	13303	0.9	1330
1975	2426	3312	5738	0.1	574	6312	0.03	6572	12884	0.9	1288
1976	3147	4446	7593	0.1	759	8352	0.04	7837	16190	0.9	1619
1977	5604	5636	11240	0.1	1124	12364	0.05	15219	27583	0.9	2758
1978	1770	1882	3652	0.1	365	4017	0.02	6018	10036	0.9	1004
1979	4430	8729	13159	0.1	1316	14475	0.05	17119	31594	0.9	3159
1980	4940	9503	14443	0.1	1444	15887	0.08	24924	40811	0.9	4081
1981	6933	13223	20156	0.1	2016	22172	0.07	21835	44006	0.9	4401
1982	7270	19760	27030	0.1	2703	29733	0.11	50938	80671	0.9	8067
1983	5227	8756	13983	0.1	1398	15381	0.06	13288	28669	0.9	2867
1984	8312	21648	29960	0.1	2996	32956	0.11	30465	63421	0.9	6342
1985	23961	16320	40281	0.1	4028	44309	0.10	32488	76797	0.9	7680
1986	18753	12481	31234	0.1	3123	34357	0.10	55314	89672	0.9	8967
1987	7912	16321	24233	0.1	2423	26656	0.08	44656	71312	0.9	7131
1988	52852	13579	66431	0.1	6643	73074	0.23	196910	269984	0.9	26998
1989	19076	11986	31062	0.1	3106	34168	0.16	72231	106400	0.9	10640
1990	6453	14635	21088	0.1	2109	23197	0.17	66321	89518	0.9	8952
1991	6613	10683	17296	0.1	1730	19026	0.12	35756	54782	0.9	5478
Mean	8369	9247	17616	0.1	1762	19377	0.07	30547	49924	0.9	4992

Restoration goal: 9985



Estimated natural production [P(f,n,ba)] for fall-run in Battle Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on the fact that Coleman National Fish Hatchery is located on Battle Creek.

No abundance estimate is available for spring-run chinook in Battle Creek, while winter-run chinook are believed to have been extirpated.

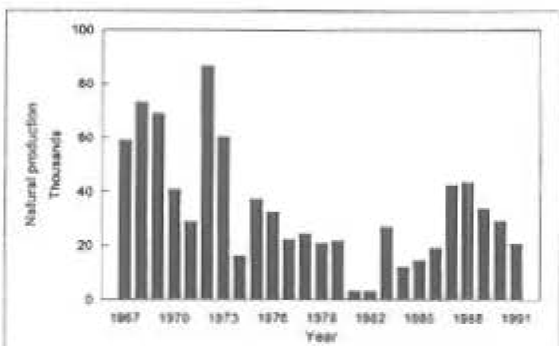
Description of variables named in worksheet:

E(f,n,ba)	Escapement (naturally spawning fish in Battle Creek)
E(f,h,ba)	Escapement (to hatcheries in Battle Creek)
E(f,t,ba)	Escapement naturally and to hatcheries in Battle Creek)
H(f,i,ba)	Harvest (in Battle Creek, estimated as E(f,t,ba)* prop. harvested instream)
P(f,i,ba)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ba)	Harvest (ocean harvest of fall-run salmon assigned to Battle Creek)
P(f,t,ba)	Production (total Battle Creek)
h	Proportion hatchery
P(f,n,ba)	Production (natural production for Battle Creek)
DFG	Data taken from Mills and Fisher (1994).

Battle Creek: Production estimates for late-fall-run chinook salmon.

Year	DFG E(l,n,ba)	DFG E(l,h,ba)	E(l,t,ba)	Proportion harvested instream	H(l,i,ba)	P(l,i,ba)	P(l,i,ba)/ P(l,i,cv)	H(l,o,ba)	P(l,t,ba)	h	P(l,n,ba)
1967											
1968											
1969		787	787	0.2	157	944	0.02	646	1590	0.9	159
1970		3060	3060	0.2	612	3672	0.12	3429	7101	0.9	710
1971		1209	1209	0.2	242	1451	0.06	1207	2658	0.9	266
1972		549	549	0.2	110	659	0.02	984	1643	0.9	164
1973		403	403	0.2	81	484	0.02	712	1195	0.9	120
1974		705	705	0.2	141	846	0.07	1074	1920	0.9	192
1975		1498	1498	0.2	300	1798	0.07	1872	3669	0.9	367
1976		609	609	0.2	122	731	0.03	686	1417	0.9	142
1977		756	756	0.2	151	907	0.06	1117	2024	0.9	202
1978		1853	1853	0.2	371	2224	0.15	3331	5555	0.9	555
1979		829	829	0.2	166	995	0.08	1177	2171	0.9	217
1980		867	867	0.2	173	1040	0.09	1632	2673	0.9	267
1981		2605	2605	0.2	521	3126	0.55	3078	6204	0.9	620
1982		1886	1886	0.2	377	2263	0.35	3877	6140	0.9	614
1983		958	958	0.2	192	1150	0.06	993	2143	0.9	214
1984		628	628	0.2	126	754	0.08	697	1450	0.9	145
1985		388	388	0.2	78	466	0.04	341	807	0.9	81
1986		788	788	0.2	158	946	0.08	1522	2468	0.9	247
1987		803	803	0.2	161	964	0.05	1614	2578	0.9	258
1988		457	457	0.2	91	548	0.04	1478	2026	0.9	203
1989		882	882	0.2	176	1058	0.07	2237	3296	0.9	330
1990		192	192	0.2	38	230	0.02	659	889	0.9	89
1991		279	279	0.2	56	335	0.04	629	964	0.9	96
Mean		1000	1000	0.2	200	1200	0.09	1521	2721	0.9	272

Restoration goal: 544



Estimated natural production [P(l,n,ba)] for late-fall-run in the Battle Creek for each of the years in the baseline period.

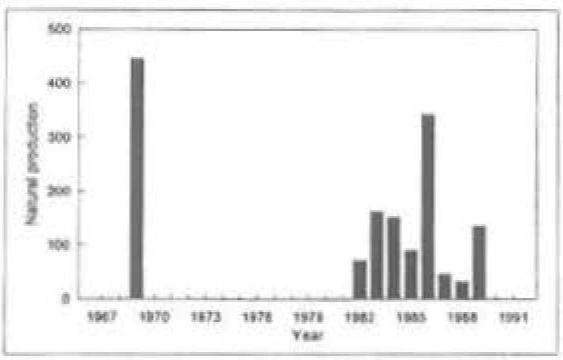
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Estimate of h (proportion of production produced in a hatchery) based on the fact that Coleman National Fish Hatchery is located on Battle Creek and that late-fall-run chinook salmon spawn on Battle Creek.

Description of variables named in worksheet:

E(l,n,ba)	Escapement (naturally spawning fish in Battle Creek)
E(l,h,ba)	Escapement (to hatcheries in Battle Creek)
E(l,t,ba)	Escapement naturally and to hatcheries in Battle Creek)
H(l,i,ba)	Harvest (in Battle Creek, estimated as E(l,t,ba)* prop. harvested instream)
P(l,i,ba)	Production (total escapement plus instream harvest)
P(l,i,cv)	Production (total Central Valley)
H(l,o,ba)	Harvest (ocean harvest of late-fall-run salmon assigned to Battle Creek)
P(l,t,ba)	Production (total Battle Creek)
h	Proportion hatchery
P(l,n,ba)	Production (natural production for Battle Creek)
DFG	Data taken from Mills and Fisher (1994)

Paynes Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,pa)	DFG E(f,h,pa)	E(f,t,pa)	Proportion harvested instream	H(f,i,pa)	P(f,i,pa)	P(f,i,pa)/ P(f,i,cv)	H(f,o,pa)	P(f,t,pa)	h	P(f,n,pa)
1967											
1968											
1969	300	0	300	0.1	30	330	0.00	226	556	0.2	445
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982	30	0	30	0.1	3	33	0.00	57	90	0.2	72
1983	100	0	100	0.1	10	110	0.00	95	205	0.2	164
1984	90	0	90	0.1	9	99	0.00	92	191	0.2	152
1985	60	0	60	0.1	6	66	0.00	48	114	0.2	92
1986	150	0	150	0.1	15	165	0.00	266	431	0.2	345
1987	20	0	20	0.1	2	22	0.00	37	59	0.2	47
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	50	0	50	0.1	5	55	0.00	116	171	0.2	137
1990											
1991											
Mean	90	0	90	0.1	9	99	0.00	107	206	0.2	165
									Restoration goal:		330



Estimated natural production [P(f,n,pa)] for fall-run in Paynes Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Abundance estimates for other runs of chinook salmon are not available, although these other runs may opportunistically utilize the stream.

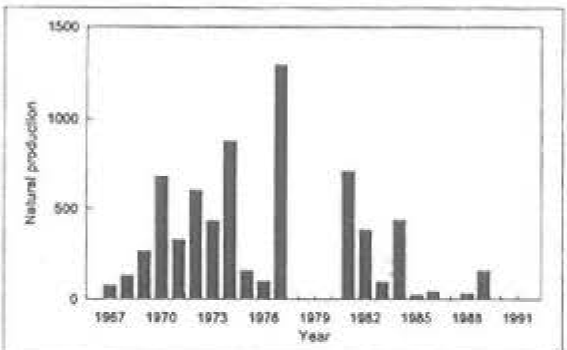
Description of variables named in worksheet:

E(f,n,pa)	Escapement (naturally spawning fish in Paynes Creek)
E(f,h,pa)	Escapement (to hatcheries in Paynes Creek)
E(f,t,pa)	Escapement naturally and to hatcheries in Paynes Creek)
H(f,i,pa)	Harvest (in Paynes Creek, estimated as E(f,t,pa)* prop. harvested instream)
P(f,i,pa)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,pa)	Harvest (ocean harvest of fall-run salmon assigned to Paynes Creek)
P(f,t,pa)	Production (total Paynes Creek)
h	Proportion hatchery
P(f,n,pa)	Production (natural production for Paynes Creek)
DFG	Data taken from Mills and Fisher (1994)

Antelope Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,an)	DFG E(f,h,an)	E(f,t,an)	Proportion harvested instream	H(f,i,an)	P(f,i,an)	P(f,i,an)/ P(f,i,cv)	H(f,o,an)	P(f,t,an)	*h*	P(f,n,an)
1967	60	0	60	0.1	6	66	0.00	29	95	0.2	76
1968	80	0	80	0.1	8	88	0.00	80	168	0.2	134
1969	180	0	180	0.1	18	198	0.00	135	333	0.2	267
1970	400	0	400	0.1	40	440	0.00	411	851	0.2	681
1971	205	0	205	0.1	21	226	0.00	188	413	0.2	331
1972	275	0	275	0.1	28	303	0.00	452	754	0.2	603
1973	200	0	200	0.1	20	220	0.00	324	544	0.2	435
1974	440	0	440	0.1	44	484	0.00	614	1098	0.2	879
1975	90	0	90	0.1	9	99	0.00	103	202	0.2	162
1976	60	0	60	0.1	6	66	0.00	62	128	0.2	102
1977	660	0	660	0.1	66	726	0.00	894	1620	0.2	1296
1978											
1979											
1980											
1981	407	0	407	0.1	41	448	0.00	441	889	0.2	711
1982	162	0	162	0.1	16	178	0.00	305	483	0.2	387
1983	60	0	60	0.1	6	66	0.00	57	123	0.2	98
1984	260	0	260	0.1	26	286	0.00	264	550	0.2	440
1985	15	0	15	0.1	2	17	0.00	12	29	0.2	23
1986	20	0	20	0.1	2	22	0.00	35	57	0.2	46
1987											
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	60	0	60	0.1	6	66	0.00	140	206	0.2	164
1990											
1991											
Mean	192	0	192	0.1	19	211	0.00	241	452	0.2	361

Restoration goal: 723



Estimated natural production [P(f,n,an)] for fall-run in Antelope Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Insufficient information is available to provide abundance estimates for late-fall and spring-run chinook salmon in Antelope Creek.

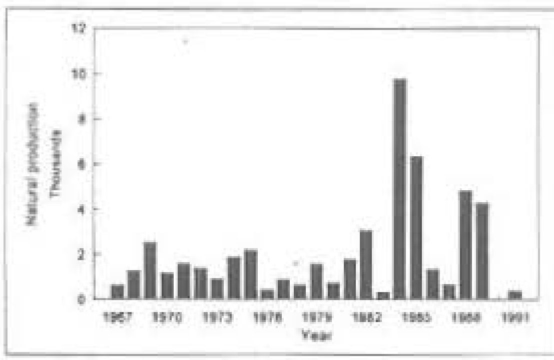
Description of variables named in worksheet:

E(f,n,an)	Escapement (naturally spawning fish in Antelope Creek)
E(f,h,an)	Escapement (to hatcheries in Antelope Creek)
E(f,t,an)	Escapement naturally and to hatcheries in Antelope Creek)
H(f,i,an)	Harvest (in Antelope Creek, estimated as E(f,t,an)* prop. harvested instream)
P(f,i,an)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,an)	Harvest (ocean harvest of fall-run salmon assigned to Antelope Creek)
P(f,t,an)	Production (total Antelope Creek)
h	Proportion hatchery
P(f,n,an)	Production (natural production for Antelope Creek)
DFG	Data taken from Mills and Fisher (1994).

Mill Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,mi)	DFG E(f,h,mi)	E(f,t,mi)	Proportion harvested instream	H(f,i,mi)	P(f,i,mi)	P(f,i,mi)/ P(f,i,cv)	H(f,o,mi)	P(f,t,mi)	h	P(f,n,mi)
1967	500	0	500	0.1	50	550	0.00	242	792	0.2	633
1968	750	0	750	0.1	75	825	0.00	750	1575	0.2	1260
1969	1700	0	1700	0.1	170	1870	0.01	1279	3149	0.2	2519
1970	690	0	690	0.1	69	759	0.00	709	1468	0.2	1174
1971	980	0	980	0.1	98	1078	0.00	897	1975	0.2	1580
1972	631	0	631	0.1	63	694	0.00	1037	1731	0.2	1384
1973	420	0	420	0.1	42	462	0.00	680	1142	0.2	914
1974	944	0	944	0.1	94	1038	0.00	1318	2356	0.2	1885
1975	1208	0	1208	0.1	121	1329	0.01	1384	2712	0.2	2170
1976	245	0	245	0.1	25	270	0.00	253	522	0.2	418
1977	456	0	456	0.1	46	502	0.00	617	1119	0.2	895
1978	300	0	300	0.1	30	330	0.00	494	824	0.2	660
1979	810	0	810	0.1	81	891	0.00	1054	1945	0.2	1556
1980	320	0	320	0.1	32	352	0.00	552	904	0.2	723
1981	1020	0	1020	0.1	102	1122	0.00	1105	2227	0.2	1782
1982	1290	0	1290	0.1	129	1419	0.01	2431	3850	0.2	3080
1983	200	0	200	0.1	20	220	0.00	190	410	0.2	328
1984	5800	0	5800	0.1	580	6380	0.02	5898	12278	0.2	9822
1985	4180	0	4180	0.1	418	4598	0.01	3371	7969	0.2	6375
1986	574	0	574	0.1	57	631	0.00	1017	1648	0.2	1318
1987	282	0	282	0.1	28	310	0.00	520	830	0.2	664
1988	1487	0	1487	0.1	149	1636	0.01	4408	6043	0.2	4835
1989	1564	0	1564	0.1	156	1720	0.01	3637	5357	0.2	4286
1990											
1991	150	0	150	0.1	15	165	0.00	310	475	0.2	380
Mean	1104	0	1104	0.1	110	1215	0.00	1423	2638	0.2	2110

Restoration goal: 4220



Estimated natural production [P(f,n,mi)] for fall-run in Mill Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

There are no estimates of late-fall-run chinook salmon abundance in Mill Creek during the baseline period.

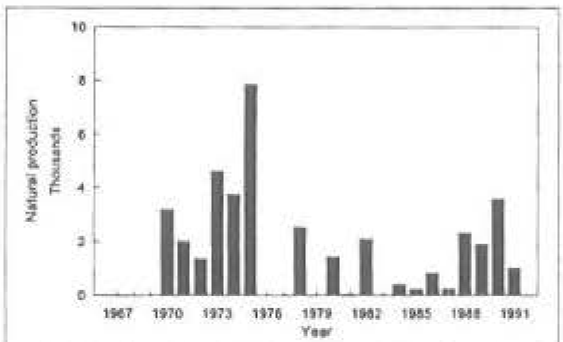
Description of variables named in worksheet:

E(f,n,mi)	Escapement (naturally spawning fish in Mill Creek)
E(f,h,mi)	Escapement (to hatcheries in Mill Creek)
E(f,t,mi)	Escapement naturally and to hatcheries in Mill Creek)
H(f,i,mi)	Harvest (in Mill Creek, estimated as E(f,t,mi)* prop. harvested instream)
P(f,i,mi)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,mi)	Harvest (ocean harvest of fall-run salmon assigned to Mill Creek)
P(f,t,mi)	Production (total Mill Creek)
h	Proportion hatchery
P(f,n,mi)	Production (natural production for Mill Creek)
DFG	Data taken from Mills and Fisher (1994).

Mill Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,mi)	DFG E(s,h,mi)	E(s,t,mi)	Proportion harvested instream	H(s,i,mi)	P(s,i,mi)	P(s,i,mi)/ P(s,i,cv)	H(s,o,mi)	P(s,t,mi)	h	P(s,n,mi)
1967											
1968											
1969											
1970	1500	0	1500	0.1	150	1650	0.19	1541	3191	0	3191
1971	1000	0	1000	0.1	100	1100	0.11	915	2015	0	2015
1972	500	0	500	0.1	50	550	0.06	821	1371	0	1371
1973	1700	0	1700	0.1	170	1870	0.14	2752	4622	0	4622
1974	1500	0	1500	0.1	150	1650	0.18	2094	3744	0	3744
1975	3500	0	3500	0.1	350	3850	0.14	4009	7859	0	7859
1976											
1977											
1978	925	0	925	0.1	93	1018	0.11	1524	2542	0	2542
1979											
1980	500	0	500	0.1	50	550	0.04	863	1413	0	1413
1981	15	0	15	0.1	2	17	0.00	16	33	0	33
1982	700	0	700	0.1	70	770	0.02	1319	2089	0	2089
1983											
1984	191	0	191	0.1	19	210	0.02	194	404	0	404
1985	121	0	121	0.1	12	133	0.01	98	231	0	231
1986	291	0	291	0.1	29	320	0.01	515	835	0	835
1987	89	0	89	0.1	9	98	0.01	164	262	0	262
1988	572	0	572	0.1	57	629	0.05	1695	2325	0	2325
1989	556	0	556	0.1	56	612	0.07	1293	1905	0	1905
1990	844	0	844	0.1	84	928	0.15	2654	3583	0	3583
1991	319	0	319	0.1	32	351	0.19	659	1010	0	1010
Mean	824	0	824	0.1	82	906	0.08	1285	2191	0.0	2191

Restoration goal: 4382



Estimated natural production [P(s,n,mi)] for spring-run in Mill Creek for each of the years in the baseline period.

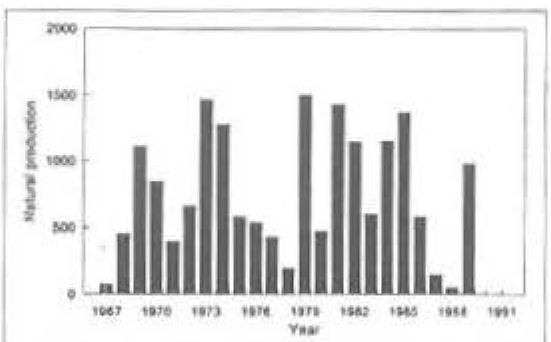
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Description of variables named in worksheet:

E(s,n,mi)	Escapement (naturally spawning fish in Mill Creek)
E(s,h,mi)	Escapement (to hatcheries in Mill Creek)
E(s,t,mi)	Escapement naturally and to hatcheries in Mill Creek)
H(s,i,mi)	Harvest (in Mill Creek, estimated as E(s,t,mi)* prop. harvested instream)
P(s,i,mi)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,mi)	Harvest (ocean harvest of spring-run salmon assigned to Mill Creek)
P(s,t,mi)	Production (total Mill Creek)
h	Proportion hatchery
P(s,n,mi)	Production (natural production for Mill Creek)
DFG	Data taken from Mills and Fisher (1994)

Deer Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,de)	DFG E(f,h,de)	E(f,t,de)	Proportion harvested instream	H(f,i,de)	P(f,i,de)	P(f,i,de)/ P(f,i,cv)	H(f,o,de)	P(f,t,de)	h	P(f,n,de)
1967	60	0	60	0.1	6	66	0.00	29	95	0.2	76
1968	270	0	270	0.1	27	297	0.00	270	567	0.2	454
1969	750	0	750	0.1	75	825	0.00	564	1389	0.2	1111
1970	500	0	500	0.1	50	550	0.00	514	1064	0.2	851
1971	248	0	248	0.1	25	273	0.00	227	500	0.2	400
1972	304	0	304	0.1	30	334	0.00	499	834	0.2	667
1973	676	0	676	0.1	68	744	0.00	1094	1838	0.2	1470
1974	640	0	640	0.1	64	704	0.00	893	1597	0.2	1278
1975	328	0	328	0.1	33	361	0.00	376	737	0.2	589
1976	315	0	315	0.1	32	347	0.00	325	672	0.2	537
1977	220	0	220	0.1	22	242	0.00	298	540	0.2	432
1978	90	0	90	0.1	9	99	0.00	148	247	0.2	198
1979	780	0	780	0.1	78	858	0.00	1015	1873	0.2	1498
1980	210	0	210	0.1	21	231	0.00	362	593	0.2	475
1981	820	0	820	0.1	82	902	0.00	888	1790	0.2	1432
1982	480	0	480	0.1	48	528	0.00	905	1433	0.2	1146
1983	370	0	370	0.1	37	407	0.00	352	759	0.2	607
1984	680	0	680	0.1	68	748	0.00	691	1439	0.2	1152
1985	900	0	900	0.1	90	990	0.00	726	1716	0.2	1373
1986	256	0	256	0.1	26	282	0.00	453	735	0.2	588
1987	64	0	64	0.1	6	70	0.00	118	188	0.2	151
1988	16	0	16	0.1	2	18	0.00	47	65	0.2	52
1989	356	0	358	0.1	36	394	0.00	832	1226	0.2	981
1990											
1991											
Mean	406	0	406	0.1	41	446	0.00	506	952	0.2	762
										Restoration goal:	1523



Estimated natural production [P(f,n,de)] for fall-run in Deer Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

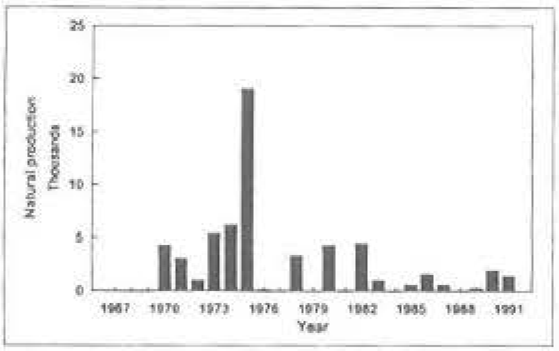
An unknown number of late-fall-run chinook salmon spawn in Deer Creek, but they are probably strays, and may not be a self-sustaining population.

Description of variables named in worksheet:

E(f,n,de)	Escapement (naturally spawning fish in Deer Creek)
E(f,h,de)	Escapement (to hatcheries in Deer Creek)
E(f,t,de)	Escapement naturally and to hatcheries in Deer Creek)
H(f,i,de)	Harvest (in Deer Creek, estimated as E(f,t,de)* prop. harvested instream)
P(f,i,de)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,de)	Harvest (ocean harvest of fall-run salmon assigned to Deer Creek)
P(f,t,de)	Production (total Deer Creek)
h	Proportion hatchery
P(f,n,de)	Production (natural production for Deer Creek)
DFG	Data taken from Mills and Fisher (1994).

Deer Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,de)	DFG E(s,h,de)	E(s,t,de)	Proportion harvested instream	H(s,i,de)	P(s,i,de)	P(s,i,de)/ P(s,i,cv)	H(s,o,de)	P(s,t,de)	h	P(s,n,de)
1967											
1968											
1969											
1970	2000	0	2000	0.1	200	2200	0.26	2054	4254	0	4254
1971	1500	0	1500	0.1	150	1650	0.16	1373	3023	0	3023
1972	400	0	400	0.1	40	440	0.04	657	1097	0	1097
1973	2000	0	2000	0.1	200	2200	0.16	3238	5438	0	5438
1974	2500	0	2500	0.1	250	2750	0.30	3490	6240	0	6240
1975	8500	0	8500	0.1	850	9350	0.35	9736	19086	0	19086
1976	44	0	44	0.1	4	48	0.00	45	94	0	94
1977											
1978	1200	0	1200	0.1	120	1320	0.14	1978	3298	0	3298
1979											
1980	1500	0	1500	0.1	150	1650	0.12	2589	4239	0	4239
1981	25	0	25	0.1	3	28	0.00	27	55	0	55
1982	1500	0	1500	0.1	150	1650	0.05	2827	4477	0	4477
1983	500	0	500	0.1	50	550	0.10	475	1025	0	1025
1984											
1985	301	0	301	0.1	30	331	0.02	243	574	0	574
1986	543	0	543	0.1	54	597	0.03	962	1559	0	1559
1987	200	0	200	0.1	20	220	0.02	369	589	0	589
1988											
1989	77	0	77	0.1	8	85	0.01	179	264	0	264
1990	458	0	458	0.1	46	504	0.08	1440	1944	0	1944
1991	449	0	449	0.1	45	494	0.26	928	1422	0	1422
Mean	1317	0	1317	0.1	132	1448	0.12	1812	3260	0.0	3260
									Restoration goal:		6520



Estimated natural production [P(s,n,de)] for spring-run in Deer Creek for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

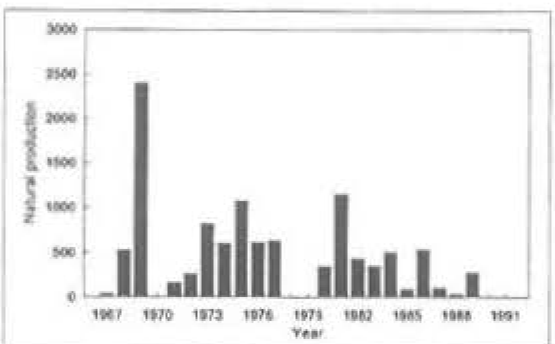
Description of variables named in worksheet:

E(s,n,de)	Escapement (naturally spawning fish in Deer Creek)
E(s,h,de)	Escapement (to hatcheries in Deer Creek)
E(s,t,de)	Escapement naturally and to hatcheries in Deer Creek)
H(s,i,de)	Harvest (in Deer Creek, estimated as E(s,t,de)* prop. harvested instream)
P(s,i,de)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,de)	Harvest (ocean harvest of spring-run salmon assigned to Deer Creek)
P(s,t,de)	Production (total Deer Creek)
h	Proportion hatchery
P(s,n,de)	Production (natural production for Deer Creek)
DFG	Data taken from Mills and Fisher (1994).

Miscellaneous creeks: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ms)	DFG E(f,h,ms)	E(f,t,ms)	Proportion harvested instream	H(f,i,ms)	P(f,i,ms)	P(f,i,ms)/ P(f,i,cv)	H(f,o,ms)	P(f,t,ms)	h	P(f,n,ms)
1967	30	0	30	0.1	3	33	0.00	14	47	0.2	38
1968	310	0	310	0.1	31	341	0.00	310	651	0.2	521
1969	1620	0	1620	0.1	162	1782	0.00	1219	3001	0.2	2401
1970											
1971	100	0	100	0.1	10	110	0.00	92	202	0.2	161
1972	120	0	120	0.1	12	132	0.00	197	329	0.2	263
1973	376	0	376	0.1	38	414	0.00	609	1022	0.2	818
1974	300	0	300	0.1	30	330	0.00	419	749	0.2	599
1975	600	0	600	0.1	60	660	0.00	687	1347	0.2	1078
1976	356	0	356	0.1	36	392	0.00	367	759	0.2	607
1977	320	0	320	0.1	32	352	0.00	433	785	0.2	628
1978											
1979											
1980	151	0	151	0.1	15	166	0.00	261	427	0.2	341
1981	660	0	660	0.1	66	726	0.00	715	1441	0.2	1153
1982	180	0	180	0.1	18	198	0.00	339	537	0.2	430
1983	210	0	210	0.1	21	231	0.00	200	431	0.2	344
1984	300	0	300	0.1	30	330	0.00	305	635	0.2	508
1985	60	0	60	0.1	6	66	0.00	48	114	0.2	92
1986	230	0	230	0.1	23	253	0.00	407	660	0.2	528
1987	45	0	45	0.1	5	50	0.00	83	132	0.2	106
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	100	0	100	0.1	10	110	0.00	233	343	0.2	274
1990											
1991											
Mean	304	0	304	0.1	30	334	0.00	348	683	0.2	546

Restoration goal: 1092



Estimated natural production [P(f,n,ms)] for fall-run in miscellaneous creeks for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

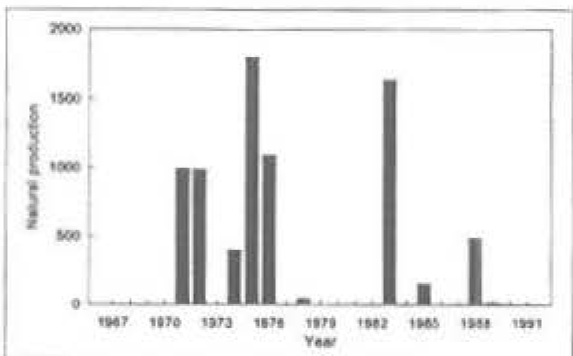
Description of variables named in worksheet:

E(f,n,ms)	Escapement (naturally spawning fish in miscellaneous creeks)
E(f,h,ms)	Escapement (to hatcheries in miscellaneous creeks)
E(f,t,ms)	Escapement naturally and to hatcheries in miscellaneous creeks)
H(f,i,ms)	Harvest (in miscellaneous creeks, estimated as E(f,t,ms)* prop. harvested instream)
P(f,i,ms)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ms)	Harvest (ocean harvest of fall-run salmon assigned to miscellaneous creeks)
P(f,t,ms)	Production (total Miscellaneous Creeks)
h	Proportion hatchery
P(f,n,ms)	Production (natural production for miscellaneous creeks)
DFG	Data taken from Mills and Fisher (1994).

Butte Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,bu)	DFG E(f,h,bu)	E(f,t,bu)	Proportion harvested instream	H(f,i,bu)	P(f,i,bu)	P(f,i,bu)/ P(f,i,cv)	H(f,o,bu)	P(f,t,bu)	h	P(f,n,bu)
1967											
1968											
1969											
1970											
1971	615	0	615	0.1	62	677	0.00	563	1239	0.2	992
1972	450	0	450	0.1	45	495	0.00	739	1234	0.2	987
1973											
1974	200	0	200	0.1	20	220	0.00	279	499	0.2	399
1975	1000	0	1000	0.1	100	1100	0.00	1145	2245	0.2	1796
1976	640	0	640	0.1	64	704	0.00	661	1365	0.2	1092
1977											
1978	20	0	20	0.1	2	22	0.00	33	55	0.2	44
1979											
1980											
1981											
1982											
1983	1000	0	1000	0.1	100	1100	0.00	950	2050	0.2	1640
1984											
1985	100	0	100	0.1	10	110	0.00	81	191	0.2	153
1986											
1987											
1988	150	0	150	0.1	15	165	0.00	445	610	0.2	488
1989	5	0	5	0.1	1	6	0.00	12	17	0.2	14
1990											
1991											
Mean	418	0	418	0.1	42	460	0.00	491	951	0.2	760

Restoration goal: 1521



Estimated natural production [P(f,n,bu)] for fall-run in Butte Creek for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).
Late-fall-run chinook salmon have been reported in Butte Creek, however, no systemic counts have been made to verify numbers.

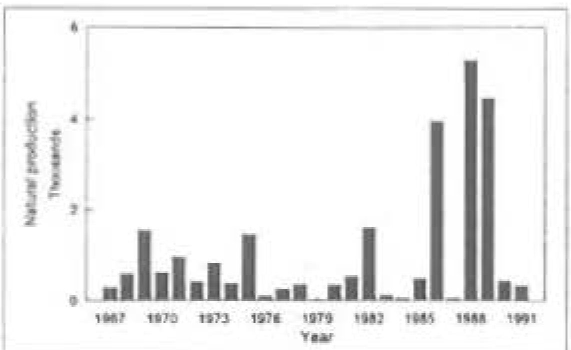
Description of variables named in worksheet:

E(f,n,bu)	Escapement (naturally spawning fish in Butte Creek)
E(f,h,bu)	Escapement (to hatcheries in Butte Creek)
E(f,t,bu)	Escapement naturally and to hatcheries in Butte Creek)
H(f,i,bu)	Harvest (in Butte Creek, estimated as E(f,t,bu)* prop. harvested instream)
P(f,i,bu)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,bu)	Harvest (ocean harvest of fall-run salmon assigned to Butte Creek)
P(f,t,bu)	Production (total Butte Creek)
h	Proportion hatchery
P(f,n,bu)	Production (natural production for Butte Creek)
DFG	Data taken from Mills and Fisher (1994).

Butte Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,bu)	DFG E(s,h,bu)	E(s,t,bu)	Proportion harvested instream	H(s,i,bu)	P(s,i,bu)	P(s,i,bu)/ P(s,i,cv)	H(s,o,bu)	P(s,t,bu)	h	P(s,n,bu)
1967	180	0	180	0.1	18	198	0.01	87	285	0	285
1968	280	0	280	0.1	28	308	0.02	280	588	0	588
1969	830	0	830	0.1	83	913	0.03	625	1538	0	1538
1970	285	0	285	0.1	29	314	0.04	293	606	0	606
1971	470	0	470	0.1	47	517	0.05	430	947	0	947
1972	150	0	150	0.1	15	165	0.02	246	411	0	411
1973	300	0	300	0.1	30	330	0.02	486	816	0	816
1974	150	0	150	0.1	15	165	0.02	209	374	0	374
1975	650	0	650	0.1	65	715	0.03	745	1460	0	1460
1976	46	0	46	0.1	5	51	0.00	47	98	0	98
1977	100	0	100	0.1	10	110	0.01	135	245	0	245
1978	128	0	128	0.1	13	141	0.01	211	352	0	352
1979	10	0	10	0.1	1	11	0.00	13	24	0	24
1980	119	0	119	0.1	12	131	0.01	205	336	0	336
1981	250	0	250	0.1	25	275	0.01	271	546	0	546
1982	534	0	534	0.1	53	587	0.02	1006	1594	0	1594
1983	50	0	50	0.1	5	55	0.01	48	103	0	103
1984	23	0	23	0.1	2	25	0.00	23	49	0	49
1985	254	0	254	0.1	25	279	0.02	205	484	0	484
1986	1371	0	1371	0.1	137	1508	0.07	2428	3936	0	3936
1987	14	0	14	0.1	1	15	0.00	26	41	0	41
1988	1300	0	1300	0.1	130	1430	0.10	3853	5283	0	5283
1989	1300	0	1300	0.1	130	1430	0.17	3023	4453	0	4453
1990	100	0	100	0.1	10	110	0.02	314	424	0	424
1991	100	0	100	0.1	10	110	0.06	207	317	0	317
Mean	360	0	360	0.1	36	396	0.03	617	1012	0.0	1012

Restoration goal: 2025



Estimated natural production [P(s,n,bu)] for spring-run in Butte Creek for each of the years in the baseline period.

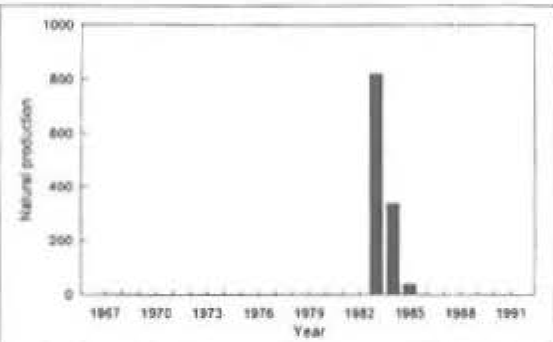
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Snorkel surveys conducted by PG&E indicate that CDFG spring-run estimates may be low by about 20%.

Description of variables named in worksheet:

- E(s,n,bu) Escapement (naturally spawning fish in Butte Creek)
- E(s,h,bu) Escapement (to hatcheries in Butte Creek)
- E(s,t,bu) Escapement naturally and to hatcheries in Butte Creek)
- H(s,i,bu) Harvest (in Butte Creek, estimated as E(s,t,bu)* prop. harvested instream)
- P(s,i,bu) Production (total escapement plus instream harvest)
- P(s,i,cv) Production (total Central Valley)
- H(s,o,bu) Harvest (ocean harvest of spring-run salmon assigned to Butte Creek)
- P(s,t,bu) Production (total Butte Creek)
- *h* Proportion hatchery
- P(s,n,bu) Production (natural production for Butte Creek)
- DFG Data taken from Mills and Fisher (1994).

Big Chico Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,bc)	DFG E(f,h,bc)	E(f,t,bc)	Proportion harvested instream	H(f,i,bc)	P(f,i,bc)	P(f,i,bc)/ P(f,i,cv)	H(f,o,bc)	P(f,t,bc)	h	P(f,n,bc)
1967											
1968											
1969											
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982											
1983	500	0	500	0.1	50	550	0.00	475	1025	0.2	820
1984	200	0	200	0.1	20	220	0.00	203	423	0.2	339
1985	25	0	25	0.1	3	28	0.00	20	48	0.2	38
1986											
1987											
1988											
1989											
1990											
1991											
Mean	242	0	242	0.1	24	265	0.00	233	499	0.2	399
									Restoration goal:		798



Estimated natural production [P(f,n,bc)] for fall-run in Big Chico Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

In years without significant autumn rain, no fall-run of chinook salmon is possible in Big Chico Creek.

Late-fall-run chinook salmon have been reported in Big Chico Creek, but no abundance estimates are available due to scarcity of data.

Spring-run chinook salmon are thought to have been extirpated from Big Chico Creek, although fry were transplanted from the Feather River from 1987 to 1992, and spring-run fry were captured in a fyke net in the spring of 1994.

Fall- and Late-Fall-run chinook salmon have been reported to spawn in Mud and Rock Creeks, tributaries to Big Chico Creek, but there is no quantitative data to support abundance estimates.

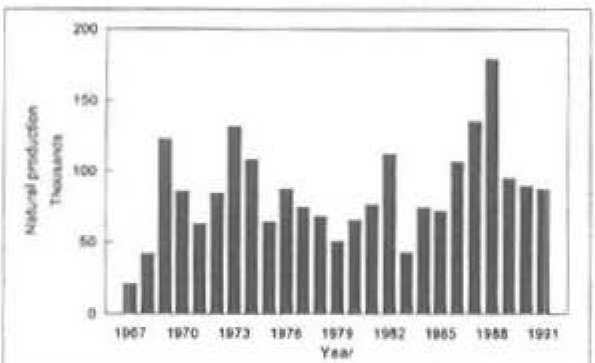
Description of variables named in worksheet:

E(f,n,bc)	Escapement (naturally spawning fish in Big Chico Creek)
E(f,h,bc)	Escapement (to hatcheries in Big Chico Creek)
E(f,t,bc)	Escapement naturally and to hatcheries in Big Chico Creek)
H(f,i,bc)	Harvest (in Big Chico Creek, estimated as E(f,t,bc)* prop. harvested instream)
P(f,i,bc)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,bc)	Harvest (ocean harvest of fall-run salmon assigned to Big Chico Creek)
P(f,t,bc)	Production (total Big Chico Creek)
h	Proportion hatchery
P(f,n,bc)	Production (natural production for Big Chico Creek)
DFG	Data taken from Mills and Fisher (1994).

Feather River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,fe)	E(f,h,fe)	E(f,t,fe)	Proportion harvested instream	H(f,i,fe)	P(f,i,fe)	P(f,i,fe)/ P(f,i,cv)	H(f,o,fe)	P(f,t,fe)	h	P(f,n,fe)
1967	10100	2002	12102	0.2	2420	14522	0.07	6380	20902	0	20902
1968	12200	6160	18360	0.2	3672	22032	0.09	20042	42074	0	42074
1969	56200	4490	60690	0.2	12138	72828	0.20	49819	122647	0	122647
1970	58170	3590	61760	0.2	12352	74112	0.27	69205	143317	0.4	85990
1971	43500	4025	47525	0.2	9505	57030	0.20	47453	104483	0.4	62690
1972	43200	3891	47091	0.2	9418	56509	0.31	84385	140895	0.4	84537
1973	65100	8682	73782	0.2	14756	88538	0.26	130304	218842	0.4	131305
1974	59300	6844	66144	0.2	13229	79373	0.28	100727	180099	0.4	108060
1975	37735	5956	43691	0.2	8738	52429	0.22	54595	107024	0.4	64214
1976	58802	3911	62713	0.2	12543	75256	0.32	70617	145872	0.4	87523
1977	37668	8905	46573	0.2	9315	55888	0.25	68793	124681	0.4	74808
1978	33000	4961	37961	0.2	7592	45553	0.25	68247	113800	0.4	68280
1979	28415	4140	32555	0.2	6511	39066	0.14	46203	85269	0.4	51161
1980	31605	3812	35417	0.2	7083	42500	0.20	66674	109175	0.4	65505
1981	44738	8751	53489	0.2	10698	64187	0.20	63211	127398	0.4	76439
1982	47956	9473	57429	0.2	11486	68915	0.25	118063	186978	0.4	112187
1983	22823	9411	32234	0.2	6447	38681	0.16	33416	72097	0.4	43258
1984	42671	10850	53521	0.2	10704	64225	0.21	59372	123597	0.4	74158
1985	50192	7443	57635	0.2	11527	69162	0.16	50711	119873	0.4	71924
1986	46844	9934	56778	0.2	11356	68134	0.20	109693	177826	0.4	106696
1987	58974	11321	70295	0.2	14059	84354	0.26	141314	225668	0.4	135401
1988	54216	13313	67529	0.2	13506	81035	0.25	218361	299396	0.4	179637
1989	29986	12656	42642	0.2	8528	51170	0.24	108174	159344	0.4	95607
1990	25000	7431	32431	0.2	6486	38917	0.28	111267	150184	0.4	90111
1991	27802	14661	42463	0.2	8493	50956	0.32	95764	146719	0.4	88032
Mean	41048	7465	48512	0.2	9702	58215	0.22	79711	137926	0.4	85726

Restoration goal: 171452



Estimated natural production [P(f,n,fe)] for fall-run in the Feather River for each of the years in the baseline period.

Notes:

Estimate of hatchery-spawned fish is the total number of chinook salmon identified as fall and spring run at Feather River hatchery. Fall- and spring-run chinook salmon were combined because hatchery produced spring-run are believed to be distinct from naturally produced spring run in other rivers and because returns of coded-wire tagged spring run adults suggest that they are not behaviorally distinct from fall run.

Estimate of "Proportion harvested instream" based on data in draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990) and in Dettman and Kelley (1987). Proportion of production produced in a hatchery assumed to be 0 prior to first expected returns of progeny produced at the Feather River Hatchery.

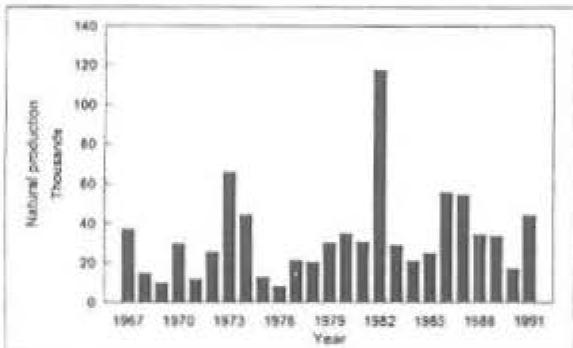
Description of variables named in worksheet:

E(f,n,fe)	Escapement (naturally spawning fish in the Feather River)
E(f,h,fe)	Escapement (to hatcheries in the Feather River)
E(f,t,fe)	Escapement naturally and to hatcheries in the Feather River)
H(f,i,fe)	Harvest (in the Feather River, estimated as E(f,t,fe)* prop. harvested instream)
P(f,i,fe)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,fe)	Harvest (ocean harvest of fall-run salmon assigned to the Feather River)
P(f,t,fe)	Production (total Feather River)
h	Proportion hatchery
P(f,n,fe)	Production (natural production for the Feather River)
DFG	Data taken from Mills and Fisher (1994).

Yuba River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,yu)	DFG E(f,h,yu)	E(f,t,yu)	Proportion harvested instream	H(f,i,yu)	P(f,i,yu)	P(f,i,yu)/ P(f,i,cv)	H(f,o,yu)	P(f,t,yu)	h	P(f,n,yu)
1967	23500	0	23500	0.1	2350	25850	0.12	11356	37206	0	37206
1968	7000	0	7000	0.1	700	7700	0.03	7004	14704	0	14704
1969	5230	0	5230	0.1	523	5753	0.02	3935	9688	0	9688
1970	13830	0	13830	0.1	1383	15213	0.06	14206	29419	0	29419
1971	5650	0	5650	0.1	565	6215	0.02	5171	11386	0	11386
1972	9258	0	9258	0.1	926	10184	0.06	15207	25391	0	25391
1973	24119	0	24119	0.1	2412	26531	0.08	39046	65577	0	65577
1974	17809	0	17809	0.1	1781	19590	0.07	24860	44450	0	44450
1975	5641	0	5641	0.1	564	6205	0.03	6461	12666	0	12666
1976	3779	0	3779	0.1	378	4157	0.02	3901	8058	0	8058
1977	8722	0	8722	0.1	872	9594	0.04	11810	21404	0	21404
1978	7416	0	7416	0.1	742	8158	0.04	12222	20379	0	20379
1979	12430	0	12430	0.1	1243	13673	0.05	16171	29844	0	29844
1980	12406	0	12406	0.1	1241	13647	0.06	21409	35055	0	35055
1981	14025	0	14025	0.1	1403	15428	0.05	15193	30621	0	30621
1982	39367	0	39367	0.1	3937	43304	0.16	74187	117491	0	117491
1983	14256	0	14256	0.1	1426	15682	0.06	13547	29229	0	29229
1984	9965	0	9965	0.1	997	10962	0.04	10133	21095	0	21095
1985	13066	0	13066	0.1	1307	14373	0.03	10538	24911	0	24911
1986	19406	0	19406	0.1	1941	21347	0.06	34367	55714	0	55714
1987	18510	0	18510	0.1	1851	20361	0.06	34110	54471	0	54471
1988	8501	0	8501	0.1	850	9351	0.03	25198	34549	0	34549
1989	9837	0	9837	0.1	984	10821	0.05	22875	33696	0	33696
1990	4000	0	4000	0.1	400	4400	0.03	12580	16980	0	16980
1991	13979	0	13979	0.1	1398	15377	0.10	28899	44276	0	44276
Mean	12868	0	12868	0.1	1287	14155	0.05	18975	33130	0.0	33130

Restoration goal: 66261



Estimated natural production [P(f,n,yu)] for fall-run in the Yuba River for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

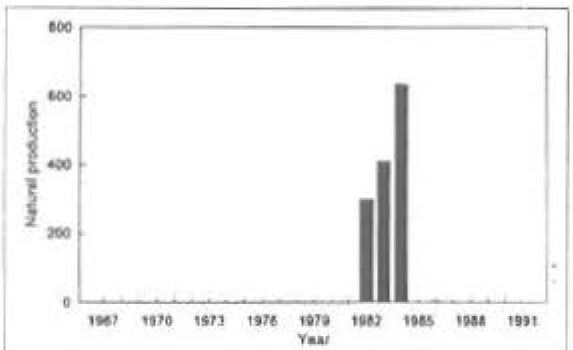
Description of variables named in worksheet:

E(f,n,yu)	Escapement (naturally spawning fish in the Yuba River)
E(f,h,yu)	Escapement (to hatcheries in the Yuba River)
E(f,t,yu)	Escapement naturally and to hatcheries in the Yuba River)
H(f,i,yu)	Harvest (in the Yuba River, estimated as E(f,t,yu)* prop. harvested instream)
P(f,i,yu)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,yu)	Harvest (ocean harvest of fall-run salmon assigned to the Yuba River)
P(f,t,yu)	Production (total Yuba River)
h	Proportion hatchery
P(f,n,yu)	Production (natural production for the Yuba River)
DFG	Data taken from Mills and Fisher (1994)

Bear River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,be)	DFG E(f,h,be)	E(f,t,be)	Proportion harvested instream	H(f,i,be)	P(f,i,be)	P(f,i,be)/ P(f,i,cv)	H(f,o,be)	P(f,t,be)	h	P(f,n,be)
1967											
1968											
1969											
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978	0	0	0	0.1	0	0	0.00	0	0	0	0
1979											
1980	0	0	0	0.1	0	0	0.00	0	0	0	0
1981											
1982	100	0	100	0.1	10	110	0.00	188	298	0	298
1983	200	0	200	0.1	20	220	0.00	190	410	0	410
1984	300	0	300	0.1	30	330	0.00	305	635	0	635
1985											
1986	1	0	1	0.1	0	1	0.00	2	3	0	3
1987											
1988											
1989											
1990											
1991											
Mean	100	0	100	0	10	110	0	114	224	0	224

Restoration goal: 449



Estimated natural production [P(f,n,be)] for fall-run in the Bear River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Due to inadequate flow releases below the South Sutter Water District's diversion dam, there are no self-sustaining runs of chinook salmon in the Bear River.

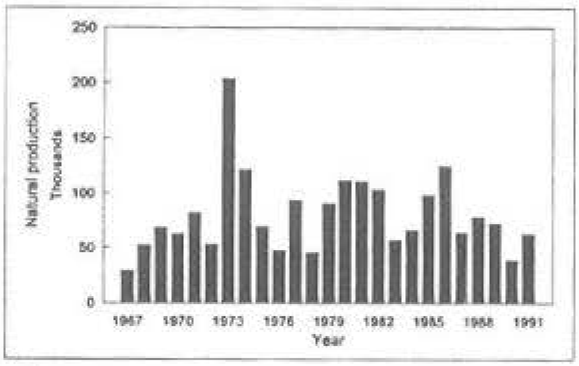
Description of variables named in worksheet:

E(f,n,be)	Escapement (naturally spawning fish in the Bear River)
E(f,h,be)	Escapement (to hatcheries in the Bear River)
E(f,t,be)	Escapement naturally and to hatcheries in the Bear River)
H(f,i,be)	Harvest (in the Bear River, estimated as E(f,t,be)* prop. harvested instream)
P(f,i,be)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,be)	Harvest (ocean harvest of fall-run salmon assigned to the Bear River)
P(f,t,be)	Production (total Bear River)
h	Proportion hatchery
P(f,n,be)	Production (natural production for the Bear River)
DFG	Data taken from Mills and Fisher (1994).

American River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,am)	DFG E(f,h,am)	E(f,t,am)	Proportion harvested instream	H(f,i,am)	P(f,i,am)	P(f,i,am)/ P(f,i,cv)	H(f,o,am)	P(f,t,am)	*h*	P(f,n,am)
1967	18000	5147	23147	0.45	10416	33563	0.16	14745	48308	0.4	28985
1968	26200	5233	31433	0.45	14145	45578	0.19	41461	87039	0.4	52223
1969	43660	3605	47265	0.45	21269	68534	0.18	46882	115416	0.4	69250
1970	28680	8629	37309	0.45	16789	54098	0.20	50516	104614	0.4	62768
1971	41680	10110	51790	0.45	23306	75096	0.27	62485	137580	0.4	82548
1972	17459	7042	24501	0.45	11025	35526	0.20	53052	88578	0.4	53147
1973	82242	12535	94777	0.45	42650	137427	0.41	202253	339680	0.4	203808
1974	53596	8200	61796	0.45	27808	89604	0.31	113711	203315	0.4	121989
1975	32132	7412	39544	0.45	17795	57339	0.24	59707	117046	0.4	70227
1976	23159	5215	28374	0.45	12768	41142	0.18	38606	79748	0.4	47849
1977	41605	6868	48473	0.45	21813	70286	0.31	86516	156802	0.4	94081
1978	12929	8162	21091	0.45	9491	30582	0.17	45817	76399	0.4	45839
1979	37315	10351	47666	0.45	21450	69116	0.26	81742	150858	0.4	90515
1980	34259	15543	49802	0.45	22411	72213	0.34	113287	185500	0.4	111300
1981	43462	20593	64055	0.45	28825	92880	0.30	91468	184348	0.4	110609
1982	33000	10898	43898	0.45	19754	63652	0.23	109048	172700	0.4	103620
1983	26400	8900	35300	0.45	15885	51185	0.21	44218	95403	0.4	57242
1984	27447	12249	39696	0.45	17863	57559	0.19	53209	110769	0.4	66461
1985	56120	9093	65213	0.45	29346	94559	0.22	69333	163891	0.4	98335
1986	49372	5695	55067	0.45	24780	79847	0.23	128551	208398	0.4	125039
1987	21145	6497	27642	0.45	12439	40081	0.12	67145	107226	0.4	64336
1988	15879	8625	24504	0.45	11027	35531	0.11	95743	131274	0.4	78764
1989	17078	9740	26818	0.45	12068	38886	0.18	82205	121091	0.4	72655
1990	6708	4857	11565	0.45	5204	16769	0.12	47944	64714	0.4	38828
1991	18145	7128	25273	0.45	11373	36646	0.23	68871	105517	0.4	63310
Mean	32307	8733	41040	0.45	18468	59508	0.22	74741	134249	0.4	80549

Restoration goal: 161098



Estimated natural production [P(f,n,am)] for fall-run in the American River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data in draft summaries of 1991-1993 angler surveys.

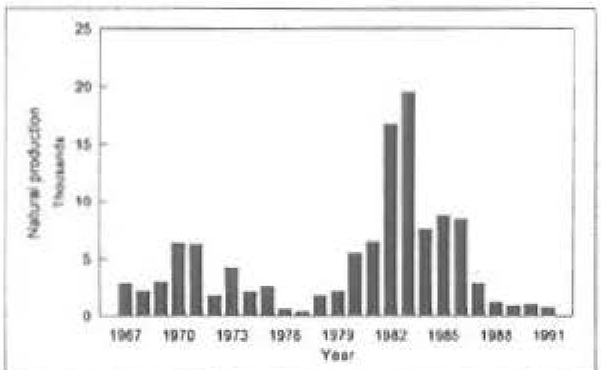
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990) and in Dettman and Kelley (1986, 1987).

Description of variables named in worksheet:

E(f,n,am)	Escapement (naturally spawning fish in the American River)
E(f,h,am)	Escapement (to hatcheries in the American River)
E(f,t,am)	Escapement naturally and to hatcheries in the American River)
H(f,i,am)	Harvest (in the American River, estimated as E(f,t,am)* prop. harvested instream)
P(f,i,am)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,am)	Harvest (ocean harvest of fall-run salmon assigned to the American River)
P(f,t,am)	Production (total American River)
h	Proportion hatchery
P(f,n,am)	Production (natural production for the American River)
DFG	Data taken from Mills and Fisher (1994).

Mokelumne River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,mo)	DFG E(f,h,mo)	E(f,t,mo)	Proportion harvested instream	H(f,i,mo)	P(f,i,mo)	P(f,i,mo)/ P(f,i,cv)	H(f,o,mo)	P(f,t,mo)	*h*	P(f,n,mo)
1967	2750	250	3000	0.1	300	3300	0.02	1450	4750	0.4	2850
1968	753	954	1707	0.1	171	1878	0.01	1708	3586	0.4	2151
1969	2070	615	2685	0.1	269	2954	0.01	2020	4974	0.4	2984
1970	4092	908	5000	0.1	500	5500	0.02	5136	10636	0.4	6381
1971	3970	1230	5200	0.1	520	5720	0.02	4759	10479	0.4	6288
1972	749	353	1102	0.1	110	1212	0.01	1810	3022	0.4	1813
1973	2192	408	2600	0.1	260	2860	0.01	4209	7069	0.4	4241
1974	1202	220	1422	0.1	142	1564	0.01	1985	3549	0.4	2130
1975	1501	399	1900	0.1	190	2090	0.01	2176	4266	0.4	2560
1976	399	74	473	0.1	47	520	0.00	488	1009	0.4	605
1977	250	0	250	0.1	25	275	0.00	339	614	0.4	368
1978	602	484	1086	0.1	109	1195	0.01	1790	2984	0.4	1791
1979	1000	507	1507	0.1	151	1658	0.01	1961	3618	0.4	2171
1980	2592	639	3231	0.1	323	3554	0.02	5576	9130	0.4	5478
1981	3568	1386	4954	0.1	495	5449	0.02	5367	10816	0.4	6490
1982	6695	2677	9372	0.1	937	10309	0.04	17662	27971	0.4	16782
1983	11293	4573	15866	0.1	1587	17453	0.07	15077	32530	0.4	19518
1984	5075	959	6034	0.1	603	6637	0.02	6136	12773	0.4	7664
1985	7479	223	7702	0.1	770	8472	0.02	6212	14684	0.4	8811
1986	3006	1913	4919	0.1	492	5411	0.02	8711	14122	0.4	8473
1987	1020	630	1650	0.1	165	1815	0.01	3041	4856	0.4	2913
1988	384	128	512	0.1	51	563	0.00	1518	2081	0.4	1248
1989	400	80	480	0.1	48	528	0.00	1116	1644	0.4	987
1990	363	68	431	0.1	43	474	0.00	1355	1830	0.4	1098
1991	410		410	0.1	41	451	0.00	848	1299	0.4	779
Mean	2553	820	3340	0.1	334	3674	0.01	4098	7772	0.4	4663
									Restoration goal:		9326



Estimated natural production [P(f,n,mo)] for fall-run in the Mokelumne River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

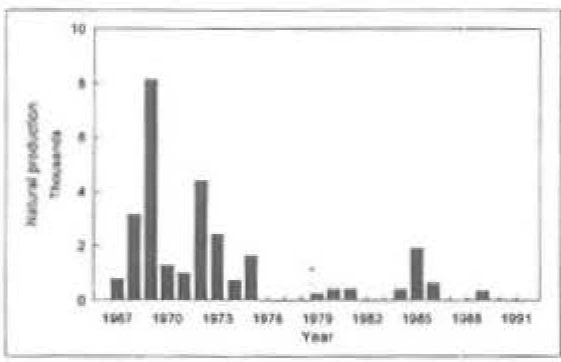
Description of variables named in worksheet:

E(f,n,mo)	Escapement (naturally spawning fish in the Mokelumne River)
E(f,h,mo)	Escapement (to hatcheries in the Mokelumne River)
E(f,t,mo)	Escapement naturally and to hatcheries in the Mokelumne River)
H(f,i,mo)	Harvest (in the Mokelumne River, estimated as E(f,t,mo)* prop. harvested instream)
P(f,i,mo)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,mo)	Harvest (ocean harvest of fall-run salmon assigned to the Mokelumne River)
P(f,t,mo)	Production (total Mokelumne River)
h	Proportion hatchery
P(f,n,mo)	Production (natural production for the Mokelumne River)
DFG	Data taken from Mills and Fisher (1994)

Cosumnes River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,co)	DFG E(f,h,co)	E(f,t,co)	Proportion harvested instream	H(f,i,co)	P(f,i,co)	P(f,i,co)/ P(f,i,cv)	H(f,o,co)	P(f,t,co)	h	P(f,n,co)
1967	500	0	500	0.1	50	550	0.00	242	792	0	792
1968	1500	0	1500	0.1	150	1650	0.01	1501	3151	0	3151
1969	4400	0	4400	0.1	440	4840	0.01	3311	8151	0	8151
1970	600	0	600	0.1	60	660	0.00	616	1276	0	1276
1971	500	0	500	0.1	50	550	0.00	458	1008	0	1008
1972	1600	0	1600	0.1	160	1760	0.01	2628	4388	0	4388
1973	900	0	900	0.1	90	990	0.00	1457	2447	0	2447
1974	285	0	285	0.1	29	314	0.00	398	711	0	711
1975	725	0	725	0.1	73	798	0.00	830	1628	0	1628
1976											
1977											
1978											
1979	100	0	100	0.1	10	110	0.00	130	240	0	240
1980	150	0	150	0.1	15	165	0.00	259	424	0	424
1981	200	0	200	0.1	20	220	0.00	217	437	0	437
1982	5	0	5	0.1	1	6	0.00	9	15	0	15
1983											
1984	200	0	200	0.1	20	220	0.00	203	423	0	423
1985	1000	0	1000	0.1	100	1100	0.00	807	1907	0	1907
1986	220	0	220	0.1	22	242	0.00	390	632	0	632
1987											
1988											
1989	100	0	100	0.1	10	110	0.00	233	343	0	343
1990											
1991											
Mean	764	0	764	0.1	76	840	0.00	805	1645	0.0	1645

Restoration goal: 3291



Estimated natural production [P(f,n,co)] for fall-run in the Cosumnes River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

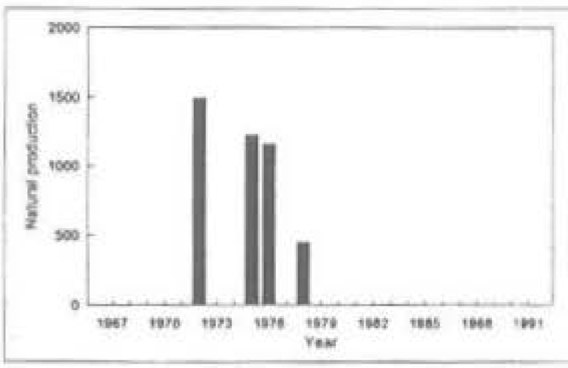
Abundance estimates for runs of chinook salmon other than fall-run have have not been made.

Description of variables named in worksheet:

E(f,n,co)	Escapement (naturally spawning fish in the Cosumnes River)
E(f,h,co)	Escapement (to hatcheries in the Cosumnes River)
E(f,t,co)	Escapement naturally and to hatcheries in the Cosumnes River)
H(f,i,co)	Harvest (in the Cosumnes River, estimated as E(f,t,co)* prop. harvested instream)
P(f,i,co)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,co)	Harvest (ocean harvest of fall-run salmon assigned to the Cosumnes River)
P(f,t,co)	Production (total Cosumnes River)
h	Proportion hatchery
P(f,n,co)	Production (natural production for the Cosumnes River)
DFG	Data taken from Mills and Fisher (1994).

Calaveras River: Production estimates for winter-run chinook salmon.

Year	DFG E(w.n.ca)	DFG E(w.h.ca)	E(w.t.ca)	Proportion harvested instream	H(w.i.ca)	P(w.i.ca)	P(w,i,ca)/ P(w.i.cv)	H(w.o.ca)	P(w.t.ca)	h	P(w.n.ca)
1967											
1968											
1969											
1970											
1971											
1972	500	0	500	0.2	100	600	0.01	896	1496	0	1496
1973											
1974											
1975	500	0	500	0.2	100	600	0.02	625	1225	0	1225
1976	500	0	500	0.2	100	600	0.01	563	1163	0	1163
1977											
1978	150	0	150	0.2	30	180	0.01	270	450	0	450
1979											
1980											
1981											
1982											
1983											
1984											
1985											
1986											
1987											
1988											
1989											
1990											
1991											
Mean	413	0	413	0.2	361	495	0.01	588	1083	0.0	1083
									Restoration goal:		2167



Estimated natural production [P(w,n,ca)] for winter-run in the Calaveras River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

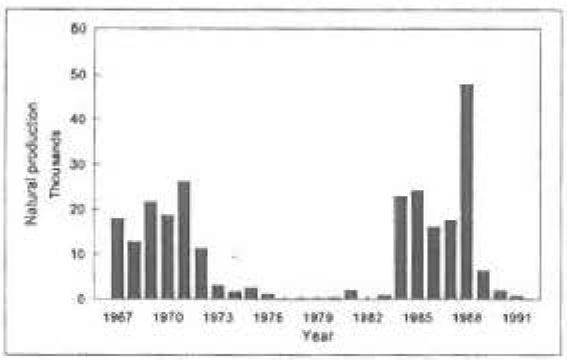
Estimate of h (proportion of production produced in a hatchery) based on absence of hatchery production of winter-run chinook salmon prior to 1991.

Description of variables named in worksheet:

E(w,n,ca) Escapement (naturally spawning fish in the Calaveras River)
E(w,h,ca) Escapement (to hatcheries in the Calaveras River)
E(w,t,ca) Escapement naturally and to hatcheries in the Calaveras River)
H(w,i,ca) Harvest (in the Calaveras River, estimated as E(w,t,ca)* prop. harvested instream)
P(w,i,ca) Production (total escapement plus instream harvest)
P(w,i,cv) Production (total Central Valley)
H(w,o,ca) Harvest (ocean harvest of fall-run salmon assigned to the Calaveras River)
P(w,t,ca) Production (total Calaveras River)
h Proportion hatchery
P(w,n,ca) Production (natural production for the Calaveras River)
DFG Data taken from Mills and Fisher (1994)

Stanislaus River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,st)	DFG E(f,h,st)	E(f,t,st)	Proportion harvested instream	H(f,i,st)	P(f,i,st)	P(f,i,st)/ P(f,i,cv)	H(f,o,st)	P(f,t,st)	h	P(f,n,st)
1967	11885	0	11885	0.05	594	12479	0.06	5482	17961	0	17961
1968	6385	0	6385	0.05	319	6704	0.03	6099	12803	0	12803
1969	12327	0	12327	0.05	616	12943	0.03	8854	21797	0	21797
1970	9297	0	9297	0.05	465	9762	0.04	9115	18877	0	18877
1971	13621	0	13621	0.05	681	14302	0.05	11900	26202	0	26202
1972	4298	0	4298	0.05	215	4513	0.02	6739	11252	0	11252
1973	1234	0	1234	0.05	62	1296	0.00	1907	3203	0	3203
1974	750	0	750	0.05	38	788	0.00	999	1787	0	1787
1975	1200	0	1200	0.05	60	1260	0.01	1312	2572	0	2572
1976	600	0	600	0.05	30	630	0.00	591	1221	0	1221
1977	0	0	0	0.05	0	0	0.00	0	0	0	0
1978	50	0	50	0.05	3	53	0.00	79	131	0	131
1979	100	0	100	0.05	5	105	0.00	124	229	0	229
1980	100	0	100	0.05	5	105	0.00	165	270	0	270
1981	1000	0	1000	0.05	50	1050	0.00	1034	2084	0	2084
1982											
1983	500	0	500	0.05	25	525	0.00	454	979	0	979
1984	11439	0	11439	0.05	572	12011	0.04	11103	23114	0	23114
1985	13322	0	13322	0.05	666	13988	0.03	10256	24244	0	24244
1986	5888	0	5888	0.05	294	6182	0.02	9953	16136	0	16136
1987	6292	0	6292	0.05	315	6607	0.02	11068	17674	0	17674
1988	12344	0	12344	0.05	617	12961	0.04	34926	47887	0	47887
1989	1968	0	1968	0.05	98	2066	0.01	4368	6435	0	6435
1990	492	0	492	0.05	25	517	0.00	1477	1994	0	1994
1991	272	0	272	0.05	14	286	0.00	537	822	0	822
Mean	4807	0	4807	0.05	240	5047	0.02	5773	10820	0	10820
									Restoration goal:		21640



Estimated natural production [P(f,n,st)] for fall-run in the Stanislaus River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

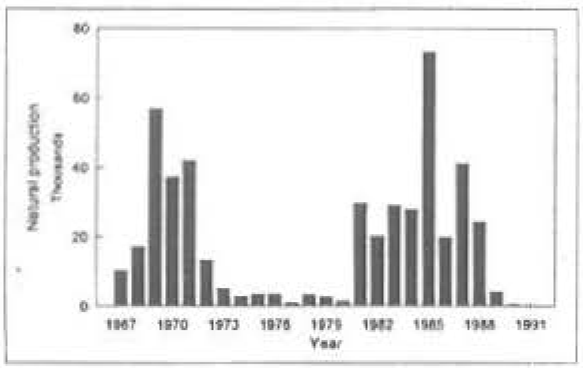
Estimate of h (proportion of production produced in a hatchery) based on lack of a hatchery on the Stanislaus River.

Description of variables named in worksheet:

E(f,n,st)	Escapement (naturally spawning fish in the Stanislaus River)
E(f,h,st)	Escapement (to hatcheries in the Stanislaus River)
E(f,t,st)	Escapement naturally and to hatcheries in the Stanislaus River)
H(f,i,st)	Harvest (in the Stanislaus River, estimated as E(f,t,st)* prop. harvested instream)
P(f,i,st)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,st)	Harvest (ocean harvest of fall-run salmon assigned to the Stanislaus River)
P(f,t,st)	Production (total Stanislaus River)
h	Proportion hatchery
P(f,n,st)	Production (natural production for the Stanislaus River)
DFG	Data taken from Mills and Fisher (1994).

Toulumne River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,to)	DFG E(f,h,to)	E(f,t,to)	Proportion harvested instream	H(f,i,to)	P(f,i,to)	P(f,i,to)/ P(f,i,cv)	H(f,o,to)	P(f,t,to)	h	P(f,n,to)
1967	6800	0	6800	0.05	340	7140	0.03	3137	10277	0	10277
1968	8600	0	8600	0.05	430	9030	0.04	8214	17244	0	17244
1969	32200	0	32200	0.05	1610	33810	0.09	23128	56938	0	56938
1970	18400	0	18400	0.05	920	19320	0.07	18041	37361	0	37361
1971	21885	0	21885	0.05	1094	22979	0.08	19120	42100	0	42100
1972	5100	0	5100	0.05	255	5355	0.03	7997	13352	0	13352
1973	1989	0	1989	0.05	99	2088	0.01	3074	5162	0	5162
1974	1150	0	1150	0.05	58	1208	0.00	1532	2740	0	2740
1975	1600	0	1600	0.05	80	1680	0.01	1749	3429	0	3429
1976	1700	0	1700	0.05	85	1785	0.01	1675	3460	0	3460
1977	450	0	450	0.05	23	473	0.00	582	1054	0	1054
1978	1300	0	1300	0.05	65	1365	0.01	2045	3410	0	3410
1979	1183	0	1183	0.05	59	1242	0.00	1469	2711	0	2711
1980	559	0	559	0.05	28	587	0.00	921	1508	0	1508
1981	14253	0	14253	0.05	713	14966	0.05	14738	29704	0	29704
1982	7126	0	7126	0.05	356	7482	0.03	12819	20301	0	20301
1983	14836	0	14836	0.05	742	15578	0.06	13457	29035	0	29035
1984	13802	0	13802	0.05	690	14492	0.05	13397	27889	0	27889
1985	40322	0	40322	0.05	2016	42338	0.10	31043	73381	0	73381
1986	7288	0	7288	0.05	364	7652	0.02	12320	19972	0	19972
1987	14751	0	14751	0.05	738	15489	0.05	25947	41436	0	41436
1988	6349	0	6349	0.05	317	6666	0.02	17964	24630	0	24630
1989	1274	0	1274	0.05	64	1338	0.01	2828	4166	0	4166
1990	96	0	96	0.05	5	101	0.00	288	389	0	389
1991	53	0	53	0.05	3	56	0.00	105	160	0	160
Mean	8923	0	8923	0.05	446	9369	0.03	9504	18872	0	18872
									Restoration goal:		37745



Estimated natural production [P(f,n,to)] for fall-run in the Toulumne River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

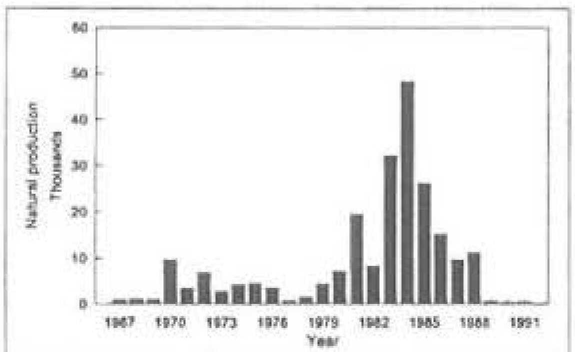
Estimate of h (proportion of production produced in a hatchery) based on lack of a hatchery on the Toulumne River.

Description of variables named in worksheet:

E(f,n,to) Escapement (naturally spawning fish in the Toulumne River)
E(f,h,to) Escapement (to hatcheries in the Toulumne River)
E(f,t,to) Escapement naturally and to hatcheries in the Toulumne River)
H(f,i,to) Harvest (in the Toulumne River, estimated as E(f,t,to)* prop. harvested instream)
P(f,i,to) Production (total escapement plus instream harvest)
P(f,i,cv) Production (total Central Valley)
H(f,o,to) Harvest (ocean harvest of fall-run salmon assigned to the Toulumne River)
P(f,t,to) Production (total Toulumne River)
h Proportion hatchery
P(f,n,to) Production (natural production for the Toulumne River)
DFG Data taken from Mills and Fisher (1994).

Merced River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,me)	DFG E(f,h,me)	E(f,t,me)	Proportion harvested instream	H(f,i,me)	P(f,i,me)	P(f,i,me)/ P(f,i,cv)	H(f,o,me)	P(f,t,me)	*h*	P(f,n,me)
1967	600	0	600	0.05	30	630	0.00	277	907	0	907
1968	550	0	550	0.05	28	576	0.00	525	1103	0	1103
1969	600	0	600	0.05	30	630	0.00	431	1061	0	1061
1970	4700	100	4800	0.05	240	5040	0.02	4706	9746	0	9746
1971	1590	200	1790	0.05	90	1880	0.01	1564	3443	0	3443
1972	2528	120	2648	0.05	132	2780	0.02	4152	6932	0	6932
1973	797	375	1172	0.05	59	1231	0.00	1811	3042	0.1	2738
1974	1000	1000	2000	0.05	100	2100	0.01	2665	4765	0.1	4288
1975	1700	700	2400	0.05	120	2520	0.01	2624	5144	0.1	4630
1976	1200	700	1900	0.05	95	1995	0.01	1872	3867	0.1	3480
1977	350	0	350	0.05	18	368	0.00	452	820	0.1	738
1978	525	100	625	0.05	31	656	0.00	983	1639	0.1	1475
1979	1920	227	2147	0.05	107	2254	0.01	2666	4921	0.1	4428
1980	2851	157	3008	0.05	150	3158	0.02	4955	8113	0.1	7302
1981	9491	924	10415	0.05	521	10936	0.03	10770	21705	0.1	19535
1982	3074	189	3263	0.05	163	3426	0.01	5870	9296	0.1	8366
1983	16453	1795	18248	0.05	912	19160	0.08	16552	35713	0.1	32141
1984	24660	1885	26545	0.05	1327	27872	0.09	25766	53638	0.1	48274
1985	14841	1211	16052	0.05	803	16855	0.04	12358	29213	0.1	26291
1986	5523	650	6173	0.05	309	6482	0.02	10435	16917	0.1	15225
1987	2895	958	3853	0.05	193	4046	0.01	6777	10823	0.1	9741
1988	2760	457	3217	0.05	161	3378	0.01	9102	12480	0.1	11232
1989	129	82	211	0.05	11	222	0.00	468	690	0.1	621
1990	24	49	73	0.05	4	77	0.00	219	296	0.1	266
1991	119	41	160	0.05	8	168	0.00	316	484	0.1	435
Mean	4035	477	4512	0.05	226	4738	0.02	5133	9870	0.1	8976
									Restoration goal:		17952



Estimated natural production [P(f,n,me)] for fall-run in the Merced River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

Estimate of h (proportion of production produced in a hatchery) based on the following considerations: 1) There are not existing estimates; 2) The first returns of Merced River Fish Facility produced chinook salmon were expected in 1973; 3) The Merced River Fish Facility is small in relation to chinook salmon production facilities elsewhere in the Central Valley for which existing estimates of h were less than 0.4.

Description of variables named in worksheet:

E(f,n,me)	Escapement (naturally spawning fish in the Merced River)
E(f,h,me)	Escapement (to hatcheries in the Merced River)
E(f,t,me)	Escapement naturally and to hatcheries in the Merced River)
H(f,i,me)	Harvest (in the Merced River, estimated as E(f,t,me)* prop. harvested instream)
P(f,i,me)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,me)	Harvest (ocean harvest of fall-run salmon assigned to the Merced River)
P(f,t,me)	Production (total Merced River)
h	Proportion hatchery
P(f,n,me)	Production (natural production for the Merced River)
DFG	Data taken from Mills and Fisher (1994).

APPENDIX B

Estimation of Natural Production of Steelhead Upstream of RBDD

To estimate the restoration goal for steelhead spawning in the Sacramento River upstream of RBDD during the baseline period, it was assumed that no naturally produced fish spawned in the hatchery and that the proportion of hatchery-produced fish that spawned naturally was 0.29% of the total of inland harvest and natural escapement (Table B-1).

Table B-1. Inland harvest, escapement, and natural production for steelhead during the baseline period in the mainstem Sacramento River upstream of RBDD (Mills and Fisher 1994).

Year	Inland harvest	Natural escapement	Natural production
1967	5,819	15,312	15,003
1968	7,454	19,615	19,219
1969	5,784	15,222	14,915
1970	5,031	13,240	12,973
1971	4,517	1,187	11,647
1972	2,296	6,041	5,919
1973	3,390	8,921	8,714
1974	2,717	7,150	7,006
1975	2,120	5,579	5,466
1976	3,383	8,902	8,722
1977	2,318	6,099	5,976
1978	960	2,527	2,476
1979	1,330	3,499	3,428
1980	4,517	11,887	11,647
1981	1,278	3,363	3,295
1982	1,048	2,757	2,701
1983	1,325	3,486	3,416
1984	774	2,036	1,995
1985	1,706	4,489	4,398

Year	Inland harvest	Natural escapement	Natural production
1986	1,432	3,769	3,693
1987	863	2,272	2,226
1988	179	1,872	1,834
1989	711	470	461
1990	863	2,272	2,226
1991	377	991	971
Mean	2,488	6,546	6,414
SD	1,946	5,120	5,017
Goal			>=12,828

F. STRIPED BASS

Baseline Natural Production and Goals

Baseline period abundance of adult striped bass (fish 15 inches FL before 1982 and fish 16.5 inches FL since 1982) was estimated from mark-recapture studies conducted since 1969. A modified Petersen estimator was used:

$$N = M(C+1)/(R+1)$$

Where N = bass abundance
M = number of tagged fish released
C = number of fish subsequently examined for tags
R = number of tagged fish in the recapture sample

Gill nets and fyke traps are used to capture bass during their spring spawning migration to the Delta and Sacramento River. The fish are tagged with individually numbered disc-dangler tags and released. The population is sampled during a census of angler catches that is conducted during subsequent spring tagging.

From 3,100 to 18,400 tags have been applied annually. Creel census clerks, sampling at four to six fishing ports from Wednesday to Sunday each week, have observed from 1,500 to 38,700 bass and from 16 to 891 tags annually. Since 1969, the tagged:untagged ratio has varied from 1:37 (1973) to 1:108 (1985). The abundance estimation procedures are complicated by sex- and age-sampling biases; therefore, all tagging and recapture samples are stratified by sex and age.

Table 3-Xf-1. Estimated abundance of adult striped bass in the Central Valley, 1967-1991.

Year	Adult striped bass abundance	Year	Adult striped bass abundance
1967	1,948,000	1980	1,115,999
1968	1,944,000	1981	911,300
1969	1,646,026	1982	825,126
1970	1,727,394	1983	1,009,748
1971	1,599,715	1984	1,042,668
1972	1,882,907	1985	1,024,188

Year	Adult striped bass abundance	Year	Adult striped bass abundance
1973	1,637,159	1986	1,037,127
1974	1,477,213	1987	998,349
1975	1,849,770	1988	892,413
1976	1,581,076	1989	724,580
1977	924,301	1990	574,364
1978	1,151,642	1991	625,702
1979	1,155,701	Mean	1,252,259

Goals - Production goals are double the estimated abundance shown in Table 3-Xf-1, about 2.5 million adult striped bass.

Outflow, export, and stocking considerations - The model developed for the technical team by Dr. Loo Botsford of the University of California, Davis, (Botsford and Brittnacher 1994) related abundance of adult striped bass to Delta outflow, total exports, and stocking of yearling striped bass. Exports include water pumped at the State Water Project (SWP), Central Valley Project (CVP), Contra Costa Canal (CCC), and North Bay Aqueduct from August through March and at all of these and Delta agricultural diversions from April through July. Because most of the spawning and rearing habitat for striped bass is located in the delta and the lower reaches of the Sacramento and San Joaquin rivers, the team has not included recommendations for the specific contributions of individual tributaries to total outflow. If the recommendations were implemented, flow should be allocated between the Sacramento and San Joaquin rivers, and between individual tributaries, to reflect requirements of the other anadromous fish species.

The Striped Bass Technical Team has noted that because the export and outflow levels required to double the striped bass population will be viewed as unreasonable by water user groups, they are unlikely to be implemented. In addition, the standards established by the December 15, 1994 Delta Accord are viewed by many parties as a constraint on further adjustments to outflow and exports for a period of at least 3 years. With this in mind, the team evaluated projected outflow and exports levels with the model developed by Botsford and Brittnacher.

Delta Accord based outflow and exports, as predicted by DWRSIM (Tables 3-Xf-2 and 3-Xf-3), appear to be inadequate to restore the striped bass population. The Botsford-Brittnacher model predicts that conditions resulting from the Delta Accord would maintain 697,000 adult striped bass systemwide; the California Department of Fish and Game=s model predicts 425,000 adults. If the actual number falls between these predicted values, the resulting adult population would be similar to the current low level of 550,000.

Table 3-Xf-2. Monthly Average Delta Outflow (cfs) required to meet 15 December 1994 Delta Accord X2 salinity standards as projected by DWRSIM.

Month	Wet	Above normal	Below normal	Dry	Critical
October	11,344	6,315	7,443	6,071	4,507
November	18,766	13,931	8,260	8,323	5,196
December	50,715	16,631	13,446	8,124	6,002
January	78,116	42,363	19,623	9,778	7,383
February	94,325	61,425	35,884	18,015	11,207
March	75,981	59,919	22,220	17,847	10,415
April	53,118	27,423	15,493	11,829	8,667
May	34,189	18,048	12,799	8,785	5,645
June	19,357	10,281	8,640	6,936	6,120
July	9,528	8,985	7,532	6,995	4,979
August	5,933	6,176	5,622	5,256	3,418
September	8,021	4,239	3,838	3,711	3,008
Total	27,675	16,599	9,672	6,733	4,616

Note: Data are preliminary and subject to change.

Table 3-Xf-3. Combined CVP/SWP exports (cfs) under the 15 December 1995 Delta Accord X2 as projected by DWRSIM.

Month	Wet	Above normal	Below normal	Dry	Critical
October	10,472	9,648	8,981	7,871	5,487
November	9,819	10,292	9,286	7,618	5,105

December	8,962	10,484	10,783	9,322	8,632
January	9,964	11,434	10,184	9,583	9,62
February	9,263	9,582	8,576	9,031	6,993
March	7,802	8,286	8,573	7,740	5,433
April	7,591	6,913	6,002	4,464	3,269
May	7,080	6,795	5,641	4,064	2,978
June	8,734	7,030	6,678	5,583	4,947
July	8,001	8,553	10,638	10,640	5,869
August	6,160	7,521	8,413	8,443	2,836
September	9,546	7,216	6,767	6,254	3,684
Total (taf)	6,295	6,279	6,090	5,488	3,926

Note: Data are preliminary and subject to change.

Based on these projections, several SBTT members feel that reestablishing a stocking program is essential to the restoration of the striped bass population and the recreational fishery that it supports. The team previously considered the potential of stocking as an initial measure to increase spawning stock and enable the population to sustain itself at a higher level. The Botsford-Brittnacher model suggests that, in absence of any meaningful changes in outflow and exports, the concept of stocking as an initial, temporary measure is not valid; after stocking is terminated, the population will return to levels dictated by outflow and exports. Stocking would increase the total number of adult striped bass over the period for which it is maintained. For example, based on the Botsford-Brittnacher model, stocking 3,000,000 yearling striped bass annually would increase adult numbers to about 900,000. While this would benefit the fishery, it would not contribute to achieving AFRP goals, which, based on Section 3403(h) of Title 34, must be measured as the number of Afish produced to adulthood without direct human intervention in the spawning, rearing or migration processes@.

The technical team notes that in the absence of a substantial improvement in the standards established by the Delta Accord, and/or a renewed stocking program, the striped bass fishery is likely to remain in its current, poor condition, or to decline further. Because the focus of the Anadromous Fish Restoration Program is limited to Anatural production@ it is inappropriate for the SBTT to recommend stocking as a restoration measure; however, the team does recommend that stocking and other measures to restore the striped bass fishery be considered under Section 3406(b)(18), which requires the federal government to Aif requested by the State of California, assist in developing and implementing management measures to restore the striped bass fishery of the Bay-Delta estuary@.

Sacramento-San Joaquin Delta -

Table 3-Xf-4. Limiting factors and potential solutions for striped bass.

Limiting factors	Potential solutions
1. Reduced Delta outflow	1. Increase Delta outflow requirements 2. Reduce export/diversion levels
2. Egg, larvae, and juvenile entrainment and losses at the SWP and CVP Delta pumping plants	1. Reduce export/diversion levels when eggs and larvae and/or juvenile bass appear in great abundance 2. Improve SWP and CVP salvage and transport effectiveness 3. Close the DCC and Georgiana Slough while bass eggs and larvae are passing down the Sacramento River 4. Provide Delta the outflow necessary to move eggs and larvae toward the western Delta and Suisun Bay 5. Install fish screens to prevent entrainment of predator fish into Clifton Court Forebay (CCF) 6. Remove and transplant predators from CCF in winter and early spring
3. Egg, larvae, and juvenile loss and entrainment at the Contra Costa Canal (CCC) diversion	1. Reduce export/diversion levels when eggs and larvae and/or juvenile bass appear in great abundance 2. Develop and implement a salvage- transport program
4. Egg, larvae, and juvenile mortality and entrainment at the PG&E power generating plants	1. Reduce pumping levels when bass egg and/or larvae abundance is high at the intakes 2. If feasible, place a barrier outside of the intakes to keep fish from entering
5. Egg, larvae, and juvenile	1. Consolidate and/or relocate diversions to areas with

Limiting factors	Potential solutions
mortality and entrainment at Sherman and Twitchell Island diversions	low bass egg/larvae concentrations 2. Convert islands to a wildlife management area and modify or eliminate diversions
6. Egg, larvae, and juvenile loss and entrainment at private agricultural diversions	1. Consolidate and/or relocate diversions to areas with low bass egg/larvae concentrations 2. Screen all larger diversions on a priority basis to keep out bass longer than 1.5 inches 3. Improve water distribution and use schemes throughout the Delta to minimize bass losses while meeting water demands
7. San Joaquin River water quality barrier to migration of adult striped bass	1. Increase Delta inflow, especially in the San Joaquin River at Vernalis 2. Implement more stringent salinity standards for the lower San Joaquin River 3. Improve the quality of agricultural return water
8. High toxic chemical and trace metal concentrations in Delta water	1. Regulate agricultural pesticides in Delta return drains to ensure proper fishery safeguards 2. Support SWRCB and RWQCB programs to control point and nonpoint sources of water pollution 3. Continue aggressive program to detect violations of water pollution laws, improve pollution investigations, and improve incident response capabilities
9. High toxic chemical and trace metal concentrations in dredge spoils, and spoil disposal turbidity	1. Discontinue current in-bay dredge and spoil disposal practices, and dispose of spoils in a deep ocean site instead 2. Deny approval of on-land disposal sites where there is potential for adverse impacts on wetlands or other fish or wildlife habitats

Limiting factors	Potential solutions
	3. Allow only spoils free of toxicity and/or contaminants to be discharged to estuary or ocean waters
10. Reduction of habitat, especially for juveniles, resulting from the filling of Bay and Delta tidelands	1. Identify fill projects that should be opposed because of impacts on striped bass and their habitat 2. Prohibit all but public water- dependent fill projects 3. Require from the projects that are approved mitigation in the form of wetlands and/or tidal waters to compensate for unavoidably filled habitat
11. Illegal take and poaching	1. Encourage public and angler use of the Cal-Tip program 2. Increase law enforcement efforts 3. Inform the involved courts and judges of concerns about the striped bass resource so that maximum penalties are imposed on violators
12. Competition of introduced exotic species with bass and/or their food supplies	1. Develop federal legislation controlling ballast water management within the Sacramento-San Joaquin Estuary 2. Support the Federal Aquatic Nuisance Species Task Force

Restoration Actions

Action 1: Implement a recommended Delta outflow schedule.

Objective: Provide conditions necessary to sustain a population of 2 million adult striped bass.

Location: Sacramento-San Joaquin Delta.

Narrative Description: The striped bass population of the Delta and its major tributaries has declined from a historical level of 3.0 million adults during the late 1950s and early 1960s to approximately 0.6 million adults today. Delta and upstream diversions and storage by irrigation districts, water agencies, the SWP, and the CVP have collectively resulted in a reduction in Delta outflows. Reduced Delta outflow has resulted in lower San Joaquin River salinity increasing above levels desirable for bass spawning during dry years.

Flows recommended by the Striped Bass Technical Team are based on a model developed by Loo Botsford of the University of California, Davis (Botsford and Brittnacher 1994). The Botsford/Brittnacher model builds on an earlier DFG model, with modifications to provide a better mechanistic representation for the purpose of increasing confidence for projections outside the range of conditions that were extant when the data were collected (Botsford and Brittnacher 1994). Model output consisted of average outflows and exports for April-July and August-March required to sustain a specified number of adult striped bass.

The model results indicate that flows required to double the baseline-period population of adult striped bass exceeded mean unimpaired runoff over the period of record (1922-1990). To limit recommendations to the range of conditions that are likely to occur in the future, flows were reduced to reflect mean unimpaired runoff. The Botsford-Brittnacher model predicts that these flows, in conjunction with a year-round export ceiling of 1,200 cfs, would sustain an adult striped bass population of 2.0 million. Average flows for the two periods were allocated to reflect the month-to-month pattern exhibited by the unimpaired hydrograph (Table 3-Xf-3).

Table 3-Xf-5. Required Delta outflow (cfs) at Chipps Island to sustain a 2.0 million population of striped bass.

Month	Year type				
	Wet	Above normal	Below normal	Dry	Critical
October	11,500	7,500	6,500	7,500	7,000
November	29,500	24,000	13,000	13,500	8,000
December	80,500	36,000	24,500	19,500	12,500
January	100,500	85,500	36,500	20,000	18,000
February	103,000	85,500	57,500	40,000	18,000
March	101,000	89,500	51,000	50,500	24,500
April	96,500	73,000	68,000	49,500	25,500
May	99,500	77,500	65,500	46,500	27,000
June	67,500	44,500	36,000	24,000	16,500
July	27,000	16,000	12,000	8,500	6,000
August	11,000	7,000	6,000	5,000	3,500

Month	Year type				
	Wet	Above normal	Below normal	Dry	Critical
September	8,000	6,500	5,500	4,500	3,500
Total (taf)	43,940	32,952	22,690	17,162	10,067

Related actions that may impede or augment the action: AFRP and other upstream flow recommendations could either limit or be limited by outflow recommendations for striped bass.

Agency and organization roles and responsibilities: If this measure is implemented, CVP, SWP, and other reservoir managers upstream of the Delta would be responsible for providing releases needed to meet the recommended flow schedule. DWR and USGS would need to provide information from their gaging stations so that flow levels can be evaluated and adjusted.

Potential obstacles to implementation: Flow recommendations are likely to be considered unreasonable by water users. Operations of many of the Central Valley reservoirs that do not fall under the jurisdiction of the CVP would have to be modified to meet the proposed flow schedule. Cooperation from the entities that operate these impoundments would be needed to meet instream flow goals. Flow simulation modeling for the CVPIA PEIS indicates that in some years striped bass flow recommendations may exceed unimpaired runoff. Management of water to meet striped bass restoration goals would probably limit availability for other anadromous fish species and other water users.

Projected benefits: Increased outflow will benefit striped bass by facilitating downstream dispersal of juveniles into the western estuary, especially Suisun Bay and San Pablo Bay. Reduced salinity and increased export of nutrients from upstream reaches would be expected to increase food production and habitat quality for juvenile striped bass. Implementation of the recommended flow schedule, in concert with export restrictions, will reduce losses resulting from direct and indirect effects of entrainment and result in doubling of the adult striped bass population.

Action 2: Reduce exports at the SWP and CVP pumping plants; establish a moratorium on net increases in Delta diversions and withdrawals at the CCC.

Objective: Reduce direct and indirect losses of striped bass resulting from the operation of the pumps and diversions.

Location: Sacramento-San Joaquin Delta.

Narrative description: Exporting water at the SWP and CVP pumping facilities often results in reverse flows in the San Joaquin River east of Antioch, entraining striped bass eggs and juveniles and disrupting the migrations of young and adult bass throughout the Delta. The CCC diversion contributes to reverse flows as well. A percentage of the bass eggs, larvae, and juveniles that drift and migrate down the Sacramento River are diverted into the DCC at Locke and are carried 30 miles through the central Delta to the CVP and SWP pumping plants. Bass eggs, larvae, and fry are lost through fish screens into the California Aqueduct and Delta-Mendota Canal. Plankton, an important source of food for juvenile bass in the western Delta and Suisun Bay, have been depleted by entrainment into Delta diversions and by rapid water transport through most major Delta channels.

The DCC and Georgiana Slough should be closed when eggs and larvae are passing down the Sacramento River, to reduce numbers of striped bass entrained by the pumps. In addition to following Delta outflow recommendations, the following export schedule should be implemented to attain/maintain a naturally reproducing population of 2 million adult striped bass.

The Striped Bass Technical Team recommends establishing a ceiling of 1,200 cfs for combined CVP/SWP exports throughout the year and in all water-year types. Although the available data suggest that eliminating exports completely would result in optimum conditions for successful striped bass reproduction and recruitment, the technical team has modified its recommendations based on the understanding that exports of 1,200 cfs are required to meet public health and safety standards. In addition to the prescribed reductions in CVP/SWP exports, the team recommends that Delta agricultural diversions and CCC withdrawals not exceed the current maximum rates of 3,100 cfs and 300 cfs, respectively.

Related actions that may impede or augment the action: Flow recommendations for rivers upstream of the Delta could either increase or reduce the vulnerability of striped bass to the south Delta pumping operations.

Agency and organization roles and responsibilities: If this measure were implemented, CVP and SWP managers would be responsible for operating within the provided guidelines.

Potential obstacles to implementation: Establishing a 1,200-cfs export ceiling would severely affect water users south of the Delta.

Projected benefits: This action will increase recruitment by reducing direct impacts of Delta exports and diversions. The Striped Bass Technical Team believes that implementation of these export restrictions, in concert with the recommended flow schedule, will result in increasing the adult striped bass population to 2 million fish.

Action 3: Reduce predation at and near the SWP and CVP fish salvage facilities.

Objective: Improve survival of striped bass eggs, larvae, and juveniles entrained by the SWP and CVP pumps.

Location: Sacramento-San Joaquin Delta, CVP pumping plant, and especially CCF at SWP pumping plant.

Narrative description: Predation on juvenile striped bass by larger bass and other predators occurs in CCF and near the CVP intake.

Entrances to CCF should be screened to prevent larger bass and other predatory fish from being entrained. If this proves infeasible, predators should be removed and transplanted during winter and early spring. Covering the "secondary fish screen" at the Skinner (SWP) fish screen facility, thereby darkening it, may also help reduce predation losses.

Related actions that may impede or augment the action: Implementation of outflow and export standards would reduce the number of fish exposed to predation at and near the fish salvage facilities. Predation is only one factor contributing to losses of entrained eggs and fish; the value of reducing predation depends on relative effects of losses in Delta channels and during salvage.

Agency and organization roles and responsibilities: Measures to reduce predation losses would be implemented by DFG in cooperation with DWR and USBR.

Potential obstacles to implementation: Effectively screening CCF in a manner that would permit continued exports may be infeasible or prohibitively expensive. Removal of predators from CCF may not be feasible.

Projected benefits: Losses of striped bass eggs, larvae, and juveniles to predation in CCF may be greatly reduced.

Action 4: Improve CVP and SWP salvage operations.

Objective: Improve survival of the bass eggs, larvae, and juveniles collected at CVP and SWP fish salvage facilities.

Location: Sacramento-San Joaquin Delta, Skinner and Banks pumping plants.

Narrative description: Striped bass salvaged at both SWP and CVP facilities are subject to high mortality during collection, handling, and trucking to Delta release sites. Further, fish that have been salvaged and trucked are generally stressed, disoriented, and vulnerable to predation by larger striped bass and other fish that congregate at the release sites.

Suggested methods for improving the salvage and transport are: 1) reducing the number of fish held in "fish collection buckets", 2) limiting holding time to 5 minutes, 3) adding salt (0.4% NaCl concentration) to the fish truck water when directed to do so by DFG biologists, 4) using compressed oxygen (4 psi) to maintain proper DOC in the fish truck, and 5) not using water venturi aerators in the fish truck tanks. Salvaged fish could be reared in pens to increase survival. Varying the sites and/or times of release may reduce the predation occurring when salvaged bass are put back into the Delta.

Related actions that may impede or augment the action: Delta outflow recommendations and export restrictions may or may not reduce striped bass vulnerability to the pumps, depending on the magnitude of the outflow, thus reducing the need to improve salvage operations. Section 3406(b)(4) develops and implements a program to mitigate fishery impacts associated with operations of the Tracy pumping plant.

Agency and organization roles and responsibilities: Salvage and transport operations are conducted by DFG.

Potential obstacles to implementation: Costs of making modifications that will result in significant increases in survival of salvaged fish are probably high. Because salvaged fish represent a small percentage of total losses to entrainment, potential benefits may not be sufficient to justify this action.

Projected benefits: Survival of bass subjected to the salvage/transport process may increase.

Action 5: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at the CCC diversion.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: CCC diversion, south Sacramento-San Joaquin Delta.

Narrative description: Bass eggs, larvae, and juveniles are entrained by the unscreened CCC diversion. This diversion, which has a capacity of 350 cfs, also contributes to reverse flows in the Delta east of Antioch, increasing the number of bass eggs and young entrained at the south Delta pumps and disrupting the migrations of young and adult bass throughout the Delta.

DFG and Contra Costa County Water Agency (CCCWA) should enter into an agreement similar to the one between DWR and DFG for direct and indirect fish losses at the Banks pumping plant. Alternatives for reducing bass losses at the CCC are: 1) installing a fish screen at the intake, 2) relocating the intake to an offstream storage reservoir, and 3) relocating the intake to CCF. Diversion rate should be reduced when bass eggs and/or larvae appear in great abundance at the CCC intake. A salvage and transport program could be developed and implemented.

Related actions that may impede or augment the action: Delta outflow and export recommendations, as well as DCC and Georgiana Slough closures, to a large degree determine the numbers of striped bass eggs, larvae, and juveniles at risk of entrainment at the CCC. Reducing exports at SWP and CVP facilities would substantially reduce the number of juveniles and eggs that are vulnerable to entrainment at the CCC. Section 3406(b)(5), develop and implement a program to mitigate fishery impacts resulting from operations of CCC Pumping Plant Number 1.

Agency and organization roles and responsibilities: CCCWA manages the CCC diversion. CCCWA, DWR, and DFG would cooperatively investigate and implement the salvage/transport project and look at alternatives to improve survival.

Potential obstacles to implementation: Relocating the CCC intake would take years to implement and would be costly. Screening would present some major technical difficulties. CCCWA will likely resist any major changes in its water delivery practices and costs involved in starting a salvage/transport program.

Projected benefits: Reduced losses of bass eggs, larvae, and juveniles into the CCC should result in increased overall bass survival and recruitment.

Action 6: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at the PG&E power generating plants.

Objective: Improve survival of striped bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: PG&E power generating plants at Antioch and Pittsburg.

Narrative description: The Antioch and Pittsburg power plants draw water for cooling purposes, then return it to the estuary. Their combined capacity is roughly 3,100 cfs. Problems for striped bass include entrainment and mortality resulting from factors ranging from abrasion and thermal shock for juveniles and eggs to impingement on the screens for adults. The power plant also entrains plankton that would otherwise have been available as food for juvenile striped bass.

PG&E should continue to reduce pumping rates when bass egg and larvae abundance is high at the intakes, and the situation should be monitored for potential feasible improvements. The possibility of placing a barrier outside the intakes to further reduce entrainment should be evaluated and implemented if feasible.

Related actions that may impede or augment the action: Increased outflow would probably reduce vulnerability of striped bass eggs and juveniles to entrainment and reduce the need to modify plant operations.

Agency and organization roles and responsibilities: PG&E should continue to monitor bass abundance at the power plant intakes and manage pumping levels accordingly. DFG may help in providing methods to determine the timing and levels of bass abundance near the intakes.

Potential obstacles to implementation: The detection of bass eggs and larvae may present difficulties. Feasibility of constructing and installing an effective barrier has not been evaluated.

Projected benefits: Bass mortality associated with the PG&E power plants would be reduced, and bass food supplies (plankton) may increase.

Action 7: Eliminate, relocate, or reduce Sherman and Twitchell Island diversions.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: Sherman and Twitchell Islands, west Sacramento-San Joaquin Delta.

Narrative description: Bass eggs, larvae, and juveniles in transit down the lower Sacramento River pass in close proximity to Sherman and Twitchell Islands, where agricultural diversions are located. The impacts of these diversions on striped bass are unknown but are potentially significant.

Sherman and/or Twitchell Island could be converted to wildlife management areas. Should these islands continue as agricultural producers, some diversions could be consolidated and/or relocated to areas with low bass egg and larval concentrations.

Related actions that may impede or augment the action: Export levels at the south Delta pumping plants, as well as DCC and Georgiana Slough closures, may determine the abundance of bass vulnerable to the island diversions.

Agency and organization roles and responsibilities: DFG and/or USFWS would be involved in the purchase of land to develop a wildlife management area. Private land owner cooperation would be necessary for land purchase or modification or relocation of agricultural diversions.

Potential obstacles to implementation: Private land owners would likely resist any elimination of the islands as agricultural producers and any major changes in their water use practices. Funds to purchase land and establish the wildlife management area(s) may not be available.

Projected benefits: Striped bass egg, larvae, and juvenile losses resulting from entrainment at Sherman and Twitchell Island diversions would be reduced or eliminated.

Action 8: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at private agricultural diversions.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: Sacramento-San Joaquin Delta.

Narrative description: Up to 1,800 private unscreened agricultural diversions have operated in the Delta for decades. Approximately 2,500-4,800 cfs are diverted from May through August, with lesser amounts diverted during other times of the year. Striped bass eggs, larvae, and juveniles are entrained and killed in unscreened pumps and siphons. Abundance of plankton, which are a component of the diet of young bass in the western Delta and Suisun Bay, has also been reduced by entrainment in Delta agricultural diversions.

Whenever feasible, agricultural diversions should be consolidated and relocated to areas with low bass egg and larval concentrations. All the larger existing agricultural water diversions should be screened on a priority basis to exclude bass longer than 1.5 inches, and existing screened diversions should be examined for identification of desirable improvements. The "area-wide" rescheduling of water diversions should be considered by all parties in select locations when bass eggs and larvae are at peak abundance during spring and early summer. DFG, Delta agriculture interests, and other appropriate agencies should cooperatively establish and negotiate future screening needs and irrigation schemes to protect young bass.

Related actions that may impede or augment the action: Delta outflow and export levels, as well as DCC and Georgiana Slough closures, may determine the numbers of bass vulnerable to the various private diversions.

Agency and organization roles and responsibilities: DFG and USFWS would need to cooperate with private land owners to implement any of the above actions. DFG would play a major role in determining screening needs and overseeing screen monitoring and installations. Funding should be available under Section 3406(b)(21) of Title 34. Area water interests and public agencies would need to work together to implement any plans of action.

Potential obstacles to implementation: Agricultural diverters might resist major changes in their water use operations and the costs associated with screening. Screens may reduce efficiency of diversions and increase the need for maintenance. Available funds may be insufficient to adequately do the job.

Projected benefits: Striped bass egg, larvae, and juvenile mortality associated with private agricultural diversions would be reduced. Reduced or relocated diversions could result in an increase of bass food supplies.

Action 9: Support measures to prevent the development of a water quality barrier to adult striped bass migration in the San Joaquin River near Stockton.

Objective: Ensure access to spawning areas in the San Joaquin River upstream of Stockton.

Location: San Joaquin River near Stockton.

Narrative description: Low flows in the San Joaquin River near Stockton often combine with agricultural drain water to create an effective dissolved solids (and dissolved oxygen) barrier to upstream migration and spawning by striped bass. This problem is caused by upstream water diversions and agricultural wastewater high in total dissolved solids (TDS).

Salinity standards, particularly in the lower San Joaquin River downstream of Stockton, should be upgraded to levels at which striped bass can use the river upstream of the Delta for spawning. This problem would be solved with implementation of AFRP flow recommendations for San Joaquin River chinook salmon and flow and export restrictions recommended in Actions 1 and 2. DFG and collective San Joaquin Valley and south Delta agricultural interests should develop ways to provide better water quality in agricultural drain discharges into the San Joaquin River.

Related actions that may impede or augment the action: Water quality would be substantially improved with implementation of Striped Bass Technical Team flow and export recommendations and San Joaquin Basin Technical Team flow and export recommendations.

Agency and organization roles and responsibilities: EPA, DFG, and local authorities would set and enforce water quality standards necessary to eliminate the barrier to spawners. DWR, USBR, and the South Delta Water Agency need to continue to work together to improve and maintain water levels, circulation patterns, and quality in the south Delta through the South Delta Agreement.

Potential obstacles to implementation: Private land owners may resist changes necessary to improve the quality of agricultural drain discharges. Non-CVP water agencies may not provide flows needed to meet water quality objectives.

Projected benefits: Spawning habitat available to striped bass spawners in the lower San Joaquin River would increase.

Action 10: Reduce toxic chemical and trace-metal pollution.

Objective: Provide better water quality for all life stages of striped bass.

Location: Throughout the Sacramento-San Joaquin Delta.

Narrative description: Water pollutants, including toxic chemicals (petrochemicals, chlorinated hydrocarbons, pesticides, etc.) and trace metals (mercury, selenium, copper, cadmium, and zinc) are harmful in many ways to all striped bass life stages. Toxic chemicals and trace metals potentially stress, debilitate, or kill bass eggs, larvae, young, and adults and their food (and possibly affect primary productivity) throughout the Sacramento-San Joaquin Estuary. Studies on Atlantic Coast stocks of striped bass show that the combination of toxic chemicals and trace metals found in those waters significantly decreased survival of young bass. Chronic exposure to toxic chemicals appears universal, and continues today, in Bay-Delta bass. For example, 67% of 46 adult bass examined in 1987 contained unmetabolized DDT in the liver. State water quality control agencies project increases in the volume and complexity of municipal, industrial, and agricultural waste discharges into the Bay-Delta system. Each year billions of gallons of storm water runoff wash into the estuary, carrying toxic and other waste materials from streets, parking lots, and other areas that are often incidental dumping grounds for all kinds of urban waste, trash, and garbage. It is common for municipal operations to have upsets in their treatment systems, with the result that large amounts of highly toxic chlorine and other materials are discharged directly to the receiving waters. The incidence and severity of fish diseases and parasites are influenced by water quality.

SWRCB's routine field checking program for regulated waste discharges should be strengthened. Agricultural pesticides in Delta return drains should be regulated and monitored by appropriate agencies to ensure proper fishery safeguards. DFG should continue to support SWRCB and RWQCB programs to control point and nonpoint sources of water pollution. Efforts to detect violations of water pollution laws and improve pollution investigations and incident response capabilities should be maintained by appropriate agencies.

Related actions that may impede or augment the action: Flow into and out of the Delta may affect the concentrations of various pollutants and exposure time for fish. Actions restricting dredge and fill activities may reduce the suspension of toxic chemicals.

Agency and organization roles and responsibilities: DFG, EPA, SWRCB, RWQCB, and other water agencies should all be involved in Delta water quality issues. Private land owner cooperation will also be required.

Potential obstacles to implementation: Funding for studies related to water quality, a strengthened field checking program, and increased levels of enforcement activity may be limited or unavailable. Agricultural, municipal, and industrial interests will likely resist any actions to improve water quality if their operations are significantly affected.

Projected benefits: The overall health of the Sacramento-San Joaquin Estuary will likely be improved. Potential benefits for striped bass are not known.

Action 11: Eliminate or reduce dredging and dredge spoil contributions to water pollution.

Objective: Provide better water quality for all life stages of striped bass.

Location: Throughout the Sacramento-San Joaquin Delta.

Narrative description: Dredging and in-bay spoil disposal recirculate toxic chemicals and trace metals deposited previously in bottom muds, whereby they then become concentrated in striped bass, partly via the food web. In addition, concurrent turbidity abrades fish gills, reduces phytoplankton, and smothers bottom organisms. The practice of slurrying spoils before disposal instead of disposing of the more solidified material from clamshell dredging appears to have exacerbated problems by causing excessive turbidities and enhanced release of toxic materials to the water column.

A deep ocean spoil disposal site should be used in place of current in-bay dredge and spoil disposal practices. Disposal at on-land sites, where there is potential for adverse impacts on wetlands or other fish or wildlife habitats, should be prohibited. Only spoils free of toxicity and/or contaminants should be allowed to be discharged to estuary or ocean waters. Dredge spoils should not be slurried before release. A survey of bottom muds of the Sacramento-San Joaquin Estuary should be conducted to identify areas with high concentrations of toxic chemicals.

Related actions that may impede or augment the action: Dredging activities necessary to keep shipping channels operational may diminish the effectiveness of recommended actions.

Agency and organization roles and responsibilities: The Corps would be responsible for carrying out its dredging operations in a manner not detrimental to biological resources. EPA, as well as state and local authorities, would assist in assessing levels of contamination in dredge spoils and bottom muds to be dredged.

Potential obstacles to implementation: The Corps and other groups responsible for dredging channels may resist changes in their operations. The development and use of an ocean disposal site would be highly controversial. A bottom mud survey would be costly and may be beyond present Corps capabilities.

Projected benefits: The overall health of the Sacramento-San Joaquin Estuary will likely be improved. Potential benefits for striped bass are not known but may be substantial.

Action 12: Eliminate or reduce unnecessary landfill projects.

Objective: Reduce or eliminate habitat loss resulting from the filling of Bay and Delta tidelands.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: The loss of open water areas by filling of Bay and Delta tidelands has reduced bass and bass-food habitats. Research reports by the San Francisco Bay Conservation and Development Commission (BCDC) reveal that such filling also reduces the estuary's total water volume and its ability to assimilate certain pollutants. State reports document that between 1860 and 1959, almost 50% of the potentially fillable marshlands and tidelands were filled or diked off. An example is the Mare Island Training Wall (Dike 12), a landfill project completed in 1908, which probably eliminated at least 10 square miles of open water habitat in San Pablo Bay.

Fill projects that DFG should oppose because they are overly detrimental to bass and their habitat should be identified. All but public water-dependent fill projects (i.e., port development) should be prohibited unless there is reason to believe that fish and wildlife would benefit. Projects involving landfills should be required to provide mitigation in the form of wetlands and/or tidal waters to compensate for unavoidably filled habitat.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: Permitting agencies will need to adopt the recommended actions as policy or regulations. DFG and USFWS will need to oppose any landfill projects detrimental to striped bass. Cooperation between numerous agencies and organizations will be needed because most fill activities take place on private land adjacent to Delta and Bay waters.

Potential obstacles to implementation: Developers will certainly resist any regulation or policy changes concerning landfills that would affect them.

Projected benefits: Habitat loss resulting from landfill projects in the Bay-Delta will be eliminated. Habitat lost as a result of past landfill projects may be mitigated.

Action 13: Eliminate or reduce illegal take and poaching.

Objective: Reduced impacts of illegal fishing on striped bass populations.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: Illegal take and poaching are frequent problems in Bay-Delta waters. DFG wardens have cited anglers for bass overlimits and undersized fish, and have arrested people using illegal nets and set lines for striped bass. "Stings" have uncovered marketing of illegally caught bass in the Bay-Delta area. Available levels of enforcement effort are insufficient to prevent all of the poaching.

The general public and anglers should be encouraged to routinely use the Cal-Tip program to advise DFG of poachers, illegal selling of striped bass, and violations of angling regulations. DFG should continue to augment night and overtime patrols and purchase special equipment to aid striped bass enforcement, such as night-vision scopes and specialized boats. Courts and prosecutors that judge violations of striped bass laws should be fully informed of the grave plight of the bass resource so that maximum legal penalties will be imposed to deter future violations.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: DFG enforcement personnel will carry out most of the actions necessary to reduce illegal take and poaching. Environmental and angling groups will need to share responsibility for making people aware of the problem and what they can do about it.

Potential obstacles to implementation: Limited availability of funding may greatly hinder DFG's ability to increase enforcement presence and effectiveness.

Projected benefits: Striped bass mortality associated with illegal take and poaching will likely decrease. Overall benefits in terms of increases in the striped bass population are unknown.

Action 14: Eliminate or reduce the introduction of exotic aquatic organisms.

Objective: Reduce impacts of exotic species on striped bass and their food supplies.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: For decades there have been continual, unauthorized introductions of worldwide exotic aquatic plants and animals into the Sacramento-San Joaquin Estuary through the discharge of ballast water from ships entering San Francisco Bay from foreign ports. Some introductions may have resulted in major detrimental impacts on populations of existing aquatic organisms, including striped bass and their food supplies. Several species of exotic aquatic organisms originally from China and Japan have become extremely abundant. These include the yellowfin goby (*Acanthogobius flavimanus*), and zooplankton *Sinocalanun doerii*, *Pseudodiaptomus marinus*, and *P. forbesi*.

Discharges of ship ballast water within the Sacramento-San Joaquin Estuary should be restricted through federal legislation and regulations. DFG should participate on the Federal Aquatic Nuisance Species Task Force. Methods of eliminating or reducing populations of exotic organisms already established in the estuary should be investigated.

Related actions that may impede or augment the action: Largely undocumented impacts of exotic species may limit effectiveness of all other restorations actions.

Agency and organization roles and responsibilities: DFG would carry out any studies involving the detection and elimination of undesirable exotic aquatic species. Legislative bodies would need to take action to change present laws. The U.S. Coast Guard and other regulatory agencies would be needed to carry out enforcement and monitoring activities.

Potential obstacles to implementation: Shipping companies and vessel operators will likely resist any changes in their operational procedures. Exotic species already present in the Bay-Delta may be impossible to control or eliminate.

Projected benefits: The natural integrity of the Sacramento-San Joaquin Estuary ecosystem will not be further degraded and may even be improved.

G. AMERICAN SHAD

Baseline Period Production and Production Goals

Because there are no data to estimate the adult component of the American shad population for any years except 1976 and 1977, juvenile abundance in the California Department of Fish and Game fall midwater trawl (MWT) was used as an index of production. The MWT survey is conducted at about 90 sampling sites from the Delta downstream through San Pablo Bay from September to December. To reflect the fact that the juvenile index is related to abundance of spawning adults 3-5 years later, it would have been ideal to consider the index for 1962-1988. However, because the MWT survey was not begun until 1967, it was necessary to estimate the baseline period average and to establish the restoration goal on the basis of data collected from 1967 through 1988.

Additional deficiencies in MWT data occur because sampling does not include the entire period that juvenile shad are present in the system and because a portion of the system that is known to be utilized by juvenile shad is not sampled at all. Sampling does occur during October and November when the greatest numbers of juvenile shad are migrating to the ocean and, consequently, abundance of juveniles in the Delta is highest.

Table 3-Xg-1. Young-of-the year and adult American shad abundance estimates in the Sacramento-San Joaquin River system.

Year	Young-of-the-year MWT index	Adults abundance[a]
1964	1,531	
1965	4,064	
1966	1,991	
1967	3,501	
1968	773	
1969	4,055	
1970	871	
1971	1,543	
1972	335	
1973	1,084	

Year	Young-of-the-year MWT index	Adults abundance[a]
1974	5,275	
1975	2,486	
1976	354	3,040,000
1977	646	2,790,000
1978	2,461	
1979	1,953	
1980	3,903	
1981	1,434	
1982	5,386	
1983	2,928	
1984	846	
1985	1,596	
1986	1,860	
1987	899	
1988	1,459	
Mean	2,129	291,500

[a] Abundance derived from mark-recapture population estimates.

Goal - Based on mean juvenile shad abundance from 1967 through 1988, the AFRP goal for MWT index is 4,258.

Basis for flow recommendations - Because of the limited quantity of adult shad data, the degree of uncertainty associated with predicting population response to flow is probably greater for American shad than for other species. A regression relationship between Delta inflow and juvenile shad abundance in the MWT has been recognized for several years (Painter et al. 1979, Stevens and Miller 1983, Stevens et al. 1987). In general, the years with the highest Delta inflow have been the years when the abundance of juvenile shad was highest. More recently, this relationship deteriorated, reflecting several years (1990, 1991, 1992) when juvenile abundance was high despite relatively low inflow.

April through June is the most important period for providing flow for the purpose of increasing production of shad (Painter et al. 1979). The regression equation incorporating all the available data indicates that April-June Delta inflow would have to exceed unimpaired levels to meet the restoration goal established for the MWT index. To avoid this problem, flows needed for doubling were estimated by averaging the flows that occurred during years that the MWT index actually equaled or exceeded the established restoration goal of 4,258 (1974 and 1982). The flow generated by this method was in the range of mean unimpaired flow and was considered to be the average required across all year types.

Recommendations for individual year types were generated by identifying the proportion of total unimpaired inflow that would have occurred, on average, during each year type for the period of record (1922-1990). Within year types, flows were allocated to individual rivers known to be important for shad spawning to reflect historical (1922-1990) percent contribution to unimpaired runoff.

Sacramento River Basin - Upper Mainstem Sacramento River

Limiting factors and potential solutions -

Table 3-Xg-2. Limiting factors and potential solutions for American shad in the upper Sacramento River (Colusa to Red Bluff).

Limiting factors	Potential solutions
1. Inadequate flows for spawning, incubation, and rearing	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
2. Water temperatures higher than optimum range during May and June (temperatures exceed 68°F)	1. Manage Sacramento River and tributary flows to levels specified in the proposed restoration program 2. Manage Shasta Dam releases to maintain water temperatures between 61°F and 65°F in the Sacramento River
3. Entrainment of juveniles at diversions from Colusa to Red Bluff on the Sacramento River	1. Increase Sacramento River and tributary flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
	2. Provide proper spawning temperatures (≥61 °F) beginning May 1 to stimulate spawning so eggs and larvae can be transported past GCID and other diversions prior to peak irrigation season

Restoration actions -

Action 1: Provide adequate flows for shad spawning and survival of eggs and larvae as presented in the following table.

Table 3-Xg-3. Instream flow regime believed necessary to double natural production of American shad in the Sacramento River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	25,800	19,100	16,600	11,900	7,400
May	16,500	12,200	10,700	8,500	7,100
June	10,300	7,200	7,000	6,200	5,600

Objective: Improve shad spawning success, and increase survival of eggs and larvae.

Location: Sacramento River at Grimes (RM 125).

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature standards for American Shad. Flow and temperature recommendations for other anadromous fish species.

Agency and organization roles and responsibilities: Meeting flow standard would be the responsibility of USBR. Monitoring success and making recommendations to improve conditions would be the responsibility of USFWS and/or DFG.

Potential obstacles to implementation: Flows are generally higher than those recommended for other species of anadromous fish. In many years, use of water to meet American shad needs would reduce availability for other species and for waters users.

Projected benefits: Providing the recommended flows would result in improved conditions for spawning and increased survival of eggs and larvae in the upper mainstem Sacramento River.

Action 2: Maintain mean daily water temperatures between 61 °F and 65 °F for 1 month between April 1 and June 30.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the upper Sacramento River.

Location: Upper Sacramento River.

Narrative description: Maintaining mean daily water temperatures between 61 °F and 65 °F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of the Shasta Reservoir temperature curtain should be used. A secondary goal is to provide appropriate spawning temperatures as early in spring as possible to minimize overlap between spawning and the peak of the irrigation season. It is anticipated that early spawning would result in transport of eggs and larvae past GCID and other diversions before the peak irrigation season.

Related actions that may impede or augment the action: Flow and temperature requirements are also recommended by the upper Sacramento River chinook salmon and sturgeon technical teams.

Agency and organization roles and responsibilities: USBR would be responsible for implementation, but USFWS and/or DFG would be responsible for monitoring success and making recommendations to modify the action.

Potential obstacles to implementation: Increased Shasta Dam releases are likely to decrease power generation prior to completion of the temperature control structure.

Projected benefits: Maintaining water temperatures within the specified range should increase survival of American shad eggs and larvae in the upper Sacramento River.

Lower Sacramento River and Delta Tributaries

Limiting factors and potential solutions -

Table 3-Xg-4. Limiting factors and potential solutions for American shad in the lower Sacramento River (Hood to Colusa).

Limiting factors	Potential solutions
1. Inadequate Sacramento River flows for spawning, incubation, and early life stage rearing	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
2. Temperatures outside the optimum range during May and June (temperatures exceed 68°F)	1. Increase Sacramento River and tributary flows to levels specified in the proposed restoration program 2. Maintain water temperatures between 65°F and 68°F by releasing water from lower outlets of upstream reservoirs with temperature control facilities
3. Water quality in the lower Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
4. Fish entrained at diversions located between Hood and Colusa on the Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
5. Reduced quality and quantity of suitable rearing habitat in the lower Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program

Restoration actions -

Action 1: Maintain mean daily water temperatures between 65°F and 68°F for 1 month between April 1 and June 30 by managing releases from dams with water temperature control facilities.

Objective: Improve spawning success and survival of eggs and larvae in the lower Sacramento River.

Location: Sacramento River from Hood to Colusa.

Narrative description: Maintaining mean daily water temperatures between 61 °F and 65 °F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available.

Related actions that may impede or augment the action: Flow and temperature requirements are also recommended by the upper Sacramento River and sturgeon technical teams.

Agency and organization roles and responsibilities: USBR would be responsible for implementing this action in association with other dam operators with the ability to control water temperatures with releases. USFWS and/or DFG will be responsible for monitoring success and making recommendations to provide optimum benefits.

Potential obstacles to implementation: Increased Shasta Dam releases are likely to decrease power generation.

Projected benefits: Maintaining temperatures within the specified range should increase survival of eggs and larvae in the lower Sacramento River.

Feather River

Limiting factors and potential solutions -

Table 3-Xg-5. Limiting factors and potential solutions for American shad in the Feather River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase Feather and Yuba River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range for spawning, incubation, and early rearing	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Manage pumpback operations at Thermalito Reservoir to keep mean daily temperatures at Nicolaus between 61 °F and 68 °F

Limiting factors	Potential solutions
3. Fish entrainment at diversions in the Feather River below the Yuba River confluence	Increase Feather and Yuba River flows to levels specified in the proposed restoration program

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-6. Instream flow regime believed necessary to double natural production of American shad in the Feather River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	17,500	13,400	12,600	9,000	4,200
May	17,100	12,100	10,100	6,600	3,600
June	9,800	5,700	4,900	3,300	2,500

Objective: Improve conditions for spawning, and increase survival of eggs and larvae.

Location: Feather River at Nicolaus.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for other anadromous fish species..

Agency and organization roles and responsibilities: DWR would be responsible for meeting the recommended flow schedule. DWR, with possible assistance from DFG and/or USFWS would be responsible for monitoring results and adjusting flows to provide optimum benefits.

Potential obstacles to implementation: Flows recommended for American shad are generally higher than those recommended for other species. Reservoir storage may be insufficient to supply recommended flows in many years. Use of water to meet flow needs for shad would reduce ability to meet requirements for other species and limit availability to water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, have the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61^{o}F and 65^{o}F for at least 1 month between April 1 and June 30 by managing pumpback operations at Thermalito Reservoir.

Objective: Improve spawning success and egg survival in the Feather River.

Location: Feather River.

Narrative description: Maintaining mean daily water temperatures between 61^{o}F and 65^{o}F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions, depending on the source of water for these flows.

Agency and organization roles and responsibilities: All public and private entities with control over sources and quantities of water flowing into the Feather River share responsibility for meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria (work currently conducted by University of California, Davis researchers). Implementation will likely require Oroville Dam releases to meet temperature standards downstream. Increased Oroville Dam releases are likely to decrease power generation.

Projected benefits: Maintaining temperatures within the specified range should increase survival of eggs and larvae in the lower Sacramento River. Insufficient data are available to determine the specific increase in survival.

Yuba River

Limiting factors and potential solutions -

Table 3-Xg-7. Limiting factors and potential solutions for American shad in the Yuba River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase Yuba and Feather River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range during May and June (temperatures below 61°F or above 68°F)	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Maintain mean daily water temperatures between 61°F and 65°F at Marysville by using multilevel outlet at New Bullards Bar Reservoir

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-8. Instream flow regime believed necessary to double natural production of American shad in the Yuba River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	8,200	7,100	7,200	5,500	2,800
May	9,900	8,100	7,100	4,900	2,600
June	6,400	3,900	3,200	2,000	1,400

Objective: Improve shad attraction and spawning and survival of eggs and larvae.

Location: Yuba River at Marysville.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for other anadromous fish species.

Agency and organization roles and responsibilities: Yuba County Water Agency would be responsible for implementation. DFG and/or USFWS would be responsible for monitoring and making recommendations to improve conditions for American shad.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61° F and 65°F for at least 1 month between April 1 and June 30 using multilevel outlets.

Objective: Improve shad spawning success and egg survival in Yuba River.

Location: Yuba River.

Narrative description: To the extent possible, mean daily water temperatures during May and June should be kept between 61° F and 65°F for optimum spawning and egg incubation in the Yuba River. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of the New Bullards Bar Dam multilevel outlets should be used. USBR would need to enter into an agreement with Yuba County Water Agency, the dam operator, to implement this action.

Related actions that may impede or augment the action: Flows recommended for American shad and other species.

Agency and organization roles and responsibilities: Yuba County Water Agency would be responsible for managing water temperatures.

Potential obstacles to implementation: Competing water uses.

Projected benefits: Increased survival of eggs and larvae is expected in the Yuba River. Insufficient data are available to determine the specific increase in survival expected.

American River

Limiting factors and potential solutions -

Table 3-Xg-9. Limiting factors and potential solutions for American shad in the American River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase American River flows to levels specified in the proposed restoration program
2. Higher than optimum water temperatures during May and June (temperatures below 61°F or above 68°F)	If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program Note: Without multilevel outlets at Folsom Dam, water temperatures cannot be controlled in the American river, except by flows

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-10. Instream flow regime believed necessary to double natural production of American shad in the American River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	10,200	8,400	8,600	6,500	3,100
May	12,200	9,600	8,700	6,100	3,100
June	8,100	4,800	4,200	2,700	1,700

Objective: Improve shad spawning success and egg and larvae survival.

Location: American River at H Street Bridge.

Narrative description: Delta inflow was assumed to be an index of flow in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for chinook salmon and steelhead.

Agency and organization roles and responsibilities: USBR would be responsible for implementation, but USFWS and/or DFG would be responsible for monitoring success and making recommendations to modify the action.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Mokelumne River

Limiting factors and potential solutions -

Table 3-Xg-11. Limiting factors and potential solutions for American shad in the Mokelumne River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	1. Increase Mokelumne River flows to levels specified in the proposed restoration program 2. Minimize flow fluctuations resulting from peaking power operations at Comanche Dam
2. Higher than optimum water temperatures during May and June (temperatures	Increase Mokelumne River flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
above 68°F)	

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-12. Instream flow regime believed necessary to double natural production of American shad in the Mokelumne River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	2,600	2,300	2,400	2,000	1,100
May	4,500	3,800	3,400	2,500	1,300
June	3,500	2,200	1,900	1,100	700

Objective: Improve shad spawning success and egg and larvae survival.

Location: Mokelumne River downstream of Woodbridge Dam.

Narrative description: Delta inflow was assumed to be an index of flow in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendation for American shad; flow and temperature recommendations for chinook salmon.

Agency and organization roles and responsibilities: EBMUD and FERC would implement recommended flows and USFWS and/or DFG would monitor populations.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Minimize flow fluctuations resulting from peaking power operations at Camanche Dam.

Objective: Improve survival of eggs, larvae, and juvenile shad in the Mokelumne River.

Location: Mokelumne River.

Narrative description: Flow fluctuations resulting from peaking power operations at Camanche Dam affect fisheries resources downstream. These operations would likely adversely affect shad production in the Mokelumne River.

Related actions that may impede or augment the action: Flows specified for other species.

Agency and organization roles and responsibilities: EBMUD and FERC would implement recommended flows and USFWS and/or DFG would monitor populations.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet the needs of other water users.

Projected benefits: Reduced flow fluctuations would benefit shad production by increasing survival of eggs, larvae, and juveniles.

Sacramento-San Joaquin Delta

Limiting factors and potential solutions -

Table 3-Xg-13. Limiting factors and potential solutions for American shad in the Sacramento-San Joaquin Delta.

Limiting factors	Potential solutions
1. Delta inflow and outflow are frequently inadequate for dispersing juvenile shad downstream and to provide optimum rearing conditions within the Delta	Establish Delta inflow to levels specified in the proposed restoration program

Limiting factors	Potential solutions
2. Poor Delta water quality	Dilute toxic compounds by increasing Delta inflow to levels specified in the proposed restoration program
3. Fish entrainment at Delta diversions	1. Increase Delta inflow to levels specified in the proposed restoration program 2. Close the DCC during the peak fall migration period (October-December)

Restoration actions -

Action 1: Provide systemwide flows needed for successful American shad spawning, incubation, and early downstream migration.

Table 3-Xg-14. Delta inflow required to double natural production of American shad in the Sacramento-San Joaquin Rivers.

Month	Wet	Above normal	Below normal	Dry	Critical
April	104,800	79,500	74,500	54,400	28,900
May	104,500	82,000	69,700	49,800	29,800
June	74,100	49,800	40,4000	27,800	19,700

Objective: Improve shad spawning and egg and larvae survival.

Location: Delta inflow is a calculated quantity.

Narrative description: These required minimum flows, in association with higher flows that would occur during high natural runoff conditions and during reservoir releases to meet other beneficial uses over and above shad needs, would provide the most substantial element in the restoration program for American shad.

The sources of water are not currently available to the federal government in all the river basins, and additional water will need to be purchased or exchanged to meet the needs. A number of water-sharing formulas could also be implemented on a statewide basis to meet the recommended requirements.

Comprehensive systemwide flow increases in April-June are needed to ensure doubling of shad populations. The flow increases for the various tributaries with shad spawning and rearing need to be maintained downstream as Delta inflow so that the systemwide benefits are realized. Only in this manner can shad be distributed throughout the Sacramento-San Joaquin River system and double their populations within each general spawning location.

Related actions that may impede or augment the action: Flow recommendations for all rivers and species.

Agency and organization roles and responsibilities: Meeting the recommended Delta inflow standards would depend on releases from upstream impoundments and would require cooperation and coordination between a number of agencies and organizations. USBR would be responsible for meeting instream flow requirements on rivers with USBR storage and/or diversion facilities. Monitoring would be coordinated with the Interagency Ecological Program and the ongoing efforts to monitor effects of the provisions of the recent Delta Water Quality Standards Decision.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad. It is estimated that increasing minimum instream flow requirements will increase production by approximately 60%-80%. Unfortunately, no data or models are available to verify this estimate, which is based on professional experience and judgment and on review of the best available information. Instream flow requirements are the most important management tool for doubling American shad production, and there is firm agreement among members of the American Shad Technical Work Group on this point. The specific mechanisms are not documented but are thought to be increased attraction into desirable spawning locations, increased egg-larval survival, and increased survival during early juvenile rearing and outmigration.

Action 2: Close the DCC during the peak fall migration period in October-December.

Objective: Improve survival of juvenile shad migrating downstream in fall.

Location: Delta Cross Channel at Walnut Grove.

Narrative description: The DCC has been effectively operated to increase chinook salmon outmigrant survival. Similar methods should be used to improve survival of American shad by keeping emigrating shad away from the CVP and SWP pumping facilities. The DCC should be closed during the peak fall outmigration period during October-December. USBR would be responsible for implementing this action.

Related actions that may impede or augment the action: Flow and export recommendations for all species. DCC recommendation for chinook salmon.

Agency and organization roles and responsibilities: USBR would be responsible for operating the Delta Cross Channel in a manner that would prevent entrainment of juvenile American shad. Insufficient data are available to determine the specific increase in survival that could be expected, but it is anticipated that the increase would be significant.

Potential obstacles to implementation: Measures to protect outmigrating salmon restricted on Delta Cross Channel use at other times of the year. This action would increase the period of time during which cross channel use and export capabilities would be affected.

Projected benefits: This action would result in increased survival of downstream-migrating American shad from the Sacramento River system. Insufficient data are available to determine the specific increase in survival that could be expected, but it is anticipated that the increase would be significant.

San Joaquin River

Limiting factors and potential solutions -

Table 3-Xg-15. Limiting factors and potential solutions for American shad in the San Joaquin River.

Limiting factors	Potential solutions
1. Inadequate San Joaquin River flows during key life history activities (April-June)	Increase San Joaquin River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range during May and June (temperatures below 61° F or above 68° F)	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Maintain mean daily water temperatures between 65°F and 68°F at Vernalis by using multilevel outlets of upstream reservoirs
3. Poor San Joaquin River water quality	1. Increase San Joaquin River flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
	2. Corrective actions implemented for striped bass will benefit American shad
4. Fish entrainment at diversions located below the Stanislaus River	Increase San Joaquin River flows to levels specified in the proposed restoration program
5. Reduced quality of lower San Joaquin River rearing habitat	1. Increase San Joaquin River flows to levels specified in the proposed restoration program 2. Implement an overall lower San Joaquin River aquatic habitat improvement program between the Stanislaus River confluence and Vernalis

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-16. Instream flow regime believed necessary to double natural production of American shad in the San Joaquin River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	5,200	4,400	4,600	3,500	2,200
May	10,200	8,900	7,400	5,400	3,100
June	10,300	8,200	5,700	3,900	2,400

Objective: Improve shad spawning and egg survival and larvae survival.

Location: San Joaquin River at Vernalis.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad. Chinook salmon flow and temperature recommendations for San Joaquin River tributaries.

Agency and organization roles and responsibilities: Providing the recommended flows for the San Joaquin River would require cooperation between multiple agencies and organizations.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61^{o}F and 65^{o}F for 1 month between April 1 and June 30 below dams with temperature control facilities.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the lower San Joaquin River.

Location: Lower San Joaquin River.

Narrative description: To the extent possible, mean daily water temperatures during a 1-month period from April through June should be between 65^{o}F and 68^{o}F for optimum spawning and egg incubation in the lower San Joaquin River. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available. USBR would be responsible for implementing this action, in association with other dam operators with the ability to control temperatures of water releases.

Related actions that may impede or augment the action: Flow recommendations for American shad. Flow and temperature recommendations for chinook salmon in San Joaquin River tributaries.

Agency and organization roles and responsibilities: Meeting recommended temperature criteria for the San Joaquin River would require cooperation between multiple agencies and organizations.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Increased survival of eggs and larvae is expected in the lower San Joaquin River. Insufficient data are available to determine the specific increase in survival expected. Meeting the recommended temperature criteria, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Lower San Joaquin River Tributaries - Stanislaus River

Limiting factors and potential solutions -

Table 3-Xg-17. Limiting factors and potential solutions for American shad in the Stanislaus River.

Limiting factors	Potential solutions
1. Inadequate Stanislaus River flows during key life history activities (April-June)	Increase Sacramento River and tributary flows to levels specified in proposed restoration program
2. Higher than optimum water temperatures during May and June (temperatures below 61°F or above 68°F)	1. Manage Sacramento River and tributary flows to levels specified in proposed restoration program. 2. Manage Shasta Dam releases to maintain water temperatures between 61°F and 65°F in the Sacramento River

Action 1: Provide adequate flows as presented in the following table.

Objective: Improve shad spawning and egg and larval survival.

Location: Stanislaus River at Goodwin Dam.

Table 3-Xg-18. Instream flow regime believed necessary to double natural production of American shad in the Stanislaus River for five water years types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	4,200	3,700	3,800	3,000	1,600
May	6,800	5,700	5,000	3,400	1,800
June	5,100	3,400	2,800	1,800	1,000

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Existing flow agreement between USBR and DFG. Vernalis flow recommendations. Section 3406(b)(2), dedication of 800,000 af of water annually for fish, wildlife, and habitat restoration. Section 3408(b) purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of flows will require cooperation and coordination between USFWS, DFG, USBR, and numerous water user groups and irrigation districts.

Potential obstacles to implementation: Neither the existing USBR/DFG agreement nor the 800,000 af of water dedicated to fish and wildlife purposes by 3406(b)(2) of Title 34 are sufficient to meet flow needs identified by the Anadromous Fish Restoration Program. Implementing the AFRP flow schedule would reduce water availability to meet needs of other user groups and would thus require purchase of additional water.

Projected benefits: Providing the recommended flows in concert with other recommended actions has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61°F and 65°F for 1 month between April 1 and June 30 below dams with temperature control structures.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the Stanislaus River.

Location: Stanislaus River

Narrative description:

Related actions that may impede or augment the action: Flows specified under Action 1 may help meet temperature requirements.

Agency and organization roles and responsibilities: USBR is responsible for New Melones Dam releases that may be necessary for temperature control.

Potential obstacles to implementation: Competing water uses.

Projected benefits: Maintaining temperatures within specified range should increase survival of egg and larvae in the Stanislaus River.

H. WHITE AND GREEN STURGEON

Baseline Natural Production and Goals

White sturgeon tagging and data analysis - Tagging studies were carried out by DFG to obtain mark-recapture population estimates of white sturgeon greater than or equal to 40 inches total length (TL) (the minimum legal size until 1990). Sturgeon were captured using trammel nets during fall in San Pablo and Suisun bays. Captured fish were measured for total length, tagged with disc-dangler reward tags attached below the anterior edge of the dorsal fin, and released near the site of capture. Tag recaptures during tagging were used to estimate abundance using the mark-recapture methods of Petersen and Schumacher-Eschmeyer.

Some assumptions inherent in mark-recapture techniques are likely to be violated. These are:

1) Assumptions of random distribution of tagged fish in the untagged population and equal vulnerability of tagged and untagged fish to the fishing gear are likely violated by the multiple census technique of Schumacher-Eschmeyer.

2) Both methods deal with a population that is probably not closed and the proportion of the entire population represented by the estimate is unknown and may vary between estimates.

Annual harvest rates, mortality rates, and migration patterns were estimated from reward tags returned by anglers. Harvest and natural production estimates for the baseline period were available for only 8 years. For the other years, no sampling took place. Catch was estimated by multiplying the population estimate by harvest rate. Production was estimated by multiplying the population estimate by an estimated age fraction determined through length-age analysis. Age 15 is approximately the mean age of recruitment of females to the spawning population.

Escapement is not addressed because of the multi-age spawning population structure of sturgeons. Spawning periodicity reported by several investigators is quite varied. Welch and Beamsederfer (1993) suggest that spawning occurs every 2 to 4 years in Columbia River white sturgeon, while Roussow (1957) reports spawning intervals between 4 years and 7 years in lake sturgeon. Kohlhorst (pers. comm.) found evidence of white sturgeon spawning every 4 years in females and every 2 years in males in the Sacramento-San Joaquin Estuary. As a result of this variable spawning periodicity, there also can be variability in strength of year classes returning to spawn as a result of annual environmental influence.

Table 3-Xh-1. Catch and natural production (abundance at age 15) for white sturgeon in the Sacramento-San Joaquin Estuary during the baseline period.

Year	Population estimate	Catch	Natural production
1967	114,700	8,373	11,470
1968	40,000	2,600	3,200
1974	20,700	1,159	1,449
1979	74,500	6,183	3,725
1984	119,800	10,466	7,188
1985	107,700	12,385	7,539
1987	106,100	7,482	7,427
1990	36,700	858	2,569
Mean			5,571

Goal - Based on mark-recapture and length-age data, the mean annual production for white sturgeon during the baseline period is estimated to be 5,571. The goal of the CVPIA is to at least reach a population level of twice that amount, or 11,142.

Green sturgeon tagging and data analysis - During the baseline period, 143 green sturgeon were tagged. An additional 26 were tagged between 1954 and 1965. None have been recaptured during subsequent sampling, so no independent estimate of abundance was possible. As an alternative, green sturgeon abundance in the estuary in fall was estimated by dividing white sturgeon abundance estimates by the ratio of white sturgeon to green sturgeon observed during tagging (Table 3-Xh-2). Additionally, since the number of green sturgeon captured each year was so low, no length-age analysis was available to provide information regarding production. Assumptions in the calculation of green sturgeon abundance are: 1) green and white sturgeon are equally vulnerable to trammel nets, 2) green and white sturgeon are randomly dispersed, and 3) equal numbers of green and white sturgeon reside within the sampling area. Green sturgeon abundance estimates are probably low because fewer green sturgeon are believed to reside year-round in San Pablo and San Francisco bays compared to white sturgeon.

Goal - Based on the ratio of white to green sturgeon observed during tagging, the estimate of green sturgeon abundance during the baseline period is 983. The goal under the CVPIA is to reach a population level of twice the amount, or 1,966.

Table 3-Xh-2. Green sturgeon abundance estimates in the Sacramento-San Joaquin Estuary during the baseline period.

Year	White sturgeon abundance	Ratio of white to green sturgeon	Green sturgeon abundance
1967	11,4700	62:1	1,850
1968	40,000	38.6:1	1,036
1974	20,700	101.9:1	203
1979	74,500	52.6:1	1,416
1984	119,800	106.3:1	1,127
1985	107,700	127.3:1	846
1987	106,100	163.7:1	648
1990	36,700	49.6:1	738
Mean	77,525		983

Approach

The Sturgeon Technical Team's approach to developing recommendations for the AFRP was to assign drainages to individual team members (Table 3-Xh-3). Each team member was responsible for taking the lead role in developing recommendations for that assigned drainage. Individual team members enlisted the help of additional authors to help write sections, or additional authors were enlisted by the team leader.

Table 3-Xh-3. List of team members and additional authors assigned to writing sections for each of the listed drainages.

Drainage[a]	Assigned member	Additional authors[b]
Sacramento	Kurt Brown, USFWS	Jim De Staso, USFWS
Feather	Patrick Foley, UCD	Jim De Staso, USFWS
Bear	Jim De Staso, USFWS	
San Joaquin	Dan Castleberry, USFWS	
Delta	Dave Kohlhorst, DFG	Jim De Staso, USFWS

[a] The list of drainages includes rivers for which the team could find evidence of sturgeon spawning during the baseline period.

[b] In addition to the listed authors, formatting and editorial changes were made by USFWS, primarily at the request of the Core Group.

To develop this report, the team first developed a list of potential limiting factors. This list is not included in the report. Each team member then selected those factors that were potentially limiting in the drainage and included those factors under the header "Limiting factors and potential solutions". Team members then selected a subset of those factors that they considered to be of primary importance and described restoration actions for these factors under the header "Restoration actions".

The task for the team was complicated by the fact that little is known about white sturgeon and less is known about green sturgeon in the Central Valley. Investigations have not been conducted to determine where and when sturgeon spawn, except for white sturgeon on the mainstem Sacramento River. The team often depended on information from anglers and DFG wardens and on entrainment data to help determine where and when sturgeon spawned. Also, except for Delta outflow, no information was available on flows needed for successful spawning and recruitment of sturgeon in the Central Valley. Because data collected for sturgeon in other drainages showed a direct relationship between high spring flows and recruitment, and because data for white sturgeon in the Delta showed the same relationship, the team developed a method for estimating flows necessary for successful reproduction of sturgeon.

Methods used to develop flow recommendations and predict benefits - Year-class indices (YCIs) and data on sturgeon salvage at the SWP, contained in WRINT-DFG-Exhibit 28, were used to identify years with good recruitment of white sturgeon in the Sacramento-San Joaquin river system. Of the years for which YCIs were presented in Figures 3 and 4 of Exhibit 28 (1968-1990), those with YCIs of at least twice the other YCIs were classified as good recruitment years. These years were 1969, 1975, 1978, 1980, 1982, and 1983. All remaining years were classified as poor recruitment years.

Flow recommendations were developed for gauging stations on the Sacramento, Feather, Bear, and San Joaquin rivers and in the Delta. For each year between 1968 and 1990, the mean monthly February-May flows were ranked from highest to lowest discharge. All good recruitment years occurred in either wet or above-normal years and their flows ranked at or near the top. Generally, the good recruitment year with the lowest mean monthly February-May flow was adopted as the flow standard. However, for some stations the good recruitment year with the second lowest mean February-May flow was selected as the flow standard because adoption of the lowest year's flow did not appreciably increase baseline production. Newly derived flow standards were set only for wet and above-normal water years.

Predicted benefits from implementation of flow recommendations were also calculated for each river. A mean YCI was calculated for years between 1968 and 1990. A mean YCI was also calculated for years having flows equal to or greater than that recommended. The mean YCI from years with flows equal to or greater than the recommendation were substituted for YCIs in wet and above-normal years with flows less than the recommendation. After these substitutions, a new mean YCI was calculated for the period between 1968 and 1990. The new YCI for the years 1968 through 1990 represents increased sturgeon production after implementation of flow standards. Percent increase in mean YCIs before and after flow implementation was calculated and assumed to represent increases in sturgeon production after increasing flows.

Research Needs

1. Continue tagging adult sturgeon to estimate abundance, distribution, mortality rates, and movement patterns. These activities will be necessary to determine the success of restoration actions.

2. Map and survey available broodstocks and spawning grounds, including their physical and chemical parameters, number of brood fish, Aspawnability@, and embryo survival.

3. Estimate juvenile sturgeon abundance and year-class strength. Monitor environmental parameters to relate year-class strengths to environmental conditions.

4. Evaluate effects of trace elements and organic contaminants on adult health, gamete viability, and early life stages. Address sources of contamination if adult health, viability of gametes, or early life-stage development is found to limit production. In particular, examine effects of selenium and PCBs.

5. Determine diets of larval and juvenile sturgeon. No studies on wild larval sturgeon diets have been conducted (Pacific States Marine Fisheries Commission 1992). White sturgeon larval diet probably consists of zooplankton while YOY white sturgeon, less than 51 inches, eat small crustaceans and aquatic insect larvae (Pacific States Marine Fisheries Commission 1992). If prey items are limiting, efforts to increase their abundance may increase larval survival.

6. Determine effects of predation on sturgeon eggs and early life stages. Currently, information on sturgeon egg and larva predation is limited. In the Columbia River, bottom feeders such as prickly sculpin, largescale sucker, common carp, and northern squawfish prey on white sturgeon eggs (Miller and Beckman 1993). In the Central Valley, carp (Anonymous 1940) and white catfish (Turner 1966) ingest sturgeon eggs, and striped bass may prey on early life stages (Anonymous 1940). Steelhead, squawfish, and various centrarchids that prey on juvenile salmon may also prey on early life stages of sturgeon. Predation rates may also increase near structures creating water turbulence and casting shadows on the water surface and boundary edges (Cooper and Crowder 1979).

7. Develop a green sturgeon culture program. A culture program would be beneficial in determining food preferences, physical and chemical habitat requirements and tolerances, early life stage development, and effects of toxins.

Sacramento River

Limiting factors and potential solutions - Information is currently being gathered on poaching, harvest regulations, predation, and habitat suitability. Actions for these limiting factors may be added to future drafts.

Table 3-Xh-4. Limiting factors and potential solutions for white and green sturgeon in the Sacramento River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and transport and rearing of larvae and juveniles	1. Provide minimum or greater flows to ensure suitable conditions for sturgeon to migrate and spawn and their progeny to survive 2. Reduce or eliminate drastic changes in flow during critical periods (i.e., maintain constant flows).
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	1. Provide water at temperatures suitable for sturgeon to migrate, undergo the final stages of sexual maturation, and spawn and for their progeny to survive 2. Reduce or eliminate drastic temperature fluctuations during critical periods (e.g., large releases of cold water from reservoirs)
3. Loss of larval and juvenile sturgeon at water diversions	1. Identify extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae and juveniles
4. Passage past RBDD	Raise RBDD gates from mid-September through June
5. Poor water quality	1. Increase flow of high-quality water 2. Prevent Iron Mountain Mine waste release into the Sacramento River 3. Decrease contamination of the river by agricultural chemicals and drainwater 4. Decrease exposure to excessive levels of trace

	elements or other contaminants to acceptable levels
6. Possible construction of the GRF at the GCID diversion	Find alternative means of increasing head differential at GCID

Restoration actions -

Action 1: Provide mean monthly flows of at least 17,700 cfs at Grimes (RM 125) and at least 31,100 cfs at Verona (RM 80) between February and May for wet and above-normal water years.

Objective: Provide flows to allow adult migration from the estuary or ocean to spawning grounds, spawning, and downstream larval transport.

Location: Sacramento River at Grimes and Verona.

Narrative description: Flows for successful sturgeon reproduction in the Sacramento River have not been identified. In good recruitment years, mean monthly February-May flows ranged from 13,836 cfs to 25,763 cfs at Grimes and 31,050 cfs to 60,202 cfs at Verona (Table 3-Xh-5).

Table 3-Xh-5. Mean monthly February-May discharge (cfs) at Grimes (USGS station 11390500) and Verona (USGS station 11425500) on the Sacramento River.

Year	Mean February-May discharge at Grimes	Year	Mean February-May discharge at Verona
1983	25,763	1983	60,202
1982	20,928	1982	49,176
1974	20,676	1974	44,873
1975	19,161	**1969**	42,080
1969	18,712	1986	37,741
1978	17,710	1975	34,276
1973	16,686	1978	33,874
1986	16,599	1973	33,168
1971	15,677	1980	31,050
1970	14,368	1970	29,977
1980	13,836	1971	28,644

Year	Mean February-May discharge at Grimes	Year	Mean February-May discharge at Verona
1968	13,456	1968	22,816
1981	11,500	1984	20,548
1972	11,098	1989	20,079
1979	10,632	1979	19,052
1984	10,579	1981	18,000
1989	10,307	1972	16,087
1987	9,770	1987	14,378
1976	8,372	1985	12,581
1988	7,858	1990	12,221
1985	7,202	1988	11,633
1990	6,411	1976	11,392
1977	5,259	1977	7,028

Note: Years are ranked from highest to lowest discharge with years with good white sturgeon recruitment in bold print.

In addition to empirical relationships of flow with reproduction, other information (e.g., water depth necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow recommendations are adopted. Until these data are available interim flow standards should be as follows: for above-normal and wet years, mean monthly February-May flows of at least 17,700 cfs at Grimes (flows needed for spawning) and at least 31,100 cfs at Verona (flows needed for attraction).

Related actions that may impede or augment the action: Sacramento River flows must be accompanied by other habitat restoration measures in the Sacramento-San Joaquin Delta and in San Francisco and San Pablo bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Sacramento River production could be reduced by mortality in these other areas.

Agency and organization roles and responsibilities. The Sacramento River is a CVP stream with flow controlled by USBR.

Potential obstacles to implementation. Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Between 1968 and 1990, wet and above-normal water years occurred 12 times. During those 12 years, flows of at least 17,700 cfs occurred six times at Grimes, and flows of at least

31,100 cfs occurred nine times at Verona. Increasing flows in the remaining 6 above-normal and wet years to at least 17,700 cfs at Grimes will increase sturgeon production by 40%; increasing flows in the remaining 3 above-normal and wet years to at least 31,100 cfs at Verona will increase production by 20%.

Action 2: Maintain water temperatures below 17 °C (63 °F) in sturgeon spawning areas from February to June in wet and above-normal water years.

Objective: Ensure that in-river temperatures are maintained at levels that optimize spawning, incubation, and survival of sturgeon early life stages.

Location: Sacramento River from ACID's irrigation dam (RM 299) to Verona.

Narrative description: Water temperatures greater than 17 °C (63 °F) can increase sturgeon egg and larval mortality (PSMFC 1992). Water temperatures near RBDD historically occur within optimum ranges for sturgeon reproduction. However, temperatures downstream of RBDD, especially later in the spawning season, are frequently above 17 °C.

Observations from DFG and USFWS biologists indicate that sturgeon spawning has taken place near RBDD, and that temperatures during these times ranged from 10°C to 17 °C (50-63 °F). Water temperatures between Keswick Dam (RM 302) and RBDD historically have been suitable for spawning and early life-stage development. In 1973, 93% of spawning occurred in March and April at water temperatures between 46° and 64 °F and eggs hatched at water temperatures up to 72 °F.

Water temperatures downstream of RBDD are not always suitable for sturgeon reproduction. Daily minimum water temperatures were examined for the Sacramento River at Grimes for above-normal and wet years between February and June 1968-1994. Minimum temperatures were greater than or equal to 17 °C (63 °F) in 5 of 12 years in May, and 9 of 11 years in June. High water temperatures may deleteriously effect egg and larval survival, especially for late-spawning fish in drier water years. Minimum/maximum water temperatures at Verona were unavailable, but temperatures are assumed to increase downstream of Grimes to Verona further affecting early life-stage survival. Water temperatures should be maintained below 17 °C (63 °F) in sturgeon spawning areas from February through May during above-normal and wet years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 may contribute to temperature reductions that would depend on the source of water for these flows. Use of the USBR temperature control model and other model development will help evaluate the potential for maintaining optimum sturgeon temperatures.

Agency and organization roles and responsibilities: USBR controls releases from Shasta and Keswick dams. Releases from these dams would be necessary for temperature control in the Sacramento River.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Maintaining temperature standards late in the season may be difficult. Small tributary streams, with water temperatures that cannot be controlled, may affect Sacramento River temperatures downstream of RBDD.

Predicted benefits: Temperatures in the Sacramento River appear high enough in some years to reduce egg and larval survival. Temperature reductions below 17°C in May and June have the potential to restore spawning habitat and increase survival of early life stages of sturgeon. The contribution toward restoration goals cannot be quantified.

Action 3: Reduce sturgeon entrainment at both screened and unscreened diversions.

Objective: Increase sturgeon production by reducing entrainment losses.

Location: Sacramento River from Keswick Dam to Verona. Sites of specific concern are the Bonnyview pumping plant (RM 292), RBDD, GCID (RM 206), and the ACID diversion (RM 298.5).

Narrative description: More than 300 unscreened diversions exist on the Sacramento River from Keswick to Verona. The majority of diversions operate from April through October, which could result in larval and juvenile sturgeon entrainment. Specific studies on sturgeon entrainment in the Sacramento River do not exist, but limited data show that entrainment occurs at RBDD and GCID.

At RBDD, salmonid entrainment has nearly been eliminated with the installation of a new drum screen facility in 1991. However, eight larval sturgeon were captured in the TCC fyke nets between 1987 and 1991, even though screens meet NMFS criteria to protect salmon fry. Because sturgeon larvae are considerably smaller than salmonid fry of the same age, current mesh criteria may not prevent entrainment. To determine if larval sturgeon entrainment is significant, monitoring in the TCC and the Corning Canals should continue. Juvenile sturgeon entrainment also occurs at RBDD. Several juvenile green sturgeon were impinged on a diffuser grate, apparently unable to escape water velocities entering a diffuser bay. Inadequate diffuser bay design and approach velocities may result in juvenile impingement.

Estimates of sturgeon entrainment at GCID are unknown, but it is likely that 1,162 sturgeon were captured at or near GCID between 1986 and 1993. Of the limited number of larvae and juveniles identified, all were green sturgeon. To minimize entrainment, fish screens were installed at GCID in 1972, but since then screen effectiveness has been reduced by substantial changes in water depth and velocity at the diversion entrance. DFG has identified increased approach velocities and predation as main causes of juvenile fish mortality.

Legislation passed in 1992 authorized 75% federal funding for new screens (Waterline 1993). Until the design is agreed on and the EIR reviewed, GCID will rely on interim modifications to alleviate the problem. The diversion should continue to be monitored to assess impacts on larval and juvenile sturgeon.

To reduce losses at unscreened diversions, USBR conducted screening workshops for Sacramento River diverters in 1993. Attendees included diverters, screen designers, fabricators, and vendors. Another action initiated under CVPIA Section 3406(b)(21) is the unscreened diversions program. USFWS developed an accelerated effort to allow the screening of some diversions in fiscal year 1994. Roughly 23 proposed projects have been selected and will be evaluated for effectiveness.

For entrainment to be reduced at screened and unscreened diversions, information should be gathered on the following: 1) numbers, types, and sizes of unscreened and screened diversions on the Sacramento River; 2) fish losses caused by diversions; 3) feasibility of installing positive barrier screens to reduce losses; 4) estimated costs of screen design, installation, maintenance, and evaluation; 5) availability of funding; 6) feasibility of seasonal management options (e.g., pumping restrictions, monitoring requirements, or alternative water supplies) that would reduce losses; and 7) swimming capabilities of various sturgeon life stages.

Sturgeon entrainment at both screened and unscreened diversions should be reduced through employment of state-of-the-art screening technology and evaluation of management options. Also, design of diffuser gates and bays at RBDD should be examined.

Related actions that may impede or augment the action: Work on the Research Pumping Plant may produce alternative methods for diverting water while minimizing entrainment at RBDD.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and local diverters.

Potential obstacles to implementation: Costs associated with redesigning screens to prevent entrainment.

Predicted benefits: Because no numeric estimates of sturgeon entrainment are available at GCID, RBDD, or other diversions, benefits cannot be quantified. If sturgeon entrainment is reduced or eliminated, production would increase.

Action 4: Raise RBDD gates from mid-September through June.

Objective: Provide unimpeded adult sturgeon migration to spawning habitat above RBDD.

Location: RBDD.

Narrative description: Major physical barriers to adult sturgeon migration on the mainstem Sacramento River are RBDD and ACID's diversion dam. Unimpeded migration past RBDD occurs when gates are raised roughly between mid-September through early May as mandated by NMFS. Passage past the ACID diversion dam occurs from November through March when flashboards are removed. Both RBDD and the ACID diversion dam have fish ladders primarily designed to facilitate salmonid passage.

With RBDD gates and ACID open, Keswick Dam (RM 302) is theoretically the upstream migration barrier. Current upstream migration limits are unknown, but when sturgeon are provided with the opportunity to migrate to Keswick Dam, migration appears to end between Ball's Ferry and Jelly's Ferry bridges (Wigham pers. comm.). No adult sturgeon have been observed above or below the ACID diversion dam in recent memory (Preston pers. comm.).

Current operations closing RBDD gates in mid-May pose three problems for sturgeon. First, some sturgeon may be prevented from spawning. Evidence suggests that females prevented from reaching preferred spawning grounds reabsorb eggs and forgo spawning (Barannikova 1968). Second, potential spawning habitat is blocked. Keeping gates open through June will provide 25 additional miles of spawning habitat for an additional 45 days. Habitat between RBDD and Jelly's Ferry Bridge (RM 267) contains swift current and pools over 20 feet deep preferred by spawning sturgeon. Third, adult and larvae are prevented from migrating downstream after spawning. Larvae trapped behind RBDD gates may experience mortality as a result of entrainment and from high shear forces as larvae pass under the gates. Mortality of juvenile salmon passing under RBDD gates is high as a result of shear forces, and similar effects are likely for larval sturgeon (Williams pers. comm.). Effects on adult sturgeon attempting downstream migration with gates lowered are unknown. Measures to provide unimpeded passage past RBDD are likely to benefit mostly green sturgeon because most appear to spawn further upstream than white sturgeon.

To facilitate passage of adult and juvenile sturgeon, RBDD gates should be raised from mid-September through June.

Related actions that may impede or augment the action: Actions for other anadromous fish may recommend keeping gates open longer. Completion and testing of the Research Pumping Plant may permit water diversion without RBDD gates being closed. At present, the Research Pumping Plant may not be able to provide enough water for demands through June.

Agency and organization roles and responsibilities: USBR has control over RBDD operations. Also, the Tehama-Colusa Irrigation District and other water users may play a role in operations.

Potential obstacles to implementation: Tehama-Colusa Irrigation District, USBR, and recreational users may resist implementation.

Predicted benefits: Keeping gates open through June will provide increased spawning habitat and allow unimpeded downstream migration of larvae and adults. Benefits cannot be quantified.

Action 5: Improve water quality.

Objective: Improve sturgeon production by providing water quality essential to adult and early life-stage survival.

Location: Sacramento River from Keswick Dam to Verona.

Narrative description: Organic contaminants from agricultural drainwater, urban and agricultural runoff from storm events, and high trace element concentrations may deleteriously affect early life-stage survival of fish in the Sacramento River. Principal sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, USBR District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough, and the principal source of heavy metal pollution is Iron Mountain Mine discharges.

Discharge of rice irrigation water and its collection at the edge of the zone of initial dilution has caused mortality to both *Ceriodaphnia* and fathead minnows in the Sacramento River. Mortality was attributed to various organic compounds contained in rice field discharges. Also, DFG found correlations between larval striped bass abundance in the Delta and pounds of methyl parathion applied to rice fields (CVRWQCB 1991). Based on available data, it is believed that rice field discharges in May and June could effect sturgeon larvae survival. Also, recent studies in the Sacramento-San Joaquin basin indicate that application of the dormant spray pesticide dianzinon during January can lead to pulses in the Sacramento and San Joaquin rivers following rain. Pulses in both rivers were found to be acutely toxic to aquatic invertebrates. Effects on sturgeon through direct or indirect exposure are unknown (Foe 1995).

Trace elements can also decrease sturgeon early life-stage survival. Trace elements can cause abnormal development and high mortality in yolk-sac fry sturgeon at concentrations at the level of parts per billion (Dettlaff et al. 1981). Water discharges from Iron Mountain Mine, contaminated with heavy metals, have affected survival of fish downstream of Keswick Dam. Trace element concentrations were reduced in 1963 with construction of Spring Creek Debris Dam. Iron Mountain Mine drainage is partially controlled by water being stored and discharged with available dilution flows from Shasta Dam and Spring Creek Debris Dam. But storage limitations in Spring Creek Reservoir and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances. Five fish kills have occurred downstream of Keswick Dam since 1963. Also, rainbow trout livers sampled between 1981 and 1987 contained high levels of cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Although the impact of trace elements (specifically from Iron Mountain Mine) on sturgeon production is not completely understood, negative impacts are suspected. It is also not known how far downstream impacts occur and under what conditions trace elements are mobilized.

To reduce impacts of heavy metal contamination, implementation of the EPA Superfund Program, which would eventually eliminate Iron Mountain Mine dilution flow releases, should continue.

Related actions that may impede or augment the action: Increased flows of uncontaminated water may help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: USBR, EPA, RWQCB, and other agencies involved with setting water quality standards.

Potential obstacles to implementation: Entities accustomed to using chemicals and discharging contaminated water into the Sacramento River are likely to resist implementation of the action. Cost associated with treatment of runoff, if necessary, may cause resistance to implementation.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Sturgeon egg and larval survival would increase, but benefits cannot be quantified.

Action 6: Devise alternative methods other than the GRF to increase head differential for the GCID bypass system.

Objective: Facilitate unimpeded passage past GCID.

Location: GCID diversion.

Narrative description: GCID diverts water from the Sacramento River at RM 206. A plan exists for screen modifications and possible construction of a GRF. The GRF consists of an instream structure designed to raise upstream river levels, allowing more flow directed toward the screening facility and pumping plant.

A draft EIR/EIS (Resource Consultants and Engineers 1994) reports that the GRF may impede upstream-migrating adult sturgeon and downstream transport of larvae. Current information on sturgeon swimming speeds is not sufficient for evaluation of potential passage problems imposed by the GRF. Swimming speeds vary for each sturgeon life stage and the GRF configuration may not suit all stages (HDR Engineering 1994). The draft EIR/EIS does not include a GRF as a preferred alternative, but recommends consideration of other methods, such as a screw pump system.

Related actions that may impede or augment the action: Work on the Research Pumping Plant at Red Bluff may negate the need for a GRF.

Agency and organization roles and responsibilities: NMFS, USFWS, DFG, and GCID.

Potential obstacles to implementation: Cost associated with developing alternatives to the GRF.

Predicted benefits: Alternative methods for increasing head differential that would lessen impacts on adult and larval sturgeon passage will decrease losses of larval and juvenile sturgeon at GCID. Benefits cannot be quantified.

Feather River

Limiting factors and potential solutions -

Table 3-Xh-6. Limiting factors and potential solutions for white and green sturgeon in the Feather River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and transport and rearing of larvae and juveniles	1. Provide mean monthly February-May flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus during above-normal and wet water years 2. Reduce or eliminate drastic changes in flow during critical periods
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	1. Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas and below 20°C (68°F) throughout the Feather River during February-May during wet and normal years 2. Reduce or eliminate drastic temperature fluctuations during critical periods
3. Barriers that prevent or slow the migration of sturgeon to spawning habitat	1. Identify potential barriers (physical as well as water quality barriers) 2. Evaluate the extent of the problem 3. Remove barriers or facilitate passage around barriers
4. Loss of sturgeon larvae and juveniles resulting from entrainment	1. Identify the extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae

5. Size of spawning stock	1. Improve conditions for production of sturgeon 2. Reduce mortality of early life stages 3. Reduce mortality of adults (identify extent of fishing mortality and poaching)
6. Poor water quality	1. Increase flows of high-quality water 2. Decrease contamination of the river by agricultural chemicals and drain water 3. Decrease exposure to excessive levels of trace elements or other contaminants to acceptable levels
7. Availability of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning substrates 3. If substrates limit success of sturgeon spawning, take appropriate corrective action

Restoration actions -

Action 1: Provide mean monthly February-May flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus during wet and above-normal water years.

Objective: Provide minimum or greater flows to ensure suitable conditions for adult sturgeon to migrate upstream and spawn and for their progeny to survive. Reduce or eliminate drastic flow changes during critical reproductive periods.

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Little information exists on green or white sturgeon in the Feather River. Although sturgeon are known to migrate into the Feather River, little effort has been made to document reproduction. Despite the lack of technical information, enough evidence exists in the form of observations by biologists, anglers, fishing guides, and tackle shop employees to provide a basis for making recommendations needed to increase sturgeon production in the Feather River.

Adult sturgeon migrated into the Feather River historically and in more recent times. Several articles recount large sturgeon having been caught in the Feather River in the early 1900s (Talbitzer 1959, Anonymous

1918). More recent observations include the recovery of one tagged adult sturgeon in April 1968 (Miller 1972a). Green sturgeon were caught every year during the mid-1970s to early 1980s (anonymous fishing guide). The majority of catches occurred between March and May with occasional catches in July and August. Although adult sturgeon were present in the Feather River in the 1970s, efforts to sample larval sturgeon at the mouth of the Feather River in 1973 were unsuccessful. During spring 1991, two radio-tagged adult white sturgeon were tracked 2.5 miles up the Feather River. Subsequent efforts to relocate these fish were unsuccessful (Schaffter 1991). Finally, during spring 1993, several adult green sturgeon (lengths of 60-72 inches) were caught at Thermalito Afterbay outlet (Foley pers. comm.).

White sturgeon in the Sacramento River start migrating in October and spawning in February (Schaffter pers. comm.). Most white sturgeon in the Central Valley spawn in March and April, and approximately 20%-30% spawn in February and June (Doroshov pers. comm.). Adult green and white sturgeon catches in the Feather River indicate that most spawning occurs between March and May. Exact spawning locations are unknown, but based on angler catches, likely spawning locations are considered to be downstream of Thermalito Afterbay outlet and Cox's Spillway, just downstream of Gridley Bridge. The upstream migration barrier is likely a steep riffle 1 mile upstream of the Afterbay outlet. This riffle is approximately 394 feet long with average water depth of 6 inches.

In good sturgeon recruitment years, mean monthly February-May flows ranged from 3,488 cfs to 20,505 cfs at Gridley and 7,028 cfs to 35,234 cfs at Nicolaus (Table 3-Xh-7).

Table 3-Xh-7. Mean monthly February-May discharge (cfs) at Gridley (USGS station 11407150) and Nicolaus (USGS station 11425000) on the Feather River.

Gridley		Nicolaus	
Year	**Discharge**	**Year**	**Discharge**
1983	20,505	**1983**	35,234
1986	15,370	**1982**	29,513
1982	14,797	1970	26,511
1974	12,611	1974	22,489
1969	10,911	**1969**	21,028
1971	7,427	1973	11,582
1980	6,956	**1978**	11,453
1970	6,067	1971	11,113
1973	5,914	**1975**	8,272
1978	5,090	**1980**	7,028

Gridley		Nicolaus	
1984	4,409	1979	6,627
1975	3,488	1981	4,336
1979	3,186	1972	4,070
1990	3,171	1976	2,582
1985	2,818	1977	1,458
1981	2,780		
1972	2,552		
1988	2,261		
1976	2,001		
1989	1,928		
1987	1,846		
1968	1,354		
1977	1,275		

Note: Years ranked from highest to lowest discharge, with years with good white sturgeon recruitment in bold print. Only years for which discharge data were available for each site are listed. Data for the Nicolaus station were recorded only between 1969 and 1983.

In addition to empirical relationships of flow with reproduction, other information (e.g., water depth necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow recommendations are set. Until these data are available, interim flow standards should be as follows: above-normal and wet water-year mean February-March flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus.

Related actions that may impede or augment the action: Feather River flows must be accompanied by other habitat restoration measures in the Sacramento River, Sacramento-San Joaquin Delta, and San Francisco and San Pablo bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Feather River production could be reduced by mortality in these other areas.

Agency and organization roles and responsibilities: All public and private entities responsible for setting and meeting flow standards on the Feather River.

Potential obstacles to implementation: Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Twelve above-normal and wet water years occurred between 1968 and 1990. Flows exceeded 7,000 cfs at Gridley in 7 of 12 years. Increasing flows to at least 7,000 cfs at Gridley in the remaining 5 years will increase production by 20%.

Action 2: Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas and below 20°C (68°F) throughout the Feather River during February-May during above-normal and wet water years.

Objectives: Provide water temperatures required for initiation of spawning, final sexual maturation of adults, and survival of eggs and larvae. Reduce or eliminate drastic temperature fluctuations during critical periods (e.g., large releases of cold water from Oroville Dam).

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Daily minimum and maximum water temperatures were examined in the Feather River just downstream of Thermalito Afterbay outlet for March-June 1991-1994. Minimum daily temperatures exceeded 17°C in April in 1 year and exceeded 17°C in June in all 4 years. High water temperatures are in part caused by water releases from Thermalito Afterbay. Releases can raise water temperatures in approximately 14 miles of river (from the Afterbay outlet to the mouth of Honcut Creek) compared to water in the low-flow channel. Effects of Thermalito Afterbay releases can vary with ambient air temperature, release rates, residence time, and flow contribution from the low-flow channel. Based on these data, it is likely that high water temperatures may deleteriously affect sturgeon egg and larval development, especially for late-spawning fish in drier water years.

Water temperatures should be maintained below 17°C (63°F) in sturgeon spawning areas, and below 20°C (68°F) throughout the Feather River during February-May of above-normal and wet years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions that would depend on the source of water for these flows. DWR has contracted with the University of California, Davis, to develop a water temperature model for the Feather River. This model could be used to help manage water temperatures for successful sturgeon spawning. Completion of the temperature model should improve ability of managers to meet temperature criteria. Control of water temperatures may be complicated by Thermalito Afterbay releases, agricultural returns, and warmer ambient air temperatures as spring progresses.

Agency and organization roles and responsibilities: DWR, local municipalities, and private irrigation districts control the quantity of water flowing into the Feather River share responsibility in meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Increased Oroville Dam releases may be required to meet temperature standards downstream. Increased Oroville Dam releases are likely to decrease power generation.

Predicted benefits: Temperatures in the Feather River appear high enough in some years to reduce egg and larval survival. Temperature reductions below 17°C in May and June have the potential to restore spawning habitat and increase survival of early life-stages of sturgeon. The contribution toward restoration goals cannot be quantified.

Action 3: Remove physical and water quality barriers that impede access to spawning habitat.

Objective: Identify potential physical and water quality barriers and determine the extent of the problem. Once barriers identified, remove or facilitate passage around these barriers.

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Although not well documented, low flows and physical obstructions can impede sturgeon migration. For example, blasting was required to remove an in-river obstacle on the Klamath River that was determined to impede sturgeon migration (USFWS 1982). If delays at barriers cause later spawning, then removal should result in earlier spawning. Earlier spawning sturgeon are less likely to be exposed to high temperatures and poor water quality commonly occurring in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching. Potential physical barriers to upstream migration in the Feather River are a rock dam at Sutter Extension Water District's sunrise pumps, shallow water at Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to Thermalito Afterbay outlet. Ted Sommer (pers. comm.) thought each of the above listed physical barriers could impede adult upstream migration during low flows.

Potential water quality barriers on the Feather River have not been identified. However, discharge from the Gridley Waste Water Treatment Plant and agriculture drainwater, particularly from Jack Slough, may produce low dissolved oxygen levels and contain organic contaminants creating water quality problems impeding migration.

Sturgeon migration barriers should be identified and action taken to eliminate or reduce impacts.

Related actions that may impede or augment the action: Flows specified under Action 1 should help reduce passage problems associated with low flows.

Agency and organization roles and responsibilities: All public and private entities with control over placement and removal of barriers and setting Feather River flow standards. Also, all entities responsible for waste or drainwater discharge into the Feather River.

Potential obstacles to implementation: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation. Dischargers are likely to resist implementation.

Predicted benefits: If barriers exist, then their removal will allow sturgeon access to new spawning habitat, allow access to spawning habitat earlier in the spawning season, require less energy for sturgeon to reach spawning habitat, and decrease the vulnerability of sturgeon to capture during migration. If barriers exist and are removed or modified, sturgeon production may increase, but such increase cannot be quantified.

Action 4: Reduce sturgeon entrainment.

Objective: Identify the extent of sturgeon entrainment. Increase survival of sturgeon larvae and juveniles by reducing or eliminating entrainment.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Eight large diversions (greater than 10 cfs) are located on the Feather River between the confluence with the Sacramento River and Thermalito Afterbay outlet: Hamatani Brothers (RM 9.75), Garden Highway Mutual Water Company (RM 13.1), Feather Water District (RM 15.2), Plumas Mutual Water Company (RM 17.5), Tudor Mutual Water Company (RM 18.4), Feather Water District (RM 20.4), City of Yuba City (RM 29.6), and Sutter Extension Water District's sunrise pumps (RM 38.1). Additionally, approximately 60 small, unscreened diversions exist along the Feather River, each with pumping rates of approximately 1-10 cfs (Libby pers. comm.).

No studies have specifically examined sturgeon entrainment on the Feather River. However, Menchen (1980) showed that diverters could entrain significant numbers of chinook salmon. In 1977-1978, DFG studied juvenile salmon entrainment at the Sutter Extension Water District's sunrise pumps. In 1977, 23,461 af of water was diverted, resulting in an estimated loss of 30,413 salmon. In 1978, 6,877 af of water was diverted, resulting in salmon losses estimated at 3,887 (Menchen 1980). Although Menchen (pers. comm.) recalls no larval or juvenile sturgeon being captured, the use of **3**-inch mesh at the cod end likely allowed larval sturgeon to pass through.

Sturgeon are vulnerable to entrainment elsewhere in the Central Valley. Sturgeon have been collected at RBDD and the GCID diversion dam on the Sacramento River and at the CVP and SWP pumps in the Delta.

The extent of the problem on the Feather River should be investigated. If a problem is found to exist, these diversions should be screened with state-of-the-art fish screening technology. Entrainment can also be reduced by limitations being placed on diversions.

Related actions that may impede or augment the action: Flows described in Action 1 may decrease residence time of larval sturgeon, thereby reducing time they are susceptible to entrainment.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and other diverters.

Potential obstacles to implementation: Lack of information on extent of sturgeon entrainment on the Feather River. Also, the cost of installing and maintaining screens may be an obstacle.

Predicted benefits: Entrainment of sturgeon, if a problem, should be eliminated. The level of contribution toward the restoration goal remains unknown, but benefits would include decreased early life-stage mortality.

Action 5: Determine effects of poaching and fishing on spawning stock size.

Objective: Increase the size of the spawning stock if it is significantly reduced by poaching or fishing.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: A sturgeon fishery exists on the Feather River with catches occurring every year, especially during wet years. However, lack of catch, effort, and stock size data precludes exploitation estimates. Estimates on the above parameters would allow managers to regulate the fishery to optimize production. Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration may be areas of high adult mortality from increased fishing effort and poaching.

Poaching appears rare on the Feather River and therefore probably has a minimal impact on adult mortality (Hodges pers. comm.). Although poaching does not appear to be a significant problem, poaching on the Bear River (see "Bear River" subsection, below) raises concern over similar activities on the Feather River.

Because so little is known about how stock size, exploitation rates, and poaching affect production, the Feather River sturgeon fishery should be closely monitored by biologists and game wardens. If production is significantly reduced by fishing or poaching, corrective efforts should be initiated.

Related actions that may impede or augment the action: Increased flows and removal or modification of barriers would make sturgeon less vulnerable to angling and poaching.

Agency and organization roles and responsibilities: Population monitoring can be conducted by federal, state, and private consulting firms. The California Fish and Game Commission and DFG are responsible for fishing regulations and law enforcement activities.

Potential obstacles to implementation: None identified.

Predicted benefits: Because so little is known about how stock size, exploitation rates, and poaching affect production, monitoring and surveillance of the fishery will provide data necessary to regulate production.

Action 6: Improve water quality.

Objective: Improve the survival and condition of sturgeon.

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Organic contaminants from agricultural returns, urban and agricultural runoff from storm events, and high trace-element concentrations may affect early life stages of fish in the Feather River (Foe pers. comm.; Schnagl pers. comm.).

Feather River water collected at Verona on May 27 and June 5, 1987, resulted in a 50% and 60% mortality in *Ceriodaphnia* and fathead minnow bioassays, respectively. Similar effects of Feather River water were seen in 1988 and 1989 (RWQCB 1991). Toxic effects were attributed to organic contaminants in rice irrigation water released into Jack Slough and into Honcut Creek and Bear River to a lesser degree (Foe pers. comm.). Based on these data, it is reasonable to suspect negative impacts on sturgeon eggs and larvae in the Feather River in May and June.

Trace elements can also negatively affect embryos and prelarval sturgeon survival, with concentrations as low as a few micrograms per liter being toxic to fish (Dettlaff 1993). From 1978 to 1987, various fish species in the Feather River had levels of arsenic, chromium, copper, and mercury exceeding median international standards. Presence of these trace elements may negatively affect sturgeon early life-stage development.

Contaminant levels in the Feather River should be reduced through enforcement of existing regulations or by creation and enforcement of new regulations. Monitoring should be increased especially at known discharge points.

Related actions that may impede or augment the action: Increased flows of uncontaminated water would help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: Water dischargers and chemical users in the Feather River drainage. Federal, state, and local agencies involved with enforcement and creation of water quality standards.

Potential obstacles to implementation: Dischargers are likely to resist implementation of the action. Cost associated with treatment of runoff, if necessary, may cause resistance to implementation.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Increased egg and larval survival would increase production. Benefits cannot be quantified.

Action 7: Identify availability of suitable spawning habitat.

Objective: Identify potential sturgeon spawning sites and evaluate availability of such sites to adults. Take corrective actions if suitable spawning habitat is limiting.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Sturgeon spawning habitat can vary greatly by species, geographic location, and habitat availability. Sturgeon outside the Central Valley commonly spawn over large gravel, rocks, or compact clay substrates with depths greater than 32.8 feet and velocities of 4.9-9.8 fps (Doroshov pers. comm.). Schaffter (1990) found evidence of Sacramento River sturgeon spawning over gravel and rubble bottoms, and sturgeon spawning in the San Joaquin River were observed using shallow, soft-bottom stream reaches (Rutherford pers. comm.).

Spawning habitat/substrate of sturgeon in the Feather River is unknown. Spawning may be limited to areas directly below Thermalito Afterbay outlet and Cox's Spillway. Substrate in the Feather River closely resembles that of the upper Sacramento River (above Hamilton City). Nearly exclusive collection of young green sturgeon near GCID and the apparent high ratio of green to white sturgeon on the Feather River may indicate different spawning habitat preferences for white and green sturgeon. Sturgeon spawning habitat and its accessibility should be determined.

Related actions that may impede or augment the action: Increased flow and removal or modification of barriers could increase available spawning sites.

Agency and organization roles and responsibilities: Those entities responsible for flows, channel morphology and restoration, and removal or modification of barriers.

Potential obstacles to implementation: Information on sturgeon spawning needs is fragmentary. Because of depths and velocities of suspected spawning habitat, information is difficult to obtain.

Predicted benefits: If lack of spawning habitat and/or access to spawning habitat is limiting, corrective measures could increase reproduction. Benefits cannot be quantified.

Bear River

Limiting factors and potential solutions -

Table 3-Xh-8. Limiting factors and potential solutions for white and green sturgeon in the Bear River.

Limiting factors	Potential solutions
1. Insufficient flows for attraction, upstream migration, spawning, rearing and downstream larvae transport	Provide mean monthly flows of at least 900 cfs at Wheatland from February to May for wet and above-normal water years
2. Inadequate water temperatures for initiation of spawning, final maturation of adults, and survival of eggs and larvae	Maintain water temperatures below 17°C (63°F) throughout the Bear River from February to May for wet and above-normal water years
3. Decreased production from poaching and early life-stage mortality	1. Improve conditions for the production of sturgeon 2. Reduce mortality of adults (poaching and potentially fishing) 3. Reduce mortality of early life stages (see entrainment, water quality, water temperature, etc.)
4. Barriers that prevent or slow sturgeon migration to spawning habitat	1. Identify potential barriers to upstream sturgeon migration (physical and/or water quality barriers) 2. Evaluate extent of the problem 3. Remove barriers or facilitate passage around
5. Loss of sturgeon larvae resulting from entrainment	1. Identify possible entrainment sites 2. Reduce or eliminate entrainment of sturgeon larvae
6. Poor habitat quality resulting from organic compound and	1. Identify potential sites of poor water quality

heavy metal contamination	2. Increase flow of uncontaminated water 3. Decrease contamination by agricultural return flows and heavy metals 4. Decrease exposure to contaminants to acceptable levels
7. Lack of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning substrates 3. If spawning habitat is limited, take appropriate corrective measures

Restoration actions -

Action 1: Provide mean monthly February-May flows of at least 900 cfs at Wheatland for above-normal and wet water years.

Objective: Provide minimum or greater flows to ensure suitable conditions for adult sturgeon to migrate upstream and spawn and for their progeny to survive. Reduce or eliminate drastic flow changes during critical reproductive periods.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Little information exists for green or white sturgeon in the Bear River. Although sturgeon are known to migrate into the Bear River, no effort has been made to document reproduction. Despite the lack of technical information, enough evidence exists in the form of observations by biologists, anglers, fishing guides, and tackle shop employees to provide a basis for making recommendations needed to increase sturgeon production in the Bear River.

Both green and white sturgeon are known to enter the Bear River typically during spring of most wet and some normal water years (Lenihan, Meyer, and Turner pers. comms.). Adult sturgeon were observed in shallow pools between the Highway 70 and Highway 65 bridges during spring of 1989, 1990, and 1992 (Lenihan pers. comm.).

During July 1989, approximately 100 sturgeon were trapped in pools between the Highway 70 and Highway 65 bridges as a result of reduced flows (Meyer pers. comm.). At least 30-40 sturgeon (ranging from 60 pounds and 100 pounds and at least 5 feet long) were poached from this area during a 2-week period in July. Of seven sturgeon confiscated by DFG Game Wardens, all were white sturgeon.

Direct evidence of sturgeon reproduction does not exist, but observations of adults between Highway 70 and Highway 65 bridges indicates that spawning is likely in this area. The presence of preferred spawning habitat of pools 20-30 feet deep and firm substrate also support the conclusion that spawning in this area is likely. Although no adult sturgeon have been observed above the Highway 65 Bridge, anecdotal accounts of large fish being hooked below the SSWD irrigation dam may indicate that sturgeon migrate to this point (Milton pers. comm.).

Flows for successful sturgeon reproduction in the Bear River have not been identified. During good production years, mean monthly February-May flow was at least 900 cfs at Wheatland. Until data are available to establish final flow standards, interim flow standards should be as follows: for above-normal and wet water years, mean monthly February-May flows of at least 900 cfs at Wheatland.

Related actions that may impede or augment the action: Bear River flows must be accompanied by other habitat restoration measures in the Feather and Sacramento rivers, the Delta, and San Pablo and San Francisco bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Bear River production could be decreased by mortality in these downstream areas.

Agency and organization roles and responsibilities: All public and private entities responsible for setting and meeting flow standards on the Bear River.

Potential obstacles to implementation: Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Twelve above-normal and wet water years occurred between 1969 and 1987. Nine of the 12 years had flows above 900 cfs. Increasing flows in the remaining 3 years to at least 900 cfs would increase sturgeon production in the Bear River by 20%.

Action 2: Maintain water temperatures below 17°C (63°F) throughout the Bear River from February through May during above-normal and wet water years.

Objective: Improve cues for sturgeon migration and final sexual maturation and improve spawning success and larval survival.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Data on daily minimum and maximum temperatures for the Bear River are unavailable. However, limited water temperature data presented in the incomplete *Lower Bear River*

Fishery Management Plan indicate that temperatures have been consistently above 75°F at Wheatland in July and August since 1963.

Temperatures should be maintained below 17°C (63°F) throughout the Bear River from February through May during above-normal to wet water years. Development of a temperature model dictating operations of Camp Far West Reservoir, other upstream reservoirs, and diversions downstream of Camp Far West Reservoir may be required for managers to meet criteria. Because data are lacking, installation of thermographs should occur during sturgeon spawning months to determine if water temperatures limit production.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions.

Agency and organization roles and responsibilities: All public and private entities with control over sources and quantities of water flowing into the Bear River share responsibility for meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. If additional flow is required to meet temperature criteria, water users may oppose this action.

Predicted benefits: Temperatures in the Bear River appear high enough in some months and years to reduce egg and larval survival. Reducing temperatures to below 17°C during February-May has the potential to improve sturgeon production in the Bear River. Benefits cannot be quantified.

Action 3: Reduce mortality of spawners.

Objective: Increase the size of the spawning stock.

Location: The Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Both legal harvest and poaching have the potential to decrease sturgeon spawning populations on the Bear River. However, only poaching is known to have recently decreased sturgeon stock size.

During years when sturgeon enter the Bear River, poaching may substantially reduce the number of spawners. For example, during July 1989, approximately 30-40 adult sturgeon in the lower Bear River were illegally harvested during a 2-week period (see Action 1). Despite the large numbers of poachers, DFG Game Wardens were able to quickly stop all poaching activities once they became aware of the problem. Although poaching has only been documented in 1989, it is likely that it has occurred in other years (Lenihan pers. comm.).

Legal harvest of sturgeon on the Bear River is almost nonexistent for the following reasons (Lenihan pers. comm.): 1) large numbers of sturgeon are only intermittently present, 2) most anglers are unaware that sturgeon enter the Bear River, and 3) privately owned land limits river access.

Because so little is known about stock size, exploitation rates, and poaching activities on the Bear River, the sturgeon fishery should be closely monitored by biologists and game wardens. Law enforcement patrols should be increased during years in which sturgeon are expected to enter the Bear River.

Related actions that may impede or augment the action: Increased flow and removal/modification of barriers would make sturgeon less vulnerable to angling and poaching.

Agency and organization roles and responsibilities: Stock monitoring can be conducted by federal and state agencies and private consulting firms. The California Fish and Game Commission and DFG are responsible for fishing regulations and law enforcement activities.

Potential obstacles to implementation: Increased cost and lack of personnel may prevent increased law enforcement.

Predicted benefits: Enforcement may increase the number of sturgeon spawning in the Bear River, which will increase the production of larvae and juveniles in the river.

Action 4: Remove or facilitate passage around migration barriers.

Objective: Identify potential physical and water quality barriers to upstream sturgeon migration and determine the extent to which migration is impeded. Once barriers are identified, facilitate rapid migration of sturgeon around these barriers.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Barriers can delay upstream migration. If delays at barriers cause later spawning, then removal should result in earlier spawning. Earlier spawning sturgeon are less likely to be exposed to high temperatures and poor water quality commonly occurring in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching. The upstream limit to sturgeon migration is the SSWD diversion dam. Several miles downstream of the diversion dam is a culvert crossing at Patterson Sand and Gravel. The Patterson Sand and Gravel culvert could impede sturgeon migration in low-flow years (Meyer pers. comm.). When flows are reduced, adult sturgeon outmigration is further impeded by shallow riffle areas downstream of the Highway 65 bridge. Flows should be kept high enough to allow adult outmigration after spawning.

Potential water quality barriers impeding adult migration are currently unknown, but it is believed that organic contaminants from agriculture runoff may affect migration.

Barriers to sturgeon passage and actions necessary to eliminate or reduce impacts should be determined. Flows should remain high enough to permit adult outmigration, especially for late-spawning fish.

Related actions that may impede or augment the action: Flows specified under Action 1 should help reduce passage problems associated with low flows.

Agency and organization roles and responsibilities: All public and private entities with control over placement and removal of barriers and establishment of Bear River flow standards, and all entities responsible for waste or drainwater discharge into the Bear River.

Potential obstacles to implementation: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation.

Predicted benefits: If barriers exist, their removal will likely result in increased sturgeon production because access will be provided to new spawning habitat and to spawning areas earlier in the spawning season, sturgeon will require less energy to reach spawning areas, and the vulnerability of sturgeon to capture during migration will be decreased. Sturgeon production may increase, but such an increase cannot be quantified.

Action 5: Reduce or prevent entrainment of sturgeon larvae.

Objective: Identify possible sources of entrainment, and if sources are identified, reduce or eliminate entrainment.

Location: From SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Despite the presence of water diversions on the Bear River, no entrainment studies have been conducted to determine impacts on sturgeon. The most recent enumeration of Bear River water diversions (1959) shows four small diversion (siphons 5-10 inches in diameter) between RM 7 and RM 11. Although the number of lower Bear River diversions appear small and entrainment is therefore probably minimal, an updated census on diversions and level of entrainment should be conducted.

The extent of entrainment on the Bear River should be investigated. If a problem is found to exist, these diversions should be screened with state-of-the-art fish screening technology. Also, entrainment can be reduced through limitations being placed on diversions.

Related actions that may impede or augment the action: Flows described in Action 1 may decrease residence time of larval sturgeon, thereby reducing the time they are susceptible to entrainment.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and other diverters.

Potential obstacles to implementation: Lack of information on the extent to which sturgeon are entrained on the Bear River. Cost of installing and maintaining screens.

Predicted benefits: Entrainment of sturgeon, if entrainment is found to be a problem, should be eliminated. Benefits include decreased early life-stage mortality. Sturgeon production may increase, but such an increase cannot be quantified.

Action 6: Monitor water quality, especially at sites of known wastewater discharge.

Objective: Maintain adequate water quality needed for upstream migration, spawning, and early life-stage survival.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Specific studies examining water quality problems on the Bear River do not exist. However, Feather River water sampled between 1987 and 1989 was acutely toxic to invertebrates (CVRWQCB 1991). Toxicity was in part attributed to agriculture return flows entering the Feather River via the Bear River (Foe pers. comm.). The level of Bear River contribution to poor Feather River water quality and the number of contaminant discharge sites are unknown.

Heavy metals can deleteriously affect embryos and pre-larval sturgeon, with concentrations as low as a few micrograms per liter toxic to fish (Dettlaff 1993). Negative impacts on sturgeon from heavy metals in the Bear River are unknown. However, green sunfish liver tissue have shown high levels of nickel and cadmium. Potential for negative impacts of heavy metals on adult and early life-stages exist and should be evaluated.

Sites of agriculture return flows and heavy metal contamination should be located and monitored for impacts. Contaminant levels in the Bear River may be reduced through enforcement of existing regulations or by creation and enforcement of new regulations.

Related actions that may impede or augment the action: Increased flows of uncontaminated water may help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: Water dischargers and chemical users within the Bear River drainage. Federal, state, and local agencies involved with enforcing and creation of water quality standards.

Potential obstacles to implementation: Dischargers are likely to resist implementation of the action.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Increased egg and larvae survival would increase production. Benefits cannot be quantified.

San Joaquin River

Limiting factors and potential solutions -

Table 3-Xh-9. Limiting factors and potential solutions for white and green sturgeon in the mainstem San Joaquin River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and for transport and rearing of larvae and juveniles	Provide mean monthly flows of at least 7,000 cfs at Newman and 14,000 cfs at Vernalis from February to May during wet and above-normal water years
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas and below 20°C (68°F) throughout the San Joaquin River during February-May during wet and above-normal water years
3. Barriers that prevent or slow the migration of sturgeon to spawning habitat	1. Identify potential barriers (physical as well as water quality barriers) 2. Evaluate the extent of the problem 3. Remove barriers or facilitate passage around barriers
4. Loss of sturgeon larvae and juveniles at major and minor diversions on the San Joaquin River resulting from entrainment	1. Identify the extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae and juveniles
5. Size of spawning stock	1. Improve conditions for production of sturgeon 2. Reduce mortality of early life stages (see entrainment, water quality, etc.)

Limiting factors	Potential solutions
	3. Reduce mortality of adults (fishing mortality, especially poaching [including possible contribution of increased flows to reduction in accessibility of migrating and spawning adults to poachers])
6. Poor water quality	1. Increase flows of high quality water 2. Decrease contamination of river by agricultural chemicals and drain water 3. Decrease exposure to excessive levels of trace elements (e.g., selenium) or other contaminants to acceptable levels
7. Availability of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning habitat 3. If habitat limits success of sturgeon spawning, take appropriate corrective action
8. Viability of gametes/health of spawners	1. Evaluate viability of gametes, especially trace-element (e.g., selenium from refineries) and contaminant burdens 2. Evaluate health of spawners 3. If viability of gametes or health of spawners limit sturgeon production, take appropriate corrective action (address sources of contamination or poor health)

Restoration actions -

Action 1: Provide mean monthly flows of at least 7,000 cfs at Newman and 14,000 cfs at Vernalis from February to May during above-normal and wet water years.

Objective: Provide minimum or greater flows to ensure suitable conditions for sturgeon to migrate and spawn and for their progeny to survive.

Location: San Joaquin River upstream of sturgeon spawning areas to the confluence with the Delta downstream.

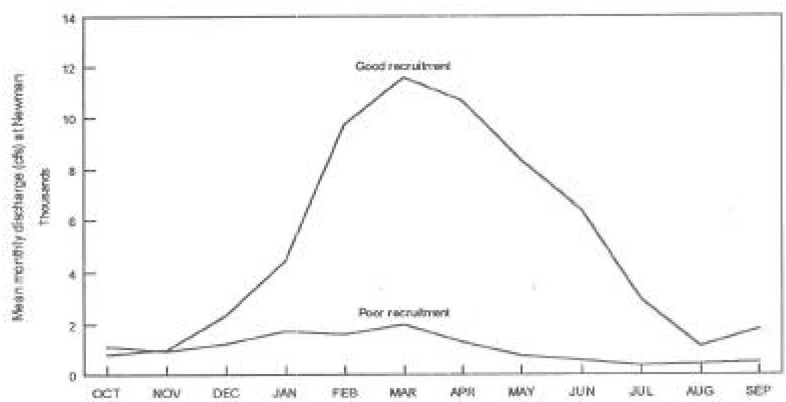
Narrative description: There exists very little information on white or green sturgeon in the San Joaquin River or its tributaries. Although sturgeon are known to migrate into the San Joaquin River (Fry 1973, Kohlhorst et al. 1991), no efforts have been made to document sturgeon reproduction in the San Joaquin River system. In addition, entrainment data are not regularly collected at diversions in the San Joaquin River and those data that do exist either do not identify sturgeon (i.e., sturgeon were lumped in with other species [Rose pers. comm.]) or are for studies that were of short duration and did not capture sturgeon (Hallock and Van Woert 1959). Despite the lack of technical information specific to sturgeon in the San Joaquin River, enough evidence exists in the form of casual observations by biologists, wardens, and anglers to provide a basis for making recommendations to improve conditions for sturgeon production in the river.

Based on the ratio of tagged sturgeon recovered in the San Joaquin River to tagged sturgeon recovered in the Sacramento River, Kohlhorst et al. (1991) estimated that approximately 10% of the white sturgeon in the Sacramento-San Joaquin river system migrate up the San Joaquin River. A small fishery exists for sturgeon (species unknown, but suspected to consist of both white and green sturgeon) on the San Joaquin River upstream of its confluence with the Tuolumne River. Sturgeon are captured from as far south on the San Joaquin River as the mouth of the Merced River. DFG Warden Hugh Rutherford (pers. comm.) has observed anglers in the vicinity of Laird Park and Dos Rios Road (RM 90) taking female and male sturgeon (identified as white sturgeon) in advanced stages of sexual maturation. Warden Rutherford's observations suggest that sturgeon captured there are spawning close to the capture site. Based on these observations, it is likely that sturgeon spawn in the San Joaquin River, at least upstream of the Tuolumne River and downstream of the Merced River. No sampling has been done to confirm the presence of eggs, larvae, or juveniles in the San Joaquin River. It is also possible that sturgeon spawn in the major tributaries to the river.

Data from the Sacramento River indicate that white sturgeon start migrating into the river in October and spawn as early as February (Schaffter pers. comm.). Observations on gonadal development and hatchery spawning of wild-caught and captive white sturgeon suggest that the majority of the Central Valley stocks spawn during March-May, and approximately 20%-30% spawn in February and June (Doroshov pers. comm.). Anglers in the San Joaquin River capture sturgeon as early as late December and fishing improves from January through February, is generally best in March and April, and falls off rapidly as the weather warms, although some stragglers are captured in June (pers. comms. with the following: Red Bartley, angler; Gene Thomas, The Old Fishermen Bait and Tackle; and Ron Wilson, Modesto Bee). Therefore, flow standards would be effective implemented as early as February and possibly as late as June.

Years with good recruitment of white sturgeon showed higher mean monthly discharge rates in February through May than years with poor recruitment (Figure 3-Xh-1). Ranking years by mean monthly outflow in February-May shows that 5 of the 6 years with the highest flows were years with good recruitment of white sturgeon. February-May mean monthly flows in these years were above 7,000 cfs immediately downstream of the Merced River (as indicated by discharge at Newman) and 14,000 cfs where the San Joaquin River meets the Delta (as indicated by discharge at Vernalis). Only one of the years with good recruitment was not in the top six, but it rated ninth at Newman and thirteenth at Vernalis (Table 3-Xh-10). None of the years with good recruitment had February-May mean monthly flows below about 1,900 cfs at Newman or 5,000 cfs at Vernalis.

Figure 3-Xh-1. Mean monthly discharge at two locations on the San Joaquin River for years with good and poor recruitment of sturgeon.



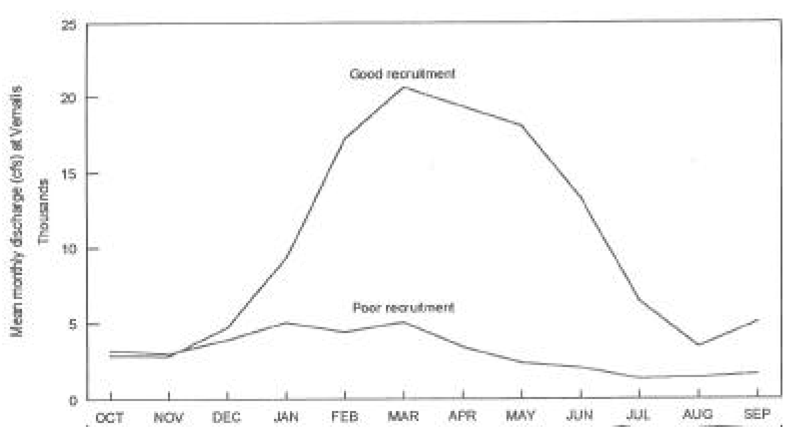


Table 3-Xh-10. Mean monthly discharge (cfs) for February-May at Newman (USGS Hydrologic Unit 18040002, located 650 feet downstream of the Merced River) and Vernalis (Unit 18040003, located 2.6 miles downstream of the Stanislaus River) on the San Joaquin River.

Newman		Vernalis	
Year	Discharge	Year	Discharge
1983	19,545	**1983**	34,965
1969	15,235	**1969**	27,538
1978	9,285	**1980**	16,061
1986	8,116	1986	15,535
1982	7,495	**1982**	14,579
1980	7,221	**1978**	14,485
1973	2,408	1984	6,464
1979	2,080	1973	5,685
1975	1,887	1979	5,455

Newman		Vernalis	
1970	1,643	1970	5,109
1984	1,463	1974	4,967
1974	1,350	**1975**	4,957
1981	892	1971	2,694
1985	837	1987	2,649
1987	828	1985	2,644
1988	667	1981	2,625
1971	652	1968	2,009
1989	647	1988	1,889
1968	601	1989	1,780
1990	549	1976	1,543
1972	527	1972	1,466
1976	517	1990	1,428
1977	232	1977	481

Note: Years are ranked from highest to lowest discharge, and years in bold print were classified as years with good recruitment of white sturgeon.

Flows necessary for successful reproduction of sturgeon need to be determined. In addition to empirical relationships between flow and reproduction, other information (e.g., depth of water necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow standards are set. Until these data are available, interim flow standards should be as follows: February-May mean monthly flows of at least 7,000 cfs immediately downstream of the Merced River as indicated by discharge at Newman and at least 14,000 cfs at Vernalis in wet and above-normal years.

Related actions that may impede or augment the action: Provision of flows in the San Joaquin River must be accompanied by other habitat restoration measures in the San Joaquin River, the Delta, and the San Francisco Bay system.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities responsible for setting flow standards and meeting them on the San Joaquin, Merced, Tuolumne, and Stanislaus rivers all share responsibility.

Potential obstacles to implementation: Competing uses of water and lack of substantive data on which to base a recommendation.

Predicted benefits: Twelve of the 22 years between 1968 and 1990 (the years for which YCIs are available) were wet or above-normal water-year types. Of these 12, only 6 had flows above the recommended standard. If the flow standards were met in the remaining 6 wet and above-normal years, the average YCI for 1968 through 1990 would increase by 60%. If the same assumptions were only applied to wet years, the average YCI would increase by 20%.

Action 2: Maintain water temperatures below 17 °C (63 °F) in sturgeon spawning areas and below 20 °C (68 °F) throughout the San Joaquin River from February through May during wet and above-normal water years.

Objective: Provide water at temperatures suitable for sturgeon to migrate, undergo the final stages of sexual maturation, and spawn and for their progeny to survive.

Location: The San Joaquin River upstream of sturgeon spawning areas to the river's confluence with the Delta.

Narrative description: Temperatures in the San Joaquin River potentially limit production of sturgeon. DFG Exhibit 15 to SWRCB for Phase I of the Bay-Delta hearings indicated that in years when the Vernalis flow was 5,000 cfs or less in May, water temperatures were at levels associated with chronic stress in juvenile chinook salmon (Reynolds et al. 1993). The optimal temperatures for spawning and egg and larval survival of white sturgeon are 10-17°C (50-63°F) (PSMFC?? 1992). Survival of early developmental stages is greatly reduced at temperatures above 20°C (68°F) (Doroshov pers. comm.). Maximum temperatures recorded in the San Joaquin River at the USGS gaging station (USGS Hydrologic Unit 18040003) 650 feet downstream of the Merced River exceeded 20°C (68°F) as early as late February and as late as early May during the 4 years for which data exist (1988, 1989, 1993 and 1994). Clearly, temperatures in sturgeon spawning areas often exceed temperatures conducive to successful spawning of sturgeon, suggesting that temperatures may limit production of sturgeon. Temperatures downstream of this area in spring are usually higher and may also limit production, although temperature tolerance increases with age.

Temperatures should be maintained below 17 °C (63°F) in areas in which sturgeon spawn and below 20 °C (68°F) throughout the San Joaquin River from February through May of wet and normal years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 above will contribute to reductions in temperatures that would depend on the source of water for these flows. As spring progresses and air temperatures warm, the relative contribution of agricultural return flows will become an important factor determining water temperatures in the river. Actions taken to restore habitat upstream of Mendota Pool or to restore riparian vegetation in the San Joaquin drainage will potentially reduce the temperature of the water flowing downstream of the Merced River.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities with control over sources and quantities of water flowing into the San Joaquin River share responsibility for meeting temperature criteria on the San Joaquin River.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Identification of flows may be complicated by the complexity of the watershed, especially the contribution of agricultural return flows to overall San Joaquin River flows. Flows necessary to maintain temperatures are likely to exceed available water, especially in April and May.

Predicted benefits: Temperatures are high enough in the San Joaquin River to prevent successful reproduction by sturgeon during all or at least portions of the spawning season. Reducing temperatures below 17 ^{o}C (63^{o}F) has the potential to greatly improve the frequency and success of sturgeon spawning in the San Joaquin River.

Action 3: Remove barriers to sturgeon migration.

Objective: Remove barriers that prevent or slow the migration of sturgeon to areas in which sturgeon spawn.

Location: The San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Although undocumented, low flows may result in passage problems for sturgeon through shallow areas. Anglers describe sturgeon migrating through shallow water, and believe that low water slows migration. Adult passage studies for chinook salmon in the upper San Joaquin River have been conducted (USFWS 1994), but similar studies for sturgeon in the San Joaquin River have not been conducted.

Low dissolved oxygen levels commonly occur in the vicinity of Stockton each fall as a result of dredging activities in the Stockton Ship Channel and turning basin, flow reversals resulting from high Delta exports, and effluent discharge from the Stockton Municipal Sewage Plant and other sources. Low dissolved oxygen levels have been shown to inhibit adult salmon migration in the vicinity of Stockton. The quality and quantity of agricultural drainwater may also inhibit adult sturgeon migration. Whether low dissolved oxygen levels or other water quality conditions inhibit passage of adult sturgeon is unknown and needs to be investigated.

Barriers to sturgeon migration should be identified and actions taken to eliminate or reduce impacts.

Related actions that may impede or augment the action: Flows specified under Action 1 should prevent passage problems associated with low flows or dissolved oxygen levels. Barriers delay upstream migration. If delays at barriers cause sturgeon to spawn later in the spawning season, then removal of barriers should result in sturgeon spawning earlier. Earlier spawning sturgeon are less likely to be exposed to high temperatures that commonly occur in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching.

DWR installs a barrier at the head of Old River during fall when flows are low or critical problems are predicted. This barrier is believed to improve dissolved oxygen concentrations. Improved treatment of Stockton Municipal Sewage Plant discharge has also helped alleviate the low dissolved oxygen problem. DWR staff members have identified dredging in the ship channel as the major factor contributing to a recent low dissolved oxygen event.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities responsible for setting flow standards and meeting them on the San Joaquin River all share responsibility, as will any entities responsible for waste or drainwater discharge, should these factors be identified as contributing to barriers to sturgeon migration.

Potential obstacles to implementation: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation.

Predicted benefits: If barriers exist, their removal will likely allow sturgeon access to new spawning habitat and to spawning areas earlier in the spawning season, requiring sturgeon to expend less energy to reach spawning areas, and will likely decrease the vulnerability of sturgeon to capture during migration.

Action 4: Reduce or eliminate entrainment of sturgeon.

Objective: Reduce or eliminate entrainment of sturgeon larvae and juveniles at major and minor diversion on the San Joaquin River.

Location: The San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Four major diversions are located on the mainstem San Joaquin River in areas accessible to sturgeon. These are the Banta-Carbona, El Solyo, West Stanislaus, and Patterson Irrigation District diversions. The El Solyo diversion can withdraw up to 80 cfs; the other three diversions each can withdraw 249 cfs. These diversions can cumulatively diver most of the river flow, particularly in dry years. Numerous small- and medium-sized irrigation diversions also exist on the mainstem San Joaquin River.

These diversions entrain significant numbers of chinook salmon (Hallock and Van Woert 1959), but the effects of these diversions on sturgeon are unknown. Entrainment data are not regularly collected at diversions in the San Joaquin River and those data that do exist either do not identify sturgeon (i.e., sturgeon were lumped in with other species [Rose pers. comm.]) or studies were of short duration and did not capture sturgeon (Hallock and Van Woert 1959). Sturgeon are vulnerable to entrainment elsewhere in the Central Valley as evidenced by data collected at the GCID Diversion on the Sacramento River and the CVP and SWP pumps in the Delta. The extent of the problem in the San Joaquin River should be investigated. Any actions taken to alleviate entrainment of chinook salmon should also consider needs of sturgeon.

Several alternatives are being considered to reduce or prevent entrainment of juvenile chinook salmon at these sites: rescreening using state-of-the-art fish screening technology, using alternative electronic or sonic avoidance technology, or providing the irrigation districts with alternative water supplies from the Central Valley Project in lieu of diverting directly from the San Joaquin River. The last alternative is recommended here because it will definitely prevent entrainment of sturgeon in the San Joaquin River (although it might transfer this problem to the Delta), whereas the other alternatives are less likely to succeed. In addition, relocating diversions to the Delta will increase flows throughout the San Joaquin River.

Related actions that may impede or augment the action: This action would keep water that would otherwise be diverted in the San Joaquin River, at least as far as the Delta.

Agency and organization roles and responsibilities: Responsibility would be shared by the state and federal government, especially DWR and USBR, as well as the irrigation districts and other diverters and customers of the SWP and CVP.

Potential obstacles to implementation: Developing alternative water supplies for the districts from the CVP through the Delta-Mendota Canal has been discussed, but little progress has been made (Reynolds et al. 1993). This action would probably require making formal changes in the districts' water rights, constructing new diversion facilities, and extending lateral canals.

Predicted benefits: Benefits would be realized in the form of reduced mortality of juvenile sturgeon from entrainment and increased production of sturgeon resulting from increased San Joaquin River flows and improved riverine habitat.

Action 5: Reduce the mortality of spawners.

Objective: Increase the size of the spawning stock.

Location: San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: A fishery exists for sturgeon on the San Joaquin River and some portion of the population is snagged. Dave Kohlhorst (see III.C.5.) observed during tagging studies that about 10% of the tagged white sturgeon were recaptured in the San Joaquin River. Assuming this number to be representative of the proportion of the white sturgeon population that spawns in the San Joaquin River, the spawning population of white sturgeon in the San Joaquin River can be estimated to have been approximately 910 fish (690 males and 220 females) in 1990. DFG Warden Hugh Rutherford (pers. comm.) estimates that 60-100 sturgeon spawn in the San Joaquin River in the vicinity of Laird Park and the end of Dos Rios Road in a single season (estimate is Warden Rutherford's guess based on visual observation of sturgeon activity). Both estimates indicate that the population of white sturgeon spawning in the San Joaquin River is small. Most observers agree that the number of sturgeon spawning in the San Joaquin River has declined during the last 25 years.

The small population experiences heavy fishing pressure on its spawning grounds. Fishing pressure, especially that resulting from illegal snagging of fish, may be more than this small population can support. Kohlhorst et al. (1991) expressed concern that white sturgeon populations overall were being overexploited, and angling regulations were drafted in 1990 to reduce harvest. Because white sturgeon in the San Joaquin River are a small and probably separate component of the Central Valley white sturgeon population, it is likely that exploitation rates acceptable for the population as a whole are unacceptable for white sturgeon in the San Joaquin River.

Illegal snagging can be limited through a combination of passage of new laws restricting terminal weight and hook placement and size and enforcement of those laws. Gear restrictions are currently being considered by the California Fish and Game Commission that would make snagging nearly impossible. If, however, gear restrictions are not implemented or are ineffective in reducing snagging, closure of the sturgeon fishery should be considered.

Related actions that may impede or augment the action: Increases in flow would help make sturgeon less vulnerable to poaching. Possible closure of the sturgeon fishery would be consistent with the closure of the chinook salmon fishery currently in effect on the San Joaquin River and its tributaries.

Agency and organization roles and responsibilities: The California Fish and Game Commission and DFG are responsible for fishing regulations.

Potential obstacles to implementation: No potential obstacles to adoption of gear restrictions have been identified. If closure of the fishery is deemed necessary, angler groups may resist.

Predicted benefits: Eliminating or reducing illegal harvest will increase the number of sturgeon spawning in the San Joaquin River, which will increase the production of larvae and juveniles in the river. Because the number of fish illegally harvested is unknown, benefits cannot be quantified.

Action 6: Improve water quality.

Objective: Improve survival and condition of sturgeon.

Location: The San Joaquin River from upstream of sturgeon spawning areas on the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Water quality monitoring in the San Joaquin River often shows river water to be toxic to a variety of organisms. Toxicity often occurs during the time period when sturgeon are spawning in the San Joaquin River. Gamete and larval stages of sturgeon are particularly vulnerable to exposure to contaminants. The extent to which contaminants affect sturgeon production in the San Joaquin River is unknown, but is potentially a problem. Contaminants can reduce sturgeon production directly by causing mortality or decreasing physiological condition, or indirectly by reducing availability of food or vulnerability to other direct sources of mortality.

Contaminant levels in the San Joaquin River should be reduced through enforcement of existing regulations or by creation and enforcement of new regulations.

Related actions that may impede or augment the action: Increases in flows of uncontaminated water needed to meet other actions will help dilute contaminant concentrations in the river.

Agency and organization roles and responsibilities: Waste dischargers and chemical users in the San Joaquin River drainage. Federal, state, and local agencies with responsibility for creation and enforcement of environmental regulations.

Potential obstacles to implementation: Dischargers are likely to resist implementation of this action.

Predicted benefits: Benefits are expected to be far reaching, improving habitat for all organisms in the San Joaquin River.

Sacramento-San Joaquin Delta

Limiting factors and potential solutions - Information is currently being gathered on poaching, harvest regulations, and predation. Actions for these limiting factors may be added to future drafts.

Table 3-Xh-11. Limiting factors and potential solutions
for white and green sturgeon in the Delta.

Limiting factors	Potential solutions
1. Inadequate flows for adult sturgeon passage and juvenile production	Provide mean April-May outflow index at Chipps Island of 25,000 cfs in wet and above-normal years; minimum daily Delta outflow index in April not less than 20,000 cfs, and not less than 15,000 cfs in May
2. Loss of larval and juvenile sturgeon at the	Identify the extent of the problem
3. Loss of larval and juvenile sturgeon at	Identify the extent of the problem
4. Poor water quality	1. Increase flows of high quality water 2. Decrease discharge of contaminated water 3. Decrease exposure to excessive levels of trace elements (e.g., selenium) and other contaminants to acceptable levels

Restoration actions -

Action 1: Provide a mean April-May Delta outflow index of at least 25,000 cfs in above-normal and wet year types. The minimum daily Delta outflow index will not be less than 20,000 cfs in April and will not be less than 15,000 cfs in May.

Objective: Increase white sturgeon production by providing adequate Delta outflow in above-normal and wet year types.

Location: Delta outflow index at Chipps Island.

Narrative description: Between 1969 and 1987, good sturgeon production and high Delta outflow occurred in 8 years (1969, 1971, 1974, 1975, 1978, 1980, 1982, and 1983). During these years, mean April-May Delta outflow exceeded approximately 25,000 cfs, with minimum daily Delta outflow of at least 19,712 cfs for April and at least 15,316 cfs for May.

It is not clear whether Delta outflow itself is important in affecting production or whether upstream flows in the Sacramento and San Joaquin rivers and their tributaries, for which Delta outflow is a surrogate, are the important limiting factors. Irrespective of the mechanism of Delta outflow on sturgeon production, outflow requirements should be consistent with upstream flow requirements for sturgeon and other anadromous species so they augment one another.

For successful sturgeon reproduction, a mean April-May Delta outflow index of at least 25,000 cfs in above-normal and wet year types and a minimum daily Delta outflow index of 20,000 cfs in April and 15,000 cfs in May should be provided.

Related actions that may impede or augment the action: Recommended Delta outflows are contingent on recommended flows being met on the Sacramento, San Joaquin, and eastside tributary rivers.

Agency and organization roles and responsibilities: Federal, state, and local agencies responsible for setting Delta flow standards and meeting them.

Potential obstacle to implementation: Implementation of this action may be affected by the availability of water, demands in other months for restoration of other anadromous species, needs of upstream water diverters, and levels of diversions and exports in the Delta.

Predicted benefits: Between 1968 and 1987, there were 12 above-normal and wet water years. Mean April-May Delta outflow exceeded approximately 25,000 cfs in 9 years. Increasing flows in the remaining 3 above-normal and wet years to at least 25,000 cfs would increase average white sturgeon production by approximately 23%. Similar calculations for green sturgeon were not conducted because few green sturgeon were sampled at the facilities and positive identification could not be guaranteed. However, increases in April-May Delta outflow are assumed to also benefit green sturgeon.

Action 2: Limit entrainment at the state and federal pumping facilities.

Objective: Increase sturgeon production by decreasing larval and juvenile sturgeon entrainment.

Location: State and federal pumping facilities in the Delta.

Narrative description: Between 1979 and 1994, the state and federal pumping facilities entrained approximately 39,443 sturgeon. Of the sturgeon measured, approximately 80% were 0.4-0.16 inches in total length. Accurate entrainment estimates of sturgeon less than 2 inches in length are not available because larval and postlarval sturgeon are ineffectively screened. Research on sturgeon swimming capabilities at all life stages is vital to determining approach and sweeping velocities needed for efficient salvage.

Research determining approach and bypass velocities needed to effectively screen larval and juvenile sturgeon should be conducted.

Related actions that may impede or augment the action: Export reductions as recommended by other technical teams may reduce entrainment.

Agency and organization roles and responsibilities: DWR and USBR, as well as customers of the SWP and CVP.

Potential obstacles to implementation: If limiting entrainment requires reducing exports, competing water uses may hinder implementation. Also, funding may limit research needed to determine approach and sweeping velocities and possible screen modifications.

Predicted benefits: Benefits would include increased larval and juvenile sturgeon survival in the Delta. Benefits cannot be quantified.

Action 3: Screen all unscreened water diversions.

Objective: Increase sturgeon production by decreasing larval and juvenile sturgeon entrainment.

Location: Delta.

Narrative description: The abundance of sturgeon larvae in the Delta is related to Delta inflow. During high-flow years sturgeon larvae are transported from upstream spawning areas to the Delta, while during low-flow years larvae remain farther upstream. In 1967, Sacramento flows of 49,217 cfs produced high larval catches in the Delta. In 1966 and 1968, Sacramento flows were 21,820 cfs and 13,600 cfs, respectively. During 1966 few sturgeon larvae were caught in the Delta, and none were caught in 1968.

The level of sturgeon entrainment in Delta agricultural diversions is unknown. A pilot study conducted by Spaar (1992) examined entrainment at Delta agricultural diversions from April to October 1992. No sturgeon larvae or juveniles were collected during the study, probably because of low Sacramento River flow during a critical water year. However, high entrainment of shad, cyprinids, and centrarchid eggs and larvae raises concerns over sturgeon vulnerability during years of high flow.

To reduce or eliminate entrainment, additional information should be gathered on the following: 1) numbers, types, and sizes of unscreened and screened Delta diversions; 2) magnitude of fish losses caused by unscreened diversions; 3) feasibility of installing positive barrier screens to reduce losses; 4) estimated costs of screen design, installation, maintenance, and evaluation; 5) availability of funding mechanisms; and 6) feasibility of management options that would reduce losses (i.e., seasonal pumping restrictions, monitoring requirements, or alternative water supplies). There also is a need for research into the swimming capabilities of early life stages of sturgeon. This information is vital to determining approach and sweeping velocities and how screens should be designed.

Alternatives to reduce entrainment at irrigation diversion and intakes would be screening using state-of-the-art fish screen technology or, potentially, sonic barriers. Investigations to determine minimum mesh size to prevent YOY sturgeon entrainment should be conducted.

Related actions that may impede or augment the action: Techniques used to reduce entrainment at the state and federal water projects may be applied to agricultural diversions.

Agency and organization roles and responsibilities: Federal and state agencies, irrigation districts, and other diverters.

Potential obstacles to implementation: Screening Delta diversions presents many problems resulting from species diversity and water transport rates. Additionally, it may require a long time to develop and evaluate alternative screening methods or sonic barriers.

Predicted benefits: Benefits include reduced entrainment mortality of larvae and juvenile sturgeon. Benefits cannot be quantified.

Action 4: Improve water quality.

Objective: Improve the survival and condition of sturgeon.

Location: The Delta.

Narrative description: Organic compounds and trace elements can negatively affect sturgeon reproduction. White sturgeon in the Sacramento-San Joaquin Estuary accumulate PCBs, dioxin, mercury, and selenium in egg tissue, and these toxins may reduce reproductive potential (Pacific States Marine Fisheries Commission 1992; Kohlhorst 1980; Kohlhorst pers. comm.). PCBs are of special concern for sturgeon in the Central Valley (Kohlhorst 1980). Sturgeon in San Pablo Bay showed gonadal PCB concentrations of 49.3±24.7 ppm and 23.3±27.8 ppm in males and females, respectively (Kohlhorst 1980). Although sturgeon sampled in subsequent years showed lower PCB levels than those reported in 1980, the potential exists for negative impacts on sturgeon.

Trace elements may also adversely affect sturgeon. Sturgeon sampled in the estuary in 1989 and 1990 had selenium levels in muscle tissue of 14.6 ppm (dry weight) and 15.0 ppm (dry weight), respectively. USFWS (USFWS 1990b) reported that selenium levels found in sturgeon are near levels that produce chronic and acute effects in other freshwater fish species. Selenium levels of 16-18 ppm (dry weight, whole body samples [whole body levels most comparable to muscle]) in adult bluegill caused partial to complete mortality of fry during the yolk-sack stage. Also, chinook salmon fry began to die when whole body selenium levels were 5-8 ppm (dry weight). Applicability of these data to sturgeon are unknown. Therefore, effects of selenium and other trace elements on sturgeon production should be investigated.

Related actions that may impede or augment the action: Increases in flows of uncontaminated water needed to meet other actions will help dilute contaminant concentrations in the river.

Agency and organization roles and responsibilities: Waste dischargers and chemical users within the Sacramento-San Joaquin River system. Federal, state, and local agencies with responsibility for creation and enforcement of environmental regulations.

Potential obstacles to implementation: Entities accustomed to using chemicals and discharging contaminated water are likely to resist implementation of this action.

Predicted benefits: Benefits are expected to be far reaching, improving habitat for all organisms in the Delta.

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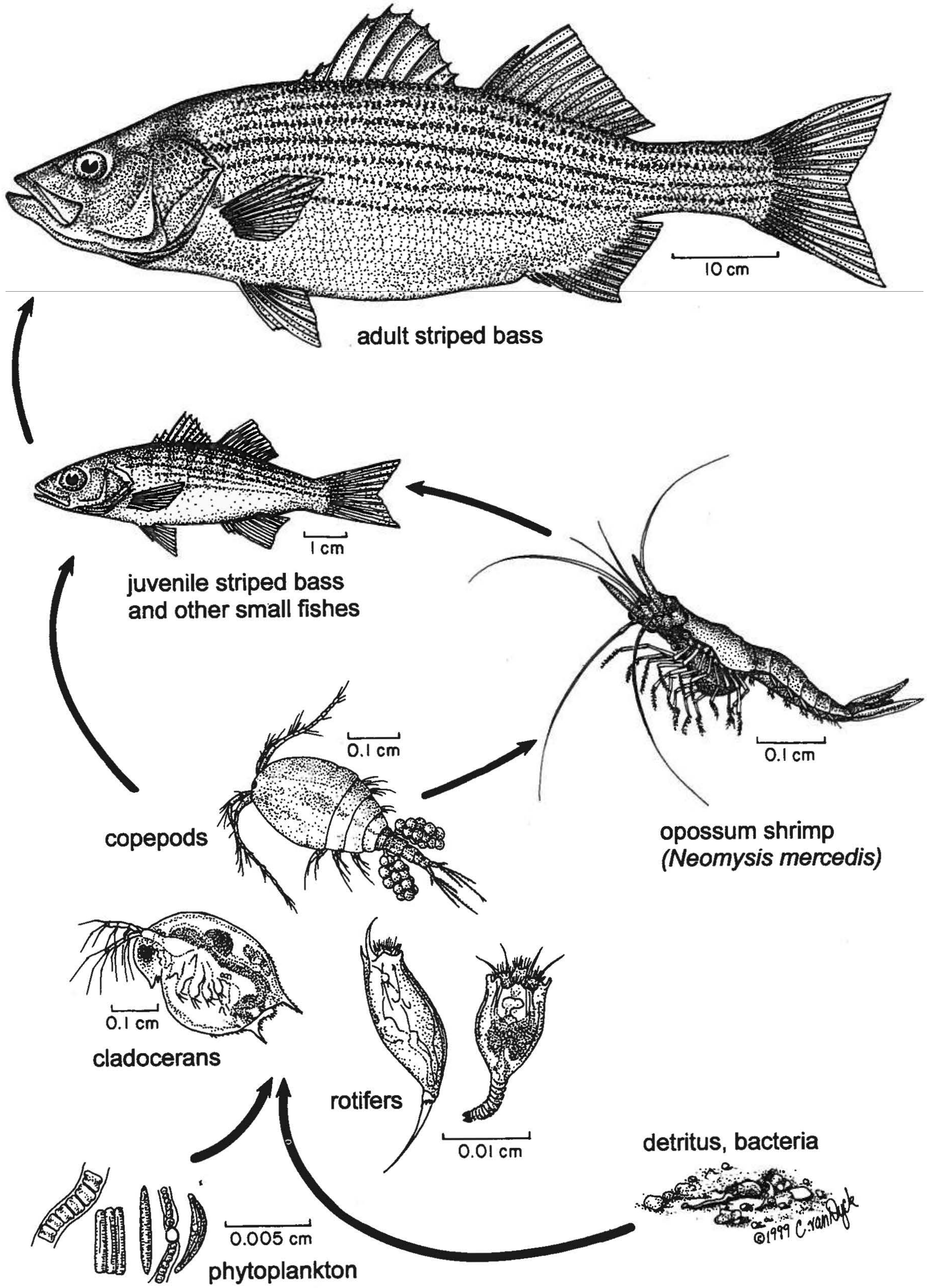

Figure 10. Food web involving striped bass in the Sacramento–San Joaquin estuary. Although adult bass will eat virtually any fish in the estuary, their principal prey is juvenile striped bass, which in turn depend heavily on opossum shrimp and other planktonic crustaceans. The opossum shrimp is a predator on small zooplankton, which in turn feed largely on algae, bacteria, and detritus. From Kegley et al. (1999).

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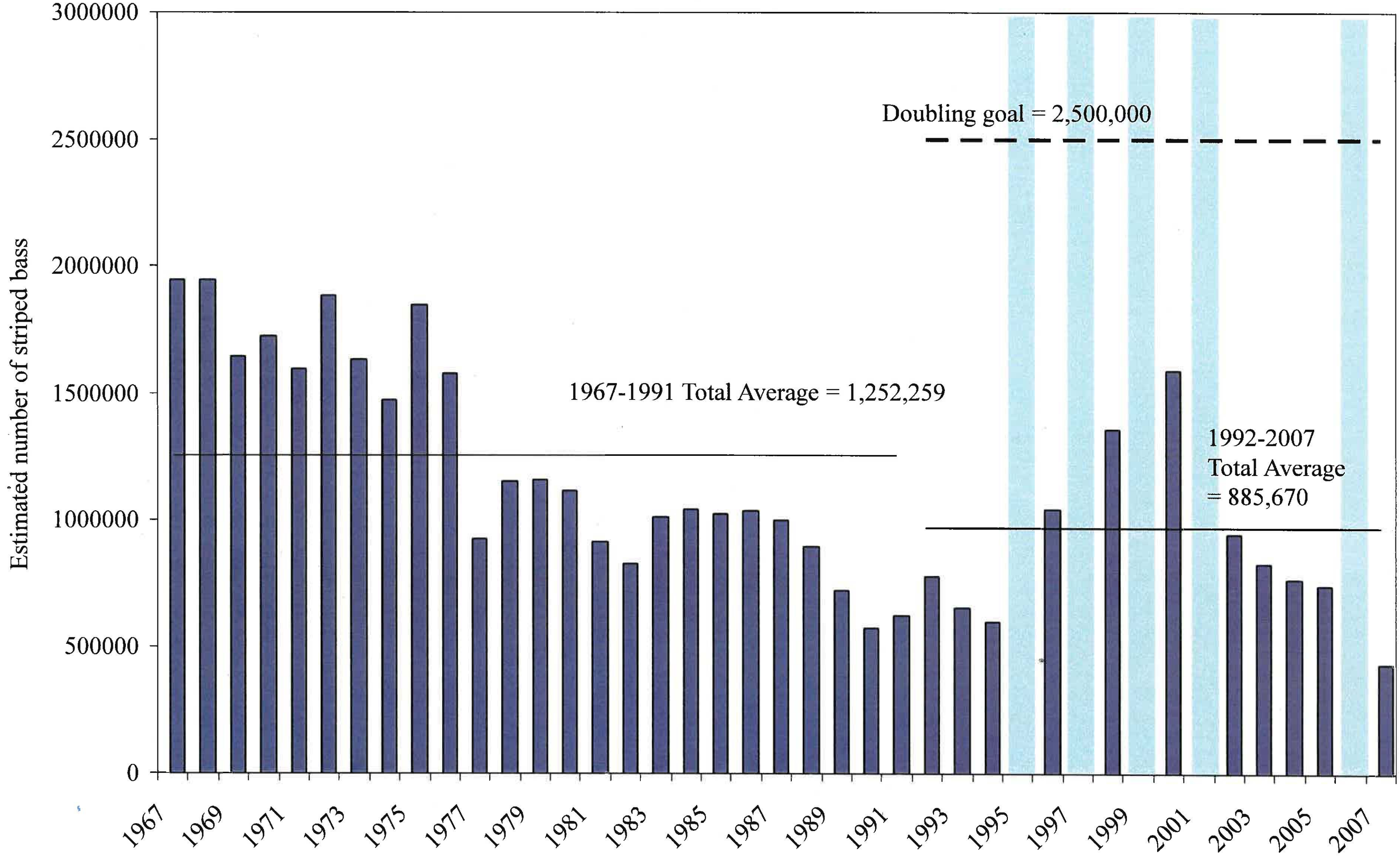

Figure 40. Yearly estimated abundance of adult sized (> 15 inches before 1982, and > 16.5 inches thereafter) striped bass in the Central Valley. Data is from the Mills and Fisher (1967-1991), and CDFG, Bay Delta (1992-2007). ▭ = data was not available for 1995, 1997, 1999, 2001, and 2006.

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Meral retires but Delta plan endures

Published: Thursday, Dec. 26, 2013 - 1:10 pm

Re "Top water official linked to tunnel plans to retire" (Page A4, Dec 15): I am the California Water Impact Network analyst who reported Jerry Meral's comment that the Bay Delta Conservation Plan was never about saving the Delta. The comment by the state's top water official was rumored to have triggered his retirement as a deputy resources secretary. I do believe his candid comments about the BDCP had much to do with his retirement. Unfortunately, the fiscally irresponsible and environmentally disastrous project he promoted as the twin tunnels endures. The Westlands Water District recently learned that it will cost contractors an extra $1.2 billion to complete design work on the tunnels. This extraordinary cost inflation should be taken as a harbinger for the entire project. And who will pay? Ratepayers, which means almost everyone who receives a municipal water bill in California. We don't need this boondoggle.

-- Tom Stokely, Mt. Shasta, water policy analyst, California Water Impact Network

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High Country News
For people who care about the West

Tunneling under California's Bay Delta water wars

by Emily Green

On July 25, California Gov. Jerry Brown announced to an expectant press corps that the state plans to construct a pair of multibillion-dollar tunnels under the Sacramento-San Joaquin Bay Delta in order to modernize and possibly expand the export of Northern California's water, mostly south to farms and cities. After decades of rancor over what was once envisioned as the "peripheral canal," there had been enough studies. There had been enough policy groups. Above all, there had been enough fighting. "I want to get shit done," said Brown.

Central and Southern California water contractors have long supported the plan, and initially some critics saw the governor's announcement as yet another blow to the Delta's fisheries -- already devastated by a combination of pumping, drought and chronic mismanagement. Yet alongside Brown stood an administrator from the National Marine Fisheries Service, which has been fighting tooth-and-nail in federal court to protect the Delta's fish from water exporters. This was no shotgun wedding, William Stelle insisted. His department and its parent agency, the National Oceanic and Atmospheric Administration, support the tunnels. In fact, he argued, properly operated new intakes -- scaled down to the size that his scientists believe are safe -- might actually help Delta smelt, salmon and steelhead.

"The point of departure for evaluating the merits is the current environmental conditions for fish and wildlife," Stelle said, "and they are awful." That's because the pumping stations now exporting water to the Central Valley and the cities of Southern California are located in the South Delta, where their sheer force reverses the water's natural flow to the ocean. According to Stelle, most San Joaquin River juvenile salmon perish near or in the pumps, while the survival rate for Sacramento River migrants can be as low as 40 percent. As Stelle sees it, the ability to turn off South Delta pumps during migration and draw water instead from new pumps roughly 45 miles north would improve life for both the fish and the water exporters.

The carnage caused by the South Delta pumps is better understood now than it was when California voters first rejected the proposed peripheral canal in 1982. At the time, Brown was a second-term governor. "I hadn't heard the word 'smelt' before," he said. Then as now, diverting fresh water before it could reach the brackish estuary was unpopular. Delta farmers worried that it would leave them salt water for irrigation, while fishermen saw the canal as an attempt to steal the entire flow of the Delta's most fecund tributary, the Sacramento River. And environmentalists believed that concentrated Delta pollutants would harm the estuary's natural outlet, the San Francisco Bay.

In contrast, the peripheral canal's proponents appeared greedy, unconvincing, irresolute or impotent. Central Valley cotton king J.G. Boswell wanted more water unencumbered by fish protections. The support of the Metropolitan Water District of Southern California, which served the suburbs steadily radiating out of Los Angeles, struck Northern Californians as simply a plea for more water for swimming pools. The case made by the California Department of Fish and Game, which used many of the same arguments that Stelle does now, never gained traction. The South Delta pumps had slowly been coming online from the 1950s through the 1980s, and the fish toll had yet to register.

Then, in 1986, licensing of four new South Delta pumps increased capacity from 11,000 cubic feet per second to nearly 15,000. Almost simultaneously, drought hit California, where, due to serried ranges, almost half the state's stream flow ends up in the Sacramento-San Joaquin Delta system. As fish numbers tanked, and species such as the Delta smelt and chinook salmon became increasingly endangered, it dawned on horrified water managers that the Delta fisheries' continued collapse could shut off water to 3 million irrigated acres and cities from the Bay Area to San Diego.

Governor after governor called in policy wonks. Pete Wilson's "Delta Oversight Council" morphed into the federal and state "CALFED" program under Gray Davis and the Clinton administration. Then Schwarzenegger began the Bay Delta Conservation Plan, a caveat-rich operating manual for the state water hub that is still in environmental review. This was accompanied by a multi-year study called "Delta Vision." By the time Jerry Brown returned to office in 2011, Delta Vision had transmogrified into the "Delta Stewardship Council," charged with the policy side of getting rival factions to agree on "co-equal" goals. Throughout it all, report after report, the peripheral canal kept coming up.

By 2008, fish stocks had plummeted so badly that salmon fleets were dry-docked and water exports from the Delta fell by almost 2 million acre-feet; Fresno County farmworkers formed breadlines, and Central Valley water districts sued federal fish and wildlife agencies. Ample rain in 2011 offered some respite, but 2012 brought another dry year, by which point Brown declared a hopeless case of "analysis paralysis." Exasperation was such that every federal and state agency involved in Delta oversight stood with him as he revived the peripheral canal plan, this time offering lower pumping capacity than before (reduced from 15,000 to 9,000) and no guarantees of new water for anyone.

Many Delta communities are still worried about rising salinity if a freshwater tributary is tapped before it reaches the estuary. And whether Brown has converted environmentalists or merely disarmed them remains unclear. The Nature Conservancy, Sierra Club and Natural Resources Defense Council all want more details about who will man any new pumps, as well as how much water will be taken, when and from where. Environmentalists also wonder whether other existing commitments to habitat restoration and increased water conservation will be kept. But, this time, they better understand the cost of inaction. "The NRDC is still at the table trying to make the Bay Delta Conservation Plan work," said Kate Poole, the council's senior attorney. "We wouldn't be there if we didn't think it could."

This story was made possible with support from the Kenney Brothers.

July 19, 2010

Mr. Jim Kellogg, President
California Fish and Game Commission
1416 Ninth Street
P.O. Box 944209
Sacramento, California 94244-2090

RE: National Marine Fisheries request to the California Fish & Game Commission to remove fishing regulations on striped bass.

Dear President Kellogg and Commission members:

I am a Research Scientist studying the collapse of the fisheries in the San Francisco Bay Estuary ecosystem using striped bass as a biological model for ecosystem health for 22 years (1987 – 2009) in my research at U.C. Davis. My laboratory has been part of the Pelagic Organism Decline research team supported by various state and federal agencies. I work in close collaboration and communication with the other laboratories and agencies working on the problems related to the collapse of fisheries and this ecosystem.

I have reviewed the letter sent by Maria Rea of the National Marine Fisheries Service (NMFS) to the California Fish & Game Commission requesting the commission to remove fishing restrictions on striped bass. I am dumbfounded by this letter as their own NMFS report cites the likely cause for the collapse of the fall run Chinook salmon as poor ocean conditions not predation by striped bass or other species. I feel the commission should be made aware that there is no valid scientific evidence that striped bass predation on native endangered species has an effect on their population levels. The vast majority, if not all independent scientists, conclude that predation is the lowest level stressor of the stressors affecting the health of the San Francisco Estuary system and its fisheries.

There are far too many important stressors/problems with the San Francisco Estuary ecosystem that require immediate action as identified by leading scientists investigating the Pelagic Organism Decline, CALFED, a National Academy of Science (NAS) expert review panel as well as by State and Federal Agencies. This request to deregulate the striped bass sport fishery is merely an attempt by special interest groups pressuring government agencies and distracting attention from addressing the real problems in the estuary. In fact in a State Water Resources Control Board Hearing a few months ago a panel of expert scientists studying the delta were asked to rate the various stressors affecting fish populations. The panel was unanimous in rating predation (by striped bass and other predators) at the very bottom of the stressor list and they stated that it is not a significant stressor affecting endangered fish in the San Francisco Estuary ecosystem.

There is absolutely no credible scientific evidence of any kind that striped bass predation on salmon, delta smelt or any endangered species is responsible for the decline of these species. If I thought that striped bass was adversely affecting endangered fish or the ecosystem I would be the first person raising a red flag and asking for action. However this is just not the case. Striped bass, salmon, delta smelt and various other fish populations coexisted and thrived in this estuary for over a hundred years when the estuary was a healthy environment for aquatic life. Sadly, we are now faced with a collapsing ecosystem. According to the best available science, the small amount of predation that does take place will not impact the populations of listed species.

All of the research groups from various universities, state and federal agencies are working together to understand the collapse of the fish populations and ecosystem in general. In none of these studies or biological opinions is striped bass predation considered even remotely the cause of the fish declines in this ecosystem. Rather, it is the combined effect of what we call multiple stressors on the ecosystem including: the impacts from water project operations pumping 5 to 6 million acre feet of water out of the system on average per year, lack of appropriately timed river flows in proper amounts, the impacts of toxic pollution and their effects in the delta's waters, unintentionally introduced invasive clams & zooplankton species, habitat deterioration as well as climate change.

We no longer have a dynamic estuary ecosystem with appropriate river flows, tidal influences, salt marshes and the natural habitat required for salmon, delta smelt and striped bass populations to survive, recover and thrive. What we have now in the San Francisco Estuary is a severely anthropomorphically altered ecosystem similar to a huge fresh water reservoir suitable for fish like large mouth bass, small mouth bass and the plant life found in such a habitat. This along with other stressors such as contaminants and introduced invasive clams/zooplankton is why all of these fish populations including striped bass have concurrently declined to extremely low levels some bordering on extinction.

These population declines are not due to striped bass predation. Managing and maintaining a healthy striped bass population would be one of the best things for this ecosystem. If the striped bass population were healthy, it would indicate a healthy **estuarine** ecosystem for all of the local endangered endemic fish whose populations would all benefit. This is not only my opinion but one held by many other fisheries biologists including Dr. Peter Moyle the pre-eminent freshwater/estuarine fishery biologist on the West Coast of the United States.

In the following, please note my responses to the citations in the NMFS letter and additional information I feel is important for the committee to understand when evaluating the merits of the NMFS request:

1) **Hanson 2009:** This is not a peer reviewed report; it was paid for by special interest groups, the State Water Contractors, and is being used as evidence in a current lawsuit against the California Department of Fish and Game. Interestingly, it is the only report I have seen that says "Striped bass predation in rivers tributary to the

Delta appears to be the largest single cause of mortality of juvenile salmon migrating through the delta…" In fact there is no evidence for this and much evidence to the contrary. Recently an array of radio receivers has been placed from the upper reaches of the rivers to the Golden Gate Bridge such that radio tagged fish movements can be tracked in real time with the lead person in charge being a NMFS scientist and colleague. Results from the 2007 tagging of late fall Chinook smolts and juvenile Steelhead indicate survival estimates of ~20% from the release point at Coleman Hatchery (near Red Bluff) to ORD Bend near Chico (see graph at the end of this letter). Although there may be a very few individual resident striped bass in the area of ORD Bend and downstream, over 95% of the striped bass population is located at or downstream of the confluence of the Sacramento and San Joaquin Rivers during this period of time. Only during the spawning run (April-May) do significant numbers of striped bass inhabit the upper Sacramento (or other rivers) and only travel up river to the area between Knights Landing and Colusa which is downstream of ORD Bend. However, the native Sacramento Pike minnow inhabits these sections of the river and are known to congregate and feed on Salmon smolts and juvenile Steelhead. In a 2008 attempt to avoid pike minnow & other predators, aggregations of tagged fish were released at 3 sites downriver of the hatchery and the survival to ORD Bend was similar (pers. communication with Dr. Pete Klimley on 4/20/09). This suggests the vast majority of mortality is occurring in areas where striped bass are not present and that other factors such as other predators (eg. pike minnow, birds…), water quality, river flows and food are responsible for the vast majority of salmon smolt and Steelhead mortality seen in recent years.

2) **DWR 2008 & Gingras 1997:** Here we have again references to artificial predation caused by water project operations. They state that they "presume" it is striped bass eating the pit tagged steelhead and salmon but there is no gut content evidence to support this! In fact the analysis of gut contents of ~2000 striped bass from Clifton Court Forebay conducted by Marty Gingras of the California Department of Fish and Game in 1995 when salmon, delta smelt and striped bass were significantly more abundant showed no delta smelt in the stomachs of striped bass and only one salmon. However, if you have huge pumps that entrain prey and predator fish into a confined area like Clifton Court Forebay, it is expected that the predators will eat the disoriented prey fish. If you removed every single striped bass and other predators from Clifton Court Forebay the fish would succumb to the largest predator in the estuary, the pumps, where there is documentation on the millions of salmon, steelhead, striped bass and delta smelt that have been killed and are killed every year directly by water project operations. The salmon smolts and other endangered fish have virtually no chance once in the Forebay to ever make it back into the ecosystem required for their survival. There was a refusal by the water exporters to comply with the CalFed Record of Decision that requested they finance a study on the effectiveness of state of the art fish screens for Clifton Court Forebay to prevent any fish from entering the Forebay. Had that been done and the screens installed predation in the Forebay would likely be non-existent.

3) **Lindley and Mohr 2003:** The passage quoted from this paper provided **is taken out of context** and the paper concludes that striped bass predation at current and predicted population levels will **NOT** affect the quasi-extinction of the winter run Chinook salmon. The purpose of creating the model in the quoted paper was to try and determine what would happen if the current striped bass population was

<u>artificially enhanced and tripled using various mitigation techniques</u>. There are no current efforts to mitigate the losses of striped bass caused by the State and Federal Water Projects that have substantially contributed to a continual population decline since the 1970s. This paper is a mathematical exercise and based solely on the population abundances of the two species. It is not based on nor does it contain any information on real predation rates of striped bass on Chinook salmon nor does it report any gut contents of striped bass that indicate any real rate of consumption of Chinook salmon by striped bass. The authors state there are better models to address predation but it would require more money and time to produce the better more realistic models. <u>One of many unknown parameters they estimate is the 9% predation rate.</u> The estimated 9% predation rate does not adequately take into account that striped bass are not dependent on salmon for any portion of their diet (and they admit this within the paper). **They based their 9% predation rate as being reasonable by comparing it to predation rates estimated for squawfish in the Columbia River system. The Columbia River system is very different and not comparable to the San Francisco estuary and squawfish are not related to striped bass and fill a different ecological niche in the ecosystem.** A more realistic predation rate based on what is known and reported by those of us who've worked in the system for decades is <3%. If the <3% rate were used in their model striped bass predation would have no effect on salmon quasi-extinction. In their own analysis they determined **<u>that "at current striped bass population levels there is no statistical difference between the quasi-extinction of Chinook salmon as compared to zero striped bass in the model" (in the San Francisco estuary).</u>** This is further stated in the second last line of the paper **<u>"The predicted decline of the adult striped bass population from 700,000 to 512,000 contributes a smaller effect to increase survival probability than does the effect of conservation measures."</u>** Therefore this paper supports the notion that the striped bass population at current and estimated future levels does not have any significant effect on the quasi-extinction of Chinook salmon.

4) To put this in simple perspective predation in these artificial man-made reservoirs such as Clifton Court Forebay, diversion dams & salvage operations are no different than what happens when you feed your home aquarium and the fish come to the area of the tank where the food is being distributed. If you provide a food source of disoriented, stressed fish to predators in a confined area, they will readily eat the food provided. This is not natural predation on salmon or delta smelt, it has not been shown to affect population levels and, to repeat, all of these fish populations thrived together for over 100 years when this estuary was a suitable habitat for all of these fish.
5) Predation on early life stages of fish with reproductive strategies such as Chinook salmon, Steelhead and striped bass is a normal natural part of the food web, and part of ecosystem checks and balances in a healthy environment. For a young salmon to survive it must grow as fast as it can because the larger it gets the likelihood of predation becomes less, and then it must get to the ocean as fast as possible. This requires good water quality, appropriate habitat and adequate food supplies. Current river flows and water quality has been shown to be poor, habitat has deteriorated or destroyed, and food for salmon smolts is much less abundant now that in the past when the population was healthy.

6) Striped bass, Chinook Salmon & Steelhead populations co-existed and thrived in this Estuary/ecosystem for over a hundred years together. It was not until multiple stressors beginning with water project operations in the 1970s followed by contaminants, unintentionally introduced invasive clams and zooplankton, poor river flows and extensive habitat deterioration that all of the species including striped bass concurrently began and continue to decline. Striped bass and salmon populations on the East Coast of the US have co-existed and thrived for thousands of years. So to conclude that striped bass in this ecosystem are causing the decline of salmon and other species has no credible scientific basis and in my opinion is absurd.
7) I have been involved in electro-fishing for adult striped bass for laboratory spawning and research during the spring spawning runs almost every year since 1988. In examining the gut contents of hundreds of adult male and female striped bass I have never found a salmon smolt, delta smelt or adult salmon. The gut contents of striped bass during the spring spawning run are made up almost exclusively of American Shad. Striped bass prefer much larger prey than salmon smolts and the shad run the river at the same time as striped bass.
8) Would the proposed new regulation attempting to control striped bass predation be effective and allow the endangered species populations to increase? The answer is no. So many other factors are suppressing fish populations ranging from exporting massive amounts of water out of the delta, other water project operations, contaminants, wastewater discharges, inadequate timing and amount of delta inflows controlled by the water projects, increasing water temperatures as well as unfavorable ocean conditions (for salmon). All of these stress fish potentially changing behavior making it likely they are less able to avoid predation. A predator removal program would also have to be complete to be effective. Predation control could not just focus on one species (striped bass) but would have to focus on all possible predators including largemouth bass, channel catfish, Sacramento pikeminnow, steelhead, sea lions, otters and fish-eating birds. Probably the most abundant fish eating predator in the delta today is the largemouth bass, because of the decline in striped bass. So do we now change those fishing regulations as well? Where does it stop? Efforts would be better spent on restoring the delta habitat to estuarine conditions and in changing water project operations to protect fish and not provide hot spots of predation rather than singling out and vilifying striped bass.
9) An important food source for adult striped bass has historically been juvenile striped bass. So if we allow anglers to overfish the adult population it is likely that the juvenile survival rates would increase. Due to habitat changes juvenile striped bass no longer have the previously abundant Neomysis shrimp to eat (their historical food source) and have switched to benthic (more contaminated) prey and small fish to survive. The proposed change in the fishing regulations could possibly increase juvenile striped bass predation on salmon smolts, delta smelt and other fish species in peril.
10) Predation by striped bass on juvenile salmon and steelhead is documented, but there is no evidence it makes a difference to numbers of returning salmon. The majority of salmon that are eaten by striped bass are confused naive **hatchery** fish. These are fish that have never lived in a river or ecosystem but only in a controlled hatchery with artificial conditions and are newly released into the delta ecosystem. This

problem is more likely to be alleviated by changing hatchery and release practices rather than attempting to eradicate the striped bass population.

11) Serious human health and social justice implications if the proposed regulations are adopted: By changing the sport fishing regulations anglers will likely first overfish the largest striped bass. These large fish are known to be laden with mercury and other contaminants. Human consumption guidelines have been in place for years such that only a few fish at most should be eaten every month. Human consumption of striped bass from this estuary is discouraged as they are regarded as unsafe to eat. It is unlikely that anglers would catch and discard the fish (not eat them) in an effort to eradicate striped bass. If any regulations should be changed there are good reasons for a catch-and-release fishery with no human consumption allowed. The adverse human health risks and social justice implications of low income anglers that fish to provide food for their families is unacceptable! Changing the striped bass fishing regulations as suggested would encourage subsistence fishermen in the delta to catch and eat more contaminated and unhealthy (to consume) striped bass. Is that something that the Fish and Game Commission or NMFS really wants to advocate?

Am I wrong? Are Dr. Peter Moyle, the POD agencies/scientists, the NAS panel of experts and the State Water Resources expert panel all wrong? How can the proponents of this change in striped bass fishing regulations expect serious consideration of it when the experts working on delta problems and the NAS independent panel all conclude that predation is an extremely low priority stressor and that the most significant stressor, poor delta water management, needs to be addressed immediately?

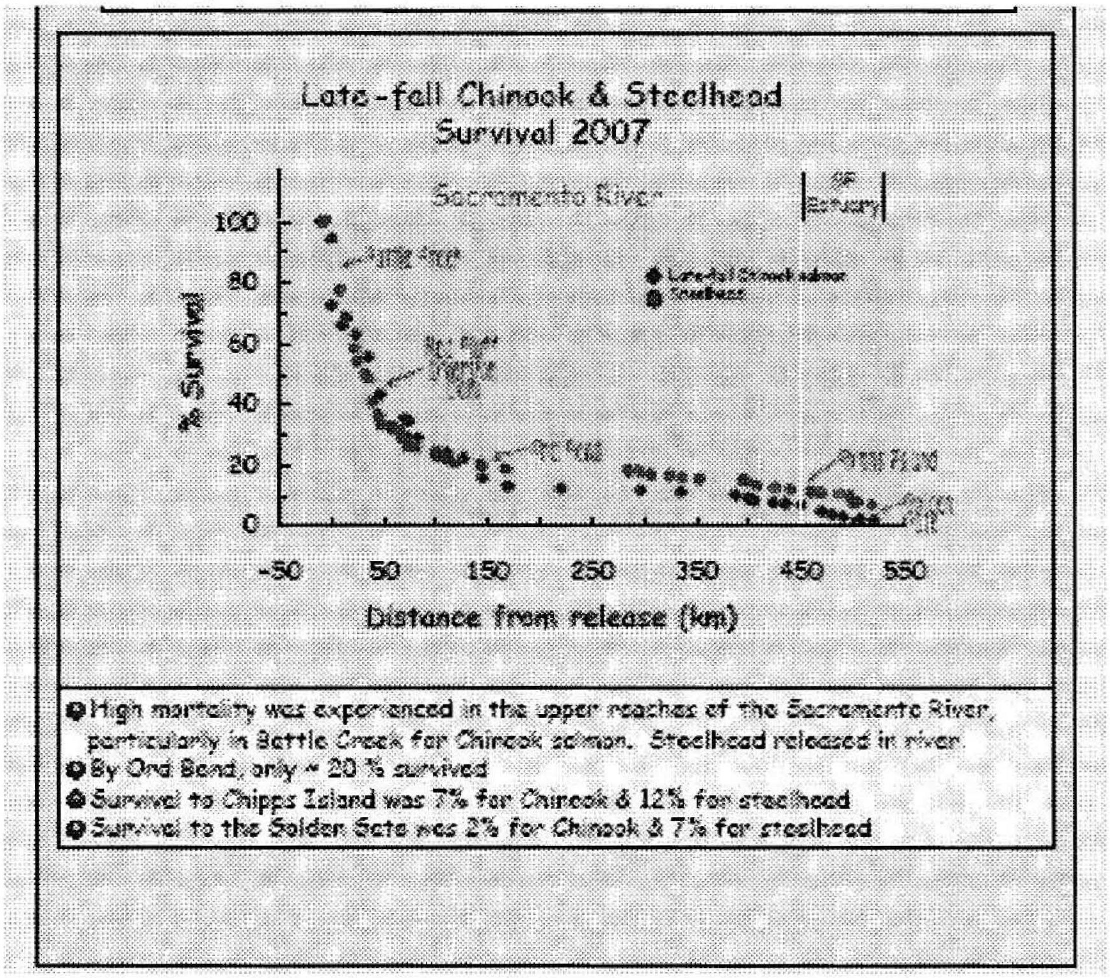
I implore you to reject the NMFS request to deregulate/change the regulations regarding striped bass fishing in California and the San Francisco Estuary system. If these recommended regulations are approved, it will do nothing to restore California's once great fisheries, it provides absolutely no benefit to the San Francisco Estuary and in fact would likely cause further ecosystem harm.

I am available to meet with you and/or the entire commission or members of the NMFS in person to discuss this further. If you require any additional information or clarification please don't hesitate to contact me.

Sincerely,

David J. Ostrach Ph.D.

The graph below is a portion of the poster titled: Survival & Migratory Patterns of Central Valley Juvenile Salmonids: Overview (McFarlane et al., 2007). It shows as discussed in comment #1 above salmon smolt and Steelhead mortality from the release points indicating approximately 80% mortality by the time they reach ORD bend. This is an area of the river not inhabited by significant numbers of striped bass during the late-fall Chinook and Steelhead migration.



Environmental Water Caucus

Sierra Club California

California Sportfishing Protection Alliance
CSPA
Since 1983

Pacific Coast Federation of Fishermen's Associations
PCFFA
Stewards of the Fisheries

food&water watch

RESTORE THE DELTA
Fishable, Swimmable, Drinkable, Farmable by 2010

Planning and Conservation League

Friends of the

Northern California Council
Catch Release
Federation of Fly Fishers

AQUALLIANCE
Defending Northern California Waters

Institute for Fisheries Resources
Unite. Protect. Restore.

Clean Water Action
California

Winnemem Wintu Tribe
Middle River People

50 Years
1961-2011
Save the Bay

North Coast Rivers Alliance

Lower Sherman Island Duck Hunters Association

Resource Renewal Institute
Innovations for a Sustainable Future

Southern California Watershed Alliance

The Fish Sniffer

Desal Response Group

Calif. Striped Bass Assoc.

Revive the San Joaquin

Center for Biological Diversity

Butte Environmental Council

Southwest Council FFF
Many Clubs...One Goal

epic
Keeping Northwest California wild since 1977

Sacramento, The River City Chapter

GGFA

GoldenGate Salmon Association

Berkley Catch More Fish

Environmental Justice Coalition For Water

CA Save Our Streams Council

california water impact network

SalmonWater

June 12, 2012

The Honorable Ken Salazar
Secretary of Interior
Department of the Interior
1849 C Street, N.W.
Washington DC 20240

Dear Mr. Secretary:

The State of California is poised to make an enormous mistake, and potentially drag the Department of Interior and the American people along with it. California Secretary for Natural Resources, John Laird, recently informed us in a May 24, 2012, briefing that the State intends to proceed with construction of a world-record-size tunnel or pipes capable of diverting 15,000 cubic feet per second from the Sacramento River - nearly all of its average freshwater flow. Diversion of this water, which is the most pristine source of water to the San Francisco Bay Delta Estuary, would have devastating ecological impacts. Scientists within the Department of Interior have been pivotal in assessing these impacts and have raised "red-flag" warnings. This $20 to $50 billion dollar, highly controversial project will primarily serve to deliver Sacramento River water, through State and Federal pumps, to provide subsidized irrigation water to corporate agricultural operations of the western San Joaquin Valley.

In addition to the ecological devastation, the project will destroy jobs dependent on tourism, farming, recreation, fishing and seafood production in California and the entire

Pacific Coast. The decision outlined in the May 24th briefing has stirred urgent concerns among fishing communities, farming communities, and conservation organizations throughout the West Coast. This project is a poorly conceived assault on the public trust that desperately needs a strong hand of reason from your Department.

The State has not provided the details of how it reached this proposed action—nor have they answered questions about significant constructability challenges, provided blueprints, or developed a plan of operations. The State has not answered our questions regarding how the 22 species facing extinction in the Delta Estuary will be protected from this massive engineering project and water diversion. We are not reassured by the State's announcement that this project proposal was not pre-decisional and would not undermine the lawful environmental consideration of the project. We were surprised and dismayed that the State of California is headed in this direction, as it appears to contradict or ignore the consensus of expert opinions repeatedly expressed by scientists with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the National Research Council of the National Academy of Sciences. Most recently, State and Federal fishery and wildlife agencies issued official "red flag memos" detailing their concerns that the 50-year permit could hasten the extinction of Central Valley salmon, Delta smelt, longfin smelt and other fish species.

We need you, Mr. Secretary, to take a stand for the public. It would be folly for the Department of Interior to follow the State of California down this risky path. We hope that Interior will instead work to dissuade the State from pursuing this misguided policy. As you know, the Federal and State funding and cooperative assistance agreement, signed in March 2009, promised the following: *"Reclamation will, upon completion of the Program, have the documentation and engineering information* ***to gain Congressional approval to move toward feasibility, design, and implementation of restoration projects to benefit fish and wildlife habitat."*** *[Emphasis added Cooperative Agreement 09FC200011 Page 3 of 32]*

We urge you to uphold the Obama Administration's promise to ensure the Department of Interior's scientific integrity and not bow to political pressure. Circumventing peer-reviewed science with faulty modeling, analysis, and engineering, as the State is proposing, is legally questionable and will damage public trust. Further, protecting our national public trust demands the Department of Interior champion the State of California's flow criteria to protect public trust resources for the San Francisco Bay-Sacramento-San Joaquin Delta (Delta) ecosystem and water quality.

The Department of Interior should also raise the Cooperative Agreement's requirement to *"...address measures that improve conditions for and allow conservation and rehabilitation of habitat supporting the Federally-listed endangered Delta smelt, winter-run Chinook salmon..... These species are considered by many to be the gauge of the health of the Delta ecosystem. Additionally, ... consider measures that benefit other fish, wildlife, and bird species that have been negatively affected by changes to the natural ecosystem, some caused by Central Valley Project operations."* [*Cooperative Agreement 09FC200011 Page 2 of 32.]* No justification has been given for the scale of the proposed tunnels or pipe, nor is there any assurance of operations consistent with ecosystem goals.

Please do not put the interests of South-of-Delta water contractors before the public and San Francisco Bay-Delta dependent farmers, fishermen, and local communities. Narrow special interests should not be allowed to take these public water resources for private gain without regard to costs to one of our nation's most important estuaries. Mr. Secretary, two-thirds of existing Delta Estuary water exports serves corporate irrigators of the western San Joaquin Valley, which accounts for less than .5 percent of California's economy and population. Less than a third of the water goes to the urban areas that make up half of the state's population and economy. Levels of water demand are artificially high due to taxpayer subsidies. Basic fairness, binding commitments, and economic reality all demand that the fast tracking of this massive engineering experiment be rejected because it cannot meet basic legal, economic, and scientific requirements.

We urge you to take the rightful stand against this project and reject these unsustainable water demands and their high public costs, and instead invest in more efficient use of our scarce water resources through cost-effective water conservation and recycling. This will not only protect the pocket books of millions of California ratepayers and U.S. taxpayers, but will help ensure that legally-required salmon doubling goals, estuary restoration, and public trust values are honored for future generations. The planning for California's water future must return to a lawful, science-based, inclusive, and transparent process. The San Francisco Bay-Delta Estuary must not be stripped of the freshwater flows upon which so many vital public trust resources and West Coast communities depend. From its inception, this plan has been crafted by, and for, South-of-Delta exporters. They have used their economic power to influence and rush this half-baked, multi-billion dollar water tunnel.

Planning for California's legitimate water needs, and preserving recreational, fishery, environmental and agricultural resources are way too important to be rushed. California voters said "No" thirty years ago to a plan to dewater the Delta Estuary. It is doubtful they will like the idea any better this time. As Representative Grace Napolitano determined from Congressional testimony, water efficiency and conservation can save one million acre feet of water quickly and cost-effectively—and can start now.

It will be an unimaginable shame if the Department of Interior, the keeper of the public trust resources of our Nation, makes the mistake of going along with the State's poorly conceived and destructive plan.

Sincerely,

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Golden West Women Flyfishers.

Lloyd Carter
President
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Jennifer Clary
Water Policy Analyst
Clean Water Action

Capt Jim Cox
Vice President State Board of Directors
California Striped Bass Assoc.

Robyn DiFalco
Executive Director
Butte Environmental Council

Frank Egger,
President
North Coast Rivers Alliance

Victor Gonella
President
Golden Gate Salmon Association

Huey D. Johnson
Founder and President
Resource Renewal Institute

David Lewis
Executive Director
Save The Bay

Gene Kaczmarek
President, Northern California Council
Federation of Fly Fishers

Roger Mammon
President

Lower Sherman Island Duck Hunters Association

Jim Martin
Conservation Director
Berkley Conservation Institute, Pure Fishing

Pietro Paravano
Chairman of the Board
Institute for Fishery Resources

Dick Pool
President
Water4Fish

Nate Rangel
President
California Outdoors

Michael Schweit
President
Southwest Council, Federation of Fly Fishers

Roger Thomas
President
The Golden Gate Fishermen's Association

Cc: Governor Jerry Brown
Interested Parties

(661) 634-1400

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3200 Rio Mirada Dr.
Bakersfield, CA 93308

July 27, 2012

Ken Salazar, Secretary
U.S. Department of the Interior
1849 C Street, N.W.
Washington, DC 20240

John Laird, Secretary
California Natural Resources Agency
1416 Ninth Street, Suite 1311
Sacramento, CA 95814

Re: Kern County Water Agency's Participation in the BDCP Process

Dear Secretary Salazar and Secretary Laird:

The Kern County Water Agency (Agency) greatly appreciates Wednesday's joint announcement by Governor Brown and Secretary Salazar and the commitment it represents to completing the Bay Delta Conservation Plan (BDCP) by June 2013. The announcement bolstered the Agency's confidence that the issues faced in completing the BDCP can be resolved. Yesterday, the Agency's Board of Directors continued the Agency's participation in the BDCP for the next 90 days. As you are aware, the Agency's participation in the BDCP is contingent upon its Member Units continuing to provide the necessary funding.

The Agency was encouraged by the Governor's and the Secretary's commitment to issue a significant report in 90 days that addresses the two issues of greatest concern to the Agency. As described in the Agency's letter on May 24, 2012, the Agency is interested in defining the various components of the financing plan for the BDCP and the decision-tree concept in a manner that allows potential participants to evaluate the cost-benefit (or feasibility) of participating in the project. Developing appropriate financing mechanisms and a scientifically defensible decision-tree to operate a new conveyance facility are critical elements necessary to identify a project that provides sufficient benefits to be affordable (and therefore financeable) for agriculture. Other critical elements include permittee status for the Public Water Agencies and an acceptable biological opinion reconsultation process to determine Central Valley Project and State Water Project operations before a preferred project is completed. The Agency is committed to continuing active participation in resolving these issues.

Thank you for your personal efforts to bring the BDCP to this point and for the dedication that U.S. Bureau of Reclamation Commissioner Michael Connor, California Natural Resources Agency Deputy Secretary Dr. Jerry Meral, California Department of Water Resources Director Mark Cowin and California Department of Fish and Game Director Chuck Bonham have shown throughout this process.

As the Governor stated in his remarks, completing this project is "... another test of whether we can govern ourselves." We stand with the Governor in our belief that we can.

Sincerely,

Terry Rogers

Terry Rogers
Board President

cc: Honorable Edmund G. Brown Jr.
Honorable Dianne Feinstein
Kern County Congressional and Legislative Delegation
Honorable Karen Ross
Honorable Matt Rodriguez
Honorable Michael Connor
Honorable Mark Cowin
Honorable Don Glaser
Ms. Nancy McFadden
Ms. Martha Guzman-Aceves
Mr. Cliff Rechtschaffen
Dr. Jerry Meral
Mr. Chuck Bonham
Kern County Water Agency Board of Directors
State Water Contractors
San Luis & Delta-Mendota Water Authority
The Gualco Group, Inc.

State of California | California Natural Resources Agency

Memorandum

Date: May 6, 2014

To: All DWR Employees

From: **Department of Water Resources**

Subject: Establishment of the DWR BDCP Office and the DHCCP Design and Construction Enterprise

As many of you are keenly aware, the Department of Water Resources (DWR) has been deeply engaged in the development of the Bay Delta Conservation Plan (BDCP) since 2006. Several DWR offices and divisions are currently working on BDCP, either as part of the Delta Habitat Conservation and Conveyance Program (DHCCP) or as part of the planning and analysis of the overall BDCP program.

We are approaching a critical juncture for BDCP as the planning phase reaches completion, State and federal resource agencies consider permitting decisions, and a more detailed financing plan is developed. While many milestones remain before a positive decision to implement BDCP is achieved, DWR must begin to prepare to carry out its critical role in the implementation phase of this important project, should a conclusion be reached to move forward. To this end, we are establishing two new DWR organizations beginning June 1, 2014 - the DWR BDCP Office and the Delta Conveyance Facilities Design and Construction Enterprise (known as the DCE).

First, a new BDCP Office will be established within the Executive Division. The initial focus will be the completion of the conservation plan while providing early coordination and transition to implementation of BDCP conservation measures 2 through 22, including, for example, tidal marsh restoration, Yolo Bypass fishery enhancement and urban stormwater treatment. This team will work to plan, manage, and integrate coordination among DWR's various divisions involved with development of BDCP and initiate preliminary evaluations needed to implement BDCP. In addition, this team will play an important role in agency and stakeholder engagement needed to complete the plan. To help facilitate the completion of BDCP, including the needed close coordination with the Governor's Office and the State administration, the office will initially be led by the Chief Deputy Director.

This office will lay the foundation for the implementation of BDCP, and once the BDCP is finalized, that work will be merged into the formal BDCP Implementation Office as is defined in Chapter 7 of the BDCP. This organization will likely be a multi-agency effort involving DWR or supported by DWR.

Second, a Delta Conveyance Facility Design and Construction Enterprise (DCE) will be established within the Department as a new program to support activities associated with design and construction of conservation measure 1, the Delta Conveyance facilities. The mission of this enterprise is intended to be limited to this singular focus, and the life span of the enterprise will be limited to the time necessary to complete construction of these facilities. The organizational structure and staffing of the DCE is envisioned to be somewhat unique in comparison to a typical DWR organization. It will be managed by a Program Manager under contract to DWR, and will be staffed by highly qualified individuals from within DWR, participating regional and local public water agencies, and private consulting firms. As part of DWR, it will have the capacity to issue contracts for consulting services as well as construction, using DWR's authority and in keeping with all applicable State contracting statutes. Initially the DCE will be located in the Bonderson Building, but it is anticipated that it will move to another location to accommodate the growth needed to complete the design and construction of the conveyance facilities.

Undoubtedly, a number of questions will arise about how these two structures will mesh with our existing organization at DWR, and we will be working with you all to elicit your questions and develop solutions together. I look forward to your continued support as we enter into this exciting phase of the BDCP which will shape the future of Delta ecological restoration and water project operations.

/s/
Mark W. Cowin
Director

Delta Independent Science Board

980 NINTH STREET, SUITE 1500
SACRAMENTO, CALIFORNIA 95814
HTTP://DELTACOUNCIL.CA.GOV
(916) 445-5511

September 30, 2015

To: Randy Fiorini, Chair, Delta Stewardship Council
Charlton Bonham, Director, California Department of Fish and Wildlife

From: Delta Independent Science Board

Subject: Review of environmental documents for California WaterFix

We have reviewed the partially Recirculated Draft Environmental Impact Report/ Supplemental Draft Environmental Impact Statement for the Bay Delta Conservation Plan/California WaterFix (herein, "the Current Draft"). We focused on how fully and effectively it considers and communicates the scientific foundations for assessing the environmental impacts of water conveyance alternatives. The review is attached and is summarized below.

The Current Draft contains a wealth of information but lacks completeness and clarity in applying science to far-reaching policy decisions. It defers essential material to the Final EIR/EIS and retains a number of deficiencies from the Bay Delta Conservation Plan Draft EIR/EIS. The missing content includes:

1. Details about the adaptive-management process, collaborative science, monitoring, and the resources that these efforts will require;
2. Due regard for several aspects of habitat restoration: landscape scale, timing, long-term monitoring, and the strategy of avoiding damage to existing wetlands;
3. Analyses of how levee failures would affect water operations and how the implemented project would affect the economics of levee maintenance;
4. Sufficient attention to linkages among species, landscapes, and management actions; effects of climate change on water resources; effects of the proposed project on San Joaquin Valley agriculture; and uncertainties and their consequences;
5. Informative summaries, in words, tables, and graphs, that compare the proposed alternatives and their principal environmental and economic impacts.

The effects of California WaterFix extend beyond water conveyance to habitat restoration and levee maintenance. These interdependent issues of statewide importance warrant an environmental impact assessment that is more complete, comprehensive, and comprehensible than the Current Draft.

Review by the Delta Independent Science Board of the

Bay Delta Conservation Plan/California WaterFix Partially Recirculated Draft Environmental Impact Report/ Supplemental Draft Environmental Impact Statement

September 30, 2015

Contents

EXPECTATIONS FOR IMPACT ASSESSMENT OF CALIFORNIA WATERFIX

The Sacramento – San Joaquin Delta presents interconnected issues of water, biological resources, habitat, and levees. Dealing with any one of these problem areas is most usefully considered in light of how it may affect and be affected by the others. The effects of any actions further interact with climate change, sea-level rise, and a host of social, political, and economic factors. The consequences are of statewide importance.

These circumstances demand that the California WaterFix EIR/EIS go beyond legal compliance. This EIR/EIS is more than just one of many required reports. Its paramount importance is illustrated by the legal mandate that singles it out as the BDCP document we must review.

It follows that the WaterFix EIR/EIS requires extraordinary completeness and clarity. This EIR/EIS must be uncommonly complete in assessing important environmental impacts, even if that means going beyond what is legally required or considering what some may deem speculative (below, p. 4). Further, the WaterFix EIR/EIS must be exceptionally clear about the scientific and comparative aspects of both environmental impacts and project performance (p. 9).

These reasonable expectations go largely unmet in the Bay Delta Conservation Plan/California WaterFix Partially Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement Draft (herein, "the Current Draft"). We do not attempt to determine whether this report fulfills the letter of the law. But we find the Current Draft sufficiently incomplete and opaque to deter its evaluation and use by decision-makers, resource managers, scientists, and the broader public.

BACKGROUND OF THIS REVIEW

The Delta Reform Act of 2009, in §85320(c), directs the Delta Independent Science Board (Delta ISB) to review the environmental impact report of the Bay Delta Conservation Plan (BDCP) and to provide the review to the Delta Stewardship Council and the California Department of Fish and Wildlife. On May 14, 2014, we submitted our review of the BDCP's Draft Environmental Impact Report/Draft Environmental Impact Statement (herein, the "Previous Draft"), which had been posted for review on December 9, 2013. This review[1] contained three main parts: an extended summary, detailed responses to charge questions from the Delta Stewardship Council, and reviews of individual chapters. Although the Previous Draft considered vast amounts of scientific information and analyses to assess the myriad potential environmental impacts of the many proposed BDCP actions, we concluded that the science in the Previous Draft had significant gaps, given the scope and importance of the BDCP.

The proposed BDCP actions have now been partitioned into two separate efforts: water conveyance under California WaterFix[2] and habitat restoration under California EcoRestore[3]. Environmental documents in support of California WaterFix (the Current Draft) were made available for a 120-day comment period that began July 10, 2015. The Current Draft focuses on three new alternatives for conveying Sacramento River water through the Sacramento – San

[1] http://deltacouncil.ca.gov/sites/default/files/documents/files/Attachment-1-Final-BDCP-comments.pdf
[2] http://www.californiawaterfix.com/
[3] http://resources.ca.gov/ecorestore/

Joaquin Delta. One of them, Alternative 4A, is the preferred alternative, identified as California WaterFix.

The Delta Stewardship Council asked us to review the Current Draft and to provide our comments by the end of September 2015. We are doing so through this report and its summary, which can be found in the cover letter.

The review began in July 2015 with a preliminary briefing from Laura King-Moon of California Department of Water Resources (three Delta ISB members present). The Delta ISB next considered the Current Draft in a public meeting on August 13–14 (nine of the ten members present)[4]. The meeting included a briefing on California EcoRestore by David Okita of California Natural Resources Agency and a discussion of the Current Draft and California WaterFix with Cassandra Enos-Nobriga of California Department of Water Resources (DWR) and Steve Centerwall of ICF International.

The initial public draft of this review was based on our study of Sections 1-4 of the Current Draft and on checks of most resource chapters in its Appendix A. This public draft was the subject of a September 16 meeting that included further discussions with Cassandra Enos-Nobriga[5] and comments from Dan Ray of the Delta Stewardship Council staff. Additional comments on that initial draft were provided by DWR in a September 21 letter to the Delta ISB chair[6]. These discussions and comments helped clarify several issues, particularly on expectations of a WaterFix EIR/EIS.

This final version of the review begins with a summary in the cover letter. The body of the report continues first with a section on our understanding of major differences between the BDCP and California WaterFix. Next, after noting examples of improvement in the Current Draft, we describe our main concerns about the current impact assessments. These overlap with main concerns about the Previous Draft, which we revisit to consider how they are addressed in the Current Draft. Finally, we offer specific comments on several major Sections and Chapters.

DIFFERENCES BETWEEN THE BDCP AND CALIFORNIA WATERFIX

The project proposed in the Current Draft differs in significant respects from what was proposed as the BDCP in December 2013. Here we briefly state our understanding of some main differences and comment on their roles on this review:

- The time period for permitting incidental take under Section 7 of the federal Endangered Species Act (ESA) and Section 2081(b) of the California Endangered Species Act (CESA) is substantially less than the 50 years envisioned as part of a Habitat Conservation Plan (HCP) and Natural Community Conservation Plan (NCCP) in BDCP. As a result, the science associated with many impacts of climate change and sea-level rise may seem less relevant. The permitting period for the project proposed in the Current Draft remains in place unless environmental baseline conditions change substantially or other permit requirements are not met. Consequently, long-term effects of the proposed project remain important in terms of operations and expected benefits (p. 8).

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[4] http://deltacouncil.ca.gov/docs/delta-isb-meeting-notice-meeting-notice-delta-isb/delta-independent-science-board-isb-august-13

[5] Written version at https://s3.amazonaws.com/californiawater/pdfs/63qnf_Delta_ISB_draft_statement_-_Enos_-_FINAL.pdf

[6] http://deltacouncil.ca.gov/docs/response-letter-dwr

- In this shortened time frame, responsibility for assessing WaterFix's effects on fish and wildlife would fall to resource agencies (National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife). Other impacts would be regulated by a variety of federal and state agencies (Current Draft Section 1).
- The proposed habitat restorations have been scaled back. The Current Draft incorporates elements of 11 Conservation Measures from BDCP to mitigate impacts of construction and operations. Most habitat restoration included in the Previous Draft has been shifted to California EcoRestore. Our review of the Previous Draft contained many comments on the timing of restoration, species interactions, ecological linkages of conservation areas, locations of restoration areas and the science supporting the efficiency and uncertainty of effective restoration. Some of these comments apply less to the Current Draft because of its narrower focus on water conveyance.
- There remains an expected reliance on cooperative science and adaptive management during and after construction.
- It is our understanding that the Current Draft was prepared under rules that disallow scientific methods beyond those used in the Previous Draft. The rules do allow new analyses, however. For example, we noticed evidence of further analyses of contaminants, application of existing methods (e.g. particle tracking) to additional species (e.g., some of the non-covered species), and occasional selection of one model in place of the combined results of two models (e.g., fish life cycle models SALMOD and SacEFT).

IMPROVEMENTS ON THE PREVIOUS DRAFT

A proposed revamping of water conveyance through the Sacramento-San Joaquin Delta involves a multitude of diverse impacts within and outside of the Delta. Unavoidably, the EIR/EIS for such a project will be complex and voluminous, and preparing it becomes a daunting task in its own right. The inherent challenges include highlighting, in a revised EIR/EIS, the most important of the changes.

The new Sections 1 through 4 go a long way toward meeting some of these challenges. Section 1 spells out the regulatory context by discussing laws and agencies that establish the context for the Current Draft. Section 2 summarizes how the Previous Draft was revised in response to project changes and public input. Section 3 describes how the preferred alternative in the Previous Draft (Alternative 4) has been changed. Section 4 presents an impressive amount of detailed information in assessing the sources of habitat loss for various species and discussing how restoration and protection can mitigate those losses. Generally comprehensive lists of "Resource Restoration and Performance Principles" are given for the biological resources that might be affected by construction or operations. For example, page 4.3.8-140 clearly describes a series of measures to be undertaken to minimize the take of sandhill cranes by transmission lines (although the effectiveness of these measures is yet to be determined).

Section 4 also contains improvements on collaborative science (4.1.2.4, mostly reiterated in ES.4.2). This part of the Current Draft draws on recent progress toward collaborative efforts in monitoring and synthesis in support of adaptive management in the Delta. The text identifies the main entities to be involved in an expected memorandum of agreement on a monitoring and adaptive-management program in support of the proposed project.

Appendix A describes revisions to the resource chapters of the Previous Draft. Track-changed versions of the chapters simplify the review process, although this was not done for the key chapter on aquatic resources (p. 17). We noticed enhanced analyses of contaminants and application of methods such as particle tracking to additional species, including some of the non-covered taxa; a detailed treatment of *Microcystis* blooms and toxicity; more information about disinfection byproducts; improved discussion of vector control arising from construction and operational activities; and revised depiction of surficial geology. Potential exposure of biota to selenium and methylmercury is now considered in greater detail. Evaluations will be conducted for restoration sites on a site-specific basis; if high levels of contaminants cannot otherwise be addressed, alternative restoration sites will be considered (page 4.3.8-118). Incidentally, this is a good example of adaptive management, although it is not highlighted as such. Explanations were provided for why the nitrogen-to-phosphorus ratio was not specifically evaluated, why dissolved vs. total phosphorus was used in the assessment, and how upgrades to the Sacramento Regional Wastewater Treatment Plant would eventually affect phosphorus concentrations.

CURRENT CONCERNS

These and other strengths of the Current Draft are outweighed by several overarching weaknesses: overall incompleteness through deferral of content to the Final EIR/EIS (herein, "the Final Report"); specific incompleteness in treatment of adaptive management, habitat restoration, levees, and long-term effects; and inadequacies in presentation. Some of these concerns overlap with ones we raised in reviewing the Previous Draft (revisited below, beginning on p. 10).

Missing content

The Current Draft lacks key information, analyses, summaries, and comparisons. The missing content is needed for evaluation of the science that underpins the proposed project. Accordingly, the Current Draft fails to adequately inform weighty decisions about public policy. The missing content includes:

1. Details on adaptive management and collaborative science (below, p. 5).
2. Modeling how levee failures would affect operation of dual-conveyance systems (below, p. 7). Steve Centerwall told us on August 14 that modeling of the effects of levee failure would be presented in the Final Report.
3. Analysis of whether operation of the proposed conveyance would alter the economics of levee maintenance (below, p. 7).
4. Analyses of the effects of climate change on expected water exports from the Delta. "[A]n explanation and analysis describing potential scenarios for future SWP/CVP system operations and uncertainties [related to climate change] will be provided in the Final Report" (p. 1-35 of the Current Draft).
5. Potential impacts of climate change on system operations, even during the shortened time period emphasized in the Current Draft (below, p. 8 and 11).
6. Potential effects of changes in operations of the State Water Project (SWP) and Central Valley Project (CVP), or other changes in water availability, on agricultural practices in the San Joaquin Valley (p. 12).
7. Concise summaries integrated with informative graphics (below, p. 9 and 13). The Current Draft states that comparisons of alternatives will be summarized in the Final Report (p. 1-35).

While some of the missing content has been deferred to the Final Report (examples 2, 4, and 7), other gaps have been rationalized by deeming impacts "too speculative" for assessment.

CEQA guidance directs agencies to avoid speculation in preparing an EIR/EIS[7]. To speculate, however, is to have so little knowledge that a finding must be based on conjecture or guesswork. Ignorance to this degree does not apply to potential impacts of WaterFix on levee maintenance (example 3; see p. 7) or on San Joaquin Valley agriculture (example 6; p. 12).

Even if content now lacking would go beyond what is legally required for an EIR/EIS, providing such content could assist scientists, decision-makers, and the public in evaluating California WaterFix and Delta problems of statewide importance (above, p. 1).

Adaptive management

The guidelines for an EIR/EIS do not specifically call for an adaptive-management plan (or even for adaptive management). However, if the project is to be consistent with the Delta Plan (as legally mandated), adaptive management should be part of the design.

The Current Draft relies on adaptive management to address uncertainties in the proposed project, especially in relation to water operations. The development of the Current Draft from the Previous Draft is itself an exercise in adaptive management, using new information to revise a project during the planning stage. Yet adaptive management continues to be considered largely in terms of how it is to be organized (i.e., coordinated with other existing or proposed adaptive-management collaborations) rather than how it is to be done (i.e., the process of adaptive management). Adaptive management should be integral with planned actions and management—the Plan A rather than a Plan B to be added later if conditions warrant. The lack of a substantive treatment of adaptive management in the Current Draft indicates that it is not considered a high priority or the proposers have been unable to develop a substantive idea of how adaptive management would work for the project.

There is a very general and brief mention of the steps in the adaptive management process in Section 4 (p. 4.1-6 to 4.1-7), but nothing more about the process. We were not looking here for a primer on adaptive management. Rather, we expected to find serious consideration of barriers and constraints that have impeded implementation of adaptive management in the Delta and elsewhere (which are detailed in the Delta Plan), along with lessons learned on how adaptive management can be conducted overcome these problems.

The Current Draft contains general statements on how collaborative science and adaptive management under California WaterFix would be linked with the Delta Collaborative Science and Adaptive Management Program (CSAMP) and the Collaborative Adaptive Management Team (CAMT). These efforts, however, have taken place in the context of regulations and permits, such as biological opinions and biological assessments required under the Endangered Species Act. We did not find examples of how adaptive management would be applied to assessing—and finding ways to reduce—the environmental impacts of project construction and operations.

Project construction, mitigation, and operations provide many opportunities for adaptive management, both for the benefit of the project as well as for other Delta habitat and ecosystem initiatives, such as EcoRestore. To be effective in addressing unexpected outcomes and the need for mid-course corrections, an adaptive-management management team should evaluate a broad range of actions and their consequences from the beginning, as plans are being developed, to facilitate the early implementation and effectiveness of mitigation activities.

[7] https://s3.amazonaws.com/californiawater/pdfs/bo0lx_Delta_ISB_Draft_Statement_&_Response_Letter_-_Enos_-_FINAL.pdf

The Current Draft defers details on how adaptive management will be made to work: "An adaptive management and monitoring program will be implemented to develop additional scientific information during the course of project construction and operations to inform and improve conveyance facility operational limits and criteria" (p. ES-17). This is too late. If adaptive management and monitoring are central to California WaterFix, then details of how they will be done and resourced should be developed at the outset (now) so they can be better reviewed, improved, and integrated into related Delta activities. The details could include setting species-specific thresholds and timelines for action, creating a Delta Adaptive Management Team, and capitalizing on unplanned experiments such as the current drought[8]. Illustrative examples could use specific scenarios with target thresholds, decision points, and alternatives. The missing details also include commitments and funding needed for science-based adaptive management and restoration to be developed and, more importantly, to be effective.

The protracted development of the BDCP and its successors has provided ample time for an adaptive-management plan to be fleshed out. The Current Draft does little more than promise that collaborations will occur and that adaptive management will be implemented. This level of assurance contrasts with the central role of adaptive management in the Delta Plan and with the need to manage adaptively as climate continues to change and new contingencies arise.

Restoration as mitigation

Restoration projects should not be planned and implemented as single, stand-alone projects but must be considered in a broader, landscape context. We highlighted the landscape scale in our review of the Previous Draft and also in an earlier review of habitat restoration in the Delta[9]. A landscape approach applies not just to projects that are part of EcoRestore, but also to projects envisioned as mitigation in the Current Draft, even though the amount of habitat restoration included (as mitigation) in the Current Draft has been greatly reduced. On August 13 and 14, representatives of WaterFix and EcoRestore acknowledged the importance of the landscape scale, but the Current Draft gives it little attention. Simply because the CEQA and NEPA guidelines do not specifically call for landscape-level analyses is not a sufficient reason to ignore them.

Wetland restoration is presented as a key element of mitigation of significant impacts (example below in comments on Chapter 12, which begin on p. 18). We noticed little attention to the sequence required for assessing potential impacts to wetlands: first, avoid wetland loss; second, if wetland loss cannot be avoided, minimize losses; and third, if avoidance or minimization of wetland loss is not feasible, compensate. Much of the emphasis in the Current Draft is on the third element. Sequencing apparently will be addressed as part of the permitting process with the US Army Corps of Engineers (USACE) for mitigation related to the discharge of dredged or fill material.[10] However, it is difficult to evaluate the impacts on wetlands in advance of a clarification of sequencing and criteria for feasibility.

Mitigation ratios

Restoring a former wetland or a highly degraded wetland is preferable to creating wetlands from uplands[11]. When an existing wetland is restored, however, there is no net gain of

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[8] http://deltacouncil.ca.gov/docs/adaptive-management-report-v-8
[9] http://deltacouncil.ca.gov/sites/default/files/documents/files/HABITAT%20RESTORATION%20REVIEW%20FINAL.pdf
[10] Letter from Cassandra Enos-Nobriga, DWR, September 21, 2015.
[11] http://www.nap.edu/openbook.php?isbn=0309074320

area, so it is unclear whether credits for improving existing wetlands would be considered equivalent to creating wetlands where they did not recently exist.

In view of inevitable shortcomings and time delays in wetland restorations, mitigation ratios should exceed 1:1 for enhancement of existing wetlands. The ratios should be presented, rather than making vague commitments such as "restore or create 37 acres of tidal wetland…." The Final Draft also needs to clarify how much of the wetland restoration is out-of-kind and how much is in-kind replacement of losses. It should examine whether enough tidal area exists of similar tidal amplitude for in-kind replacement of tidal wetlands, and whether such areas will exist with future sea-level rise. We agree that out-of-kind mitigation can be preferable to in-kind when the trade-offs are known and quantified and mitigation is conducted within a watershed context, as described in USACE's 2010 guidance for compensatory wetland mitigation.[12] Since then, many science-based approaches have been developed to aid decision-making at watershed scales, including the 2014 Watershed Approach Handbook produced by the Environmental Law Institute and The Nature Conservancy[13].

Restoration timing and funding

To reduce uncertainty about outcomes, allow for beneficial and economical adaptive management, and allow investigators to clarify benefits before the full impacts occur, mitigation actions should be initiated as early as possible. Mitigation banks are mentioned, but are any operational or planned for operation soon? The potential for landowners to develop mitigation banks could be encouraged so restoration could begin immediately, engendering better use of local knowledge, financial profit, and local support for the project. We are told that the timing of mitigation will be coordinated with other review processes that are currently ongoing.[6]

Levees

A comprehensive assessment of environmental impacts should relate California WaterFix to levee failure by examining the consequences each may have for the other. The interplay between conveyance and levees is receiving additional attention through the Delta Levee Investment Strategy.

On the one hand, the Current Draft fails to consider how levee failures would affect the short-term and long-term water operations spelled out in Table 4.1-2. A rough estimate was proposed under the Delta Risk Management Study[14] and another is part of a cost-benefit analysis for the BDCP[15]. The Final Report should provide analyses that incorporate these estimates.

On the other hand, the Current Draft also fails to consider how implementing the project would affect the basis for setting the State's priorities in supporting Delta levee maintenance. This potential impact is illustrated by a recent scoring system of levee-project proposals that awards points for expected benefits to "export water supply reliability"[16]. Further efforts to quantify these benefits have been recommended as part of a comprehensive risk assessment that

[12] http://www.sac.usace.army.mil/Portals/43/docs/regulatory/Guidelines_for_Preparing_a_Compensatory_Mitigation_Planf.pdf
[13] https://www.eli.org/sites/default/files/eli-pubs/watershed-approach-handbook-improving-outcomes-and-increasing-benefits-associated-wetland-and-stream_0.pdf
[14] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/Delta_Seismic_Risk_Report.pdf
[15] http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Draft_BDCP_Statewide_Economic_Impact_Report_8513.sflb.ashx
[16] http://www.water.ca.gov/floodsafe/fessro/docs/special_PSP14_final.pdf

would guide the Delta Levees Investment Strategy[17]. Public safety, a focus of the Delta Flood Emergency Management Plan,[18] is just one asset that levees protect. The Current Draft does not evaluate how the proposed project may affect estimates of the assets that the levees protect.

The Current Draft cites levee fragility mainly as a reason to build isolated conveyance for Sacramento River water (examples, p. 1-1, 1-7, 1-9). In a similar vein, the California WaterFix website states, "Aging dirt levees are all that protect most of California's water supplies from the affects [*sic*] of climate change. Rising sea levels, intense storms, and floods could all cause these levees to fail, which would contaminate our fresh water with salt, and disrupt water service to 25 million Californians"[19]. Neither the Previous Draft nor the Current Draft, however, provides a resource chapter about Delta levees. Such a chapter would be an excellent place to examine interacting impacts of conveyance and levees.

Long-term effects

With the shortened time period, several potential long-term impacts of or on the proposed project no longer receive attention. While these effects may not become problematic during the initial permit period, many are likely to affect project operations and their capacity to deliver benefits over the long operational life of the proposed conveyance facilities. In our view, consideration of these long-term effects should be part of the evaluation of the science foundation of the proposed project.

The No-Action alternative establishes the baseline for evaluating impacts and benefits of the proposed alternative(s). It is therefore important to consider carefully how the baseline is established, as this can determine whether particular consequences of the alternatives have costs or benefits. Climate change, for example, is considered under the No-Action alternative in the Current Draft, as is sea-level rise. Climate change is expected to reduce water availability for the proposed northern intakes, and both climate change and sea-level rise are expected to influence tidal energy and salinity intrusion within the Delta[20]. Changes in water temperature may influence the condition of fishes that are highly temperature-dependent in the current analyses. These environmental effects, in turn, are likely to influence environmental management and regulation; from the standpoint of water quality they may even yield environmental benefits if agricultural acreage decreases and agricultural impacts are reduced.

Rather than consider such effects, however, the Current Draft focuses on how the proposed project would affect "the Delta's resiliency and adaptability to expected climate change" (Current Draft section 4.3.25). Quite apart from the fact that "resiliency" and "adaptability" are scarcely operational terms, the failure to consider how climate change and sea-level rise could affect the outcomes of the proposed project is a concern that carries over from our 2014 review and is accentuated by the current drought (below, p. 11).

The Current Draft states that "Groundwater resources are not anticipated to be substantially affected in the Delta Region under the No Action Alternative (ELT) because surface water inflows to this area are sufficient to satisfy most of the agricultural, industrial, and municipal water supply needs" (p. 4.2-16). This conclusion is built on questionable assumptions; the current drought illustrates how agriculture turns to groundwater when surface-water availability diminishes. Groundwater regulation under the recently enacted Sustainable

[17] http://deltacouncil.ca.gov/docs/delta-levee-investment-strategy/dlis-peer-review-technical-memorandum-31
[18] http://www.water.ca.gov/floodmgmt/hafoo/fob/dreprrp/InterdepartmentalDraftDFEMP-2014.pdf.
[19] http://www.californiawaterfix.com/problem
[20] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024465

Groundwater Management Act (SGMA) can also be expected to have long-term effects on the proposed project—effects that the Current Draft does not assess. Ending of more than a million acre-feet of overdraft in the southern Central Valley under the SGMA is likely to increase demand for water exports from the Delta in the coming decades. The Current Draft discusses the potential effects of the project on groundwater (for example, in Sections 4.3.3 and 5.2.2.3), but we found only two brief, descriptive mentions of SGMA in the 235 pages of Section 5. The implications of prolonged droughts (e.g., on levee integrity) and of the consequences of SGMA receive too little attention in the Current Draft.

The Current Draft suggests that unnamed "other programs" that are "separate from the proposed project" will use elements of the Previous Draft to implement long-term conservation efforts that are not part of California WaterFix (Current Draft, p. 1-3). The Final Report should provide assurances that such other programs will step in, and could go further in considering their long-term prospects.

Informative summaries and comparisons

According to guidance for project proponents, "Environmental impact statements shall be written in plain language and may use appropriate graphics so that decision-makers and the public can readily understand them" (Code of Federal Regulations, 40 CFR 1502.8). Far-reaching decisions should not hinge on environmental documents that few can grasp.

This guidance applies all the more to an EIR/EIS of the scope, complexity, and importance of the Current Draft. It demands excellent comparative descriptions of alternatives that are supported by readable tables and high-quality graphics, enumeration of major points, well-organized appendices, and integration of main figures with the text. For policy deliberations, the presentation of alternatives should include explicit comparisons of water supply deliveries and reliabilities as well as economic performance. For decision-makers, scientists, and the public, summaries of impacts should state underlying assumptions clearly and highlight major uncertainties. The Current Draft is inadequate in these regards.

The Previous Draft provided text-only summaries for just the two longest of its resource chapters (Chapters 11 and 12). A fragmentary comparison of alternatives was buried in a chapter on "Other CEQA/NEPA required sections" (part 3 of Chapter 31) but fell far short of what was needed. Both the Previous and Current Drafts have been accompanied by a variety of outreach products for broad audiences (e.g., the descriptive overview of the BDCP Draft EIR/EIS[21]). These products do little to compensate for the overall paucity of readable summaries and comparisons in the Previous and Current Drafts.

For over three years, the Delta ISB has been specifically requesting summaries and comparisons: first in June 2012[22], then in June 2013[23], and again in a review of the Previous Draft in May 2014 (footnote 1, p. 1). Appallingly, such summaries and comparisons remain absent in the Current Draft. The generally clear writing in Sections 1 through 4 shows that the preparers are capable of providing the requested summaries and comparisons. Prescriptions in CEQA and NEPA in no way exclude cogent summaries, clear comparisons, or informative graphics. And three years is more than enough time to have developed them.

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[21] Highlights+of+the+Draft+EIS-EIR+12-9-13.pdf

[22] http://deltacouncil.ca.gov/sites/default/files/documents/files/DISB_Letter_to_JMeral_and_DHoffman-Floerke_061212.pdf

[23] http://deltacouncil.ca.gov/sites/default/files/documents/files /DISB%20Comments%20on%20Draft%20BDCP%20Document.doc_.pdf

On August 14, 2015, representatives of California WaterFix assured us that this kind of content would eventually appear, but only in the Final Report. That will be far too late in the EIR/EIS process for content so critical to comprehending what is being proposed and its potential impacts.

PRIOR CONCERNS AND THEIR RELEVANCE TO THE CURRENT DRAFT

The Delta ISB review of May 14, 2014 emphasized eight broad areas of concern about the scientific basis for the Previous Draft. Each is summarized below, followed by a brief appraisal of how (or whether) the concern has been dealt with in the Current Draft. While the reduced scope of the proposed project has reduced the relevance of some issues, particularly habitat restoration and other conservation measures, other concerns persist.

Our persistent concerns include the treatment of uncertainty, the implementation of adaptive management, and the use of risk analysis. These topics receive little or no further attention in the Current Draft. We also found few revisions in response to points we raised previously about linkages among species, ecosystem components, or landscapes; the potential effects of climate change and sea-level rise; and the potential effects of changes in water availability on agricultural practices and the consequent effects on the Delta. Our previous comments about presentation also pertain.

Effectiveness of conservation actions

Our 2014 review found that many of the impact assessments hinged on optimistic expectations about the feasibility, effectiveness, or timing of the proposed conservation actions, especially habitat restoration.

This is arguably less of a concern now, given the substantially shorter time frame of the revised project and narrower range of conservation actions designed for compensatory restoration. Nonetheless, the Current Draft retains unwarranted optimism, as on page 4.3.25-10: “By reducing stressors on the Delta ecosystem through predator control at the north Delta intakes and Clifton Court Forebay and installation of a nonphysical fish barrier at Georgiana Slough, Alternative 4A will contribute to the health of the ecosystem and of individual species populations making them stronger and more resilient to the potential variability and extremes caused by climate change.” A scientific basis for this statement is lacking, and an adaptive or risk-based management framework is not offered for the likely event that such optimism is unfulfilled.

Is it feasible for even the reduced amounts of mitigation and restoration to be completed within the time period proposed? Perhaps yes. Is it feasible that these actions will mitigate impacts over the long term? This is more problematic. To be effective, mitigation actions should deal with both the immediate and long-term consequences of the project. The proposed permitting should allow for monitoring long enough to assess the effectiveness of habitat restoration measures, which will need to extend beyond the initial permitting period.

Uncertainty

The 2014 review found the BDCP encumbered by uncertainties that were considered inconsistently and incompletely. We commented previously that modeling was not used effectively enough in bracketing uncertainties or exploring how they may propagate or be addressed.

In the Current Draft, uncertainties and their consequences remain inadequately addressed, improvements notwithstanding. Uncertainties will now be dealt with by establishing "a robust program of collaborative science, monitoring, and adaptive management" (ES 4.2). No details about this program are provided, so there is no way to assess how (or whether) uncertainties will be dealt with effectively. Although sensitivity modeling was used to address the effects of changes in the footprint and other minor changes of the revised project, full model runs were not carried out to assess the overall effects of the specific changes. Consequently, modeling that would help to bracket ranges of uncertainties or (more importantly) assess propagation of uncertainties is still inadequate.

Many of our prior concerns about uncertainties pertained to impacts on fish. If those uncertainties have now been addressed in Chapter 11, they are difficult to evaluate because changes to that chapter have not been tracked in the public draft (below, p. 17).

There are also uncertainties with the data generated from model outputs, although values are often presented with no accompanying error estimates. This situation could be improved by presenting results from an ensemble of models and comparing the outputs.

Effects of climate change and sea-level rise on the proposed actions

Our 2014 review stated concerns that the Previous Draft underestimated effects of climate change and sea-level rise across the 50-year timeline of the BDCP. With the nominal duration shortened substantially, most of the projected impacts of climate change and sea-level rise may occur later. But climate-related issues remain.

First, the Current Draft is probably outdated in its information on climate change and sea-level rise. It relies on information used in modeling climate change and sea-level rise in the Previous Draft, in which the modeling was conducted several years before December 2013. The absence of the climate-change chapter (Chapter 29) in the Previous Draft from Appendix A in the Current Draft indicates that no changes were made. In fact, the approaches and assumptions in the Current Draft remained unchanged from the Previous Draft in order to ensure consistency and comparability across all the Alternatives, even though newer scientific information had become available.[6] Yet climatic extremes, in particular, are a topic of intense scientific study, illustrated by computer simulations of ecological futures[24] and findings about unprecedented drought[25]. The Current Draft does not demonstrate consideration of recently available climate science, and it defers to the Final Report analysis of future system operations under potential climate and sea-level conditions. In fact, the Current Draft generally neglects recent literature, suggesting a loose interpretation of "best available science."

Second, climate change and sea-level rise are now included in the No-Action Alternative, as they will transpire whether or not WaterFix moves forward. A changed future thus becomes the baseline against which Alternative 4A (and the others) are compared. Changes in outflow from the Delta due to seasonal effects of climate change and the need to meet fall X2 requirements are considered in Section 4.3.1. The difference in outcomes then depends on assumptions about the facility and operations of Alternative 4A and the other Alternatives. Sensitivity analyses indicate that the impacts of the different Alternatives are generally similar in comparison to the No Action Alternative under the range of climate projections considered.[6] Thus, "Delta exports would either remain similar or increase in wetter years and remain similar

[24] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024465

[25] Cook, B.I., Ault, T.R., and Smerdon, J.E., 2015, Unprecedented 21st century drought risk in the American Southwest and Central Plains: *Science Advances*, v. 1, doi:10.1126/sciadv.1400082.

or decrease in the drier years under Alternative 4A as compared to the conditions without the project." (p. 4.3.1-4). Such an inconclusive conclusion reinforces the need to be able to adapt to different outcomes. Simply because the Alternatives are expected to relate similarly to a No Action Alternative that includes climate change does not mean that the Alternatives will be unaffected by climate change.

Interactions among species, landscapes, and the proposed actions

The Previous Draft acknowledged the complexities produced by webs of interactions, but it focused on individual species, particular places, or specific actions that were considered in isolation from other species, places, or actions. Potential predator-prey interactions and competition among covered and non-covered fish species were not fully recognized. Confounding interactions that may enhance or undermine the effectiveness of proposed actions were overlooked. In our 2014 review we recommended describing and evaluating the potential consequences of such interactions, particularly in Chapters 11 (Fish and aquatic resources) and 12 (Terrestrial resources).

The Current Draft recognizes that mitigation measures for one species or community type may have negative impacts on other species or communities, and mitigation plans may be adjusted accordingly. But the trade-offs do not seem to be analyzed or synthesized. This emphasizes the need for a broader landscape or ecosystem approach that comprehensively integrates these conflicting effects.

Effects on San Francisco Bay, levees, and south-of-Delta environments

In 2014 we pointed to three kinds of impacts that the Previous Draft overlooked: (1) effects on San Pablo Bay and San Francisco Bay in relation to Delta tides, salinity, and migratory fish; (2) effects of levee failures on the proposed BDCP actions and effects of isolated conveyance on incentives for levee investments; and (3) effects of increased water reliability on crops planted, fertilizers and pesticides used, and the quality of agricultural runoff. The Current Draft responds in part to point 1 (in 11.3.2.7) while neglecting point 2 (above, p. 7) and point 3.

On point 3: Although the Current Draft considers how the project might affect groundwater levels south of the Delta (7.14 to 7.18), it continues to neglect the environmental effects of water use south of (or within) the Delta. Section 4.3.26.4 describes how increased water-supply reliability could lead to increased agricultural production, especially during dry years. Elsewhere, a benefit-cost analysis performed by ICF and the Battle Group[26] calculated the economic benefits of increased water deliveries to agriculture in the Delta. The Current Draft does not fully consider the consequences of these assumptions, or of the projections that the project may enhance water-supply reliability but may or may not increase water deliveries to agriculture (depending on a host of factors). We have been told that to consider such possibilities would be "too speculative" and that such speculations are explicitly discouraged in an EIR/EIS. Yet such consequences bear directly on the feasibility and effectiveness of the project, and sufficient information is available to bracket a range of potential effects. Our previous concerns are undiminished.

The impacts of water deliveries south of the Delta extend to the question of how each intake capacity (3,000, 9,000, or 15,000 cfs) may affect population growth in Southern

[26] Hecht, J., and Sunding, D., Draft Bay Delta Conservation Plan statewide economic impact report, August 2013.

California. Section 4.4.1-9 treats the growth-enabling effects of alternative 2D lightly, saying that additional EIS review would be needed for future developments.

Implementing adaptive management

In the Previous Draft, details about adaptive management were to be left to a future management team. In our 2014 review we asked about situations where adaptive management may be inappropriate or impossible to use, contingency plans in case things do not work as planned, and specific thresholds for action.

Although most ecological restoration actions have been shifted to California EcoRestore (p. 5), we retain these and other concerns about adaptive management under California WaterFix. If the mitigation measures for terrestrial resources are implemented as described, for example, they should compensate for habitat losses and disturbance effects of the project. The test will be whether the measures will be undertaken as planned, be as effective as hoped, and continue long enough to fully mitigate effects. This is where adaptive management and having contingency plans in place becomes critically important. It is not apparent that the mitigation plans include these components.

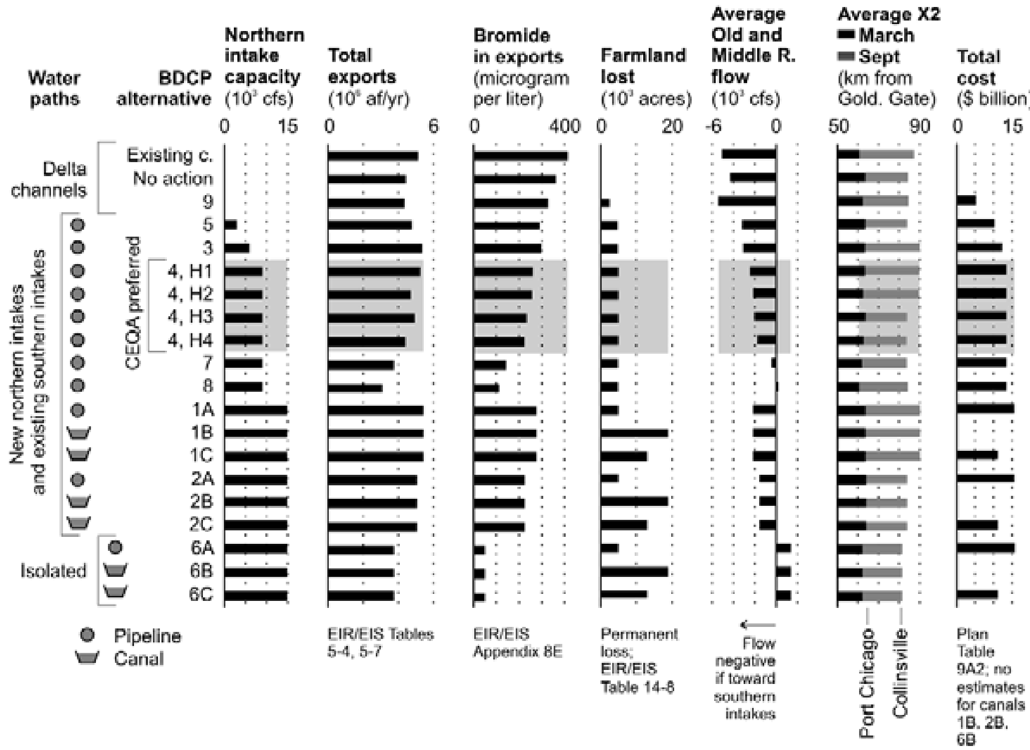
Reducing and managing risk

Our 2014 review advised using risk assessment and decision theory in evaluating the proposed BDCP actions and in preparing contingency plans. We noticed little improvement on this issue, just a mention that it might be considered later. This is not how the process should be used.

Comparing BDCP alternatives

The Previous Draft contained few examples of concise text and supporting graphics that compare alternatives and evaluate critical underlying assumptions. Rudimentary comparisons of alternatives were almost entirely absent. The Current Draft retains this fundamental inadequacy (p. 9).

Our 2014 review urged development and integration of graphics that offer informative summaries at a glance. We offered the example reproduced below. If the Current Draft contains such graphics, they would need to be ferreted out from long lists of individual pdf files. Because they are not integrated into the text where they are referenced in the Current Draft, the figures cannot readily illustrate key points.



COMMENTS ON INDIVIDUAL SECTIONS AND CHAPTERS

This final section of the review contains minimally edited comments on specific points or concerns. These comments are organized by Section or Chapter in the Current Draft. Many are indexed to pages in the section or chapter named in the heading.

Alternatives 4A, 2D, and 5A (Section 4)

It is good that the proposed alternatives are seen as flexible proposals, as it is difficult to imagine that any proposal for such a complex and evolving system could be implemented precisely as proposed. Some initial and ongoing modifications seem desirable, and unavoidable.

The operating guidance for the new alternatives seems isolated from the many other water management and environmental activities in and upstream of the Delta likely to be important for managing environmental and water supply resources related to Delta diversions. While it is difficult to specify detailed operations for such a complex system, more details on the governance of operations (such as the Real Time Operations process) would be useful. The operational details offered seem to have unrealistic and inflexible specificity. Presentations of delivery-reliability for different alternatives remain absent. Environmental regulations on Delta diversions have tended to change significantly and abruptly in recent decades, and seem likely to change in the future. How sensitive are project water supply and environmental performance to changes in operating criteria?

The collaborative science ideas seem philosophically attractive, but are not given much substance. Monitoring is mentioned, but details of organization, intent, and resources seem lacking. Adequate funding to support monitoring, collaborative science, and adaptive management is a chronic problem. Section ES.4.2 states that "Proponents of the collaborative science and monitoring program will agree to provide or seek additional funding when existing resources are insufficient." This suggests that these activities are lower in priority than they should be.

The three new alternatives, 4A, 2D, and 5A, seem to have modest changes over some previous alternatives, with the exception of not being accompanied by a more comprehensive environmental program. In terms of diversion capacities, they cover a wide range, 3,000 cfs (5A), 9,000 cfs (4A), and 15,000 cfs (2D). The tables comparing descriptions of the new alternatives to previous Alternative 4 are useful, but should be supplemented by a direct comparison of the three new alternatives.

The new Sustainable Groundwater Management Act (SGMA) seems likely to increase demands for water diversions from the Delta to the south to partially compensate for the roughly 1.5-2 maf/year that is currently supplied by groundwater overdraft.

The State seems embarked on a long-term reduction in urban water use, particularly outdoor irrigation. Such a reduction in urban water use is likely to have some modest effects on many of the water-demand and scarcity impacts discussed.

The climate change analysis of changes in Delta inflows and outflows is useful, but isolating the graphs in a separate document disembodies the discussion. The fragmentation of the document by removing each Section 4 figure into a separate file is inconvenient for all, and makes integrated reading practically impossible for many.

The details of the alternative analyses seem mostly relevant and potentially useful. Much can be learned about the system and the general magnitude of likely future outcomes from patient and prolonged reading of this text. An important idea that emerges from a reading of the No Action Alternative is that the Delta, and California water management, is likely to change in many ways with or without the proposed project. The No Action and other alternatives also illustrate the significant inter-connectedness of California's water system. The range of impacts considered is impressive, but poorly organized and summarized.

The discussion of disinfection by-product precursor effects in Delta waters is improved significantly, but could be made more quantitative in terms of economic and public-health impacts.

The discussion on electromagnetic fields is suitably brief, while the tsunami discussion could be condensed.

The effects of the likely listing of additional native fish species as threatened or endangered seems likely to have major effects on project and alternative performance. These seem prudent to discuss, and perhaps analyze.

Is Alternative 2D, with 15,000 cfs capacity, a serious alternative? Does it deserve any space at all?

Table 4.1-8 implies that tidal brackish/*Schoenoplectus* marsh. Should some of this be considered tidal freshwater marsh?

The dynamics of the Delta are largely determined by water flows. The Current Draft acknowledges that water flows and salinity will change in complex ways. There are statements about how inflows, outflows, and exports will change in Alternative 4A in relation to baseline (No-Action) conditions (p. 4.3.8-13). What is the scientific basis on which these changes will be managed? Will models be used? What confidence should we have in current projections? Have the effects of droughts or deluges been considered?

4.3.7-10, line 13: Text on disturbing sediments and releasing contaminants needs to add nitrogen and phosphorus to the concerns.

Water quality (Chapter 8)

8-3, line 13: *Microcystis* is singled out as a cyanobacterium that can (but doesn't always) produce the toxin, myrocystin; however, there are other cyanobacteria that sometimes produce other toxins. Different genera can differ in the nutrient that limits their blooms (see 2014 letter by Hans Paerl in Science 346(6406): 175-176). For example, *Microcystis* blooms can be triggered by N additions because this species lacks heterocysts, while toxin-producing *Anabaena* blooms can be triggered by P additions, because *Anabaena* has heterocysts and can fix N. The frequently repeated discussion of cyanobacteria blooms needs to be updated. Also cite Paerl on page 8-45 line 8. Ditto on page 8-103 and 8-106 line 34.

8-8. In our earlier comments, we recommended that carbon be separated into its dissolved and particulate forms for consideration of water quality impacts because dissolved organic carbon (DOC) is the form most likely to react with chloride and bromide and result in formation of disinfection by-products. The section on bromide focuses on interactions with total organic carbon (TOC), rather than DOC. Carbon is primarily considered with respect to formation of disinfection by-products but carbon plays a central role in the dynamics of the Delta, affecting processes such as metabolism, acidity, nutrient uptake, and bioavailability of toxic compounds. Carbon cycling determines ecosystem structure and function in aquatic systems. It also modifies the influence and consequences of other chemicals and processes in aquatic systems. Dissolved organic carbon (DOC), for example, influences light and temperature regimes by absorbing solar radiation, affects transport and bioavailability of metals, and controls pH in some freshwater systems. Respiration of organic carbon influences dissolved oxygen concentrations and pH.

8-18, line 12 says that salt disposal sites were to be added in 2014; were they?

8-19 and 8-20: "CECs" is not defined and seems to be used incorrectly. Change "CECs" to "EDCs" on page 8-19 and to "PPCPs" on page 8-20.

8-21, line 18-19: Such a statement should be qualified. The conclusion that marine waters are N-limited and inland waters are P-limited is outdated. Recent papers, including the above, find more complex patterns.

8-22, lines 18 and 30: Choose either "cyanobacteria" or "blue-green algae;" using both will confuse readers who may perceive them as different.

8-23, lines 15-16: Say how the N:P ratio changed composition, not just that it did change composition.

8-23 through 8-25: Uncertainties (e.g., standard deviation or standard error of the mean) associated with the mean concentrations of DOC should be presented. It is impossible to interpret differences between the values that are presented without knowledge of the variation around the mean values (e.g., without knowledge of variation around the mean, it is difficult to evaluate whether DOC concentrations at south vs. north-of-Delta stations and Banks headworks differ from one another; 3.9 to 4.2 mg/L vs. 4.3 mg/L).

8-65, line 12: Specify if DO is for daytime or night, and for surface, bottom or mid-water column.

8-75, line 6: The failure to consider dissolved P (DP) should be addressed; there is much greater uncertainty. The adherence of some P to sediment does not prevent considerable discharge of P as DP. Also on page 8-95 line 40, qualify predictions due to lack of consideration of DP.

8-82, line 4-5: It seems unlikely that current levels of *Microcystis* growth in the Delta are dependent on the exclusive uptake of ammonia. Temperature is one of the primary factors driving *Microcystis* blooms and global warming could promote bloom occurrence. Consider revising this section to, "Because it seems unlikely that current levels of *Microcystis* growth in the Delta are dependent on the exclusive uptake of ammonia, the frequency, magnitude and geographic extent of *Microcystis* under future scenarios is difficult to predict."

8-105, line 8: Would total nitrogen be dominated by nitrate just by increasing ammonia removal? Depending on redox and microbiota, why wouldn't nitrate be converted to ammonium?

A lot of attention is given to factors controlling *Microcystis* blooms in this chapter but little attention is given to its toxicity. Just as factors controlling blooms are not fully understood, the regulating factors of cellular toxin contents remain poorly understood. As a result, the impact of blooms on the environment can vary (e.g., large blooms of non-toxic or low toxin organisms may have impacts on environmental variables such as nutrient uptake and dissolved oxygen consumption while small blooms of highly toxic organisms could impact food webs) [see: Ma et al. (2015) Toxic and non-toxic strains of *Microcystis aeruginosa* induce temperature dependent allelopathy toward growth and photosynthesis of *Chlorella vulgaris*. Harmful Algae 48: 21–29].

Fish and aquatic resources (Chapter 11)

We found individual conclusions or new analyses difficult to identify in this key chapter because changes to it were not tracked in the public version of the Current Draft and there was no table of contents that could have assisted in side-by-side comparison with the Previous Draft.

Effects of temperature

We noticed more emphasis on temperature concerning the fish 'downstream' impacts (but without tracked changes this becomes difficult to document).

The main temperature variable used expresses the percentage of time when monthly mean temperatures exceed a certain rate or fall within a certain boundary. The biological impact, however, is difficult to assess with these numbers. If all of the change occurred just during operations or just during one day, the biological impact could be much different than a small change every day (provided by using means). Graphs of changes and listing of extreme highs and lows during a model run would have more biological meaning. Also, comparisons were made using current baseline conditions and did not consider climate change effects on temperatures.

Fish screens

It is unclear how (and how well) the fish screens would work. The description of fish screens indicates that fish >20 mm are excluded, but what about fish and larvae that are <20 mm, as well as eggs? Table 11-21 seems out of date, because some fish screens appear to have been installed, but data on their effects are not given. Despite the lack of specific data on how well screens function, the conclusion that there will be no significant impact is stated as certain (e.g., page 1-100 line 38).

Here, as in many other places, measures are assumed to function as planned, with no evidence to support the assumptions. The level of certainty seems optimistic, and it is unclear whether there are any contingency plans in case things don't work out as planned. This problem persists from the Previous Draft.

Invasive plants

Cleaning equipment is mentioned, but it is not specifically stated that large machinery must be cleaned before entering the Delta. Section 4.3.8-358 says equipment would be cleaned if being moved within the Delta. Cleaning is essential to reduce transfer of invasive species; a mitigating measure is to wash equipment, but it must also be enforced.

Weed control (fire, grazing) is suggested, but over what time frame? It may be needed in perpetuity. That has been our experience at what is considered the world's oldest restored prairie (the 80-yr-old Curtis Prairie, in Madison, WI).

Weed invasions can occur after construction is completed; how long will the project be responsible for weed control? 3-5 years won't suffice.

4.3.8-347. Herbicides are prescribed to keep shorebird nesting habitat free of vegetation, but toxic effects of herbicides on amphibians etc. are not considered.

4.3.8-354. Impacts of invasive plants seem underestimated. Impact analysis implies that the project disturbance area is the only concern, when dispersal into all areas will also be exacerbated. At the Arboretum, a 1200-ac area dedicated to restoration of pre-settlement vegetation, invasive plants are the main constraint. A judgment of no significant impact over just the disturbance area is overly optimistic.

4.3.8-356. Does not mention need to clean equipment to minimize import of seeds on construction equipment.

Cryptic acronym and missing unit

Figure 2: SLR x year: y axis lacks units; reader has to continue on to table 11-20 to find that it is cm.

Terrestrial biological resources (Chapter 12)

Effects on wetlands and waters of the United States (WOTUS)

Page 12-1, line 18-19 says: "Under Alternatives 2D, 4 , 4A , and 5A, larger areas of non-wetland waters of the United States would be filled due to work in Clifton Court Forebay; however, the Forebay would ultimately expand by 450 acres and thus largely offset any losses there." Is the assumption that, acre for acre, all jurisdictional waters are interchangeable, whether of different type or existing vs. created? The literature does not support this assumption.

The text argues that the wetlands would be at risk with levee deterioration, sea-level rise, seismic activity, etc. But the solution is for "other programs" to increase wetlands and riparian communities. What if this project causes the problem, e.g. via vibration?

CM1 alternative 4A would fill 775 acres of WOTUS (491 wetland acres); Alt 2D would fill 827 (527 wetland) + 1,931 ac temporary fill at Clifton Court Forebay; Alt 5A would fill 750 (470 wetland). That's a lot of area. The timing and details of mitigation measures are not provided. References to the larger Delta Plan suggest that compensations would come at unknown times. Piecemeal losses such as indicated here: "Only 1% of the habitat in the study area would be filled or converted" (Chapter 12, line 29, page 12-22) is how the US has lost its historical wetlands. What are the overall cumulative impacts of wetland losses in the Delta? What is the tipping point beyond which further wetland losses must be avoided? The proposed project is one part of the broader array of management actions in the Delta and should be considered in that broader context.

Habitat descriptions

How will mudflats be sustained for shorebirds? Exposed mud above half-tide can become vegetated rapidly. In the Delta, the bulrush *Schoenoplectus californicus* tolerates nearly continuous tidal submergence.

Are soils clayey enough for the proposed restoration of up to 34 acres of vernal pool and alkali seasonal wetland near Byron? These areas will need to pond water, not just provide depressions.

12-243, line 18: How would adding lighting to electrical wires eliminate any potential impact to black rails? This mitigation is overstated.

Several of the species accounts (e.g., bank swallow) indicate that there is uncertainty about how construction or operations will impact the species. In most cases, monitoring is proposed to assess what is happening. But to be effective, the monitoring results need to be evaluated and fed into decision-making, as visualized in the adaptive-management process. There is little explicit indication of how this will be done or funded.

Land use (Chapter 13)

Alternative 4A would allow water diversion from the northern Delta, with fish screens, multiple intakes, and diversions limited to flows that exceed certain minima, e.g., 7000 cfs. This would reduce flood-pulse amplitudes and, presumably, downstream flooding. How does this alter opportunities for riparian restoration? Which downstream river reaches are leveed and not planned to support riparian restoration? Where would riparian floodplains still be restorable?

Over what surface area does the pipeline transition to the tunnel? At some point along the pipeline-tunnel transition, wouldn't groundwater flow be affected?

Up to 14 years of construction activities were predicted for some areas (e.g., San Joaquin Co.); this would have cumulative impacts (e.g., dewatering would affect soil compaction, soil carbon, microbial functions, wildlife populations, and invasive species). What about impacts of noise on birds; e.g., how large an area would still be usable by greater sandhill cranes?

State how jurisdictional wetlands have been mapped and how the overall project net gain or net loss of wetland area has been estimated. If mitigation consists only of restoration actions in areas that are currently jurisdictional wetlands, then there would be an overall net loss of wetland area due to the project. A mitigation ratio >1:1 would be warranted to compensate for reduced wetland area. This was also a concern for Chapter 12.

Up to 277 ac of tidal wetlands are indicated as restorable; text should indicate if these are tidal freshwater or tidal brackish wetlands (or saline, as is the typical use of "tidal wetlands").

13-19. On the need to store removed aquatic vegetation until it can be disposed: there are digesters for this purpose, and they might be efficient means of mitigation if management of harvested aquatic plants will be long-term. A waste product could be turned into a resource (methane fuel).

13-19, line 12: Text says that "predator hiding spots" will be removed. What are these?

13-19, line 20: What are the E16 nonphysical fish barriers? An electrical barrier?

13-20, line 19: Boat-washing stations are mentioned; would these discharge pollutants (soap, organic debris?)

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IN THE UNITED STATES DISTRICT COURT

FOR THE EASTERN DISTRICT OF CALIFORNIA

COALITION FOR A SUSTAINABLE DELTA, BELRIDGE WATER STORAGE DISTRICT, BERRENDA MESA WATER DISTRICT, LOST HILLS WATER DISTRICT, WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT, and DEE DILLON, Plaintiffs, vs. **DONALD KOCH, in his official capacity as Director, California Department of Fish and Game,** Defendant, **CENTRAL DELTA WATER AGENCY, et al.,** Defendant-Intervenors, **CALIFORNIA SPORTFISHING PROTECTION ALLIANCE, et al.,** Defendant-Intervenors..	Case No.: 1:08-CV-00397-OWW-GSA (Related to Case Nos. 1:05-CV-022-GSA and 1:06-CV-00245-OWW-GSA) **DECLARATION OF MATTHEW L. NOBRIGA IN OPPOSITION TO PLAINTIFFS' MOTION FOR SUMMARY ADJUDICATION OF ISSUES** Date: June 19, 2009 Time: 12:00 p.m. Courtroom: 3 Judge Hon. Oliver W. Wanger

I, Matthew L. Nobriga, declare:

1. I am a Senior Environmental Scientist with the California Department of Fish and Game. I earned a Master of Science degree in Biological Sciences at the California State University at Sacramento in 1998. I make this declaration based upon my personal knowledge and would testify under oath to the contents herein if called upon to do so.

2. I am presently the Supervisor of the Performance Measures Unit for the Ecosystem Restoration Program, and a technical advisor to the Bay Delta Conservation Plan, the U.S. Fish and Wildlife Service's Smelt Working Group, and the Water Operations Management Team. All references cited in this declaration are identified and listed in Exhibit A. A summary of my professional background is attached hereto as Exhibit B.

Food Web Complexities and Species Adaption

3. Food webs can be thought of as combinations of many individual food chains that link different predators with different prey at different times. They are often shown as connections between predators and prey. Exhibit C shows a food chain for striped bass in the Delta that provides a simple pictorial summary of striped bass food habits studies from the 1960s (Stevens 1966; Thomas 1967). The Bay-Delta's actual food web is much more complex. It has many more links between different predators and prey, and it has forged new predator-prey linkages as species invasions have forced striped bass to change their feeding habits (Feyrer et al. 2003; Bryant and Arnold 2007; Nobriga and Feyrer 2008).

4. The Plaintiffs have assumed that predation by striped bass substantively affects the viability of delta smelt and listed salmonids. Although, striped bass eat these fish (Stevens 1966; Thomas 1967; DFG 1999), simply being eaten does not support the conclusion that striped bass have caused or contributed to these species' declines or that striped bass affect

their future viability. By virtue of their small size, both delta smelt and emigrating salmon are forage fishes that have faced predation pressure throughout their evolutionary history and have built substantial resilience to predation into their life-histories. This is particularly true for small annual fishes like delta smelt (Winemiller and Rose 1992).

5. Chinook salmon and delta smelt have been found among striped bass stomach contents in the Delta so they are a part of its food web (Stevens 1966; Thomas 1967; DFG 1999 and references therein; Nobriga and Feyrer 2007). However, the listed fishes – particularly the ocean-going salmonids, are also parts of food webs that are not influenced by striped bass.

6. The invasion of the San Francisco Estuary by the overbite clam provides a local example of the difficulty of predicting how a food web will respond to a major change. By all food web accounts that existed up to the time this clam was introduced in 1986 (i.e., Exhibit C), the clam should have decimated the striped bass population – but so far, it has not. By 1988, the clam's grazing removed most of the small plants and zooplankton that fueled the food web that historically produced striped bass (Kimmerer and Orsi 1996). The abundance of young-of-the-year striped bass has declined, but even that has not been unequivocally attributed to the clam (Kimmerer 2002), though the clam has probably played a role (Kimmerer et al. 2000; Feyrer et al. 2003; Sommer et al. 2007). Despite the decline of the young bass, the adult population has not declined since 1986 (Exhibit D).

7. The likely reason striped bass were not extirpated is that they adjusted their food habits. Young striped bass supplemented their historical diet with new zooplankton (Bryant and Arnold 2007) that were able to invade the estuary because they were not as susceptible to the effects of clam grazing as the previously dominant forms. Young striped bass also might have gotten some help from a change in the distribution of northern

anchovy (Kimmerer 2006). Northern anchovies were historically the most abundant fish in the striped bass (and delta smelt) nursery habitat, but when the overbite clam took the food away, the anchovies left. This probably freed up young striped bass from some historical competition so that the clam's effects on its food supply were muted. Juvenile striped bass also responded by eating more fish than they had historically (Feyrer et al. 2003) – especially common non-native species like threadfin shad, yellowfin goby and Mississippi silverside (Nobriga and Feyrer 2007; 2008).

8. Mississippi silversides (formerly thought to be the closely related inland silverside) are a small, annual fish native to eastern North America (Moyle 2002). They invaded the Delta in the 1970s and have flourished; they are the most numerous fish occurring in shallow habitats throughout the Bay-Delta estuary (Matern et al. 2002; Nobriga et al. 2005; Cohen and Bollens 2008). They are ecologically similar to delta smelt, but are more tolerant of warm water, clear water, and salinity variability (Moyle 2002).

9. In general, the abundance of Mississippi silversides has increased over the past 35 years while the abundance of delta smelt has declined (Exhibit E). Bennett and Moyle (1996) and Bennett (2005) have reported that they believe this trend is due to the combined effects of predation and competition by silversides on delta smelt. Bennett (2005) presented evidence that Mississippi silversides would out compete delta smelt where they co-occur. He showed the results of a short-term study that found when delta smelt and silversides were held in captivity together, delta smelt growth was impaired, but silverside growth was not (Bennett 2005). Bennett and Moyle (1996) discussed a separate study that showed silversides readily ate striped bass larvae and were efficient predators of striped bass larvae in Delta waters that were enclosed with nets (Bennett and Moyle 1996).

Striped bass larvae reside in the Delta at the same times and places as delta smelt larvae, so Bennett and Moyle (1996) and Bennett (2005) logically consider this finding evidence that delta smelt larvae (or eggs) are similarly vulnerable to Mississippi silverside predation.

10. The Plaintiffs contend that relieving delta smelt of predation by striped bass will increase delta smelt abundance. However, delta smelt are fundamentally limited by an unquantified mixture of several factors that probably includes predation, but only in the context of physiologic stress from warm summer water temperatures, low river outflows during fall that constrain delta smelt's habitat, and the expansion of aquatic weeds that have decreased the turbidity of Delta waterways - an important form of cover for delta smelt (Bennett 2005; Feyrer et al. 2007; Bennett 2008; Nobriga et al. 2008). It should be kept in mind that striped bass also eat delta smelt's predators and competitors (Nobriga and Feyrer 2007; 2008). Thus, if striped bass predation affects delta smelt survival, it probably also affects Mississippi silverside survival. Therefore, if the striped bass population is depleted, there are actually three possible outcomes with regard to delta smelt. One is that delta smelt abundance increases because they are released from striped bass predation and they have no other significant predators or competitors. A second possibility is that delta smelt abundance does not change or continues to decline because no predators or competitors are significant limiting factors to them. The third possibility is that delta smelt abundance decreases further because striped bass predation on Mississippi silversides (or another predator or competitor or combination of other predators and competitors) is released, enabling greater predation/competition with delta smelt. It is my professional judgement that the most likely outcome in this list is not discernable with existing data because, as with the clam example I described above, major food web perturbations can cause changes that were not predictable in advance.

The Relationship Between the Abundance of Striped Bass and Other Species

11. It is logical that if predation by one species is strong enough to cause declines in another that the abundance of the prey species would go down when the abundance of the predator goes up. One way to examine this possible "covariation" in species abundances is with linear regression. Linear regression is a commonly applied statistical technique to test the ability of one or more "independent" or "explanatory variables" to explain variation in a "dependent" or "response variable." Positive regression slopes indicate that the response variable increases when the explanatory variable increases. Negative regression slopes indicate that the response variable decreases when the explanatory variable increases.

12. DFG (1999; citing Chadwick and Von Geldern 1964) provided an example of a regression analysis that found a positive slope between striped bass and salmon catches that contradicted the hypothesis that striped bass predation had a major influence on salmon survival.

13. I performed similar analyses using data from the 1960s or 1970s (depending on data availability) into the current decade, but I could not find any evidence for such obvious effects – except possibly for Mississippi silverside preying on delta smelt.

14. I started my analysis of Mississippi silverside effects on delta smelt abundance with a "stock-recruit relationship" for delta smelt because the abundance of delta smelt in the fall survey of maturing adults is a statistically significant predictor of the abundance of young produced (known as recruits) when the young are surveyed in the subsequent summer. The likely reason for this is that the fall survey estimates the number of spawners (or eggs spawned) that gave rise to the recruits. From 1975 → 1976 through 2007 → 2008 the fall abundance of delta smelt predicts 51% of the subsequent recruit abundance. The probability that this relationship is spurious is about 0.000004.

15. As I described above, Mississippi silversides are a small fish like delta smelt so they can only eat smelt eggs or larvae. Therefore, the abundance of silversides might be contributing to the 49% of delta smelt summer abundance that isn't explained by the number of parents or eggs spawned, but it could not for instance directly affect the number of juvenile or adult smelt because they are too big to be eaten by silversides. I tested for evidence that silverside predation negatively affects delta smelt by using a second linear regression with inland silverside "biomass" data (survey numbers multiplied by weight of a silverside) that I obtained from Interagency Ecological Program staff. I used the silverside biomass estimates as the explanatory variable and the "residual" variation from the delta smelt stock-recruit relationship as the response variable. This relationship had a statistically significant negative slope, which is evidence that silverside abundance may have reduced the per capita number of smelt surviving to the summer (Exhibit E).

16. The relationship between striped bass abundance and winter-run salmon's abundance three years later was significantly positive (Exhibit F). I used salmon abundance three years later because most winter-run spawn when they are three years old, so they would have been vulnerable to striped bass predation three years prior to spawning when they were young fish moving seaward (Lindley and Mohr 2003).

17. There is no relationship between adult striped bass abundance and spring-run abundance three years later (Exhibit F), nor is there a relationship between adult striped bass abundance and delta smelt abundance based on either the summer or fall surveys (Exhibit G). In the case of delta smelt, the abundances are compared for the same year because the smelt only live one year.

18. Kimmerer (2008) used a ratio of the fall delta smelt index to the summer index as an annual indicator of summer survival. He showed this "survival index" was significantly

correlated with zooplankton biomass – presumably because more food translates into better smelt survival (Exhibit H). I have plotted adult striped bass abundance versus this delta smelt survival index. They are not correlated (Exhibit I).

19. I did not generate an equivalent graph for steelhead because reliable and consistently collected abundance estimates are not available. However, I doubt that results would be different for steelhead for the reasons discussed by DFG (1999), most importantly their large body size when they emigrate through the Delta. In the Delta, apparently the only place that striped bass have been shown to eat steelhead smolts is Clifton Court Forebay (DFG 1999; Clark et al. 2009).

The Lindley and Mohr Paper

20. A lack of a simple correlation or regression slope between predator and prey abundances is evidence that a predator is not strongly affecting a prey species, but it cannot demonstrate or refute weaker influences of predators on prey. Lindley and Mohr (2003) used a sophisticated statistical analysis to try to isolate the effect of striped bass predation on winter-run salmon viability. The primary goal of their study was to estimate how much effect striped bass predation had on the likelihood that winter-run salmon would go extinct versus recover to a population level of 20,000 adults in the next 50 years.

21. Lindley and Mohr (2003) used available time series of winter-run salmon and striped bass abundance data for 1967-1996. They constructed a basic life cycle model for winter-run salmon meaning they described the population trends of winter-run with a set of mathematical equations. They used a modern statistical approach in which the model's 'unknown' quantities were estimated by solving many thousands of variations of the equations on a computer to find out which values were the most likely and how variable they were. Their most important assumptions were 1) the number of adult winter-run

spawning in the Sacramento River in any given year was made up of fish that were spawned 3-4 years prior because most winter-run salmon live 3-4 years; 2) the number of winter-run spawning in a given year was mathematically predicted by the number of spawners that gave rise to the current generation times a predicted average productivity times the chance that the fish were 3 versus 4 years old when they returned to spawn (89% chance of spawning at age-3 and 11% chance of spawning at age-4); 3) that winter-run productivity could be mathematically estimated as an average population growth rate, a step-change in population growth rate starting in 1989 when Red Bluff Diversion Dam operations were changed to protect winter-run, the striped bass predation rate on the cohort of young produced by the adults and a "density-dependent" term designed to provide a biologically likely effect of "diminishing returns" as adult winter-run fill up the limited habitat they have available in the Sacramento River below Keswick Dam. They used versions of the life cycle model that had this density-dependence term turned on and off to test the sensitivity of their results to this assumption.

22. Lindley and Mohr (2003) found that a greatly increased striped bass population of 3 million adults would likely have a negative effect on winter-run extinction risk and reduce their likelihood of recovery. However, during the past 40 years of monitoring the striped bass population reached about 2 million adults during the 1970s, declined to less than 1 million adults in the early 1990s and in recent years has hovered around 1 million adults. Lindley and Mohr (2003) concluded that "A limited program aimed at stabilizing the striped bass population at its recent size might pose an acceptably small risk: the model indicates with 95% certainty that the stabilization program would add less than 3.1% to the baseline extinction risk of 28%." Further, their analysis indicated that completely eliminating the striped bass from the system (0 adults) would only increase winter-run

recovery probabilities by a few percent and they would still have about a one in five chance of "quasi-extinction" in the next 50 years because predation by striped bass is not the primary driver of winter-run abundance.

23. I compared recent trends in winter-run salmon abundance to those predicted using Lindley and Mohr's model. I used the means of their parameter values to estimate what their model predicts winter-run abundance would have been from 1996-2004 given the actual trend in striped bass population shown in Exhibit D. I estimated striped bass abundance values for missing years by interpolating between the available data. Their density-dependent model predicts continued very low and declining abundance of winter-run salmon that was not observed (labelled "DD" in Exhibit J). Their density-independent model predicts a modest abundance increase well below what was actually seen (labelled "DI" in Exhibit J). This suggests to me that Lindley and Mohr's model overestimated the relevance of striped bass predation to winter-run Chinook viability.

Conclusion

24. Based on the information I have presented above, it is my professional opinion that it cannot be concluded that removal of striped bass fishing regulations will result in a substantive increase in the abundance of the listed fishes. Food web complexity has often led to incorrect guesses about how aquatic ecosystems will respond to the addition or removal (or depletion) of important fishes (Pine et al. 2009). I think it is impossible to forecast the population responses of the Bay-Delta food web to the removal of striped bass, one of its keystone species. Further, the Pacific Ocean food web adds additional uncertainty into predictions for rebounds of salmonid fishes released from what by several accounts (DFG 1999; Lindley and Mohr 2003) appear to be a very minor constraint of striped bass predation.

I declare under penalty of perjury that the foregoing is true and correct and that this declaration is executed this 19th day of May, 2009, at Sacramento, California.

Matthew L. Nobriga

SA2008300616
Dec of Matthew L. Nobriga

List of Exhibits for the declaration of Matt Nobriga in case No.: 1:08-CV-00397-OWW-GSA

Exhibit A: References cited in the declaration of Matt Nobriga in case No.: 1:08-CV-00397-OWW-GSA

Exhibit B: Curriculum vitae for Matt Nobriga (current as of May 14, 2009)

Exhibit C: general food chain conceptual model for striped bass taken from Peter Moyle (2002). Inland fishes of California, revised and expanded

Exhibit D: Estimated abundance of adult striped bass, 1969-2005. The official estimate is shown as black squares; the 95% confidence interval is shown as dashes connected by lines when estimates were made in consecutive years.

Exhibit E. Trends in Mississippi silverside biomass based on IEP beach seine data and the delta smelt Fall Midwater Trawl index (above). Plot of Mississippi silverside biomass versus the variation in delta smelt abundance during summer surveys after the variation due to the number of spawners has been accounted for (right). The line shown through the data is a 'smoother' not a linear regression line. A linear regression of the data on the right is statistically significant: the probability that there is no slope is 0.009, the r-square is 0.21, so the regression explains 21% of the variance in the relationship.

Exhibit F. The abundance of adult striped bass (base 10 logarithm) plotted against the abundance of winter- and spring-run Chinook salmon (also base 10 logarithms). The linear regression results are included.

Exhibit G. The abundance of adult striped bass (base 10 logarithm) plotted against two abundance indices of delta smelt (also base 10 logarithms). The linear regression results are included.

Exhibit H. The estimated weight per unit of water sampled of delta smelt's food versus a 'summer to fall survival index' for delta smelt. Figure taken from Kimmerer (2008).

Exhibit I. The abundance of adult striped bass (base 10 logarithm) plotted against the delta smelt survival index shown in Figure 6. The linear regression results are included.

Exhibit J. Predicted abundance of winter-run salmon 1996-2004 using the model of Lindley and Mohr (2003), which assumes a measurable influence of striped bass predation on winter-run abundance and the actual returns of winter-run salmon to the Sacramento River for the same period.

Exhibit A

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Exhibit B

Exhibit B – curriculum vitae for Matthew L. (Matt) Nobriga

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EDUCATION

1988-1993	Bachelor of Science, Biological Sciences, Stanislaus State University
1993-1998	Master of Science, Biological Sciences, Sacramento State University

FULL-TIME PROFESSIONAL POSITIONS

2008-present — *Senior Environmental Scientist*, California Department of Fish and Game (Water Branch), Sacramento, CA, Supervisor of Performance Measures Unit for the Ecosystem Restoration Program, technical advisor to Bay-Delta Conservation Plan, USFWS Smelt Working Group, and Water Operations Management Team

2008 — *Staff Environmental Scientist*, California Department of Fish and Game (Water Branch), Sacramento, CA, DFG technical advisor to the Ecosystem Restoration Program, Bay-Delta Conservation Plan, Operations Criteria and Plan, and other policy directives to balance fisheries and human water needs in the San Francisco Bay-Delta

2007 – 2008 — *Staff Environmental Scientist*, CALFED Science Program, Sacramento, CA Environmental Water Account Coordinator, Interagency Ecological Program Liason, Interagency Ecological Program Pelagic Organism Decline Management Team member, Organizer of several Science Program workshops, contract manager for Science Program grants

2006 – 2007 — *Environmental Scientist C*, CALFED Science Program, Sacramento, CA Environmental Water Account Coordinator, Organizer of several Science Program workshops, contract manager for Science Program grants

2000-2006 — *Environmental Scientist C*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA , Interagency Ecological Program researcher and Management Team member, Interagency Ecological Program Pelagic Organism Decline researcher and Management Team member, Delta Smelt Working Group member, CALFED Data Assessment Team (DAT) note-taker

1998-2000 — *Environmental Specialist II*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA, Interagency Ecological Program researcher, technical writer

PART-TIME PROFESSIONAL POSITIONS

1997-1998	*Scientific Aide*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA
1995-1997	*Fisheries Biologist* (GS-5), U.S. Fish and Wildlife Service (Juvenile Salmonid Monitoring Program), Stockton, CA
1995-1996	*Scientific Aide/Graduate Student Assistant*, California Department of Fish and Game (Bay-Delta Division), Stockton, CA
1995	*Scientific Aide*, California Department of Fish and Game (Region II Water Pollution Control Laboratory), Rancho Cordova, CA
1994	*Scientific Aide*, California Department of Fish and Game (Region II Headquarters), Rancho Cordova, CA
1991-1994	*Scientific Aide*, California Department of Fish and Game (Bay-Delta Division), Stockton, CA

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MISCELLANEOUS

2000-present	Member of the American Fisheries Society
2003-Present	Referee for Technical Journals (Transactions of the American Fisheries Society, Fisheries, San Francisco Estuary and Watershed Science, Aquatic Ecology, Environmental Science & Policy, California Fish and Game)

Exhibit C

Exhibit C: general food chain conceptual model for striped bass taken from Peter Moyle (2002), Inland fishes of California, revised and expanded

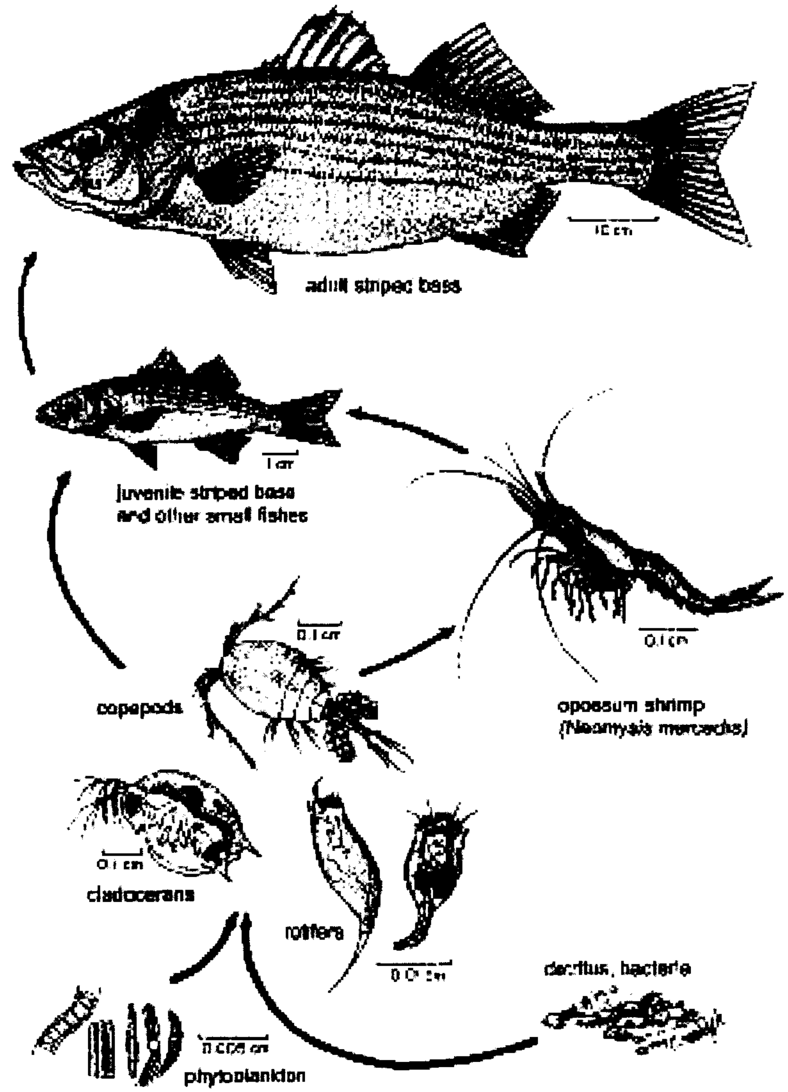


Figure 11. [illegible] striped bass in the Sacramento–San Joaquin estuary. Although adult bass [illegible] any fish in the estuary, [illegible] juvenile striped bass, which in turn depend heavily on opossum shrimp and other planktonic crustaceans. The opossum shrimp is a predator on small zooplankton, which in turn feed largely on algae, bacteria, and detritus. [illegible] (1981) [illegible] Moyle (2002)

Exhibit D

Exhibit D: Estimated abundance of adult striped bass, 1969-2005. The official estimate is shown as black squares; the 95% confidence interval is shown as dashes connected by lines when estimates were made in consecutive years.

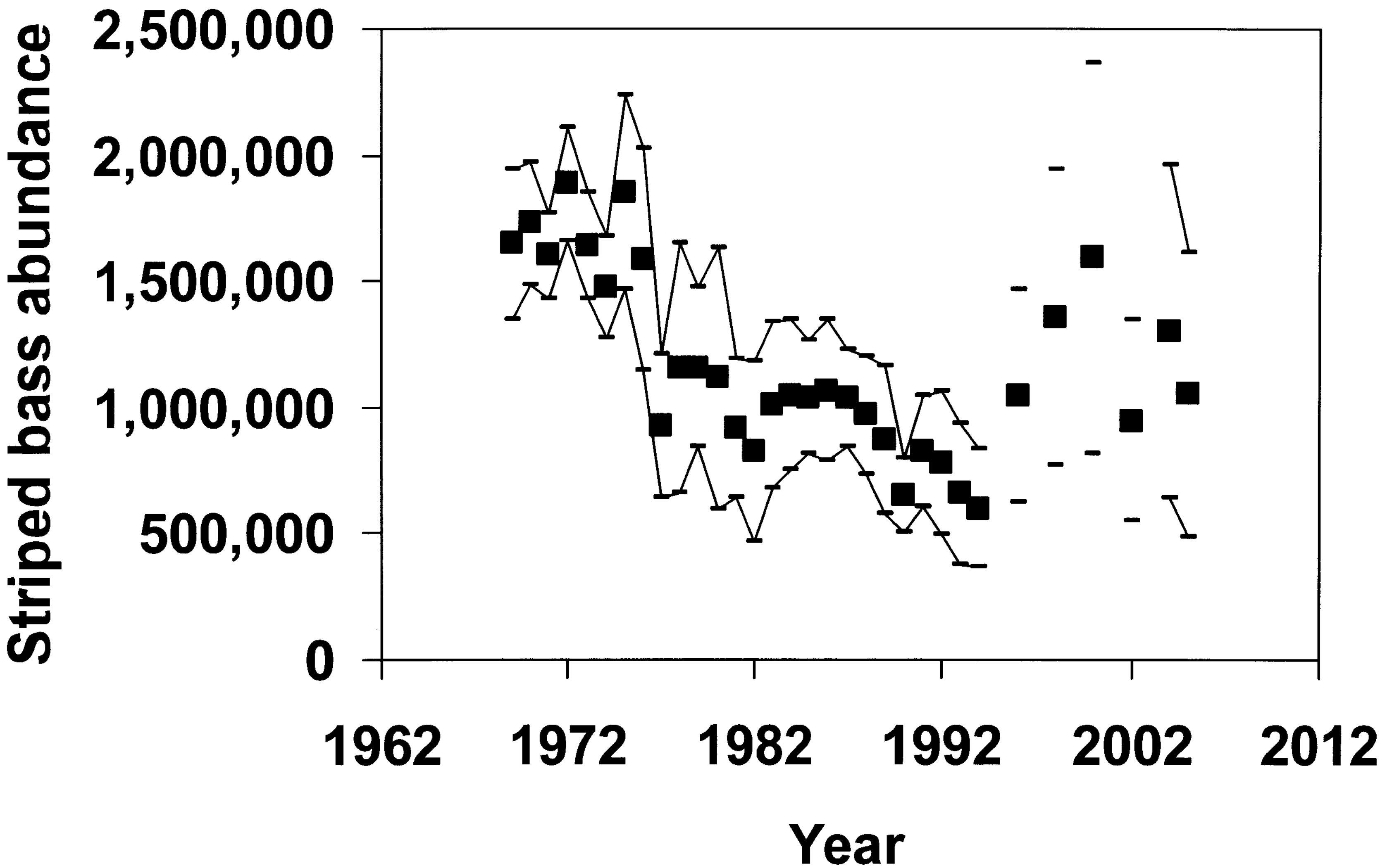


Exhibit E

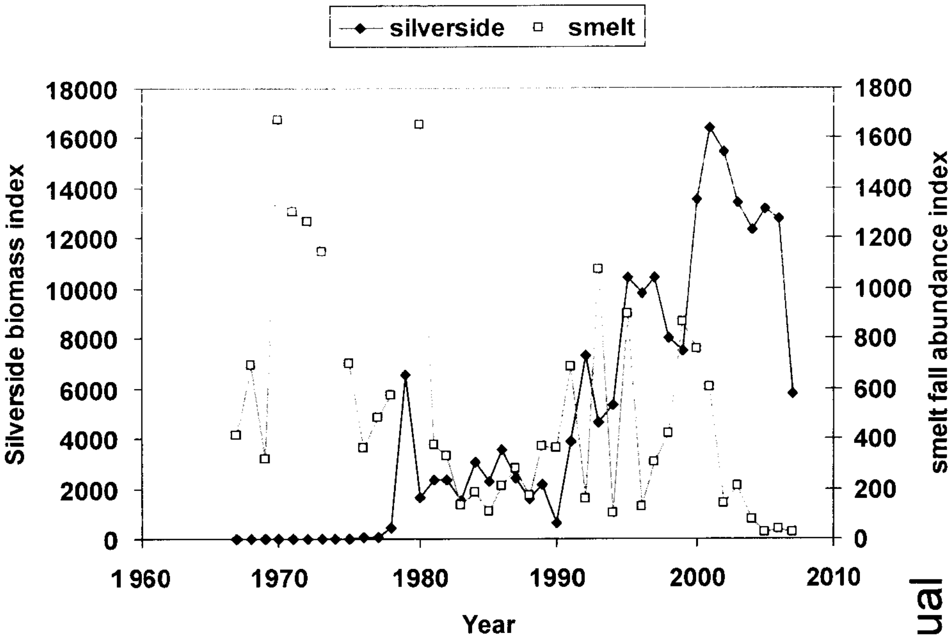


Exhibit E. Trends in Mississippi silverside biomass based on IEP beach seine data and the delta smelt Fall Midwater Trawl index (above). Plot of Mississippi silverside biomass versus the variation in delta smelt abundance during summer surveys after the variation due to the number of spawners has been accounted for (right). The line shown through the data is a ‘smoother’ not a linear regression line. A linear regression of the data on the right is statistically significant: the probability that there is no slope is 0.009, the r-square is 0.21, so the regression explains 21% of the variance in the relationship.

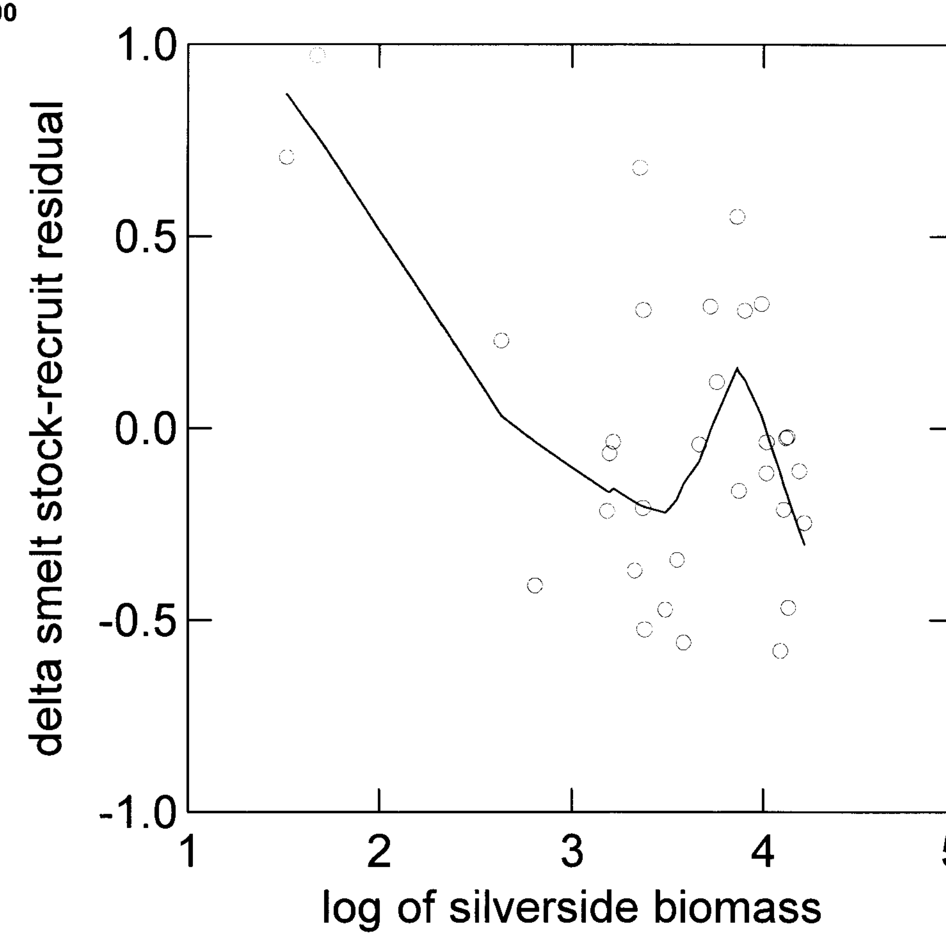


Exhibit F

Exhibit F. The abundance of adult striped bass (base 10 logarithm) plotted against the abundance of winter- and spring-run Chinook salmon (also base 10 logarithms). The linear regression results are included.

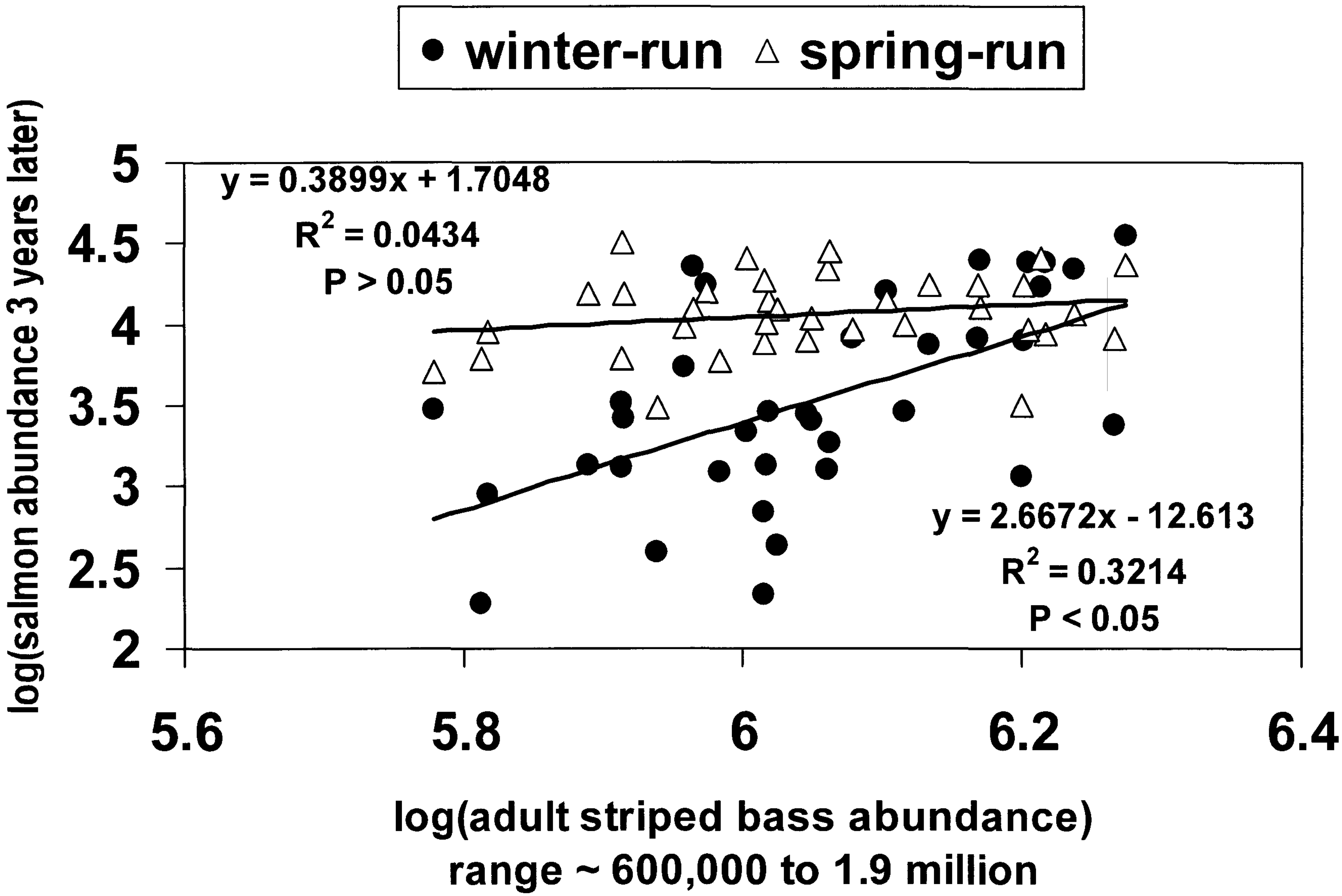


Exhibit G

Exhibit G. The abundance of adult striped bass (base 10 logarithm) plotted against two abundance indices of delta smelt (also base 10 logarithms). The linear regression results are included.

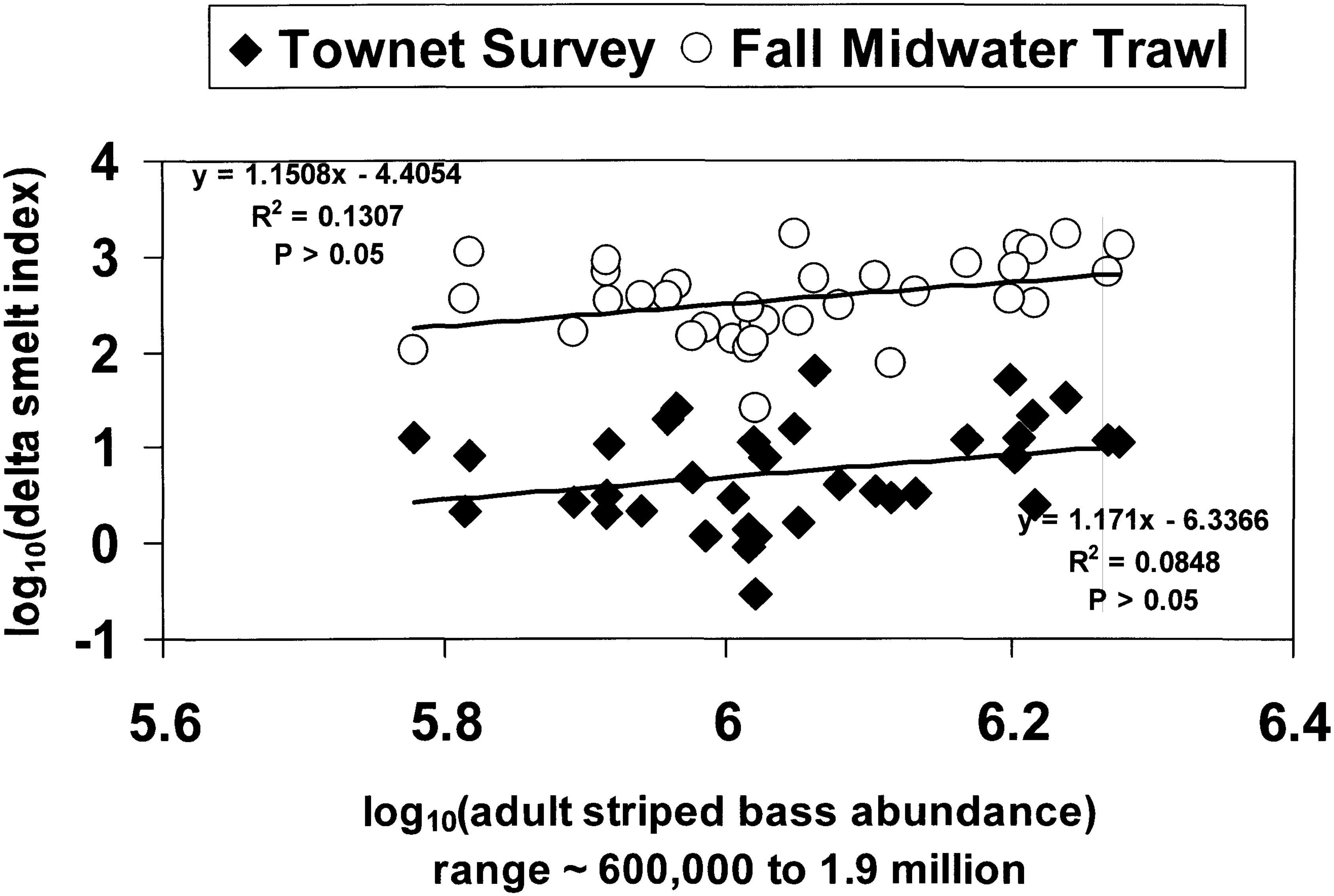


Exhibit H

ESTUARY WATERSHED

Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta

Wim J. Kimmerer, San Francisco State University

Exhibit H. The estimated weight per unit of water sampled of delta smelt's food versus a 'summer to fall survival index' for delta smelt. Figure taken from Kimmerer (2008).

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

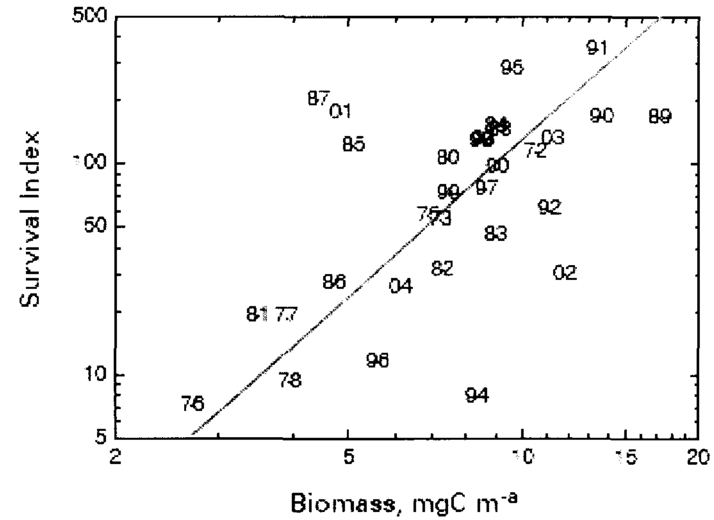


Figure 17. Relationship of survival index (fall trawl index / summer townet index) of delta smelt vs. mean zooplankton biomass during July–September for all stations in a salinity range of 0.15 to 2.09, the central 50% of the summer delta smelt distribution. The line is the geometric mean regression for log(10)-transformed data, $y = 2.48x - 0.36$. The correlation coefficient for the log-transformed data is 0.58 with a 95% confidence interval of (0.26, 0.78).

Exhibit I

Exhibit I. The abundance of adult striped bass (base 10 logarithm) plotted against the delta smelt survival index shown in Figure 6. The linear regression results are included.

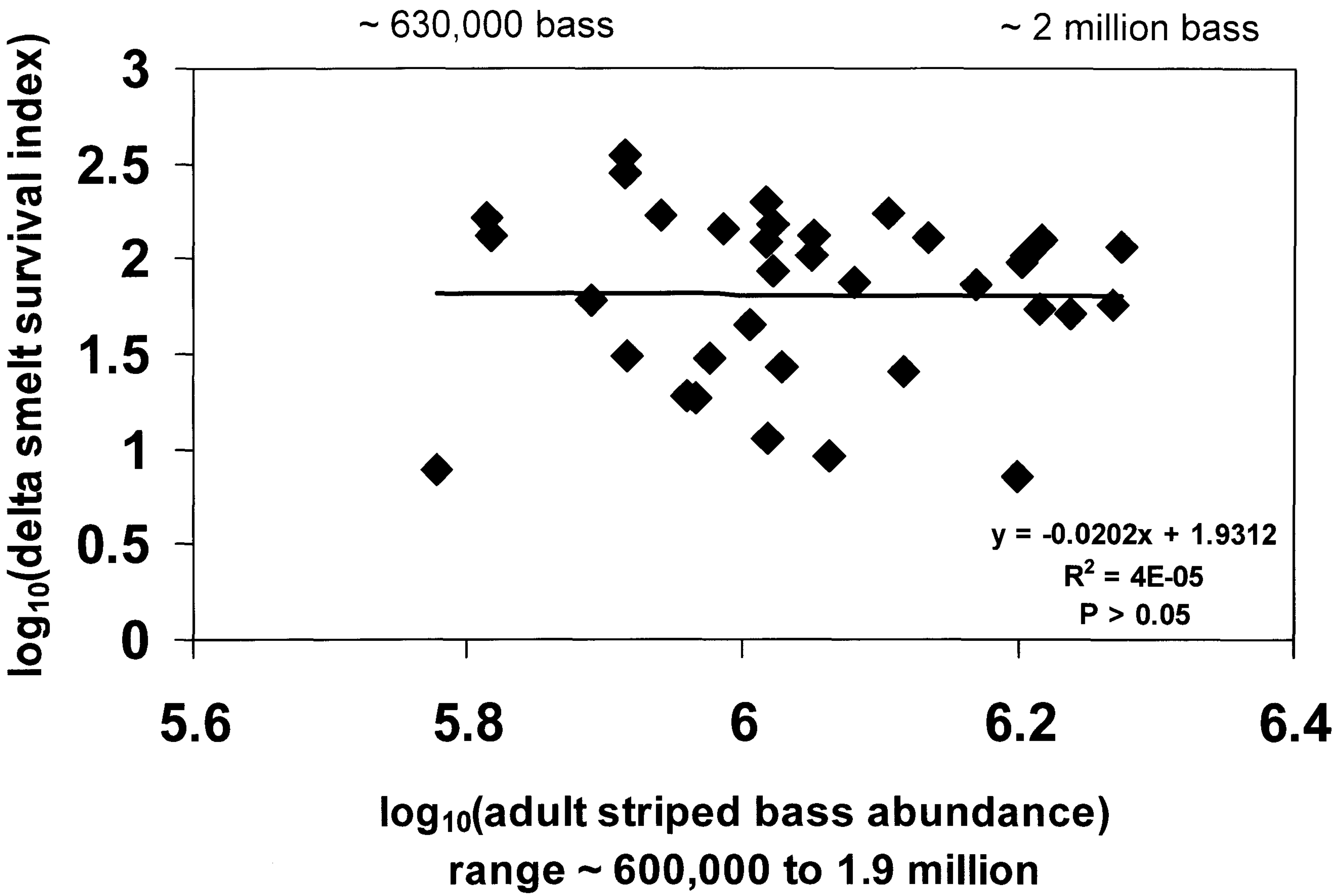
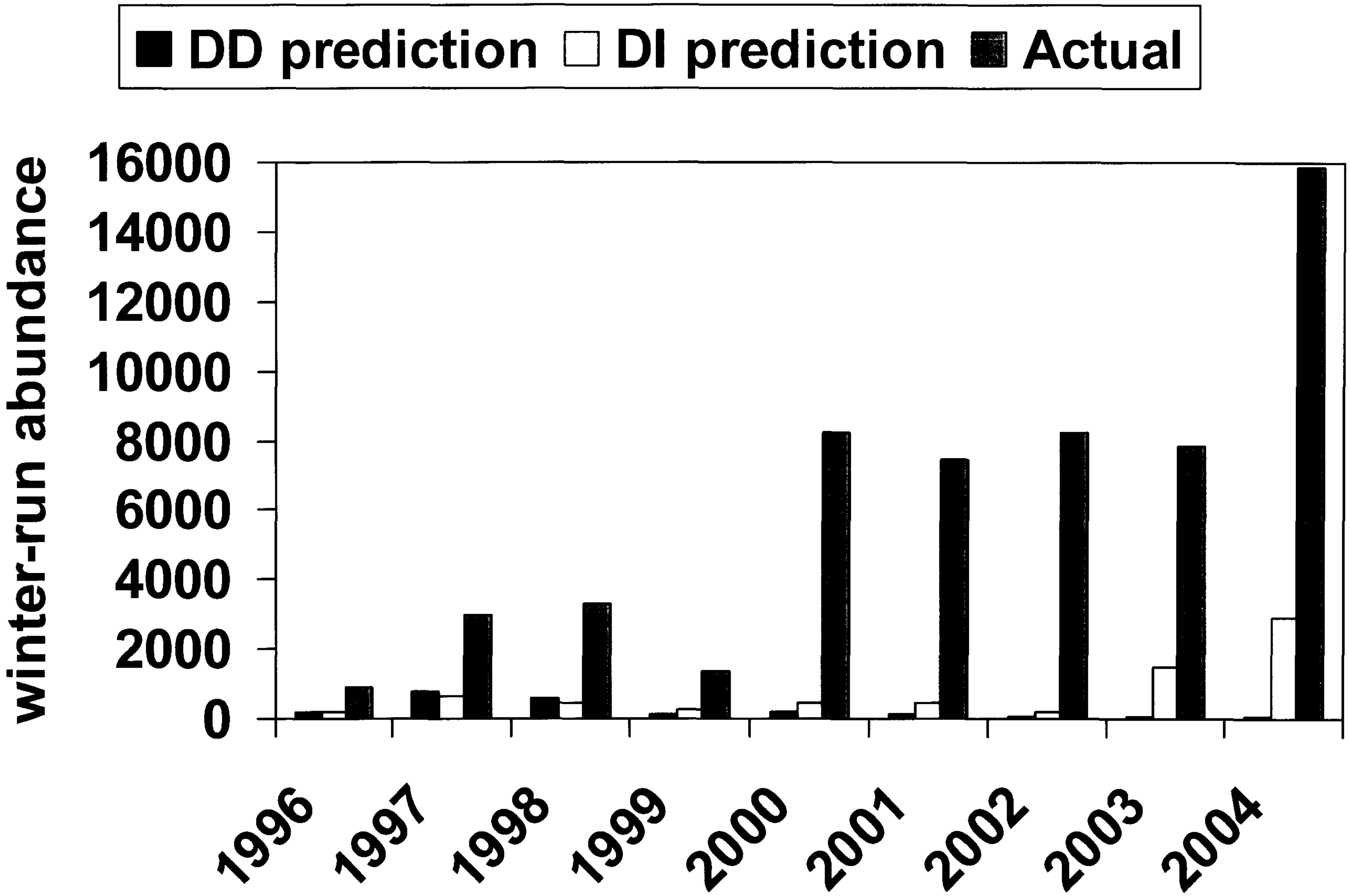


Exhibit J

Exhibit J. Predicted abundance of winter-run salmon 1996-2004 using the model of Lindley and Mohr (2003), which assumes a measurable influence of striped bass predation on winter-run abundance and the actual returns of winter-run salmon to the Sacramento River for the same period.



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ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8751

August 26, 2010

To: Mr. Jim Kellogg, President, Fish and Game Commission,

From: Peter B. Moyle and William A. Bennett, Center for Watershed Sciences

Re: Striped bass predation on listed fishes: can a control program be justified?

Recently, the Commission has been requested to remove all regulations from the striped bass fishery, as a way of reducing predation on salmon, delta smelt, and other threatened fishes. Our basic message is that the Commission should exercise extreme caution in making this change; new regulations to control striped bass are more likely to be harmful than helpful to native species of concern.

Striped bass are an abundant alien predator on fish and other aquatic organisms in the San Francisco Estuary and its tributaries (Moyle 2002). Salmon, delta smelt, and other native fishes are in decline. Therefore, it is presumed that reducing striped bass numbers can help to increase populations of threatened fishes. Over the past two years, this argument has been the focus of litigation, proposed legislation, and most recently a request by NMFS to the Fish and Game Commission to remove all restrictions on the striped bass fishery. Given the ample evidence that fishing can greatly reduce abundance of target species, it is a reasonable assumption that removing restrictions on striped bass would significantly reduce their numbers, particularly if fishing concentrated on immature fish and large, older females. However, whether or not threatened salmon, steelhead, and smelt populations would rebound is an open question. Here are some of the assumptions, or, untested hypotheses, that would need to be true and work in concert before native fishes might benefit from fewer striped bass.

Assumption 1. Predation by striped bass regulates populations of salmon, steelhead, and smelt, with other predators (other fish, birds, marine mammals, etc.) playing a minor role.

Assumption 2. Other predators will not exhibit compensatory increases in predation on threatened fish if striped bass are removed.

Assumption 3. Other species on which striped bass prey, such as Mississippi silverside, will not increase in abundance, causing harm by competing and preying on threatened species.

Assumption 4. Reducing striped bass numbers can measurably compensate for the massive changes to the estuary and watershed caused by water diversions and other factors, which also reduce fish populations.

Before any of the above assumptions can be accepted several factors need to be taken into consideration:
1. Striped bass are generalist and opportunistic predators that tend to forage on whatever prey are most abundant, from benthic invertebrates to their own young to juvenile salmon and shad (Stevens 1966, Moyle 2002, Nobriga and Feyrer 2008).

2. Delta smelt were a minor item in striped bass diets when they were highly abundant in the early 1960s (Stevens 1966), as well as in recent years at record low abundance (Nobriga and Feyrer 2008). Striped bass are unlikely to be a major predator of delta smelt because smelt are semi-transparent (hard to see in turbid water) and do not school (they aggregate loosely where conditions are favorable), unlike more favored prey such as threadfin shad, juvenile striped bass, and Mississippi silverside.

3. Striped bass will feed heavily on juvenile salmon and steelhead in the rivers, as they migrate seaward, which is well documented. However, most salmon eaten are likely to be naïve fish from hatcheries, high predation on them has little bearing on the degree of predation encountered by more wary juveniles from natural spawning. Predation on hatchery-reared juveniles may even buffer wild fish from such predation, given that wild fish are warier and less conspicuous than the more abundant hatchery fish. Lindley and Mohr (2003) present a model that suggests an annual loss of 9% to striped bass predation is sufficient to increase the probability of extinction of winter run Chinook salmon. However it is important to appreciate the considerable uncertainty associated with this modeling result, given the difficulty of estimating juvenile salmon abundance.

4. All measurements of predation and mortality are very rough, with high variation around any estimate. Unfortunately, such estimates are often presented as single values which tend to be taken as absolute values (e.g., Hansen 2009). The multiple sources of uncertainty that affect these values include abundance of adult striped bass, prey abundance, rates of prey encounter and consumption (which are now based only on stomach contents), as well as biases inherent in the designs and methods of different studies. Models, such as Lindley and Mohr (2003), can produce estimates of salmon loss to striped bass, but they are only as good as the information used to produce them, which is extremely limited in quality and amount. The Lindley and Mohr (2003) model, while excellent, has results that are merely a demonstration that striped bass *could* affect winter run Chinook numbers rather than a proof that they actually do.

5. There is a tendency to conflate all predation losses of salmon with striped bass and/or to dismiss the effects of other predators as being insignificant (e.g. Hansen 2009). In fact, there are a multitude of other predators on juvenile salmon in the system, from birds (e.g., mergansers, cormorants, terns) to other fish, native and non-native, including juvenile steelhead. The most abundant fish predator in the Delta today is probably largemouth bass, as the result of changes in hydrodynamics related to the ever-increasing export of water (Moyle and Bennett 2008). If a control program for striped bass can be justified, then it is likely one should also be instituted for largemouth bass, as well as for spotted bass, channel catfish, and other non-native predatory fish.

6. Applying mortality rates due to predation that were estimated using hatchery-reared salmon juveniles may have little bearing on those of fish from natural spawning. Thus, applying a predation mortality rate of 90% or so to represent what happens to out-migrating juvenile salmon from natural spawning has to done very carefully. Such a high predation rate is based only on observations of

hatchery juveniles, which are typically released in large numbers over limited time periods. Because these fish are adapted for life in crowded hatchery troughs, where food comes from above in the form of pellets, they have never experienced the threat of predation. It is astonishing in many respects that as many of these fish survive as do. Wild fish, in contrast, are more wary, spending much of their time in cover with well-developed predator avoidance behavior; they tend to migrate at night and spend the days along the shoreline hiding in whatever cover is available.

7. Much of the predation on juvenile salmon (from multiple predator species) seems to take in place in conjunction with artificial structures and poor release practices. These include releases of fish from hatcheries and those trucked to the estuary from the export facilities in the south Delta. Opportunistic predators, such as striped bass, are extremely quick to cue on predictable events, such as regularly timed releases of smolts at a single location. Changing the simple-minded protocols associated with fish releases may be a wiser approach for reducing such predation, rather than using observations of these events to blame striped bass and justify predator control programs. Reducing predation opportunities at various artificial structures may also have large benefits and needs investigation.

8. If the striped bass is indeed the dominant predator on other fishes in the Delta and Sacramento River (the reason for a control program), then this predatory effect should be greatest on populations of other species that are more frequently consumed. The 'release' from predation pressure associated with reducing striped bass numbers is thus highly likely to benefit many other alien fish which are also known predators and competitors on fishes of concern. This assertion is widely supported by ecological theory and numerous investigations in a variety of systems, including estuaries elsewhere. For example, Mississippi silversides are important in the diets of 1-3 year old striped bass, so bass predation could be regulating the silverside population. If true, then relieving silversides from striped bass predation pressure is likely to increase their numbers, which could have negative effects on delta smelt through predation on eggs and larvae (Bennett and Moyle 1996). This strongly suggests that any proposal to initiate a control program for striped bass should carefully consider the likely consequences, as well as involve an intensive study effort on the impact of program to make sure the alleged cure is not worse than the supposed disease.

The take home message from all this is that reducing the striped bass population may or may not have a desirable effect. In our opinion, it is most likely to have a negative effect. While the ultimate cause of death of most fish may be predation, the contribution of striped bass to fish declines is not certain. By messing with a dominant predator (if indeed it is), the agencies are inadvertently playing roulette with basic ecosystem processes that can change in unexpected ways in response to reducing striped bass numbers. Overall, the key to restoring populations of desirable species and to diminish populations of undesirable species (Brazilian waterweed, largemouth bass, etc.) is to return the Delta to being a more variable, estuarine environment. This is likely to happen naturally with sea level rise interacting with levee collapses (Lund et al 2007, 2008), but the populations of delta smelt and similar fishes may not be able to last that long. We stress that attempting to reduce striped bass and other predator populations is unlikely to make a difference in saving endangered fishes, and will serve only to distract attention from some of the real problems. However, efforts to reduce predation opportunities (not necessarily predators) in some locations with a focused effort may make a difference in the survival rates of depleted salmon and other species and provide some assistance to their recovery.

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Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. B. Moyle. 2010. Comparing futures for the Sacramento-San Joaquin Delta. Berkeley, University of California Press. 230 pp.

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A Synopsis of the State of Science Regarding the Feeding Ecology of San Francisco Estuary Striped Bass and its Effects on Listed Fishes

Matthew L. Nobriga

Senior Environmental Scientist

California Department of Fish and Game, Water Branch

October 1, 2009

I. Introduction

My name is Matt Nobriga and I am a Senior Environmental Scientist with the California Department of Fish and Game. I have worked on fisheries issues in California's Central Valley for 18 years (Exhibit A). I have reviewed the Plaintiff's amended complaint (Coalition et al. 2008) and I have been asked to provide evidence and opinions regarding the scientific claims therein. This report summarizes my pertinent findings.

In this report, I:

- discuss the trends in juvenile and adult striped bass abundance over the past several decades

- provide examples of the complexity of the San Francisco Estuary and other aquatic food webs to demonstrate that simple food *chain* predictions can lead to wrong guesses about how food *webs* will change when species are added or depleted

- review and evaluate the evidence for population dynamic effects of predation by striped bass on delta smelt and Chinook salmon.

- review recent modeling results of striped bass predation on winter-run salmon and bioenergetic demands of the San Francisco Estuary striped bass population to help put these results in context for this case.

Background information on striped bass:

The striped bass (*Morone saxatilis*) was intentionally introduced into the San Francisco Estuary in 1879 and 1882 from coastal rivers in New Jersey (Moyle 2002). San Francisco Estuary striped bass were fished commercially from 1888-1935. They support a sport fishery to the present day. Since 1969, the abundance of adult striped bass has been monitored by DFG using consistent methods based on a sampling design in which fish are tagged and subsequently recaptured in creel surveys or other monitoring programs. Adult striped bass abundance declined abruptly from numbers near 2 million to numbers closer to 1 million in 1977 (Exhibit B). Abundance declined further to numbers consistently below 1 million during the first half of the 1990s. Then, beginning about 1996, abundance rebounded to about 1-1.5 million fish. Recent abundance peaked near 2 million fish in 2000. The most recent estimate indicates abundance has declined again to fewer than 1 million, but this is a preliminary estimate that could change as additional years of recaptured fish add data to the calculation of the abundance estimate.

Unlike the adults, the relative abundance of young-of-the-year striped bass has shown a substantial and sustained long-term decline from peak index values in the latter 1960s (Exhibit C). Several relative abundance estimates during the current decade have been less than one half of one percent of the peak value recorded in the 1960s. The downward trend is very similar based on two separate surveys of juvenile striped bass – one conducted during the summer and the other conducted during the fall.

The rehabilitation of striped bass in their native Atlantic coast habitats has suppressed some pelagic fish populations

During the 1980s, the Atlantic States Marine Fisheries Commission and the federal government implemented strict fishery regulations to recover Atlantic coast striped bass stocks (Richards and Rago 1999). The exact protections varied by state and increased in intensity over time.

However, Maryland and Delaware prohibited catch or sale of striped bass in 1985 and the US government required minimum sizes of 38 inches by 1990. These measures worked very well and the population rebounded, and was declared fully recovered in 1995, at a population size slightly over 40 million age-1 and older fish (NMFS 2005; Grout 2006). The population continued to increase after 1995 and by 2004, it had reached nearly 60 million age-1 and older fish, and 6-7 million age-8 and older fish. Thus, the Atlantic coast striped bass population is very large compared to the San Francisco Estuary population.

The Atlantic coast striped bass population also rebounded very rapidly, which would place a large and conspicuous demand on prey that the Atlantic coastal ecosystems might need time to adjust to. During the first 10 years of the recovery effort, the population increased by a factor of six (NMFS 2005; Grout 2006). As of 2004, there were about 10 times as many striped bass (and about 10 times as much striped bass biomass) as there had been 20 years prior when recovery efforts started. In contrast, the San Francisco Estuary's striped bass population roughly doubled between 1990 and 2000 and recent data indicate it is declining again (Exhibit B). Thus the rate of increase was slower, and the duration shorter, in the San Francisco Estuary than along the Atlantic coast.

The very large and rapidly increasing striped bass population along the Atlantic coast is a significant source of mortality for some fishes, mostly estuarine and anadromous members of the herring family like Atlantic menhaden (*Brevoortia tyrannus*), alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), and blueback herring (*A. aestivalis*) (Hartman 2003), but this list also may also include Atlantic salmon (*Salmo salar*; Grout 2006). The available evidence from Chesapeake Bay indicates menhaden are not able to absorb the predation demand of the restored striped bass population and remain commercially viable at recent fishing levels (Uphoff 2003). Atlantic salmon recovery efforts also may be affected (Grout 2006). Similarly, the Conneticut Department of Environmental Protection thinks the recovered striped bass population has contributed to record low returns of alewife and blueback herring (http://www.ct.gov/dEP/cwp/view.asp?A=2711&Q=412578). Thus, it must be acknowledged that a rapid, large change in a striped bass population can have a substantial demand on prey resources. Below, I describe why the evidence is insufficient to determine whether the ecological effects observed during the recovery of the Atlantic coast striped bass stocks would apply to listed fishes in the San Francisco Estuary.

II. Food Web Complexities and Species Adaptation

General background on food webs:

Food webs can be thought of as combinations of many individual food chains that link different predators with different prey at different times. They are often shown artistically as flow charts connecting predators and prey. Exhibit D shows a food chain for striped bass in the Delta that provides a simple pictorial summary of striped bass food habits studies from the 1960s (mainly based on Stevens 1966). The estuary's actual food web is much more complex. Even several decades ago, the striped bass food web had many more links between different predators and prey (Thomas 1967). As they continue to do, striped bass diets varied by season. However, dominant prey varied greatly depending on whether the fish were collected in saltwater, brackish water or freshwater. Anchovies, herring, shiner perch and bay shrimp dominated the marine diet. Mysid shrimp, Chinook salmon, carp, crayfish, threadfin shad and cannibalized striped bass dominated the diets of striped bass collected in fresh and brackish water, with the relative importance of these also varying by year and the specific location of collection (Stevens 1966; Thomas 1967). More recently, striped bass inhabiting brackish and freshwater habitats have forged new predator-prey linkages as species invasions have forced them to change their feeding habits (Feyrer et al. 2003; Bryant and Arnold 2007; Nobriga and Feyrer 2008).

What has happened to prey fish assemblages in other aquatic systems when predators were depleted or removed?

There are no studies available to determine the response of the San Francisco Estuary to the depletion or removal of a keystone predatory fish. The Sacramento perch (*Archoplites interruptus*), a cousin of the largemouth bass (*Micropterus salmoides*), that is native to the Delta, has been extirpated from the estuary and its watershed. However, detailed ecological data were not collected on Sacramento perch before and after they declined and they have been functionally replaced by other non-native predators (Moyle 2002). Due to the lack of data specific to the San Francisco Estuary, I have summarized findings from other locations. The best analogs come from summaries of lake manipulation experiments and from studies of overfished freshwater and marine systems.

There is no question that removing predators from aquatic ecosystems results in major changes to the food webs of those systems (Kitchell et al. 1994; Jackson et al. 2001). These changes sometimes, but not always, include increases in the abundance of prey species (Kitchell et al. 1994; Jackson et al. 2001; Friedlander and DeMartini 2002; Chapman et al. 2003). However, the net effect of removing keystone grazers and predators has often been to rapidly shift ecosystems toward new ecological states. Often, these altered systems have been characterized by instability, pollution, species invasions and disease, but it has been noted that these secondary stressors followed overfishing and its "ecological extinction" of the grazers and predators that most strongly controlled the historical food webs (Jackson et al. 2001).

In one of the world's most famous examples, Nile perch (*Lates niloticus*), were introduced into Africa's Lake Victoria (and its smaller "satellite" lakes). The Nile perch depleted the native fish fauna through predation. Subsequently, overfishing Nile perch has allowed the native fish assemblage to partially rebound (Kitchell et al. 1997; Chapman et al. 2003). Thus, Lake Victoria is an example of a system in which predator removal is an effective strategy to combat the decline of native fishes.

In contrast, in North America's great lakes, the loss of predatory lake trout (*Salvelinus namaycush*) through overfishing and sea lamprey (*Petromyzon marinus*) predation allowed non-native, plankton-eating fish populations to explode (Kitchell et al. 1994). This was associated with decreases in the native plankton-eating fishes and it contributed to lake eutrophication because of increased predation on zooplankton (by plankton-eating fishes) that historically helped keep plant plankton under control. In contrast to the African example, these ecological problems have been partly reversed by stocking both lake trout and non-native Pacific salmonids. These predators have reduced the abundances of non-native plankton-eaters, which improved water quality and helped the native plankton-eating fishes rebound.

The coral reef ecosystems of the Hawaiian Islands include the heavily fished main islands with high human populations and a larger number of more distant islands and atolls which have had much less fishing pressure (Friedlander and DeMartini 2002). The fish assemblages in these two groups of islands are markedly different. The main islands are extremely depleted in terms of apex predators, but prey fish densities are no higher than they are in the more remote locations that still have high predator densities. The likely reason in this case is overfishing of species that are prey of apex predators as well as the predators themselves. This example shows that fish may not recover if they are subject to multiple sources of mortality and only one is removed.

The overbite clam invasion as a local example of the difficulty in predicting what will happen when a food web changes

The food web of the San Francisco Estuary is very complex and at least somewhat adaptable. The striped bass food chain shown in Exhibit D is an intentionally simplified depiction of the circa 1960s understanding of how part of the estuary's food web worked. In 1986, the estuary was invaded by a mollusk called the overbite clam (*Corbula amurensis*). This invasion started a series of biological changes in the food web that based on the Exhibit D depiction, should have decimated the striped bass population. As shown by Exhibit B, this has not happened, so the overbite clam invasion provides a local example of how difficult it is to predict how a food web will respond to a major change.

The overbite clam amassed very dense populations very quickly and by 1988 it had caused declines in the microscopic plants that feed the zooplankton that feed many of the estuary's small fish including juvenile striped bass (Exhibit D). Simply put, the overbite clam has greatly limited the potential fishery production that can arise from the estuary's 1960s food web. As I stated above, the juvenile striped bass numbers have declined substantially (Exhibit C). But surprisingly, there is still a scientific debate occurring about how much of this decline is due to effects of the overbite clam. Some analyses suggest the clam was a large contributor to the juvenile bass decline (Kimmerer et al. 2000; Feyrer et al. 2003; Sommer et al. 2007; Nobriga and Feyrer 2008), while others do not (Kimmerer 2002; Bryant and Arnold 2007). Either way, the trend in the adult population is evidence that so far, striped bass have found enough alternative prey to supplement their depleted historical prey and prevent the older fish from crashing in tandem with the juvenile fish.

Why could striped bass persist and even rebound when the food web that historically sustained their young was so radically changed? The available evidence suggests there were at least two reasons. First, young striped bass changed their diets. Young striped bass supplemented their historical diet with new zooplankton (Bryant and Arnold 2007) that were able to invade the estuary because they were not as susceptible to the effects of clam grazing as the previously dominant forms. Older juvenile striped bass also incorporated newly introduced invertebrates into their diet and ate more fish than they had historically (Feyrer et al. 2003) – especially common non-native species like threadfin shad (*Dorosoma petenense*), yellowfin goby (*Acanthogobius flavimanus*), and Mississippi silverside (*Menidia audens*) (Nobriga and Feyrer 2007; 2008).

Second, a change in the distribution of northern anchovies (*Engraulis mordax*) may have helped them out. Northern anchovies historically maintained about twice the biomass in the low-salinity zone[1] as all other pelagic fishes combined (Kimmerer 2006). However, when the overbite clam took their food away, most of the anchovies retreated to saltier water. From 1988-2001 their low-salinity zone biomass decreased to about 6% of what it had been prior to the overbite clam invasion. This exodus of the anchovies probably reduced competition for food among the pelagic plankton-eating fishes in the low-salinity zone, offsetting some of the clam's effects on juvenile striped bass food supply. As Kimmerer et al. (2008) pointed out regarding the overbite clam invasion in the CALFED Science Program's State of Bay-Delta Science report, "This sequence of events would not have been predictable in advance, and provides a cautionary tale for predicting the outcomes of future introductions."

Being eaten is a part of life for small fishes

Striped bass eat delta smelt (*Hypomesus transpacificus*) and juvenile Chinook salmon (*Oncorhyncus tschawytscha*) (Stevens 1963; Stevens 1966; Thomas 1967), but being eaten is a natural ecosystem process for small fishes. In and of itself, being eaten by striped bass does not support the conclusion that striped bass have caused or contributed to a species' decline or that being eaten by striped bass will affect a species' viability.

Like most large predatory fishes, the diet composition of striped bass tracks prey availability (Nobriga and Feyrer 2007; 2008). Thus, the occasional occurrence of rare fish like delta smelt and listed runs of Chinook salmon in striped bass stomachs is expected. The converse is also true – both delta smelt and Chinook salmon were more frequently eaten in the past when and where they were more abundant. During the 1960s for instance, it was observed that some striped bass keyed in on releases of hatchery fall-run Chinook salmon from the American River

[1] The low-salinity zone is the nursery habitat for young striped bass, delta smelt, and several other fishes.

(Stevens 1963; Thomas 1967) and delta smelt spawning aggregations in the Sacramento River (Stevens 1963), but when the Delta-resident striped bass were surveyed throughout the region, most of their diet was composed of the fishes that were most abundant in trawl catches at that time (e.g., baby striped bass and threadfin shad; Stevens 1966). My colleague Fred Feyrer and I have recently shown more explicitly that striped bass prey use is a function of prey density – particular prey get eaten more frequently when and where they are abundant (Nobriga and Feyrer 2008). Thus, abundant nonnative fishes now make up most of the fish fraction of the striped bass diet in the Delta (Nobriga and Feyrer 2007; 2008). However, I am not aware of any scientific expectation that these fishes will persistently decline simply because they are major prey for striped bass.

The inability of native fishes to thrive in the Delta reflects an environment that is changing away from the one they evolved in, not an inherent inability of these fishes to sustain predation pressure. By virtue of their small size, both delta smelt and emigrating salmon have always been forage fishes faced with predation pressure. This is particularly true for small annual fishes like delta smelt (Winemiller and Rose 1992). According to Winemiller and Rose (1992) who conducted an extensive survey of the life-histories of more than 200 North American fishes, small, annual fishes (called 'opportunistic strategists') "are well equipped to repopulate habitats following disturbances or in the face of continuous high mortality in the adult stage…These small fishes frequently maintain dense populations in marginal habitats (e.g., ecotones, constantly changing habitats) and frequently experience high predation mortality during the adult stage." Note that natural estuaries are both ecotones (transitional habitats between river and ocean) and "constantly changing" habitats. Opportunistic fishes have adapted to handle variable environments and heavy predation pressure by maturing quickly and spawning frequently over extended spawning seasons. This allows them to put new generations out very fast – but the strategy only works if some of the progeny find suitable places to grow to adulthood. This life-history strategy worked for delta smelt during its 10,000 years or so of co-evolution with the San Francisco Estuary and as far as our limited data can tell, it also worked in the face of striped bass predation pressure for many decades (DFG 1999).

The Mississippi silverside in the San Francisco Estuary

Mississippi silversides (formerly thought to be the closely related inland silverside) are a small, annual fish native to eastern North America (Moyle 2002). They invaded the Delta in the 1970s and have flourished; they are the most numerous fish occurring in shallow habitats throughout the estuary's fresh and brackish waters (Matern et al. 2002; Nobriga et al. 2005; Cohen and Bollens 2008). Like delta smelt, they are opportunistic strategists, but silversides are more tolerant of warm water, clear water, and extremes of salinity (Moyle 2002). Thus, silversides find the present-day San Francisco Estuary's environment suitable for their version of the opportunistic life-history strategy, and due to their abundance, silversides are now a common prey of striped bass and other predatory fishes in the Delta (Nobriga and Feyrer 2007).

In general, the abundance of Mississippi silversides has increased over the past 35 years while the abundance of delta smelt has declined (Exhibit E). Bennett and Moyle (1996) and Bennett (2005) have reported that they believe these inverse trends are due to the combined effects of predation and competition by silversides on delta smelt. Bennett (2005) presented evidence that Mississippi silversides would out-compete delta smelt where they co-occur. He showed the results of a short-term study that found when delta smelt and silversides were held in captivity together, delta smelt growth was impaired, but silverside growth was not (Bennett 2005). Bennett and Moyle (1996) discussed a separate study that showed silversides readily ate striped bass larvae and were efficient predators of striped bass larvae in Delta waters that were enclosed with nets. Striped bass larvae reside in the Delta at the same times and places as delta smelt larvae, so Bennett and Moyle (1996) and Bennett (2005) logically consider this finding evidence that delta smelt larvae[2] are similarly vulnerable to Mississippi silverside predation. Note that at all life stages, Chinook salmon and steelhead are too large to be vulnerable to predation by Mississippi silversides.

It should also be kept in mind that striped bass eat delta smelt's predators and competitors (Nobriga and Feyrer 2007; 2008). Thus, if striped bass predation affects delta smelt survival, it probably also affects Mississippi silverside survival. Therefore, based on the case studies I presented above, there are actually three possible outcomes with regard to delta smelt if the striped bass population is depleted. One is that delta smelt abundance increases because they are released from striped bass predation and they have no other significant predators or competitors. This is analogous to the example from Lake Victoria. A second possibility is that delta smelt abundance does not change or continues to decline because other factors continue to impose strong limits on their productivity. This is analogous to the example from the Hawaiian reefs. The third possibility is that delta smelt abundance decreases further because Mississippi silversides (or another predator or competitor or combination of other predators and competitors) are released from striped bass predation, enabling greater predation and competition with delta

[2] In my opinion, delta smelt eggs would be more vulnerable to silverside predation than the larvae because the eggs probably co-occur on sandy shorelines where silversides are common. Delta smelt larvae are more common in offshore environments that are not known to be used extensively by silversides.

smelt. This is analogous to the example from North America's Great Lakes. It is my professional judgement that the most likely outcome in this list is not discernable with existing data because, as I described above, major food web perturbations can cause changes that are not predictable in advance.

The Pelagic Organism Decline

The Pelagic Organism Decline or "POD" is the name given to a sudden drop in the relative abundance of four open-water fish species of the upper estuary around 2002 (Sommer et al. 2007). The four POD fishes are delta smelt, longfin smelt (*Spirinchus thaleichthys*), threadfin shad, and age-0 striped bass; age-0 refers to striped bass in their first year of life. Sommer et al. (2007) proposed a conceptual (pictorial) model of four groups of interacting factors that *together* they hypothesized could have caused the POD. The four groups of factors were low adult numbers to begin with (stock-recruit), changed habitat conditions (habitat suitability, toxicity, etc.), low food production for pelagic fish (bottom-up factors), and losses to entrainment and predation (top-down factors). A similar multiple interacting stressors conceptual model for striped bass and delta smelt declines was previously proposed by Bennett and Moyle (1996).

Following Sommer et al.'s (2007) conceptual modeling effort, the Interagency Ecological Program[3] commissioned an independent quantitative modeling effort based on its datasets. The results of this effort have been reported in two draft manuscripts currently being considered for publication (Mac Nally et al. 2009; Thompson et al. 2009). Thompson et al. focused on time periods where fish densities changed abruptly, trying to account for these 'change-points' with

[3] A government agency group made up of managers and scientists from California Department of Water Resources, California Department of Fish and Game, US Bureau of Reclamation, US Fish and Wildlife Service, and several others.

environmental variables like X_2, turbidity, temperature, and water exports. In essence they were primarily testing the hypothesis of whether a POD occurred in 2002 or whether it was just an extension of longer-term fish declines previously linked to these and other environmental variables. Mac Nally et al. used a different technique to more explicitly account for stock-recruit, physical environment, and food web effects. In essence, they were at least partly testing the Sommer et al. (2007) conceptual model and the robustness of conclusions from the Thompson et al. (2009) change-point model.

The Thompson et al. and Mac Nally et al. manuscripts are in draft form and pre-decision at the journal they have been submitted to, so it would not be appropriate for me to report highly detailed results since peer-review may cause some of their conclusions to change. However, there are a couple key points that the authors felt were robust enough to present at a public workshop on September 8, 2009:

- The *long-term trends* in the four POD fish densities were associated with different environmental factors for each species. This means the data do not support hypotheses like delta smelt and longfin smelt declines were driven by the same factors.

- The *2002 fish decline* reported by Sommer et al. (2007) was supported as a statistically demonstrable occurrence; it was not just part of the longer-term fish declines. Although the long-term trends in these species were explained by several environmental factors, none of these factors clearly explained the 2002 decline. This may mean that there are additional unmeasured factors, or that there was some sort of tipping point when the cumulative effects of the different factors finally pushed the pelagic community into collapse (see below).

Based on the evidence accumulated to date, the Interagency Ecological Program is revising its conceptual model of the POD toward one depicting a 'regime shift' in the Delta ecosystem. In this context, regime shift refers to a major change in the organisms inhabiting the Delta region and thus, the food web they comprise. In this new conceptual model, the time period around 2002 is seen as the point at which the cumulative effects of all the preceding system changes tipped the scales toward the new ecosystem, rendering the historical one that supported striped bass, the smelts, and threadfin shad less viable.

In the context of POD, predation is one stressor that at present is only a hypothesized stressor, and must also be considered in the context of several other system stressors with which it is presumed to interact. Thus, a fish like delta smelt is fundamentally limited by an unquantified mixture of several factors that probably includes predation, but only in the context of changed habitat including additional 'predation' in the form of losses to entrainment (Bennett 2005), physiologic stress from low food supply and warm summer water temperatures (Bennett et al. 2008), low river outflows during fall, and decreased turbidity of Delta waterways (Feyrer et al. 2007). All of these factors constrain delta smelt habitat and limit their resilience.

The same basic idea applies to Central Valley salmonid fishes except that in addition to the estuary, changed habitat conditions in the watershed and the ocean also strongly influence salmonid fish resilience (Lindley et al. 2009).

III. The Relationship Between the Abundance of Striped Bass and Other Species

Overview of linear regression:

It is logical that if predation by one species is strong enough to cause declines in another that the abundance of the prey species would go down when the abundance of the predator goes up. This has been reported for striped bass and Atlantic salmon following the recovery of Atlantic coast striped bass (Grout 2006). One way to examine this possible "covariation" in species abundances is with linear regression. Linear regression is a common statistical technique used to test the ability of one or more "independent" or "explanatory variables" to explain variation in a "dependent" or "response variable" (Zar 1984). When a person applies linear regression to data they are by default assuming the independent variable *causes* changes in the dependent variable. Mathematically speaking, linear regression finds an equation that best describes several aspects of the relationship between the independent and dependent variables.

First, the regression produces a slope and intercept that define a line predicting how the dependent variable changes as the independent variable changes. Positive regression slopes indicate that the dependent variable increases when the independent variable increases. Negative regression slopes indicate that the dependent variable decreases when the independent variable increases.

Second, the regression provides an estimate of how well the line predicts the dependent variable's response to changes in the independent variable. It does this by determining how much of the "variance" in the dependent variable can be mathematically explained by the independent variable. The proportion (sometimes provided as a percentage) of variance explained is called the "r-squared." For instance, an r-squared of 0.50 or 50% suggests the independent variable explains 50% of the variation in the dependent variable.

Lastly, the technique provides the probability that the regression equation depicts a real response of the dependent variable to changes in the independent variable. By statistical convention, if the probability (or *P*-value) of the regression is less than 0.05 (5%), that is taken as sufficient evidence of a real relationship between the variables (Zar 1984). However, it should be kept in mind that the ability of linear regression to discern statistically significant relationships between variables is extremely dependent on sample size. When sample sizes are low (e.g., less than 10 observations), very high r-squares are required for the probability to dip under 0.05. If there are dozens of observations, as there are when several decades of monitoring data are available, regressions can be statistically significant even with low r-squares. In other words, when a lot of data are available, a regression can be statistically significant even when the independent variable can only explain a small percentage of the variance in the dependent variable.

An example of an early attempt to test for strong predator-prey interactions (1939-1961)

DFG (1999; citing Chadwick and Von Geldern 1964) provided an example of a correlation analysis that found a positive slope between striped bass and Chinook salmon catches that contradicted the hypothesis that striped bass predation had a major influence on salmon abundance. This analysis used the 1939-1961 commercial catch data for Chinook salmon and recreational catch data for striped bass and found a positive correlation coefficient of 0.52 ($P <$

0.05). At this writing, I do not have access to the original Chadwick and Von Geldern document, but based on the extended quote provided by DFG (1999), Chadwick and Von Geldern reported a correlation coefficient of 0.52. The correlation coefficient “r” is squared in linear regression, so $(0.52)^2$ translates to an r-squared of 0.27. The use of linear correlation is most appropriate when a researcher is not assuming the variation in an independent variable actually *causes* the variation in the dependent variable. Thus, I am assuming that Chadwick and Von Geldern did not assume that striped bass abundance was a cause of Chinook salmon abundance. Rather, they were just testing for correlation in abundance over time.

Multiple regression:

Simple linear regression can be extended to multiple regression, a similar statistical technique in which more than one independent variable is tested simultaneously for effects on a dependent variable. The interpretation of results is similar except that an adjusted multiple r-square is used to evaluate how much variation the independent variables collectively explain. The *P*-value of each variable is an output of multiple regression, but the variance explained by each variable is not.

Multiple regression outputs

The details of all of the multiple regression analyses I performed for this report are provided in Exhibit F. The details of what I tested and why are described below. A brief summary of the overall results is also provided below. The outputs in Exhibit F include the regression ‘coefficients.’ The first in the list labelled ‘constant’ is the intercept of the regression line. The other coefficients are the slope terms for each independent variable. As with simple linear regression, positive slope terms reflect positive associations of the indepdent and dependent variables and negative slope terms reflect inverse associations. The *P*-values for each of these are provided in the far right hand side of the coefficients table. Note that the *P*-value for the intercept is the probability it passes through the origin (the X = 0, Y = 0 point on a graph). The *P*-values for the other coefficients are the probability that there is no relationship between the independent and dependent variables.

In a simple linear regression with one independent and one dependent variable, it is easy to see the results using a scatterplot. However, there is not an easy way to see the combined results of a multiple regression and make judgements about the model fits to the data. To this end, the regression outputs also include plots of residuals against predicted values. These are graphs of the values of the response variable that were predicted by the regression equation, plotted against the deviations of these predictions from the regression line. A simple way to think about it is that the regression line has been made into a horizontal line in these plots with a value of zero. Data points above the zero line are those that were above the regression line. Data points below the zero line were those that were below the regression line.

These plots help an analyst determine whether the regression model fits the data reasonably well. A random scatter of points around the zero lines in these plots is evidence that the regression models fit the data without any major biases because the residual error in the regression is equally distributed above and below the regression line and at high and low prediction values. The residuals appeared to me to look randomly distributed in the majority of the plots. However, two to five of the 20 had residual patterns that indicated possibly biased results. This was most evident for two of the plots of winter-run salmon that involved age-2 striped bass because the residuals had a dome-shaped pattern when plotted against predicted values (see Exhibit F pages 4 and 5). This means that these regressions under-predict winter-run salmon abundance at low and high escapement values and overpredict it at mid-range values. To a lesser degree, three delta smelt residual plots (Exhibit F; pages 13-15) also had a pattern with negative residuals at the extremes of the predictions, but these were not as obviously curved as the winter-run plots. I provided this information in the spirit of full disclosure. It has no particular influence on the overall conclusion drawn from the collective regression results.

Setting up the analyses: the conceptual model

The data I used in the multiple regression analyses are described in Exhibit G. These include data sets for two potential predators, striped bass and Mississippi silverside and three potential prey[4], delta smelt, winter-run Chinook salmon and spring-run Chinook salmon. Note that I considered striped bass a potential predator in every case, but silversides were only considered a potential predator of delta smelt during time periods encompassing the egg and larval stages because silversides are not large enough to eat juvenile or adult delta smelt or salmonid fish of any life stage.

I used multiple regression for the updated analyses because in several cases the number or relative abundance of listed fish spawners was a statistically significant predictor of their

[4] I did not generate an equivalent set of analyses for steelhead because reliable and consistently collected abundance estimates are not available. However, I doubt that results would be different for steelhead for the reasons discussed by DFG (1999). Most importantly the large body sizes of steelhead when they emigrate through the Delta makes them less susceptible to striped bass than the other listed fishes (Hartman 2000). In the Delta, the only place that striped bass have been shown to eat steelhead smolts is Clifton Court Forebay (DFG 1999; Clark et al. 2009).

subsequent abundance. This means that spawners and predators both needed to be accounted for when testing for an effect of predation on listed fish abundance. For each listed fish, I tested five variations of striped bass abundance. These were:

- legal-sized striped bass abundance
- total adult striped bass abundance , which is legal-sized striped bass and three-year-old fish that are still less than the 18-inch minimum size limit
- age-2 striped bass, which like DFG (1999), I estimated by using the age-3 abundance estimate from one year later as an index of age-2 abundance in the year being tested
- age-2 and age-3 striped bass, which I estimated by adding the age-2 and age-3 abundance estimates for the year being tested
- age-2 and older striped bass, which I estimated by adding the age-2 abundance estimate to the total adult striped bass estimate for the year being tested

Note that the variations of striped bass abundance involving age-2 fish are really abundance *indices* because there is mortality between age-2 and age-3, so the age-2 abundance is actually higher than at age-3, but likely to be generally proportional to age-3 abundance, which is all that is required to derive an abundance index. For the recent years where adult striped bass abundance estimates were not available, I estimated abundance in the missing years by interpolating between years with available data. By interpolation I mean that I averaged the abundance estimates from the two years surrounding the missing data point to estimate its value.

The linkages among the various fish abundance estimates and indices that I used for the multiple regressions are shown in Exhibit H. For example, Chinook salmon that returned to spawn in 1980 produced juveniles that emigrated to the ocean in 1981 at which time they were potentially vulnerable to striped bass predation. These juveniles mostly reached adulthood and returned to spawn in 1983. So the multiple regressions for Chinook salmon take the form: Chinook salmon abundance in year x + 3 = Chinook salmon abundance in year x ± striped bass abundance in year x + 1.

The delta smelt regressions are similar, but involve less time. They take one of two forms:
1) delta smelt fall index in year x = delta smelt summer index in year x ± striped bass abundance in year x
and
2) delta smelt summer index in year x = delta smelt fall index in year x-1 ± striped bass abundance in year x ± silverside abundance in year x

I perfomed 20 separate multiple regression analyses. A hypothesis being tested in all of these models is that striped bass are a substantial predator of the listed fishes that causes listed fish abundance to go down when its abundance goes up. Thus, the expectation is that some, if not many, of the variations of the multiple regressions would produce statistically significant *negative* slope terms for the striped bass variables. However, I found the opposite. To make this point clearly, I extracted the slope terms for the striped bass variables from Exhibit F and summarized them in Exhibit I. Twelve of the 20 regressions produced statistically significant *positive* slope terms for the striped bass variables (Exhibit I). The other 8 were not statistically significant. They had *P*-values that ranged from.0.12 to 0.89 (Exhibit F), which means they should be interpreted as having *no detectable influence* on the dependent variables. I interpret this finding the same way that DFG (1999) did – that environmental conditions that have been good for striped bass have generally also been good for the listed fishes.

In conclusion, I found no evidence that striped bass predation has an obvious negative effect on the abundance of winter-run or spring-run Chinook salmon or delta smelt. The only potential predator that I found evidence for a statistically significant negative influence on a listed fish was for Mississippi silverside effects on delta smelt (Exhibit F; pages 16-20). It is not known whether silversides are in fact predators of early life stage delta smelt, but Bennett and Moyle (1996) and Bennett (2005) have contended that they are.

IV. The Lindley and Mohr Paper

The lack of a significant regression slope between predator and prey abundances is evidence that a predator is not strongly affecting a prey species, but it cannot demonstrate or refute weaker influences of predators on prey. Lindley and Mohr (2003) used a sophisticated statistical analysis to try to isolate the effect of striped bass predation on winter-run salmon viability. The primary goal of their study was to estimate a striped bass predation rate that was a function of striped bass abundance and apply that function to estimate how much effect striped bass predation had on the likelihood that winter-run salmon would go extinct versus recover to a population level of 20,000 adults in the next 50 years.

In essence, their approach was similar to the multiple regressions that I presented above. They generated a mathematical model that forecasted winter-run salmon returns based on their prior abundance and the abundance of adult striped bass. The major differences are that their model allowed for two winter-run generations (3 and 4 year old fish) to give rise to future generations and they used an approach that calculated many thousands of iterations of their models to develop probability distributions of possible outcomes. The following discussion summarizes their paper and provides a simplified extension of their work using more current data. Based on my extension of their work and the multiple regression analyses I described above, I am not convinced that striped bass have as much effect on winter-run salmon viability as Lindley and Mohr (2003) estimated it to be. In particular, I do not know how the data generated Lindley and Mohr's negative slope between striped bass abundance and the winter-run stock-recruit relationship.

Lindley and Mohr (2003) used available time series of winter-run salmon and striped bass abundance for 1967-1996. They used a "Bayesian" statistical approach in which the salmon model's 'unknown' quantities were guessed in advance and then tested and determined by solving many thousands of variations of the life cycle equations on a computer to find out which values were the most likely and how variable they could be. Their equations with the mean (most likely) values of the unknowns predicted the number of winter-run spawners (W) in a given year (t) as:

$$\{W_{t-3} \times [-0.694 + 0.683 - (1.86 \times 10^{-6} \times S_{t+1}) - (7.16 \times 10^{-5} \times W_t) + 1.20] \times 0.89\}$$
$$+$$
$$\{W_{t-4} \times [-0.694 + 0.683 - (1.86 \times 10^{-6} \times S_{t+1}) - (7.16 \times 10^{-5} \times W_t) + 1.20] \times 0.11\}$$

and

$$\{W_{t-3} \times [-0.777 + 0.823 - (2.19 \times 10^{-6} \times S_{t+1}) + 1.18] \times 0.89\}$$
$$+$$
$$\{W_{t-4} \times [-0.777 + 0.823 - (2.19 \times 10^{-6} \times S_{t+1}) + 1.18] \times 0.11\}$$

Lindley and Mohr's model assumes the number of adult winter-run that spawned in the Sacramento River in any given year was made up of fish that were spawned 3-4 years prior because most winter-run salmon live 3-4 years; three year old fish are W_{t-3} in the above equations and four year old fish are W_{t-4}. They determined that 0.89 (89%) of winter-run spawn at age-3 and 0.11 (11%) at age-4 so the 3- and 4-year-old parts of the equations are weighted by these multipliers. They assumed that winter-run productivity could be mathematically estimated as an average negative population growth rate plus a step-change to a positive population growth rate starting in 1989 when Red Bluff Diversion Dam operations were changed to protect winter-run, minus the striped bass predation rate on the cohort of young produced by the adults. One form of their model had a "density-dependent" term designed to provide a biologically reasonable effect of "diminishing returns" as adult winter-run fill up the limited habitat they have available in the Sacramento River below Keswick Dam. They used versions of the life cycle model that had this density-dependence term included and not included to test the sensitivity of their results to this assumption. The second and shorter version of the equations shown above is the density-independent version. The abundance of striped bass is "S_{t+1}" in the model because it represents the abundance of striped bass in the year following the winter-run abundance estimate because the progeny of the winter-run migrate through the Delta the calendar year after they were spawned and it is the progeny that are potentially vulnerable to striped bass predation.

Lindley and Mohr concluded that striped bass could considerably increase the extinction risk of winter-run Chinook salmon if striped bass rebounded to an adult population size of 3 million. Based on their analysis, the risk of winter-run extinction over the next 50 years was predicted to nearly triple when they compared a zero striped bass population to a 3 million striped bass population. However, striped bass populations of 500,000-700,000 were predicted to have a comparatively minor influence on winter-run salmon extinction risk (≤ 6.4% higher than the zero striped bass baseline for the density-dependent model and ≤ 7.0% for the density-independent model). Lindley and Mohr (2003) concluded that "A limited program aimed at stabilizing the striped bass population at its recent size[5] might pose an acceptably small risk: the model indicates with 95% certainty that the stabilization program would add less than 3.1% to the baseline extinction risk of 28%."

Using more recent winter-run salmon and striped bass abundance data, I compared recent trends in winter-run salmon abundance to those predicted using Lindley and Mohr's equations. Like the multiple regression results presented above, this comparison does not appear to support the fairly strong influence of striped bass abundance on winter-run Chinook abundance they reported, though I do acknowledge that I have applied a simpler version of Lindley and Mohr's

[5] Lindley and Mohr were referring to an adult striped bass population size of 700,000 fish.

equations that does not use the many thousands of computer-driven iterations of equations that their version used. Rather, I used the means of their parameter values to estimate what their model predicts winter-run abundance would have been from the 1996-1997 to 2007-2008 seasons given the actual trend in striped bass population shown in Exhibit B. I used the means because these were the "most likely" values that resulted from the many iterations of their modeling. The equations shown above are the versions I used for this analysis.

As with the multiple regression analyses, I estimated striped bass abundance values for missing years by interpolating between the available data. Exhibit J shows the empirical time series of winter-run salmon returns for 1970-2008 and two modeled series of returns based on Lindley and Mohr's equations. To develop the time series of predicted winter-run salmon abundances shown in Exhibit J, I started by predicting the abundance of the 1996-1997 winter-run cohort because Lindley and Mohr's predictions stopped at the 1995-1996 return. The equations shown above require salmon abundance estimates 3 and 4 years prior to the prediction year, so my version of the model started by using empirical (i.e., actual data) salmon abundance estimates from 1993 and 1992. My version continued using empirical abundance estimates until the simulation caught up to its 1996 start date. From that point, I continued the simulation using model predictions of winter-run abundance rather than the empirical data. For instance, when the simulations predicted winter-run abundance for 1999, they used the predicted abundance for 1996 (3 years prior), but the empirical abundance for 1995 (4 years prior) because that was still before the start of my simulation. Starting in 2000 all prior abundances that were input to the model were predictions output from it.

Lindley and Mohr's density-dependent model predicted continued very low and declining abundance of winter-run salmon that was not observed (labelled "DD" in Exhibit J). This is because of the negative influence of striped bass in their model and because the density-dependent term constrained the population's ability to produce new cohorts. Their density-independent model predicted a modest abundance increase well below what was actually seen (labelled "DI" in Exhibit J) due to the negative influence of striped bass. It also predicted an abundance increase in 2007 because the abundance of striped bass declined in 2003-2004. This predicted increase in 2007 did not occur. Thus, the comparison of empirical data since 1996 to Lindley and Mohr's model suggests that it overestimated the relevance of striped bass predation to winter-run Chinook salmon viability.

V. The Loboschefsky et al. paper

Bioenergetics models are mathematical tools that estimate animal growth based on consumption, or consumption based on growth. Hartman and Brandt (1995) developed a bioenergetics model for Chesapeake Bay striped bass. This is the model that was used by Loboschefsky et al. I think the results of this work are generally correct in a relative sense (trends through time). For instance, it makes sense that striped bass abundance drives the population-level consumption. Likewise it makes sense that slower growth rates of adult striped bass or faster growth rates of juvenile striped bass produce model estimates of lower and higher per capita consumption respectively. However, their results are less certain in an absolute sense (meaning the absolute values of the consumption estimates). There are two main reasons for this lower certainty. First, the estimates of juvenile striped bass growth in particular, are very uncertain, which the authors acknowledged. Second, the bioenergetics model uses fish weight which the authors had to estimate from fish lengths using an equation provided by Kimmerer et al. (2005). This equation was developed using striped bass that were only about 1-12 inches long, so it is very uncertain how well it predicts the weights of the striped bass modeled by Loboschefsky et al. because most age-2 and older striped bass are more than 12 inches long.

Limitations of currently available striped bass diet data

It is my opinion that the report is somewhat misleading with regard to its implications about how the San Francisco Estuary striped bass population meets its consumption demand because the diet composition data used by Loboschefsky et al. do not apply to the striped bass population writ large. The juvenile striped bass population (meaning the 1-2 year old fish) is distributed throughout the estuary. The adult striped bass population is distributed throughout the estuary, along the Pacific coast and seasonally in the rivers of the San Francisco Estuary watershed. However, all of the striped bass diet data used by Loboschefsky et al. were taken from striped bass collected from the legal Delta or Suisun Marsh and never from both of these locations at the same time. This leads a reader to assume that most of the striped bass production is supported by the prey discussed by the authors, which is not the case.

As Loboschefsky et al. suggest, the consumption demand of the adult striped bass population is quite high (they estimated ~ 10-30 million kilograms per year, which equals 22-66 million pounds of food per year). A typical fish eaten by a striped bass in the Delta weighs about 1-3 grams and individual invertebrates usually weigh even less. I have stated above why Loboschefsky et al.'s absolute consumption estimates may not be accurate, but assuming for the sake of argument that they are in the right ballpark, 10-30 million kilograms translates to about one billion fish per year. The admittedly dated evidence (Thomas 1967) suggests to me that this demand is strongly subsidized by highly abundant marine pelagic fishes like anchovies and herring as well as marine shrimps. This is further supported by Kimmerer (2006) who estimated that even after their exodus from the upstream edge of their range, northern anchovy comprise about 20% of the pelagic fish biomass in the low-salinity zone. Anchovies are even more abundant in San Francisco Bay where salinity is higher.

In the freshwater Delta, the fishes that are currently most abundant like threadfin shad, Mississippi silversides, and gobies (Nobriga et al. 2005) *seasonally* support some of the striped bass consumption demand (Nobriga and Feyrer 2007). In addition to these broad generalizations, small fractions of the striped bass population learn to focus on feeding opportunity areas within the Delta. The best known example is the special case of Clifton Court Forebay where striped bass appear to have very high prey capture success (Gingras 1997; Clark et al. 2009). The listed fishes could not and do not support any meaningful fraction of this demand, but they *would* if the estuary functioned in a manner that supported their productivity and resilience.

VI. Conclusion

Based on the information I have read and presented above, it is my professional opinion that the Plaintiffs are relying on an oversimplified conceptual model of aquatic food webs to make their case. I think it is impossible to forecast the population responses of any member of the San

Francisco Estuary's food web to the removal of striped bass, one of its keystone species. Thus, it cannot be concluded that removal of striped bass fishing regulations will result in a substantive increase in the abundance of the listed fishes. As the examples from other systems demonstrate, partial recovery of listed fishes is only one of several possible outcomes. It is also very possible that nothing detectable would happen, or ironically, that their situation could worsen. This is particularly true for delta smelt, which spend their entire lives in the estuary. The Pacific Ocean food web, which Chinook salmon and steelhead enter once they leave the estuary, adds additional uncertainty into predictions for rebounds of salmonid fishes released from striped bass predation (Lindley et al. 2009).

As my resume indicates, I am employee of the Department of Fish and Game. I have not been specifically compensated by any person or entity for this report or my testimony in this case. I have not testified as an expert witness at trial or deposition in any matter in the past four years.

Matthew L. Nobriga

Exhibit A

Matthew L. (Matt) Nobriga
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Water Branch
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Sacramento, CA 95811

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EDUCATION

1988-1993	Bachelor of Science, Biological Sciences, Stanislaus State University
1993-1998	Master of Science, Biological Sciences, Sacramento State University

FULL-TIME PROFESSIONAL POSITIONS

2008-present	*Senior Environmental Scientist*, California Department of Fish and Game (Water Branch), Sacramento, CA, Supervisor of Performance Measures Unit for the Ecosystem Restoration Program, technical advisor to Bay-Delta Conservation Plan, USFWS Smelt Working Group, and Water Operations Management Team
2008	*Staff Environmental Scientist*, California Department of Fish and Game (Water Branch), Sacramento, CA, DFG technical advisor to the Ecosystem Restoration Program, Bay-Delta Conservation Plan, Operations Criteria and Plan, and other policy directives to balance fisheries and human water needs in the San Francisco Bay-Delta
2007 – 2008	*Staff Environmental Scientist*, CALFED Science Program, Sacramento, CA Environmental Water Account Coordinator, Interagency Ecological Program Liason, Interagency Ecological Program Pelagic Organism Decline Management Team member, Organizer of several Science Program workshops, contract manager for Science Program grants
2006 – 2007	*Environmental Scientist C*, CALFED Science Program, Sacramento, CA Environmental Water Account Coordinator, Organizer of several Science Program workshops, contract manager for Science Program grants
2000-2006	*Environmental Scientist C*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA , Interagency Ecological Program researcher and Management Team member, Interagency Ecological Program Pelagic Organism Decline researcher and Management Team member, Delta Smelt Working Group member, CALFED Data Assessment Team (DAT) note-taker
1998-2000	*Environmental Specialist II*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA, Interagency Ecological Program researcher, technical writer

PART-TIME PROFESSIONAL POSITIONS

1997-1998	*Scientific Aide*, California Department of Water Resources (Ecological Studies Branch), Sacramento, CA
1995-1997	*Fisheries Biologist* (GS-5), U.S. Fish and Wildlife Service (Juvenile Salmonid Monitoring Program), Stockton, CA
1995-1996	*Scientific Aide/Graduate Student Assistant*, California Department of Fish and Game (Bay-Delta Division), Stockton, CA
1995	*Scientific Aide*, California Department of Fish and Game (Region II Water Pollution Control Laboratory), Rancho Cordova, CA
1994	*Scientific Aide*, California Department of Fish and Game (Region II Headquarters), Rancho Cordova, CA
1991-1994	*Scientific Aide*, California Department of Fish and Game (Bay-Delta Division), Stockton, CA

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MISCELLANEOUS

2000-present	Member of the American Fisheries Society
2003-Present	Referee for Technical Journals (Transactions of the American Fisheries Society, Fisheries, San Francisco Estuary and Watershed Science, Aquatic Ecology, Environmental Science & Policy, California Fish and Game)

Exhibit B

Exhibit B: Estimated abundance of adult striped bass, 1969-2007. The bar shows the estimated number of legal sized striped bass and the thin protruding lines show the total adult abundance estimate which includes three-year-old fish that have not reached the minimum catchable size.

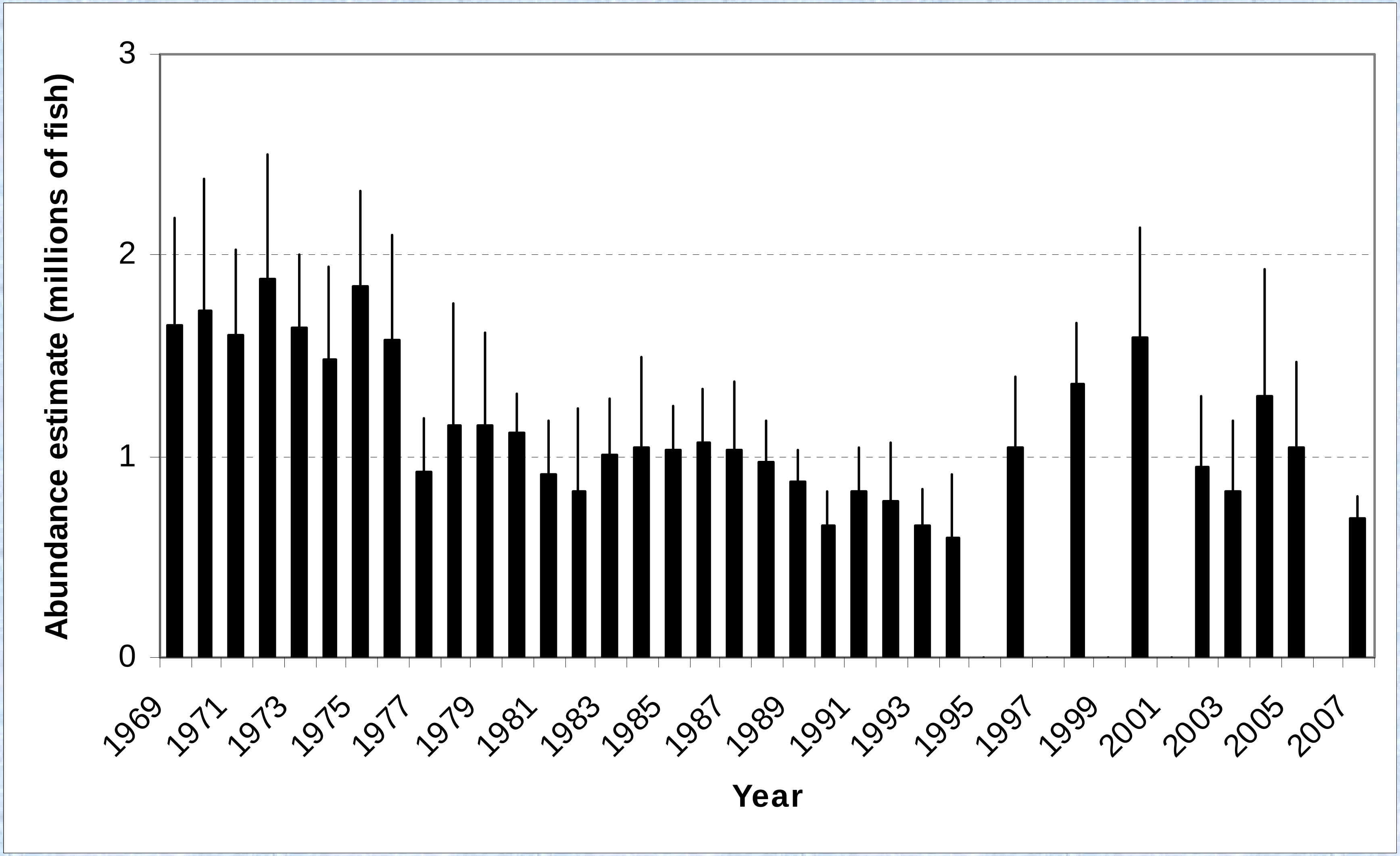


Exhibit C

Exhibit C: Relative abundance indices for young-of-year striped bass, 1959-2008. These trends are based on the Summer Townet Survey (red line) and the Fall Midwater Trawl (black line). Note that fall sampling began in 1967. Breaks in the lines indicate years the survey was not conducted or years when an index could not be calculated from the catch.

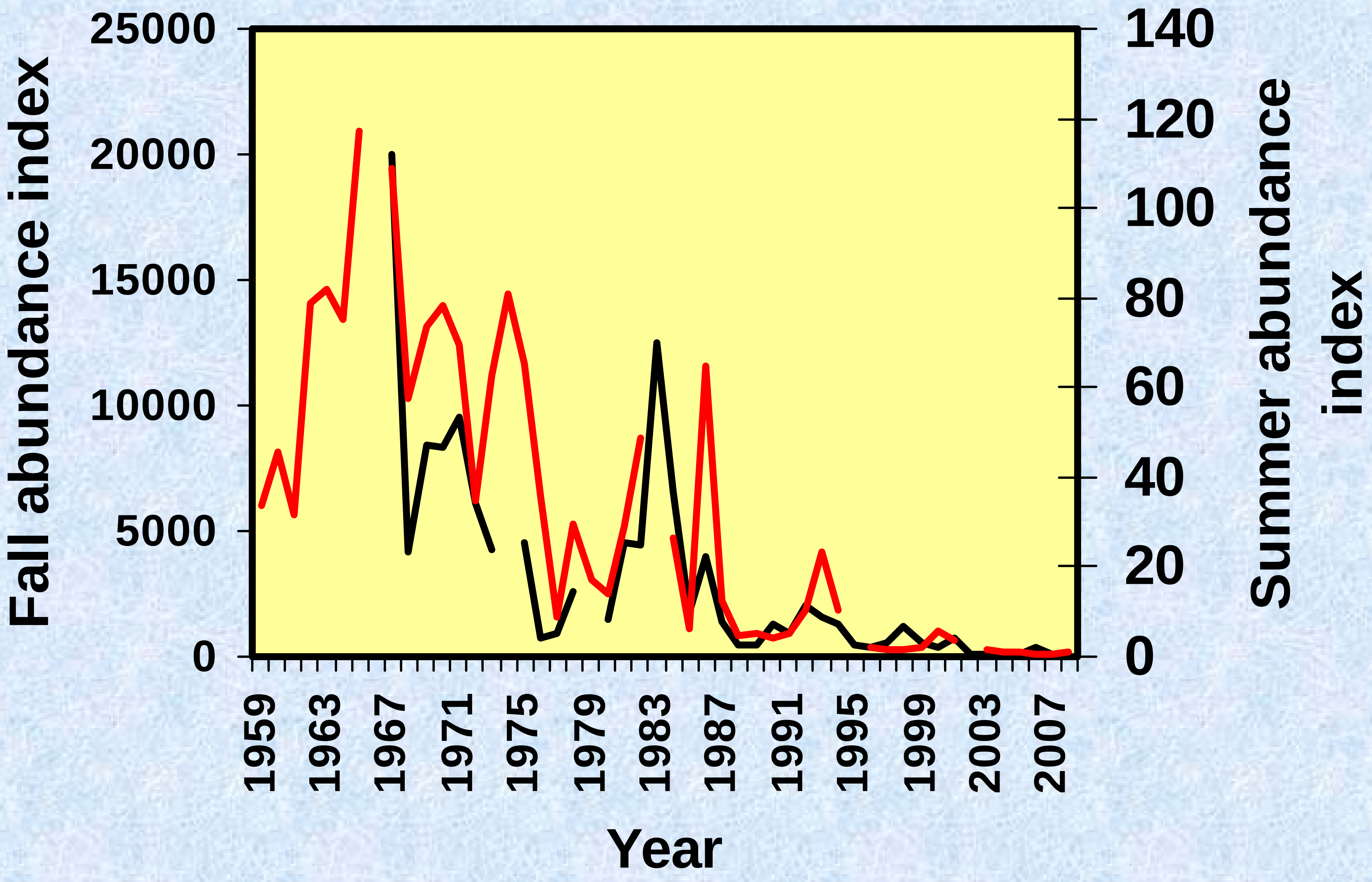


Exhibit D

Exhibit D: general food chain conceptual model for striped bass taken from Moyle (2002), Inland fishes of California, revised and expanded

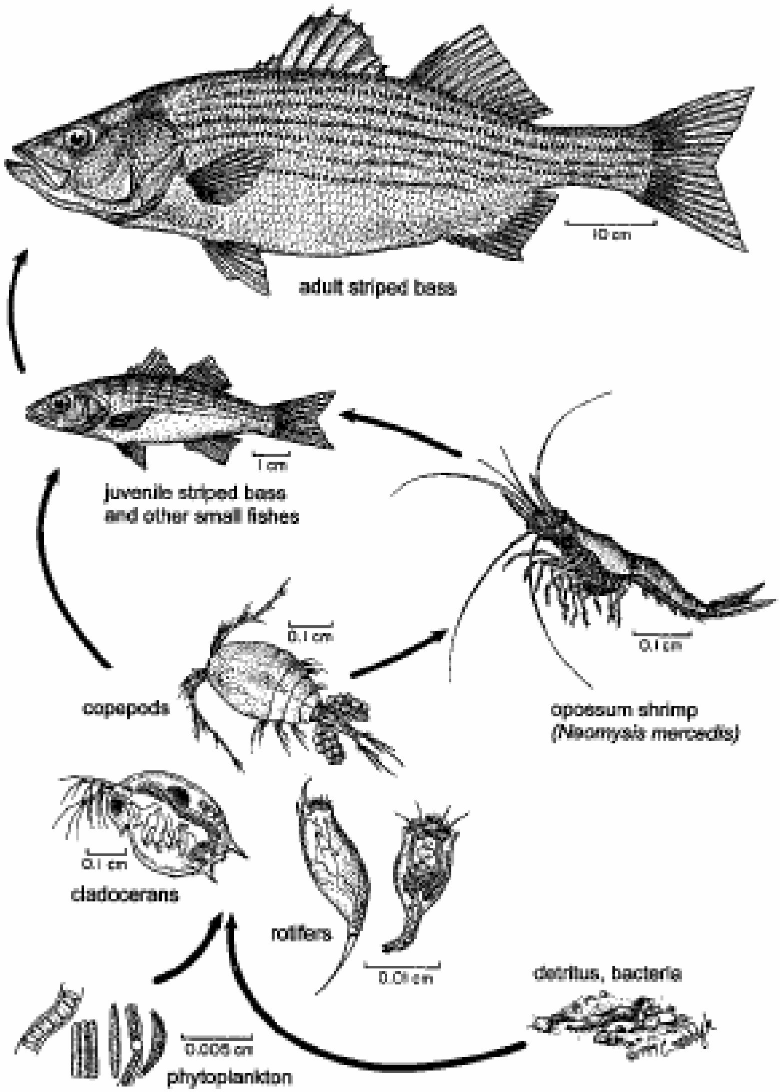


Figure 10. Food web involving striped bass in the Sacramento–San Joaquin estuary. Although adult bass will eat virtually any fish in the estuary, their principal prey is juvenile striped bass, which in turn depend heavily on opossum shrimp and other planktonic crustaceans. The opossum shrimp is a predator on small zooplankton, which in turn feed largely on algae, bacteria, and detritus. From Kegley et al. (1989). as shown in Moyle (2002)

Exhibit E

Exhibit E: Trends in Mississippi silverside biomass based on IEP beach seine data and the delta smelt Fall Midwater Trawl index (above).

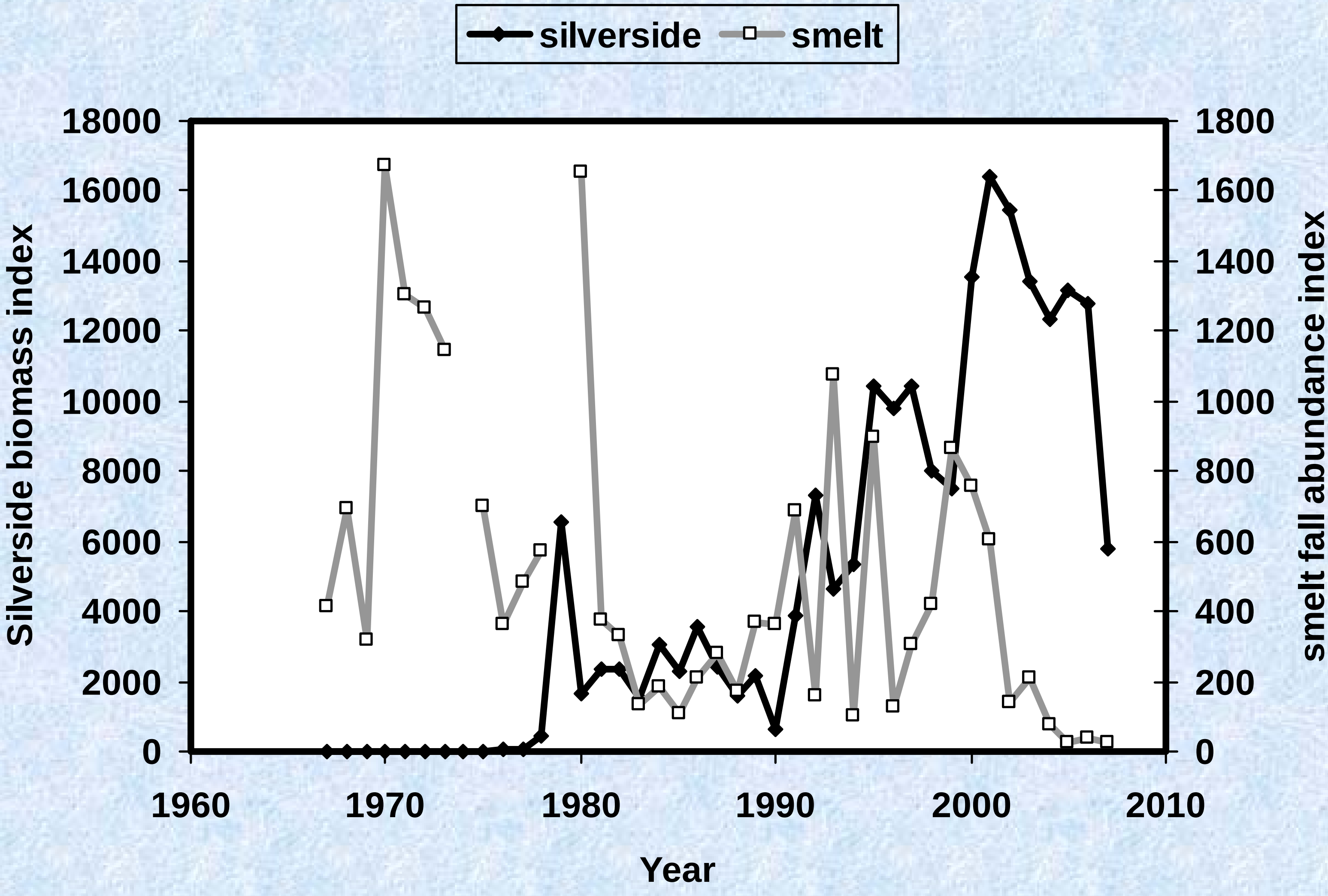


Exhibit F

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionVersion.syo

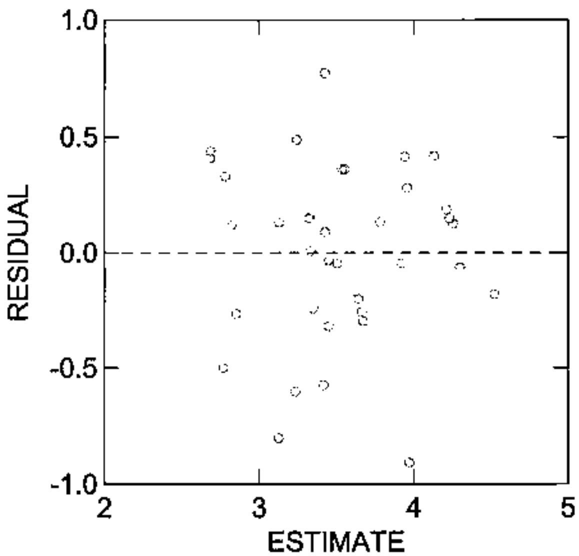
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-12.736	4.073	0.000	.	-3.127	0.004
LOGWR7005	0.355	0.129	0.388	0.593	2.761	0.009
LOGTOTALBASS	2.435	0.707	0.484	0.593	3.445	0.002

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	8.398	2	4.199	26.686	0.000
Residual	5.035	32	0.157		

Durbin-Watson D Statistic 1.741
First Order Autocorrelation 0.121

Plot of Residuals against Predicted Values



Output for test of age 3 and older striped bass on winter-run salmon

PAGE 1 of 20

1 case(s) deleted due to missing data.

Partial output for one of the spring-run tests; printed in full elsewhere

Dep Var: LOGSR7308 N: 35 Multiple R: 0.434 Squared multiple R: 0.188

Adjusted squared multiple R: 0.137 Standard error of estimate: 0.231

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionVersion.syo

1 case(s) deleted due to missing data.

Dep Var: LOGWR7308   N: 35   Multiple R: 0.769   Squared multiple R: 0.592

Adjusted squared multiple R: 0.566   Standard error of estimate: 0.414

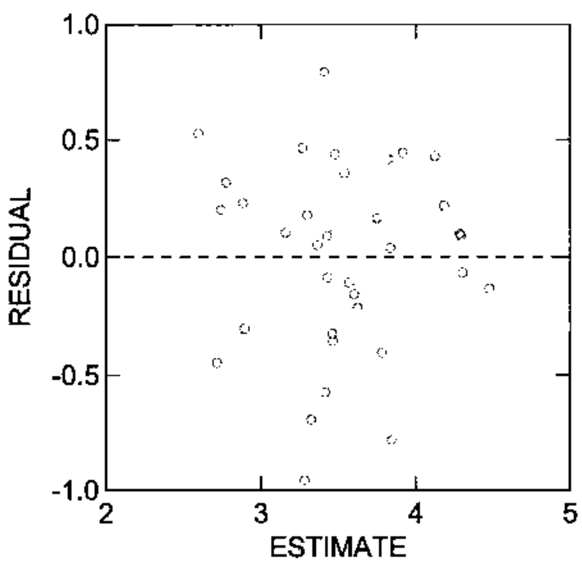
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-10.127	3.970	0.000	.	-2.551	0.016
LOGWR7005	0.409	0.131	0.447	0.627	3.132	0.004
LOGLEGALBASS	2.019	0.702	0.410	0.627	2.876	0.007

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	7.948	2	3.974	23.186	0.000
Residual	5.485	32	0.171		

Durbin-Watson D Statistic 1.536
First Order Autocorrelation 0.227

Plot of Residuals against Predicted Values



Output for test of legal striped bass on winter-run salmon

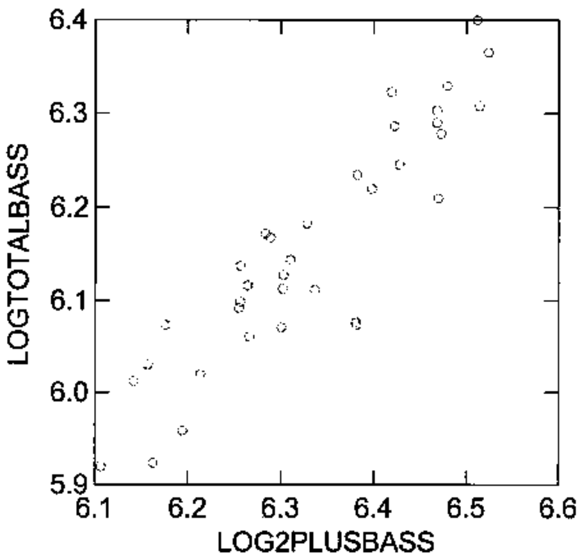
PAGE 2 of 20

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionAge2Bass.syo

SYSTAT Rectangular file C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionVersion.SYD,
created Thu Sep 03, 2009 at 11:45:23, contains variables:

LOGWR7005	LOGWR7308	LOGLEGALBASS	LOGTOTALBASS	LOGSR7005	LOGSR7308



PAGE 3 of 20

Error check to make sure I've got all these lags right - this is the all bass 2 years old and older versus the 3 years old and older.

referring to scatterplot comment inserted by me [initials]

Output for test of age 2 [redacted] striped bass on winter-run salmon

```
Dep Var: LOGWR7308   N: 36   Multiple R: 0.766   Squared multiple R: 0.587

Adjusted squared multiple R: 0.562   Standard error of estimate: 0.410
```

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-5.592	2.285	0.000	.	-2.447	0.020
LOGWR7005	0.540	0.105	0.596	0.935	5.158	0.000
LOGAGE2BASS	1.235	0.405	0.353	0.935	3.050	0.004

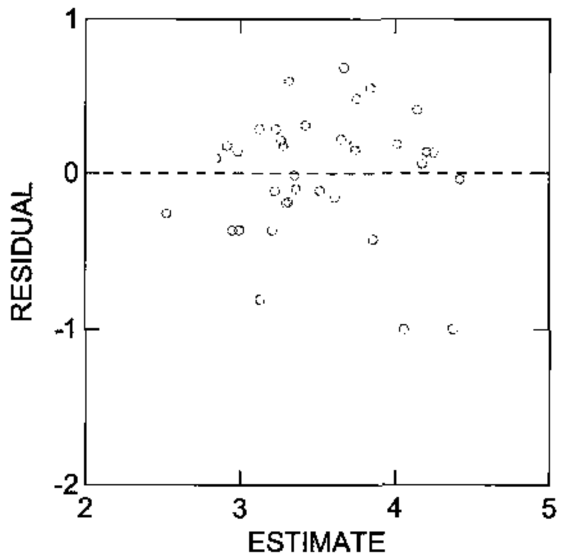
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	7.894	2	3.947	23.496	0.000
Residual	5.543	33	0.168		

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionAge2Bass.syo

Plot of Residuals against Predicted Values



Residual plot for test of age-2 + older striped bass on winter-run salmon

Note curvature in residuals = iffy model fit

PAGE 4 of 20

Output for test of age-2 + age 3 striped bass on winter-run salmon

Dep Var: LOGWR7308   N: 36   Multiple R: 0.820   Squared multiple R: 0.673

Adjusted squared multiple R: 0.653   Standard error of estimate: 0.365

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-11.591	2.877	0.000	.	-4.029	0.000
LOGWR7005	0.408	0.102	0.451	0.784	4.007	0.000
LOG2AND3BASS	2.227	0.494	0.507	0.784	4.505	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	9.038	2	4.519	33.893	0.000
Residual	4.400	33	0.133		

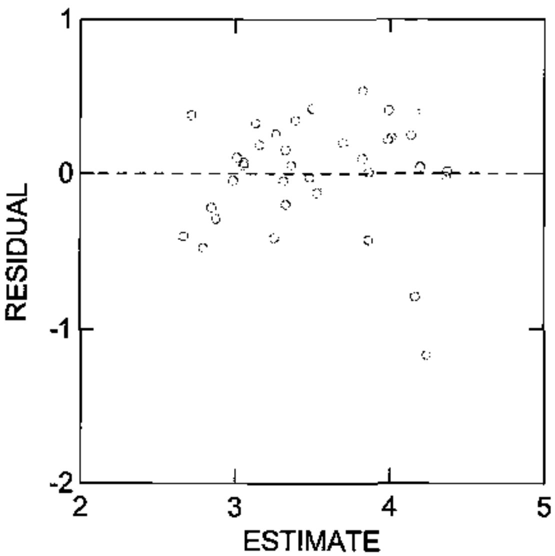
*** WARNING ***

Case 8 is an outlier (Studentized Residual = -4.089)

Durbin-Watson D Statistic 1.934

First Order Autocorrelation 0.021

Plot of Residuals against Predicted Values



Residual plot for age 2 + age 3 striped bass on winter-run salmon

Note curvature in residuals = iffy model fit

PAGE 5 of 20

Output for test of age 2 + older striped bass on winter-run salmon

Dep Var: LOGWR7308   N: 36   Multiple R: 0.843   Squared multiple R: 0.711

Adjusted squared multiple R: 0.694   Standard error of estimate: 0.343

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-17.446	3.591	0.000	.	-4.858	0.000
LOGWR7005	0.280	0.107	0.309	0.628	2.621	0.013
LOG2PLUSBASS	3.155	0.603	0.618	0.628	5.235	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	9.555	2	4.778	40.616	0.000
Residual	3.882	33	0.118		

*** WARNING ***

Case 8 is an outlier (Studentized Residual = -3.278)

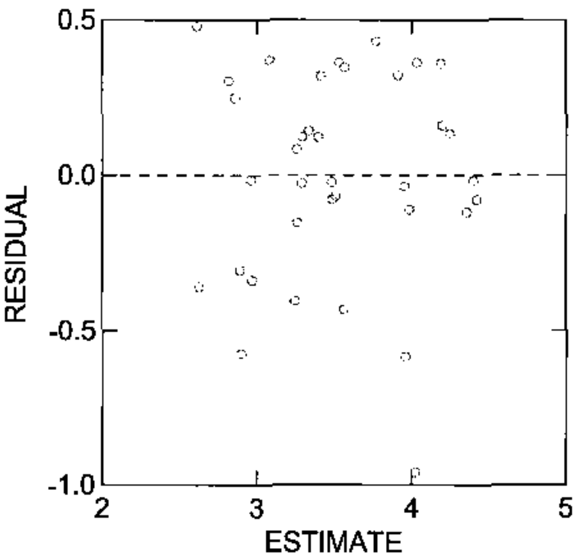
Durbin-Watson D Statistic 1.720

First Order Autocorrelation 0.122

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionAge2Bass.syo

Plot of Residuals against Predicted Values



Residual plot for age 2 + older striped bass on winter-run salmon

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Output for test of age 2 striped bass on spring-run salmon

```
Dep Var: LOGSR7308   N: 36   Multiple R: 0.272   Squared multiple R: 0.074

Adjusted squared multiple R: 0.018   Standard error of estimate: 0.248
```

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	2.841	1.496	0.000	.	1.900	0.066
LOGSR7005	-0.164	0.169	-0.163	0.995	-0.968	0.340
LOGAGE2BASS	0.324	0.237	0.229	0.995	1.365	0.181

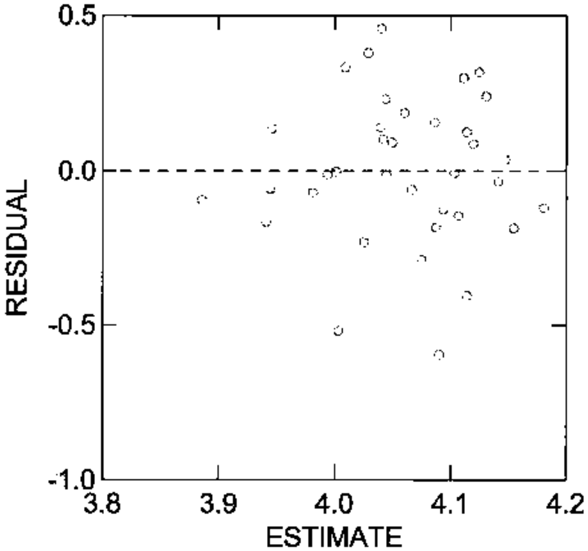
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.161	2	0.081	1.314	0.282
Residual	2.026	33	0.061		

```
Durbin-Watson D Statistic      1.522
First Order Autocorrelation    0.233
```

RECIRC2849

Plot of Residuals against Predicted Values



Residual plot of age 2 striped bass on spring-run salmon

PAGE 7 of 20

Output for test of age 2 + age 3 striped bass on spring-run salmon

Dep Var: LOGSR7308 N: 36 Multiple R: 0.382 Squared multiple R: 0.146

Adjusted squared multiple R: 0.094 Standard error of estimate: 0.238

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	1.006	1.788	0.000	.	0.563	0.578
LOGSR7005	-0.205	0.164	-0.204	0.974	-1.252	0.219
LOG2AND3BASS	0.634	0.289	0.358	0.974	2.195	0.035

Analysis of Variance

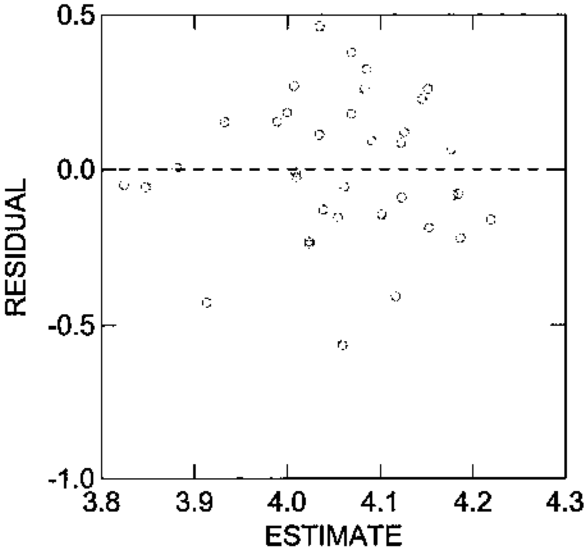
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.320	2	0.160	2.823	0.074
Residual	1.868	33	0.057		

Durbin-Watson D Statistic 1.593
First Order Autocorrelation 0.196

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionAge2Bass.syo

Plot of Residuals against Predicted Values



Residual plot for age 2 + age 3 striped bass on spring-run salmon

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Output for test of age 2 + older striped bass on spring-run salmon

Dep Var: LOGSR7308   N: 36   Multiple R: 0.469   Squared multiple R: 0.220

Adjusted squared multiple R: 0.173   Standard error of estimate: 0.227

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-0.975	2.043	0.000	.	-0.477	0.636
LOGSR7005	-0.199	0.156	-0.198	0.987	-1.278	0.210
LOG2PLUSBASS	0.923	0.319	0.448	0.987	2.897	0.007

Analysis of Variance

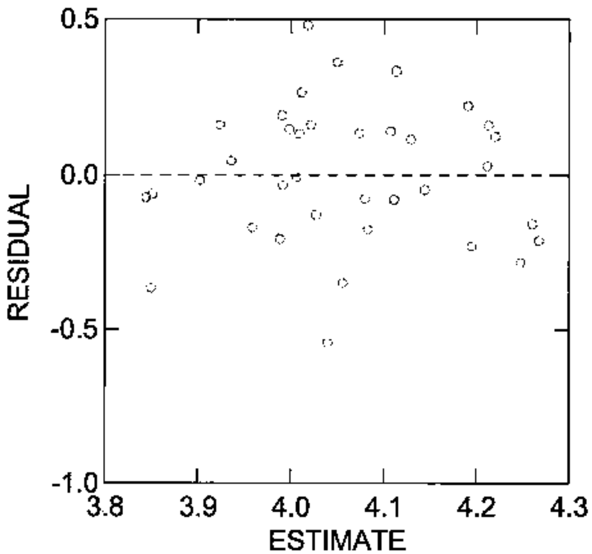
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.481	2	0.240	4.649	0.017
Residual	1.706	33	0.052		

Durbin-Watson D Statistic 1.640
First Order Autocorrelation 0.166

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionAge2Bass.syo

Plot of Residuals against Predicted Values



Residual plot for age 2+older striped bass on spring-run salmon

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1 case(s) deleted due to missing data.

Dep Var: LOGSR7308 N: 35 Multiple R: 0.434 Squared multiple R: 0.188

Adjusted squared multiple R: 0.137 Standard error of estimate: 0.231

Note minus signs printed above value on this one

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-0.135	1.929	0.000	.	-0.070	0.945
LOGSR7005	-0.173	0.159	-0.174	0.989	-1.087	0.285
LOGLEGALBASS	0.812	0.313	0.416	0.989	2.598	0.014

Note minus signs above circled numbers

Analysis of Variance

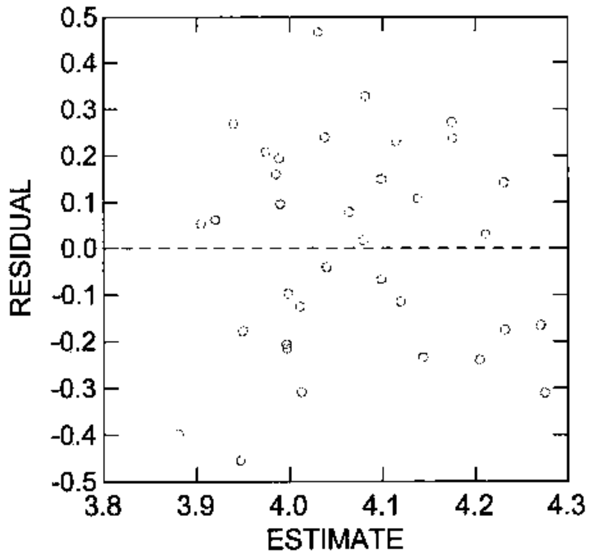
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.398	2	0.199	3.710	0.036
Residual	1.715	32	0.054		

Durbin-Watson D Statistic 1.587
First Order Autocorrelation 0.197

Output for test of legal sized striped bass on spring-run salmon

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionVersion.syo

Plot of Residuals against Predicted Values



Residual plot for test of legal sized striped bass on spring-run salmon

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Output for test of age 3 and older striped bass on spring-run salmon

1 case(s) deleted due to missing data.

Dep Var: LOGSR7308 N: 35 Multiple R: 0.452 Squared multiple R: 0.204

Adjusted squared multiple R: 0.154 Standard error of estimate: 0.229

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-0.522	1.970	0.000	.	-0.265	0.793
LOGSR7005	-0.191	0.158	-0.193	0.980	-1.209	0.236
LOGTOTALBASS	0.871	0.318	0.437	0.980	2.743	0.010

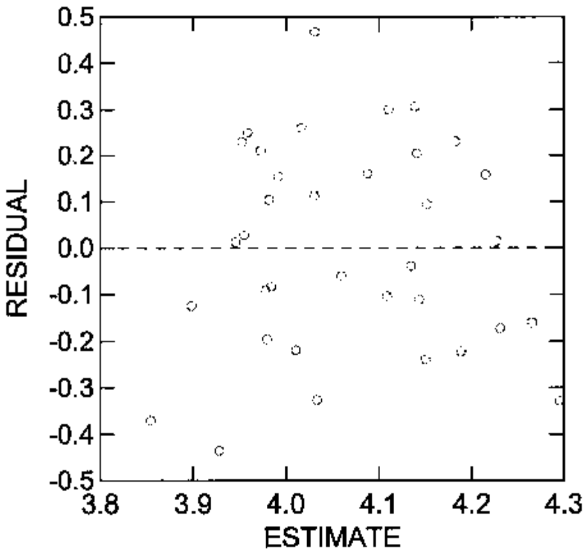
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.431	2	0.216	4.104	0.026
Residual	1.681	32	0.053		

Durbin-Watson D Statistic 1.630
First Order Autocorrelation 0.175

RECIRC2849

Plot of Residuals against Predicted Values



Residual plot for test of age3 + older striped bass on spring-run salmon

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36 cases and 6 variables processed and saved.

SYSTAT Rectangular file C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SalmonMultipleRegressionVersion.SYD,
created Thu Sep 03, 2009 at 11:45:23, contains variables:

LOGWR7005 LOGWR7308 LOGLEGALBASS LOGTOTALBASS LOGSR7005 LOGSR7308

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltSummerFallMultipleRegression.syo

Dep Var: LOGFMWT   N: 37   Multiple R: 0.701   Squared multiple R: 0.492

Adjusted squared multiple R: 0.462   Standard error of estimate: 0.346

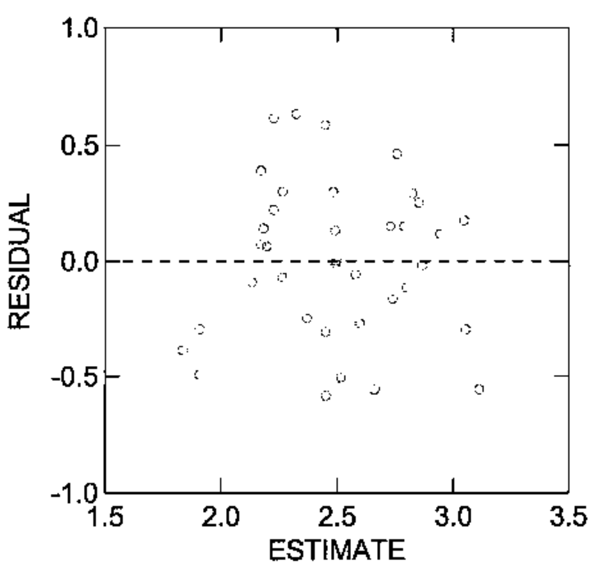
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-2.304	2.766	0.000	.	-0.833	0.411
LOGTNS	0.482	0.108	0.591	0.850	4.460	0.000
LOGLEGALBASS	0.741	0.463	0.212	0.850	1.601	0.119

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	3.932	2	1.966	16.465	0.000
Residual	4.060	34	0.119		

Durbin-Watson D Statistic 2.071
First Order Autocorrelation -0.054

Plot of Residuals against Predicted Values



Output for test of legal sized striped bass on delta smelt

TNS → FMWT

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File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltSummerFallMultipleRegressionWithAge2Bass.syo

SYSTAT Rectangular file C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltSummerFallMultipleRegression.SYD,
created Thu Sep 03, 2009 at 13:32:28, contains variables:

YEAR LOGFMWT LOGTNS LOGLEGALBASS LOGTOTALBASS

1 case(s) deleted due to missing data.

Dep Var: LOGFMWT N: 36 Multiple R: 0.647 Squared multiple R: 0.419

Adjusted squared multiple R: 0.383 Standard error of estimate: 0.348

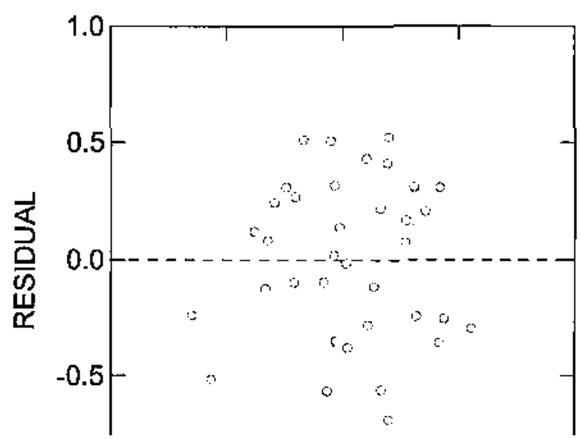
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-0.200	2.218	0.000	.	-0.090	0.929
LOGTNS	0.431	0.125	0.541	0.714	3.445	0.002
LOGAGE2BASS	0.416	0.389	0.168	0.714	1.069	0.293

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2.872	2	1.436	11.880	0.000
Residual	3.989	33	0.121		

Durbin-Watson D Statistic 2.018
First Order Autocorrelation -0.016

Plot of Residuals against Predicted Values



Output for test of age 2 striped bass on delta smelt
TNS → FMWT

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File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltSummerFallMultipleRegressionWithAge2Bass.syo

Adjusted squared multiple R: 0.363   Standard error of estimate: 0.353

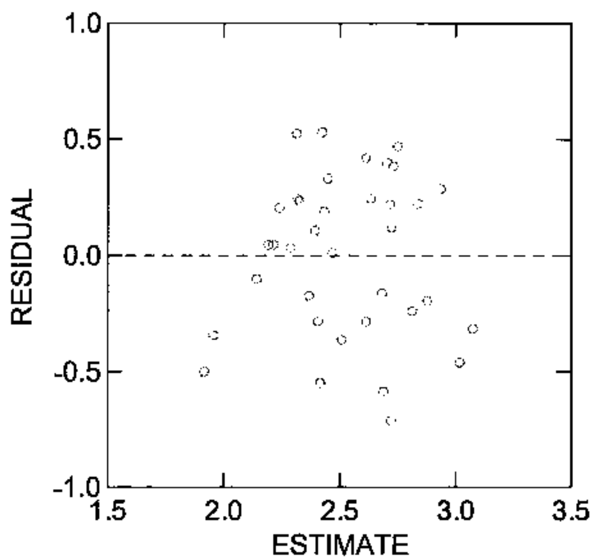
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	1.667	2.837	0.000	.	0.588	0.561
LOGTNS	0.490	0.126	0.617	0.727	3.897	0.000
LOGAGE2AND3	0.083	0.470	0.028	0.727	0.177	0.861

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	2.738	2	1.369	10.956	0.000
Residual	4.124	33	0.125		

Durbin-Watson D Statistic 2.063
First Order Autocorrelation -0.047

Plot of Residuals against Predicted Values



Output for test of age 2 + age 3 striped bass on delta smelt
TNS → FMWT

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1 case(s) deleted due to missing data.

Dep Var: LOGFMWT   N: 36   Multiple R: 0.645   Squared multiple R: 0.416

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltFallSummerBassAndSilverside.syo

SYSTAT Rectangular file C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltFallSummerBassAndSilverside.SYD,
created Thu Sep 03, 2009 at 13:38:58, contains variables:

FMWTYEAR LOGFMWT LOGNEXTTNS LOGLEGALBASS LOGTOTALBASS LOGMSSBIOMAS

6 case(s) deleted due to missing data.

Dep Var: LOGNEXTTNS N: 31 Multiple R: 0.791 Squared multiple R: 0.626

Adjusted squared multiple R: 0.585 Standard error of estimate: 0.362

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	0.252	3.682	0.000	.	0.069	0.946
LOGFMWT	0.785	0.156	0.626	0.897	5.036	0.000
LOGLEGALBASS	-0.088	0.620	-0.017	0.954	-0.141	0.889
LOGMSSBIOMAS	-0.304	0.103	-0.358	0.938	-2.946	0.007

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	5.919	3	1.973	15.081	0.000
Residual	3.533	27	0.131		

*** WARNING ***
Case 7 has large leverage (Leverage = 0.464)

Durbin-Watson D Statistic 1.644
First Order Autocorrelation 0.174

Output of test for legal sized striped bass + silverside effects on delta smelt stock recruit

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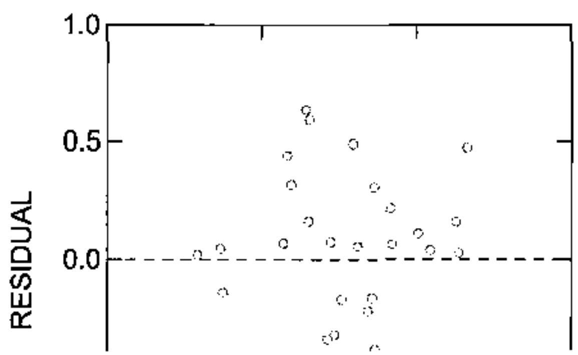
Plot of Residuals against Predicted Values



RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltFallSummerBassAndSilverside.syo

6 case(s) deleted due to missing data.

Dep Var: LOGNEXTTNS   N: 31   Multiple R: 0.791   Squared multiple R: 0.626

Adjusted squared multiple R: 0.585   Standard error of estimate: 0.362

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	0.298	3.600	0.000	.	0.083	0.935
LOGFMWT	0.784	0.155	0.625	0.909	5.067	0.000
LOGTOTALBASS	-0.093	0.594	-0.019	0.969	-0.157	0.876
LOGMSSBIOMAS	-0.304	0.103	-0.357	0.937	-2.940	0.007

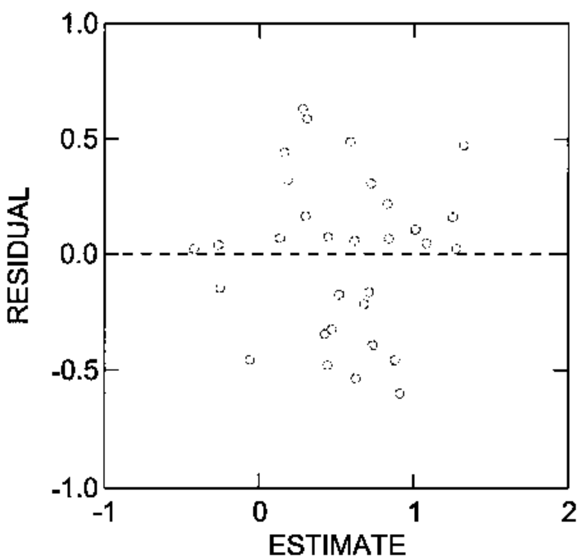
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	5.920	3	1.973	15.085	0.000
Residual	3.532	27	0.131		

*** WARNING ***
Case 7 has large leverage (Leverage = 0.470)

Durbin-Watson D Statistic 1.636
First Order Autocorrelation 0.178

Plot of Residuals against Predicted Values



Output for test of age 3 + older striped bass + silverside effects on delta smelt stock-recruit

RECIRC2849

SYSTAT Rectangular file C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltFallSummerBassAndSilverside.SYD,
created Thu Sep 03, 2009 at 13:38:58, contains variables:

FMWTYEAR LOGFMWT LOGNEXTTNS LOGLEGALBASS LOGTOTALBASS LOGMSSBIOMAS

```
***WARNING***
The file
                C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats
files\SmeltFallSummerBassAndSilverside.SYD
was read for processing, and its contents have been replaced by saving
the processed data into it.
```

37 cases and 9 variables processed and saved.

Output for test of age 2 striped bass + silverside effects on delta smelt stock-recruit

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8 case(s) deleted due to missing data.

Dep Var: LOGNEXTTNS N: 29 Multiple R: 0.819 Squared multiple R: 0.671

Adjusted squared multiple R: 0.631 Standard error of estimate: 0.322

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-6.163	2.079	0.000	.	-2.965	0.007
LOGFMWT	0.590	0.168	0.438	0.840	3.502	0.002
LOGAGE2BASS	1.092	0.369	0.365	0.864	2.958	0.007
LOGMSSBIOMAS	-0.289	0.093	-0.366	0.958	-3.120	0.005

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	5.298	3	1.766	16.982	0.000
Residual	2.600	25	0.104		

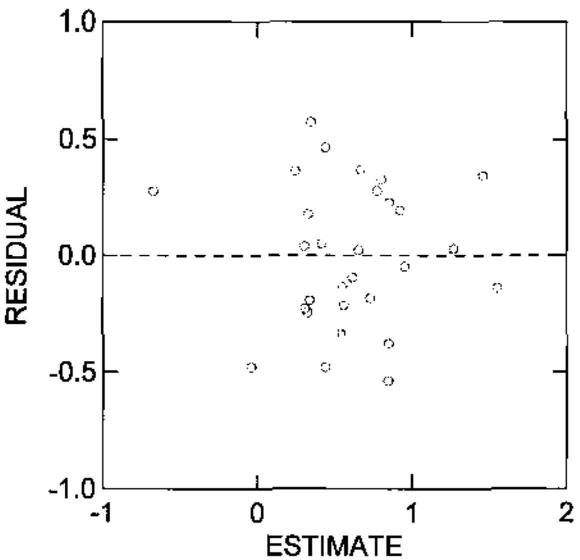
```
*** WARNING ***
Case        7 has large leverage   (Leverage =      0.442)

Durbin-Watson D Statistic         1.937
First Order Autocorrelation       0.013
```

RECIRC2849

File: C:\Documents and Settings\MNOBRIGA\My Documents\StrBasLawsuit\Stats files\SmeltFallSummerAge2BassAndSilverside.syo

Plot of Residuals against Predicted Values



Residual plot for age 2 striped bass + silversides

Output for test of age 2 + age 3 striped bass + silverside effects on delta smelt stock-recruit

8 case(s) deleted due to missing data.

Dep Var: LOGNEXTTNS N: 29 Multiple R: 0.816 Squared multiple R: 0.666

Adjusted squared multiple R: 0.626 Standard error of estimate: 0.325

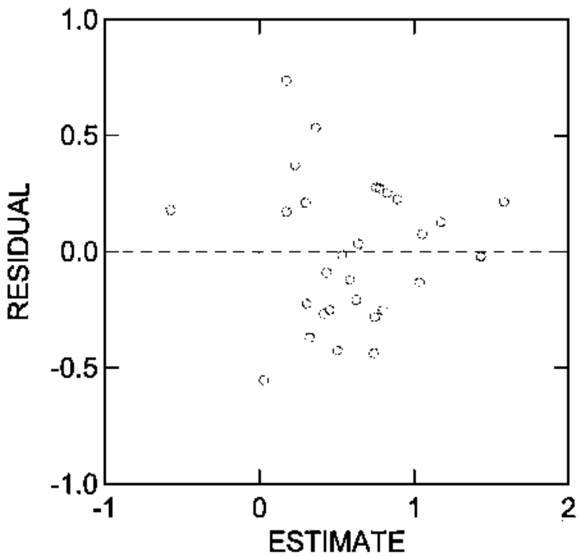
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-8.284	2.858	0.000	.	-2.898	0.008
LOGFMWT	0.598	0.169	0.445	0.846	3.537	0.002
LOG2AND3BASS	1.383	0.482	0.355	0.875	2.871	0.008
LOGMSSBIOMAS	-0.296	0.093	-0.375	0.960	-3.178	0.004

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	5.258	3	1.753	16.600	0.000
Residual	2.640	25	0.106		

Durbin-Watson D Statistic 1.805
First Order Autocorrelation 0.092

Plot of Residuals against Predicted Values



Residual plot for age 2 + age 3 striped bass + silversides

Output for test of age 2 + older striped bass + silverside effects on delta smelt stock-recruit

8 case(s) deleted due to missing data.

Dep Var: LOGNEXTTNS   N: 29   Multiple R: 0.790   Squared multiple R: 0.624

Adjusted squared multiple R: 0.579   Standard error of estimate: 0.344

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	-8.488	3.903	0.000	.	-2.175	0.039
LOGFMWT	0.666	0.175	0.495	0.891	3.813	0.001
LOG2PLUSBASS	1.345	0.629	0.273	0.921	2.139	0.042
LOGMSSBIOMAS	-0.292	0.099	-0.370	0.959	-2.957	0.007

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	4.931	3	1.644	13.850	0.000
Residual	2.967	25	0.119		

Durbin-Watson D Statistic 1.819
First Order Autocorrelation 0.088

Exhibit G

Exhibit G. Data sources used for this expert report. CDFG = California Department of Fish and Game; USFWS = U.S. Fish and Wildlife Service.

Species and data source	Years available	URL
Adult striped bass abundance – Striped bass are collected by CDFG during their spring spawning migration and tagged. Tags are recovered by CDFG, anglers, and other programs and persons. The estimates are made using a modification of the Peterson mark-recapture equation.	1969-1994, 1996, 1998, 2000, 2002, 2004-2005	These data were emailed to me by DFG biologist Marty Gingras on April 30 and May 1, 2009 in Excel spreadsheets titled “DRAFT thru 2007 ASB abundance updates.xls” and “ASB population summary stats.xls”.
Winter-run salmon escapement – Winter run salmon carcasses are counted and tagged by CDFG staff. Tags are recovered in subsequent carcass surveys. Winter run salmon returning to spawning habitats are also counted as they pass the fish ladder at Red Bluff Diversion Dam.	1969/1970 season to 2007/2008 season	http://dnn.calfish.org/portals/2/Home/tabid/70/Default.aspx
Spring-run salmon escapement - Spring run salmon carcasses are counted and tagged by	1969/1970 season to	http://dnn.calfish.org/portals/2/Home/tabid/70/Default.aspx

CDFG staff. Tags are recovered in subsequent carcass surveys.	2007/2008 season	
Delta smelt summer relative abundance - CDFG samples up to 32 stations in the San Francisco Estuary at least twice each summer. A relative abundance index is calculated annually for delta smelt based on survey catches.	1969-2008	http://www.delta.dfg.ca.gov/
Delta smelt fall relative abundance – CDFG samples up to 116 stations in the San Francisco Estuary four times each fall. A relative abundance index is calculated annually for delta smelt based on survey catches.	1969-1973, 1975-1978, 1980-2008	http://www.delta.dfg.ca.gov/
Mississippi silverside biomass estimated from USFWS beach seine catch. The USFWS samples up to XX sites in the Delta on an up to weekly basis throughout the year. An academic team at UC Santa Barbara's National Center for Ecological Analysis and Synthesis under contract from the IEP compiled	1976-2007	These data were emailed to me by US Bureau of Reclamation biologist Fred Feyrer on May 5, 2009 in an Excel spreadsheet titled "silverside and largemouth.xls". They were used in a recently submitted manuscript by Thompson et al. http://knb.ecoinformatics.org/knb/metacat?action=read&qformat=nceas&sessionid=0&docid=reeves.48.6

the USFWS data for Mississippi silversides and converted the catch totals to biomass estimates.		

Exhibit H

Exhibit H: Flow chart showing the timing of linkages among the fish variables used in the multiple regression analyses.

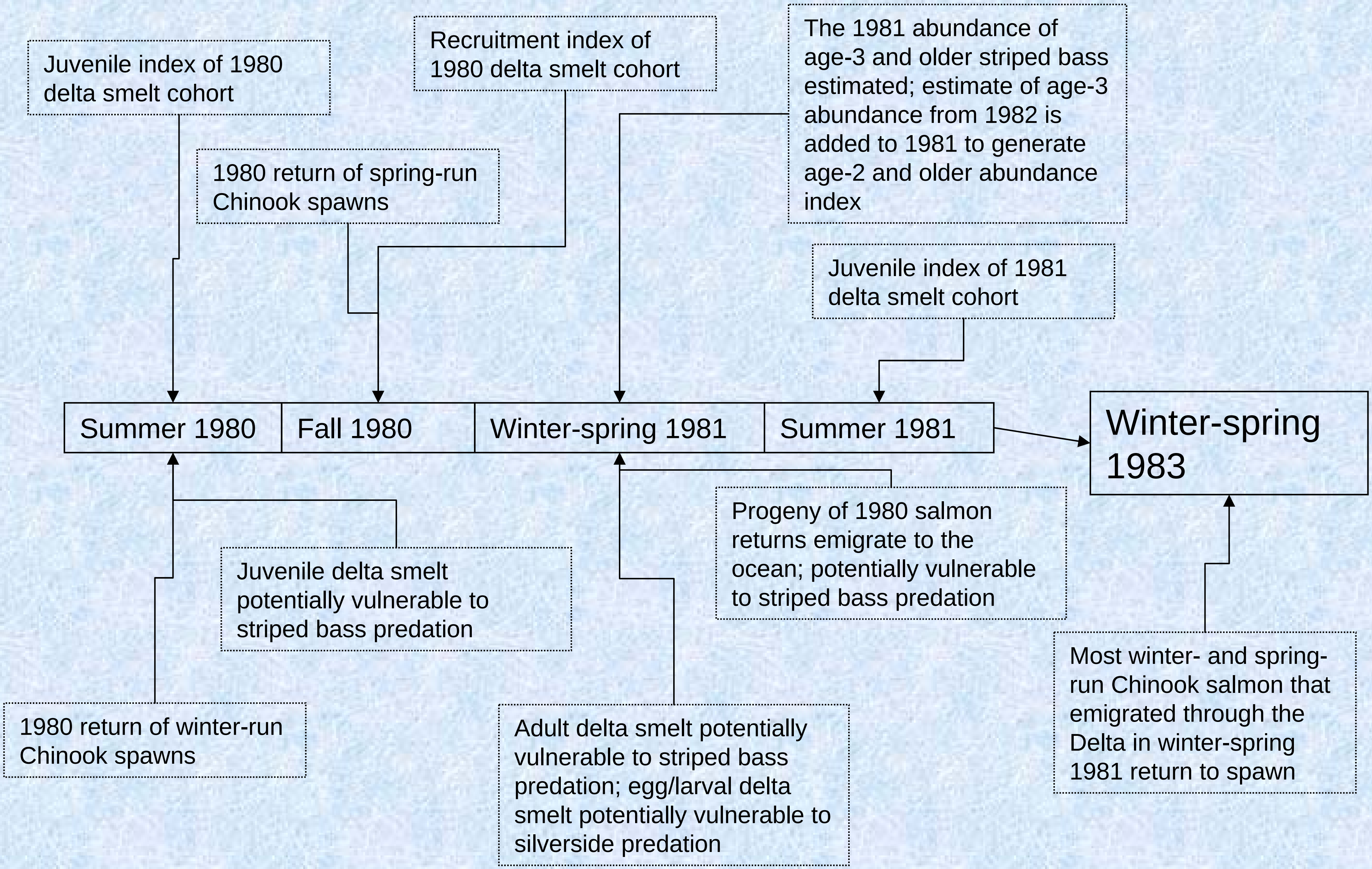


Exhibit I

RECIRC2849

Exhibit I: Summary of the striped bass slope terms from the various multiple regression analyses. Statistically significant (P < 0.05) slopes are denoted with asterisks. The regressions in which the striped bass abundance term was not statistically significant are unmarked.

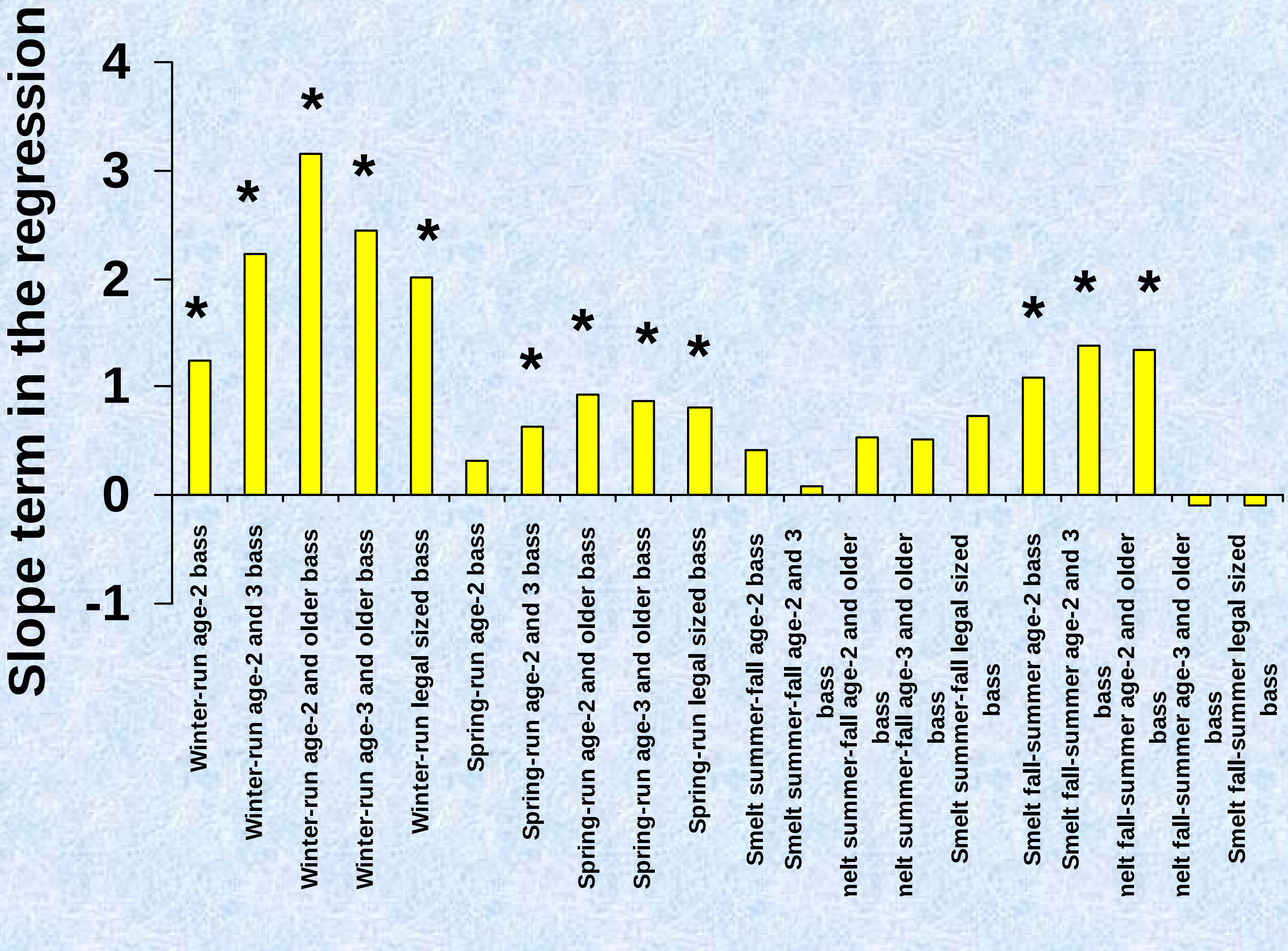


Exhibit J

Exhibit J: Observed winter-run salmon abundance 1970-2008 and predicted abundance for 1996-2008 using the models of Lindley and Mohr (2003). DD = density dependent; DI = density independent

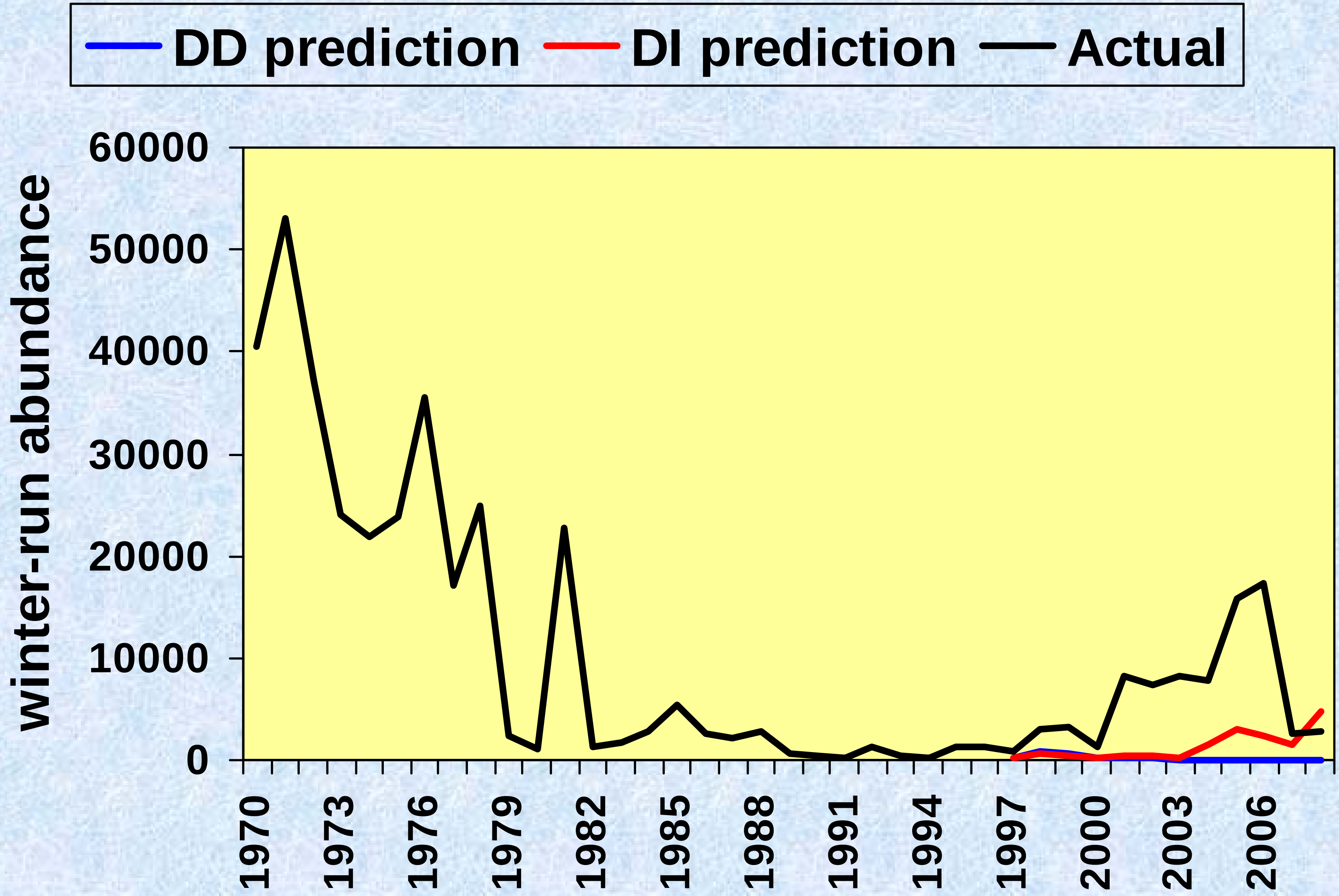


Exhibit K

Exhibit K: References cited in the expert report of Matt Nobriga in Case No.: 1:08-CV-00397-OWW-GSA

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science **3:** Issue 2, Article 1. http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1.

Bennett, WA, Hobbs, JA, Teh, S. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final Report to the Interagency Ecological Program.

Bennett, WA, Moyle, PB. 1996. Where have all the fishes gone? Interactive factors producing fish declines. Pages 519-541 in Hollibaugh, JT, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

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NOTICE OF EXEMPTION

TO: Contra Costa County
Clerk's Office
555 Escobar Street
Martinez, CA 94553

From: Contra Costa Water District
P.O. Box H20
Concord, CA 94524

PROJECT TITLE: Rock Slough Fish Screen Log Boom Relocation

PROJECT LOCATION: The project is located at the Contra Costa Water District's (District's) Rock Slough Fish Screen (RSFS) in the south Sacramento-San Joaquin Delta approximately four miles east of the City of Oakley, California (see Attachment 1). The facility serves as the intake to the District's Contra Costa Canal that delivers untreated water to the District's customers. Construction of the RSFS was completed in 2011.

PROJECT DESCRIPTION:
At roughly 320 ft of screen width, 14 ft of depth and 350 cfs of capacity, the RSFS is a large untreated water intake. The fish screens are designed to operate at contemporary Delta fish screen criteria of 0.2 ft/sec approach velocity using wedge wire screen with 1.75 mm openings. The fish screens are cleaned by four mechanical rakes. The debris removed from the screens is deposited onto a conveyor system that delivers debris to each end of the screens for collection and disposal.

Since the RSFS was placed in operation in the fall of 2011, it has experienced mechanical failures, environmental releases and excessive maintenance well beyond what would be acceptable as routine. Many of these problems are likely attributable to a large amount of aquatic vegetation in the vicinity of the RSFS. Among the most common issues have been 1) alarm conditions that cause the individual screen cleaners to go off-line because of debris buildup on the rakes and rake head equipment, 2) failure of hydraulic cylinder seals causing release of hydraulic fluid, 3) failure of wire ropes on the rake head booms, 4) capturing of adult salmon by the rake heads, and 5) ineffective screen cleaning and debris removal. CCWD is working with Reclamation to remedy the above problems with various improvements at the Rock Slough Fish Screen that will be implemented in a follow-up set of actions.

Prior to the full suite of improvements needed to bring the RSFS up to workable conditions, Reclamation has, in consultation with National Marine Fisheries Service, decided that the District is required to relocate an existing log boom from directly in front of and parallel with the RSFS to approximately 600 feet upstream and perpendicular to Rock Slough. One of two existing log booms will be relocated perpendicularly across Rock Slough, extending from the edge of CCWD's property directly across Rock Slough and anchored on both sides with a 24" diameter, 8.5 foot deep concrete anchor with 6 foot by 6 foot concrete pad 1 foot below ground surface (see Attachment 2).

Construction of the anchor may require access for a well drilling rig, concrete truck, small backhoe, and/or pickup trucks. Construction is anticipated to take up to 4 weeks to excavate soil, set forms, pour concrete, and ensure concrete has reached minimum strength requirements prior to moving the log boom and connecting to the new anchor. Construction of the new anchors is expected to take place above the mean high tide level within Rock Slough, but on the streamside of the banks within Rock Slough. CCWD will obtain a streambed agreement from the California Department of Fish and Wildlife prior to commencing construction of the new log boom anchors. CCWD has coordinated with the US Coast Guard and has received concurrence with the project's scope.

Once the log boom has been relocated to the new anchor, CCWD will inspect and maintain the anchor and log boom by accessing with a boat from the water in Rock Slough up to two times per year. CCWD anticipates maintenance needs to be negligible, however infrequent access to the anchor may be required to reattach the log boom if the boom should encounter issues with debris loading. This access would be conducted from the water.

AGENCY APPROVING PROJECT: Contra Costa Water District

AGENCY CARRYING OUT PROJECT: Contra Costa Water District

REASONS WHY PROJECT IS EXEMPT: The project is exempt under CEQA Guidelines Section 15302 – *Replacement or Reconstruction (c):* "replacement or reconstruction of existing structures and facilities where the new structure will be located on the same site as the structure replaced and will have substantially the same purpose and capacity as the structure replaced."

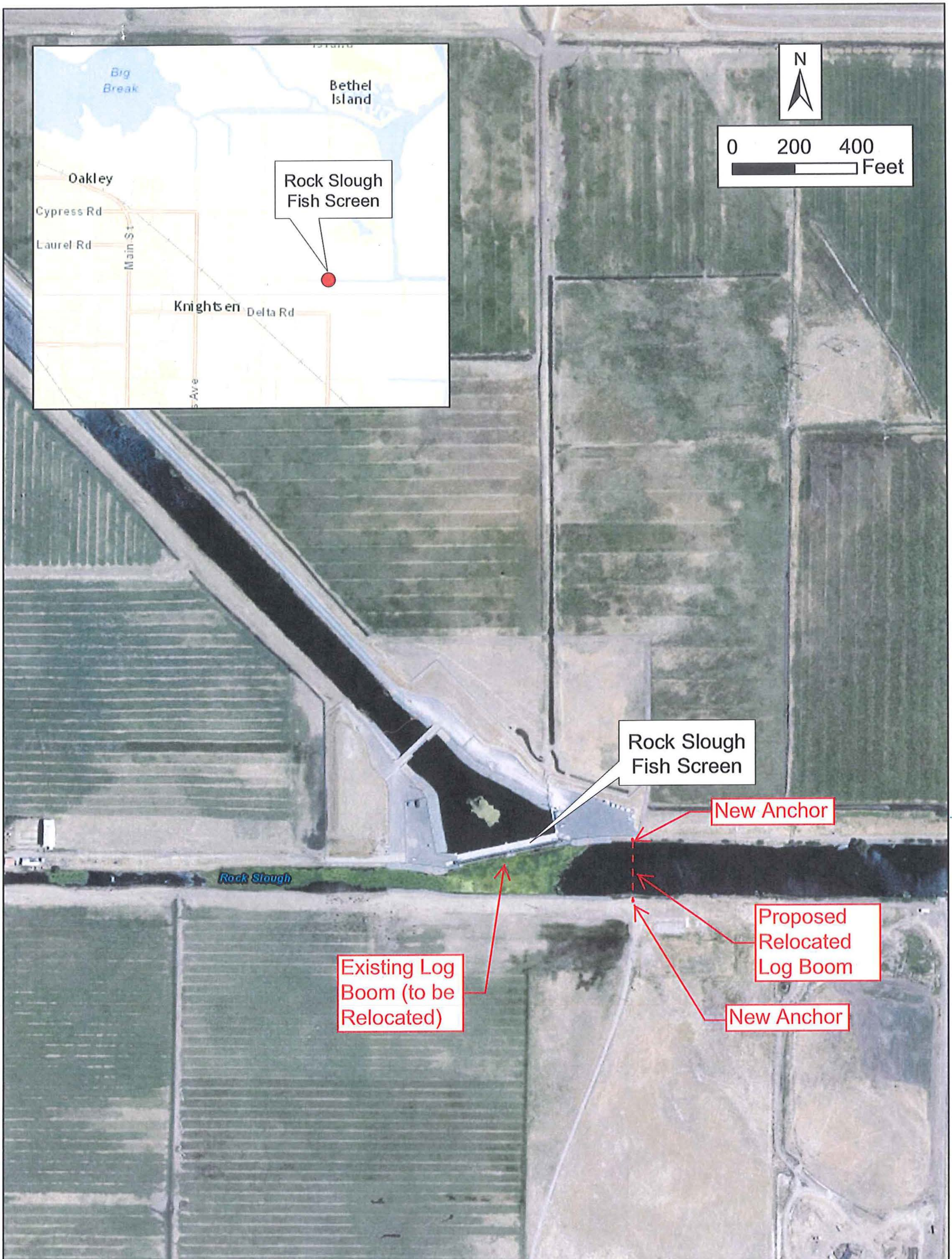
CONTACT PERSON: Dan Jones, Project Engineer (925) 688-8341.

SIGNATURE: Mark A. Seedall (signed) **DATE:** July 10, 2015

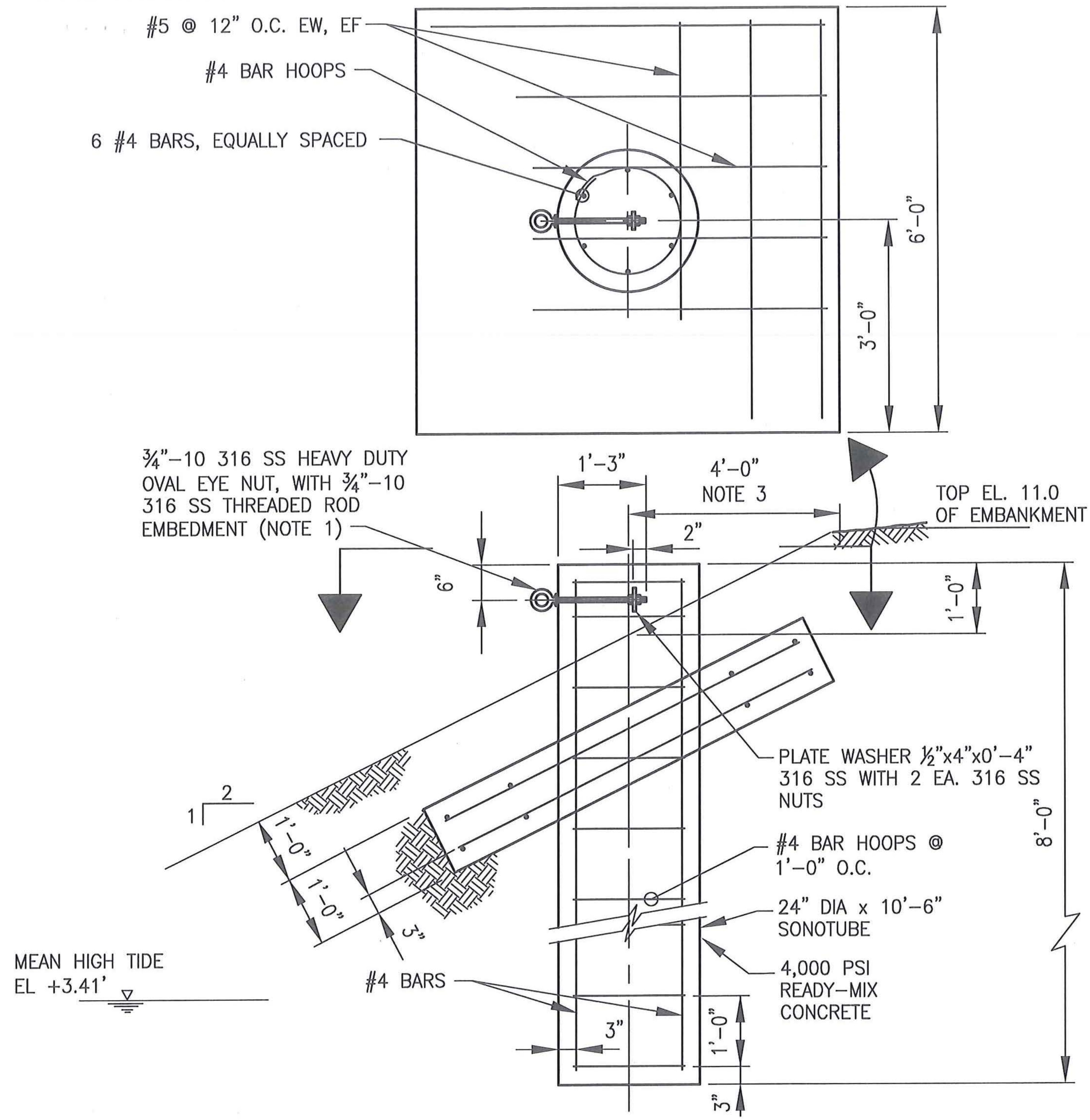
Mark A. Seedall
Principal Planner

Attachments: Attachment 1 – Project Location Map
Attachment 2 – Rock Slough Log Boom Anchor Detail

Attachment 1



FishScreenOverview.mxd



NOTES:

1. LEAVE 1½" OF THREADED ROD PROTRUDING FROM SONOTUBE FOR EYE NUT ATTACHMENT.
2. COMPACT SUBGRADE AND FILL AROUND ANCHOR POST TO 100% OF STANDARD PROCTOR.
3. TOP OF EMBANKMENT VARIES. PLACE ANCHORS 192' CENTER TO CENTER, ALIGNED PERPENDICULAR TO CHANNEL.
4. ELEVATIONS REFERENCED TO NGVD 29.

MEAN LOW TIDE
EL 0.12'

NOT TO SCALE

DEERE & AULT CONSULTANTS, INC.	CONTRA COSTA WATER DISTRICT ROCK SLOUGH DEBRIS BOOM ANCHOR	FIG-1

7-2279 (01-2014)
Bureau of Reclamation

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ASSISTANCE AGREEMENT

1A. AGREEMENT NUMBER: R14AC00081

1B. MOD NUMBER:

2. TYPE OF AGREEMENT:
☐ GRANT
☒ COOPERATIVE AGREEMENT

3. CLASS OF RECIPIENT: Special District Government

4. ISSUING OFFICE
U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
2800 Cottage Way, Room E-1815
Sacramento, California 95825-1898
DUNS: 098-86-5801 / EIN:84-1024566

5. RECIPIENT
Contra Costa Water District
2411 Bisso Lane - P.O. Box H2O
Concord, California 94524
Phone: 925-688-8028
Fax: 925-686-2187

EIN #:	946000489	County:	Contra Costa
DUNS #:	076556588	Congress. Dist:	7,10 and 11

6. GRANTS MANAGEMENT SPECIALIST
Beverly S. Breen, MP-3828
U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
2800 Cottage Way, Room E-1815
Sacramento, California 95825-1898
Phone: (916) 978-5146
Email: bbreen@usbr.gov

7. RECIPIENT PROJECT MANAGER
Chris Hentz
Engineering Manager
Contra Costa Water District
2411 Bisso Lane - P.O. Box H2O
Concord, California 94524
Phone: 925-688-8311
Fax: 925-686-2187
Email: chentz@ccwater.com

8. GRANTS OFFICER TECHNICAL REPRESENTATIVE
Carl Dealy, TO 406
Bureau of Reclamation,
SCCAO, Tracy Office
16650 Kelso Road
Byron, California 94514-1909
Phone (925) 836-6236
Email: jcdealy@usbr.gov

9A. INITIAL AGREEMENT EFFECTIVE DATE: See Block 17a

9B. MODIFICATION EFFECTIVE DATE: N/A

10. COMPLETION DATE: March 31, 2016

11A. PROGRAM STATUTORY AUTHORITY
Public Law 102-575 Sections 3406 (b)(5), 3407(e)

11B. CFDA Number: 15.512

12. FUNDING INFORMATION	RECIPIENT/OTHER	RECLAMATION
Total Estimated Amount of Agreement	$700,000.00	$2,100,000.00
This Obligation	$700,000.00	$2,100,000.00
Previous Obligation	$0.00	$0.00
Total Obligation	$700,000.00	$2,100,000.00
Cost-Share %	25%	75%

13. REQUISITION NUMBER: 20058953

14A. ACCOUNTING AND APPROPRIATION DATA
RR02162000
RA.08632822.153000

14B. TREASURY ACCOUNT FUNDING SYMBOL
14X06804A3

15. PROJECT TITLE
Fish Screen Corrective Action and Improvements

16a. Acceptance of this Assistance Agreement in accordance with the terms and conditions contained herein is hereby made on behalf of the above-named recipient

BY: [signature]

DATE: 9/17/14

17a. Award of this Assistance Agreement in accordance with the terms and conditions contained herein is hereby made on behalf of the United States of America, Department of the Interior, Bureau of Reclamation

BY: ______________________

DATE: ______________________

16b. NAME, TITLE, AND TELEPHONE NUMBER OF SIGNER
Jerry Brown
General Manager (925) 688-8034
☐ Additional signatures are attached

17b. NAME OF GRANTS OFFICER
Beverly S. Breen

TABLE OF CONTENTS

Bureau of Reclamation Form, RF-120
12-2012

Cooperative Agreement
Between
Bureau of Reclamation
And
Contra Costa Water District
For
Fish Screen Corrective Action and Improvements

I. OVERVIEW AND SCHEDULE

1. AUTHORITY

This Cooperative Agreement (Agreement) is entered into between the United States of America, acting through the Department of the Interior, Bureau of Reclamation, hereinafter referred to as "Reclamation," and Contra Costa Water District (CCWD), hereinafter referred to as the "Recipient" or "Grantee," pursuant to Public Law 102-575 Sections 3406 (b)(5), 3407(e). The following section, provided in full text, authorizes Reclamation to award this financial assistance agreement:

Public Law 102-575 Sections 3406 (b)(5), 3407(e)
Section 3406 - Fish, Wildlife and habitat Restoration

(b) FISH AND WILDLIFE RESTORATION ACTIVITIES- The Secretary, immediately upon the enactment of this title, shall operate the Central Valley Project to meet all obligations under State and Federal law, including but not limited to the Federal Endangered Species Act, 16 U.S.C. 1531, et seq., and all decisions of the California State Water Resources Control Board establishing conditions on applicable licenses and permits for the project. The Secretary, in consultation with other State and Federal agencies, Indian tribes, and affected interests, is further authorized and directed to:

(5) develop and implement a program to mitigate for fishery impacts resulting from operations of the Contra Costa Canal Pumping Plant No. 1. Such program shall provide for construction and operation of fish screening and recovery facilities, and for modified practices and operations.

Section 3407(e) of CVPIA, Funding to Non-Federal Entities, also states in part that "If the Secretary of the Interior determines that the State of California or an agency or subdivision thereof ... concerned with restoration, protection, or enhancement of fish, wildlife, habitat, or environmental values is able to assist in implementing any action authorized by this title in an efficient, timely, and cost effective manner, the Secretary is authorized to provide funding to such entity on such terms and conditions as he deems necessary to assist in implementing the identified action."

2. PUBLIC PURPOSE OF SUPPORT OR STIMULATION

The project is not primarily for the direct benefit of Reclamation or other Federal government agencies. The Federal government will not be receiving any form of deliverable product or service, unless otherwise authorized by the statute.

The project will assist the recipient in accomplishing its public purpose by protecting the threatened Delta Smelt and the endangered winter-run Chinook Salmon. Not only, will the project provide protection for the fisheries, but also, allow water diversion to serve the water users who rely on the Contra Costa Canal.

This project represents an important piece of the overall program to address environmental issues associated with Sacramento-San Joaquin Delta. Additionally, to fulfill legal requirements of the U.S. Fish and Wildlife Service's 2008 Biological Opinion for the threatened Delta smelt.

3. BACKGROUND AND OBJECTIVES

The Contra Costa Canal (Canal) is part of the Central Valley Project's Delta Division. Water from the Sacramento-San Joaquin Delta is diverted at Rock Slough conveyed to the beginning of the Canal. This Canal a major water supply and delivery system for the CCWD. Between 120,000 and 130,000 acre-feet of water per year is diverted by the Canal for irrigation and municipal and industrial uses. The Canal diversion at Rock Slough is one of the largest unscreened Delta sites. A number of resident and migratory fish species, including the threatened Delta smelt and the endangered winter-run Chinook salmon, can be drawn into the Canal. A fish screen has been constructed to keep fish from entering the Canal intake. The fish screen functions to:

1. Minimize the entrainment of fish resources associated with the diversion of water at the Rock Slough Intake of the Contra Costa Canal.
2. Reduce potential predation on target species in the Rock Slough Intake.
3. Fulfill legal requirements of the U.S. Fish and Wildlife Service's 2008 Biological Opinion for the threatened Delta smelt.
4. Complete the mitigation for the Los Vaqueros Biological Opinion.
5. Complete CVPIA requirements in Section 3406(b)(5).

The project fish screen was substantially complete in November 2011.

There have been operational problems primarily associated with the automated debris handling system. This has resulted in the take of salmon. The system has undergone extensive testing, currently all four rake units are operational, completing the construction contract obligations pending the final punch list details that were sent to the construction contractor Flatiron.

A re-design effort has been active since July 2012 to produce new specifications for retrofitting of the rake system. Monitoring of fish response to the automated debris handling system is also ongoing, having been initiated in November 2011 when the first salmon take was identified.

Objectives

This present action is to resolve problems of mechanical failures, environmental releases, excessive maintenance, and other deficiencies to ensure the Contra Costa Fish Screen can be operated safely, effectively and efficiently. This will include environmental documentation, permitting, design, and construction. The design should be based on the lowest life cycle cost and meet the needs for safe effective and efficient operation.

The elements will include:
Rake Modifications and Debris Handling
The objective is to complete the rake modifications for the remaining 3 rake units based upon prototype improvements currently installed at one of the rake units.

Extend the Rake Motor Access Platform the full width of the intake structure. To provide safe access to the screen rake(s) appurtenances in the event of rake system failure at an intermediate position.

Boat Launch Facility, and Access Improvements. The CCWD will design and build boat launch's that will adequately meets the District's needs to launch their 14 and 16 foot boats at the canal and larger maintenance boats at Rock Slough. Access improvements include stairs to provide safe access to the canal and Rock Slough.

Value Engineering Study will be conducted at the concept level (30% design) for the items proposed by CCWD.

4. PERIOD OF PERFORMANCE AND FUNDS AVAILABILITY

This Agreement becomes effective on the date shown in Block 17a of Form 7-2279, United States of America, Department of the Interior, Bureau of Reclamation, Assistance Agreement. The Agreement shall remain in effect until the date shown in Block 10 of Form 7-2279, United States of America, Department of the Interior, Bureau of Reclamation, Assistance Agreement. The period of performance for this Agreement may only be modified through written modification of the Agreement by a Reclamation Grants Officer (GO).

No legal liability on the part of the Government for any payment may arise until funds are made available, in writing, to the Recipient by the Grants Officer. The total estimated amount of federal funding for this agreement is $2,100,000.00, of which the initial amount of federal funds available is limited to $2,100,000.00 as indicated by "this obligation" within Block 12 of Form 7-2279, United States of America, Department of the Interior, Bureau of Reclamation, Assistance Agreement. Subject to the availability of Congressional appropriations, subsequent funds will be made available for payment through written modifications to this agreement by a Reclamation Grants Officer.

5. SCOPE OF WORK AND MILESTONES

Task 1: Rake Modifications

The District has performed prototype repairs to one of the screen rakes to test repairs prior to repairing all of the rakes. In general, the rake repairs include the following modifications:

1) Replacement of the rake head with a re-designed head that will effectively capture and dump debris, and clean the screen;

2) Replacement of hydraulic seals to ensure compatibility with hydraulic fluid to eliminate failures;

3) Extend the Rake Motor Access Platform the full width of the intake structure. To provide safe access to the screen rake(s) hydraulic motor if the rake fails in an intermediate position. Ending the need for personnel to climb onto the conveyor or rake motor housing while making a repair in this intermediate position;

4) Installation of hydraulic fluid bleed-back and alarm to capture and return fluid to the hydraulic reservoir to prevent releases to the Delta; and,

5) Re-programming of the rake to improve cleaning and prevent fish capture;
The objective is to complete the rake modifications for the remaining 3 units based upon prototype improvements currently installed at one of the stations.

Task 2: Debris Handling

The facility includes four screen rakes that deposit debris onto a conveyor, which transports debris to the each side of the facility. The debris loading is high because the facility is located on a dead end of the Rock Slough channel where debris accumulates. During peak conditions debris accumulation is approximately 13 cubic yards of debris production per hour.

The current debris handling system is extremely labor intensive, especially during times of high debris load. Access to the trucks along the steep pit ramp is unsafe. Dumping the debris from the truck, and removing debris that gets hung up near the end of the conveyor is also unsafe. Choose the appropriate alternative developed in the previous evaluation to improve safety and debris-handling efficiency and safety and design an improved method and structure for debris handling. The design should be based on the lowest life cycle cost and has the highest capacity for debris removal while providing a safe means of debris removal.

Task 3: Extend the Rake Motor Access Platform

The cost estimate includes additional grating, handrail, and necessary supports to extend the rake motor access platform across the full width of the intake structure.

Extending the rake motor access platform across the full width of the intake structure is necessary to provide safe access to the screen rake(s) hydraulic motor if a rake fails in an intermediate position. Returning a broken rake to the home position requires O&M staff to climb onto the conveyor or rake motor itself while tying off to a crane or manlift for fall protection in an attempt to repair from this access point; this is an unnecessarily hazardous means of rake head access. If O&M is unable to repair while climbing on the conveyor or rake motor they must winch the rake back to the home position. Repair of the rake when it fails in the intermediate position is unsafe and time consuming, which causes debris buildup on the fish screens and may be harmful to fish if the screen is not cleaned in the meantime.

The current platform only provides access to the screen rake if it fails in the home position, and the screen rakes have repeatedly failed in an intermediate position. Therefore, the screen rakes cannot be safely accesses and maintained in its current condition. The screen rakes are most likely to fail in the intermediate position because the rakes are constantly traveling across the intake screens to remove debris and failure in the intermediate position is problematic because the rake cannot travel back to home.

The cost estimate also includes additional grating to improve safety. This is necessary to allow O&M staff access to clean the debris conveyor near the debris dump; this location is currently not accessible to O&M staff due to the fall hazard.

Task 4: Boat Launch

The facility's fish screens and in water components must be routinely inspected and booms deployed if there is an accidental release of fluids. These activities require accessing the facility with a boat on the upstream (Rock Slough) side of the facility and on the downstream (Canal) side of the facility.

To address the canal side boat deployments boat launch is needed downstream of the facility near the Contra Costa Canal Bridge (i.e., the original headworks) and upstream in Rock Slough. The District will design and build a Davit Crane Boat Launch that will adequately meet the District's needs to launch their 14 and 16 foot boats at the canal, and is the most economical. The District will also design and build a boat launch on Rock Slough to launch larger maintenance boats. The design should be the simplest to construct and permit because limited in water work is required.

Task 5: Personnel Access Stairs - Canal and Rock Slough

A stairway access points are necessary for rescue and maintenance access. Stairs must be located on both north and south sides given the length of the facility and difficulty for a person in distress to swim across the canal or Rock Slough. The design and implementation of the personnel access should include landings, riser height, and handrail according to the local laws/regulations. The details of the design including how to accommodate the rise/fall of the tide, corrosion, layout, etc. will be completed during design.

Task 6: Miscellaneous Improvements

The following miscellaneous repairs necessary to improve safety and reduce O&M requirements, which shall be included;

1) Relocate conduits at each end of the structure;

2) Stilling wells for level measurement devices; and,

3) Handrails and grating on both abutments of the facility needed to access equipment and clear debris.

Task 8: Value Engineering Study

A value engineering study shall be conducted at the concept design level (30% design) for the items proposed by CCWD as improvements to fish screen facility at Rock Slough. The study shall conform to the requirements of the Bureau of Reclamation (Reclamation) Value Program. The study shall be in accordance with SAVE, Int. guidelines and incorporate all aspects of the SAVE, Int. work plan. A 1/2 day site visit the first day and a 2-hour close-out briefing for management the last day are aspects of the work plan that shall be appropriately scheduled. A study team of a minimum of 5 members shall be from Reclamation and CCWD. CCWD shall provide a minimum of 2 team members with experience in fisheries, design, construction or operation/maintenance. CCWD shall notify Reclamation a minimum of 5 weeks in advance of the intended study dates to make arrangements for the appropriate space and indicate intended members for the team. A Reclamation approved study leader at Reclamation's Tracy CA offices shall lead the study. Any non-Reclamation facilitator shall be a SAVE, Int. Certified Value Specialist (CVS). Reclamation trained facilitators are available with appropriate notification. Therefore, it is recommended that study dates be coordinated as early as possible. A draft report of findings shall be prepared prior to the close-out briefing and transmitted to management. Following publishing of the final VE report, an Accountability report shall be prepared by CCWD to meet the reporting requirements of the Reclamation Value Program.

Task 9: Environmental Documentation and Permitting.

Complete NEPA/ CEQA and ESA documentation and obtain necessary permits.

Milestone / Task / Activity	Planned Start Date	Planned Completion Date
Rake Modifications	July 2015	December 2015
Debris Handling Systems	July 2015	December 2015
Extend the Rake Motor Access Platform	July 2015	December 2015
Boat Launch	July 2015	February 2016
Personnel Access Stairs - Canal and Rock Slough	July 2015	February 2016

Remote Cameras	July 2015	February 2016
Miscellaneous Improvements	July 2015	February 2016
Value Engineering Study		October 2014
Environmental Documentation and Permitting		May 2015

6. RESPONSIBILITY OF THE PARTIES

6.1 Recipient Responsibilities

6.1.1 The Recipient shall carry out the Scope of Work (SOW) in accordance with the terms and conditions stated herein. The Recipient shall adhere to Federal, state, and local laws, regulations, and codes, as applicable, and shall obtain all required approvals and permits. If the SOW contains construction activities, the Recipient is responsible for construction inspection, oversight, and acceptance. If applicable, the Recipient shall also coordinate and obtain approvals from site owners and operators.

6.1.2 Work to be performed by the Recipient and the Bureau of Reclamation: Under this Agreement, both the Recipient and Reclamation shall be responsible for coordinating the various tasks required to complete this project and manage the work identified in the Agreement to complete all project tasks defined herein:

As set forth more specifically in the following provisions of this Agreement, Reclamation and the Recipient will perform task management in a coordinated manner. The primary responsibility for development of final designs and specifications, procurement of engineering / fisheries contractor(s), and changes in management of fish screen features shall be assigned to the Recipient as provided in this Agreement. To accomplish all work associated with engineering of fish screen features; various tasks will require development of intermediate work products, coordination, and communications from both Parties to this agreement. To accomplish individual and coordinated tasks Reclamation and Recipient shall each appoint one or more Project Managers with responsibility for day to-day coordination between the Parties and performance under this Agreement.

Progress Reviews: Any and all work undertaken by the parties pursuant to this Agreement shall be open and subject to inspection by the other party or his/her representative in accordance with applicable laws, rules and policies during the progress thereof and upon completion.

The Project may be executed pursuant to multiple contracts. The Project Managers shall determine the number of contracts and the scope of each contract. However, it is expected that the contracts will generally fall within the following categories with respective responsibilities as identified, although distribution of work may change by mutual agreement of the Parties

Reallocation of work responsibility will be made only upon written mutual agreement of the South-Central California Area Manager, the Mid-Pacific Region Grant Officer, and the Recipient

Format of deliverables under this agreement shall be as follows (See deliverable section):

a. Letters and reports include performance, progress, and financial reports, shall be prepared using Microsoft Word.
b. Specifications shall be prepared using Microsoft Word.
c. All spreadsheets shall be prepared using Microsoft Excel
d. Drawings shall be prepared using AutoCAD 2007, and Reclamation's drawing standards.

Work Performed by the Recipient: The Recipient shall obtain by contract or other mechanism consistent with the terms of this Agreement the services of an experienced consultant or provide knowledgeable and experienced staff for obtaining and analyzing design data and design criteria, and preparing designs and specifications for the type of Project work required under this Agreement.

Design of the project shall be accomplished in a partnered approach between the Recipient and Reclamation. Recipient and Reclamation will coordinate review and comment of these documents. Reclamation will have final approval of all solicitation documents offered for construction.

The Recipient is responsible for completing all scope of work activities identified in the Objective Section above.

The Recipient shall commit no funds made available through this agreement for acquisition of equipment or components until Reclamation has reviewed and approved any and all plans and specifications.

The Recipient shall comply with the property standards under this Agreement.

The Recipient shall provide documentation to support all draws of obligated funds. This documentation will he submitted to the Grants Officer's Technical Representative with the Standard Form 270.

Work Performed by Reclamation: Reclamation shall be responsible for review and approval of any and all drawings and specifications prepared in support of the Contra Costs Canal Fish Screen Facility.

6.2 Reclamation Responsibilities

6.2.1 Reclamation will monitor and provide Federal oversight of activities performed under this Agreement. Monitoring and oversight includes review and approval of financial status and performance reports, payment requests, and any other deliverables identified as part of the SOW. Additional monitoring activities may include site visits, conference calls, and other on-site and off-site monitoring activities. At the Recipient's request, Reclamation may also provide technical assistance to the Recipient in support of the SOW and objectives of this Agreement.

6.2.2 Substantial involvement by Reclamation is anticipated during the performance of activities funded under this cooperative agreement. In support of this Agreement, Reclamation will be responsible for the following:

Reclamation shall be responsible for review and approval of any and all bids, proposals, quotes, cost estimates, and any other information prepared in support of a proposed acquisition of designs, construction, other services, equipment, or components. Reclamation shall complete a cost reasonableness determination for all proposed acquisitions and shall provide comments to the Recipient in a timely manner.

Reclamations will perform, inspection services, QA/QC activities, and engineering support as required to effectively oversee and administer any contract construction work. Reclamation will coordinate construction activities with Recipient to utilize the services requested by the Section above.

7. BUDGET

7.1 Budget Estimate. The following is the estimated budget for this Agreement. As Federal financial assistance agreements are cost-reimbursable, the budget provided is for estimation purposes only. Final costs incurred under the budget categories listed may be either higher or lower than the estimated costs. All costs incurred by the Recipient under this agreement must be in accordance with any pre-award clarifications conducted between the Recipient and Reclamation, as well as with the terms and conditions of this agreement. Final determination of the allowability, allocability, or reasonableness of costs incurred under this agreement is the responsibility of the Grants Officer. Recipients are encouraged to direct any questions regarding allowability, allocability or reasonableness of costs to the Grants Officer for review prior to incurrence of the costs in question.

BUDGET ITEM DESCRIPTION	COMPUTATION		RECIPIENT FUNDING	OTHER FUNDING	RECLAMATION FUNDING	TOTAL COST
	$/Unit and Unit	Quantity				
1. SALARIES AND WAGES --Position title x hourly wage/salary x est. hours for assisted activity. Describe this information for each position.						
Director of Engineering	$92.31	80	$1,846		$5,539	$7,385
Engineering Manager	$79.88	100	$1,997		$5,991	$7,988
WS&L Manager	$79.88	40	$799		$2,396	$3,195
Planning Manager	$79.88	40	$799		$2,396	$3,195
Grant Specialist	$60.02	160	$2,401		$7,202	$9,603
Administrative Analyst	$48.11	80	$962		$2,887	$3,849
Administrative Secretary	$38.12	80	$762		$2,287	$3,050
Senior Clerk	$33.93	250	$2,121		$6,362	$8,483
Real Property Agent	$58.03	48	$696		$2,089	$2,785
Real Property Specialist	$49.09	64	$785		$2,356	$3,142

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Senior Engineer – Design	$64.43	400	$6,443		$19,329	$25,772
Associate Engineer – Design	$58.38	449	$6,553		$19,659	$26,213
Principal Engineer - Construction	$74.76	40	$748		$2,243	$2,990
Senior Engineer - Construction	$64.43	200	$3,222		$9,665	$12,886
Associate Engineer	$58.38	250	$3,649		$10,946	$14,595
Construction Inspector	$43.96	420	$4,616		$13,847	$18,463
Maintenance Superintendent	$59.44	48	$713		$2,140	$2,853
O&M Supervisor	$53.05	141	$1,870		$5,610	$7,480
Electrical Technician	$47.45	200	$2,373		$7,118	$9,490
Instrument Technician	$47.45	200	$2,373		$7,118	$9,490
Maintenance Mechanic	$39.17	400	$3,917		$11,751	$15,668
	Total					$198,575
2. FRINGE BENEFITS – Explain the type of fringe benefits and how are they applied to various categories of personnel.						
Applies to all personal listed above in Category #1 & #7, Salaries & Wages	53%		$32,396		$97,187	$129,583
	Total					129,583
3. TRAVEL—dates; location of travel; method of travel x estimated cost; who will travel						
N/A						
4. EQUIPMENT—Leased Equipment use rate + hourly wage/salary x est. hours for assisted activity—Describe equipment to be purchased, unit price, # of units for all equipment to be purchased or leased for assisted activity. Do not list contractor supplied equipment here.						
N/A						
5. SUPPLIES/MATERIALS--Describe all major types of supplies/materials, unit price, # of units, etc., to be used on this assisted activity.						
Supplies/Materials			$5,000		$15,000	$20,000
	Total					$20,000
6. CONTRACTUAL/ CONSTRUCTION—Explain any contracts or sub-Agreements that will be awarded, why needed. Explain contractor qualifications and how the contractor will be selected.						
Permitting and Design			$78,000		$234,000	$312,000
CM and Materials Testing			$33,750		$101,250	$135,000
Construction Contract			$450,000		$1,350,000	$1,800,000
	Total					$2,247,000
7. ENVIRONMENTAL and REGULATORY COMPLIANCE COSTS – Reference cost incurred by Reclamation or the applicant in complying with environmental regulations applicable to this Program, which include NEPA, ESA, NHPA etc.						
Principal Planner – NEPA and ESA Compliance	$74.42	340	$6,326		$18,977	$25,303
Senior Engineer - Planning	$64.43	320	$5,154		$15,463	$20,618
	Total					$45,920
8. OTHER –List any other cost elements necessary for your project; such as extra reporting, or contingencies in a construction contract.						
N/A						
TOTAL DIRECT COSTS--						

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9. INDIRECT COSTS - What is the percentage rate% . If you do not have a Federally-approved Indirect Cost Rate Agreement or if unapproved rates are used - Explain Why.						
Federal approval, and is awaiting approval. Applies to all personnel listed above in Category #1 & #7, Salaries & Wages	65%		$39,731		$119,192	$158,922
	Total					$158,922
TOTAL PROJECT/ACTIVITY			$700,000		$2,100,000	$2,800,000

FUNDING SOURCES	% TOTAL PROJECT COST	TOTAL COST BY SOURCE
RECIPIENT FUNDING	25%	$700,000
OTHER NON-FEDERAL FUNDING (SPECIFY SOURCE)		$
RECLAMATION FUNDING	75%	$2,100,000
OTHER FEDERAL FUNDING (SPECIFY SOURCE)		$
TOTALS	**100%**	**$2,800,000**

7.2 Cost Sharing Requirement

At least 25% non-Federal cost-share is required for costs incurred under this Agreement. If pre-award costs are authorized, reimbursement of these costs is limited to federal cost share percentage identified in this agreement.

7.3 Pre-Award Incurrence of Costs

The Recipient shall be entitled to reimbursement for costs incurred on or after May 1, 2014, which if had been incurred after this Agreement was entered into, would have been allowable, allocable, and reasonable under the terms and conditions of this Agreement.

7.4 Allowable Costs (2 CFR Part §225)

Costs incurred for the performance of this Agreement must be allowable, allocable to the project, and reasonable. The following Office of Management and Budget (OMB) Circular, codified within the Code of Federal Regulations (CFR), governs the allowability of costs for Federal financial assistance:

2 CFR Part 225 (OMB Circular A-87), "Cost Principles for State, Local, and Indian Tribal Governments"

Expenditures for the performance of this Agreement must conform to the requirements within this Circular. The Recipient must maintain sufficient documentation to support these expenditures. Questions on the allowability of costs should be directed to the GO responsible for this Agreement.

The Recipient shall not incur costs or obligate funds for any purpose pertaining to operation of the program or activities beyond the expiration date stated in the Agreement. The only costs which are authorized for a period of up to 90 days following the project performance period are those strictly associated with closeout activities for preparation of the final report.

7.5 Changes (43 CFR §12.70)

(a) *General.* Grantees and subgrantees are permitted to rebudget within the approved direct cost budget to meet unanticipated requirements and may make limited program changes to the approved project. However, unless waived by the awarding agency, certain types of post-award changes in budgets and projects shall require the prior written approval of the awarding agency.

(b) *Relation to cost principles.* The applicable cost principles (see 43 §12.62) contain requirements for prior approval of certain types of costs. Except where waived, those requirements apply to all grants and subgrants even if paragraphs (c) through (f) of this section do not.

(c) *Budget changes.*

(1) *Nonconstruction projects.* Except as stated in other regulations or an award document, grantees or subgrantees shall obtain the prior approval of the awarding agency whenever any of the following changes is anticipated under a nonconstruction award:

(i) Any revision which would result in the need for additional funding.

(ii) Unless waived by the awarding agency, cumulative transfers among direct cost categories, or, if applicable, among separately budgeted programs, projects, functions, or activities which exceed or are expected to exceed ten percent of the current total approved budget, whenever the awarding agency's share exceeds $100,000.

(iii) Transfer of funds allotted for training allowances (i.e., from direct payments to trainees to other expense categories).

(2) *Construction projects.* Grantees and subgrantees shall obtain prior written approval for any budget revision which would result in the need for additional funds.

(3) *Combined construction and nonconstruction projects.* When a grant or subgrant provides funding for both construction and nonconstruction activities, the grantee or subgrantee must

obtain prior written approval from the awarding agency before making any fund or budget transfer from nonconstruction to construction or vice versa.

(d) *Programmatic changes.* Grantees or subgrantees must obtain the prior approval of the awarding agency whenever any of the following actions is anticipated:

(1) Any revision of the scope or objectives of the project (regardless of whether there is an associated budget revision requiring prior approval).

(2) Need to extend the period of availability of funds.

(3) Changes in key persons in cases where specified in an application or a grant award. In research projects, a change in the project director or principal investigator shall always require approval unless waived by the awarding agency.

(4) Under nonconstruction projects, contracting out, subgranting (if authorized by law) or otherwise obtaining the services of a third party to perform activities which are central to the purposes of the award, *unless included in the initial funding proposal.* This approval requirement is in addition to the approval requirements of 43 §12.76 but does not apply to the procurement of equipment, supplies, and general support services.

(e) *Additional prior approval requirements.* The awarding agency may not require prior approval for any budget revision which is not described in paragraph (c) of this section.

(f) *Requesting prior approval.*

(1) A request for prior approval of any budget revision will be in the same budget format the grantee used in its application and shall be accompanied by a narrative justification for the proposed revision.

(2) A request for a prior approval under the applicable Federal cost principles (see §12.62) may be made by letter.

(3) A request by a subgrantee for prior approval will be addressed in writing to the grantee. The grantee will promptly review such request and shall approve or disapprove the request in writing. A grantee will not approve any budget or project revision which is inconsistent with the purpose or terms and conditions of the Federal grant to the grantee. If the revision, requested by the subgrantee would result in a change to the grantee's approved project which requires Federal prior approval, the grantee will obtain the Federal agency's approval before approving the subgrantee's request.

7.6 Modifications

Any changes to this Agreement shall be made by means of a written modification. Reclamation may make changes to the Agreement by means of a unilateral modification to address administrative matters, such as changes in address, no-cost time extensions, or the addition of previously agreed upon funding. Additionally, a unilateral modification may be utilized by Reclamation if it should become necessary to suspend or terminate the Agreement in accordance with 43 CFR 12.83.

All other changes shall be made by means of a bilateral modification to the Agreement. No oral statement made by any person, or written statement by any person other than the GO, shall be allowed in any manner or degree to modify or otherwise effect the terms of the Agreement.

All requests for modification of the Agreement shall be made in writing, provide a full description of the reason for the request, and be sent to the attention of the GO. Any request for project extension shall be made at least 45 days prior to the expiration date of the Agreement or the expiration date of any extension period that may have been previously granted. Any determination to extend the period of performance or to provide follow-on funding for continuation of a project is solely at the discretion of Reclamation.

8. KEY PERSONNEL

8.1 Recipient's Key Personnel

The Recipient's Project Manager for this Agreement shall be:

Chris Hentz
Engineering Manager
Contra Costa Water District
2411 Bisso Lane - P.O. Box H2O
Concord, California 94524
Phone: 925-688-8311
Fax: 925-686-2187
Email: chentz@ccwater.com
Changes to Key Personnel require compliance with 43 CFR 12.70(d)(3).

8.2 Reclamation's Key Personnel

8.2.1 Grants Officer (GO):

Beverly S. Breen, MP-3828
U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
2800 Cottage Way, Room E-1815
Sacramento, California 95825-1898
Phone: (916) 978-5146
Email: bbreen@usbr.gov

(a) The GO is the only official with legal delegated authority to represent Reclamation. The GO's responsibilities include, but are not limited to, the following:

(1) Formally obligate Reclamation to expend funds or change the funding level of the Agreement;

(2) Approve through formal modification changes in the scope of work and/or budget;

(3) Approve through formal modification any increase or decrease in the period of performance of the Agreement;

(4) Approve through formal modification changes in any of the expressed terms, conditions, or specifications of the Agreement;

(5) Be responsible for the overall administration, management, and other non-programmatic aspects of the Agreement including, but not limited to, interpretation of financial assistance statutes, regulations, circulars, policies, and terms of the Agreement;

(6) Where applicable, ensures that Reclamation complies with the administrative requirements required by statutes, regulations, circulars, policies, and terms of the Agreement.

8.2.2 Grants Officer Technical Representative (GOTR):

Carl Dealy, TO 406
Bureau of Reclamation,
SCCAO, Tracy Office
16650 Kelso Road
Byron, California 94514-1909
Phone (925) 836-6236
Email: jcdealy@usbr.gov

(a) The GOTR's authority is limited to technical and programmatic aspects of the Agreement. The GOTR's responsibilities include, but are not limited to, the following:

(1) Assist the Recipient, as necessary, in interpreting and carrying out the scope of work in the Agreement;

(2) Review, and where required, approve Recipient reports and submittals as required by the Agreement;

(3) Where applicable, monitor the Recipient to ensure compliance with the technical requirements of the Agreement;

(4) Where applicable, ensure that Reclamation complies with the technical requirements of the Agreement;

(b) The GOTR does not have the authority to and may not issue any technical assistance which:

(1) Constitutes an assignment of additional work outside the scope of work of the Agreement;

(2) In any manner causes an increase or decrease in the total estimated cost or the time required for performance; or

(3) Changes any of the expressed terms, conditions, or specifications of the Agreement.

8.2.3 Grants Management Specialist. The Grants Management Specialist is the primary administrative point of contact for this agreement and should be contacted regarding issues related to the day-to-day management of the agreement. Requests for approval regarding the terms and conditions of the agreement, including but not limited to modifications and prior approval, may only be granted, in writing, by a Reclamation Grants Officer. Please note that for some agreements, the Grants Officer and the Grants Management Specialist may be the same individual.

Beverly S. Breen, MP-3828
U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
2800 Cottage Way, Room E-1815
Sacramento, California 95825-1898
Phone: (916) 978-5146
Email: bbreen@usbr.gov

9. REPORTING REQUIREMENTS AND DISTRIBUTION

9.1 Noncompliance. Failure to comply with the reporting requirements contained in this Agreement may be considered a material non-compliance with the terms and conditions of the award. Non compliance may result in withholding of payments pending receipt of required reports, denying both the use of funds and matching credit for all or part of the cost of the activity or action not in compliance, whole or partial suspension or termination of the Agreement, recovery of funds paid under the Agreement, withholding of future awards, or other legal remedies in accordance with 43 CFR §12.83.

9.2 Financial Reports. Financial Status Reports shall be submitted by means of the SF-425 and shall be submitted according to the Report Frequency and Distribution schedule below. All financial reports shall be signed by an Authorized Certifying Official for the Recipient's organization.

9.3 Monitoring and reporting program performance (43 CFR §12.80)

(a) *Monitoring by grantees.* Grantees are responsible for managing the day-to-day operations of grant and subgrant supported activities. Grantees must monitor grant and subgrant supported activities to assure compliance with applicable Federal requirements and that performance goals are being achieved. Grantee monitoring must cover each program, function or activity.

(b) *Nonconstruction performance reports.* The Federal agency may, if it decides that performance information available from subsequent applications contains sufficient information to meet its programmatic needs, require the grantee to submit a performance report only upon expiration or termination of grant support. Unless waived by the Federal agency this report will be due on the same date as the final Financial Status Report.

(1) Grantees shall submit annual performance reports unless the awarding agency requires quarterly or semi-annual reports. However, performance reports will not be required more frequently than quarterly. Annual reports shall be due 90 days after the grant year, quarterly or semi-annual reports shall be due 30 days after the reporting period. The final performance report will be due 90 days after the expiration or termination of grant support. If a justified request is submitted by a grantee, the Federal agency may extend the due date for any performance report. Additionally, requirements for unnecessary performance reports may be waived by the Federal agency.

(2) Performance reports will contain, for each grant, brief information on the following:

(i) A comparison of actual accomplishments to the objectives established for the period. Where the output of the project can be quantified, a computation of the cost per unit of output may be required if that information will be useful.

(ii) The reasons for slippage if established objectives were not met.

(iii) Additional pertinent information including, when appropriate, analysis and explanation of cost overruns or high unit costs.

(3) Grantees will not be required to submit more than the original and two copies of performance reports.

(4) Grantees will adhere to the standards in this section in prescribing performance reporting requirements for subgrantees.

(c) *Construction performance reports.* For the most part, on-site technical inspections and certified percentage-of-completion data are relied on heavily by Federal agencies to monitor progress under construction grants and subgrants. The Federal agency will require additional formal performance reports only when considered necessary, and never more frequently than quarterly.

(d) *Significant developments.* Events may occur between the scheduled performance reporting dates which have significant impact upon the grant or subgrant supported activity. In such cases, the grantee must inform the Federal agency as soon as the following types of conditions become known:

(1) Problems, delays, or adverse conditions which will materially impair the ability to meet the objective of the award. This disclosure must include a statement of the action taken, or contemplated, and any assistance needed to resolve the situation.

(2) Favorable developments which enable meeting time schedules and objectives sooner or at less cost than anticipated or producing more beneficial results than originally planned.

(e) Federal agencies may make site visits as warranted by program needs.

(f) *Waivers, extensions.*

(1) Federal agencies may waive any performance report required by this part if not needed.

(2) The grantee may waive any performance report from a subgrantee when not needed. The grantee may extend the due date for any performance report from a subgrantee if the grantee will still be able to meet its performance reporting obligations to the Federal agency.

9.4 Report Frequency and Distribution. The following table sets forth the reporting requirements for this Agreement. Please note the first report due date listed for each type of report.

Required Reports	Interim Reports	Final Report
Performance Report		
Format	No specific format required. See content requirements within Section 9.3 (43 CFR 12.80) above.	Summary of activities completed during the entire period of performance is required. See content requirements within Section 9.3 (43 CFR 12.80) above.
Reporting Frequency	Quarterly	Final Report due upon completion of Agreement's period of performance
Reporting Period	**Quarterly Reporting:** Federal fiscal quarters ending: December 31, March 31, June 30, September 30.	Entire period of performance
Due Date*	**Quarterly:** Within 30 days after the end of the Reporting Period.	Within 90 days after the completion date of the Agreement
First Report Due Date	The first performance report is due for reporting period ending December 31, 2014	N/A
Submit to:	Grants Management Specialist	Grants Management Specialist
Federal Financial Report		
Format	SF-425 (all sections must be completed)	SF-425(all sections must be completed)

Reporting Frequency	Quarterly	Final Report due upon completion of Agreement's period of performance
Reporting Period	**Quarterly Reporting:** Federal fiscal quarters ending: December 31, March 31, June 30, September 30.	Entire period of performance
Due Date*	**Quarterly:** Within 30 days after the end of the Reporting Period.	Within 90 days after the completion date of the Agreement
First Report Due Date	The first performance report is due for reporting period ending December 31, 2014	N/A
Submit to:	Grants Management Specialist	Grants Management Specialist

* If the completion date is prior to the end of the next reporting period, then no interim report is due for that period. Instead, the Recipient is required only to submit the final financial and performance reports, which will cover the entire period of performance including the last abbreviated reporting period.

10. REGULATORY COMPLIANCE

The Recipient agrees to comply or assist Reclamation with all regulatory compliance requirements and all applicable state, Federal, and local environmental and cultural and paleontological resource protection laws and regulations as applicable to this project. These may include, but are not limited to, the National Environmental Policy Act (NEPA), including the Council on Environmental Quality and Department of the Interior regulations implementing NEPA, the Clean Water Act, the Endangered Species Act, consultation with potentially affected Tribes, and consultation with the State Historic Preservation Office.

Certain environmental and other associated compliance are Federal responsibilities, and will occur as appropriate. Reclamation will identify the need for and will complete any appropriate environmental compliance requirements, as identified above, pertinent to Reclamation pursuant to activities specific to this assisted activity. Environmental and other associated compliance shall be completed prior to the start of this project. As such, notwithstanding any other provision of this Agreement, Reclamation shall not provide any funds to the Recipient for Agreement purposes, and the Recipient shall not begin implementation of the assisted activity described in this Agreement, until Reclamation provides written notice to the Recipient that all applicable environmental and regulatory compliance analyses and clearances have been completed and that the Recipient may begin implementation of the assisted activity. If the Recipient begins project activities that require environmental and other regulatory compliance approval, such as construction activities, prior to receipt of written notice from Reclamation that all such clearances have been obtained, then Reclamation reserves the right to unilaterally terminate this agreement for cause.

II. RECLAMATION STANDARD TERMS AND CONDITIONS - STATES, LOCAL GOVERNMENTS, AND FEDERALLY RECOGNIZED INDIAN TRIBAL GOVERNMENTS

1. REGULATIONS

The regulations at 43 CFR, Part 12, Subparts A, C, E, and F, are hereby incorporated by reference as though set forth in full text. The following Office of Management and Budget (OMB) Circulars, as applicable, and as implemented by 43 CFR Part 12, are also incorporated by reference and made a part of this Agreement. Failure of a Recipient to comply with any applicable regulation or circular may be the basis for withholding payments for proper charges made by the Recipient and/or for termination of support.

1.1 Colleges and Universities that are Recipients or sub-recipients shall use the following:

2 CFR Parts 215 and 220 (Circular A 21), "Cost Principles for Educational Institutions"

Circular A 110, as amended September 30, 1999, "Uniform Administrative Requirements for Grants and Agreements with Institutions of Higher Education, Hospitals, and Other Non-Profit Organizations" (Codification by Department of Interior, 43 CFR 12, Subpart F)

Circular A-133, revised June 27, 2003, "Audits of States, Local Governments, and Non-Profit Organizations"

1.2 State, Local and Tribal Governments that are Recipients or sub-recipients shall use the following:

2 CFR Part 225 (Circular A 87), "Cost Principles for State, Local, and Indian Tribal Governments"

Circular A 102, as amended August 29, 1997, "Grants and Cooperative Agreements with State and Local Governments" (Grants Management Common Rule, Codification by Department of Interior, 43 CFR 12, Subpart C)

Circular A-133, revised June 27, 2003, Audits of States, Local Governments, and Non-Profit Organizations"

1.3 Nonprofit Organizations that are Recipients or sub-recipients shall use the following:

2 CFR Part 230 (Circular A 122), "Cost Principles for Non-Profit Organizations"

Circular A 110, as amended September 30, 1999, "Uniform Administrative Requirements for Grants and Agreements With Institutions of Higher Education, Hospitals, and Other Non-Profit Organizations" (Codification by Department of Interior, 43 CFR 12, Subpart F)

Circular A-133, revised June 27, 2003, "Audits of States, Local Governments, and Non-Profit Organizations"

1.4 Organizations other than those indicated above that are Recipients or sub-recipients shall use the basic principles of OMB Circular A-110 (Codification by Department of Interior, 43 CFR 12, Subpart F), and cost principles shall be in accordance with 48 CFR Subpart 31.2.

1.5 43 CFR 12.77 sets forth further regulations that govern the award and administration of subawards by State governments.

2. PAYMENT

2.1 Payment Standards. (43 CFR §12.61)

(a) *Scope.* This section prescribes the basic standard and the methods under which a Federal agency will make payments to grantees, and grantees will make payments to subgrantees and contractors.

(b) *Basic standard.* Methods and procedures for payment shall minimize the time elapsing between the transfer of funds and disbursement by the grantee or subgrantee, in accordance with Treasury regulations at 31 CFR part 205.

(c) *Advances.* Grantees and subgrantees shall be paid in advance, provided they maintain or demonstrate the willingness and ability to maintain procedures to minimize the time elapsing between the transfer of the funds and their disbursement by the grantee or subgrantee.

(d) *Reimbursement.* Reimbursement shall be the preferred method when the requirements in paragraph (c) of this section are not met. Grantees and subgrantees may also be paid by reimbursement for any construction grant. Except as otherwise specified in regulation, Federal agencies shall not use the percentage of completion method to pay construction grants. The grantee or subgrantee may use that method to pay its construction contractor, and if it does, the awarding agency's payments to the grantee or subgrantee will be based on the grantee's or subgrantee's actual rate of disbursement.

(e) *Working capital advances.* If a grantee cannot meet the criteria for advance payments described in paragraph (c) of this section, and the Federal agency has determined that reimbursement is not feasible because the grantee lacks sufficient working capital, the awarding agency may provide cash or a working capital advance basis. Under this procedure the awarding agency shall advance cash to the grantee to cover its estimated disbursement needs for an initial period generally geared to the grantee's disbursing cycle. Thereafter, the awarding agency shall reimburse the grantee for its actual cash disbursements. The working capital advance method of payment shall not be used by grantees or subgrantees if the reason for using such method is the unwillingness or inability of the grantee to provide timely advances to the subgrantee to meet the subgrantee's actual cash disbursements.

(f) *Effect of program income, refunds, and audit recoveries on payment.*

(1) Grantees and subgrantees shall disburse repayments to and interest earned on a revolving fund before requesting additional cash payments for the same activity.

(2) Except as provided in paragraph (f)(1) of this section, grantees and subgrantees shall disburse program income, rebates, refunds, contract settlements, audit recoveries and interest earned on such funds before requesting additional cash payments.

(g) *Withholding payments.*

(1) Unless otherwise required by Federal statute, awarding agencies shall not withhold payments for proper charges incurred by grantees or subgrantees unless—

(i) The grantee or subgrantee has failed to comply with grant award conditions, or

(ii) The grantee or subgrantee is indebted to the United States.

(2) Cash withheld for failure to comply with grant award condition, but without suspension of the grant, shall be released to the grantee upon subsequent compliance. When a grant is suspended, payment adjustments will be made in accordance with §12.83(c).

(3) A Federal agency shall not make payment to grantees for amounts that are withheld by grantees or subgrantees from payment to contractors to assure satisfactory completion of work. Payments shall be made by the Federal agency when the grantees or subgrantees actually disburse the withheld funds to the contractors or to escrow accounts established to assure satisfactory completion of work.

(h) *Cash depositories.*

(1) Consistent with the national goal of expanding the opportunities for minority business enterprises, grantees and subgrantees are encouraged to use minority banks (a bank which is owned at least 50 percent by minority group members). A list of minority owned banks can be obtained from the Minority Business Development Agency, Department of Commerce, Washington, DC 20230.

(2) A grantee or subgrantee shall maintain a separate bank account only when required by Federal-State Agreement.

(i) *Interest earned on advances.* Except for interest earned on advances of funds exempt under the Intergovernmental Cooperation Act (31 U.S.C. 6501 et seq.) and the Indian Self-Determination Act (23 U.S.C. 450), grantees and subgrantees shall promptly, but at least quarterly, remit interest earned on advances to the Federal agency. The grantee or subgrantee may keep interest amounts up to $100 per year for administrative expenses.

2.2 Payment Method

Recipients must utilize the Department of Treasury Automated Standard Application for Payments (ASAP) payment system to request advance or reimbursement payments. ASAP is a Recipient-initiated payment and information system designed to provide a single point of contact for the request and delivery of Federal funds. ASAP is the only allowable method for request and receipt of payment. Recipient procedures must minimize the time elapsing between the drawdown of Federal funds and the disbursement for agreement purposes.

Recipients must complete enrollment in ASAP for all active financial assistance agreements with Reclamation. ASAP enrollment is specific to each Agency and Bureau; meaning, if a Recipient organization has an existing ASAP account with another Federal agency or Department of the Interior bureau, but not with Reclamation, then the Recipient must initiate and complete enrollment in ASAP under Reclamation's Agency Location Code (1425) through submission of an enrollment form found at www.usbr.gov/mso/aamd/asap.html. For information regarding ASAP enrollment, please visit www.usbr.gov/mso/aamd/asap.html, or contact the Reclamation ASAP Help Desk BOR_ASAP_Enroll@usbr.gov. Further information regarding ASAP may be obtained from the ASAP website at http://www.fms.treas.gov/asap.

3. PROCUREMENT STANDARDS (43 CFR §12.76)

(a) *States.* When procuring property and services under a grant, a state will follow the same policies and procedures it uses for procurements from its non-Federal funds. The state will ensure that every purchase order or other contract includes any clauses required by Federal statutes and executive orders and their implementing regulations. Other grantees and subgrantees will follow paragraphs (b) through (i) in this section.

(b) *Procurement standards.*

(1) Grantees and subgrantees will use their own procurement procedures which reflect applicable State and local laws and regulations, provided that the procurements conform to applicable Federal law and the standards identified in this section.

(2) Grantees and subgrantees will maintain a contract administration system which ensures that contractors perform in accordance with the terms, conditions, and specifications of their contracts or purchase orders.

(3) Grantees and subgrantees will maintain a written code of standards of conduct governing the performance of their employees engaged in the award and administration of contracts. No employee, officer or agent of the grantee or subgrantee shall participate in selection, or in the award or administration of a contract supported by Federal funds if a conflict of interest, real or apparent, would be involved. Such a conflict would arise when:

(i) The employee, officer or agent,

(ii) Any member of his immediate family,

(iii) His or her partner, or

(iv) An organization which employs, or is about to employ, any of the above, has a financial or other interest in the firm selected for award. The grantee's or subgrantee's officers, employees or agents will neither solicit nor accept gratuities, favors or anything of monetary value from contractors, potential contractors, or parties to subagreements. Grantee and subgrantees may set minimum rules where the financial interest is not substantial or the gift is an unsolicited item of nominal intrinsic value. To the extent permitted by State or local law or regulations, such standards or conduct will provide for penalties, sanctions, or other disciplinary actions for violations of such standards by the grantee's and subgrantee's officers, employees, or agents, or by contractors or their agents. The awarding agency may in regulation provide additional prohibitions relative to real, apparent, or potential conflicts of interest.

(4) Grantee and subgrantee procedures will provide for a review of proposed procurements to avoid purchase of unnecessary or duplicative items. Consideration should be given to consolidating or breaking out procurements to obtain a more economical purchase. Where appropriate, an analysis will be made of lease versus purchase alternatives, and any other appropriate analysis to determine the most economical approach.

(5) To foster greater economy and efficiency, grantees and subgrantees are encouraged to enter into State and local intergovernmental agreements for procurement or use of common goods and services.

(6) Grantees and subgrantees are encouraged to use Federal excess and surplus property in lieu of purchasing new equipment and property whenever such use is feasible and reduces project costs.

(7) Grantees and subgrantees are encouraged to use value engineering clauses in contracts for construction projects of sufficient size to offer reasonable opportunities for cost reductions. Value engineering is a systematic and creative analysis of each contract item or task to ensure that its essential function is provided at the overall lower cost.

(8) Grantees and subgrantees will make awards only to responsible contractors possessing the ability to perform successfully under the terms and conditions of a proposed procurement. Consideration will be given to such matters as contractor integrity, compliance with public policy, record of past performance, and financial and technical resources.

(9) Grantees and subgrantees will maintain records sufficient to detail the significant history of a procurement. These records will include, but are not necessarily limited to the following: rationale for the method of procurement, selection of contract type, contractor selection or rejection, and the basis for the contract price.

(10) Grantees and subgrantees will use time and material type contracts only—

(i) After a determination that no other contract is suitable, and

(ii) If the contract includes a ceiling price that the contractor exceeds at its own risk.

(11) Grantees and subgrantees alone will be responsible, in accordance with good administrative practice and sound business judgment, for the settlement of all contractual and administrative issues arising out of procurements. These issues include, but are not limited to source evaluation, protests, disputes, and claims. These standards do not relieve the grantee or subgrantee of any contractual responsibilities under its contracts. Federal agencies will not substitute their judgment for that of the grantee or subgrantee unless the matter is primarily a Federal concern. Violations of law will be referred to the local, State, or Federal authority having proper jurisdiction.

(12) Grantees and subgrantees will have protest procedures to handle and resolve disputes relating to their procurements and shall in all instances disclose information regarding the protest to the awarding agency. A protestor must exhaust all administrative remedies with the grantee and subgrantee before pursuing a protest with the Federal agency. Reviews of protests by the Federal agency will be limited to:

(i) Violations of Federal law or regulations and the standards of this section (violations of State or local law will be under the jurisdiction of State or local authorities) and

(ii) Violations of the grantee's or subgrantee's protest procedures for failure to review a complaint or protest. Protests received by the Federal agency other than those specified above will be referred to the grantee or subgrantee.

(c) *Competition.*

(1) All procurement transactions will be conducted in a manner providing full and open competition consistent with the standards of §12.76. Some of the situations considered to be restrictive of competition include but are not limited to:

(i) Placing unreasonable requirements on firms in order for them to qualify to do business,

(ii) Requiring unnecessary experience and excessive bonding,

(iii) Noncompetitive pricing practices between firms or between affiliated companies,

(iv) Noncompetitive awards to consultants that are on retainer contracts,

(v) Organizational conflicts of interest,

(vi) Specifying only a "brand name" product instead of allowing "an equal" product to be offered and describing the performance of other relevant requirements of the procurement, and

(vii) Any arbitrary action in the procurement process.

(2) Grantees and subgrantees will conduct procurements in a manner that prohibits the use of statutorily or administratively imposed in-State or local geographical preferences in the evaluation of bids or proposals, except in those cases where applicable Federal statutes expressly mandate or encourage geographic preference. Nothing in this section preempts State licensing laws. When contracting for architectural and engineering (A/E) services, geographic location may be a selection criteria provided its application leaves an appropriate number of qualified firms, given the nature and size of the project, to compete for the contract.

(3) Grantees will have written selection procedures for procurement transactions. These procedures will ensure that all solicitations:

(i) Incorporate a clear and accurate description of the technical requirements for the material, product, or service to be procured. Such description shall not, in competitive procurements, contain features which unduly restrict competition. The description may include a statement of the qualitative nature of the material, product or service to be procured, and when necessary, shall set forth those minimum essential characteristics and standards to which it must conform if it is to satisfy its intended use. Detailed product specifications should be avoided if at all possible. When it is impractical or uneconomical to make a clear and accurate description of the technical requirements, a "brand name or equal" description may be used as a means to define the performance or other salient requirements of a procurement. The specific features of the named brand which must be met by offerors shall be clearly stated; and

(ii) Identify all requirements which the offerors must fulfill and all other factors to be used in evaluating bids or proposals.

(4) Grantees and subgrantees will ensure that all prequalified lists of persons, firms, or products which are used in acquiring goods and services are current and include enough qualified sources to ensure maximum open and free competition. Also, grantees and subgrantees will not preclude potential bidders from qualifying during the solicitation period.

(d) *Methods of procurement to be followed* —(1) *Procurement by small purchase procedures.* Small purchase procedures are those relatively simple and informal procurement methods for securing services, supplies, or other property that do not cost more than the simplified acquisition threshold fixed at 41 U.S.C. 403(11) (currently set at $150,000). If small purchase procedures are used, price or rate quotations shall be obtained from an adequate number of qualified sources.

(2) Procurement by *sealed bids* (formal advertising). Bids are publicly solicited and a firm-fixed-price contract (lump sum or unit price) is awarded to the responsible bidder whose bid, conforming with all the material terms and conditions of the invitation for bids, is the lowest in price. The sealed bid method is the preferred method for procuring construction, if the conditions in §12.76(d)(2)(i) apply.

(i) In order for sealed bidding to be feasible, the following conditions should be present:

(A) A complete, adequate, and realistic specification or purchase description is available;

(B) Two or more responsible bidders are willing and able to compete effectively and for the business; and

(C) The procurement lends itself to a firm fixed price contract and the selection of the successful bidder can be made principally on the basis of price.

(ii) If sealed bids are used, the following requirements apply:

(A) The invitation for bids will be publicly advertised and bids shall be solicited from an adequate number of known suppliers, providing them sufficient time prior to the date set for opening the bids;

(B) The invitation for bids, which will include any specifications and pertinent attachments, shall define the items or services in order for the bidder to properly respond;

(C) All bids will be publicly opened at the time and place prescribed in the invitation for bids;

(D) A firm fixed-price contract award will be made in writing to the lowest responsive and responsible bidder. Where specified in bidding documents, factors such as discounts, transportation cost, and life cycle costs shall be considered in determining which bid is lowest. Payment discounts will only be used to determine the low bid when prior experience indicates that such discounts are usually taken advantage of; and

(E) Any or all bids may be rejected if there is a sound documented reason.

(3) Procurement by *competitive proposals*. The technique of competitive proposals is normally conducted with more than one source submitting an offer, and either a fixed-price or cost-reimbursement type contract is awarded. It is generally used when conditions are not appropriate for the use of sealed bids. If this method is used, the following requirements apply:

(i) Requests for proposals will be publicized and identify all evaluation factors and their relative importance. Any response to publicized requests for proposals shall be honored to the maximum extent practical;

(ii) Proposals will be solicited from an adequate number of qualified sources;

(iii) Grantees and subgrantees will have a method for conducting technical evaluations of the proposals received and for selecting awardees;

(iv) Awards will be made to the responsible firm whose proposal is most advantageous to the program, with price and other factors considered; and

(v) Grantees and subgrantees may use competitive proposal procedures for qualifications-based procurement of architectural/engineering (A/E) professional services whereby competitors' qualifications are evaluated and the most qualified competitor is selected, subject to negotiation of fair and reasonable compensation. The method, where price is not used as a selection factor, can only be used in procurement of A/E professional services. It cannot be used to purchase other types of services though A/E firms are a potential source to perform the proposed effort.

(4) Procurement by *noncompetitive proposals* is procurement through solicitation of a proposal from only one source, or after solicitation of a number of sources, competition is determined inadequate.

(i) Procurement by noncompetitive proposals may be used only when the award of a contract is infeasible under small purchase procedures, sealed bids or competitive proposals and one of the following circumstances applies:

(A) The item is available only from a single source;

(B) The public exigency or emergency for the requirement will not permit a delay resulting from competitive solicitation;

(C) The awarding agency authorizes noncompetitive proposals; or

(D) After solicitation of a number of sources, competition is determined inadequate.

(ii) Cost analysis, i.e., verifying the proposed cost data, the projections of the data, and the evaluation of the specific elements of costs and profits, is required.

(iii) Grantees and subgrantees may be required to submit the proposed procurement to the awarding agency for pre-award review in accordance with paragraph (g) of this section.

(e) *Contracting with small and minority firms, women's business enterprise and labor surplus area firms.* (1) The grantee and subgrantee will take all necessary affirmative steps to assure that minority firms, women's business enterprises, and labor surplus area firms are used when possible.

(2) Affirmative steps shall include:

(i) Placing qualified small and minority businesses and women's business enterprises on solicitation lists;

(ii) Assuring that small and minority businesses, and women's business enterprises are solicited whenever they are potential sources;

(iii) Dividing total requirements, when economically feasible, into smaller tasks or quantities to permit maximum participation by small and minority business, and women's business enterprises;

(iv) Establishing delivery schedules, where the requirement permits, which encourage participation by small and minority business, and women's business enterprises;

(v) Using the services and assistance of the Small Business Administration, and the Minority Business Development Agency of the Department of Commerce; and

(vi) Requiring the prime contractor, if subcontracts are to be let, to take the affirmative steps listed in paragraphs (e)(2) (i) through (v) of this section.

(f) *Contract cost and price.*

(1) Grantees and subgrantees must perform a cost or price analysis in connection with every procurement action including contract modifications. The method and degree of analysis is dependent on the facts surrounding the particular procurement situation, but as a starting point, grantees must make independent estimates before receiving bids or proposals. A cost analysis must be performed when the offeror is required to submit the elements of his estimated cost, e.g., under professional, consulting, and architectural engineering services contracts. A cost analysis will be necessary when adequate price competition is lacking, and for sole source procurements, including contract modifications or change orders, unless price reasonableness can be established on the basis of a catalog or market price of a commercial product sold in substantial quantities to the general public or based on prices set by law or regulation. A price analysis will be used in all other instances to determine the reasonableness of the proposed contract price.

(2) Grantees and subgrantees will negotiate profit as a separate element of the price for each contract in which there is no price competition and in all cases where cost analysis is performed. To establish a fair and reasonable profit, consideration will be given to the complexity of the work to be performed, the risk borne by the contractor, the contractor's investment, the amount of subcontracting, the quality of its record of past performance, and industry profit rates in the surrounding geographical area for similar work.

(3) Costs or prices based on estimated costs for contracts under grants will be allowable only to the extent that costs incurred or cost estimates included in negotiated prices are consistent with Federal cost principles (see §12.62). Grantees may reference their own cost principles that comply with the applicable Federal cost principles.

(4) The cost plus a percentage of cost and percentage of construction cost methods of contracting shall not be used.

(g) *Awarding agency review.*

(1) Grantees and subgrantees must make available, upon request of the awarding agency, technical specifications on proposed procurements where the awarding agency believes such review is needed to ensure that the item and/or service specified is the one being proposed for purchase. This review generally will take place prior to the time the specification is incorporated into a solicitation document. However, if the grantee or subgrantee desires to have the review accomplished after a solicitation has been developed, the awarding agency may still review the specifications, with such review usually limited to the technical aspects of the proposed purchase.

(2) Grantees and subgrantees must on request make available for awarding agency pre-award review procurement documents, such as requests for proposals or invitations for bids, independent cost estimates, etc. when:

(i) A grantee's or subgrantee's procurement procedures or operation fails to comply with the procurement standards in this section; or

(ii) The procurement is expected to exceed the simplified acquisition threshold and is to be awarded without competition or only one bid or offer is received in response to a solicitation; or

(iii) The procurement, which is expected to exceed the simplified acquisition threshold, specifies a "brand name" product; or

(iv) The proposed award is more than the simplified acquisition threshold and is to be awarded to other than the apparent low bidder under a sealed bid procurement; or

(v) A proposed contract modification changes the scope of a contract or increases the contract amount by more than the simplified acquisition threshold.

(3) A grantee or subgrantee will be exempt from the pre-award review in paragraph (g)(2) of this section if the awarding agency determines that its procurement systems comply with the standards of this section.

(i) A grantee or subgrantee may request that its procurement system be reviewed by the awarding agency to determine whether its system meets these standards in order for its system to be certified. Generally, these reviews shall occur where there is a continuous high-dollar funding, and third-party contracts are awarded on a regular basis.

(ii) A grantee or subgrantee may self-certify its procurement system. Such self-certification shall not limit the awarding agency's right to survey the system. Under a self-certification procedure, awarding agencies may wish to rely on written assurances from the grantee or subgrantee that it is complying with these standards. A grantee or subgrantee will cite specific procedures, regulations, standards, etc., as being in compliance with these requirements and have its system available for review.

(h) *Bonding requirements.* For construction or facility improvement contracts or subcontracts exceeding the simplified acquisition threshold, the awarding agency may accept the bonding policy and requirements of the grantee or subgrantee provided the awarding agency has made a determination that the awarding agency's interest is adequately protected. If such a determination has not been made, the minimum requirements shall be as follows:

(1) *A bid guarantee from each bidder equivalent to five percent of the bid price.* The "bid guarantee" shall consist of a firm commitment such as a bid bond, certified check, or other negotiable instrument accompanying a bid as assurance that the bidder will, upon acceptance of his bid, execute such contractual documents as may be required within the time specified.

(2) *A performance bond on the part of the contractor for 100 percent of the contract price.* A "performance bond" is one executed in connection with a contract to secure fulfillment of all the contractor's obligations under such contract.

(3) *A payment bond on the part of the contractor for 100 percent of the contract price.* A "payment bond" is one executed in connection with a contract to assure payment as required by law of all persons supplying labor and material in the execution of the work provided for in the contract.

(i) *Contract provisions.* A grantee's and subgrantee's contracts must contain provisions in paragraph (i) of this section. Federal agencies are permitted to require changes, remedies, changed conditions, access and records retention, suspension of work, and other clauses approved by the Office of Federal Procurement Policy.

(1) Administrative, contractual, or legal remedies in instances where contractors violate or breach contract terms, and provide for such sanctions and penalties as may be appropriate. (Contracts more than the simplified acquisition threshold.)

(2) Termination for cause and for convenience by the grantee or subgrantee including the manner by which it will be effected and the basis for settlement. (All contracts in excess of $10,000.)

(3) Compliance with Executive Order 11246 of September 24, 1965, entitled "Equal Employment Opportunity," as amended by Executive Order 11375 of October 13, 1967, and as supplemented in Department of Labor regulations (41 CFR chapter 60). (All construction contracts awarded in excess of $10,000 by grantees and their contractors or subgrantees.)

(4) Compliance with the Copeland "Anti-Kickback" Act (18 U.S.C. 874) as supplemented in Department of Labor regulations (29 CFR Part 3). (All contracts and subgrants for construction or repair.)

(5) Compliance with the Davis-Bacon Act (40 U.S.C. 276a to 276a–7) as supplemented by Department of Labor regulations (29 CFR Part 5). (Construction contracts in excess of $2000 awarded by grantees and subgrantees when required by Federal grant program legislation.)

(6) Compliance with Sections 103 and 107 of the Contract Work Hours and Safety Standards Act (40 U.S.C. 327–330) as supplemented by Department of Labor regulations (29 CFR Part 5). (Construction contracts awarded by grantees and subgrantees in excess of $2000, and in excess of $2500 for other contracts which involve the employment of mechanics or laborers.)

(7) Notice of awarding agency requirements and regulations pertaining to reporting.

(8) Notice of awarding agency requirements and regulations pertaining to patent rights with respect to any discovery or invention which arises or is developed in the course of or under such contract.

(9) Awarding agency requirements and regulations pertaining to copyrights and rights in data.

(10) Access by the grantee, the subgrantee, the Federal grantor agency, the Comptroller General of the United States, or any of their duly authorized representatives to any books, documents, papers, and records of the contractor which are directly pertinent to that specific contract for the purpose of making audit, examination, excerpts, and transcriptions.

(11) Retention of all required records for three years after grantees or subgrantees make final payments and all other pending matters are closed.

(12) Compliance with all applicable standards, orders, or requirements issued under section 306 of the Clean Air Act (42 U.S.C. 1857(h)), section 508 of the Clean Water Act (33 U.S.C. 1368), Executive Order 11738, and Environmental Protection Agency regulations (40 CFR part 15). (Contracts, subcontracts, and subgrants of amounts in excess of $100,000.)

(13) Mandatory standards and policies relating to energy efficiency which are contained in the State energy conservation plan issued in compliance with the Energy Policy and Conservation Act (Pub. L. 94–163, 89 Stat. 871).

4. EQUIPMENT (43 CFR §12.72)

(a) *Title.* Subject to the obligations and conditions set forth in this section, title to equipment acquired under a grant or subgrant will vest upon acquisition in the grantee or subgrantee respectively.

(b) *States.* A State will use, manage, and dispose of equipment acquired under a grant by the State in accordance with State laws and procedures. Other grantees and subgrantees will follow paragraphs (c) through (e) of this section.

(c) *Use.*

(1) Equipment shall be used by the grantee or subgrantee in the program or project for which it was acquired as long as needed, whether or not the project or program continues to be supported by Federal funds. When no longer needed for the original program or project, the equipment may be used in other activities currently or previously supported by a Federal agency.

(2) The grantee or subgrantee shall also make equipment available for use on other projects or programs currently or previously supported by the Federal Government, providing such use will not interfere with the work on the projects or program for which it was originally acquired. First preference for other use shall be given to other programs or projects supported by the awarding agency. User fees should be considered if appropriate.

(3) Notwithstanding the encouragement in §12.65(a) to earn program income, the grantee or subgrantee must not use equipment acquired with grant funds to provide services for a fee to compete unfairly with private companies that provide equivalent services, unless specifically permitted or contemplated by Federal statute.

(4) When acquiring replacement equipment, the grantee or subgrantee may use the equipment to be replaced as a trade-in or sell the property and use the proceeds to offset the cost of the replacement property, subject to the approval of the awarding agency.

(d) *Management requirements.* Procedures for managing equipment (including replacement equipment), whether acquired in whole or in part with grant funds, until disposition takes place will, as a minimum, meet the following requirements:

(1) Property records must be maintained that include a description of the property, a serial number or other identification number, the source of property, who holds title, the acquisition date, and cost of the property, percentage of Federal participation in the cost of the property, the location, use and condition of the property, and any ultimate disposition data including the date of disposal and sale price of the property.

(2) A physical inventory of the property must be taken and the results reconciled with the property records at least once every two years.

(3) A control system must be developed to ensure adequate safeguards to prevent loss, damage, or theft of the property. Any loss, damage, or theft shall be investigated.

(4) Adequate maintenance procedures must be developed to keep the property in good condition.

(5) If the grantee or subgrantee is authorized or required to sell the property, proper sales procedures must be established to ensure the highest possible return.

(e) *Disposition.* When original or replacement equipment acquired under a grant or subgrant is no longer needed for the original project or program or for other activities currently or previously supported by a Federal agency, disposition of the equipment will be made as follows:

(1) Items of equipment with a current per-unit fair market value of less than $5,000 may be retained, sold or otherwise disposed of with no further obligation to the awarding agency.

(2) Items of equipment with a current per unit fair market value in excess of $5,000 may be retained or sold and the awarding agency shall have a right to an amount calculated by multiplying the current market value or proceeds from sale by the awarding agency's share of the equipment.

(3) In cases where a grantee or subgrantee fails to take appropriate disposition actions, the awarding agency may direct the grantee or subgrantee to take excess and disposition actions.

(f) *Federal equipment.* In the event a grantee or subgrantee is provided Federally-owned equipment:

(1) Title will remain vested in the Federal Government.

(2) Grantees or subgrantees will manage the equipment in accordance with Federal agency rules and procedures, and submit an annual inventory listing.

(3) When the equipment is no longer needed, the grantee or subgrantee will request disposition instructions from the Federal agency.

(g) *Right to transfer title.* The Federal awarding agency may reserve the right to transfer title to the Federal Government or a third part named by the awarding agency when such a third party is otherwise eligible under existing statutes. Such transfers shall be subject to the following standards:

(1) The property shall be identified in the grant or otherwise made known to the grantee in writing.

(2) The Federal awarding agency shall issue disposition instruction within 120 calendar days after the end of the Federal support of the project for which it was acquired. If the Federal awarding agency fails to issue disposition instructions within the 120 calendar-day period the grantee shall follow 12.72(e).

(3) When title to equipment is transferred, the grantee shall be paid an amount calculated by applying the percentage of participation in the purchase to the current fair market value of the property.

5. SUPPLIES (43 CFR §12.73)

(a) *Title.* Title to supplies acquired under a grant or subgrant will vest, upon acquisition, in the grantee or subgrantee respectively.

(b) *Disposition.* If there is a residual inventory of unused supplies exceeding $5,000 in total aggregate fair market value upon termination or completion of the award, and if the supplies are not needed for any other Federally sponsored programs or projects, the grantee or subgrantee shall compensate the awarding agency for its share.

6. INSPECTION

Reclamation has the right to inspect and evaluate the work performed or being performed under this Agreement, and the premises where the work is being performed, at all reasonable times and in a manner that will not unduly delay the work. If Reclamation performs inspection or evaluation on the premises of the Recipient or a sub-Recipient, the Recipient shall furnish and shall require sub-recipients to furnish all reasonable facilities and assistance for the safe and convenient performance of these duties.

7. AUDIT (31 U.S.C. 7501-7507)

Non-Federal entities that expend $500,000 or more in a year in Federal awards shall have a single or program-specific audit conducted for that year in accordance with the Single Audit Act Amendments of 1996 (31 U.S.C. 7501-7507) and revised OMB Circular A-133. Federal awards are defined as Federal financial assistance and Federal cost-reimbursement contracts that non-Federal entities receive directly from Federal awarding agencies or indirectly from pass-through entities. They do not include procurement contracts, under grants or contracts, used to buy goods or services from vendors. Non-Federal entities that expend less than $500,000 a year in Federal awards are exempt from Federal audit requirements for that year, except as noted in A-133, §___.215(a), but records must be available for review or audit by appropriate officials of the Federal agency, pass-through entity, and General Accounting Office (GAO).

8. ENFORCEMENT (43 CFR §12.83)

(a) *Remedies for noncompliance.* If a grantee or subgrantee materially fails to comply with any term of an award, whether stated in a Federal statute or regulation, an assurance, in a State plan or application, a notice of award, or elsewhere, the awarding agency may take one or more of the following actions, as appropriate in the circumstances:

(1) Temporarily withhold cash payments pending correction of the deficiency by the grantee or subgrantee or more severe enforcement action by the awarding agency,

(2) Disallow (that is, deny both use of funds and matching credit for) all or part of the cost of the activity or action not in compliance,

(3) Wholly or partly suspend or terminate the current award for the grantee's or subgrantee's program,

(4) Withhold further awards for the program, or

(5) Take other remedies that may be legally available.

(b) *Hearings, appeals.* In taking an enforcement action, the awarding agency will provide the grantee or subgrantee an opportunity for such hearing, appeal, or other administrative proceeding to which the grantee or subgrantee is entitled under any statute or regulation applicable to the action involved.

(c) *Effects of suspension and termination.* Costs of grantee or subgrantee resulting from obligations incurred by the grantee or subgrantee during a suspension or after termination of an award are not allowable unless the awarding agency expressly authorizes them in the notice of suspension or termination or subsequently. Other grantee or subgrantee costs during suspension or after termination which are necessary and not reasonably avoidable are allowable if:

(1) The costs result from obligations which were properly incurred by the grantee or subgrantee before the effective date of suspension or termination, are not in anticipation of it, and, in the case of a termination, are noncancellable, and,

(2) The costs would be allowable if the award were not suspended or expired normally at the end of the funding period in which the termination takes effect.

(d) *Relationship to Debarment and Suspension.* The enforcement remedies identified in this section, including suspension and termination, do not preclude grantee or subgrantee from being subject to "Debarment and Suspension" under E.O. 12549 (2 CFR 29.5.12 and 2 CFR 1400, Subpart C).

9. TERMINATION FOR CONVENIENCE (43 CFR §12.84)

Except as provided in 43 CFR §12.83 awards may be terminated in whole or in part only as follows:

(a) By the awarding agency with the consent of the grantee or subgrantee in which case the two parties shall agree upon the termination conditions, including the effective date and in the case of partial termination, the portion to be terminated, or

(b) By the grantee or subgrantee upon written notification to the awarding agency, setting forth the reasons for such termination, the effective date, and in the case of partial termination, the portion to be terminated. However, if, in the case of a partial termination, the awarding agency determines that the remaining portion of the award will not accomplish the purposes for which the award was made, the awarding agency may terminate the award in its entirety under either §12.83 or paragraph (a) of this section.

10. DEBARMENT AND SUSPENSION (2 CFR §1400)

The Department of the Interior regulations at 2 CFR 1400—Governmentwide Debarment and Suspension (Nonprocurement), which adopt the common rule for the governmentwide system of debarment and suspension for nonprocurement activities, are hereby incorporated by reference and made a part of this Agreement. By entering into this grant or cooperative Agreement with the Bureau of Reclamation, the Recipient agrees to comply with 2 CFR 1400, Subpart C, and agrees to include a similar term or condition in all lower-tier covered transactions. These regulations are available at http://www.gpoaccess.gov/ecfr/.

11. DRUG-FREE WORKPLACE (2 CFR §182 and §1401)

The Department of the Interior regulations at 2 CFR 1401—Governmentwide Requirements for Drug-Free Workplace (Financial Assistance), which adopt the portion of the Drug-Free Workplace Act of 1988 (41 U.S.C. 701 et seq, as amended) applicable to grants and cooperative agreements, are hereby incorporated by reference and made a part of this agreement. By entering into this grant or cooperative agreement with the Bureau of Reclamation, the Recipient agrees to comply with 2 CFR 182.

12. ASSURANCES AND CERTIFICATIONS INCORPORATED BY REFERENCE

The provisions of the Assurances, SF 424B or SF 424D as applicable, executed by the Recipient in connection with this Agreement shall apply with full force and effect to this Agreement. All anti-discrimination and equal opportunity statutes, regulations, and Executive Orders that apply to the expenditure of funds under Federal contracts, grants, and cooperative Agreements, loans, and other forms of Federal assistance. The Recipient shall comply with Title VI or the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, Section 504 of the Rehabilitation Act of 1973, the Age Discrimination Act of 1975, and any program-specific statutes with anti-discrimination requirements. The Recipient shall comply with civil rights laws including, but not limited to, the Fair Housing Act, the Fair Credit Reporting Act, the Americans with Disabilities Act, Title VII of the Civil Rights Act of 1964, the Equal Educational Opportunities Act, the Age Discrimination in Employment Act, and the Uniform Relocation Act.

Such Assurances also include, but are not limited to, the promise to comply with all applicable Federal statutes and orders relating to nondiscrimination in employment, assistance, and housing; the Hatch Act; Federal wage and hour laws and regulations and work place safety standards; Federal environmental laws and regulations and the Endangered Species Act; and Federal protection of rivers and waterways and historic and archeological preservation.

13. COVENANT AGAINST CONTINGENT FEES

The Recipient warrants that no person or agency has been employed or retained to solicit or secure this Agreement upon an Agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide offices established and maintained by the Recipient for the purpose of securing Agreements or business. For breach or violation of this warranty, the Government shall have the right to annul this Agreement without liability or, in its discretion, to deduct from the Agreement amount, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

14. TRAFFICKING VICTIMS PROTECTION ACT OF 2000 (2 CFR §175.15)

Trafficking in persons.

(a) *Provisions applicable to a recipient that is a private entity.*

(1) You as the recipient, your employees, subrecipients under this award, and subrecipients' employees may not

(i) Engage in severe forms of trafficking in persons during the period of time that the award is in effect;

(ii) Procure a commercial sex act during the period of time that the award is in effect; or

(iii) Use forced labor in the performance of the award or subawards under the award.

(2) We as the Federal awarding agency may unilaterally terminate this award, without penalty, if you or a subrecipient that is a private entity —

(i) Is determined to have violated a prohibition in paragraph a.1 of this award term; or

(ii) Has an employee who is determined by the agency official authorized to terminate the award to have violated a prohibition in paragraph a.1 of this award term through conduct that is either:

(A) Associated with performance under this award; or

(B) Imputed to you or the subrecipient using the standards and due process for imputing the conduct of an individual to an organization that are provided in 2 CFR part 180, "OMB Guidelines to Agencies on Governmentwide Debarment and Suspension (Nonprocurement)," as implemented by our agency at *2 CFR part 1400.*

(b) *Provision applicable to a recipient other than a private entity.* We as the Federal awarding agency may unilaterally terminate this award, without penalty, if a subrecipient that is a private entity—

(1) Is determined to have violated an applicable prohibition in paragraph a.1 of this award term; or

(2) Has an employee who is determined by the agency official authorized to terminate the award to have violated an applicable prohibition in paragraph a.1 of this award term through conduct that is either:

(i) Associated with performance under this award; or

(ii) Imputed to the subrecipient using the standards and due process for imputing the conduct of an individual to an organization that are provided in 2 CFR part 180, "OMB Guidelines to Agencies on Governmentwide Debarment and Suspension (Nonprocurement)," as implemented by our agency at *2 CFR part 1400.*

(c) *Provisions applicable to any recipient.*

(1) You must inform us immediately of any information you receive from any source alleging a violation of a prohibition in paragraph a.1 of this award term.

(2) Our right to terminate unilaterally that is described in paragraph a.2 or b of this section:

(i) Implements section 106(g) of the Trafficking Victims Protection Act of 2000 (TVPA), as amended (22 U.S.C. 7104(g)), and

(ii) Is in addition to all other remedies for noncompliance that are available to us under this award.

(3) You must include the requirements of paragraph a.1 of this award term in any subaward you make to a private entity.

(d) *Definitions.* For purposes of this award term:

(1) "Employee" means either:

(i) An individual employed by you or a subrecipient who is engaged in the performance of the project or program under this award; or

(ii) Another person engaged in the performance of the project or program under this award and not compensated by you including, but not limited to, a volunteer or individual whose services are contributed by a third party as an in-kind contribution toward cost sharing or matching requirements.

(2) "Forced labor" means labor obtained by any of the following methods: the recruitment, harboring, transportation, provision, or obtaining of a person for labor or services, through

the use of force, fraud, or coercion for the purpose of subjection to involuntary servitude, peonage, debt bondage, or slavery.

(3) "Private entity":

(i) Means any entity other than a state, local government, Indian tribe, or foreign public entity, as those terms are defined in 2 CFR 175.25.

(ii) Includes:

(A) A nonprofit organization, including any nonprofit institution of higher education, hospital, or tribal organization other than one included in the definition of Indian tribe at 2 CFR 175.25(b).

(B) A for-profit organization.

(4) "Severe forms of trafficking in persons," "commercial sex act," and "coercion" have the meanings given at section 103 of the TVPA, as amended (22 U.S.C. 7102).

15. NEW RESTRICTIONS ON LOBBYING (43 CFR §18)

The Recipient agrees to comply with 43 CFR 18, New Restrictions on Lobbying, including the following certification:

(a) No Federal appropriated funds have been paid or will be paid, by or on behalf of the Recipient, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying" in accordance with its instructions.

(c) The Recipient shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify accordingly. This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

16. UNIFORM RELOCATION ASSISTANCE AND REAL PROPERTY ACQUISITION POLICIES ACT OF 1970 (URA) (42 USC § 4601 *et seq.)*

(a) The Uniform Relocation Assistance Act (URA), 42 U.S.C. § 4601 *et seq.*, as amended, requires certain assurances for Reclamation funded land acquisition projects conducted by a Recipient that cause the displacement of persons, businesses, or farm operations. Because Reclamation funds only support acquisition of property or interests in property from willing sellers, it is not anticipated that Reclamation funds will result in any "displaced persons," as defined under the URA.

(b) However, if Reclamation funds are used for the acquisition of real property that results in displacement, the URA requires Recipients to ensure that reasonable relocation payments and other remedies will be provided to any displaced person. Further, when acquiring real property, Recipients must be guided, to the greatest extent practicable, by the land acquisition policies in 42 U.S.C. § 4651.

(c) Exemptions to the URA and 49 CFR Part 24

(1) The URA provides for an exemption to the appraisal, review and certification rules for those land acquisitions classified as "voluntary transactions." Such "voluntary transactions" are classified as those that do not involve an exercise of eminent domain authority on behalf of a Recipient, and must meet the conditions specified at 49 CFR § 24.101(b)(1)(i)-(iv).

(2) For any land acquisition undertaken by a Recipient that receives Reclamation funds, but does not have authority to acquire the real property by eminent domain, to be exempt from the requirements of 49 CFR Part 24 the Recipient must:

(i) provide written notification to the owner that it will not acquire the property in the event negotiations fail to result in an amicable agreement, and;

(ii) inform the owner in writing of what it believes to be the market value of the property

(d) Review of Land Acquisition Appraisals. Reclamation reserves the right to review any land appraisal whether or not such review is required under the URA or 49 CFR § 24.104. Such reviews may be conducted by the Department of the Interior's Appraisal Services Directorate or a Reclamation authorized designee. When Reclamation determines that a review of the original appraisal is necessary, Reclamation will notify the Recipient and provide an estimated completion date of the initial appraisal review.

17. CENTRAL CONTRACTOR REGISTRATION AND UNIVERSAL IDENTIFIER REQUIREMENTS (2 CFR 25, APPENDIX A)

The Central Contractor Registration (CCR) has been migrated to the System for Award Management (SAM). Recipients must continue to comply with the CCR requirements below by maintaining current registration within www.SAM.gov.

A. Requirement for Central Contractor Registration (CCR)
Unless you are exempted from this requirement under 2 CFR 25.110, you as the recipient must maintain the currency of your information in the CCR until you submit the final financial report required under this award or receive the final payment, whichever is later. This requires that you review and update the information at least annually after the initial registration, and more frequently if required by changes in your information or another award term.

B. Requirement for Data Universal Numbering System (DUNS) Numbers
If you are authorized to make subawards under this award, you:

1. Must notify potential subrecipients that no entity (*see* definition in paragraph C of this award term) may receive a subaward from you unless the entity has provided its DUNS number to you.

2. May not make a subaward to an entity unless the entity has provided its DUNS number to you.

C. Definitions
For purposes of this award term:

1. *Central Contractor Registration (CCR)* means the Federal repository into which an entity must provide information required for the conduct of business as a recipient. Additional information about registration procedures may be found at the CCR Internet site (currently at *http://www.ccr.gov*).

2. *Data Universal Numbering System (DUNS) number* means the nine-digit number established and assigned by Dun and Bradstreet, Inc. (D&B) to uniquely identify business entities. A DUNS number may be obtained from D&B by telephone (currently 866–705–5711) or the Internet (currently at *http://fedgov.dnb.com/webform*).

3. *Entity,* as it is used in this award term, means all of the following, as defined at 2 CFR part 25, subpart C:
   a. A Governmental organization, which is a state, local government, or Indian Tribe;
   b. A foreign public entity;
   c. A domestic or foreign nonprofit organization;
   d. A domestic or foreign for-profit organization; and

e. A Federal agency, but only as a subrecipient under an award or subaward to a non-Federal entity.

4. *Subaward:*

a. This term means a legal instrument to provide support for the performance of any portion of the substantive project or program for which you received this award and that you as the recipient award to an eligible subrecipient.

b. The term does not include your procurement of property and services needed to carry out the project or program (for further explanation, *see* Sec. II.210 of the attachment to OMB Circular A–133, ''Audits of States, Local Governments, and Non-Profit Organizations'').

c. A subaward may be provided through any legal agreement, including an agreement that you consider a contract.

5. *Subrecipient* means an entity that:

a. Receives a subaward from you under this award; and
b. Is accountable to you for the use of the Federal funds provided by the subaward.

18. PROHIBITION ON TEXT MESSAGING AND USING ELECTRONIC EQUIPMENT SUPPLIED BY THE GOVERNMENT WHILE DRIVING

Executive Order 13513, *Federal Leadership On Reducing Text Messaging While Driving*, was signed by President Barack Obama on October 1, 2009 (ref: http://edocket.access.gpo.gov/2009/pdf/E9-24203.pdf). This Executive Order introduces a Federal Government-wide prohibition on the use of text messaging while driving on official business or while using Government-supplied equipment. Additional guidance enforcing the ban will be issued at a later date. In the meantime, please adopt and enforce policies that immediately ban text messaging while driving company-owned or rented vehicles, government-owned or leased vehicles, or while driving privately owned vehicles when on official government business or when performing any work for or on behalf of the government.

19. REPORTING SUBAWARDS AND EXECUTIVE COMPENSATION (2 CFR 170 APPENDIX A)

I. Reporting Subawards and Executive Compensation.

a. *Reporting of first-tier subawards.*

1. *Applicability.* Unless you are exempt as provided in paragraph d. of this award term, you must report each action that obligates $25,000 or more in Federal funds that does not include Recovery funds (as defined in section 1512(a)(2) of the American Recovery and Reinvestment Act of 2009, Pub. L. 111-5) for a subaward to an entity (see definitions in paragraph e. of this award term).

2. *Where and when to report.*

i. You must report each obligating action described in paragraph a.1. of this award term to http://www.fsrs.gov.

ii. For subaward information, report no later than the end of the month following the month in which the obligation was made. (For example, if the obligation was made on November 7, 2010, the obligation must be reported by no later than December 31, 2010.)

3. *What to report.* You must report the information about each obligating action that the submission instructions posted at http://www.fsrs.gov *specify.*

b. *Reporting Total Compensation of Recipient Executives.*

1. *Applicability and what to report.* You must report total compensation for each of your five most highly compensated executives for the preceding completed fiscal year, if—

i. the total Federal funding authorized to date under this award is $25,000 or more;

ii. in the preceding fiscal year, you received—

(A) 80 percent or more of your annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

(B) $25,000,000 or more in annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

iii. The public does not have access to information about the compensation of the executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 (15 U.S.C. 78m(a), 78o(d)) or section 6104 of the Internal Revenue Code of 1986. (To determine if the public has access to the compensation information, see the U.S. Security and Exchange Commission total compensation filings at *http://www.sec.gov/answers/execomp.htm.*)

2. *Where and when to report.* You must report executive total compensation described in paragraph b.1. of this award term:

i. As part of your registration profile at *http://www.ccr.gov*.

ii. By the end of the month following the month in which this award is made, and annually thereafter.

c. *Reporting of Total Compensation of Subrecipient Executives.*

1. *Applicability and what to report.* Unless you are exempt as provided in paragraph d. of this award term, for each first-tier subrecipient under this award, you shall report the names and total compensation of each of the subrecipient's five most highly compensated executives for the subrecipient's preceding completed fiscal year, if—

i. in the subrecipient's preceding fiscal year, the subrecipient received—

(A) 80 percent or more of its annual gross revenues from Federal procurement contracts (and subcontracts) and Federal financial assistance subject to the Transparency Act, as defined at 2 CFR 170.320 (and subawards); and

(B) $25,000,000 or more in annual gross revenues from Federal procurement contracts (and subcontracts), and Federal financial assistance subject to the Transparency Act (and subawards); and

ii. The public does not have access to information about the compensation of the executives through periodic reports filed under section 13(a) or 15(d) of the Securities Exchange Act of 1934 (15 U.S.C. 78m(a), 78o(d)) or section 6104 of the Internal Revenue Code of 1986. (To determine if the public has access to the compensation information, see the U.S. Security and Exchange Commission total compensation filings at *http://www.sec.gov/answers/execomp.htm*.)

2. *Where and when to report.* You must report subrecipient executive total compensation described in paragraph c.1. of this award term:

i. To the recipient.

ii. By the end of the month following the month during which you make the subaward. For example, if a subaward is obligated on any date during the month of October of a given year (*i.e.*, between October 1 and 31), you must report any required compensation information of the subrecipient by November 30 of that year.

d. *Exemptions*

If, in the previous tax year, you had gross income, from all sources, under $300,000, you are exempt from the requirements to report:

i. Subawards,

and

ii. The total compensation of the five most highly compensated executives of any subrecipient.

e. *Definitions.* For purposes of this award term:

1. *Entity* means all of the following, as defined in 2 CFR part 25:

i. A Governmental organization, which is a State, local government, or Indian tribe;

ii. A foreign public entity;

iii. A domestic or foreign nonprofit organization;

iv. A domestic or foreign for-profit organization;

v. A Federal agency, but only as a subrecipient under an award or subaward to a non-Federal entity.

2. *Executive* means officers, managing partners, or any other employees in management positions.

3. *Subaward:*

i. This term means a legal instrument to provide support for the performance of any portion of the substantive project or program for which you received this award and that you as the recipient award to an eligible subrecipient.

ii. The term does not include your procurement of property and services needed to carry out the project or program (for further explanation, see Sec. __.210 of the attachment to OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations").

iii. A subaward may be provided through any legal agreement, including an agreement that you or a subrecipient considers a contract.

4. *Subrecipient* means an entity that:

i. Receives a subaward from you (the recipient) under this award; and

ii. Is accountable to you for the use of the Federal funds provided by the subaward.

5. *Total compensation* means the cash and noncash dollar value earned by the executive during the recipient's or subrecipient's preceding fiscal year and includes the following (for more information see 17 CFR 229.402(c)(2)):

i. *Salary and bonus.*

ii. *Awards of stock, stock options, and stock appreciation rights.* Use the dollar amount recognized for financial statement reporting purposes with respect to the fiscal year in accordance with the Statement of Financial Accounting Standards No. 123 (Revised 2004) (FAS 123R), Shared Based Payments.

iii. *Earnings for services under non-equity incentive plans.* This does not include group life, health, hospitalization or medical reimbursement plans that do not discriminate in favor of executives, and are available generally to all salaried employees.

iv. *Change in pension value.* This is the change in present value of defined benefit and actuarial pension plans.

v. *Above-market earnings on deferred compensation which is not tax-qualified.*

vi. Other compensation, if the aggregate value of all such other compensation (e.g. severance, termination payments, value of life insurance paid on behalf of the employee, perquisites or property) for the executive exceeds $10,000.

20. RECIPIENT EMPLOYEE WHISTLEBLOWER RIGHTS AND REQUIREMRENT TO INFORM EMPLOYEES OF WHISTLEBLOWER RIGHTS (SEP 2013)

(a) This award and employees working on this financial assistance agreement will be subject to the whistleblower rights and remedies in the pilot program on Award Recipient employee whistleblower protections established at 41 U.S.C. 4712 by section 828 of the National Defense Authorization Act for Fiscal Year 2013 (Pub.L. 112-239).

(b) The Award Recipient shall inform its employees in writing, in the predominant language of the workforce, of employee whistleblower rights and protections under 41 U.S.C 4712.

(c) The Award Recipient shall insert the substance of this clause, including this paragraph (c), in all subawards or subcontracts over the simplified acquisition threshold. 48 CFR § 52.203-17 (as referenced in 48 CFR § 3.908-9).

RECLAMATION
Managing Water in the West

Categorical Exclusion Checklist

Rock Slough Fish Screen Operations and Prototype Rake Testing Modifications

CEC-15-004

Prepared by:	Rain L. Emerson Supervisory Natural Resources Specialist South-Central California Area Office	Date: 02/20/2015
Concurred by:	See Attachment A Archaeologist Mid-Pacific Regional Office	Date: See Attachment A
Concurred by:	See Attachment B Native American Affairs Specialist Mid-Pacific Regional Office	Date: See Attachment B
Concurred by:	Ned Gruenhagen, Ph.D. Wildlife Biologist South-Central California Area Office	Date: 02/26/2015
Approved by:	for Michael Jackson Area Manager South-Central California Area Office	Date: 02/26/2015

U.S. Department of the Interior
Bureau of Reclamation
South-Central California Area Office

February 2015

Background

The Rock Slough Fish Screen (RSFS) facility is located at the junction Bureau of Reclamation's (Reclamation) unlined Contra Costa Canal (Canal) and Rock Slough, approximately four miles southeast of the town of Oakley, California (see Figure 1). Construction on the RSFS by Reclamation began in 2009 in order to comply with requirements of the Central Valley Project Improvement Act and the Los Vaqueros Biological Opinion issued by the U.S. Fish and Wildlife Service in 1993. The purpose of the RSFS facility is to provide protection to threatened Delta smelt and the endangered spring and winter-run Chinook salmon while allowing diversions to serve Contra Costa Water District's (CCWD's) water users. Major construction work at the RSFS is now substantially complete; however, issues with the operation of the facility remain unresolved and are currently being evaluated by Reclamation and CCWD. Consequently, the RSFS is not considered fully operational.

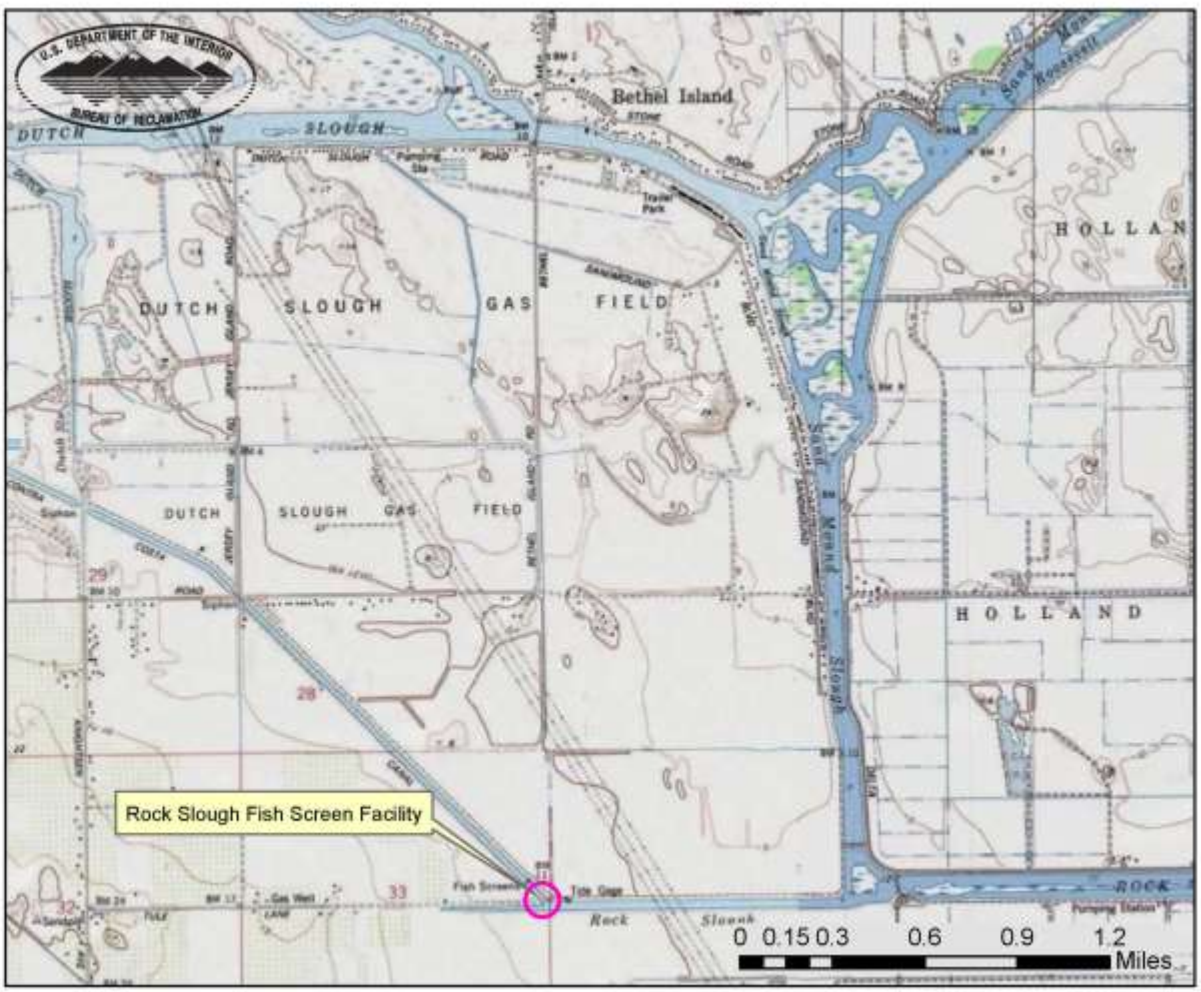


Figure 1 Proposed Action Area

Need for the Proposal

In April 2014, Reclamation completed Categorical Exclusion Checklist (CEC)-13-049 for proposed testing operations of a prototype rake (rake No. 2) at the RSFS. Based on several factors, including the presence of migratory birds at the facility, CCWD was not able to test the prototype rake fully. CCWD has recently proposed modifications to the previously approved testing plan that are outside the project description covered in CEC-13-049 and additional environmental review is needed. CCWD has an immediate need to commence testing of the prototype rake and to operate the remaining rakes as the Canal is expected to resume operations as early as February 2015.

The RSFS facility is subjected to extraordinary amounts of aquatic vegetation and consequently has, at times, been unable to maintain a vegetation free screen essential to facility function and protection of fish from entrainment. There have been ongoing operational challenges with the RSFS, primarily associated with the automated debris handling system. It is extremely important that the rakes be fully functional so that the screen can be maintained to meet design specifications to minimize impingement and entrainment of smaller sensitive aquatic species.

CCWD needs to test prototype rake No. 2 as much as possible to confirm that it will operate on a reliable basis. During testing, additional design improvements may be necessary. Once it is confirmed that rake No. 2 can operate reliably, the prototype design will be used to improve the remaining three rakes (Nos. 1, 3 and 4) at the facility. Improvements to the other three rakes will be addressed in a separate environmental review once a project description is determined.

Proposed Action

Reclamation, proposes to approve CCWD’s continued testing of prototype rake No. 2 and also the original rake designs.

The amount of overall raking will be the least amount necessary for adequate testing. And, to the degree possible, the most intensive testing (i.e., highest number of runs per day) will be conducted when special status fish are not present in the area.

Two test runs, as described below, would be utilized to evaluate the suitability of the system for meeting operating objectives. Testing would involve the original rake designs, the modified prototype rake previously described, or with rakes additionally modified as a result of new discoveries made during the testing.

Initially, two test runs (continuous and comparative test runs) will be alternated on a weekly basis. Testing is expected to begin in early February 2015 and continue seven days per week over a 3 to 9 month period. This duration may be longer if testing cannot be done on a continuous basis as described below and/or reliability of prototype rake No. 2 cannot be confirmed within the testing period.

While prototype rake No. 2 is being tested, CCWD will continue to operate rakes Nos. 1, 3 and 4 at least once but possibly up to 72 times per day, until all of the rakes have been modified to be consistent with the final prototype rake No. 2 design. Regardless, all rakes must function so that design requirements for maintaining specified flows through the screens are maintained.

The Continuous Test Run

CCWD will run prototype rake No. 2 on a continuous basis (24 hours per day for 7 days) in order to test the mechanical and hydraulic system. Rakes No. 1, 3, and 4 will be disabled during the continuous run testing intervals.

The Comparative Test Run

CCWD will test the comparative performance of prototype rake No. 2 and the original rake head design on rake No. 3. The test will run at 120 minute intervals (20 minute rake head cycle within each interval) 24 hours a day for 7days. Rakes No. 1 and 4 will be disabled during the comparative testing intervals.

A CCWD maintenance staff person or contractor will be on site once each day over the 7 day testing phases in order to observe one prototype run cycle to confirm no obvious mechanical or hydraulic system failure has occurred. Prototype SCADA alarms will notify CCWD of a potential problem and the Control Operator will shut down the prototype in an emergency; no automatic shutdown of the prototype will occur.

Reliability Operation Testing of RSFS Post Testing Period

Once rake testing is complete and results are satisfactory, CCWD, on behalf of Reclamation, will continue to operate the RSFS rakes through April 2018, as previously covered in the 2009 National Marine Fisheries Service Biological Opinion on Long Term Operation of the Central Valley Project and State Water Project and the 1993 U.S. Fish and Wildlife Service Biological Opinion for the Central Valley Project Improvement Act and the Los Vaqueros Biological Opinion.

Environmental Commitments

CCWD will implement the following environmental commitments, including those within Attachment C, to avoid any potential environmental consequences associated with the Proposed Action:

- An upstream log boom will be relocated approximately 600 feet upstream (east) of its current location in front of the RSFS. The log boom will remain in this location until the operation and maintenance is transferred from Reclamation to CCWD.
- A block net with 3/8 inch openings to allow delta smelt passage will be installed just downstream (west) of the log boom from November 1through April 30 each year.
- A preconstruction survey for migratory birds shall be conducted prior to any rake modifications.

Environmental consequences for biological resources assume the measures specified will be fully implemented.

Exclusion Category

516 DM 14.5 paragraph A (3): *Research activities, such as nondestructive data collection and analysis, monitoring, modeling, laboratory testing, calibration, and testing of instruments or procedures and nonmanipulative field studies.*

Evaluation of Criteria for Categorical Exclusion

	No	Uncertain	Yes
1. This action would have a significant effect on the quality of the human environment (40 CFR 1502.3).	☑	☐	☐
2. This action would have highly controversial environmental effects or involve unresolved conflicts concerning alternative uses of available resources (NEPA Section 102(2)(E) and 43 CFR 46.215(c)).	☑	☐	☐
3. This action would have significant impacts on public health or safety (43 CFR 46.215(a)).	☑	☐	☐
4. This action would have significant impacts on such natural resources and unique geographical characteristics as historic or cultural resources; parks, recreation, and refuge lands; wilderness areas; wild or scenic rivers; national natural landmarks; sole or principal drinking water aquifers; prime farmlands; wetlands (EO 11990); flood plains (EO 11988); national monuments; migratory birds; and other ecologically significant or critical areas (43 CFR 46.215 (b)).	☑	☐	☐
5. This action would have highly uncertain and potentially significant environmental effects or involve unique or unknown environmental risks (43 CFR 46.215(d)).	☑	☐	☐
6. This action would establish a precedent for future action or represent a decision in principle about future actions with potentially significant environmental effects (43 CFR 46.215 (e)).	☑	☐	☐
7. This action would have a direct relationship to other actions with individually insignificant but cumulatively significant environmental effects (43 CFR 46.215 (f)).	☑	☐	☐
8. This action would have significant impacts on properties listed, or eligible for listing, on the National Register of Historic Places as determined by Reclamation (LND 02-01) (43 CFR 46.215 (g)).	☑	☐	☐

	No	Uncertain	Yes
9. This action would have significant impacts on species listed, or proposed to be listed, on the List of Endangered or Threatened Species, or have significant impacts on designated critical habitat for these species (43 CFR 46.215 (h)).	☑	☐	☐
10. This action would violate a Federal, tribal, State, or local law or requirement imposed for protection of the environment (43 CFR 46.215 (i)).	☑	☐	☐
11. This action would affect ITAs (512 DM 2, Policy Memorandum dated December 15, 1993).	☑	☐	☐
12. This action would have a disproportionately high and adverse effect on low income or minority populations (EO 12898) (43 CFR 46.215 (j)).	☑	☐	☐
13. This action would limit access to, and ceremonial use of, Indian sacred sites on Federal lands by Indian religious practitioners or significantly adversely affect the physical integrity of such sacred sites (EO 13007, 43 CFR 46.215 (k), and 512 DM 3)).	☑	☐	☐
14. This action would contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area or actions that may promote the introduction, growth, or expansion of the range of such species (Federal Noxious Weed Control Act, EO 13112, and 43 CFR 46.215 (l)).	☑	☐	☐

Attachment A: Cultural Resources Determination

CULTURAL RESOURCES COMPLIANCE
Mid-Pacific Region
Division of Environmental Affairs
Cultural Resources Branch (MP-153)

MP-153 Tracking Number: 15-SCAO-068

Project Name: Rock Slough Fish Screen Operations and Prototype Rake Testing Modifications

NEPA Document: CEC-15-004

NEPA Contact: Rain Emerson, Supervisory Natural Resources Specialist

MP-153 Cultural Resources Reviewer: Joanne Goodsell, Archaeologist JG

Date: January 28, 2015

Reclamation proposes to test prototype rake No. 2 at the Rock Slough Fish Screen Facility (RSFS), located at the junction of the Contra Costa Canal and Rock Slough, near the town of Oakley, California. The testing would be completed in alternating continuous and comparative test runs over the course of several months and be used to assess the reliability of the current rake design and to determine if any improvements to it and the other RSFS rakes (Nos. 1, 3, and 4) are needed.

Reclamation has determined that the proposed action is the type of undertaking that does not have the potential to cause effects to historic properties, should such historic properties be present, pursuant to the National Historic Preservation Act (NHPA) Section 106 regulations codified at 36 CFR Part 800.3(a)(1). As such, Reclamation has no further obligations under Section 106. In concurrence with item 8 on CEC-15-004, the action would have no significant impacts on properties listed, or eligible for listing, on the National Register of Historic Places.

This document conveys the completion of the cultural resources review and NHPA Section 106 process for this undertaking. Please retain a copy in the administrative record for this action. Should changes be made to the proposed action, additional review under Section 106, possibly including consultation with the State Historic Preservation Officer, may be necessary.

Attachment B: Indian Trust Assets Determination

BISON CONNECT

Emerson, Rain <remerson@usbr.gov>

Re: RESUBMITTAL - ITA Determination Request (15-004)

STEVENSON, RICHARD <rstevenson@usbr.gov> Wed, Feb 18, 2015 at 12:54 PM
To: "Emerson, Rain" <remerson@usbr.gov>

Rain,

I have reviewed the attached project description and the prior ITA determination made for the same area last April. The proposed project does not have the potential to affect Indian Trust Assets.

Dick Stevenson
Deputy Regional Resources Manager

On Tue, Feb 17, 2015 at 4:21 PM, Emerson, Rain <remerson@usbr.gov> wrote:

> Good afternoon Mr. Stevenson,
>
> Attached is a determination request for the proposed Rock Slough Fish Screen Prototype Modifications (Word doc). I have also attached a previous determination that was made for the same area (pdf email).
>
> Rain L. Emerson, M.S.
> *Supervisory Natural Resources Specialist*
> Bureau of Reclamation, South-Central California Area Office
> 1243 N Street, Fresno, CA 93721
> Work Ph: 559-487-5196
> Cell Ph: 559-353-4032

--

Richard M. Stevenson
Deputy Regional Resources Manager
2800 Cottage Way, MP-400
Sacramento, CA 95825-1898
(916) 978-5264
(916) 396-3380 iPhone
rstevenson@usbr.gov

Attachment C: National Marine Fisheries Service Concurrence Memo

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

FEB 20 2015

Refer to NMFS No: WCR-2015--2095

David E Hyatt
Chief, Resources Management Division
U.S. Bureau of Reclamation, Mid-Pacific Region
South-Central California Area Office
1243 N Street
Fresno, California 93721-1813

Re: Endangered Species Act Section 7(a)(2) Concurrence Letter, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Testing and Modifications of the Rock Slough Fish Screen

Dear Mr. Hyatt:

On February 3, 2015, NOAA's National Marine Fisheries Service (NMFS) received your February 2, 2015, request for a written concurrence (SCC-423 Env-7.00) that Contra Costa Water District's (CCWD) continuation of testing and modification of the Rock Slough Fish Screen (RSFS, proposed action) is not likely to adversely affect (NLAA) species listed as threatened or endangered or critical habitats designated under the Endangered Species Act (ESA). This response to your request was prepared by NMFS pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402, and agency guidance for preparation of letters of concurrence.

NMFS also reviewed the proposed action for potential effects on essential fish habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), including conservation measures and any determination you made regarding the potential effects of the action. This review was pursuant to section 305(b) of the MSA, implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation. EFH designated within the Pacific Coast Salmon, Pacific Coast Groundfish, and Coastal Pelagic Species Management Plans is present in the action area. In this case, NMFS concluded that the proposed action would not adversely affect EFH. Thus, consultation under the MSA is not required for this proposed action.

This letter underwent pre-dissemination review using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The concurrence letter will be available through NMFS' Public Consultation Tracking System (https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts). A complete record of this consultation is on file at the NMFS California Central Valley Area Office.

Proposed Action

The U.S. Bureau of Reclamation (Reclamation) owns the Contra Costa Canal and built the RSFS in 2009 with funding through the American Recovery and Reinvestment Act to comply with requirements of the Central Valley Project Improvement Act and the 1993 Los Vaqueros Biological Opinion issued by the U.S. Fish and Wildlife Service (USFWS). NMFS issued a concurrence letter regarding construction of the RSFS on August 20, 2009 (PCTS 2009/03303). The USFWS issued its biological opinion regarding construction and operation of the RSFS on September 3, 2009 (81420-2009-I-1015-1). Both NMFS and the USFWS found that construction and operation of the RSFS would be beneficial to ESA-listed fish species. CCWD is responsible for the daily operation and maintenance of the RSFS. The testing and modifications of the RSFS are interrelated to the construction and operation of the RSFH, which NMFS has already concurred on (see August 20, 2009 letter). The operation of the RSFS is described in the long-term operations of the Central Valley Project and State Water Project (NMFS 2009).

The RSFS protects fish from becoming entrained into the Contra Costa Canal when water is diverted from the Delta to the Los Vaqueros Reservoir and portions of the San Francisco Bay Area. Due to the location of the RSFS at the terminal end of Rock Slough and in the southern part of the Delta, it is subjected to large amounts of aquatic vegetation that render the screen inoperable. The current rake cleaning system designed for the RSFS is unable to handle the large amounts of aquatic vegetation that ends up on the fish screen. Therefore, the fish screen has been only partially operational since 2009.

Reclamation's purposed action is to authorize the implementation of continued testing and modifications of a prototype rake design and eventually turn over the long-term operations at RSFS to CCWD. Testing and monitoring at RSFS was authorized for 9 months in 2014 (NMFS 2014/288), however, due to construction shutdowns and permit delays, the testing was not completed. Reclamation is proposing to extend the RSFS testing period from 2015 to 2018. The details of the test runs (*i.e.*, both continuous and comparative runs) are described in the biological evaluation provided with your February 2, 2015, letter. Testing is expected to begin in February 2015 and continue seven days per week over a 3- to 9-month period each year. A CCWD maintenance worker or contractor will be on site each day that the prototype rake is testing in order to observe any failure of the mechanical or hydraulic system. Once testing is completed, CCWD will resume normal operations.

In addition, CCWD will relocate the log boom approximately 600 feet upstream (east) of its current location in front of the RSFS. A block net (3/8 inch openings) will be installed just downstream (west) of the log boom from November 1 through April 30 each year, to prevent adult salmon and steelhead from becoming entrained in the rakes. Past observations at RSFS indicate that adult salmon and steelhead are not likely to present from May 1 through September 30.

Action Area

The RSFS is located at the junction of the unlined Contra Costa Canal and Rock Slough, which is part of the San Joaquin-Sacramento Delta (Delta), approximately four miles southeast of the City of Oakley in Contra Costa County, California (Latitude 37.97611°, Longitude -121.64125 °). The action area includes the adjacent waters in Rock Sough, 600 feet east (upstream) of the RSFS, and westward to the terminus of Rock Slough. No upland or wetland habitats suitable for listed species would be affected by the proposed action. The waterside areas, including those sections of the levee immediately adjacent to the RSFS, are sparsely vegetated, with dense riprap revetment, supporting very little riparian or aquatic vegetation. Rock Slough is located off of the main migratory routes through the Delta for listed fish species. However, due to tidal action, salmon and steelhead occasionally stray into Rock Slough.

The action area encompasses waterways where the following listed species are present: endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened Central Valley (CV) spring-run Chinook salmon (*O. tshawytscha*), threatened California CV steelhead (*O. mykiss*), and the threatened Southern distinct population segment (sDPS) of North American green sturgeon (*Acipenser medirostris*). Critical habitat is not present in Rock Slough for any of the above species.

Reclamation's Effects Determinations

Reclamation determined that the proposed action is wholly beneficial and, therefore, not likely to adversely affect endangered Sacramento River winter-run Chinook salmon, threatened CV spring-run Chinook salmon, threatened California CV steelhead, and the threatened sDPS of North American green sturgeon due to expected improvements to the efficiency of the RSFS. These improvements would increase the efficiency of the fish screen and reduce areas of high velocity that can entrain and impinge juvenile salmonids and sturgeon. Critical habitat for the above listed species does not extend to the waters of Rock Slough adjacent to the RSFS, therefore, the proposed action would not affect critical habitat for these species and concurrence regarding critical habitat is not being requested.

In addition, Reclamation had determined that the proposed action is not likely to adversely affect EFH for Pacific salmon (*i.e.,* fall-run and late-fall run Chinook salmon in addition to Sacramento River winter-run and CV spring-run Chinook salmon) and groundfish species such as Starry flounder (*Platichthys stellatus*), and requested concurrence from NMFS pursuant to Section 305(b)(2) of the MSA. The reasoning, similar to that for listed species, is that the improvements made to the RSFS will also improve the habitat for fall-run and late-fall run Chinook salmon by minimizing entrainment and impingement on the fish screen. As of January 20, 2015, habitat areas of particular concern (HAPCs) have been designated in the Central Valley within the Pacific Coast Salmon Fishery Management Plan (PFMC 2014). The action area lies within the estuarine HAPC for Pacific salmon. EFH designated within the Pacific Coast Groundfish and Coastal Pelagic Species Fishery Management Plans is present in the action area.

Consultation History

- March 18, 1993, NMFS issued a non-jeopardy opinion for effects of CCWD's Los Vaqueros Reservoir (including the Rock Slough Intake) on Sacramento River winter-run Chinook salmon.
- June 4, 2009, NMFS issued a biological opinion on the long-term operations of the Central Valley Project (including CCWD's diversions) and State Water Project which included incidental take for the Rock Slough Intake and future fish screen (AR 151422SWR2006SA00268).
- August 20, 2009, NMFS issued a letter of concurrence for construction of the RSFS (NMFS 2009/03303).
- February 25, 2014, NMFS issued a letter of concurrence for testing and modifications of the RSFS (NMFS 2014/288).
- January 2015, conference call and technical assistance with Reclamation, CCWD, and USFWS.
- February 3, 2015, NMFS receives request for extending testing of the RSFS.

ENDANGERED SPECIES ACT

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the listed species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action (50 CFR 402.02). The applicable standard to find that a proposed action is NLAA listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur.

The effects of the proposed action are likely to include minor operational modifications that would allow testing of the prototype rake under a range of conditions are not expected to affect ESA listed species. The new rake head is expected to improve removal of debris and vegetation, thereby reducing "hot spots" (areas of high velocity) and maintaining uniform water flow across the fish screens. This will improve fish protection (*i.e.*, screen efficiency) by minimizing the chance a listed fish will become entrained or impinged on the RSFS.

A small amount of habitat in Rock Slough (~600 feet) would be made temporarily unavailable due to the installation of a block net from November 1 to April 30. The block net and operation of the rakes would not change the habitat quality. Since the habitat in front of RSFS is of poor quality, and not currently being utilized for rearing by listed fish species (*i.e.*, migratory only), this temporary effect would be insignificant. As mentioned above, Rock Slough is located off of the main migratory routes through the Delta for listed fish species, however, due to tidal action, salmon and steelhead occasionally stray into Rock Slough.

The effects of the proposed action are wholly beneficial to listed fish species in that they will reduce entrainment or minimizing the risk of contaminants such as hydraulic fluid entering the water. NMFS assumes that by improving the efficiency of the RSFS, in the long-term, listed fish species will be protected from being diverted into the Contra Costa Canal. In addition, since the improvements are confined to the area of the RSFS itself, it is unlikely that any water quality impacts would be carried out to the larger Delta where there is designated critical habitat for the listed species.

Conclusion

Based on this analysis, NMFS concurs with Reclamation that the proposed action is not likely to adversely affect the subject listed species and designated critical habitats. In addition, NMFS has reviewed the incidental take coverage for the RSFS contained within the NMFS (2009) biological opinion. NMFS considers that incidental take for CCWD's Rock Slough Intake will continue as specified in NMFS (2009) until such time as the RSFS testing and modifications are complete and Reclamation turns over operations and maintenance to the CCWD.

Reinitiation of Consultation

Reinitiation of consultation is required and shall be requested by Reclamation or by NMFS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and (1) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (2) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this concurrence letter; or if (3) a new species is listed or critical habitat designated that may be affected by the identified action (50 CFR 402.16). This concludes the ESA portion of this consultation.

Please direct questions regarding this letter to Bruce Oppenheim, Fishery Biologist, California Central Valley Area Office at 916-930-3603 or bruce.oppenheim@noaa.gov.

Sincerely,

FOR William W. Stelle, Jr.
Regional Administrator

cc: File copy -ARN #151422SWR2014SA00018

Mark Seedall, Contra Costa Water District, P.O. Box H20, Concord, CA 94524-2099
Carl Dealy, U.S. Bureau of Reclamation, 16650 Kelso Road, Byron, CA 94514-1909
Armin Halston, U.S. Fish and Wildlife Service, 650 Capitol Mall, Suite 8-300, Sacramento, CA 95814-4700

Reference cited:

NMFS. 2009. Biological and conference opinion on the long-term operation of the Central Valley Project and State Water Project. NMFS-Southwest Region, Long Beach, California. 844 pages plus appendices. June 4.

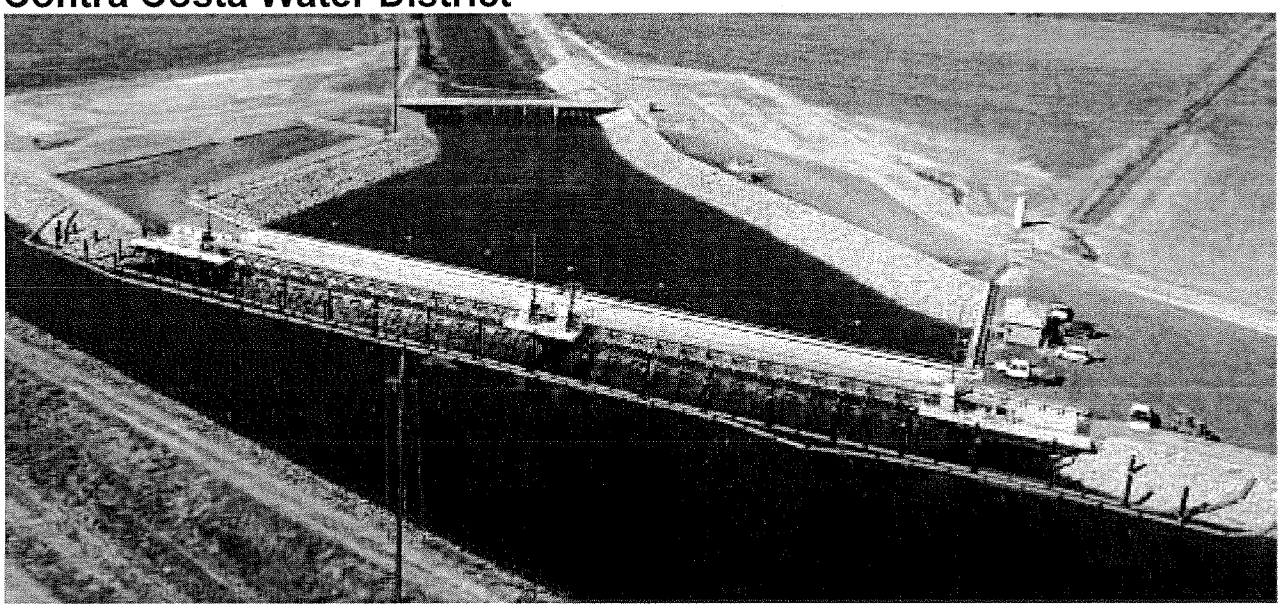
PFMC, Pacific Fisheries Management Council 2014. Appendix A, to the Pacific Coast Salmon Fishery Management Plan. 227 pp.

RECLAMATION
Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1067

Rock Slough Fish Screen Hydraulic Evaluation

Contra Costa Water District



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

September 2012

Hydraulic Laboratory Technical Memorandum PAP-1067

Rock Slough Fish Screen Hydraulic Evaluation

Joshua D Mortensen and Tracy B. Vermeyen P.E.
Prepared: Joshua D. Mortensen and Tracy B. Vermeyen, P.E.
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

Tony L. Wahl Acting
Technical Approval: Robert F. Einhellig, P.E.
Manager, Hydraulic Investigations and Laboratory Services Group, 86-68460

Connie Svoboda 8/31/2012
Peer Review: Connie D. Svoboda, P.E. Date
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

Introduction

The Rock Slough Fish Screen was recently constructed on the Rock Slough Intake upstream from a pumped diversion in the Contra Costa Canal. The fish screen structure was designed to minimize the entrainment of fish associated with the diversion of water at the Rock Slough Intake. The screen should also reduce potential predation on target species in the Contra Costa Canal. The objective of this project was to assess the hydraulic performance of the Rock Slough Fish Screen structure by measuring approach velocities near the screens to determine if the structure is operating within the established criteria for target fish species in the Sacramento - San Joaquin Delta.

Background

The Contra Costa Canal was completed by the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region (Reclamation) in 1948. The canal, which is owned by Reclamation and operated by the Contra Costa Water District (CCWD), is the primary conveyance facility for CCWD's untreated water supply. It carries water from CCWD water supply intakes for deliveries to treatment plants, large industries, and irrigation customers throughout CCWD's service area. The canal is 48 miles long with capacities ranging from 350 ft^3/sec at Pumping Plant 1 to 22 ft^3/sec at its western terminus at Martinez Reservoir. The easternmost section of the canal is hydraulically connected to Rock Slough, and is tidal; this section is approximately 4 miles in length, and is located between the new Rock Slough Fish Screen and Pumping Plant 1. Water from the Sacramento-San Joaquin Delta is diverted at Rock Slough to supply the Contra Costa Canal (Figure 1). Until recently, the canal diversion at Rock Slough was one of the largest unscreened diversions in the Delta.

Construction of the fish screen at Rock Slough is required in the Los Vaqueros Biological Opinion for Delta Smelt issued by the US Fish and Wildlife Service in 1993 (U.S. Fish and Wildlife Service, 1993) and by Section 3406(b) of the Central Valley Project Improvement Act (CVPIA). Several resident and migratory fish species, including the endangered winter-run Chinook salmon and the threatened Delta smelt, can be entrained into the Contra Costa Canal. Other species affected by the project include: steelhead, green and white sturgeon, longfin smelt, split-tail, Sacramento blackfish, hitch, hardhead, and tule perch.

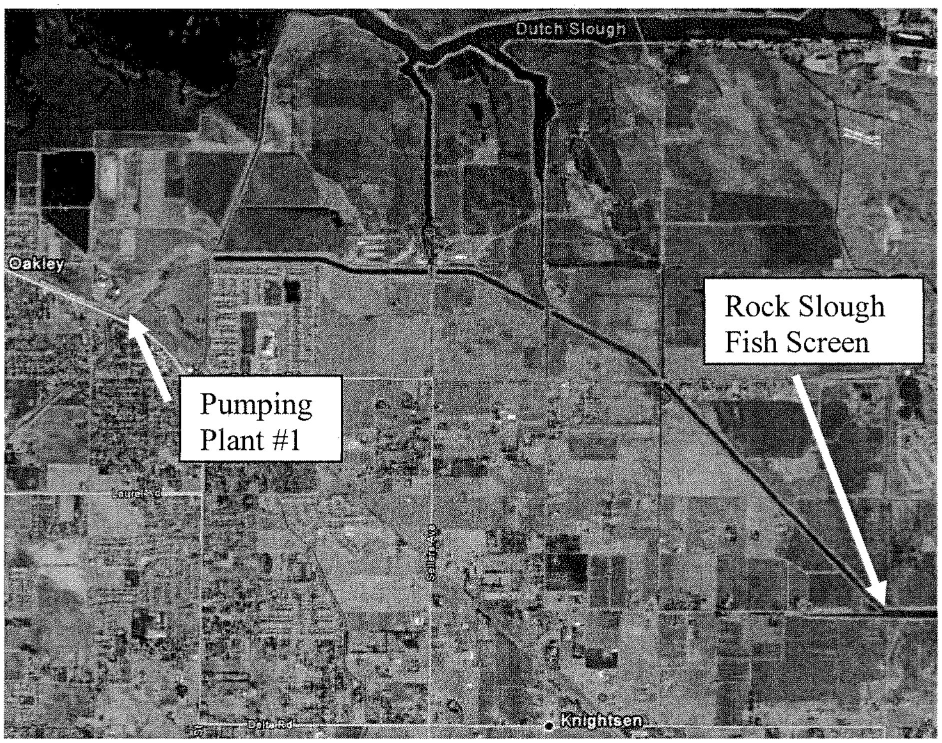


Figure 1. Location of Rock Slough Fish Screen and Pumping Plant No. 1 along Contra Costa Canal.

A Final Environmental Assessment and Finding of No Significant Impact for construction of the Rock Slough Fish Screen were published in 1997. Fish screen design began in 1997 and was completed in 1998. The original solicitation was issued and canceled in 1999 due to lack of right-of-way. Phase 1of the project was constructed in 2001 which included widened areas of an access road along the Contra Costa Canal. Phase 2 of the project was constructed in 2009 and included dewatering the channel using setback levees and cofferdams to prepare for construction of the screen structure in the channel bed. Temporary bypass pumping was installed in 2010 to supply water to the Contra Costa Canal during construction of the screen structure. Phase 3 which included solicitation, contract award and fish screen construction was awarded in May 2010. As of spring 2012, the facility is in final testing. The completion of Rock Slough Fish Screen construction is expected in 2012.

Rock Slough Fish Screen Description

The Rock Slough Fish Screen is located about 4 miles upstream from Pumping Plant No. 1 on the Contra Costa Canal. The fish screen consists of a cast-in-place reinforced concrete footing, pier, and abutment structure. The structure is founded on pre-cast/pre-stressed concrete pile foundation system and has steel sheet pile cutoffs and tied sheet pile abutment walls. The structure contains 8 structural bays with 4 fish screen panels per bay. Bays are numbered from upstream to downstream and referred to as B1 through B8 in this report, as shown in Figure 2.

The fish screens are made of stainless steel profile wire mesh. Above each screen is a stainless steel barrier panel.

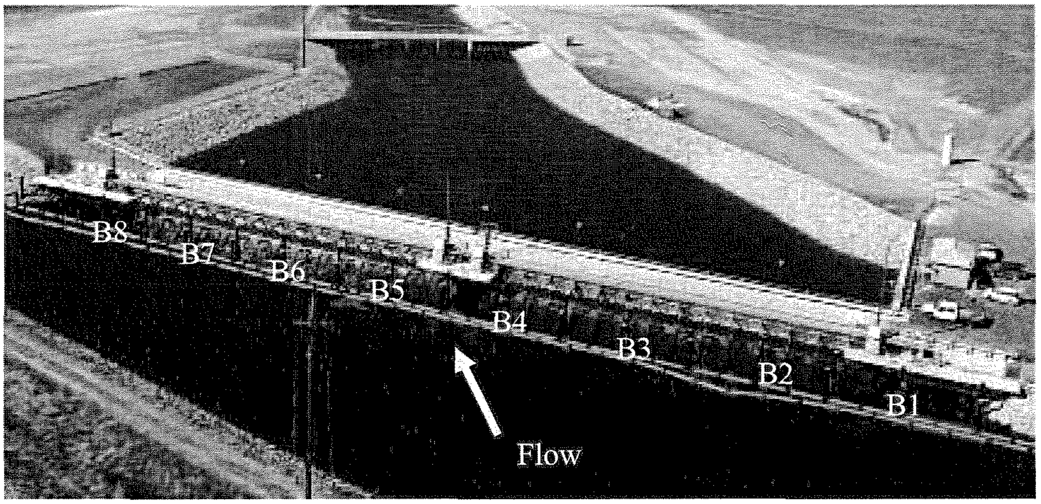


Figure 2. Rock Slough Fish Screen structure with Rock Slough in foreground and Contra Costa Canal in background (at top of photo). Screen bay reference numbers are shown.

The Rock Sough Fish Screen structure was sized for maximum diversion in Contra Costa Canal plus tidal inflows, which resulted in overall structure length of 320 ft (293 ft effective length.) The screen panels have an effective width of approximately 9.5 ft, and are 14 ft in height. Figure 3 shows fish screen structure, trash rack superstructure, and concrete footing. The fish screens are inclined 5° from vertical. The fish screen design specifies a 1.75 mm maximum slot opening and at least 40 percent open area (porosity). One bay near the middle of the structure (B4), is equipped with a solid stainless steel panel that is automatically opened for pressure relief if the head differential across the screen structure exceeds a threshold of about 18 to 21 inches. Adjustable steel baffles (with 6 adjustable vanes per screen panel) are located downstream of each panel to create uniform approach velocities along the entire screen length.

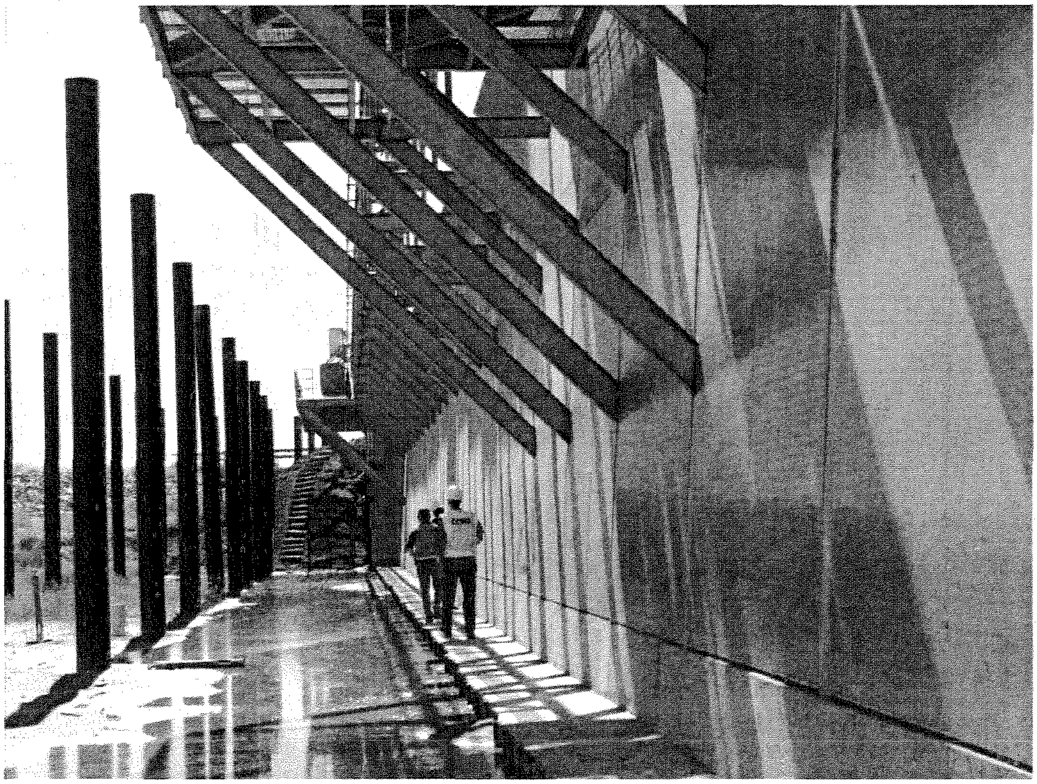


Figure 3. Rock Slough side of fish screen structure while dewatered for construction. Log boom piles, fish screen panels, concrete footing and supports for debris conveyance system are visible.

The screen is equipped with four automated hydraulic trash rakes and a debris conveyance system to keep the fish screens clean (Figure 4). The rakes are capable of cleaning the fish screens continuously or intermittently. Four rakes are included in the design to clean 31 screen panels. If the debris load warrants, two additional rakes can be added. One complete cleaning cycle time using the four rakes will not exceed 32 minutes (rake supplier estimates 16.5 minutes cleaning cycle time).

Hydraulics

Water in Rock Slough and the eastern portion of the Contra Costa Canal is hydraulically connected to the Delta, and is tidal. Tidal fluctuation of water level at the site causes flow into the Rock Slough Fish Screen as the Contra Costa Canal fills on incoming (flood) tide, and causes flow through the screen in the reverse direction, from the Canal into Rock Slough, as the Canal drains tidally on the outgoing (ebb) tide. Typical tidal change in water surface elevation at the site is from 1 to 4 feet. Design high water surface elevation is +8.0 ft and the design low water surface elevation is -1.6 ft (in reference to the National Geodetic Vertical Datum of 1929, or NGVD29). Design water surface elevation ranges were calculated using the Old River at Byron gage which is maintained by the California Department of Water Resources.

There is also a water level gage at Rock Slough above the Contra Costa Canal which is managed by California Department of Water Resources.

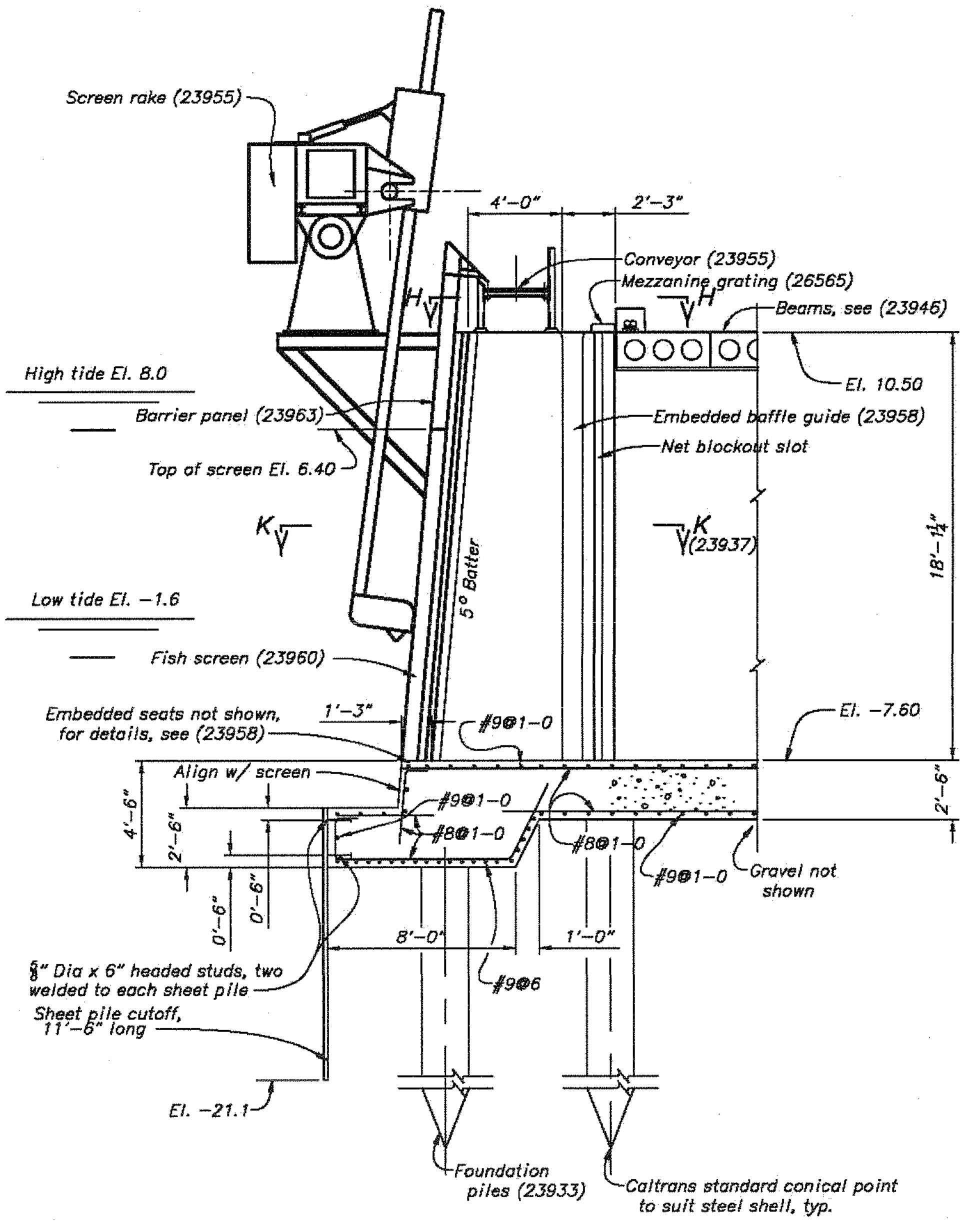


Figure 4. Section view of the trash rake cleaning system.

A 1999 physical model study performed in Reclamation's hydraulics laboratory in Denver concluded that it should be possible to set the adjustable baffles to achieve uniform approach velocities at the location which has minimal sweeping flows (Hanna and Mefford, 1999).

Fish Screening Criteria

Positive barrier fish screens are typically designed to meet velocity criteria for the protection of threatened and endangered fish species. The primary criteria are the sweeping and approach velocities at the screen face. Sweeping velocity is defined as the component parallel to the screen face and approach velocity is the component perpendicular (normal) to the screen face (DeMoyer and Vermeyen, 2009). At the Rock Slough site, the typical riverine sweeping velocity criteria cannot be met because the site is tidal and has periods of no flow or flow in either the upstream or downstream direction.

The approach velocity criteria for the Rock Slough Fish Screen are primarily for the protection of winter run Chinook salmon (*Onchorhynchus tshawytscha)* and Delta smelt (*Hypomesus transpacificus*). The National Marine Fisheries Service (NMFS) has established fish screen criteria for juvenile anadromous salmonids to be less than 0.33 ft/sec (National Marine Fisheries Service, 1997). In addition to the NMFS criteria, the U.S. Fish and Wildlife Service (USFWS) published a Biological Opinion for the Los Vaqueros Project that requires the Rock Slough Fish Screen to maintain an average approach velocity of 0.2 ft/sec or lower (U.S. Fish and Wildlife Service, 1993). The NMFS and USFWS criteria establish a maximum allowable and average approach velocity for this fish screen evaluation, respectively.

Data Collection and Analyses

Velocity Measurements

A major component of the hydraulic evaluation was velocity measurements over the majority of the fish screens. Three-dimensional velocity measurements were taken approximately 3 inches from the screen face using Acoustic Doppler Velocimeters (ADVs) as shown in Figure 5. The 10 MHz ADVs have an accuracy of ± 1% of the measured velocity with a velocity range from ±0.003 to 8.2 ft/s. Data were acquired at sampling rates of 25 Hz, allowing for the measurement of turbulence characteristics of the flow.

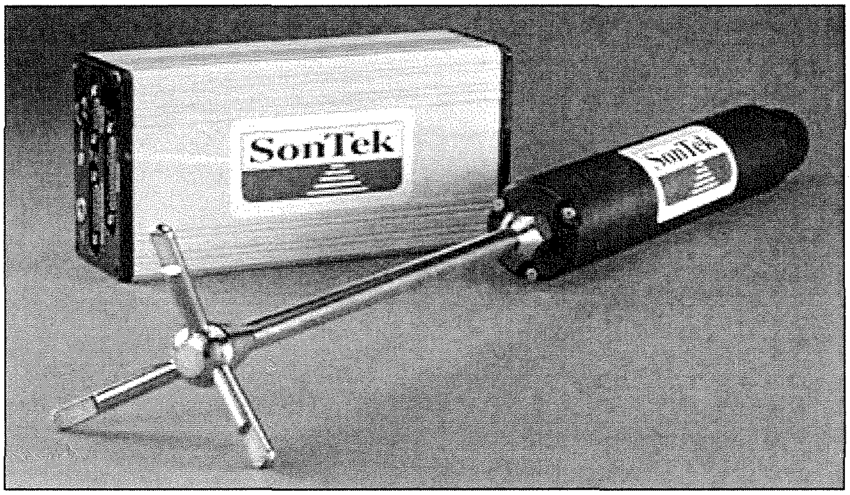


Figure 5 SonTek/YSI Field ADV probe and splash-proof signal processing module.

ADV Theory of Operation

An ADV is a high-resolution acoustic Doppler velocimeter that measures 3-dimensional velocity vectors in a remotely sampled volume. The ADV is a bi-static Doppler current meter which means the ADV uses separate acoustic transducers for transmitter and receivers (Figure 6). The transducers are mounted such that their respective beams intersect over a volume of water located some distance away, called the sampling volume. ADVs normally report velocity data in a Cartesian (X,Y,Z) coordinate system relative to the probe's orientation. Depending on the ADV model, the sampling volume can be located either 5 or 10 cm from the tip of the acoustic sensor. The 5 cm sensor is usually used in laboratories and in shallow water, and the 10 cm sensor is a more robust field probe that has less potential for flow interference in turbulent flow. The field probes were used for this project (serial numbers A254A, A693, and 1328). The probe configuration used throughout testing is shown in Table 1.

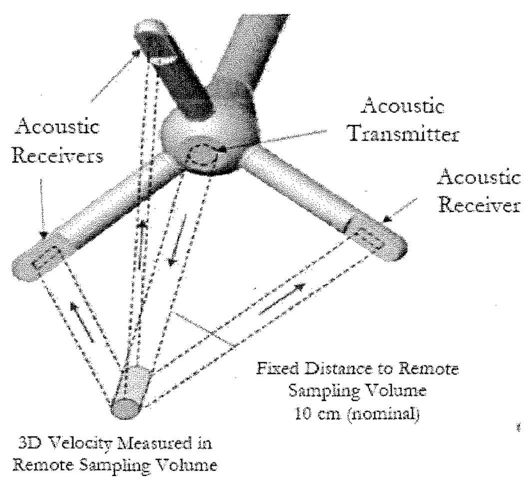


Figure 6. Schematic of ADV probe head orientation and sampling volume. (Image provided by Sontek/YSI Inc.).

Table 1. Sontek ADV Instrument Specifications and Configuration

Parameter	Value
Instrument Model	Field ADV
Instrument Serial Numbers	A254, A693, and 1328
Operating Acoustic Frequency	10 Megahertz (MHz)
Sampling Volume	0.25 cm^3 (0.015 in^3)
Distance to Sampling Volume (from acoustic transmitter)	10 cm (3.94 inches)
Resolution	0.01 cm/sec (0.0003 ft/sec)
Accuracy	±1 % of measured velocity
Instrument Configuration	
Sampling rate	25 Hz
Max Velocity Range Setting	30 cm/s (0.98 ft/s)
Data Collection Period (Burst)	24 seconds
Salinity	1 ppt (part per thousand)
Water temperature	21° C

ADV Mounting Configuration

Velocimeters were clamped onto the trash rack head as shown in Figure 7. The ADVs were positioned so that velocities were measured approximately 3 inches from the screen face with the x-velocity component perpendicular and y-velocity component parallel to the screen face. Three ADVs were used in testing and either one or two probes were used on one trash rake head. For the one probe configuration, the instrument was mounted about 1.7 ft from the left side of the rake head to be upstream from the trash rake mast. For two probes, each ADV was mounted about 1 ft in from both sides of the rake head (Figure 7). The probes were mounted facing upward to reduce flow disturbance and minimize the risk of contact with the channel floor. The ADV probes were located 31 inches above the rake head brush. This position placed the ADV sample volume 35 inches above the rake head brush. Mounting the instruments on the trash rack allowed them to be moved quickly and accurately in both vertical and horizontal directions to specific measurement locations on the screen.

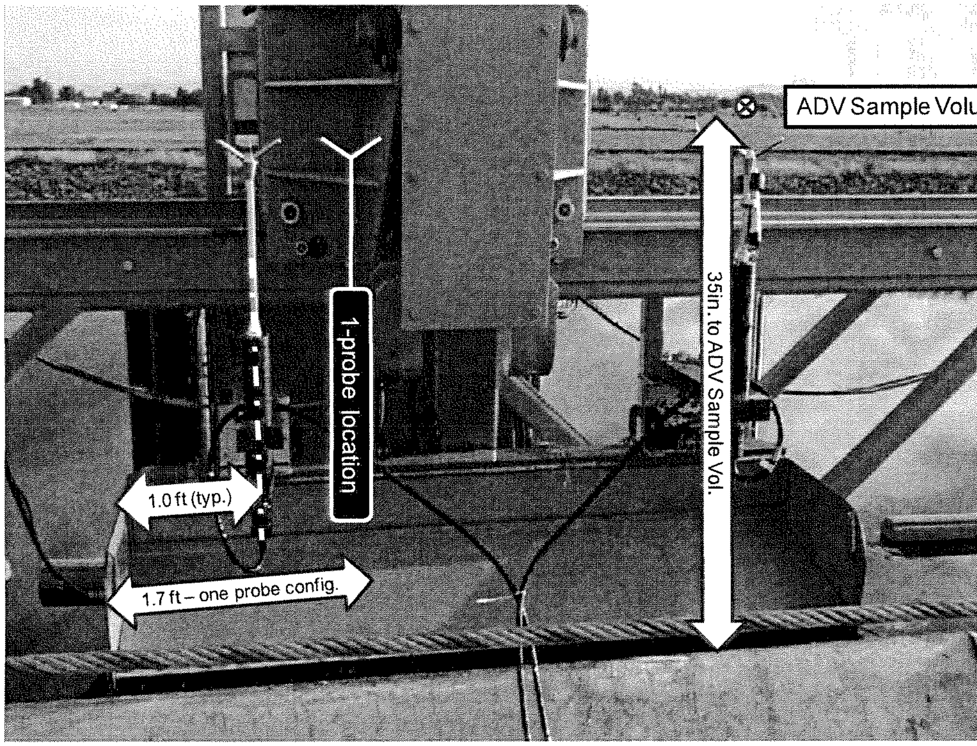


Figure 7. Two ADV probe configuration mounted on trash rake head and the approximately location of the 1 probe configuration.

Velocity Measurement Locations

1- Probe Configuration

Six measurements were made for each screen panel using the 1-probe configuration. During data collection the rake head made vertical passes at two horizontal locations on each panel and measurements were made at 3 vertical positions on each pass. The first and second horizontal measurement location was about 2.2 and 6.2 ft from the upstream end of the panel, respectively (Table 2). On test day 1, vertical positions were set to elevations -4.17 ft, -0.67 ft, and 2.8 ft. However, the 2.8 ft elevation was out of the water for the entire testing period. Adjustments were made on days 2 and 3 to position the ADVs at elevations -4.17, -1.67, and -0.47 ft.

2-Probe Configuration

Twelve measurements were made for each screen panel using the 2-probe configuration. The horizontal locations for vertical passes with the rake head were the same as the 1 probe configuration. Measurement locations for the probes are shown in Table 2. The distance and location are referenced from the upstream end of the screen panel. The two probes are referred to as the upstream (U/S) or downstream (D/S) probe as shown in the table. The vertical positions were the same as the 1-probe configuration.

Table 2. Distances for horizontal probe and location references on each screen.

Probe Configuration	Probe	Location	Distance from U/S end of panel (*ft*)
2	U/S	L1	1.5
	D/S	L2	4.5
	U/S	L3	5.5
	D/S	L4	8.5
1	-	L5	2.2
	-	L6	6.2

Water Level

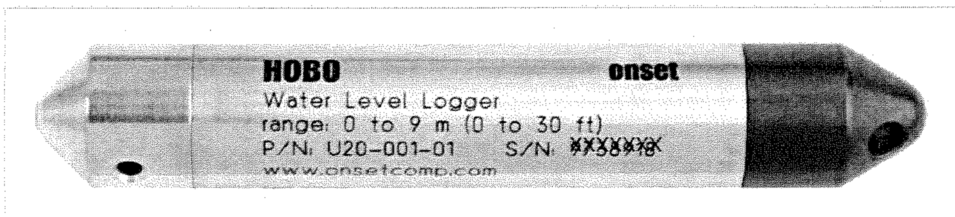
Water surface elevations were monitored during testing with water level data available online at the California Data Exchange Center (CDEC) website. CDEC stage elevations at the Rock Slough are reported with respect to the NAVD88 vertical datum. Stage data were converted to the project construction datum (NGVD 29) for the Rock Slough Fish Screen by subtracting 2.55 ft from the stage data, which is the site-specific correction from NAVD88 to NGVD29. Stage data were used before testing to plan when to start and end testing each day to ensure that the low tide and incoming flood tide conditions were captured in the testing. Low tide conditions are when the smallest amount of screen face is submerged, so flow into the screen is concentrated in a portion of the entire screen. These conditions were included in the hydraulic analysis to test whether flow into the screen through the reduced screen area exceeds the approach velocity criteria. Flood tide conditions are when the maximum tidal flow occurs through the screen. These conditions were included to test whether pumped diversions plus tidal flow through the screen would exceed approach velocity criteria. Stage records were used during post-processing and analyzing hydraulic performance.

Two HOBO® submersible water level loggers (see table 4 for manufacturer's specifications) were located at the pressure relief bay for measuring head differential across the screen structure. One logger was placed upstream and one logger downstream of the screen at the same distance from the top of the screens to log water depths. A third transducer was mounted to one of the ADV probes during testing to help monitor depth at the time of each velocity measurement. A barometric pressure logger was also deployed to collect atmospheric pressure data necessary to convert absolute pressure measurements to water depths.

Table 3. HOBO Water Level Logger performance specifications (photograph was taken from ONSET's online product brochure).

Parameter	Specification
Pressure Range	0 to 30 ft
Water level accuracy	Typical error - ±0.05% FS, 0.015 ft of water

Parameter	Specification
	Maximum error - ±0.1% FS, 0.03 ft of water
Resolution	< 0.003 psi, 0.007 ft of water
Pressure response time	90% < 1 second



Data Collection Period

The fish screen structure was tested for 3 consecutive days (October 11, 12, and 13) referred to as Day 1, Day 2, and Day 3, respectively. Approach velocity measurements were collected at low tide and through the rising flood tide with concurrent pumping at Pumping Plant No. 1. This test methodology was designed to capture the conditions in which the highest approach velocities are likely to occur. Pumping Plant No. 1 maintained a diversion rate of about 200 ft^3/sec through the screens during testing, as summarized in Table 4.

Table 4. Pumping operations and screen head differential data for testing periods for each test day.

Day	Pump Schedule PST		Average Pump Discharge (ft^3/s)	Max head differential across fish structure (ft)
1	Start	11:30	204.5	0.197
	Stop	16:05		
2	Start	12:30	204.7	0.081
	Stop	17:45		
3	Start	12:15	203.0	0.197
	Stop	18:30		

Screen Cleaning

To control debris accumulation on the fish screens, two trash rakes without probes were to be operated during testing. Unfortunately on Day 1 of testing, trash rake #2 was inoperable and parked mid-way across bay 3. This and other trash rake issues led to excessive debris accumulation during Day 1 testing. Although the full screen structure was cleaned as much as possible prior to and during testing, debris on the screen caused high velocities at some locations on the screens. Repairs to trash rake #2 were completed on Day 2 and the rake was parked at the end of bay 4. Debris was particularly problematic during later portions of the testing period on Day 2 when tidal flows were higher and the time since the last cleaning was greatest. Despite issues keeping the screen clean, the head differential across the screen never exceeded 0.2 feet (Table 4).

Debris-affected velocity data from Day 1 and Day 2 were discarded from the final analysis.

Data Analyses

Velocity data were analyzed using WinADV which is a Windows-based viewing and post-processing utility for ADV files that was developed by Reclamation (Wahl, 2000). This program provides an integrated environment for viewing, reviewing, and processing data collected using SonTek and Nortek acoustic Doppler velocimeters (ADV's). Time series velocity data were processed to determine the average velocity components (x,y,z) and summary statistics for each measurement location. Data were filtered to remove measurements with signal-to-noise ratios (SNR) less than 5 and correlation (COR) values less than 70. The filtered data were carefully analyzed to remove debris-affected velocity measurements through the fish screen then compiled to assess the performance of each bay and screen panel.

Results and Discussion

Day 1 Test Results (Oct. 11, 2011)

Velocity testing for Day 1 was conducted from 11:45 to 16:00 PST during low tide and incoming flood tide. Figure 8 shows velocity data taken for each bay and the water surface elevation at the screens throughout the testing period. Testing began with the 2-probe configuration on screen bay B1. Much of the data taken before 12:00 was discarded because of outward flow through the screen caused by an outgoing tide. These velocity measurements were repeated beginning around 13:30 as the incoming tide and pumping at Pumping Plant No. 1 generated flow through the screen into the Contra Costa Canal. Only a few measurements were made at screen bay B3 and none at B4 because access was blocked by a trash rake stuck in front of the second screen of B3.

At 13:30, velocity measurements with the 1-probe configuration were started at B8. Velocities were collected working upstream toward the middle of the structure (B5). Since the screens were not being cleaned during testing, debris was visually apparent on most of the screen panels and weeds periodically fouled the ADV probes. The increasing velocity trend in figure 8 was likely attributed to progressive debris accumulation on the screens. As a result, all velocity measurements made after 15:30 were excluded from the overall analysis of screen performance.

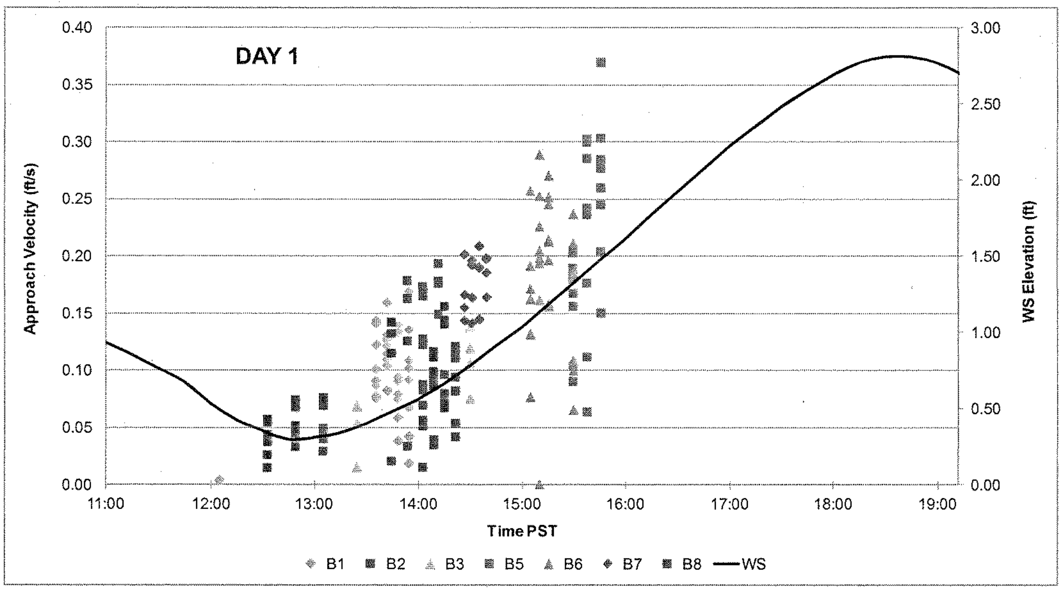


Figure 8. Approach velocity and water surface elevation data from Day 1 (October 11, 2011).

Day 2 Test Results (Oct. 12, 2011)

Day 2 testing was started at 13:40 to avoid outward flows at the screen face that were observed at the end of the ebb tide on Day 1. The 2 probe configuration was used on the downstream half of the structure, beginning at B8 and moving toward the B5. At 14:00, measurement collection using the 1 probe configuration began at B1 and also moved toward the middle of the structure. The trash rake blocking bays 3 and 4 on the first day was moved to the center of the structure, but was still unable to actively clean. This allowed every screen panel of the structure to be measured except for the center most panels on bays 4 and 5 where the inactive trash rakes were parked.

As seen in Day 1, the velocities increased with time throughout the test period (Figure 9). The trend of increasing velocities from 13:40 until about 15:30 was likely due to the increasing flow through the screen from the flood (incoming) tide. Pumping Plant No. 1 flows were held constant through testing. Until about15:30, minimal debris was observed on the screen. Despite an increased effort to keep the screens clean, debris again became an issue later in the testing period. This was evidenced by a sharp increase in velocities and debris apparent on much of the screen. Again, measurements made after 15:30 were assumed to be biased by the debris-laden screen and were not used in the overall analysis.

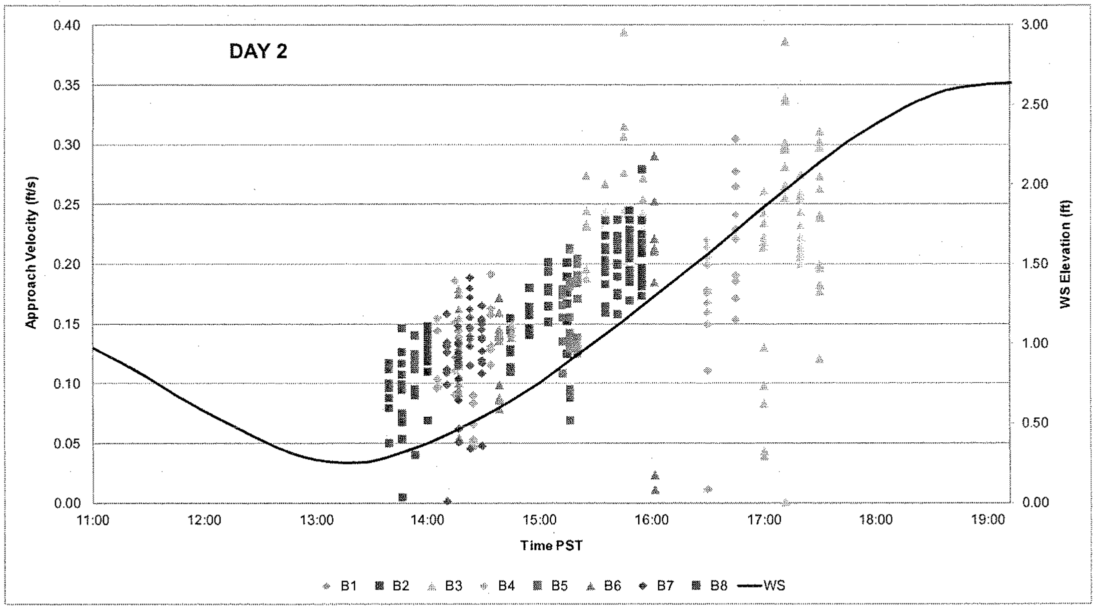


Figure 9. Approach velocity and water surface elevation data from Day 2 (October 12, 2011).

Day 3 Test Results (Oct. 13, 2011)

Testing on Day 3 began at 15:00 and ended at 18:00. Velocity data were collected during the highest flows with the incoming time. Cleaning the screens before and during testing was prioritized on Day 3, including manual operation of the rake mechanisms that had not functioned in automatic mode on Days 1 and 2. The entire structure was cleaned immediately before data collection and the downstream half of the structure (B5-B8) continued to be cleaned during testing of bays B1 through B4

Only the 2-probe configuration was used on Day 3. B7 was tested first to confirm results from Days 1 and 2. After B7 velocities were measured, the ADVs were moved to B4 and data were collected upstream to B1. The trash rake servicing bays 5-8 was restarted in automatic mode. This approach was taken because some of the upstream bays had not yet been measured during the highest flow with clean screens. Debris on the screens was not visually apparent until about 18:00 near the end of the test period. As a result, approach velocity data from Day 3 are much more uniform than the previous two days as shown in figure 10.

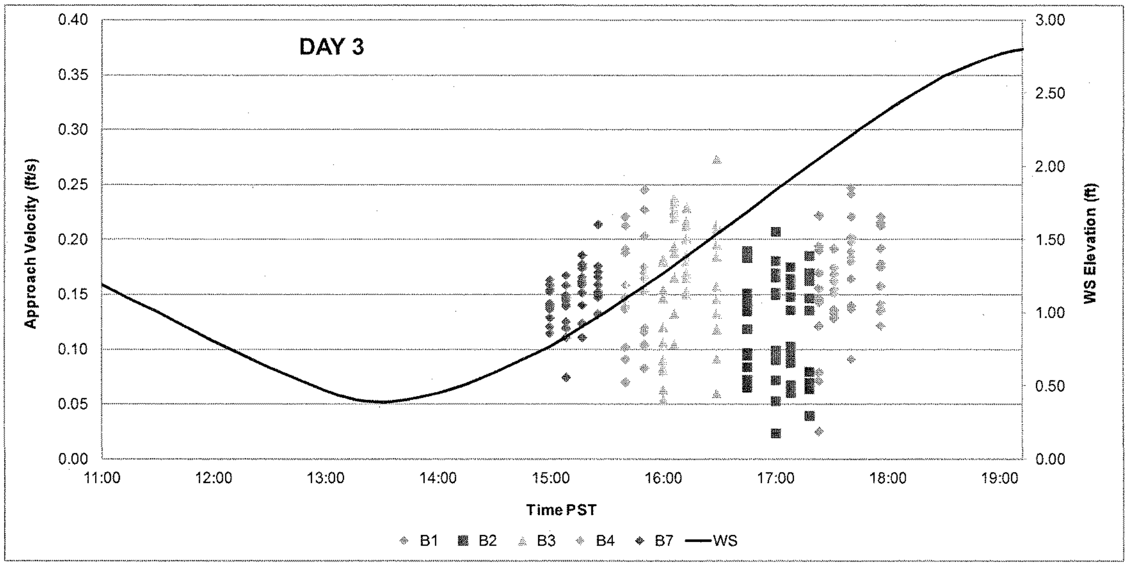


Figure 10. Approach velocity and water surface elevation data from Day 3 (October 13, 2011).

Summary of Results

Throughout the three days of testing a total of 804 velocity measurements were collected. Of that total, there were 589 that were considered valid and used in the overall screen performance analysis. Measurements taken during periods of ebbing or outgoing tide (which causes outward flow through the screen) or on screens with accumulated debris were not used for the screen performance analysis. Table 5 summarizes the approach velocities through each screen bay and the entire structure. The percentage of high velocities include any velocity that was greater than 0.2 ft/sec. These results indicate that velocities through the screens were uniform across the entire structure and that overall the screen meets the established velocity criteria.

Velocity data collected on Day 2 and Day 3 were combined to create a data set when all screen bays were relatively clean. These data were used to create a contour plot of the approach velocity distribution as shown in figure 11. The velocity distribution was relatively uniform with isolated instances of high velocities (i.e. greater than 0.2 ft/sec). Areas with orange and red fill are those where velocities were higher than velocity criteria. Area colored blue and green are less than 0.2 ft/sec.

Table 5. Summary of approach velocity (V_X) measurements at low tide and incoming tide through each Rock Slough Fish Screen bay.

Approach Velocity Data (ft/sec)									
	B1	B2	B3	B4	B5	B6	B7	B8	OVER-ALL
MAX	0.25	0.21	0.27	0.25	0.21	0.29	0.21	0.19	0.29
AVG	0.13	0.11	0.16	0.15	0.15	0.15	0.14	0.11	0.14
HIGH	8.7%	2.3%	28.6%	20.8%	10.0%	16.7%	2.7%	0.0%	8.7%

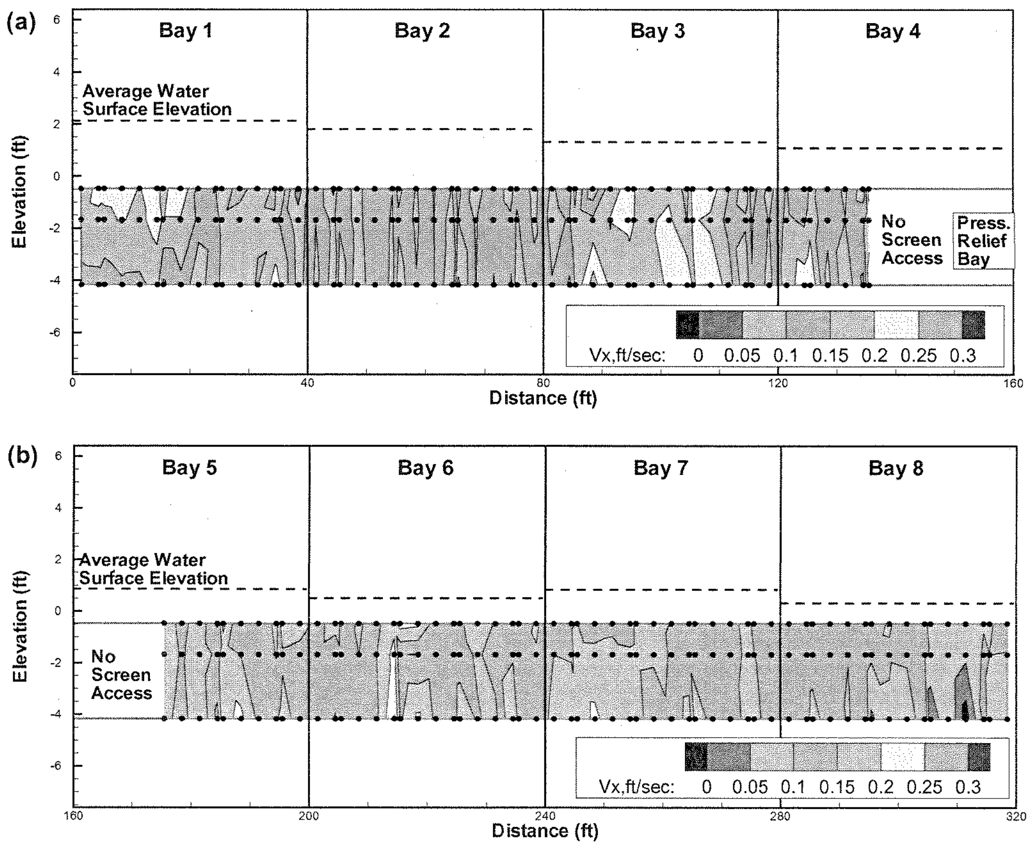


Figure 11. Plot of approach velocity (V_X) contours using clean screen data. Panel (a) contains approach velocity contours for Bay 1-4 and panel (b) has contours for bays 5-8. Dashed lines represent the average water surface elevation during data collection and black dots are data points.

Conclusions and Recommendations

The fish screen structure at the Rock Slough Intake was evaluated for hydraulic performance the week of October 10, 2011. Approach velocities measured 3 inches from the screen face indicated that the facility is capable of operating within hydraulic criteria for Delta smelt (velocity less than 0.2 ft/sec) for a range of hydraulic conditions that are influenced by both tidal flows and pumping rates (up to 200 ft^3/sec) at Pumping Plant No. 1. Uniform velocity distribution across the fish screen confirmed that the baffles were adequately positioned and do not need further adjustment.

Debris on the fish screens, mostly aquatic vegetation, was the primary issue during testing, and poses the greatest threat to future hydraulic performance. Debris was shown to have a significant impact on screen performance if the screens are not regularly cleaned. Due to the potential for heavy debris loads, it is recommended that the fish screen cleaning system be regularly evaluated for debris removal performance.

Debris removal evaluation may be more effective at assessing the structure's hydraulic operation than periodic evaluations using approach velocity measurements.

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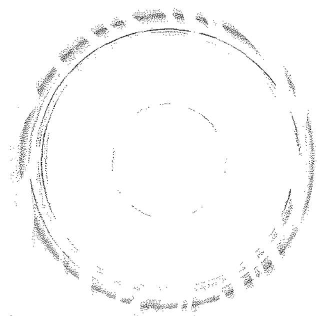

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