March 10, 1995

Mr. John Caffrey, Chairman
State Water Resources Control Board
901 P Street
P. O. Box 100
Sacramento CA 95812-0100

RE: Comments of the San Joaquin Tributary Agencies on the Draft Water Quality Control Plan and Environmental Report for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary

Dear Mr. Caffrey:

Contrary to assertions made in the Draft Plan and the accompanying Environmental Report, the CUWA/Ag proposal did not represent a consensus by all agricultural interests. In fact, most of the agricultural water agencies in the state were not present during, nor were they asked to attend, any of the deliberations on the CUWA/Ag proposal.

Included with this letter are the San Joaquin Tributary Agencies ("SJTA") comments on the Draft Water Quality Control Plan ("Draft Plan") and Environmental Report Appendix for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary. The SJTA consists of the Merced, Modesto, Oakdale, South San Joaquin and Turlock Irrigation Districts. Following is a summary of our main comments on the Draft Plan.

**SWP and CVP Pumping Impacts**

The Draft Plan notes that salmon populations have been severely affected by pumping operations in the Delta and that peak chinook salmon losses occur at the state and federal export pumps in April through June when the fall run smolts are passing through the Delta. In addition, prior testimony by DFG, USFWS, and NMFS left no doubt that the direct and indirect effects of CVP and SWP export pumping operations are responsible for declining populations of anadromous and resident fish. While valid arguments may exist regarding the various analytical tools employed to define and quantify project impacts on specific species, the inescapable fact is that exports, given the present hydraulic configuration of the Delta, significantly impact fisheries through direct entrainment, interference with migration pathways, and elimination of once productive spawning and nursery areas. Export project operations have also altered the natural and historic seasonal pattern of Delta outflows.
The burden of dealing with these project-created impacts cannot be transferred to other entities. The projects alone must be held responsible for flows necessary to permit export pumping, whether those flows are operational carriage water or additional flows to offset and mitigate these project impacts.

Salmon Models

If the statistical validity of the USFWS model is so criticized, why is the State Board using it for their analysis? The SJTA and others have presented testimony at previous State Board hearings and workshops regarding the suitability and use of the USFWS smolt survival model. As pointed out at the October 13 and October 19, 1994 workshops, the model incorrectly uses and interprets the smolt survival data. As a result, it is inappropriate to use the model for the purpose of determining outflows and for setting policy.

The models do, however, show the significance that the Old River Barrier has on the survival of salmon smolts migrating through the Delta. Figures VIII-29 and VIII-30 in the Environmental Report show that with the Old River Barrier in place, smolt survival is more than doubled. Even though we disagree with the USFWS model, that model has been incorporated in the EACH salmon population model. The SJTA evaluated various pulse flow alternatives using the EACH model. The results show that with the Old River Barrier there is a three to four fold increase in salmon population over the base case through a ten year period of analysis.

Finally, we have pointed out that with a correct interpretation of the USFWS data, salmon smolts can survive at temperatures substantially higher than those being recommended by the USFWS. Our analysis indicates that survival is relatively insensitive to temperature until about 70 degrees F.

Salinity

Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water. We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by requiring those discharging saline water into the river to cease all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying on additional fresh water flows to dilute such salt. The only real solution to the San Joaquin Valley salinity problem is to export salt from the valley through an isolated channel.

Identifying additional releases from other reservoirs as may be required through ongoing and future FERC proceedings is inappropriate. The USBR New Melones project is obligated, as a condition of its water rights permit, to meet certain salinity standards in the southern Delta. It is inappropriate to suggest that upstream water users contribute flows to meet the permit conditions of a junior water appropriator. The only appropriate way to meet the salinity objectives is to reduce, eliminate or mitigate the salt discharges to the San Joaquin River. Since much of the salt entering the San Joaquin River originates in the CVP service area, it appears that the burden to solve the salinity problem also belongs on the CVP.
San Joaquin River Flow Standards

The Draft Plan identifies two purposes for the San Joaquin River flow standards. One is to move smolts past the pumps — if the pumps are the cause of the decline to the species, then it is the export projects that must mitigate for their own project-related impacts. The second purpose is to move the smolts from the upstream areas. Moving the smolts from upstream areas is a subject that is being addressed currently in other forums and should not be included in this plan.

The SJTA objects to the proposed flows because there is no scientific basis for these flows. These flow standards were never presented at any public forum and the parties have had no opportunity to review and comment on them. The flows were agreed to during last minute negotiations prior to the December 15, 1994 Bay–Delta announcement. They appear to be based on recommendations of the USFWS for the benefit of Delta smelt rather than flows necessary for the protection of chinook salmon. These flow requirements are made necessary only by the need to move the young fish past the pumps or to keep them far enough down-stream so they are removed from the direct influence of the pumps. The proposed outflows, which often significantly exceed those experienced under pre-project periods of fishery abundance, do not serve any habitat or biological purpose so much as they attempt to separate public trust resources from the pumps.

The SJTA urges the State Board to consider including the Old River Barrier in the preferred alternative. The Draft Plan fails to include the Old River Barrier as recommended by all the parties to the Bay–Delta process and as required under the Principles for Agreement on Bay–Delta Standards between the State of California and the Federal Government. To ignore the agreement and require the use of a large quantity of water to provide protection where a physical solution is recognized as appropriately by the signatories to the Bay-Delta settlement will be a tremendous waste and an unreasonable allocation of water for public trust purposes.

Water Supply Impacts

There should be no inference, implied or otherwise, regarding the distribution of water supply impacts to anyone other than the CVP and SWP. The Draft Plan covers only a three year period. During the three year period, the USBR is required to meet the San Joaquin River flow objectives, in accordance with the Draft Plan and the biological opinion for Delta smelt. The flows provided by the USBR are described as interim flows and will be reevaluated as to timing and magnitude within the next three years. The SWRCB is not even considering allocation of flows at this time — the allocation process will be the subject of a water right proceeding which is scheduled to commence following the adoption of the Draft Plan. At that time the State Board has stated it will allocate responsibility for meeting the San Joaquin River flow objectives among the water right holders in the watershed, after considering the water right priority system, watershed protection and area of origin laws, and decisions by the Federal Energy Regulatory Commission and other regulatory agencies. Consequently, the impacts described in the Environmental Report should be limited to those areas dependent upon flows provided by USBR’s entitlement from New Melones. The proper time to evaluate the impacts of any proposed allocation scheme is during the water right phase. In addition, CEQA requires that the
State Board prepare an environmental impact report before issuing any order reallocating water to benefit public trust resources in the Bay-Delta estuary.

The SJTA members are very concerned that the State Board and its staff may not adequately consider the present and future water requirements and beneficial uses of water by SJTA agencies. This concern is heightened by the fact that for the San Joaquin River, the Draft Plan focuses almost entirely on additional water requirements for the water quality and environmental uses in the Delta. In contrast, there is almost no discussion of the very important upstream uses of water in the San Joaquin Valley.

The San Joaquin Tributary Agencies stands ready to work with the State Water Resources Control Board and the other participants to reach an acceptable solution to the problems facing the resources of the San Joaquin River and the Bay-Delta.

Respectfully submitted,

SAN JOAQUIN TRIBUTARY AGENCIES

By

ARTHUR F. GODWIN
Attorney for the Turlock Irrigation District

Encl.

cc: Paul Elias
    Barrett Kehl
    Rick Martin
    Ross Rogers
    Allen Short
COMMENTS OF THE SAN JOAQUIN TRIBUTARY AGENCIES ON THE STATE WATER RESOURCES CONTROL BOARD DRAFT WATER QUALITY CONTROL PLAN AND ENVIRONMENTAL REPORT FOR THE SAN FRANCISCO BAY/SACRAMENTO–SAN JOAQUIN DELTA ESTUARY

MARCH 10, 1995

SAN JOAQUIN TRIBUTARY AGENCIES
Merced Irrigation District
Modesto Irrigation District
Oakdale Irrigation District
South San Joaquin Irrigation District
Turlock Irrigation District
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2. Comments of the San Joaquin Tributary Agencies on the Environmental Report Appendix to the Draft Bay-Delta Water Quality Control Plan

Salinity objectives for the lower San Joaquin River are included to protect striped bass spawning habitat.

The salinity objectives in the Draft Plan appear to be in agreement with the data submitted by the SJTA and other agencies showing that there is no reason to extend striped bass spawning habitat above Prisoner's Point on the San Joaquin River. The SJTA has pointed out that (1) there is no real scientific evidence that a salinity barrier to migration exists; (2) even if such a barrier did exist, it would not affect the production of striped bass, because as broadcast spawners, they are not spawning-habitat limited; and (3) if striped bass did spawn farther upstream, the eggs and larvae would be susceptible to increased entrainment at the stated and federal pumping facilities.

However, the proposed Prisoner's Point standard under the Draft Plan may not be achievable. Although Prisoner's Point is upstream from the mouth of the Mokelumne River, the transfer of water through the central Delta to the export pumps has historically kept salinity below the 0.44 mmhos EC objective. With the Delta Cross Channel closed and exports restricted, water quality in the Prisoner's Point vicinity may reflect saltier San Joaquin River conditions instead of Mokelumne River conditions. This may be particularly true (1) in April and May, outside the pulse flow period, when the San Joaquin River is managed to meet the 0.7 mmhos EC agricultural standard; and (2) during the April 15–May 15 period when exports are restricted to 100% of the San Joaquin River flow at Vernalis, especially without the Old River barrier in place.

Table 3: San Joaquin River Salinity — San Joaquin River between Jersey Point and Prisoner's Point

Same as above comment. Note also that footnote [4] only refers to the Sacramento River Index. Conditions existing on the San Joaquin River may be very different than on the Sacramento River.

Table 3: River Flows — San Joaquin River at Airport Way Bridge, Vernalis

The value for the minimum monthly average flow shows two alternative values for any given water year. There needs to be an explanation when and how the different minimum monthly flow rates are to be determined and maintained.

Table 3: Footnotes [15] and [16].
These footnotes provide that the operations group established under the Framework Agreement is responsible for scheduling San Joaquin River pulse flows. We recommend that the San Joaquin River flow schedule be coordinated with the SJTA and the existing DFG San Joaquin River Flow Coordinator.

There may be other pulse flow combinations besides one 4-week pulse flow and two 2-week pulse flows that will benefit outmigrating salmon smolts. Model results submitted by the SJTA at the October 19, 1994 State Board workshop showed that two 7-day pulse flows with the Old River barrier in place produced three to four fold increases in salmon smolt survival over the base condition. The model results are included with these comments.

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San Joaquin Valley Water Year Hydrologic Classification

Unimpaired runoff within the San Joaquin River basin is used to determine the index. The State Board needs to take into account that a significant portion of the runoff within the San Joaquin River basin is exported for use outside the basin.

Unimpaired runoff for the Tuolumne River is not the same as runoff into Don Pedro. San Francisco diverts an average of 225,000 AF per year out of the Tuolumne River watershed. If the SWRCB does not require contribution from San Francisco to meet the Bay–Delta standards, then the SWRCB should use inflow into Don Pedro to determine the Tuolumne River portion of the San Joaquin Valley Water Year Index.

Total inflow into Millerton Lake is used to calculate the San Joaquin Valley Water Year Index, yet there is no indication that the San Joaquin River is expected to contribute to the Vernalis flow requirements. It is inconsistent to use the San Joaquin River to calculate the index and not expect some contribution from the upper San Joaquin River. If there are no contributions from upper San Joaquin River, then the value for the unimpaired inflow into Millerton Lake should be set at zero.

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During the three-year period, decisions by the Federal Energy Regulatory Commission (FERC) or other regulatory orders may increase flows to the Estuary required of upstream water users. These flows will be considered by the SWRCB in its allocation of responsibility among the water right holders in the watershed during the water right proceeding.

To the extent that the State Board allocates responsibility among water right holders on some basis other than water rights (e.g., on the basis of unimpaired flow) any additional flows ordered by FERC or other regulatory agencies, including flows required by the SWRCB pursuant to orders outside the Bay–Delta process, must be considered by the Board in allocating responsibility among water users in the San Joaquin River basin. In addition, the State Board must also consider the existing flow requirements for
the protection of upstream habitats in its allocation of responsibility among water users.

**Page 25** Elevated salinity in the southern Delta is caused by low flows and discharges of land derived salts, primarily from agricultural drainage.

We strongly disagree that elevated salinity is the result of low flows. Absent discharges of saline drainage water from the west side of the San Joaquin Valley, the flow from the east side tributaries would meet the water quality salinity objectives in the San Joaquin River. If there is any doubt to this then measuring stations should be put on the tributaries to the San Joaquin River immediately upstream of the confluence and on the main stem of the San Joaquin River immediately downstream of the confluence of each tributary.

**Page 25** This plan's objectives for flows in the San Joaquin River at Vernalis are expected to contribute to achieving the salinity objectives in the southern Delta.

Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water. We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by requiring those discharging water in excess of salinity standards into the river to cease, reduce or mitigate all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying additional on fresh water flows to dilute such salt. If the SWRCB continues to require dilution of salts, than those entities responsible for the saline water discharges to the San Joaquin River should provide the water necessary for the dilution of such salts. Sources of water include CVP water stored in San Luis Reservoir and water transfers.

Using additional releases from other reservoirs as may be required through ongoing and future FERC proceedings is inappropriate. The USBR New Melones project is obligated, as a condition of its water rights permit, to meet certain salinity standards in the southern Delta. It is inappropriate to suggest that upstream water users contribute flows to meet the permit conditions of a junior water appropriator. The only appropriate way to meet the salinity objectives is to reduce, mitigate or eliminate the salt discharges to the San Joaquin River.

**Page 25** Feasible measures to implement the dissolved oxygen objective in this plan include ... (3) providing adequate flows the San Joaquin River....

Factors that contribute to the low level dissolved oxygen are not related to the activities of the upstream San Joaquin River basin water users. There should be no obligation placed on these water users to remedy the problems caused by others.
It is important to note that Vernalis flows in the late summer and fall (August-October) have been higher historically than unimpaired flow (see, e.g., Figure V-2 in the Environmental Report.)

If there is any doubt to the effect of San Joaquin River flow on DO concentrations then measuring stations should be put on the tributaries to the San Joaquin River immediately upstream of the confluence and on the main stem of the San Joaquin River immediately downstream of the confluence.

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The out-of-valley disposal of salts is the only measure that will achieve the San Joaquin River water quality objectives.

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Evaluate the effectiveness of barriers as a means of improving fish survival in the Delta.

The recently signed Principles for Agreement on Bay-Delta Standards requires the installation of a barrier at Old River. Not requiring a barrier at the head of Old River may not make compliance "problematic" but it could make achieving the salmon doubling goals unattainable.

At the State Board's October 19, 1994 workshop, the SJTA submitted results of the EACH salmon population model. The model evaluates factors impacting the life of the salmon from spawning, through rearing, outmigration to the ocean (including ocean harvest impacts), and escapement back to spawning. The model was initially presented to the State Board during the Phase I hearing and again during the 1991 water quality hearing. The data submitted by the SJTA shows that with the Old River Barrier, there is a three to four fold increase in salmon population over the base case through a ten year period of analysis. Without the Old River Barrier, there is a less than one fold increase regardless of the alternative selected.

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Reduce the impact of introduced species on native species in the Estuary.

This is another example to support the contention that there is no justification for the protection of striped bass spawning habitat in the lower San Joaquin River. The SJTA and others believe that it is inappropriate to set standards to improve the habitat for an exotic species that is a known threat to the native chinook salmon.

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Improve hatchery programs for species of concern.

We support the establishment of a salmon hatchery in the Tuolumne River watershed.
Minimize losses of salmon and steelhead to flow fluctuations.

Ramping rates for the protection of salmon and steelhead are already given due consideration as part of the FERC licensing process. It is inappropriate for the regulatory agencies to make recommendations to the SWRCB regarding changes in water rights permits on FERC-licensed facilities.

Evaluate alternative water conveyance and storage facilities of the SWP and CVP in the Delta.

We support additional facilities in the Delta. It is becoming increasingly apparent that a peripheral canal or similar water conveyance facility is necessary to protect the quality and quantity of the water supply that must move through the Delta and to maintain and enhance the fish, wildlife, and other environmental needs of the estuary.

Develop an experimental study program on the effects of pulse flows on fish eggs and larvae in the Delta.

We support efforts to investigate and evaluate the biological effects of duration and rate of change in pulse flows on the egg and larval stages of fish that are present in the Delta in the spring.

Implement temperature control measures to reduce adverse effects on salmon and steelhead.

Numerous participants have commented in the past on the effects of reservoir releases on downstream temperatures (see e.g., WQCP-CVPWA 204). This led the State Board to conclude in its 1991 Water Quality Control Plan that reservoir releases were not a "controllable factor" for achieving water quality temperature objectives.

Additionally we have pointed out that there is no evidence that temperatures in the San Joaquin River affect either salmon recruitment or escape ment. Temperature has not been demonstrated as a significant factor in survival of outmigrating juvenile salmon in the San Joaquin River. The San Joaquin River population of chinook salmon is the most southerly population and therefore might be expected to be least susceptible to high temperatures.

Figure 1 shows the daily average water temperature for water released from New Don Pedro between 1978 and 1993. Except for a few days in 1980 the temperature of the water released from New Don Pedro has ranged from 47°F and 53°F, well below the temperatures needed for chinook salmon.
Figure 1. Daily water release temperatures from New Don Pedro Powerhouse 1978-1992. (A single temperature measurement was taken daily at each of three power generating units and averaged for water years 1989-1992. Prior to water year 1989, data were either the average of three power generating units, or from a single representative unit. Data are not available for October, November, and December 1988.)
I-4, I-5  Water Right Holders

We support the SWRCB recognition that California has an established water right system which allows for the orderly allocation and use of its water supply. Also, we agree that the watershed protection and area of origin statutes accord first priority to water rights for use within the watershed. The CVP and SWP water rights are subject to these provisions, and diversions for export by these projects are restricted until the needs in the watershed, including protections for beneficial uses in the Bay-Delta estuary, are met.

I-7  SWP

According to the report ½ of the SWP supply is comprised of excess Delta flows. To the extent that these “excess” Delta flows were previously available to meet the fish and wildlife needs of the Bay-Delta estuary, their export for use outside the watershed is subject to first meeting the beneficial uses of the Bay-Delta and for other beneficial uses within the watershed.

I-8  Decision 990

In one of the first Delta water right decisions, the State Water Rights Board recognized the importance of watershed protection principles, stating that the “public interest” requires protection of areas of origin (Decision 990, pp. 72-73). The Delta Mendota and Contra Costa canal permits prohibit export until in-basin demands are satisfied. Furthermore, the State Water Rights Board reserved jurisdiction to consider bypassing natural flow or releasing storage to meet CVP responsibility for Bay-Delta needs. The State Board should continue to require the Delta export projects to mitigate their unique environmental impacts and the hold the export projects solely responsible for providing the water needed to meet their own export uses, carriage water requirements, and their authorized responsibility for salinity control.

II-5  Salinity objectives for the lower San Joaquin River

The Draft Plan and Environmental Report include salinity objectives included to protect striped bass spawning habitat in the lower San Joaquin River. The objectives are consistent with data presented by the Modesto and Turlock Irrigation Districts, and more recently the San Joaquin Tributary Agencies, that expansion of the striped bass spawning habitat in the lower San Joaquin River is not necessary. Attached to these comments are copies of materials submitted to the SWRCB at its October 19, 1994 workshop concerning striped bass spawning in the San Joaquin River.

However, meeting the proposed Prisoner’s Point standard under the Draft Plan may not be possible. Although Prisoner’s Point is upstream from the mouth of the Mokelumne River, the transfer of water through the central Delta to the export pumps has
historically kept salinity below the 0.44 mmhos EC objective. With the Delta Cross Channel closed and exports restricted, water quality in the Prisoner’s Point vicinity may reflect saltier San Joaquin River conditions instead of Mokelumne River conditions. This may be particularly true (1) in April and May, outside the pulse flow period, when the San Joaquin River is managed to meet the 0.7 mmhos EC agricultural standard, and (2) during the April 15–May 15 period when exports are restricted to 100% of the San Joaquin River flow at Vernalis, especially without the Old River barrier in place.

Table II-3 Footnotes

Footnote [10] defines the Eight River Index as the sum of unimpaired runoff for the eight rivers listed, including the Tuolumne and San Joaquin Rivers, as published in DWR Bulletin 120.

Unimpaired runoff for the Tuolumne River is not the same as runoff into Don Pedro. San Francisco diverts an average of 225,000 AF per year out of the Tuolumne River watershed. If the SWRCB does not require contribution from San Francisco to meet the Bay–Delta standards, then the SWRCB should use inflow into Don Pedro to determine the Tuolumne River portion of San Joaquin Valley Water Year Index.

Total inflow into Millerton Lake is used to calculate the San Joaquin Valley Water Year Index, yet there is no indication that the San Joaquin River is expected to contribute to the Vernalis flow requirements. It is inconsistent to use the San Joaquin River to calculate the index and not expect some contribution from the upper San Joaquin River. If there are no contributions from the upper San Joaquin River, then the value for the unimpaired inflow into Millerton Lake should be set at zero.

San Joaquin Valley Water Year Hydrologic Classification

Footnote 2 for Table II-3 should be “Footnote 3”.

As noted above, unimpaired runoff for the Tuolumne River is not the same as runoff into Don Pedro. If the SWRCB does not require contribution from San Francisco to meet the Bay–Delta standards, then the SWRCB should use inflow into Don Pedro to determine the Tuolumne River portion of San Joaquin Valley Water Year Index. If there are no contributions from the upper San Joaquin River, then the value for the unimpaired inflow into Millerton Lake should be set at zero.

Footnote [b]

See above comments regarding the Eight River Index.

Central Valley Basin Description

The description of the aquifer underlying the Central Valley states that “Useable storage capacity in a depth zone of 200 feet below ground surface has been estimated as between 80 and 93 MAF in the San Joaquin River basin....”. The SWRCB should understand that there are literally thousands of domestic wells drilled to depths of less than 100 feet—in order to estimate the cost of emptying and filling this underground space, SWRCB will have to analyze cost of deepening all domestic wells to more than 200 feet. In addition there is already an overdraft of 209,000 acre-feet on average in the San Joaquin River Basin. This plan will only make the...
overdraft worse.

**Sacramento Valley—Surface Water Hydrology**

Average runoff from Sacramento Basin is estimated at 21.3 MAF. No similar number given for San Joaquin River Basin on p. IV-24.

**San Joaquin River Basin—Surface Water Hydrology**

The sentence "At times, no flows may also occur below diversion points on the larger streams" is only correct for portions of the San Joaquin River upstream of the mouth of the Merced River. It is not true for the Merced, Tuolumne or Stanislaus rivers, or the mainstem San Joaquin River below the mouth of the Merced River.

**Major Reservoirs in the San Joaquin River Basin**

San Francisco controls 740,000 AF of the storage in Don Pedro Reservoir, consisting of 570,000 AF plus half of any encroachment into the 340,000 AF of flood control space. The 740,000 AF of New Don Pedro capacity should be allocated to San Francisco. Also, Buchanan Dam on the Fresno River should be included in list of major reservoirs.

**San Joaquin River Basin—Surface Water Quality**

Please provide a reference for the statement that dissolved oxygen fluctuations due to algal concentrations and partially treated M&I wastewater have led to fish kills on the Stanislaus, Tuolumne and San Joaquin Rivers. The cause of these fish kills is not the responsibility of the upstream water projects. These problems should be addressed by the State and Regional Boards through their authority to regulate wastewater discharges.

The sentence "At times the entire flow in the river is comprised of used water" is only correct for portions of the San Joaquin River upstream of the mouth of the Merced River. It is not true for the Merced, Tuolumne or Stanislaus rivers, or the mainstem San Joaquin River below the mouth of the Merced River.

**San Joaquin River Basin—Land Use and Economy**

The entire discussion is limited to the land use and economy of the Delta export agricultural areas. This section should be revised to include the land use and economy of the eastside San Joaquin Valley.

**San Joaquin River Basin—Recreation**

The entire discussion is limited to recreation at the CVP and SWP facilities. There is no mention of the recreational opportunities elsewhere in the basin, including reservoir recreation at New Melones, New Don Pedro, New Exchequer and others, fishing along the basin's rivers and streams, and boating and whitewater rafting on the ma-
V-2  Water Year Types for the Sacramento and San Joaquin River Basins

As pointed out in prior proceedings by the DFG and the Modesto and Turlock Irrigation Districts, there are significant differences between the hydrology of the Sacramento and San Joaquin Rivers. Table V-1 shows that of the 63 years between 1930 and 1992 there were 15 years in which conditions in the San Joaquin River Basin were drier than in the Sacramento River Basin and 12 years in which the opposite was true. The SWRCB must keep these differences in mind when it compares environmental conditions in the two basins and it must not make the same assumptions for both basins when it is determining allocation of basin responsibilities to the Bay–Delta Estuary.

V-8  Inflows to the Delta

As pointed out below, the solution to the high salinity problem in the lower San Joaquin River is to export salt from the valley through an isolated channel.

V-9  Figure V-2

While the SJTA acknowledges that water projects within the basin have reduced the San Joaquin River spring runoff as compared to the calculated unimpaired flow, the figure is misleading in that fails to recognize that a significant portion of the water captured by upstream reservoirs during the spring peak is held for flood control purposes. The significant benefits provided by these flood control operations must be recognized by the State Board. Additionally, unlike the Sacramento River Basin, some 1,500,000 AF of San Joaquin River Basin water is exported out of the San Joaquin River Basin via the Hetch Hetchy Aqueduct and the Friant-Kern Canal. Other in-basin users should not be responsible for the obligations of the water users who divert water out of the basin.

V-18  Reverse Flows

It is important to note that tidal flows dominate water movement in the estuary. The increases in spring flows recommended for the San Joaquin River, while generally increasing the net seaward movement of water in the Delta, are not of a sufficient magnitude to overcome the tidal influences within the Delta. Once outmigrating salmon smolts have reached the Delta their movement is affected primarily by the tidal flows, not by San Joaquin River flows.

V-19  Freshwater Fish—White Catfish

According to the report, the cause of decline of this species appears to be south Delta exports. Inadequate San Joaquin River flows are not listed as a cause of decline, it is therefore unlikely that increasing flows in the San Joaquin River will benefit this species by overcoming these export project-caused impacts.
Page Comment

V-62  Estuarine Fish—Delta Smelt

The listed causes of decline include (1) restricted habitat and increased losses through entrainment by Delta diversions; (2) movement of the entrapment zone since 1984 from Suisun Bay to the Delta river channels; and (3) increases in the proportion of water diverted from the Delta. Inadequate San Joaquin River flows are not listed as a cause of decline, it is unlikely that increasing flows in the San Joaquin River will benefit this species by overcoming these export project-caused impacts, particularly when 100% of the San Joaquin River flow at Vernalis is exported during the April 15 - May 15 period.

There is no discussion of the effects, if any, that the proposed Old River Barrier may have on the Delta smelt.

V-67  Estuarine Fish—Longfin Smelt

The cause of decline is the increase in water diverted by the SWP and CVP. Inadequate San Joaquin River flows are not listed as a cause of decline, it is therefore unlikely that increasing flows in the San Joaquin River will benefit this species by overcoming these export project-caused impacts.

V-73  Anadromous Fish—Chinook Salmon

There is no scientific evidence that a late-fall run of chinook salmon exists on the San Joaquin River. Allusions to late-fall runs of chinook salmon in the San Joaquin River are of very recent origin. The discovery of this race has not been announced in the fisheries science journals, or at meetings or seminars of fishery biologists. Frank Fisher, a DFG biologist, testified at a recent Senate Water and Resources Committee hearing that the late-fall run of chinook salmon on the San Joaquin River is extinct.

The statement "The Central Valley chinook salmon population now consists primarily of fall-run fish raised in hatcheries" is inconsistent with the statement on p. V-75 that "total escapement averaged 247,100 natural spawners and 28,500 hatchery spawners.

V-76  Anadromous Fish—Chinook Salmon—Population Trends

The lowest escapement ever observed in the San Joaquin River basin was 320 fish in 1963 (WRINT-USFWS-7, p. 6).

V-80  Anadromous Fish—Chinook Salmon—San Joaquin River Basin

We suggest that you revise the statement "low population levels occurred historically and the population rebounded in the 1980's, in response to high flows" to read "low population levels ..., in association with high flows." The higher flows led to higher escapements in large part by reducing the percentage of San Joaquin River water diverted by the CVP and SWP and thereby significantly reducing smolt mortality associated with the pumps.

The Environmental Report notes the responsibility and significance that Friant Dam has had in regard to the reduced production and survival of salmon throughout the San Joaquin River system. This fact cannot be ignored when allocating responsibility. Suitable San Joaquin River flows must be provided by the USBR. Alternatives to
providing the water from Friant Dam include releases of USBR water through New Melones or transferring water through the Delta Mendota Canal and San Luis Reservoir.

V-30-82 Throughout this section are numerous statements regarding the impacts of the export projects on the San Joaquin River chinook salmon population. The report points out that the salmon populations have been severely affected by pumping operations in the Delta and that peak chinook salmon losses occur at the state and federal export pumps in April to June when the fall run smolts are passing through the Delta. The burden of dealing with these project-created impacts cannot be transferred to other entities. The projects alone must be held responsible for flows necessary to permit export pumping, whether those flows are operational carriage water or additional flows to offset and mitigate these project impacts. The State Board's greatest opportunities during the next three years may be in the creative design of operational parameters that will permit CVP and SWP operators, in consultation with the fishery agencies, to most efficiently manage their integrated export and water supply systems to meet both water user and environmental needs.

Additionally, to the extent that dissolved oxygen problems near Stockton are the result of dredging activities and effluent discharges in the Stockton Ship Channel and turning basin. The burden of mitigating these impacts cannot be transferred to other entities.

It is true that chinook salmon escapement in the San Joaquin River Basin is correlated with spring flows at Vernalis 2½ years earlier. However, the causes of this correlation require further analysis. For example, in month-by-month comparisons, the strongest correlation by far is between June flow and escapement, although the peak of the smolt outmigration is always in May. The correlation with July flow is about as strong as that with May, and stronger than with any other month except June, even though there are never any smolts in the San Joaquin River in July. These observations are difficult to reconcile with the simple cause-and-effect relationship suggested in the text.

The poorest correlations of all are for the months of September, October, and November, when the upstream migration of parent spawners takes place. It is therefore ironic that a reference to flow-escapement relations to justify increased spring flow at Vernalis is immediately followed by the claim that increased fall flow would benefit upmigrating adults (p. V-81).

V-90-94 Striped Bass—Causes of Decline

From a policy standpoint, it is inappropriate to set standards to improve the habitat for an exotic species that is a known threat to the native chinook salmon. This entire section lacks any reference to the lack of spawning habitat as a reason for the decline of striped bass. Despite this, the State Board continues to propose salinity objectives to protect striped bass spawning habitat in the lower San Joaquin River.

As pointed out on numerous occasions by the SJTA and the Modesto and Turlock Irrigation Districts there is no reason to adopt a striped bass water quality standard. We believe that (1) there is no real scientific evidence that a salinity barrier to migration exists; (2) even if such a barrier did exist, it would not affect the production of striped bass, because as broadcast spawners, they are not spawning-habitat limited;
(3) if striped bass did spawn farther upstream, the eggs and larvae would be susceptible to increased entrainment at the stated and federal pumping facilities.

**Freshwater Flows**

The State Board’s authority to impose terms and conditions on permits and licenses for the protection of beneficial uses is not without limits. Certainly the Board has authority to add terms and conditions to a permit upon issuance of a license. Once the license is issued, however, the Board’s authority is limited to those situations where it has reserved jurisdiction or it has exercised its authority pursuant to state law and State Board regulations regarding a finding of waste or a specific unreasonable use.

**Water Temperature**

Numerous participants have commented in the past on the effects of reservoir releases on downstream temperatures (see e.g., WQCP-CVPWA 204). This led the State Board to conclude in its 1991 Water Quality Control Plan that reservoir releases were not a “controllable factor” for achieving water quality temperature objectives.

We have continually pointed out that there is no evidence that temperatures in the San Joaquin River affect either salmon recruitment or escapement. Temperature has not been demonstrated as a significant factor in survival of outmigrating juvenile salmon in the San Joaquin River. The San Joaquin River population of chinook salmon is the most southerly population and therefore might be expected to be least susceptible to high temperatures. Figure 1 to SJTA’s comments on the Draft Plan is a figure showing the daily average water temperature for water released from New Don Pedro between 1978 and 1993. Except for a few days in 1980 the temperature of the water released from New Don Pedro has ranged from 47°F and 53°F, well below the temperatures needed for chinook salmon.

**Salmon Models**

Even though DWRSIM has not incorporated operations criteria for non CVP and SWP reservoirs, operations data for these reservoirs has been provided to the USBR for their SANJASM model.

If the statistical validity of the USFWS model is so criticized, why is the State Board using it for their analysis? The SJTA and others have presented testimony at previous State Board hearings and workshops regarding the suitability and use of the USFWS smolt survival model. As pointed out at the October 13 and October 19, 1994 workshops, the model incorrectly uses and interprets the smolt survival data. As a result, it is inappropriate to use the model for the purpose of determining outflows and for setting policy.

Included with these comments is a full copy of a paper entitled “Estimating the influence of temperature on the survival of chinook salmon smolts (Oncorhynchus tshawytscha) migrating through the Sacramento-San Joaquin Delta of California.” The paper points out that with a correct interpretation of the USFWS data, salmon smolts can survive at temperatures substantially higher than those being recommended by the USFWS. The USFWS analysis indicates that increases in tempera-
ture between 61 and 72 degrees F will result in a linear increase in smolt mortality. Our analysis indicates that survival is relatively insensitive to temperature until about 70 degrees F.

The models do, however, show the significance that the Old River Barrier has on the survival of salmon smolts migrating through the Delta. Figures VIII-29 and VIII-30 in the Environmental Report show that with the Old River Barrier in place, smolt survival is more than doubled.

The importance of the Old River barrier was demonstrated by the SJTA at the October 19, 1994 State Board workshop. The SJTA analyzed several pulse flow alternatives with and without the Old River Barrier using the EA Chinook Salmon model. The results showed that with the Old River Barrier in place, there was a three to four fold increase in salmon population over the base case through a ten year period of analysis. Without the Old River Barrier, there was a less than one fold increase due to smolt mortality at the export pumps.

VII-4 Modeling Assumptions—San Joaquin River Flow Requirements

The statement "if there is insufficient water in New Melones to meet all of the requirements, the model obtains additional water from the San Joaquin River upstream of the confluence with the Stanislaus River" should be revised. A more proper characterization of the model's operation is that if there is insufficient USBR water in New Melones to meet all of the requirements, the model obtains water from unspecified sources within the San Joaquin River Basin. The model demonstrates that, depending on hydrologic conditions, the interim standards are unachievable unless the USBR releases water from other sources, such as San Luis Reservoir or the Delta Mendota Canal, to supplement New Melones releases. In addition, the DWRSIM modeling runs do not evaluate potential water supply impacts of full compliance to the South Delta Agriculture standards or the Fish and Wildlife Dissolved Oxygen standard at Stockton. Furthermore, it is inappropriate to assume that there is additional water available because this evaluation is for a short term only.

VII-5 Water Supply Impacts

There should be no inference, implied or otherwise, regarding the distribution of water supply impacts to anyone other than the CVP and SWP. The Draft Plan covers only a three year period. During the three year period, the USBR is required to meet the San Joaquin River flow objectives, in accordance with the Draft Plan and the biological opinion for Delta smelt. The USBR does not have the capability to meet these objectives with its water supply from New Melones. The flows provided by the USBR are described as interim flows and will be reevaluated as to timing and magnitude within the next three years. The SWRCB is not even considering allocation of flows at this time — the allocation process will be the subject of a water right proceeding which is scheduled to commence following the adoption of the Draft Plan. At that time the State Board has stated it will allocate responsibility for meeting the San Joaquin River flow objectives among the water right holders in the watershed, after considering the water right priority system, watershed protection and area of origin laws, and decisions by the Federal Energy Regulatory Commission and other regulatory agencies. Consequently, the impacts described in the Draft Plan should only be limited to those areas dependent upon USBR water from New Melones. The
proper time to evaluate the impacts of any proposed allocation scheme is during the water right phase. In addition, CEQA requires that the State Board prepare an environmental impact report before issuing any order reallocating water to benefit public trust resources in the Bay–Delta estuary.

**Sacramento River Basin Storage Impact**

Is the increase in Sacramento River Basin storage a result of reduced exports by the CVP and the SWP, increased export of San Joaquin River flows during the spring and fall, changes in project operations as a result of the winter run biological opinion, or a combination of all three? It bears repeating that the burden of dealing with project-created impacts cannot be transferred to other entities. To the extent that Sacramento River Basin storage is increased as a result of CVP and SWP export of the additional San Joaquin River flows, the projects alone must be held responsible for providing the flows necessary to permit export pumping and additional flows to offset and mitigate project impacts.

**San Joaquin River Basin Impact**

The two alternatives—reducing storage in reservoirs and limiting deliveries to customers—are basically the same alternative. There should be no water supply impacts to anyone other than the CVP and the SWP. As pointed out above, the Draft Plan covers only a three year period, during which time the USBR is required to meet the San Joaquin River flow objectives, in accordance with the biological opinion for Delta smelt. The SWRCB is not even considering allocation of flows at this time—the allocation process will be the subject of a water right proceeding which is scheduled to commence following the adoption of the Draft Plan.

The San Joaquin River flow requirements are such that the water supply impacts to the San Joaquin River basin are actually greater in wet, above normal and below normal years than the export projects’ water supply impacts. The upstream projects cannot be held responsible for providing flow for the benefit of the export projects. The CVP and SWP alone must provide the flows necessary to permit export pumping. The proposed outflows do not serve any habitat or biological purpose so much as they attempt to separate public trust resources from the pumps.

The most important and efficient way to reduce the amount of water necessary to maintain water quality in the south Delta is to remove the salt discharged to the San Joaquin River. This would leave more water available in New Melones for fish flows and to meet USBR obligations. It is improper and illegal to allocate responsibility for water quality control and excess fish flows to non-CVP and SWP reservoirs.

**New Melones Reservoir Carryover Storage and San Joaquin River Flow**

The term “average annual additional water” is inconsistent between these two sections. Is “average annual additional water” the amount of water needed from New Melones to meet the Vernalis flow requirement under the preferred alternative as compared to the base case or does it refer to the shortage on the San Joaquin River after attempting to meet the San Joaquin River flow requirement from New Melones?

**Figure VII-15**

Figure VII-5 shows San Luis Reservoir will be filled over ½ of the time by the end of
March. Some of this water should be dedicated for discharge to the San Joaquin River to meet the current and future federal obligation for fish flows and water quality.

VIII-1 Environmental Effects of Preferred Alternative

There should be no inference, implied or otherwise, regarding the distribution of water supply impacts to anyone other than the CVP and SWP. The Draft Plan covers only a three year period. During the three year period, the USBR is required to meet the San Joaquin River flow objectives, in accordance with the Draft Plan and the biological opinion for Delta smelt. The SWRCB is not even considering allocation of flows at this time — the allocation process will be the subject of a water right proceeding which is scheduled to commence following the adoption of the Draft Plan. At that time the State Board has stated it will allocate responsibility for meeting the San Joaquin River flow objectives among the water right holders in the watershed, after considering the water right priority system, watershed protection and area of origin laws, and decisions by the Federal Energy Regulatory Commission and other regulatory agencies. Consequently, the impacts described in the Draft Plan should only be limited to those areas dependent upon USBR water from New Melones. The proper time to evaluate the impacts of any proposed allocation scheme is during the water right phase. In addition, CEQA requires that the State Board prepare an environmental impact report before issuing any order reallocating water to benefit public trust resources in the Bay-Delta estuary.

The 1984-92 reference period used for the environmental analysis is totally inappropriate. It is not representative of conditions on the San Joaquin River. The reference period had 6 critical years in a row, and the one wet year was a subnormal snow melt where most of the runoff occurred in one month. The stated purpose for using this reference period instead of 1922-92 period used for the hydrological analysis is because the Bay-Delta never actually experienced those modeled conditions. The same can be said of the base period for hydrological analysis—it is based on using DWRSIM with D-1485 conditions at the 1995 level of demand assuming a repeat of the 1922-92 historical hydrology. The upstream water users, export projects, farmers, cities, recreationsists, and other water users never experienced those conditions either.

The Bay-Delta environment never "actually experienced" the conditions of the preferred alternative to which the base case is being compared. It is never appropriate to evaluate an alternative by comparing modeled values of abundance or survival indices under the alternative with observed index values: modeled results should always be compared with modeled results. The models, however, can be applied to the water supply base conditions as easily as to historic conditions.

VIII-6 Delta Exports

The export limit for February is based on the Eight River Index. Please see earlier comments on the use of the Eight River Index, page II-9.

VIII-9 Salinity (X2 and Vernalis)

Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water. We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by re-
quiring those discharging water in excess of salinity standards into the river to cease, mitigate or reduce all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying additional on additional fresh water flows to dilute such salt. The only real solution to the San Joaquin Valley salinity problem is to export salt from the valley through an isolated channel.

Identifying additional releases from other reservoirs as may be required through ongoing and future FERC proceedings is inappropriate. The USBR is obligated, as a condition of its water rights permit for New Melones, to meet certain salinity standards in the southern Delta. It is inappropriate to suggest that upstream water users contribute flows to meet the permit conditions of a junior water appropriator. The only appropriate way to meet the salinity objectives is to reduce or eliminate the salt discharges to the San Joaquin River. Since much of the salt entering the San Joaquin River originates in the CVP service area, it appears that the burden to solve the salinity problem also belongs on the CVP.

VIII-15 Spring—Delta Outflow

There is no biological justification for the increased flows in February through June with the exception of pulse flows to move smolts through the Bay—Delta. The April-May San Joaquin River outflows are to promote the production of chinook salmon.

VIII-17 Spring—San Joaquin River Flow

The stated purpose for the San Joaquin River flow standards is to move smolts past the pumps (an export-related impact) or move them from the upstream areas (not a Delta issue). If the pumps are the cause of the decline to the species, then it is the export projects that must mitigate for their own project-related impacts. Moving the smolts from upstream areas is a subject that is being addressed currently in other forums and should not be included in this plan.

The SJTA opposes the proposed San Joaquin River flows standards for the following reasons:

1. There is no scientific basis for these flows. These flow standards were never presented at any public forum, and the parties have had no opportunity to review and comment on the proposed flows. The flows for the San Joaquin River were agreed to during last minute negotiations prior to the December 15, 1994 Bay—Delta announcement. They appear to be based on recommendations of the USFWS for the benefit of Delta smelt rather than flows necessary for the protection of chinook salmon.

2. The preferred alternative fails to include an Old River Barrier despite frequent references in the Environmental report to the benefits of the barrier and despite the fact that the Principles for Agreement on Bay—Delta Standards between the State of California and the Federal Government require the installation of a barrier. According to USFWS smolt survival model results, the preferred alternative would increase the San Joaquin smolt survival index by only 0.01, using the 1984-92 baseline, and only 0.03 using the 1922-92 baseline, over the index resulting from historical flows. The alternative achieves these trivial gains at enormous costs to upstream water users. In
contrast the same USFWS model predicts increases of 0.16 to 0.20 when the barrier is present. The use of so much water where a physical solution has been endorsed by the signatories to the Principles for Agreement would be a tremendous waste and an unreasonable allocation of water for public trust purposes.

3. The Environmental Report states that spring flow requirements in the San Joaquin River outside the salmon outmigration period are meant to benefit various estuarine species by improving salinity conditions in the central and southern Delta, and by providing transport flows out of the central Delta. We object to these conclusions because:

- Delta pumping obviously has adverse effects on salinity and on flow conditions in the central and southern Delta. However, the Draft Plan does not impose any direct limits on spring export, except during the salmon outmigration. The plan does limit the ratio of export to total Delta inflow, but since total inflow is driven primarily by Sacramento flow and releases from upstream projects in the Sacramento River Basin, this has little relevance to conditions in the southern Delta.

- Salinity problems on the San Joaquin River are the responsibility of those discharging water in excess of salinity standards into the river.

4. The Draft Plan includes increased San Joaquin River flows at Vernalis in February through June. The outmigration of smolts takes place primarily in April and May (with small fractions occasionally outmigrating in March or June). Inflow requirements at times when the San Joaquin River salmon are not present are not benefits to San Joaquin River salmon.

VIII-20  Summer—Delta Outflow
The statement "The derivation of the recommended flows is not based on the results of habitat or population studies, rather on scientific judgment" is an example of how these proposed standards are lacking in sound scientific analysis and are without any scientific or biological justification.

VIII-22  Fall—San Joaquin River Flow
There is no scientific evidence which supports the need for attraction pulse flows in the Tuolumne or Stanislaus Rivers:

1. There is no evidence that salmon are having trouble finding the San Joaquin River. Coded wire tag returns show that San Joaquin salmon rarely stray to the Sacramento system, or to rivers entering the Delta from the east.

2. The perceived need for Merced River attraction flows is directly related to the lack of any required fishery flows from the upper San Joaquin. As the uppermost river in the system, the upper San Joaquin River fall flows were a part of the flows which helped guide salmon from all four Basin rivers back to spawn. In the absence of upper San Joaquin River flows, the burden is now being unreasonably placed on the Merced River, as the uppermost river with a salmon run, and on the Tuolumne and Stanislaus Rivers, to mitigate for the lack of flows from the Upper San Joaquin River.
The lack of a scientific basis is supported by the report which states, in part that “The scientific basis for this standard is largely subjective and based on biological judgment.”

To the extent that dissolved oxygen problems near Stockton are the result of dredging activities in the Stockton Ship Channel and turning basin and effluent discharges near Stockton, the burden of mitigating these impacts cannot be transferred to other entities. Dissolved oxygen problems resulting from net reverse flows in the lower San Joaquin River are export-related, and the burden of mitigating these impacts must be placed on the export projects.

It is not clear that dissolved oxygen problems can be significantly improved by changes in San Joaquin River flows as explained below:

1. Testimony presented by the CVPWA concluded that (1) DO concentrations in the San Joaquin River near Stockton are strongly influenced by local factors that reduce DO regardless of relatively high DO concentrations upstream; (2) DO concentrations are strongly influenced by temperature and only weakly influenced by flow; and (3) the temporary barrier installed by DWR in Old River to influence DO in Stockton had no specific effect on DO. (WQCP-CVPWA 202.)

2. Hallock et al. 1970 suggests that export pumping exacerbates the dissolved oxygen problem on the lower San Joaquin River by denying alternate routes to migrating salmon. This is due to the effects of reverse flows in the southern Delta which prevent any San Joaquin Basin water from reaching the western Delta by routes other than the lower San Joaquin River.

The SJTA and the San Joaquin River Flow Coordinator need to make decisions regarding the timing and duration of pulse flows rather than the Operations Group established by the Framework Agreement. Monitoring needs to be conducted to verify the need for and effectiveness of the fall pulse flow.

VIII-29 Aquatic Resource Model Results—Smolt Survival Models

As pointed out above, smolt survival will be more than doubled by the operation of the Old River Barrier during the spring outmigration period. Requiring high spring flows without the Old River Barrier would be a waste and unreasonable use of water.

VIII-30 Figures VIII-29 and VIII-30

Figures VIII-29 and VIII-30 show that without the Old River Barrier there is only a 0.01 improvement in the salmon smolt survival between the calculated and the preferred alternative using the 1984-92 reference period hydrology. According to the model results, there is essentially no benefit to salmon smolts as a result of the proposed San Joaquin River flows. Therefore, as stated previously, it makes no sense to require such high spring flows without the Old River Barrier in place. It appears that the San Joaquin River flow requirements were arrived at through political consensus rather than scientific analysis in order to provide for export of 100% of the Vernalis flow during the pulse flow period. Given that the Old River barrier is not included in the preferred alternative (as called for in the Federal-State Bay-Delta Principles for Agreement), and allowing for export of 100% of the Vernalis flow, there might be an actual decline in salmon smolt survival as opposed to the minuscule in-
crease predicted by the USFWS model.

If the State Board continues to use the 1984-1992 hydrology as a reference period for its environmental analysis, then the portion of the graph showing the model results under the 1922-1992 hydrology should be eliminated.

VIII-50 Agricultural Supply

The report states that the "SWRCB will address the issue of flow allocation, and its intention to implement the objectives, during the water right phase" If the SWRCB is delaying the issue of flow allocation until the water right phase, why does this report analyze the impacts of the standards based upon some assumed allocation? The process for allocating responsibility for flows is not the subject of the Draft Plan, therefore, impacts from the proposed San Joaquin River flows must be allocated to the CVP and the discussion on flow allocation to the others must be eliminated.

VIII-51 Effects in Upstream Areas

The term "upstream area" is defined as the Sacramento Valley and the eastside San Joaquin Valley. The definition excludes the Friant service area, the San Joaquin River exchange contractors, and others who use the waters of the San Joaquin River. If the State Board insists on including the upstream areas in its analysis of the impacts of the Draft Plan, then it must include all users, not just select groups.

VIII-52 River Flows

According to the report there are no Sacramento River impacts since the required flows are similar to the base flows. For the San Joaquin River, the Vernalis flow requirements result in substantial impacts to San Joaquin River flows. In fact, under current conditions, the proposed standards could not be met even in wet years.

VIII-58 Land Use

The report states that water users in upstream areas will be required to contribute an unknown amount of water to meet Bay-Delta standards. The report then refers the reader to Chapter XII for a quantitative assumption regarding the allocation of water supply impacts in the eastside San Joaquin Valley. Chapter XII has no discussion. There is no explanation of the methods used by the State Board to allocate responsibility among the upstream users. We are left to speculate as to how the State Board may have assigned such responsibility.

VIII-61 Recreation

The report states that reservoir levels are likely to decline, but the impacts cannot be determined because reservoir levels will be dependent upon "management decisions" made by reservoir operators, i.e., reducing storage in reservoirs or limiting deliveries to customers. This lack of analysis merely masks the fact that if upstream areas have to make substantial flow contributions, recreation will be significantly affected.

VIII-63 Depletion of Ground Water Resources

As Table VIII-4 points out, the preferred alternative will only exacerbate the current groundwater overdraft situation in the San Joaquin Valley. We agree that the reduced surface water supplies will probably be replaced with groundwater, where
available, and that the overdraft will increase the magnitude of the water supply impact. The discussion of water supply impacts should also state that groundwater overdraft will increase significantly under the preferred alternative.

**VIII-75 Cumulative Impacts:**

This section should also include a discussion of pending FERC decisions on the Mokelumne and Tuolumne Rivers and the pending SWRCB water right decision on the Yuba River.

**VIII-77 Federal ESA**

The report states that requirements under the federal ESA are not incorporated into the base case analysis. This is inconsistent with the base case assumptions on p. VII-4 which states "The base case for this analysis is D-1485 conditions, modified to account for upstream requirements on the Sacramento River imposed by the NMFS to protect winter-run chinook salmon."

**IX-1 to 5 Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water.** We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by requiring those discharging water not meeting salinity requirements into the river to cease all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying additional on additional fresh water flows to dilute such salt. The only appropriate way to meet the salinity objectives is to reduce, mitigate or eliminate the salt discharges to the San Joaquin River. If the SWRCB continues to require dilution of salts, than those entities responsible for the saline water discharges to the San Joaquin River should provide the water necessary for the dilution of such salts. Sources of water include CVP water stored in San Luis Reservoir and water transfers.

We support the SWRCB recommendation to the USBR to study the San Luis Drain—the other in basin alternatives do not solve the salt management problem.

**IX-5 Recommendations to Improve Habitat Conditions**

There needs to be a detailed and open process for prioritizing and funding habitat improvement activities.

**IX-9 The Use of Barriers in the Delta**

There have been no studies to date regarding the potential effect of the Old River Barrier on Delta smelt. Such reservations are made based on speculation and judgment. Requiring high spring flows without the Old River Barrier would be a waste and unreasonable use of water.

**IX-11 Improve Hatchery Programs for Species of Concern**

We support the construction of a hatchery on the Tuolumne River.

**IX-11 Flow Fluctuations**

Ramping rates for the protection of salmon and steelhead are already given due consideration as part of the FERC licensing process. It would be inappropriate for
the SWRCB to recommend changes in instream flow requirements in water rights permits on FERC-licensed facilities.

**Temperature Control**

Numerous participants have commented in the past on the effects of reservoir releases on downstream temperatures (see e.g., WQCP-CVPWA 204). This led the State Board to conclude in its 1991 Water Quality Control Plan that reservoir releases were not a "controllable factor" for achieving water quality temperature objectives.

Additionally we have pointed out that there is no evidence that temperatures in the San Joaquin River affect either salmon recruitment or escapement. Temperature has not been demonstrated as a significant factor in survival of outmigrating juvenile salmon in the San Joaquin River. The San Joaquin River population of Chinook salmon is the most southerly population and therefore might be expected to be least susceptible to high temperatures.

As discussed previously, current release temperatures are not a problem on the Tuolumne River. Except for a few days in 1980 the temperature of the water released from New Don Pedro on the Tuolumne River has ranged from 47°F and 53°F, well below the temperatures needed for chinook salmon.

**Description of Alternatives**

The SWRCB only included complete regulatory alternatives and did not evaluate the SJTA proposal for the San Joaquin River, which requires far less water and provides significant equivalent benefits to the salmon fishery.

Which of the alternatives include the Old River Barrier? It is not apparent from the discussion which alternatives, if any, include the Old River Barrier. The figures comparing smolt survival indices under the various alternatives should be rearranged so that the preferred alternative (which does not include the Old River Barrier) can be compared to the alternatives as proposed (whether or not they include an Old River Barrier). It is misleading to tout the benefits of the Old River Barrier when the State Board's preferred alternative does not include the barrier.

**Fish Migration Criteria (Salmon Smolt Survival Standard)**

See comments above on the suitability and use of the USFWS smolt survival index.

**Impacts of Alternatives on Aquatic Resources—San Joaquin River Salmon**

What is the "base" for purposes of this discussion? Chapter VIII uses a 1982-92 reference period hydrology, while Chapter XII apparently uses the 1922-92 historical hydrology.

**Impacts on Agriculture**

Although some growers may in fact fallow land or change crops in response to reduced water deliveries, those acreages devoted to permanent crops can not accommodate such reductions. Within the Modesto and Turlock Irrigation Districts approximately 40% of the lands under cultivation are currently devoted to permanent crops; within the Merced Irrigation District the amount of permanent crops is ap-
proximately 37% of the irrigated acreage.

**Water Supplies—Eastside Districts**

Again the report incorrectly assumes that deliveries are reduced by an amount equal to the upstream contribution for additional flow. The process of allocating responsibility for flows is not the subject of this Draft Plan, therefore, impacts from the proposed San Joaquin River flows must be allocated solely to the CVP.

**Water Transfers**

The analysis assumes that water can be transferred freely within the 21 areas. Although physically the capability exists to freely transfer water, current state policies and the limitations discussed in Chapter X, section C do not promote the free transfer of water. Until such time as those institutional constraints can be reduced or eliminated the transfer of water is not a viable option to most regions. The SWRCB should look at the following factors which need to be resolved to permit transfers under this order:

1. Conserved water and/or water produced through conjunctive use operations may be transferred. While we recognize that conserved water in most regions within the Bay-Delta watershed do not result in runoff to salt sinks, the practical effect of transferring surface water over the long term will result in increased use of groundwater upstream of the Bay-Delta. It would seem prudent for the SWRCB to allow for conjunctive use and conservation plans to be part of the Bay-Delta planning process rather than allow uncontrolled overdrafts to occur as a result the implementation of the Bay-Delta standards.

2. The SWRCB should limit the scope of any hearing for the temporary change in place of use to the issues in the petition.

3. The SWRCB needs to adopt a policy that agencies that elect to transfer water will not “lose” the water in the future.

4. The SWRCB should streamline the water transfer process.

5. The SWRCB should not require “refill criteria” in its conditions approving water transfers. To require artificial constraints for the future delivery of water to the projects in exchange for current deliveries will not provide incentives to transfers and will prohibit transfers in the long run.

**Employment Impacts**

The report indicates that displaced jobs do not represent a permanent job loss to the region. This is not true because without the loss of water, the regional job market would have increased faster as opposed to remaining stable or decreasing.

**Impacts on Hydroelectric Power Production**

Does the inclusion of PG&E and SCE in the analysis imply that they will also be re-
required to contribute to Bay-Delta flows? Is the same true for SMUD which does not appear in the analysis? Who will pay for the impacts on hydroelectric purchase agreements?

XII-23 Benefits

The benefits listed in Table XII-7 are highly questionable—most do not apply to the Bay-Delta or to California. If the State Board is not estimating the benefits accruing from its proposal, then what is the purpose for including a table such as this?

XII-24 We agree that the "relationship between smolt survival and the size of the adult population, evidence of a significant positive relationship is lacking."

XIII-35 Winter-run Chinook Salmon

It is stated that the proposed standards, including San Joaquin River pulse flows in April-May and increased base flows from February to June, will benefit winter-run smolts. Additional spring flows on the San Joaquin River have never been identified in any winter-run chinook salmon biological assessment or biological opinion as having a benefit to that species. There is no scientific or biological justification for this statement. The decline of the winter run is strictly related to Sacramento River conditions and export-caused impacts.

XIII-39 Delta Smelt

The upstream projects should not be required to provide increased flows on the San Joaquin River in order to maintain net seaward flows while export project pumping continues. The Delta smelt problem and the causes of its decline are strictly a project-related, export problem.

In addition the report itself notes that the declines in Delta smelt have been attributed primarily to restricted habitat and increased losses through entrainment by Delta diversions (Environmental Report, p. V-62). The decline in Delta smelt coincides with the increases in the proportion of water diverted since 1984. Prior to 1984, and before the sharp decline in Delta smelt abundance, the entrapment zone was generally located in the western Delta. Since 1984, however, the increased export pumping has shifted the entrapment zone upstream into the Delta river channels. See also Table 2.3 in USFWS, Technical/Agency Draft Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes, December 1994, which evidences the decline in Delta smelt abundance after 1982. The proposed standards will require non-project San Joaquin River flows to offset the impacts of increased export pumping.

We recommend that if the Old River Barrier is not installed during the spring outmigration period for San Joaquin River chinook salmon, then the SWRCB should require a complete cessation of export pumping for a minimum of four weeks during the April–May period. The precise four weeks should be determined each year by the SJTA and the San Joaquin River Basin Flow Coordinator depending on the time the smolt outmigration takes place.
San Joaquin Tributary Agencies
Additional Material Submitted in Response to State Water Resources Control Board
Draft Water Quality Control Plan and Environmental Report for the San Francisco
Bay/Sacramento–San Joaquin Delta Estuary

1. The salinity barrier and striped bass ecology: an evaluation. Prepared by EA Engineering,
Science and Technology for the San Joaquin Tributary Agencies.

2. Figure — Percentages of striped bass eggs between 0 and 8 hours old collected in
segments of the Sacramento–San Joaquin Delta and Suisun Bay at different flows for the

3. Table — Factors affecting striped bass abundance in the Sacramento-San Joaquin River

4. Figure — Percentage of striped bass eggs collected above Venice Island at various
spawning flows, 1966-1972. Prepared by EA Engineering, Science and Technology for the
San Joaquin Tributary Agencies.

5. Table — Observations in literature of striped bass spawning upstream of Venice Island
and/or Stockton. Prepared by EA Engineering, Science and Technology for the San Joaquin
Tributary Agencies.

6. Striped bass bibliography. Prepared by EA Engineering, Science and Technology for the
San Joaquin Tributary Agencies.

Joaquin Delta. WQCP MID/TID 2.

8. Map — Reported striped bass spawning locations in the Sacramento-San Joaquin Delta,
1903-1946.

9. Migratory response of juvenile chinook to pulses in flow. Prepared by Steven P. Cramer for
the Oakdale Irrigation District, South San Joaquin Irrigation District, and TriDam Project.

salmon smolts(Oncorhynchus tshawytscha) migrating through the Sacramento-San Joaquin
Delta of California.

11. Table — Modeled San Joaquin chinook salmon escapement under selected pulse flow
alternatives. Prepared by EA Engineering, Science and Technology for the San Joaquin
Tributary Agencies.

12. Figure — Modeled San Joaquin chinook salmon escapement under selected pulse flow
alternatives. Prepared by EA Engineering, Science and Technology for the San Joaquin
Tributary Agencies.

These materials were originally submitted by the San Joaquin Tributary Agencies at the State Water
The Salinity Barrier and Striped Bass Ecology: an Evaluation

The San Joaquin Tributary Agencies do not believe that there is a scientific basis for setting a salinity standard in the San Joaquin River to allow the upstream spawning migration of striped bass. We believe that (1) there is no real evidence that a salinity barrier to migration exists; (2) even if such a barrier did exist, it would not affect the production of striped bass, because as broadcast spawners they are not spawning-habitat limited; and (3) if striped bass could be induced to spawn farther upstream in the San Joaquin this would be to their detriment, as it would increase the potential entrainment of eggs and larvae into the state and federal export facilities. Finally, from a policy standpoint it seems inappropriate to be setting standards to enhance an exotic species that is known threat to an endangered native species, the Sacramento winter run chinook salmon.

The San Joaquin River, especially in years of low flow, has a high concentration of total dissolved solids due primarily to saline agricultural discharges, creating a reverse salinity gradient in the region upstream of the mouth of the Mokelumne River. It has been suggested that striped bass are often restricted from using spawning areas in the San Joaquin River by a salinity barrier beyond which migrating adult bass will not pass.

The basis for this belief rests upon inconclusive evidence obtained in the 1960s from field observations of adult striped bass distribution during the spawning season. Radtke and Turner (1967), sampling adult bass throughout the reverse salinity gradient, found the highest numbers of fish in TDS concentrations between 250 and 300 ppm. They found lower numbers both below 200 and above 350 ppm TDS. On the basis of these observations, they concluded that 350 ppm TDS formed a barrier to striped bass movement. This occurred in the vicinity of Venice Island.

Such anecdotal evidence in no way proves that a salinity barrier exists. It might lead one to hypothesize that salinity can prevent upstream migration and then one could go on to test that hypotheses experimentally. However, no such tests have been conducted. An alternative hypothesis would be that the fish stopped near Venice Island for any one of a number of other reasons having nothing to do with salinity. There are data that support this second hypothesis.

Striped bass in the Sacramento-San Joaquin system spawn primarily the Sacramento River from Coloma to Sacramento and in the San Joaquin Delta from Antioch to Venice Island. There is considerable evidence that striped bass spawn in the same area of the San Joaquin River year after year, regardless of flow. The three-dimensional bar graph of striped bass spawning locations vs. flow shows that negligible spawning occurs in the vicinity of Venice Island regardless of flow. One would expect that if salinity was preventing upstream migration fish would spawn farther upstream in years of higher flow.

Striped bass in the Delta have been shown to spawn in salinities of up to 1,500 microsiemens.

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1 Prepared by EA Engineering, Science and Technology for San Joaquin Tributary Agencies.
(approximately 1,000 ppm TDS) and greater in years of low flow when ocean salinities intrude in to the western Delta. Such conditions in 1972 were not shown to adversely affect egg survival (Turner 1976), and laboratory studies have corroborated that these levels of salinity are not harmful to egg survival (Turner and Farley 1971). Water quality records dating from about 1929 show that salinities in the San Joaquin River in los flow years have exceeded those felt to constitute a barrier to striped bass migration even during the period when the bass population was flourishing (Paterson 1989).

There is no evidence that striped bass populations are limited by area available for spawning. In fact, there are several reasons why this is highly unlikely. The species is a mass spawner that spawns in groups of fish of from 5 to 30 individuals. There is no territorial behavior that would translate into a “carrying capacity” of the area to accommodate spawning adults. Historically, bass presumably spawned in much higher numbers and densities in the same areas when their populations were at a higher level, with no attendant ill effects on egg or larval survival. Eggs do not remain in the spawning area but are immediately carried by the current to downstream nursery areas; the actual area in which they were spawned is only inhabited for a short period of time. There is no evidence showing that egg or larval survival is related to density-dependent effects on the spawning grounds.

To conclude, we feel that there is no evidence to support the belief that a salinity barrier restricts striped bass from spawning in the San Joaquin River above Venice Island. In addition, even if such a barrier existed and spawning habitat area was reduced in size, there is no evidence that a reduction in area available for spawning would adversely affect the bass population. We have reviewed almost 400 articles on striped bass ecology and management and have found no evidence of salinity barriers or spawning habitat limitations.
Percentages of striped bass eggs between 0 and 8 hours old collected in segments of the Sacramento-San Joaquin Delta and Suisun Bay at different flows (San Joaquin River mean May flow at Vernalis), for the years 1968-1973, 1975-1977, and 1984-1986. (Km 0 is the Golden Gate.)

<table>
<thead>
<tr>
<th>Location</th>
<th>Sampled Month</th>
<th>Percentage of Sampled Views with Abundant Striped Bass</th>
<th>Mean Abundance</th>
<th>Standard Deviation</th>
<th>10th Percentile</th>
<th>50th Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioch</td>
<td>(4/15-5/9)</td>
<td>0.7</td>
<td>0.2</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>(6/15-7/7)</td>
<td>0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>(7/15-8/7)</td>
<td>0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Venice</td>
<td>(4/15-5/9)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>(6/15-7/7)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>(7/15-8/7)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Rio Vista</td>
<td>(4/15-5/9)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>(6/15-7/7)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>(7/15-8/7)</td>
<td>0.5</td>
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<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Note: Based on sampling of CPQ (Coastal) area only and larger survey stations from Marin County.

2) Based on sampling of CPQ (Coastal) area only and larger survey stations from Marin County.

3) Based on sampling of CPQ (Coastal) area only and larger survey stations from Marin County.
Percentage of striped bass eggs collected above Venice Island at various spawning flows, 1966-1972.
### TABLE 1. OBSERVATIONS IN LITERATURE OF STRIPED BASS SPAWNING UPSTREAM OF VENICE ISLAND AND/OR STOCKTON

<table>
<thead>
<tr>
<th>Year</th>
<th>Flow (cfs)</th>
<th>Spawning Activity Upstream of Venice Island</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946</td>
<td>13,058</td>
<td>striped bass in spawning condition u/s of Stockton (Woodhull 1947)</td>
</tr>
<tr>
<td>1948</td>
<td>5,001</td>
<td>~ 10% of eggs originated upstream of Stockton (Erkkila et al. 1950)</td>
</tr>
<tr>
<td>1949</td>
<td>3,520</td>
<td>7% of eggs collected at Mossdale site (Erkkila et al. 1950)</td>
</tr>
<tr>
<td>1952</td>
<td>27,639</td>
<td>eggs and larvae collected in Old River from Frank’s Tract to Coney Island (USBR &amp; USFWS 1957, as cited in Paterson 1989)</td>
</tr>
<tr>
<td>1963</td>
<td>9,339</td>
<td>many eggs collected from Stockton to Mossdale (Farley 1966)</td>
</tr>
<tr>
<td>1964</td>
<td>703</td>
<td>very few eggs collected from Stockton to Mossdale (Farley 1966)</td>
</tr>
<tr>
<td>1966</td>
<td>863</td>
<td>0.5% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1967</td>
<td>20,365</td>
<td>3.1% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1968</td>
<td>891</td>
<td>0.5% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1969</td>
<td>24,613</td>
<td>0.9% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1970</td>
<td>2,393</td>
<td>3.2% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1971</td>
<td>1,833</td>
<td>0.0% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
<tr>
<td>1972</td>
<td>744</td>
<td>0.7% of eggs collected above Venice Island (Turner 1976)</td>
</tr>
</tbody>
</table>

1 Mean San Joaquin River discharge at Vernalis for month of May

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HISTORIC SPAWNING LOCATIONS OF STRIPED BASS
IN THE SACRAMENTO-SAN JOAQUIN DELTA

Alan M. Paterson, Ph.D.
Consulting Historian

February 13, 1990

One-third to one-half of the striped bass in the Bay-Delta estuary spawn in the Delta. The recent interest in extending the present Delta spawning area to include the San Joaquin River from Prisoner's Point on Venice Island to Vernalis is apparently based in part on the perception that it was once a valuable spawning area. The following report summarizes the readily available information on Delta spawning locations, and the relative importance of those locations.

The earliest reports of striped bass spawning in California can be found in the report of the State Board of Fish Commissioners for 1907. The increasing popularity of striped bass in the commercial market raised fears that the stock would soon be depleted. To offset "the enormous drain that is made on the supply of these fishes" (Ca. Bd. of Fish Commissioners, 1907, p. 41), the decision was made to set up a striped bass hatchery. The federal Bureau of Fisheries was consulted and Captain G.H. Lambson was dispatched to assist state officials.

Captain Lambson, in company with our Chief Deputy, made an extended trip through those sections from which the largest number of spawning fish are shipped to market. Several points near the mouth of the San Joaquin and Sacramento rivers were inspected, and Bouldin Island in San Joaquin
County has been selected as the best point at which to establish an experiment station. In the month of May the spawning fish are captured there in large numbers. (Ca. Bd. of Fish Commissioners, 1907, p. 41)

Just how abundant spawning bass were at Bouldin Island can be seen in the report that:

In the years 1903, 1904, and 1905 spawn bass were so plentiful about Bouldin Island that the fishermen, in order not to glut the market, agreed among themselves to catch no more than 600 pounds to the boat each twenty-four hours. They frequently got more than double this amount at one drift of a gill net. (Scofield, 1910, p. 105)

With this in mind a hatchery was set up on Bouldin Island in 1907 and efforts were begun to study striped bass and locate their spawning grounds. In 1908 and 1909 the spawning runs were described as "very light" and "exceedingly poor." In an effort to find eggs or newly hatched fish, and thus the spawning grounds where ripe fish might be found, gauze nets were towed in the river and adjacent sloughs, and even in flooded islands, but without success. The 1910 run was better but ripe female fish were still scarce. "The river above Bouldin and all sloughs within ten miles were fished . . . The Mokelumne River was also explored. Bass were taken only near Bouldin island mostly in the main river." (Scofield, 1910, p. 108)

Theories as to why the fish had apparently abandoned their former spawning area centered on the effects of reclamation. Dredgers were silting up the river and it was suggested that bass were running up the Sacramento River instead. Indeed by 1910 Cache Slough was being mentioned as a potential hatchery location. As flooded islands were encircled by levees and pumped out "many tons of bass" were trapped. (Scofield, 1910, pp. 108-109)

For whatever reason, the spawning locale was shifting and in 1926 it was reported that "although there is a spawning migration of bass on the lower San Joaquin River, the larger run is now in the Sacramento River." (Scofield and Bryant, 1926, p. 60)

A major striped bass research project was begun by Eugene C. Scofield in
1925, with the results published as Fish Bulletin No. 29 in 1931. Scofield described the Delta islands and explained how they were sometimes flooded. Based on his research he concluded that,

It is in these flooded areas that the striped bass appear to spawn in the greatest numbers. Here the special nets used in this investigation captured an abundance of ripe, flowing and spent bass, while in the adjacent sloughs very few were caught. (Scofield, 1931, p. 51)

The report has no details regarding which islands and sloughs were sampled and the text contains only vague references to the Delta spawning area as being "adjacent to Suisun Bay and many miles up the Sacramento and San Joaquin river country." (Scofield, 1931, p. 58) A somewhat more precise definition of the spawning range as understood at that time can be reconstructed from the list of Delta locations in Table 5, "Water Salinity in the Spawning Region of Striped Bass." They were Pittsburg, Antioch, Antioch Bridge, Broad Slough, False River, Middle River, Mokelumne mouth, Mokelumne River, South Fork of Mokelumne, Sycamore Slough, Sherman Island, Rio Vista, Cash [sic] Slough, Steamboat Slough, Sacramento and Feather River. (Scofield, 1931, p. 52). No points upstream of Bouldin Island on the San Joaquin River main channel are mentioned.

Construction work on the Central Valley Project led to a new round of studies in 1939. Efforts in that year to locate the spawning area failed although specimens were collected in False River and Washington Cut and in Sycamore Slough. (Hatton, 1940, p. 361) The following year, larvae were netted in Piper Slough, Three Mile Slough and the San Joaquin River below Three Mile Slough, all in the western Delta. (Hatton, 1942, p. 65)

Striped bass spawning could be indicated by the presence of ripe fish, floating eggs or the appearance of a spawning activity known as a "rock fight" in which the fish would appear at the surface agitated and splashing. The latter activity formed the basis of reports that on May 11, 1943 bass were spawning at the mouth of Middle River and in the lower five miles of the Mokelumne River. On May 5, 1944 wardens observed spawning at Fisherman's Cut. On May 6, 1946 a rock fight was observed near Venice Island in the Mandeville Reach of the San Joaquin River. (Woodhull, 1947, pp. 98-99)
Reports of "rock fights" were, like previous indications of spawning location, restricted mainly to the western and central portion of the Delta and the Mokelumne River. However it was believed that striped bass spawned much farther up the San Joaquin River. Woodhull reported that fish in spawning condition had been found as far upstream as the town of Patterson and that he himself had found ripe bass at San Joaquin City [near Durham Ferry Bridge] in April 1946. (Woodhull, 1947, pp. 98-99) A 1948 progress report on striped bass studies said:

An attempt was made to evaluate the importance of the San Joaquin River above the Delta as a striped bass spawning area. 1947 was an abnormally dry year, and the flows in the San Joaquin River were negligible in comparison with those in the Sacramento. No eggs or larvae were recovered in the course of limited sampling at Mossdale and San Joaquin City. However, in years of normal rainfall the San Joaquin above the Delta is probably a spawning area of some importance, for it is known from catch records that a migration of ripe striped bass ascends the river for a considerable distance in some years. (Calhoun and Woodhull, 1948, pp. 175-176)

In 1946, the U.S. Fish and Wildlife Service initiated a study of the impact the Delta Cross-Channel and Tracy Pumping Plant would have on Delta fisheries. The study hoped to locate striped bass spawning areas in the Delta and track the subsequent movement of larvae and juvenile fish. During the spawning seasons of 1948 and 1949 twenty-five Delta stations were sampled using plankton tow nets in a series of three- to eight-day cycles. Seventeen of the stations were on the San Joaquin-Middle River-Old River system from Mossdale to Antioch Bridge, and the remaining stations were on the Sacramento River below Ryde and on the Mokelumne River.

In 1948, two-thirds of the eggs collected were taken in a single sample at the station on Middle River above Empire Cut. The remaining eggs were widely distributed in the San Joaquin Delta, with very few at the Sacramento or Mokelumne sites. The main stem of the San Joaquin River above Venice Island accounted for about ten percent of the eggs collected that year, but no eggs
The distribution of eggs was different in 1949. Almost half the eggs came from the Antioch Bridge station and over two-thirds were collected between that site and San Andreas Landing. As in the previous year, less than ten percent of the total came from the San Joaquin River above Venice Island and only a single egg was taken between Venice Island and Stockton. (Erkkila, et.al., 1950, p. 70)

The study report concluded:

Assuming that the number of eggs recovered from week to week in the San Joaquin Delta is an index of spawning intensity, it is evident that the initial spawning was heaviest in the southern and central portion of the Delta, with a gradual shift to the western or lower San Joaquin River portion. Very few eggs were taken at stations located in Sacramento and Mokelumne Rivers. As in 1948, the most productive area was the San Joaquin River from the mouth of Old River to Antioch. (Erkkila, 1950, p. 25)

On the basis of later studies (see Radtke and Turner, 1967), it has been assumed that striped bass do not prefer to migrate through salinities higher than 350 mg/l or spawn in salinities higher than 180 mg/l TDS. Monthly average TDS at Vernalis was lower than 350 mg/l in April and under 180 mg/l during May in both 1948 and 1949. (SDWA, 1987)

Confirmation of the pattern of spawning locations came from the recoveries of tagged striped bass in 1950-51. Reporting on "Annual Migrations of California Striped Bass" in 1952, A.J. Calhoun noted that his Figure 6, "Recoveries During April," was "of particular interest because it illustrates the spreading out of the striped bass into the remoter sections of the Delta and its tributary rivers to spawn." (Calhoun, 1952, p. 394) Several tagged fish were recovered near Antioch Bridge and Big Break and the largest group appeared to be from Three Mile Slough to Venice Island. Several more fish were collected in the main river and Middle River around Medford and McDonald Islands and some south of Franks Tract in Old River. The scale of the map makes further identification difficult, but it appears to confirm that spawning was centered in the western and central Delta from Venice Island to Antioch and a short distance up Middle River and Old River. Figure 7, showing recoveries from May 1 to June 15 showed
almost all the fish scattered in the main channel from Venice Island to Suisun Bay.

By the 1960s spawning migration patterns had changed. The recovery of bass tagged 1958-1961 was compared to the 1950-1952 tagging study. In the earlier study, 16 percent of the recovered tags came from the Delta east of Old River and Georgiana Slough, while in 1958-1961 only three percent of the recoveries came from that area. During the spawning period represented by the months March through May the decline was even more apparent with the proportion down from 10 percent in 1950-52 to one percent later. (Chadwick, 1967, Table 12, p. 337) It was hypothesized that the importance of the Sacramento River spawning area had increased. Export pumping and a dry period beginning in 1959 may also have influenced the results.

Although it had been inferred that there was a connection between salinity and spawning as early as Eugene Scofield’s work in the 1920s, definite conclusions were lacking until the mid-1960s. Studies of spawning location in 1963-64 indicated that no significant spawning occurred in salinities above 180 ppm TDS. (Farley, 1966, p. 28) In 1963 there were two major spawning areas; Antioch to Venice Island and Stockton to Mossdale. The next year was dry, salinities were higher and there was little spawning above Venice Island.

The hypothesis that salinity could block spawning migrations was further investigated in 1966 in the San Joaquin River from Venice Island to near Stockton. This was an area where substantial spawning had never been reported. The authors themselves admitted that, “In the past, very little spawning has occurred in our study area" and "the run of striped bass above Stockton is small even under ideal conditions." (Radtke and Turner, 1967, pp. 406-407) Five stations were monitored from March 21 to May 31, although few bass were caught before mid-April. Bass were found in the greatest abundance at salinities from 250 to 300 ppm TDS and never above 350 ppm TDS. Eggs were found in salinities under 150 ppm TDS, apparently confirming the earlier conclusion that no serious spawning took place above 180 ppm TDS. (Radtke and Turner, 1967) This study became the basis for subsequent descriptions of striped bass spawning preferences. (for example see Ca. Dept.
While the limits of spawning salinity were presumably established in 1967, bass have been known to spawn in higher salinities since that time. "In 1968, substantial spawning occurred in salinities up to 600 mg/l TDS." (Ca. Dept. of Fish and Game, 1972, p. 36) Another dry year occurred in 1972, with similar results:

In 1968 and even more so in 1972, salinities increased in the western part of the spawning area but bass still spawned in essentially the same place. Thus in 1972, approximately 45% of the eggs taken in our sampling were collected at salinities between 500 and 1,000 mg/l TDS and another 25% at salinities between 1,000 and 1,500 mg/l TDS. The proportion of dead eggs in our samples was essentially equal in all salinities, suggesting that salinity did not affect the survival of eggs. While these results indicate less dependence on salinity than initially thought, they are not sufficient to evaluate the effects of consistent salinity intrusion of the magnitude experienced during spawning in 1972. (Ca. Depts. of Fish and Game and Water Resources, et. al., 1973, p. 9)

Considerable data was collected between 1963 and 1972 showing the location of spawning and the percentage of eggs spawned in various salinities. On the average, from 1966 to 1972, about two-thirds of the spawning occurred in the ten-mile stretch of the river upstream from Antioch in the western Delta. Over 12 percent was downstream from Antioch with the remainder from about False River to Venice Island. (Turner, 1976, p. 113) As noted above, there was a tendency to return to the same spawning area even in the face of less-than-ideal salinity conditions. Although there was evidence that in some years spawning could occur farther upstream, DFG collected eggs only between Martinez and the Venice Island area. This sampling program was continued, with subsequent years showing results similar to those reported in Turner's 1976 report. (see Ca. Dept. of Fish and Game, 1987, pp. 44-46)
CONCLUSION

For almost ninety years, biologists have sought to find out where striped bass spawn. During that time, the most important change appears to be the establishment of the Sacramento River spawning run.

Much of the early evidence is anecdotal in nature, but it is far from unimportant. Fishery experts, and fishermen, looked where experience and observation told them spawning stripers were most likely to be found. In the Delta, those locations were in the San Joaquin River from the vicinity of Bouldin and Venice islands downstream, and in adjacent channels.

Although the best known and probably most important spawning area was in the central and western Delta, observational evidence suggested that striped bass spawned farther up the San Joaquin River. The work of the U.S. Fish and Wildlife Service in 1948 and 1949 demonstrated that, in some years at least, spawning striped bass were widely distributed in the San Joaquin Delta. However, their results also suggested that the most consistently important Delta spawning area was west of Venice Island. Subsequent tag return and spawning surveys by DFG tended to confirm that the principal Delta spawning area remained in approximately the same location it had been in since the turn-of-the-century.
REFERENCES


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Scofield, N.B., Notes on the Striped Bass in California, 1910, in Appendix to Twenty-first Biennial Report of the Board of Fish and Game Commissioners.


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MIGRATORY RESPONSE OF JUVENILE CHINOOK TO PULSES IN FLOW

Comments by Steven P. Cramer

for Oakdale Irrigation District, South San Joaquin Irrigation District, and TriDam Project

1. Overview

2. Stanislaus Experience
   Description of Sampling
   Rotary-Screw Trap, April 21 - June 29, 1993 near Oakdale
   Flows
   Regulated pulses of 1,500 for 17 and 13 days
   Earlier flow spikes before sampling began
   Juvenile Chinook catches
   Efficiency was 1/2 of percentage flow sampled
   Expanded catches peaked first day of 1500 cfs

Conclusions
   Some juvenile chinook were stimulated to migrate almost immediately by increased flows, but sustained high flows did little to stimulate migration after the initial migration spike. There was no indication that the sustained high flows "flushed" juvenile chinook out of the river. Mean lengths of fish captured throughout the season indicated that chinook were stimulated to migrate as they reach a threshold size.

Observations Consistent with Other Rivers

Final Report Complete by mid November

3. Recommendations
Studies on streams elsewhere on the west coast have demonstrated that outmigration of juvenile chinook is stimulated temporarily by changes in flow, not by high constant flow. We cite here examples from the Yakima River in Washington and the Rogue River in Oregon. The outmigration of juvenile chinook was studied extensively in the Yakima River for nine years, 1982 through 1990, and in the final report of that study (Fast et al. 1992), the following conclusions were offered:

"Flow-induced stimulation of passage is especially pronounced when it occurs on the heels of a number of days of declining flows. Interestingly, the peak of the migratory response to increased flows usually occurs before the discharge peak."

"Inspection of daily passage and flow data has revealed that consecutive days of declining, or even stable, flows are usually associated with declining outmigration rates. It should be noted that descending flows stall passage, even when absolute discharge during the decline remains relatively high. During such periods, smolts accumulate somewhere between Sunnyside and Prosser dams, and are subject to longer periods of vulnerability to predators."

"Stalled migrations are stimulated by rapid increases in flow. The increase need not be especially large, but should be abrupt; gradual increases do not evoke a sharp response in passage. An analysis of natural flow pulses gauged below Sunnyside Dam indicates the "minimal stimulated pulse" should be about 20% of the pre-pulse "base flow," and that the pulse should occur over no more that two days."

Similarly, studies in the Rogue River, where the peak outmigration of juvenile chinook is typically during mid summer, showed that a sharp increase in flow during the period of juvenile outmigration, stimulated a sharp, but short-lived, increase in the number of outmigrant chinook (Cramer et al. 1985). Cramer et al. (1985) found that a unique event during the 10 year study occurred in 1976 when a record setting freshet caused a sharp increase in flow during early August. Immediately following the increase in flows, the number of outmigrants passing Savage Rapids Dam (RM 173) increased dramatically. However, the peak in outmigration lasted less than one week (outmigration for the season was only about 50% complete), while the river flows remained at double the summer base flow for more than three weeks. Cramer et al. (1985) did not observe similar spikes in outmigration (or flow during the summer) during any other year of the study.

The relatively slow change in the mean lengths of chinook we captured is consistent with the widely observed phenomena that juvenile chinook are stimulated to migrate as they reach a threshold size (Figure 9). Smolting generally occurs when juvenile chinook are 80 to 100 mm long. The outmigration of fish when they reach this size range continuously removes the largest fish in the population and causes the mean length of the population to increase slower than the actual growth rate.
These findings indicate that the response of juvenile chinook to pulses in flow is modulated by their own physiological readiness to migrate. The physiological process of smolting in juvenile chinook peaks at a consistent time of year for the population as a whole, but there can be several months of variation between individuals in the time that they reach physiological readiness to migrate. We conclude that individual fish which are physiologically ready to migrate will respond to the stimulus of a sharp increase in flow, while the remainder of the population will not. This being the case, periodic pulses in flow, perhaps two weeks apart, which allowed time between flow pulses for additional fish to reach physiological readiness to migrate, should be more effective at stimulating outmigration than a constant high flow. However, it remains to be determined what level of increased survival of smolts would be achieved by such a scenario.

RECOMMENDATIONS

1. Migration of juvenile chinook is stimulated by a rapid increase in flow, not by a sustained high flow. This behavior is consistent for populations of chinook throughout the West Coast.

2. Only the portion of juvenile chinook physiologically ready to smolt will be stimulated by flow pulses to migrate to the ocean. Therefore, flow pulses spaced at intervals through the outmigration season will be necessary to stimulate migration of the entire population.

3. The magnitude of increase in flow required to stimulate migration is uncertain, but is at least 20%.

4. The duration of the flow pulse needed to stimulate migration is 1 to 3 days. Longer periods of high flow may be needed to sustain desirable conditions in the Delta until the fish stimulated to migrate have passed through.

5. The magnitude of benefits to be gained from pulsing flows is uncertain and should be evaluated by field tests.

REFERENCES


April may have moved many juveniles downstream. High flows in March and early April were not sampling. High flows at high periods of high

Figure 8. Graph of daily Stanislaus River flow showing periods of high flow.
Figure 7. Daily chinook outmigrant index and Stanislaus River flow.
Fig. 17. Average weekly flow in the Rogue River at Grants Pass (km 166) during the summers of 1975 and 1976.
Fig. 18. Weekly catch/trap hour of juvenile chinook salmon at Savage Rapids in 1974, 1975 and 1976.
Subyearling Chinook Passage
Lower Granite Dam - 1994

Subyearling Chinook Index

Flow (kcsf)

- Fish
- Flow

Dates:
25-Jun 05-Jul 15-Jul 25-Jul 04-Aug 14-Aug 24-Aug 03-Sep
Figure 44. Daily passage of wild spring chinook smolts at Prosser Dam and daily mean flows at Prosser Dam, 1987.
Estimating the influence of temperature on the survival of
chinook salmon smolts \textit{(Oncorhynchus tshawytscha)} migrating
through the Sacramento - San Joaquin River Delta of California

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Abstract. Data collected and reported by the U. S. Fish and Wildlife Service are used to investigate the relationship between water temperature and survival of hatchery-raised fall-run chinook salmon (*Oncorhynchus tshawytscha*) smolts migrating through the Sacramento - San Joaquin Delta of California. A formal statistical model is presented for the release of smolts marked with coded-wire tags (CWTs) in the lower Sacramento River and the subsequent recovery of marked smolts in mid-water trawls in the Delta. This model treats survival as a logistic function of water temperature, and the release and recovery of different CWT groups as independent mark-recapture experiments. Iteratively reweighted least-squares is used to fit the model to the data, and simulation is used to establish confidence intervals for the fitted parameters. The upper incipient lethal temperature inferred from the trawl data by this method is 23.01 ± 1.08°C at the 95% confidence level. This is in good agreement with experimental results of Brett (1952) (24.3 ± 0.1°C and 25.1 ± 0.1°C for chinook salmon acclimatized to 10°C and 20°C, respectively), particularly when it is observed that Brett's results were obtained under controlled conditions, whereas the present work deals with survival in the natural environment. This agreement has implications for the applicability of laboratory findings to natural systems.

INTRODUCTION

For many years, the U.S. Fish and Wildlife Service (USFWS), in cooperation with the California Department of Fish and Game (CDFG) through the Inter-Agency Ecological Study Program, has conducted trawls for chinook salmon (*Oncorhynchus tshawytscha*) smolts near Chipps Island in the Sacramento - San Joaquin Delta of California during the main periods of smolt outmigration (USFWS 1983–1992). The data arising from the Chipps Island trawls
are used by USFWS and others to address a variety of questions about California's chinook salmon, such as smolt abundance, timing of outmigration, migration rates, and survival (Stevens et al. 1984; USFWS 1987; Kjelson et al. 1989).

An important part of these data consists of the recoveries of hatchery-reared fall-run smolts bearing coded-wire tags (CWTs) from a series of releases by USFWS and CDFG since 1978. These releases are made at a number of locations in the lower Sacramento River and northern Delta specifically to provide information about smolt survival in the Delta.

The usual treatment of these data has been as follows: an estimate is made of the survivorship associated with each individual release, the estimates are plotted against proposed explanatory variables (water temperature, smolt size, etc.), and a hypothesized survival curve is fitted through these points. Disagreements over the interpretation of the data have turned on the method used to estimate the individual survivorships and the functional form of the curve to be fitted (Kjelson et al. 1989; Baker et al. 1992).

This approach is reasonable and straightforward. It also has some limitations: it does not provide objective ways of assessing the extent to which a proposed survival function is consistent with the data, and it does not produce confidence bounds on fitted parameters that might be used to make informed policy decisions. Questions about goodness of fit and statistical uncertainty can only be formulated properly in the context of statistical models.

In this paper, we restrict our attention to the problem of estimating smolt survival as a function of water temperature, from trawl recoveries of CWT-marked smolts released at a single location. We show that a biologically reasonable model fits the data well enough to permit quantitative assessments of the uncertainty in the fitted parameters. The fitted values are shown to agree well with the results of laboratory studies.

**Data**

In this paper, \( r \) denotes the number of smolt release groups. For the \( i \)th release, \( 1 \leq i \leq r \), \( n_i \) is the number of smolts released, \( m_i \) is the number of smolts recovered, \( p_i \) is the trawl effort, and \( T_i \) is the water temperature at Ryde at the time of release, in degrees centigrade.
The data used in the models are those from the 15 releases in the lower Sacramento River at Ryde from 1983 through 1990 that are listed in Table 1. These data were assembled from (USFWS 1983–1992) and (Johnson and Longwill 1991). The smolts were all fall-run chinook salmon, reared at the Feather River Hatchery and released at Ryde in May or June. The average weight of these smolts ranged in different years from 5.15 g to 9.40 g. Peak trawl recoveries at Chipps Island ranged from two to five days after release at Chipps Island.

Ryde is about 48 km upstream of Chipps Island, just below the last major distributary branching of the Sacramento River as it enters the Delta. From each of the other release locations, there are alternate routes to Chipps Island and a variety of conditions to be found along the different routes. Smolts released at Ryde have only one direct route to Chipps Island (a second route, around Sherman Island via Three Mile Slough, is probably of minor importance), and survival along this route is likely to be less affected by factors other than water temperature than is survival through most other parts of the Delta. For this reason, the Ryde releases are commonly recognized as the most natural ones to consider when temperature is the primary variable of interest (Kjelson et al. 1989).

Figure 1 shows the region of the Delta under discussion.

What we are calling “trawl effort” is defined in USFWS reports as the ratio of the time spent in actual trawling to the total time interval covered by the surveys, multiplied by the ratio of the net width to the channel width. Although the USFWS reports do not always report the trawl effort, it is possible to recover it from the information that is reported. We will use the trawl effort as an estimate of the probability of capture; this assumption will be examined briefly later in this paper. The USFWS itself scrupulously refers to this quantity as simply an “expansion factor”, and to values calculated from it as “survival indices”.

THE BASE MODEL

All of our models begin with the assumption that the different CWT releases can be treated as independent mark-recapture experiments. For our first model, we treat each individual release as a binomial experiment, whose parameter is broken down into two
components: the probability of survival from Ryde to Chipps Island, which we will take to be a logistic function \( \phi(T_i) \) of water temperature \( T_i \), and the probability of capture at Chipps Island, the known constant \( p_i \). The parameters to be fitted are the location and scale parameters \( b_1, b_2 \) of the logistic function \( \phi \).

This corresponds to the likelihood function

\[
L = \prod_{1}^{r} \pi_i
\]

where

\[
\pi_i = \pi(m_i|n_i, \phi_i, p_i) = \binom{n_i}{m_i} (p_i \phi_i)^{m_i} (1 - p_i \phi_i)^{n_i - m_i}
\]

(1)

\[
\phi_i = \phi(T_i) = \frac{1}{1 + e^{-b_1 - b_2 T_i}}
\]

This is a generalized linear model with canonical link function, in the terminology of McCullagh and Nelder (1989). A model of this kind is completely specified by its mean and the dependence of the variance on the mean. In this case,

\[
E[m_i] = p_i \phi_i n_i
\]

(2)

\[
V[m_i] = E[m_i] - \frac{1}{n_i} E[m_i]^2
\]

The maximum likelihood estimate for \((b_1, b_2)\) is easily found from (2) by the algorithm of iteratively reweighted least squares.

A biologically natural alternative to the parameterization \((b_1, b_2)\) of the survival curve is \((LT50, \alpha)\), where \(LT50\) is the temperature at which the predicted survival is 0.50, and \(\alpha\) is the slope of the survival function at \(T = LT50\). We will report results in both forms.

For the data in Table 1, maximum likelihood estimation gives \(b_1 = 15.89, b_2 = -0.6873\). Equivalently, \(LT50 = 23.12, \alpha = -0.1718\).

The Pearson chi-square for the fit is 104.5 with 13 degrees of freedom. The log-likelihood ratio statistic \(D\), which is also approximately distributed as a chi-square statistic with 13
degrees of freedom, is 103.4. Both of these values are very highly significant, indicating that the base model does not fit very well.

Table 2 shows the expected and observed numbers of trawl captures, with Pearson and deviance residuals. The residuals are plotted against water temperature in Figure 2. Because there is no clear trend in the residuals, we do not attribute the lack of fit to a fundamental defect in the model structure, such as an inadequate choice of the functional form for \( \phi \). That is, the model's handling of temperature is acceptable, but the model is not flexible enough to account for all of the "noise" in the data from factors not included.

**Overdispersion**

The over-dispersion of the data with respect to the base model is not necessarily a fatal defect—in fact, over-dispersion is so common in models such as this that its absence would be more remarkable than its presence (cf. McCullagh and Nelder 1989, §4.5.1).

A conventional way to deal with over-dispersion in a situation like this is to simply inflate the variance by some constant \( \sigma^2 \). In this case, one would replace (2) by

\[
E[m_i] = p_i \phi_i n_i \\
V[m_i] = \sigma^2 (E[m_i] - \frac{1}{n_i} E[m_i]^2)
\]

The maximum-likelihood estimate for \((b_1, b_2)\) is not affected at all by the introduction of the "dispersion parameter" \( \sigma^2 \), so we are free to give \( \sigma^2 \) whatever value we want. In particular, we could force the model to have an acceptable chi-square fit simply by setting \( \sigma^2 = X^2 / \text{d.f.} \), where \( X^2 \) is the fit of the original model.

The main criticism one can make of this procedure is that it seems rather arbitrary. If a model does not fit the data, the model assumptions are inadequate in some way, and should at least be re-examined. After all, the fitted values of the model parameters will not be meaningful if the model itself has no relation to reality, regardless of how we assign confidence levels.
In fact, there is an extensive literature on the subject, which basically justifies using the unadorned model to estimate parameters like $b_1$ and $b_2$, and dealing with overdispersion as indicated above (see references in McCullagh and Nelder 1989; Burnham et al. 1987). Nevertheless, we prefer to tailor our approach to the specifics of our situation.

There are many possible sources of over-dispersion in these experiments: The probability of survival surely depends on factors other than water temperature; fish from different release groups have different histories; fish from the same release group recovered in different trawls have different histories. However, we believe that the most important uncertainty is in the capture probabilities $p_i$. It is clear from the nature of the experiment that these numbers could be in error by very large amounts. It is easy to imagine that smolts could have a preference for regions of the channel cross section which are especially likely or unlikely to be sampled in a particular trawl, or that they travel past Chipps Island in “clumps” that might or might not coincide with a trawl pass.

Furthermore, the data from some of the individual releases clearly point to errors in the capture probability estimates. In the first of the two 1990 releases, 51,878 smolts were released, of which 87 were recovered; even if the survival were 100%, the probability of recovering as many as 87 smolts, assuming that the probability of capture was really 0.001036, would be on the order of $10^{-6}$.

On the other hand, there is evidence that the recovery probability estimates are not systematically too high or too low. Fish from the CWT groups released at Ryde are also recovered in the ocean fishery as adults; information about these recoveries is available through the Pacific States Marine Fisheries Commission. These recoveries can be used to generate estimates of Delta smolt survival.

The CWT groups are recovered as two-, three-, four-, and five-year-olds (the nominal ages of fall-run chinook salmon are based on the calendar years in which spawning took place). By comparing the ocean recovery rates of two-year-olds from the Ryde groups with the ocean recovery rates for two-year-olds from groups of similar smolts released near Chipps Island at
about the same time, it is easy to obtain estimates of survival from Ryde to Chipps Island from individual releases. In fact, the closest release site to Chipps Island is Port Chicago, about 8 km downstream, so that what is being estimated is survival from Ryde to Port Chicago:

\[ S_{\text{Ocean}} = \frac{m_{\text{Ryde}}/n_{\text{Ryde}}}{m_{\text{PC}}/n_{\text{PC}}} \]

where \( n_{\text{Ryde}} \) is the number released at Ryde, \( n_{\text{PC}} \) is the number released at the Port Chicago, and \( m_{\text{Ryde}}, m_{\text{PC}} \) are the corresponding numbers recovered as two-year-olds in the ocean. These can be compared with simple estimates of survival from Ryde to Chipps Island for the same releases

\[ S_{\text{Trawl}} = \frac{m_i}{n_i p_i} \]

where \( n_i, m_i, \) and \( p_i \) are as defined earlier (cf. USFWS 1987).

Survival from Chipps Island to Port Chicago should be high, because the distance between them is fairly small, so that \( S_{\text{Ocean}}, S_{\text{Trawl}} \) are essentially estimates of the same quantity. As there is no reason to expect both estimates to be biased in the same direction and to the same extent, each serves as a check on the other. Formal analysis confirms the impression of Figure 3, that the hypothesis \( S_{\text{Ocean}} = S_{\text{Trawl}} \) cannot be rejected at the 95% confidence level. We interpret this as evidence that the \( p_i \) can be used as estimates of the expected values of the true recovery probabilities (although the co-occurrences of ocean-based estimates greater than 1 with trawl-based estimates greater than 1 remains puzzling).

More information on the relationship between the trawl-recovery and ocean-recovery estimates can be obtained from the authors.

**The Relaxed Model, the Quasilikelihood Estimator, and Simulation**

We modify the base model (1) to allow for uncertainty in the capture probabilities by assuming that the capture probability \( P \) in the \( i \)th release is itself a random variable with mean \( p_i \) and variance \( \rho^2 p_i^2 \). Here \( \rho^2 \) is taken to be the same for all release groups. (Because the capture probabilities are necessarily non-negative, and we expect the errors in the \( p_i \)
to be large, a multiplicative error structure seems called for; this leads to the assumption that the coefficient of variation, rather than the variance itself, is constant from release to release. This gives

\[
\pi(m_i|n_i, \phi_i, p_i) = \int_0^1 \binom{n_i}{m_i} (P\phi_i)^{m_i}(1 - P\phi_i)^{n_i-m_i} f_i(P) \, dP
\]

\[
\phi_i = \phi(T_i) = \frac{1}{1 + e^{-b_1 - b_2 T_i}}
\]

where \( f_i \) is the density for \( P \). We will call this the relaxed model.

Because we have not specified the distribution \( f_i \), this is not yet a well-defined likelihood. No matter what distribution we use, however, we will always have

\[
E[m_i] = p_i \phi_i n_i
\]

\[
V[m_i] = E[m_i] + \left( \frac{n_i - 1}{n_i} \rho^2 - \frac{1}{n_i} \right) E[m_i]^2
\]

(equivalently, \( E[m_i] = E[m_i|P = p_i] \), \( V[m_i] = V[m_i|P = p_i] + \frac{n_i - 1}{n_i} \rho^2 \)). If the \( \pi_i \) were in a suitable exponential family, this would be all the information necessary to find the maximum-likelihood estimate for \((b_1, b_2)\) by iteratively reweighted least-squares. This algorithm is in any case a perfectly legitimate estimator, that one would expect to inherit some of the properties of a genuine maximum-likelihood estimator. We will refer to this as the quasilielihood estimator, for reasons to be discussed in the next section.

We are interested not only in the parameter estimates themselves, but in statistical properties of the estimator such as bias and variance. The conventional way to assign confidence intervals to the parameter estimates is by the delta method. In the case of generalized linear models fitted by iteratively reweighted least-squares, the covariance matrix emerges naturally from the algorithm; when a model that is not necessarily of this form is fitted by the iteratively reweighted least-squares algorithm, the algorithm gives the covariance matrix asymptotically. In either case, the estimators are approximately unbiased and asymptotically normal (McCullagh and Nelder 1989).

However maximum-likelihood estimators can be very far from either unbiased or normal when the number of samples is not large. In any case, these compromises are entirely
unnecessary. For any particular choice of $f_i$, the properties of the quasilikelihood estimator can be determined to any desired accuracy by simulation.

We will consider two simple examples: the uniform distribution

$$f_i(P) = \begin{cases} \frac{1}{2w}, & \text{if } |P - p_i| < w \\ 0, & \text{otherwise} \end{cases}, \quad w = p_i \sqrt{3 \rho^2}$$

and the triangular distribution

$$f_i(P) = \begin{cases} \frac{1}{w} (1 - \frac{1}{w} |P - p_i|), & \text{if } |P - p_i| < w \\ 0, & \text{otherwise} \end{cases}, \quad w = p_i \sqrt{6 \rho^2}$$

The largest value of $\rho^2$ consistent with the uniform distribution is $1/3$, and the largest value consistent with the triangular distribution is $1/6$. Notice that the uniform distribution has the largest variance of any unimodal distribution symmetric about $p_i$, and so sets an upper limit on the amount of extra variation that can be reasonably attributed to uncertainty in $p_i$. Confidence estimates based on this distribution should therefore be conservative.

We have defined a model (or at least a family of models) and a fitting procedure. It still remains to choose a value for $\rho^2$. We have no good basis for selecting a value a priori. Not only do we lack a suitable understanding of the trawl capture process, but the parameter is absorbing extra variation associated with $\phi$ and with the approximation of the trawl recovery as a simple binomial process. There are methods for fitting $\rho^2$ formally as a model parameter (McCullagh and Nelder 1989), but for a data set of this size we find it more appropriate to simply pick a value that results in a reasonable model fit. We have followed the usual practice of forcing the Pearson chi-squared statistic of the fit to equal the degrees of freedom (Williams 1982).

For the data in Table 1, the fitting procedure described above produced the estimate $\rho^2 = 0.1503$. This value for $\rho^2$ seems plausible to us. It is close to the $\rho^2$ for the maximally broad triangular distribution, and comfortably within the range of $\rho^2$ values that are consistent with the derivation of the model.
For this value of $\rho^2$, the fitted parameters are $b_1 = 15.56$, $b_2 = -0.6765$, so that $LT50 = 23.01$ and $\alpha = -0.1691$.

Confidence intervals and bias for $b_1$, $b_2$, $LT50$, and $\alpha$ were estimated by simulation: the model (4) was used with both the uniform and triangular distributions for $\phi_i$ to generate 5000 data sets each, assuming the values for $\rho^2$, $b_1$, and $b_2$ given above. Each simulated data set was fitted to the model (holding $\rho^2$ constant), yielding 10000 pairs $(b_{1k}, b_{2k})$.

The mean, standard deviation, and bias of these data, and some order statistics, are shown in Table 3. Standard formulas show that the mean and standard deviation are determined by the simulation to within 2% at the 95% confidence level. The quasilikelihood estimator for $LT50$ is seen to be essentially unbiased, confirming the naturalness of this quantity as a model parameter. The shortest 95% confidence intervals were $21.96^\circ C < LT50 < 24.10^\circ C$ for the uniform distribution and $22.59^\circ C < LT50 < 23.41^\circ C$ for the triangular distribution. The corresponding symmetric 95% intervals were $21.93^\circ C < LT50 < 24.08^\circ C$ and $22.60^\circ C < LT50 < 23.42^\circ C$, respectively.

The results of the simulation are shown more vividly in Figure 4. For each model, one point has been plotted at a randomly chosen temperature on each of the 5000 fitted survival curves, to give some feeling for the shapes of the confidence surfaces.

**THE QUASILIKELIHOOD-GENERATING MODEL**

Our goal in this section is to clarify just what the "quasilikelihood estimator" of the preceding section is maximizing. From a practical point of view, the question is moot, in that the simulations described there establish completely rigorous confidence regions for the estimated parameters. This section can be skipped by readers who are primarily interested in the biological results.

Quasilikelihood theory was developed to deal with situations in which one has some (usually empirical) information about the relationship between the expected value and variance of a quantity, over a series of similar experiments, but not about the statistical mechanisms that give rise to this relation, and therefore no way to construct a likelihood function. In
such a situation, one can construct a function called a *quasilikelihood*, which turns out to have many of the properties of a true likelihood function arising from a generalized linear model. In particular, the method of iteratively reweighted least-squares can be used to maximize the quasilikelihood, and much of the asymptotic theory of maximum likelihood estimation carries over to maximum quasilikelihood (McCullagh and Nelder 1989).

Our case is rather different, in that we have the definite model (4) in mind, which is only incomplete in that we are trying to avoid committing ourselves to a particular form for the functions $f_i$.

If there were a suitable exponential family distribution having the same mean and variance as (4), the quasilikelihood estimate would be exactly the maximum likelihood estimate for this distribution. Unfortunately, it is not hard to show that no such distribution exists. The obstacle here turns out to be the requirement that the distribution is supported on the integers from 0 to $n$. If this condition is relaxed to require only that the distribution be supported on non-negative integers, there is a (unique) exponential family distribution with the desired properties:

$$
\pi(m_i | n_i, \phi_i, p_i) = \begin{cases} 
\frac{(n_i/\gamma_i)(\gamma_i p_i \phi_i)^{m_i}(1 - \gamma_i p_i \phi_i)^{n_i - m_i}}{m_i!}, & \text{for } 0 < \gamma_i < 1 \\
\frac{(\gamma_i p_i \phi_i)^{m_i} e^{-\gamma_i p_i \phi_i}}{m_i!}, & \text{for } \gamma_i = 0 \\
\frac{(-n_i/\gamma_i + m_i - 1) (-\gamma_i p_i \phi_i)^{m_i}(1 - \gamma_i p_i \phi_i)^{n_i - m_i}}{m_i!}, & \text{for } \gamma_i < 0 \end{cases}
$$

(6) where $\gamma_i = 1 - (n_i - 1)p^2$.

Except for a constant factor, this turns out to be identical to the quasilikelihood function constructed from (5), so that it reasonable to call (6) the *quasilikelihood generating model*.

Because the number of smolts in each release ($\approx 10^3, 10^4$) is very much larger than the typical number recovered ($\approx 10^1, 10^2$), it would have been quite reasonable to model the underlying survival-capture process as a Poisson process. After all, the binomial model is also only an approximation (for example, smolts from one release are actually recovered over several trawls), and it would be difficult to argue convincingly that it is a better one than the Poisson in this case. If we imitate the development of the previous section, beginning
from the Poisson model, things work out pretty much as before. The mean and variance functions of the "relaxed" model become

\[ E[m_i] = p_i \phi_i n_i \]

(7)

\[ V[m_i] = E[m_i] + \rho^2 E[m_i]^2 \]

and the quasilikelihood-generating distribution takes the form:

\[ \pi(m_i|n_i, \phi_i, p_i) = \begin{cases} \frac{(p_i \phi_i)^{n_i}}{m_i} e^{-p_i \phi_i n_i}, & \text{for } \gamma_i = 0 \\ (-\gamma_i n_i^{\gamma_i + m_i - 1})(-\gamma_i p_i \phi_i)^{m_i}(1 - \gamma_i p_i \phi_i)^{n_i - m_i}, & \text{for } \gamma_i < 0 \end{cases} \]

where \( \gamma_i = -n_i p_i^2 \) (so the first case of (6) never arises). These equations are identical to equations (5) and (6) except for obviously negligible terms of order \( 1/n_i \).

The second (negative binomial) distribution of (8), however, can also be exhibited as the model that results from the Poisson base model when the parameter \( p_i \) is replaced by a gamma variate with mean \( p_i \) and variance \( \rho^2 p_i^2 \). That is, the quasilikelihood estimate is indeed a maximum-likelihood estimate for a perfectly natural model. Our only reason for preferring the language of quasilikelihood is that the maximum-likelihood interpretation depends very delicately on making the "right" approximations.

**DISCUSSION**

We have shown that a simple and natural model of smolt survival can be fit to the data. This model predicts mean smolt survival at a given temperature to about 10% at the 95% confidence level (cf. Figure 4).

Taking the most conservative error bounds, we have estimated that chinook salmon released at Ryde and migrating to Chipps Island experience 50% mortality at 23.01 ± 1.08°C. It is interesting to compare this estimate of survival under natural conditions with the results of laboratory studies.

Laboratory studies of the direct effects of high temperatures on animal survival have been conducted in two different ways: the method of abrupt transfer and the method of
slow heating (Kilgour and McCauley 1986). These result in somewhat different measures of lethality. For our purposes we will regard the “upper incipient lethal temperature” (UILT) found in abrupt transfer experiments as comparable to the LT50 of the fitted model. We will regard the temperatures at which given fractions of the sample are lost in slow heating experiments as comparable to the temperatures at which these same losses are predicted by the model. In both kinds of experiments, the results depend on the temperature to which the animals were acclimatized.

The classic abrupt transfer experiments involving chinook salmon are those of Brett (1952):

<table>
<thead>
<tr>
<th>Acclimation (°C)</th>
<th>Brett (1952)</th>
<th>Fitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 15 20 24</td>
<td></td>
</tr>
<tr>
<td>UILT</td>
<td>24.3 ± 0.1 25.0 ± 0.1 25.1 ± 0.1 25.1 ± 0.1</td>
<td>23.01 ± 1.08</td>
</tr>
</tbody>
</table>

We regard this as a reasonable agreement.

The temperatures predicted by the fitted model to result in 10%, 50%, and 90% mortality are also consistent with the results of several slow-heating experiments reproduced in the survey of Houston (1982):

<table>
<thead>
<tr>
<th>Acclimation (°C)</th>
<th>Houston (1982)</th>
<th>Fitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 10 11 13 18 20</td>
<td></td>
</tr>
<tr>
<td>10% Loss</td>
<td>22.9 20.5 23.0 19.5 20.0 23.8</td>
<td>19.76</td>
</tr>
<tr>
<td>50% Loss</td>
<td>— — 23.5 — — 24.7</td>
<td>23.01</td>
</tr>
<tr>
<td>90% Loss</td>
<td>24.5 23.5 23.8 23.0 23.5 24.8</td>
<td>26.26</td>
</tr>
</tbody>
</table>

The laboratory studies cited above examine the effects of temperature alone. In the natural environment, however, it may be difficult or impossible to separate the direct effects of temperature from indirect effects on the ability of salmon to survive other threats, such as predation and disease. It is reasonable to inquire about the magnitude of these indirect effects.

The UILTs found by Brett for salmon acclimatized to 15°C and above are about 2°C.
higher than the LT50 found here. In addition, the range of temperatures at which significant temperature-related mortality occurs is greater in the fitted model than in any of the laboratory studies referred to above. Both of these observations would be consistent with the presence of significant indirect effects of temperature on survival in the Delta. If the possibility of differences in temperature tolerance between Central Valley salmon stocks and the more northerly stocks used in the laboratory studies is considered, there may be even more room for indirect temperature effects. On the other hand, the model makes no provision for possible sources of mortality independent of temperature. If mortality from such sources could be accounted for separately, the “LT50” associated with the remaining mortality would probably be higher.

Our analysis shows that direct effects of high temperature are sufficient to explain a large part of the smolt mortality actually observed in the Delta. In particular, the observed LT50 of 23.01 ± 1.08°C is remarkably consistent with the results of controlled experiments. This reaffirms the relevance of laboratory findings to natural systems.

ACKNOWLEDGMENTS

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REFERENCES


Table 1. Data for the release and recovery of selected coded-wire-tag groups of chinook salmon smolts released in the Sacramento River at Ryde. (From USFWS 1983–1992.)

<table>
<thead>
<tr>
<th>Coded-Wire-Tag Number(s)</th>
<th>Date of Release</th>
<th>Average Temperature (°C)</th>
<th>Number Released</th>
<th>Number Recovered</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 06-62-23</td>
<td>5/20/83</td>
<td>5.89</td>
<td>92693</td>
<td>95</td>
<td>0.00083324</td>
</tr>
<tr>
<td>2 06-42-09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06-62-29</td>
<td>6/13/84</td>
<td>5.15</td>
<td>59998</td>
<td>37</td>
<td>0.00088098</td>
</tr>
<tr>
<td>3 06-62-35</td>
<td>5/11/85</td>
<td>5.82</td>
<td>107161</td>
<td>88</td>
<td>0.00106649</td>
</tr>
<tr>
<td>4 06-62-48</td>
<td>5/30/86</td>
<td>5.34</td>
<td>101320</td>
<td>74</td>
<td>0.00112363</td>
</tr>
<tr>
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<td>51103</td>
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<tr>
<td>6 06-62-58</td>
<td>5/2/87</td>
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<td>51008</td>
<td>47</td>
<td>0.00107142</td>
</tr>
<tr>
<td>7 06-31-01</td>
<td>5/3/88</td>
<td>8.40</td>
<td>52741</td>
<td>106</td>
<td>0.00213811</td>
</tr>
<tr>
<td>8 06-31-02</td>
<td>5/6/88</td>
<td>8.56</td>
<td>53238</td>
<td>146</td>
<td>0.00214250</td>
</tr>
<tr>
<td>9 06-62-63</td>
<td>6/22/88</td>
<td>8.25</td>
<td>53961</td>
<td>46</td>
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<tr>
<td>10 06-31-03</td>
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<td>8.72</td>
<td>53942</td>
<td>39</td>
<td>0.00212647</td>
</tr>
<tr>
<td>11 06-31-12</td>
<td>5/3/89</td>
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<td>51046</td>
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<tr>
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<td>6/16/89</td>
<td>7.83</td>
<td>51134</td>
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<td>0.00097782</td>
</tr>
<tr>
<td>14 06-31-20</td>
<td>5/9/90</td>
<td>5.04</td>
<td>51878</td>
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</tr>
<tr>
<td>15 06-31-22</td>
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<td>6.87</td>
<td>50837</td>
<td>67</td>
<td>0.00105773</td>
</tr>
</tbody>
</table>
Table 2. Comparison of the trawl recoveries predicted by the fitted base model for the Ryde release groups with the corresponding actual trawl recoveries.

<table>
<thead>
<tr>
<th></th>
<th>Expected Recoveries</th>
<th>Actual Recoveries</th>
<th>Pearson Residuals</th>
<th>Deviance Residuals</th>
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<tr>
<td>1</td>
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<td>95</td>
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<td>-1.95</td>
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<td>4</td>
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<td>2.91</td>
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<td>-0.59</td>
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<td>6</td>
<td>53</td>
<td>47</td>
<td>-0.86</td>
<td>-0.88</td>
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<td>111</td>
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<td>-0.46</td>
<td>-0.46</td>
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<td>8</td>
<td>113</td>
<td>146</td>
<td>3.09</td>
<td>2.96</td>
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<tr>
<td>9</td>
<td>43</td>
<td>46</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>10</td>
<td>53</td>
<td>39</td>
<td>-1.95</td>
<td>-2.05</td>
</tr>
<tr>
<td>11</td>
<td>54</td>
<td>65</td>
<td>1.50</td>
<td>1.45</td>
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<tr>
<td>12</td>
<td>50</td>
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<tr>
<td>13</td>
<td>28</td>
<td>8</td>
<td>-3.78</td>
<td>-4.46</td>
</tr>
<tr>
<td>14</td>
<td>46</td>
<td>87</td>
<td>6.07</td>
<td>5.39</td>
</tr>
<tr>
<td>15</td>
<td>52</td>
<td>67</td>
<td>2.11</td>
<td>2.01</td>
</tr>
</tbody>
</table>
Table 3. Statistical properties of the quasilikelihood estimators, determined by simulation with respect to two models of capture probability.

<table>
<thead>
<tr>
<th></th>
<th>Canonical parameters</th>
<th>Natural parameters</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$b_1$</td>
<td>$b_2$</td>
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<tr>
<td></td>
<td>LT50</td>
<td>$\alpha$</td>
</tr>
<tr>
<td><strong>Fitted</strong></td>
<td>15.56</td>
<td>$-0.6765$</td>
</tr>
<tr>
<td><strong>Uniform</strong></td>
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<td></td>
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<tr>
<td>mean</td>
<td>18.65</td>
<td>$-0.8080$</td>
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<tr>
<td>s.d.</td>
<td>10.18</td>
<td>0.4356</td>
</tr>
<tr>
<td>bias</td>
<td>3.08</td>
<td>$-0.1315$</td>
</tr>
<tr>
<td>P1</td>
<td>5.72</td>
<td>$-2.6166$</td>
</tr>
<tr>
<td>p2.5</td>
<td>7.40</td>
<td>$-2.0770$</td>
</tr>
<tr>
<td>Q1</td>
<td>13.09</td>
<td>$-0.8957$</td>
</tr>
<tr>
<td>median</td>
<td>15.80</td>
<td>$-0.6880$</td>
</tr>
<tr>
<td>Q3</td>
<td>20.70</td>
<td>$-0.5722$</td>
</tr>
<tr>
<td>P97.5</td>
<td>47.97</td>
<td>$-0.3168$</td>
</tr>
<tr>
<td>P99</td>
<td>60.60</td>
<td>$-0.2352$</td>
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<tr>
<td><strong>Triangular</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>16.80</td>
<td>$-0.7291$</td>
</tr>
<tr>
<td>s.d.</td>
<td>5.06</td>
<td>0.2163</td>
</tr>
<tr>
<td>bias</td>
<td>1.23</td>
<td>$-0.0526$</td>
</tr>
<tr>
<td>P1</td>
<td>10.09</td>
<td>$-1.5716$</td>
</tr>
<tr>
<td>P2.5</td>
<td>10.75</td>
<td>$-1.3101$</td>
</tr>
<tr>
<td>Q1</td>
<td>13.62</td>
<td>$-0.8028$</td>
</tr>
<tr>
<td>median</td>
<td>15.62</td>
<td>$-0.6810$</td>
</tr>
<tr>
<td>Q3</td>
<td>18.54</td>
<td>$-0.5941$</td>
</tr>
<tr>
<td>P97.5</td>
<td>30.32</td>
<td>$-0.4690$</td>
</tr>
<tr>
<td>P99</td>
<td>36.23</td>
<td>$-0.4414$</td>
</tr>
</tbody>
</table>
Figure 1. North-Central Region of the Sacramento - San Joaquin Delta.

Figure 2. Pearson (open circles) and deviance (solid circles) residuals for the fitted base model, plotted against water temperature.

Figure 3. Two methods of estimating smolt survival from Ryde to Chipps Island. The diagonal line Trawl-based survival = Ocean-based survival is provided for reference.

Figure 4. Distributions of quasilikelihood estimates of smolt survival from Ryde to Chipps Island, for the fitted model, assuming that the probability of capture is drawn from (a) the uniform distribution and (b) the triangular distribution.
MODELED SAN JOAQUIN CHINOOK SALMON ESCAPEMENT UNDER SELECTED PULSE FLOW ALTERNATIVES

EACH for Windows 8.5.3, runs of 11 October 1994

<table>
<thead>
<tr>
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<th>Without Old River Barrier</th>
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</thead>
<tbody>
<tr>
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<td>JP</td>
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<tr>
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</tr>
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<td>1984</td>
<td>518</td>
<td>460</td>
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<tr>
<td>1985</td>
<td>450</td>
<td>349</td>
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<td>375</td>
<td>372</td>
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<tr>
<td>1982–1991</td>
<td>394</td>
<td>315</td>
</tr>
</tbody>
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DFG: SWRCB Alternative 4.


SJT: San Joaquin Tributary Agencies. (Export limited to 1,500 cfs from 15 April through 15 May. Two seven-day pulses, one in mid-April and one in mid-May. Pulses to total at least 1,000 cfs at Vernalis in Critical water-years, 2,000 cfs in Dry years, 3,000 cfs in Below Normal and Above Normal years, and 4,000 cfs in Wet years.)
MODELED SAN JOAQUIN CHINOOK SALMON ESCAPEMENT
UNDER SELECTED PULSE FLOW ALTERNATIVES

EACH for Windows 8.5.3, runs of 11 October 1994

Baseline

DFG

JP

SJT

With Old River Barrier

Without Old River Barrier

Prepared by EA Engineering, Science, and Technology for San Joaquin Tributary Agencies