BAY-DELTA HEARINGS

403

RECOMMENDED ELEMENTS OF A MANAGEMENT PROGRAM FOR BAY/DELTA FISH POPULATIONS

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RECOMMENDED ELEMENTS OF A MANAGEMENT PROGRAM FOR BAY-DELTA FISH POPULATIONS

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INTRODUCTION

The State Water Contractors (SWC) have developed recommendations for a management program for Bay-Delta fish populations. The recommendations involve both long- and short-term elements. The recommended elements of the short-term program are based on the recognized need to provide additional protections to reduce mortality and improve overall habitat conditions for Bay-Delta fish populations while also recognizing competing demands for limited available water supplies. Populations of a number of resident and migratory fish and invertebrate species have experienced a period of declining abundance which, in part, is attributable to direct and indirect impacts resulting from operation of the State Water Project (SWP) and Central Valley Project (CVP) water storage and diversion facilities. Although the impacts of water project system operations can be reduced through substantial reductions in the volumes of water exported and seasonal increases in the volumes of water flowing through the Sacramento and San Joaquin rivers and Delta (Delta outflow) these actions cannot be reasonably accomplished given the water project facility location, operations, and demand for water supplies which presently exist. No "quick fix" has been identified which adequately resolves the conflicting demands between changes which need to occur in the Delta to improve and protect fish populations and aquatic habitat and the established demands for municipal, industrial, and agricultural water supplies from the Bay-Delta system. In recognition of this dilemma the State Water Contractors recommend a phased program which includes a short-term program of actions (to be accomplished within five years) which offers some measure of improved conditions and protections for Bay-Delta fisheries while a comprehensive program of corrective actions, including major conveyance and storage facilities, can be implemented which will be designed to achieve the desired level of biological protection for the Delta and its aquatic populations while also meeting water supply demand. Elements of the recommended short-term management program can be implemented immediately given existing facilities and operational conditions within the Bay-Delta system. The program of short-term actions is compatible and consistent with the ultimate goal of providing improved environmental conditions which will complement the development and implementation of a comprehensive long-term solution to the existing Bay-Delta problems.

The ultimate goal is to develop and implement a program of comprehensive long-term actions which will achieve and sustain the goals and objectives of the fisheries management program. Actions taken on a short-term basis should complement and be consistent with achieving the comprehensive program goals including the quantitative evaluation of biological benefits associated with various alternative program actions. The comprehensive long-term program would be developed to improve habitat conditions and reduce sources of mortality upstream, and within the Delta environment, such as those occurring as a result of diversion of fish at the Delta Cross-channel or direct entrainment losses at the SWP and CVP intakes. The short-term program of actions is intended, in part, to provide fisheries population protection until such time as the comprehensive long-term program can be developed and fully implemented.

A number of long-term biological goals can be identified to guide the development of a comprehensive long-term solution. They include, but are not limited to, the following:

o Increased species-specific population abundance;

o Reduced mortality (increased survival) for various fish species and lifestages;

o Increased frequency of strong year classes;

o Improved growth and condition;

o Protection of reproductive adults;

- o Maintenance of species and genetic diversity; and

- o Improved availability and quality of aquatic habitat

In order to accomplish the long-term biological goals described above, substantial changes in water project operations, conveyance and export facilities, hydrologic conditions, and aquatic habitat conditions within the Bay-Delta system will need to occur. Current constraints imposed by the design of the existing SWP and CVP water export facilities and the limited water supplies available to be allocated to satisfy competing demands for environmental, urban, and agricultural usage limit the opportunities available for substantially improving Bay-Delta environmental conditions within the short-term (five years) period for interim standards. Despite these constraints a number of short-term actions have been identified which can be implemented to provide additional protections for Bay-Delta fish and invertebrate species (e.g., reduce mortality rates) which will contribute to population maintenance and improved biological conditions until a comprehensive long-term program of actions can be implemented. The program of short-term (interim) actions must be compatible, and avoid conflicts with, the development and implementation of the long-term program of actions designed to meet the biological goals while continuing to balance competing demands for limited water resources. The program of short-term actions should, in addition to providing some level of increased biological protection, be constructed to include detailed scientific monitoring and quantitative evaluation of the biological benefits resulting from a number of the short-term interim program elements which are specifically designed to provide data to be used in the development and implementation of the comprehensive long-term management program.

Outlined below is a framework for identifying potential short-term management actions designed to improve conditions for Bay-Delta and upstream fisheries populations. Primary elements of the approach are:

(1) Identify specific fisheries goal to be accomplished by the comprehensive long-term program (e.g., increased population abundance, reduced mortality, etc.);

(2) Identify and, to the extent possible, quantify the significance of various biological and environmental factors influencing

the dynamics of the target populations (e.g., legal and illegal harvest, entrainment loss, acute or chronic toxicity, etc.);

(3) Identify specific short-term actions which are not inconsistant with the long-term goals and which are designed to reduce mortality, improve habitat conditions, etc. within the Delta;

(4) Identify and implement specific actions in areas upstream of the Delta; and

(5) Identify and implement a comprehensive long-term program of actions designed to accomplish the fishery program goals and objectives.

This framework provides the basis for developing an integrated management program which considers the life history and population dynamics of larval, juvenile, and adult anadromous species such as chinook salmon, steelhead, American shad, and striped bass, and resident Delta species such as longfin and Delta smelt.

At the present time the available scientific information is sufficient for many species to identify specific management goals, factors influencing the population, and potential management actions. There remains, however, a considerable degree of uncertainty as to the quantitative magnitude of the various factors influencing populations, and the confidence which can be placed in predicting biological benefits which may be achieved through different management actions. The present level of uncertainty regarding the quantification or evaluation of specific benefits derived from various actions <u>should not</u> preclude development and implementation of a short-term program of actions designed to improve Bay-Delta conditions for various fisheries resources. The uncertainty does, however, require that the program of actions include (1) a biological monitoring and evaluation program to improve the quantitative assessment of biological benefits associated with each action; (2) a recognition that the program of actions will be modified and evolve as new biological information becomes available; and (3) management conflicts will need to be resolved between objectives for various target species and lifestages and between competing beneficial uses for available water supplies.

FACTORS INFLUENCING BAY-DELTA FISHERIES POPULATIONS

A number of factors have been identified which influence the abundance, survival, growth, and reproductive success of the Bay-Delta fisheries populations. Development of a comprehensive management program needs to recognize and address these factors which include, but are not limited to, the following:

- Water quality including seasonal and geographic variation in dissolved oxygen concentration, salinity, water temperature, and industrial, agricultural, and municipal contaminant discharges;

- Chemical loading associated with point and non-point source discharges to the Bay-Delta system;

- Water management practices including seasonal storage and release patterns from upstream impoundments, freshwater inflow from various major tributaries to the Sacramento and San Joaquin Delta, interior Delta channel hydrology, reverse flow patterns, Delta exports and diversions, and freshwater outflow from the Delta;

- Entrainment and diversion losses associated with operation of the State and Federal water project diversions and municipal, industrial, and agricultural diversions from areas within and upstream of the Delta;

- Exploitation and harvest of species in recreational, commercial, and illegal (poaching) fisheries locally and off the California Coast;

- Degradation of habitat conditions;

- Dredging and dredge spoil disposal activities which may result in chemical contaminant resuspension;

- Variation and changes to the ecological system of the Bay-Delta environment associated with introduced species, declines in phytoplankton and zooplankton production, changes in detrital loading and nutrient inputs, and dynamic changes which naturally occur between species which influence predation, competition, food availability, etc.;

- o Increased susceptibility to disease and chronic physiological stress which impact growth, survival, reproductive potential, and overall condition of fish populations;

- o Population dynamics such as reproductive potential, stock-recruitment relationships, density dependent survival, etc. which change as adult spawning stock declines; and

- o Climatelogical and other occurrences.

The identification, and to the extent possible the quantification of these and other factors influencing various Bay-Delta fisheries populations provides the technical foundation for identifying specific short- and long-term management actions which offer the opportunity for improving environmental habitat and population dynamics. It must be recognized, however, that the relative significance of various biological and environmental factors varies between years in response to variations in hydrology and environmental conditions, between species and lifestages, and between seasons within a year. This inherent high variability within the Bay-Delta system makes it difficult to prioritize actions and predict, with confidence, potential biological benefits. The dynamic nature of the changing Bay-Delta environment, which has recently been further altered by the rapid population expansion of several introduced fish and macroinvertebrate species, also makes it difficult to utilize quantitative data developed from historic surveys in projecting future population benefits associated with various potential management actions. An iterative program of short-term actions and a specific program of monitoring and evaluation appears, at this point, to be the most appropriate direction for improving Bay-Delta fisheries conditions while building toward comprehensive long-term solutions.

INTERIM PROGRAM (SHORT-TERM ACTIONS)

Short-term management actions (Table 1), those which could be implemented within a five-year time period, are identified and briefly discussed below. The list of short-term actions is not intended to be comprehensive, nor developed technically to the extent necessary for implementation, but rather are offered to illustrate the types of short-term actions which should be included in developing an interim fisheries-water management program.

The development of a short- and long-term Delta fisheries management program should recognize and complement actions which have been identified to improve habitat conditions for spawning and juvenile rearing of chinook salmon, steelhead, and other fish species in areas upstream of the Delta (e.g., Upper Sacramento River Fisheries and Riparian Habitat Management Plan). Actions to improve upstream fisheries habitat are currently being considered and/or implemented within both the Sacramento and San Joaquin river basins. Upstream actions include improvements in water quality conditions, substrate, instream flow patterns, reductions in diversion mortality, etc. These actions are designed to contribute to an increased number of migratory fish entering and passing through the Delta.

Actions such as pulsed-flow conditions to promote downstream transport of striped bass eggs and larvae need to be developed and implemented in ways which minimize potential impacts associated with rapid flow fluctuations and stranding of eggs and juvenile fish inhabiting upstream areas. Furthermore, development of seasonal patterns of freshwater inflow and Delta outflow must also take into consideration seasonal patterns in instream flow conditions, cold water storage, and water quality conditions including temperature regimes throughout the year which may positively or adversely impact fisheries populations inhabiting upstream areas. Fisheries management within the Sacramento - San Joaquin rivers and Delta must be developed on a systemwide basis to adequately identify and integrate management strategies for fisheries populations inhabiting both upstream and downstream areas.

Table 1. **Elements to be included in an interim Bay-Delta management program**

- Provide periodic closure of the Delta Cross-channel based on a real-time monitoring program for striped bass eggs and larvae (further evaluation is required to determine whether or not real-time monitoring is applicable for determining periods of Delta Cross-channel closure to protect species in addition to striped bass);

- Provide pulsed-flow conditions to promote downstream movement of striped bass eggs and larvae, juvenile chinook salmon, and potentially other fish species during years of low Sacramento River flow (pulsed flow conditions should to the extent possible, be coordinated with real-time monitoring and Delta Cross-channel closures);

- Improve screening efficiency, fish salvage and handling, and facility operations at the SWP and CVP intakes to reduce mortality of fish salvaged at the facilities;

- Develop and implement a predator management program at both the SWP and CVP intakes to reduce predation losses;

- Increase enforcement of illegal fishing (poaching) regulations within the Bay-Delta system and its tributaries and in coastal waters to protect various fish species;

- Develop and implement a fisheries management program which provides short-term protection for adult fish populations through seasonal and area closures (e.g., eliminate fishing on spawning grounds), gear restrictions to reduce capture and mortality of sub-legal fish, implementation of size slot limits, educate and promote catch-and-release recreational fishing, etc.

- Install barriers at the head of Old River and other strategic locations within the lower San Joaquin River and Delta to improve water quality conditions for migrating adult chinook salmon and improve survival of emigrating chinook salmon and steelhead;

- Implement regulatory actions to reduce the introduction and transport of exotic species into Bay-Delta waters;

- Improve hatchery management for striped bass, chinook salmon, steelhead, and other fish species including experimental hatchery programs for Delta smelt;

- Relocate and consolidate agricultural diversions from Delta channels where larval and juvenile fish have an increased susceptibility to entrainment losses. The consolidated intakes should be equipped with fish screens to further reduce susceptibility to entrainment;

- Identify alternative time periods and management scenarios for agricultural diversions from the Delta and upstream to reduce entrainment susceptibility;

- Develop a real-time entrainment monitoring program for SWP and CVP diversions designed to identify periods of peak susceptibility of various fish species to entrainment at each diversion and coordinated operations of the diversions to reduce the combined losses at the two facilities;

- Design and construct the structural temperature control device at Shasta Dam and develop and implement modifications in CVP operations, if needed, to allow for control of water temperatures sufficient to protect salmon;

- Rehabilitate and expand the Coleman National Fish Hatchery;

- Eliminate, to the extent practical, losses of salmon and steelhead resulting from flow fluctuations caused by operation of upstream impoundments;

- Expand gravel replenishment and maintenance programs for purposes of improving the availability and quantity of salmonid spawning habitat;

- Implement a program to improve fish screening and diversion bypasses, fish passage, etc. along the tributaries to the Bay-Delta estuary;

- Plan and construct a fish hatchery at Keswick Dam on the Sacramento River for winter-run and other races of salmon;

- Plan and construct a salmon and steelhead hatchery within the San Joaquin River system;

- Negotiate and execute an agreement which, when implemented, will fully mitigate the fishery impacts associated with direct entrainment losses resulting from CVP and Contra Costa Canal pumping operations.

EVALUATIONS AND STUDIES IN SUPPORT OF DEVELOPING A COMPREHENSIVE LONG-TERM MANAGEMENT PROGRAM

- Evaluate the operational and biological benefits, design criteria, and costs associated with various alternative water conveyance and storage facilities including relocation of the SWP and/or CVP diversions;

- Evaluate potential options for improving fisheries habitat conditions within the Delta including seasonal reductions in channel velocities, developing areas of greater riparian and emergent vegetation, shoal and shallow water areas for juvenile rearing habitat, etc.

- Develop water budget management scenarios, reflecting interannual and seasonal availability and demand in water supply, to reduce direct and indirect mortality associated with cross-Delta flows, reverse flow within the lower San Joaquin River, and the balance between freshwater inflow and exports (percent diverted) during periods of greatest susceptibility of various fish species and lifestages to diversion losses;

- Develop an experimental study program to provide short-term seasonal increases in outflow to promote the downstream transport and location of larval fish populations within areas of Suisun Bay to reduce susceptibility to entrainment losses at the SWP and CVP intakes and agricultural and municipal diversions within the Delta.

- Evaluate the types of chemicals, application rates, acute and chronic toxicity, and timing of agricultural, industrial, and urban discharges into the upper Sacramento River, San Joaquin River system, and Delta during spawning periods for striped bass, American shad, and other fish species (several of these evaluations are under way);

- Alternative methods and facilities for agricultural, municipal, and industrial wastewater treatment (toxicity and volume reduction) and disposal;

- Evaluate potential options for improving fisheries habitat conditions within the Delta including seasonal reductions in channel velocities, developing areas of greater riparian and emergent vegetation, shoal and shallow water areas for juvenile rearing habitat, etc.

RECOMMENDED ACTION: Provide periodic closure of the Delta Cross-channel based on a real-time monitoring program for striped bass eggs and larvae (further evaluation is required to determine whether or not real-time monitoring is applicable for determining periods of Delta Cross-channel closure to protect species in addition to striped bass).

BASIS FOR THE RECOMMENDATION: Striped bass egg and larval monitoring programs conducted in the Sacramento River over a number of years (CDFandG egg and larval monitoring; Arthur *et al.* 1991; Hanson 1992) have demonstrated that striped bass spawn upstream of the Delta Cross-channel. Results of these monitoring programs have shown that egg and larval densities reflect pulses of spawning activity resulting in short-term peaks in density as the planktonic eggs and larvae drift downstream with the flow of the Sacramento River. Data are also available (Hanson, unpublished) which show that a portion of the planktonic striped bass eggs and larvae are diverted from the Sacramento River into the Delta Cross-channel. Results of several of these monitoring programs (Arthur *et al.* 1991; Hanson 1992) have demonstrated the ability of a real-time monitoring program conducted at Bryte (upstream of the City of Sacramento) to detect the passage of a striped bass egg and larval pulse which can be used as a management tool for short-term closure of the Delta Cross-channel to reduce diversion from the Sacramento River.

The rate of downstream transport between Bryte and the Delta Cross-channel varies in response to flow within the Sacramento River. Transport of eggs and larvae between Bryte and the Delta Cross-channel during 1991 (average Sacramento River flow at "I" Street of 6500 cfs) was estimated to be approximately 84 hours (Hanson 1992). Closure of the Cross-channel gate for a period of approximately five days would have provided protection for a majority of the striped bass larvae observed in the bimodal pulse monitored during May 1991 (Figure 1). Previous studies have shown that multiple pulses of striped bass eggs and larvae may pass the Cross-channel during a spawning season.

Additional investigation is required to determine transit times between the upstream monitoring location and Delta Cross-channel and the period of susceptibility of striped bass eggs and larvae to diversion at the Delta Cross-channel under various Sacramento River flow regimes. Additional monitoring is also required to determine the

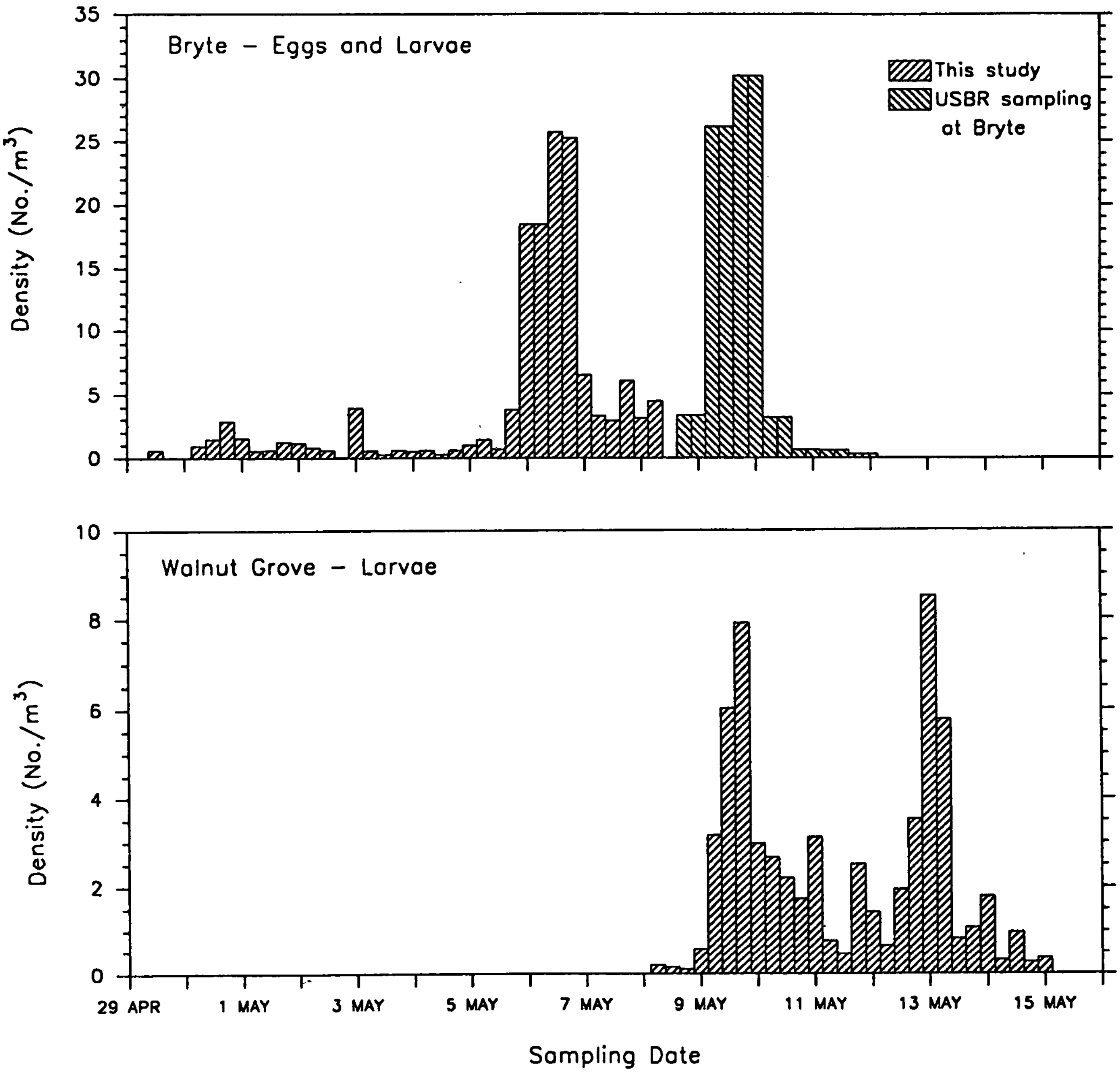

Figure 1. Six-hour average striped bass egg and larval densities observed April 29 - May 15, 1991 in the Sacramento River at Bryte and Walnut Grove. (Source: Hanson 1992).

applicability of a real-time monitoring program for Delta Cross-channel operations to protect species other than striped bass. Available data are, however, sufficient for use as a basis in the design and implementation of a real-time biological monitoring program for use in managing operations of the Delta Cross-channel gates to contribute to increased survival of striped bass eggs and larvae spawned within the Sacramento River.

Our proposal for the initial development of a real-time biological monitoring program for management of Delta Cross-channel operations is based on striped bass egg and larval sampling at Bryte, located on the Sacramento River approximately 35 miles upstream of the Delta Cross-channel. Sampling would be performed at a fixed location using a 0.5 m 500 μm mesh plankton net. Each plankton sample would be a 60-minute composite with 20 minutes at each of three depths (bottom, mid-depth, near-surface). Sampling would be performed at three-hour intervals daily for the period from April 1 through June 30 (striped bass egg and larval sampling would begin May 1 in the event that the Delta Cross-channel was closed for protection of winter-run chinook salmon emigrants during April). Striped bass egg and larval samples would be processed immediately after collection with data on striped bass egg and larval densities (number per cubic meter) documented and available within 24 hours of collection. The Delta Cross-channel gates would be closed 60 hours after detection of a pulse of eggs and larvae passing Bryte. The density threshold proposed for defining a pulse of eggs and larvae is an average density exceeding 10 striped bass eggs and larvae per cubic meter (Figure 1) during any 12-hour sampling period. The Delta Cross-channel would remain closed for a period of approximately three days (72 hours) coincident with the passage of each pulse of striped bass eggs and larvae. The frequency of Delta Cross-channel closures within a year would depend, in part, on the occurrence of striped bass egg and larval pulses and availability and demand on water supplies.

Refinements in this program to provide better coordination between the closure of the Delta Cross-channel and the passage of pulses of striped bass eggs and larvae can be developed during the interim period. Additional biological monitoring to provide data on the rate of transit of striped bass eggs and larvae between Bryte and the Delta Cross-channel under various Sacramento River flow conditions should be collected to refine the time period (transit time) between detection of a pulse of eggs and larvae at Bryte and closure of the channel. Additional biological sampling in the area adjacent to the Delta Cross-channel should also be conducted to refine the estimated period of exposure to diversion at the Delta Cross-channel under different Sacramento River flow conditions (duration of Cross-channel closures). These biological studies should be augmented by additional striped bass egg and larval sampling within the Sacramento River, the Delta Cross-channel, and Georgiana Slough for use in the development of modeling and statistical tools designed to evaluate biological benefits resulting from Cross-channel closures and in the design of Delta transfer facilities. Any water rights terms adopted by the Board should be flexible enough to allow monitoring and testing to occur and to adjust the program based on the knowledge thereby obtained.

BIOLOGICAL BENEFITS: Available data on striped bass egg and larval diversion at the Delta Cross-channel and resulting mortality rates for larvae diverted into the interior Delta are insufficient to quantify biological benefits associated with a real-time monitoring program and closure of the Delta Cross-channel. Although not quantified, it is believed that striped bass eggs and larvae diverted from the Sacramento River into interior Delta channels have increased susceptibility to entrainment losses at a number of agricultural diversion points (Figure 2) and at the State Water Project (SWP) and Central Valley Project (CVP) diversions from the south Delta. Availability of zooplankton suitable as a food resource for striped bass larvae is also believed to be less within the Central Delta than in downstream locations such as Suisun Bay. Based on these factors it is expected that survival of striped bass larvae would be increased for those fish transported downstream in the Sacramento River and into Suisun Bay in contrast to eggs and larvae diverted at the Delta Cross-channel. This observation is consistent with results of earlier analyses demonstrating a relationship between the percentage of the young striped bass population inhabiting Suisun Bay and the 38 mm index of striped bass abundance.

Closure of the Delta Cross-channel to coincide with periods of peak striped bass egg and larval densities will contribute to improved conditions for striped bass spawned in the Sacramento River. The biological benefit of short-term Delta Cross-channel closures should be increased if the closure is accompanied by a short-term pulsed flow when Sacramento River flow is less than 9,000 cfs during striped bass spawning to promote more rapid downstream transport of planktonic eggs and larvae (reduced residence time within the Sacramento River) and thereby increase the likelihood of larvae entering and subsequently rearing within Suisun Bay.

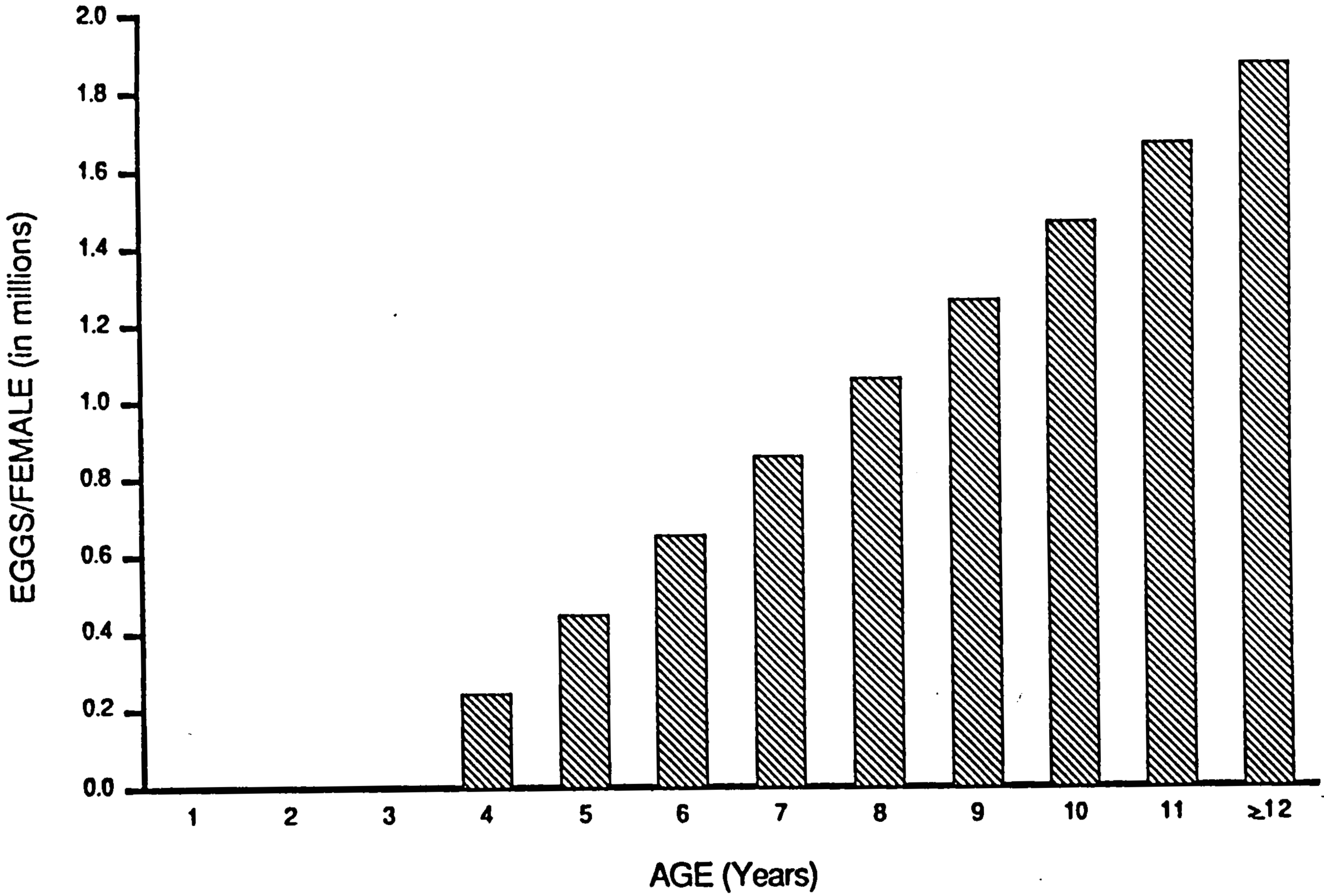

Figure 3. Relationship between striped bass age and fecundity (eggs per female). (Source: CDFandG data).

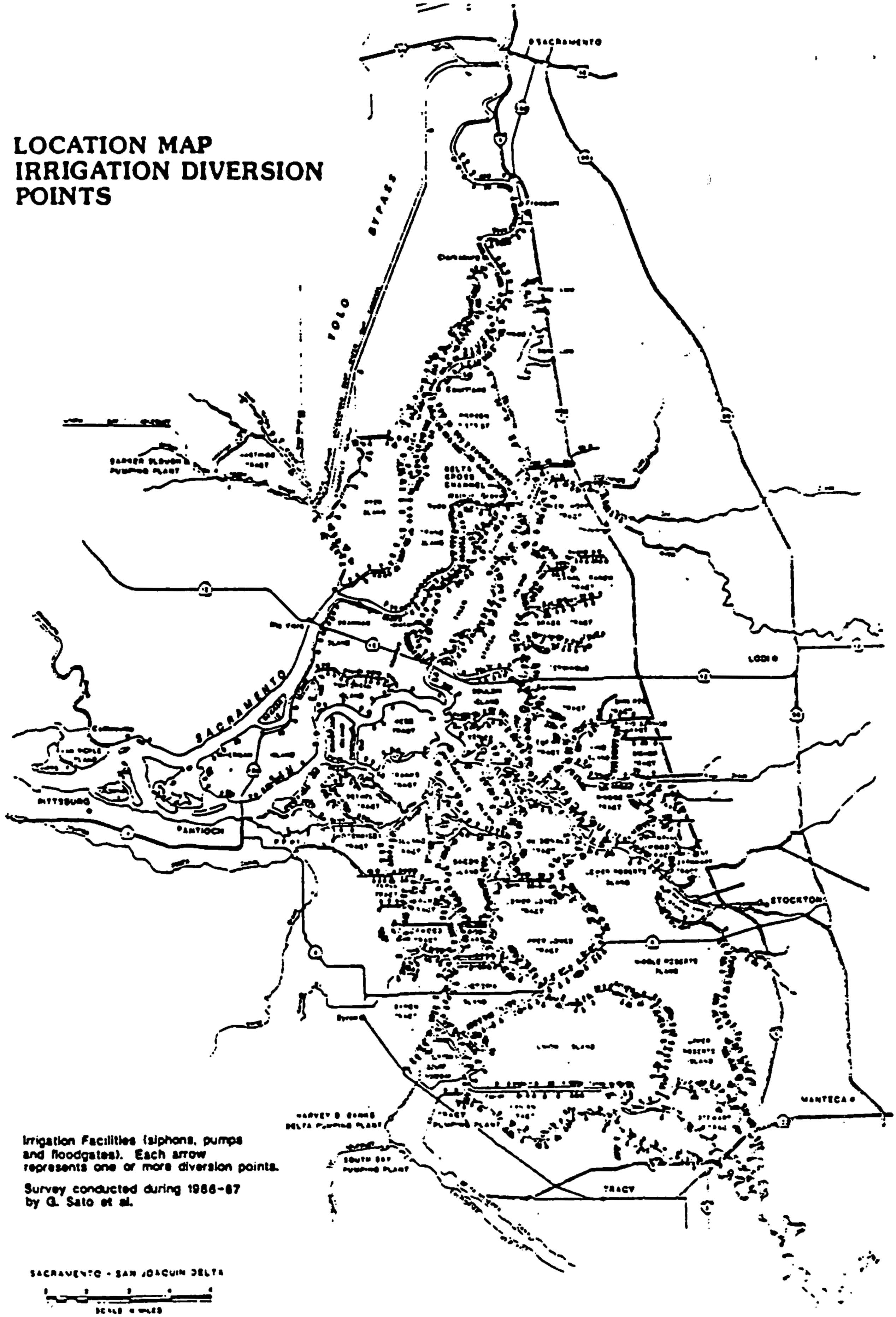

Figure 2. Water diversion locations within the Sacramento - San Joaquin Delta. (Source: DWR 1987).

Development and implementation of a real-time striped bass egg and larval monitoring program on the Sacramento River as part of the short-term (interim) program of actions will provide data useful in the development of the comprehensive long-term management program. Existing intake technologies for water diversions comparable in size to the SWP and CVP exports are not effective in excluding fish eggs and larvae. Therefore, development of the long-term plan which includes consideration of new intake facilities for the SWP and/or CVP on the Sacramento River in an effort to remove diversions from the south Delta would, in all likelihood, utilize operational curtailments, based on real-time biological monitoring, to minimize entrainment (diversion) of planktonic eggs and larvae. Similarly, development of long-term plans which retain the existing SWP and CVP diversion locations in the south Delta, with continued operation of the Delta Cross-channel, would also benefit from data available through real-time biological monitoring efforts to provide protections of planktonic eggs and larvae diverted at the Delta Cross-channel. Information gained on the design, execution, and biological effectiveness of a real-time monitoring program as part of the short-term actions will provide the scientific foundation and practical experience necessary to develop and implement this element of the comprehensive program.

RECOMMENDED ACTION: Provide pulsed-flow conditions to promote downstream movement of striped bass eggs and larvae, juvenile chinook salmon, and potentially other fish species during years of low Sacramento River flow (pulsed-flow conditions should, to the extent possible, be coordinated with real-time monitoring and Delta Cross-channel closures).

BASIS FOR THE RECOMMENDATION: Detailed scientific information is not available for use as a quantitative basis in determining either the optimum magnitude or duration of pulsed-flow events based on an assessment of increased fisheries survival and water supply impacts. Our proposal, based largely on professional judgment, recommends a pulsed increase in Sacramento River flows from 6,000-9,000 cfs during May to a level of 12,000 cfs (I Street) sustained for a six-day period coincident with a period of peak striped bass spawning activity. The proposed pulsed-flow event may also be coordinated with closure of the Delta Cross-channel, and releases of juvenile chinook salmon reared in hatcheries located on tributaries to the Sacramento River. The actual provision of the pulsed-flow management strategy would be based on consideration of spring flows occurring on the Sacramento River, water availability in upstream impoundments, and input from the real-time striped bass egg and larval monitoring programs, salmon monitoring and hatchery management conditions. Implementation of a pulsed-flow would also need to consider appropriate ramping rates to avoid stranding juvenile salmon, steelhead, and other fish species rearing in the Sacramento River and tributaries.

The rate of downstream transport for planktonic striped bass eggs and larvae varies in response to the flow within the Sacramento River. Under sustained low-flow conditions residence time for striped bass within the river may be sufficiently long that larvae exhaust their yolk-sac energy reserves in areas of the lower Sacramento River where zooplankton densities (food supply) is inadequate to support survival and growth of large numbers of striped bass larvae. Striped bass egg and larval surveys during May 1991 (Hanson 1992) when Sacramento River flows averaged 6500 cfs showed that many larvae had absorbed their yolk-sac reserves and would need to begin actively foraging on zooplankton in order to grow and survive within an area of the lower Sacramento River between Walnut Grove and Rio Vista. It has also been hypothesized that striped bass eggs, which are slightly negatively buoyant, may settle to the bottom of the Sacramento River under sustained low-flow conditions and thereby experience increased mortality. Striped bass egg and larval abundance was estimated to have decreased by approximately 75% during downstream transport between Bryte and Walnut Grove in May 1991 (Hanson 1992). The factors and mechanisms contributing to the estimated reduction in abundance, however, could not be identified as part of this study. Increased Sacramento River flow coinciding with periods of peak striped bass egg and larval transport are anticipated to contribute to reduced residence time within the river and increased survival.

Benefits of pulsed increases in Sacramento River flow during the spring period of fall-run juvenile chinook salmon emigration (e.g., May) have been evaluated, in part, by the U.S. Fish and Wildlife Service and California Department of Fish and Game. Pulsed spring flows have been utilized in an effort to increase survival of juvenile chinook salmon released from the Coleman National Fish Hatchery and to stimulate the downstream movement of juvenile chinook salmon rearing within the Sacramento River. Pulsed flows, particularly those coordinated with short-term closures of the Delta Cross-channel, will contribute to a short-term reduction in the percentage of Delta inflow diverted at various water export locations and thereby reduce susceptibility of emigrating juvenile salmon to entrainment losses. No quantitative estimates are available, however, for the increase in juvenile salmon survival which may be achieved through short-term water management practices such as pulsed-flow events.

BIOLOGICAL BENEFITS: Potential biological benefits resulting from short-term pulsed flows during the spring of low-flow years cannot be quantified using existing scientific data. Although the magnitude of biological benefit cannot be assessed (increased survival, reduced residence time, etc.) sufficient biological data exists to conclude that short-term pulsed flows, particularly if accompanied by closure of the Delta Cross-channel, would result in improved conditions for the downstream transport of striped bass eggs and larvae and emigration of juvenile chinook salmon when compared with sustained low-flow conditions throughout the spring. Short-term increases in Sacramento River flow coincident with periods of peak striped bass spawning and the subsequent downstream transport of planktonic eggs and larvae will contribute to a reduction in residence time within the Sacramento River and presumably increased transport of larvae into the lower river and Suisun Bay coincident with the period of development when larval foraging on zooplankton begins to occur. Reduced residence time of striped bass larvae within the Sacramento River during low-flow years will contribute to improved survival and growth although the actual magnitude of the biological benefits is unknown. Biological benefits associated with short-term pulsed flows are likely to vary within and between years based on both biological and environmental conditions occurring coincident with the pulsed-flow event.

RECOMMENDED ACTION: **Improved screening efficiency, fish salvage and handling, and facility operations at the SWP and CVP intakes to reduce mortality of fish salvaged at the facilities.**

BASIS FOR THE RECOMMENDATION: A variety of anadromous and resident fish species are susceptible to entrainment loss at the State Water Project (SWP) and Central Valley Project (CVP) water diversion and fish-salvage facilities. An extensive series of studies were performed at the SWP fish- salvage facility during the late 1960's and early 1970's (Skinner 1974) to evaluate the diversion efficiency of the louvered intake system under a variety of operating conditions for different sizes and species of fish. Additional studies have been performed to evaluate mortality resulting from the collection, handling, and transport of salvaged fish to be returned to the Delta (Table 2). Results of these biological evaluations have shown that although the SWP fish-salvage facilities are relatively effective, opportunities exist for further improving the efficiency of the fish-salvage facilities and reducing mortality of salvaged fish. A limited biological evaluation program was conducted at the CVP salvage facility during the late 1950's and again in the mid-1960's to determine salvage efficiency of the primary and secondary louver systems (Bates *et al.* 1960; Hallock *et al.* 1968). A number of improvements have been identified and implemented to improve the overall efficiency of the SWP fish-salvage program. Additional opportunities exist, however, for improving the design and operation of both the SWP and CVP fish-salvage facilities.

A critical review including, as necessary, additional biological tests should be initiated of all aspects of the SWP and CVP fish-salvage operations with the specific goal of identifying actions to improve efficiency and reduce mortality during the salvage operation. For example, improvements in louver alignment, debris removal, and increased control of approach velocity and bypass ratios as factors influencing diversion efficiency for various sizes and species of fish throughout the year should be examined. Improvements in fish-holding facilities to reduce collection stress and improvements in monitoring species composition and abundance should be investigated. Improvements in the design and operations of both the primary and secondary diversion systems should be evaluated, and where necessary, additional biological assessments of diversion efficiency should be performed. Operations and efficiency of loading facilities for salvaged fish, loading densities for optimum survival and water quality conditions within the transport truck (e.g., increased temperature during the summer, reduced dissolved oxygen levels, potential chemical treatment to reduce stress, etc.) should be re-evaluated.

Specific management actions to improve conditions should be identified and implemented such as the use of fish-transport trucks having onboard oxygen injection and refrigeration systems to reduce adverse water temperatures and stress during the summer and increased frequency of transport to various designated release locations. Additional actions to control predation on fish at the salvage facilities, within Clifton Court Forebay, associated with the trashrack structure, and within the fish facility and bypass are discussed below.

Table 2. **Striped bass handling and trucking 1984/85 evaluation at the John E. Skinner Fish Protective Facility.**

		Mean Mortality (%)		
Mean	Mean Fork Length (mm)	Handling Loss Rates	Trucking Loss Rates	Combined Loss Rate
May	16	31	36	67
June	33	46	21	67
July	49	17	21	38
August	52	25	37	62
September	76	22	7	29
October	83	11	0	11
November	84	3	2	5
December	87	2	9	11
January	87	2	1	3
February	83	4	0	4

Source: CDFandG 1987.

BIOLOGICAL BENEFITS: The ability to reduce the mortality of fish salvaged at the SWP and CVP diversions through improvements in fish handling and trucking operations is anticipated to vary substantially between fish species. For example, handling and trucking mortality for sensitive species such as shad is not anticipated to be improved substantially through these actions. Data available for striped bass (Table 2), however, has shown that the combined loss from handling and trucking stress is high during the spring and summer (combined loss from 29 - 67% during the period from May through September) which may be reduced substantially through improvements in the facilities and operations associated with handling and trucking of salvaged striped bass. A reduction in handling and trucking mortality will contribute directly to a proportional reduction in fish mortality attributable to operation of the SWP and CVP diversions. The biological benefits associated with these short-term actions will be directly proportional to the reductions in mortality achieved and the numbers of fish salvaged. Efforts to improve handling and trucking survival offer significant additional benefits when combined with an aggressive program to reduce predation losses on juvenile striped bass, chinook salmon, and other species at the SWP and CVP intakes (see discussion below). Substantial biological benefits can be achieved by reducing predation losses which will result in an increase in the numbers of fish salvaged when combined with a program to improve, to the maximum extent possible, the survival of those fish which are salvaged and successfully returned to the Delta (reduced handling and trucking mortality). The magnitude of these benefits will depend on the successful implementation of the predator-control program and the handling and trucking operation. The biological benefits associated with improved handling and trucking are also significant in that these efforts reduce mortality associated with water-project diversion operations for juvenile, sub-adult, and adult fish whose natural survival rates and contribution to the reproductive adult stocks are substantially greater than those for earlier lifestages such as eggs and larvae.

RECOMMENDED ACTION: Develop and implement a predator-management program at both the SWP and CVP intakes to reduce predation losses.

BASIS FOR THE RECOMMENDATION: Predation has been identified as a significant source of mortality to juvenile fish entering Clifton Court Forebay and at the fish-salvage facilities of both the SWP and CVP systems. The primary predators include striped bass, white catfish, and largemouth bass. A series of mark-recapture studies have been performed to provide a quantitative estimate of predation losses for both juvenile chinook salmon and juvenile striped bass during passage through the SWPs Clifton Court Forebay. Results of experimental releases using hatchery-reared juvenile chinook salmon during 1978, 1984, and 1985 have yielded predation loss estimates ranging from 63 to 86% with an average loss of 75% (Table 3). Estimates of predation losses for juvenile striped bass passing through Clifton Court Forebay have been 94 and 70% with an average loss of 82% based on mark-recapture studies performed by CDFandG in 1984 and 1985 (Table 3). Loss estimates attributed to predation associated with trashracks such as those at the CVP fish-salvage facility have been extrapolated from mark-recapture predation studies conducted at other intakes and are estimated to be approximately 15% predation loss (CDFandG 1987). There is considerable uncertainty, however, regarding actual predation losses within Clifton Court and associated with both the CVP and SWP fish-salvage facilities for various species and sizes of fish, between years, and during various times of the year (e.g., summer versus winter). Although difficult to quantify, results from these and other studies clearly demonstrate that predation losses can be a significant factor influencing the overall efficiency and mortality associated with operation of water diversion and fish-salvage facilities.

In recognizing the mortality occurring at both the SWP and CVP fish-salvage facilities as a direct result of predation losses, an aggressive predation-management program should be implemented. The Bureau of Reclamation has recently implemented a predator removal program at the CVP fish-salvage facility to reduce the number of predators inhabiting the water intake system and fish bypass. The California Department of Fish and Game and Department of Water Resources have also implemented a recent program at the SWP fish-salvage facility to assess the population of predatory fish inhabiting Clifton Court Forebay and to evaluate the feasibility of various methods for reducing predation losses. Although the predation studies and management programs which have been recently implemented represent an important first step, a more aggressive effort towards reducing predation losses, particularly within Clifton Court Forebay, should be undertaken. Because of the design and operation of the SWP and CVP fish-salvage systems, it is recognized that efforts to substantially reduce predation levels will require an ongoing predator control program.

Table 3. Summary of Clifton Court Forebay loss estimates for juvenile chinook salmon *(Oncorhynchus tshawtscha)* and striped bass *(Morone saxatilis)*.

Chinook Salmon

		Loss Estimate	Mean
1978 (Hall 1980)	Fingerlings	0.86	
1984 (Kano 1985a)	Smolts	0.63	0.75
1985 (Kano 1985b)	Fry	0.75	

Striped Bass

		Loss Estimate	Mean
1984 (Kano 1985a)	Juvenile	0.94	0.82
1985 (Kano 1986)	Juvenile	0.70	

Source: CDFandG 1987

Implementation of an aggressive predator-control program will require a commitment of staff resources, equipment, and modification of Clifton Court Forebay and the intake structures in order to increase the efficiency of various predator removal techniques. As a complement to the predator-removal program additional biological studies should be conducted to assess and evaluate predation losses on various sizes and species of fish susceptible to the water project diversions throughout the year. The goal of the aggressive predation-control program would be to reduce predation losses for all juvenile fish to a level of 10% at the CVP and 15% at the SWP intakes.

Development of an aggressive predator-control program at the SWP and CVP intakes (including within Clifton Court Forebay) will require both structural changes and a commitment of personnel resources. Clifton Court Forebay contains a number of snags and obstructions (e.g., remnant tree trunks and other material) which have been in the forebay since the time of its construction. These obstructions significantly limit the effectiveness of various types of fisheries collection equipment including large beach seines and trawls which may be used effectively in removing predators from the forebay. As part of the predator-control program dredging should be performed within the forebay to remove as many of the submerged obstructions as possible. In addition to removal of obstructions sand beach areas should be constructed at several strategic locations to allow for the use of large beach seines and supporting mechanical equipment. After completing the initial forebay modifications to allow effective collection, the predation-removal program should be implemented which includes the use of a variety of collection methods included, but not limited to, electrofishing, large mesh gill nets fished for successive durations not exceeding one hour to improve survival of predatory fish collected, large mesh commercial beach seining (e.g., 1,000-ft+ nets) fished during both the daytime and at night with the use of lights to attract fish to selected areas, fyke nets and other traps, and hook and line. Predator removal from the forebay is recommended to occur daily during the period from December through March, weekly during April through September, and monthly during October and November. The timing of predator removal is designed to coincide with the periods of greatest susceptibility of juvenile fish, including winter-run chinook salmon, striped bass, fall-run chinook salmon, steelhead, Delta smelt, etc. to predation loss associated with the SWP diversion. Predatory fish removed from Clifton Court Forebay and the intake structures will be captured alive and transported to release locations downstream in the Delta.

In addition to predator removal and control within Clifton Court Forebay, routine predator control should also occur in the intake areas adjacent to the bar racks, approach channels to the primary louvers, and within the bypass systems within both the SWP and CVP diversions.

The predator-removal program should be combined with additional mark-recapture evaluations, performed using juvenile chinook salmon, striped bass, and other principal prey species susceptible to predation at the intakes. These mark-recapture studies would evaluate and quantify the effectiveness of the predator-removal program at both the SWP and CVP diversions. At the State Water Project, known numbers of marked prey should be released at the tidegate entrance to Clifton Court Forebay coincident with normal operations of the forebay (e.g., flooding of the forebay during the daytime or night) with additional groups of marked fish released immediately upstream of the trashracks and within the bypass system. Analysis of data on recaptured fish from each of these release locations will provide information on the magnitude and location of predation losses. These evaluations should be performed using various sizes and species of prey and should be performed at different times of the year coincident with the period of prey susceptibility to evaluate seasonal variation in predation associated with the two diversions. The level of effort devoted to predator removal would then be adjusted based upon results of the mark-recapture studies and the patterns in catch-per-unit-effort (CPUE) of predatory fish species in the removal program.

BIOLOGICAL BENEFITS: Reduction in predation losses at the SWP and CVP intakes will contribute directly to a substantial reduction in the losses of juvenile fish as a result of the diversions. Control of predation losses, particularly within Clifton Court Forebay, will contribute to a substantial reduction in mortality for both juvenile striped bass and chinook salmon (as well as other fish species susceptible to the intake; Table 4). Although predation control is not anticipated to contribute to a reduction in entrainment losses for fish eggs and larvae, the program would contribute directly to a substantial reduction in losses of juvenile fish of all species. Increased efficiency of the fish-salvage facilities, accomplished as a result of reduced predation losses, in combination with improvements in fish-salvage operation, handling and return (see above) will collectively contribute to a substantial reduction in the direct fishery impact resulting from operation of the SWP and CVP water diversions.

Table 4. SWP Striped Bass (21-150 mm) Loss Estimates

	15% Predation	82% Predation
1980	2,786.574	17,890,368
1981	857,229	6,537,891
1982	815,078	6,001,194
1983	99,554	781,441
1984	8,491,434	51,916,079
1985	4,181,702	26,371,527
1986	15,061,909	92,705,391

SWP Chinook Salmon Loss Estimates

	15% Predation	75% Predation
1980	51,990	368,325
1981	55,657	430,191
1982	165,136	1,252,042
1983	39,936	300,436
1984	73,320	593,897
1985	87,232	629,220
1986	250,572	1,883,526

Source: Estimates of Fish Entrainment Losses Associated with the State Water Project and Federal Central Valley Project Facilities in the South Delta. DFG Exhibit 17, State Board Bay-Delta Hearings, July 1987.

RECOMMENDED ACTION: Increase enforcement of illegal fishing (poaching) regulations within the Bay-Delta system and its tributaries and in coastal waters to protect various fish species.

BASIS FOR THE RECOMMENDATION: Striped bass, chinook salmon, sturgeon, and a number of other fish species are illegally taken from the Bay-Delta system each year. For example, recreational anglers are known to keep striped bass which do not meet the 18 inch minimum size limit and sturgeon which are outside the legal slot-size limit. Recreational anglers are also known to keep more than the allowable daily possession limit of various fish species. In addition to illegal recreational harvest, various fish species such as striped bass and chinook salmon are susceptible to commercial poaching. Poachers using gill nets to harvest striped bass from the Delta and San Francisco Bay have been periodically apprehended. Poaching activity, based on snagging and spearing adult chinook salmon at fish ladders, below dams, and on spawning grounds is known to occur in upstream tributaries to the Bay-Delta system.

Although the actual magnitude of illegal harvest and poaching activity within the Bay-Delta system is unknown, illegal harvest of striped bass in recent years has been estimated at approximately 500,000 fish in one year. One individual was reported to have illegally harvested over 250 chinook salmon from the lower American River during 1991.

Striped bass illegally harvested from the Bay-Delta have been reported from both commercial fish markets and restaurants. Sturgeon and chinook salmon are also harvested illegally for sale at fish markets and restaurants.

The California Department of Fish and Game has responsibility for enforcing fishing regulations within Bay-Delta waters. Enforcement by Fish and Game wardens within the Bay-Delta system has, in recent years, been reduced as a result, in part, of departmental budget reductions. In addition to extremely limited manpower available for enforcement of fishing regulations, the legal prosecution and fines and penalties imposed for fishing code violations has not proven to be an effective deterrent. Poaching is prosecuted as a misdemeanor violation with many judges and prosecutors reluctant to address poaching and violations of Fish and Game regulations, in part, because of a lack of perceived significance for the issue and the high caseload existing for civil and criminal prosecutions.

In recognizing the need for additional enforcement of Fish and Game regulations to reduce poaching and illegal harvest impacts on Bay-Delta fisheries populations an authorization has recently been approved for two million dollars from the Delta Pumping Plant mitigation fund provided by the State Water Project for hiring six additional full-time wardens for a three-year period to enforce fishing regulations within the Bay-Delta system. In addition, a patrol boat and several skiffs will also be provided for use in the increased enforcement program. The enforcement vessels will be equipped with communications and navigational equipment to permit monitoring and surveillance under adverse conditions (e.g., at night, in fog, etc.) when poaching activity is difficult to detect. Additional enforcement and prosecution of fishing regulation violations should be implemented to further reduce the adverse effects resulting from poaching and illegal harvest.

BIOLOGICAL BENEFITS: The potential biological benefits resulting from increased enforcement of Fish and Game regulations to reduce poaching and illegal harvest of striped bass, chinook salmon, and other species within the Bay-Delta system cannot be quantified at this time. Poaching and illegal harvest targets fish which have a direct impact on adult stock abundance, population dynamics, and reproductive potential of the species. Although quantitative estimates of poaching and illegal harvest impacts on Bay-Delta fish stocks are not available, a reduction in illegal harvest through increased enforcement and prosecution will contribute to a direct and potentially very significant benefit to Bay-Delta fish stocks.

RECOMMENDED ACTION: Develop and implement a fisheries management program which provides short-term protection for adult fish populations through seasonal and area closures (e.g., eliminate fishing on spawning grounds), gear restrictions to reduce capture and mortality of sub-legal fish, implementation of size-slot limits, educate and promote catch-and-release recreational fishing, etc.

BASIS FOR THE RECOMMENDATION: Recreational angler harvest (fishing) represents a significant source of mortality to Bay-Delta populations of chinook salmon, steelhead, striped bass, American shad, sturgeon, and other game fish species. Mortality occurs as a result of both the harvest of legal fish and hooking mortality to sub-legal fish which are caught and subsequently released. A number of these fish species including striped bass, chinook salmon, steelhead, and American shad are harvested directly from spawning areas when the individuals are concentrated within restricted geographic areas thereby increasing their susceptibility to recreational anglers. Regulations governing seasonal area closure to protect species such as adult striped bass from recreational harvest from spawning grounds should be implemented as a short-term management action.

In addition, the striped bass fishery has developed as a "trophy fishery" in which the largest individuals are selectively sought and retained by recreational anglers. The reproductive potential of adult female striped bass increases with increasing size and age of the female (Figure 3) thereby resulting in the selective harvest of those reproductive individuals which contribute substantially to the reproductive potential of the species. Examination of the age structure for the adult striped bass population within the Bay-Delta system has shown a reduction over time in the age and size structure of the adult population (the age structure of the striped bass population is shifting from older, large individuals to an increase in the relative contribution of smaller fish). A size slot-limit should be implemented for striped bass to provide short-term protection of the larger individuals within the population and a rebuilding of the older age classes within the Bay-Delta stock. A size slot-limit currently exists to provide protection for larger (older) sturgeon which also support an active recreational fishery within Bay-Delta waters.

Consideration should also be given to reducing the bag limit for various fish species. For example, Fish and Game regulations currently allow for the recreational harvest of up to 25 adult American shad per day. Furthermore, consideration should be given to regulating total annual harvest of selected species such as striped bass, steelhead, and sturgeon either through implementation of a recreational angler harvest quota with seasonal closures of the fishery or an annual harvest by individual anglers which would then be enforced through a punchcard and/or tag program.

Observations and interviews with recreational anglers in Suisun Bay and the western Delta indicate that a large number of sub-legal (less than 18 inch length) striped bass are caught by recreational anglers. Fish and Game regulations require that sub-legal striped bass be released after capture, however it is anticipated that a substantial (unquantified) number of these sub-legal striped bass die as a result of hooking and handling. The large majority of sub-legal striped bass are caught by anglers fishing with natural bait (e.g., anchovy, shad, bay shrimp, etc.). As a consequence of the use of natural bait, many of the sub-legal striped bass are hooked in the esophagus and stomach contributing to high hooking mortality for those fish subsequently released. Furthermore, the use of barbed hooks in the recreational fishery also contributes to increased hooking and handling stress. It is recommended that regulations be adopted requiring the use of barbless hooks and seasonal and geographic restrictions on the use of natural bait within the striped bass fishery to reduce fishing mortality and improve survival of those striped bass released in compliance with the slot size-limit described above.

Furthermore, an aggressive program to promote catch-and-release of all species should be undertaken by the Department of Fish and Game and local angler groups. The program should include catch-and-release fishing tournaments (virtually all largemouth bass tournaments are conducted on a catch-and-release basis; a recent sturgeon fishing tournament held within the Bay-Delta system was successfully conducted using catch-and-release techniques). As part of this effort an aggressive educational program should be implemented to convey information to the angling community regarding procedures designed to protect and improve the survival of fish released in the recreational fishery.

BIOLOGICAL BENEFITS: All measures implemented to reduce mortality of sub-legal and adult fish will result in a direct benefit to Bay-Delta fish stocks. Although potential biological benefits resulting from implementation of various fishing regulations cannot be quantified with confidence, these regulations would provide protection and increase survival of adult fish stocks thereby contributing to a rebuilding of Bay-Delta populations. The increased fishing regulations, and additional enforcement, should be designed to provide additional protection for specific stocks while continuing to maintain recreational angling opportunities and the associated social and economic benefits.

A punchcard system of annual reporting for all recreational anglers harvesting selected game species (chinook salmon, steelhead, sturgeon, striped bass, American shad) should be implemented as part of the licensing program. This reporting system would provide quantitative data on angler-harvest patterns and the numbers of adult fish captured in the Bay-Delta recreational fishery for use as input in monitoring the fishery and identifying the need and benefits of future angling regulation modifications.

RECOMMENDED ACTION: Install barriers at the head of Old River and other strategic locations within the lower San Joaquin River and Delta to improve water quality conditions for upstream migrating adult chinook salmon and improve survival of emigrating juvenile chinook salmon and steelhead.

BASIS FOR THE RECOMMENDATION: Results of coded-wire tag mark-recapture studies and routine monitoring of fish salvage at the State Water Project (SWP) and Central Valley Project (CVP) intake facilities have demonstrated that juvenile chinook salmon and steelhead are susceptible to the diversions. The susceptibility of these juvenile fish to the SWP and CVP diversion is, in part, influenced by hydrologic conditions within central and south Delta channels. Operation of SWP and CVP diversions influences current speed and direction in many of these channels thereby increasing the susceptibility of juvenile salmon and steelhead to losses at the diversions.

Studies of Delta hydrology and the migration pathways for juvenile chinook salmon have shown that installations of rock barriers at strategic locations within Delta channels can contribute to a substantial reduction in diversion losses. Rock barriers were installed, on a temporary basis, during the spring of 1992 and in previous years in an effort to improve water quality conditions in the fall and improve survival of the emigrating juvenile chinook salmon during the spring. The installation of barriers at strategic locations (e.g., head of Old River) to improve salmon survival and reduce susceptibility to diversion losses is an important element of a short-term program of actions. Consideration is also being given to the potential benefits for increased survival of juvenile salmon and steelhead associated with installation of a barrier at the confluence of the Sacramento River and Georgiana Slough.

The specific location and design configuration for the rock barriers need to take into account Delta hydrologic conditions, downstream migration pathways for juvenile chinook salmon and steelhead, provisions to allow for upstream migration of chinook salmon, steelhead, and other species, and the influence of the barriers on water quality conditions within the Delta. Additional issues regarding the impacts of barriers on local navigation, state and federal permits, and appropriate environmental documentation (CEQA, NEPA) must also be addressed.

BIOLOGICAL BENEFITS: Installation of rock barriers at strategic locations within Delta channels will contribute directly to an increase in the survival of emigrating juvenile chinook salmon (also presumably juvenile steelhead). The juvenile chinook salmon survival model, developed by Kjelson *et al.*, provides a quantitative tool for assessing and evaluating potential biological benefits (e.g., increased survival of juvenile chinook salmon) associated with barrier installation. The potential effectiveness of rock barriers at strategic locations, including the head of Old River, in improving the survival of emigrating chinook salmon has being evaluated in an ongoing program using coded-wire tag mark-recapture techniques. Marked juvenile chinook salmon are released at various locations within the south Delta and the resultant survival estimated based on juvenile salmon recaptures downstream at Chipps Island. Regression analyses have been developed, based on survival data from mark-recapture studies, to estimate the change in fall-run chinook salmon smolt survival with and without a full barrier in upper Old River under various outflow and export conditions. Based on these calculations it has been estimated that, on average, the survival index for San Joaquin River fall-run chinook salmon would be approximately doubled (average San Joaquin River smolt survival index 0.10 without the barrier and an average of 0.23 assuming installation of a full barrier in upper Old River as a result of the installation of a full barrier in Old River). Although further evaluation of the potential biological benefits associated with installation of rock barriers at the head of upper Old River and other strategic locations within the Delta for improving survival of emigrating chinook salmon is ongoing, the results available todate demonstrate that significant increases in salmon survival, particularly for San Joaquin River stocks, may be achieved through short-term installation of rock barriers.

RECOMMENDED ACTION: Implement regulatory actions to reduce the introduction and transport of exotic species into Bay-Delta waters.

BASIS FOR THE RECOMMENDATION: A number of fish and invertebrate species have been intentionally and accidentally introduced into the Bay-Delta system. For example, American shad and striped bass were both intentionally introduced into Bay-Delta waters for recreational and commercial fishing. Other species such as yellowfin goby, the copepods *Pseudodiaptomus spp.* and *Sinocalanus doerrii*, and the Asian clam *Potomocorbula amurensis* have been accidentally introduced into the Bay-Delta system primarily through the discharge of ballast waters associated with international shipping traffic. Introduced fish and invertebrate species may compete with or prey upon resident species within the Bay-Delta system thereby having a direct impact on the population dynamics and abundance of various resident populations. Many introduced species rapidly expand their population abundance, often at the expense of declines in the abundance of resident species.

Virtually nothing can be done to control the abundance and biological effects of those fish and invertebrate species already introduced and established within the Bay-Delta environment. Short-term regulatory actions can be implemented, however, which will limit the occurrence of future introductions associated with such practice as ballast water discharges within the San Francisco Bay system. Regulations have been implemented to control exotic species introductions at various ports along the Atlantic Coast; similar types of regulations are being considered for application to California waters. Enforcement of shipping and ballast water discharge regulations, however, remains a major obstacle to successfully limiting further introductions of species to Bay-Delta waters.

One of the significant aspects of the introductions which have occurred, particularly those in recent years, is the impact of these species on the Delta ecosystem. An extensive number of biological investigations and a tremendous amount of information has been collected over the past four decades on the response of selected species such as striped bass, chinook salmon, smelt, *Mysid* shrimp, and others to changes in seasonal patterns in the magnitude of freshwater outflow from the Delta, Delta hydrology, entrainment losses, and the location of the entrapment (mixing) zone as factors influencing growth, survival, and population abundance. The interaction between various fish species and lifestages and seasonal and annual variation in environmental factors (e.g., seasonal patterns of freshwater outflow) are complex. The recent introduction of a number of fish and invertebrate species whose populations have experienced dramatic increases in abundance in recent years has added a further degree of complexity and uncertainty to the overall understanding of the biological and physical mechanisms and relationships which influence the abundance and dynamics of Bay-Delta fish and invertebrate populations.

Given the recent significant changes that have occurred in the Bay-Delta ecosystem there is now considerable uncertainty regarding the validity and confidence which can be placed in data collected prior to the introduction of these species in predicting the response of the target population to specific management actions implemented to provide environmental protections. For example, historic data suggested that a positive correlation existed between freshwater outflow during the spring and resulting year-class strength for several fish species including striped bass. In part, changes in the Delta ecosystem resulting from recent introductions of various species (e.g., changes in phytoplankton and zooplankton abundance as a result of increased consumption by introduced species, changes in species composition of available prey such as copepods, and increases in the abundance of potential predatory species such as yellowfin goby) have contributed to a high degree of uncertainty that an increase in freshwater outflow during the spring would result in an increase in the abundance of juvenile striped bass of the magnitude suggested by historic data.

BIOLOGICAL BENEFITS: The biological benefits associated with limiting further species introductions into the Bay-Delta system cannot be quantified. To the extent that introduced species represent either competitors or predators with resident species further introductions and expansion of the populations of introduced species would be detrimental to the population dynamics (growth, survival, production, etc.) of resident populations. Introduced species may also, however, provide an additional or alternative prey resource for various species and lifestages of resident fish and invertebrate populations. As a result of the uncertainties and high potential for adverse effects on resident populations, aggressive efforts should be made to minimize future species introductions into Bay-Delta waters.

RECOMMENDED ACTION: Improve hatchery management for striped bass, chinook salmon, steelhead, and other fish species including experimental hatchery programs for Delta smelt.

BASIS FOR THE RECOMMENDATION: As a result of the loss of stream spawning and rearing habitat for species such as chinook salmon and steelhead due to the construction of a number of dams and impoundments, increasing harvest pressure from recreational and commercial fisheries, and the need to provide additional short-term support for various fish populations until a comprehensive long-term management program can be implemented within the Bay-Delta system, hatchery production of various fish species plays an important role in the overall management of the Bay-Delta system. The hatchery program, and management of the resultant combined in-river and hatchery produced stock, is an integral element in the overall development of both short-term and long-term management programs. In the long-term, hatchery production should complement and not serve as a substitute for either species or habitat protection within the Bay-Delta system and upstream tributaries. Hatchery management practices must recognize genetic diversity, the maintenance of timing and integrity of various runs, diet and pre-release conditioning, the size and location for releases, etc. Hatchery management practices should emphasize the rebuilding of depleted runs and stocks and the maintenance of populations during dry and critically dry years (environmental and habitat protections should be emphasized when hydrologic conditions are good with an increasing reliance on hatchery production to sustain stocks during years when hydrologic conditions are poor). The use of grow-out facilities to improve survival of "wild stocks" for species such as striped bass collected in the fish-salvage operations of the SWP and CVP should be encouraged and expanded.

The role and contribution of hatchery production for various fish species and the balance between hatchery and "wild" fish in the recreational and commercial harvest, however, needs to be carefully examined as part of the development of a long-term comprehensive Bay-Delta management program.

The striped bass hatchery program, including the rearing of juvenile fish collected from the SWP salvage operation, experimental pen-rearing, and conventional hatchery production for mitigation of SWP diversion losses are key elements in providing stability and maintenance of the Bay-Delta striped bass stock during the interim period before a comprehensive long-term management program can be implemented. The recent decision by the Department of Fish and Game to curtail planting hatchery-reared striped bass within the Bay-Delta system, in an effort to reduce potential predation on juvenile winter-run chinook salmon, has the potential to seriously undermine efforts to maintain the existing striped bass stock until the comprehensive management program can be developed. Although we agree with the overall objective of habitat improvement, protection, and enhancement of Bay-Delta fish stocks including striped bass and winter-run salmon, hatchery production represents an integral part of the short-term program of actions. The striped bass hatchery program, which in recent years has produced two-to-three million fish per year for release into Bay-Delta waters has contributed directly to the recreational fishery and the adult population. A relatively large percentage of the striped bass produced in hatcheries were to mitigate for losses occurring at the SWP diversion representing fish that would have otherwise been inhabiting Bay-Delta waters. Part of the short-term program recommends that losses of striped bass as a result of entrainment at the SWP diversion (existing agreement), the Pacific Gas & Electric Company power plants located at Antioch and Pittsburg (existing agreement), and at the CVP and Contra Costa Water District intake (no agreement) be mitigated through hatchery production of yearling striped bass released into Bay-Delta waters throughout the interim period of this program. The hatchery propagation of striped bass should complement aggressive programs to reduce losses at diversion points and mitigate for those losses which are unavoidable.

Biologists representing the California Department of Fish and Game, National Marine Fisheries Service, and U.S. Fish and Wildlife Service should work together to develop a specific management program for the rearing and release of hatchery-produced striped bass into Bay-Delta waters in a way which minimizes the risk of increased predation on winter-run salmon. Alternative methods and strategies for the release of striped bass reared as part of the mitigation obligation such as dispersal over a larger area to avoid large concentrations of hatchery-reared striped bass at single points of release, releases within San Francisco Bay and coastal waters, etc. should be evaluated. In addition, the evaluation should consider releases of hatchery-reared striped bass produced for mitigation during the late spring and summer, after juvenile winter-run chinook salmon have emigrated from the Bay-Delta system, and other potential management techniques. The evaluation of the striped bass hatchery program for mitigation purposes should be completed by the resource agencies no later than January 1, 1993 to allow hatchery propagation of the 1993 striped bass yearclass for mitigation purposes.

In addition to developing a strategy for the striped bass hatchery propagation program for mitigation purposes, the Department of Fish and Game should complete, within 12 months, a detailed review and evaluation of hatchery production methods and release strategies for chinook salmon and steelhead released into Bay-Delta waters. The evaluation of hatchery practices should address questions related to protection and maintenance of genetic diversity of various fish stocks, the optimum size and lifestage for hatchery releases to promote a rebuilding of Bay-Delta stocks in addition to providing fish in support of commercial and recreational harvest, and methods of release designed to improve survival and ultimately the return of adults. Concern has been expressed, for example, regarding Department of Fish and Game hatchery releases of juvenile fall-run chinook salmon at specific locations within San Francisco Bay (e.g., Benecia) which contribute to an accumulation of predatory striped bass in the area where the releases are made. Observations of these juvenile salmon releases indicate that relatively high losses may be occurring as a result of predation by striped bass and that the accumulation of predatory species attracts recreational anglers resulting in an increased harvest of striped bass and other predatory species.

BIOLOGICAL BENEFITS: The production of chinook salmon, steelhead, and striped bass in hatcheries contributes substantially to population abundance and the harvest of these species in local fisheries. Hatchery programs have played an important role in sustaining various stocks which have been adversely impacted by blockage of spawning and rearing areas, habitat degradation, and increased mortality rates from a variety of sources.

The Department of Fish and Game is conducting an ongoing evaluation of the contribution of hatchery-reared striped bass to the recreational angler harvest and the adult stock. Many of the hatchery-reared striped bass have been marked using coded-wire tags which can then be used to determine the yearclass, origin, and planting location for recaptured individuals. The mark-recapture program also allows for the development of estimates for the survival and contribution of bass produced in the hatchery to the adult stock. At the present time it has been estimated that the striped bass hatchery program represents approximately 15% of the adult population harvested by recreational anglers within the Bay-Delta system. Hatchery-reared striped bass adults have also been recovered from spawning areas, although the contribution of these fish to the reproductive potential of the population has not been documented. The most recent estimates of the abundance of adult striped bass (Petersen estimates) produced by the Department of Fish and Game indicate that in 1991 the abundance of legal striped bass (18 inches and greater) was 1.2 million fish, of which approximately 200,000 were estimated to have been contributed by the hatchery program (17%). The data available on the adult stock abundance and the recreational angler harvest clearly demonstrate the biological benefits associated with the striped bass hatchery planting program as a short-term action to provide additional support for the Bay-Delta striped bass stock.

Hatchery programs for fall-run chinook salmon and steelhead on the Sacramento River system contribute substantially to the ocean commercial and recreational harvest of salmon and the spawning escapement for both chinook salmon and steelhead within the Bay-Delta system. No estimates are available, however, to allow a precise determination of the relative contribution of hatchery production and in-river production for either fall-run chinook salmon or steelhead. Recently, a program has been implemented at the Coleman National Fish Hatchery for hatchery production of winter-run chinook salmon. One element of the winter-run hatchery program is a captive breeding program to provide additional protections for the winter-run gene pool. A salmon and steelhead hatchery devoted to improving production and overall abundance of fish within the San Joaquin drainage system also offers biological benefits for supporting and maintaining these stocks, particularly during low-flow drought conditions until a comprehensive long-term management plan can be developed which includes habitat improvements within the San Joaquin Basin.

RECOMMENDED ACTION: Relocate and consolidate agricultural diversions from Delta channels where larval and juvenile fish have an increased susceptibility to entrainment losses. The consolidated intakes should be equipped with fish screens to further reduce susceptibility to entrainment.

BASIS FOR THE RECOMMENDATION: There are an estimated 1,600 water diversions within the Delta (Figure 2) which provide water for municipal, industrial, and agricultural purposes. The majority of these diversions are unscreened. Operation of these diversions results in unquantified entrainment losses to various fish and macroinvertebrate species. The susceptibility of organisms to entrainment losses at various diversion locations varies in response to the temporal and spatial distribution of the species within the Delta, the location of the point of diversion, seasonal patterns in diversion volumes, and a number of other factors. Species which have planktonic egg and/or larval stages such as striped bass, longfin smelt, Delta smelt, and various planktonic invertebrates are particularly susceptible to entrainment losses at water diversions. It is anticipated that species such as chinook salmon and steelhead which enter the Delta as larger juveniles have the necessary swimming performance capability to avoid diversions thereby reducing their susceptibility to entrainment. The Department of Water Resources initiated a biological monitoring program in April 1992 which is designed to quantify the numbers, seasonal distribution, and species composition of fish entrained at five selected agricultural diversion points within the Delta (Figure 4) which will provide useful information in estimating overall entrainment losses. The study will also provide information on the effectiveness of intake screens in reducing diversion losses for various species at agricultural intakes.

Data collected in the California Department of Fish and Game striped bass egg and larval surveys and other sampling programs provides information which can be used to identify specific areas within the Delta where the densities of various organisms susceptible to diversion losses are greatest. The available biological data includes information for various water-year-types reflecting changes in the geographic distribution of the early life history stages for a number of species in response to changes in freshwater outflow. Data available from these historic and ongoing monitoring and evaluation programs should be compiled and critically reviewed to identify those geographic areas within the Delta where larval fish occur in greatest densities and therefore where the maximum biological benefit associated with intake consolidation, relocation, and fish screening may be achieved. After identifying specific areas where intake modifications may be most biologically beneficial, a site-specific engineering and cost analysis should be performed. Based upon results of this assessment program of intake modifications to reduce entrainment mortality occurring within the Delta, a specific long-term program should be developed and implemented to reduce, to the extent practical, losses at unscreened intakes and other water diversions

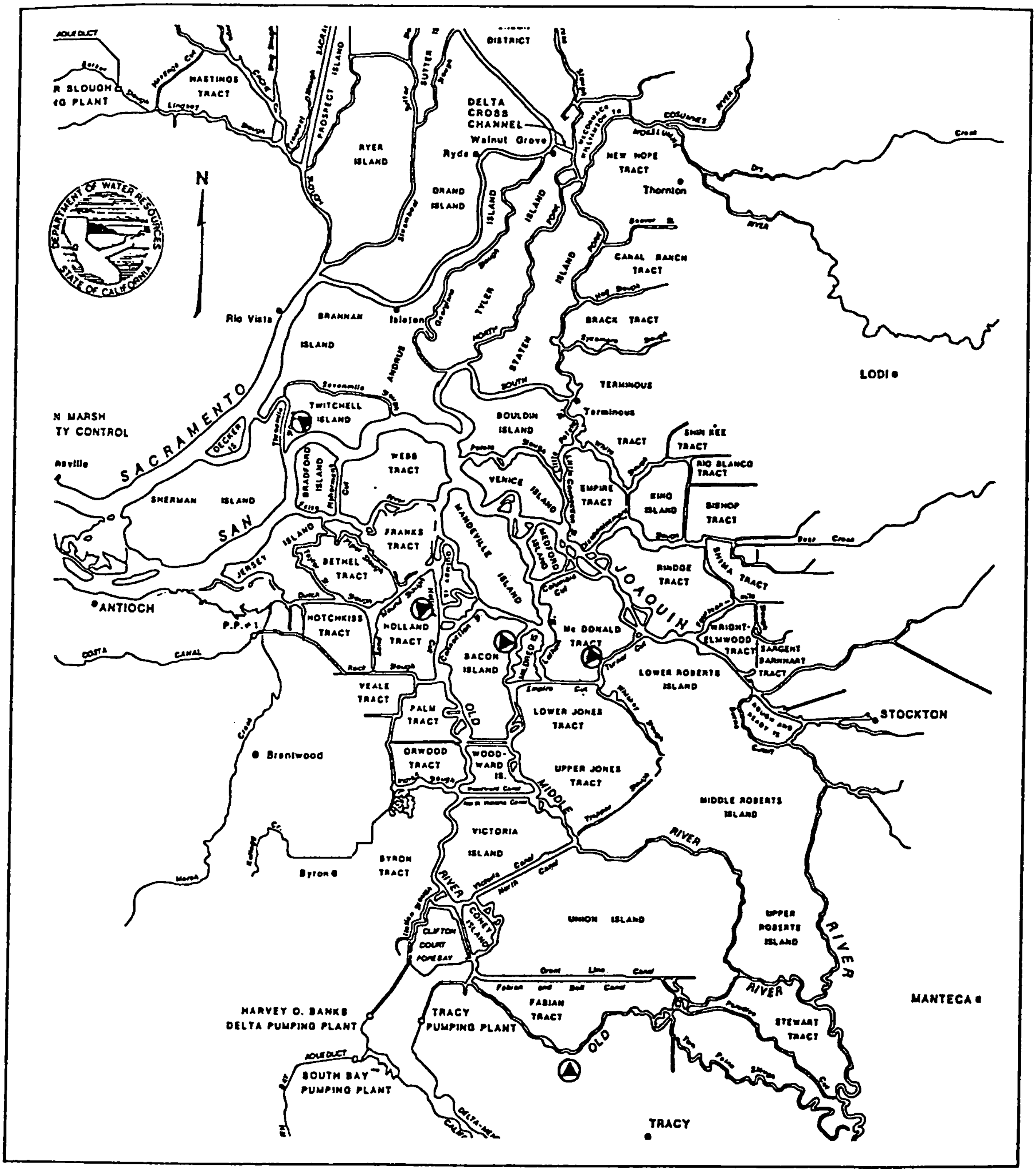

Figure 4. Agricultural diversion sites sampled for entrained larval fish by DWR, 1992. (Source: DWR).

within the Delta and upstream tributaries on both the Sacramento and San Joaquin rivers.

BIOLOGICAL BENEFITS: The magnitude of potential biological benefits associated with reductions in entrainment mortality through modification in the design and operation of various water diversion structures located throughout the Delta and in upstream tributaries cannot be quantified at the present time. The cost of site-specific modifications to various intakes, including installation and maintenance of fish screens, and quantitative estimates of the reduction in entrainment losses which may be achieved through intake modification will be developed as part of this assessment program. Consolidation, relocation, and installation of fish screens on selected water diversion sites will contribute directly to a reduction in mortality rates for various fish and macroinvertebrate species susceptible to diversion losses.

RECOMMENDED ACTION: Identify alternative time periods and management scenarios for agricultural diversions from the Delta and upstream to reduce entrainment susceptibility.

BASIS FOR THE RECOMMENDATION: A large percentage of the existing diversions from the Delta (Figure 2) provide water supplies on a seasonal basis for use in agricultural irrigation. As part of the overall evaluation and assessment of water diversion operations and the potential susceptibility of various fish and invertebrate species to direct entrainment losses (see discussion above), opportunities should be identified in which flexibility exists in the seasonal timing of diversions which could be used in developing management scenarios to reduce entrainment mortality. Management options may include the coordination of selective diversion curtailments to occur during periods of pulsed flows designed to provide downstream transport for planktonic striped bass eggs and larvae within the Sacramento River or the emigration of juvenile chinook salmon and steelhead from the San Joaquin River drainage. Management of individual diversions may also, to the extent possible, be coordinated with periodic closure of the Delta Cross-channel. Crop shifting and selective fallowing within the Delta would contribute to (1) reduced diversion rates and subsequently increased water availability for other uses (water banking, allocations for environmental protection, etc.) and (2) reduced entrainment mortality for various fish species and life stages susceptible to the agricultural diversion.

It is recommended that a program of evaluation be implemented to identify specific opportunities for implementing alternative water management strategies designed to reduce fish losses at Delta and upstream diversions. The evaluation of operational management alternatives should be coordinated and complement the assessment of options for modifying, consolidating, or relocating selected water diversions as described above. The evaluation should be conducted by an interdisciplinary team (e.g., agricultural specialists, biologists, and engineers) during a two-year time period. The assessment would include a specific set of recommended actions to be included in the development of the comprehensive management plan for reducing fish mortality and improving habitat conditions within the Bay-Delta system.

BIOLOGICAL BENEFITS: A variety of fish and invertebrate species inhabiting the Bay-Delta system experience mortality as a direct result of entrainment losses at local diversion points. Development of a long-term operational management plan for Delta and upstream diversions will contribute directly to improved survival and other biological benefits for fish and invertebrate populations. The evaluation program is designed, in part, to identify opportunities for operational flexibility and to provide a quantification of the biological benefits and potential costs associated with implementation of a long-term management strategy for operation of Delta diversions.

RECOMMENDED ACTION: **Develop a real-time entrainment monitoring program for the SWP and CVP diversions designed to identify periods of peak susceptibility of various fish species to entrainment at each diversion and coordinated operations of the diversions to reduce the combined losses at the two facilities.**

BASIS FOR THE RECOMMENDATION: Review of biological data collected in association with operation of the CVP and SWP intakes has shown that the susceptibility of striped bass eggs and larvae to entrainment and juvenile striped bass, chinook salmon, and other fish species to salvage varies between the two intakes.

Susceptibility of these species to entrainment is, at some times, greatest at the SWP intake while at other times susceptibility is greater at the CVP intake. In addition to variability between the two diversion locations the available data also demonstrate that susceptibility to entrainment varies seasonally between years. A detailed analysis of the temporal distribution and susceptibility of various species and lifestages to the two intake systems should be conducted to provide the necessary technical foundation to assess potential opportunities for reducing fish losses at the two locations through coordinated operations. The evaluation would identify operational flexibility in diversions between the two intakes which could be used, in combination with information on the susceptibility of various target organisms to entrainment, to reduce diversion losses without substantial impacts on water project yield.

After completing the initial evaluation of operational flexibility and coördinated operations between the two water projects to reduce fish losses, a short-term program would be implemented to utilize real-time biological monitoring data as input to management decisions regarding the rate of water diversion between the SWP and CVP intakes. The real-time biological monitoring may include data on the densities of larval fish, including striped bass, Delta smelt, longfin smelt, etc. (reported as number of larvae per cubic meter) or on salvage of juvenile fish including chinook salmon, striped bass, and other fish species at the two intake locations. The intake location having the lowest densities of susceptible target species would then be preferentially operated thereby resulting in a reduction in organism losses for the two diversions combined.

Implementation of the real-time biological monitoring at both the SWP and CVP diversions would also provide useful information on managing the operation of the diversions to reduce losses during periods of peak biological susceptibility within a season. This monitoring program would provide the necessary information to make fine-scale adjustments in diversion operations based on the actual opportunities to reduce diversion losses (generate the largest biological benefit possible from short-term reductions in water diversion operations). This program would also offer the opportunity to increase the rate of diversion using actual biological monitoring data to determine those periods when susceptibility of key target species are reduced.

The first phase of implementing coordinated operations of two water diversions based on real-time biological data is a feasibility analysis to assess potential biological benefits, operational flexibility, and potential constraints on operations of the two diversion locations in an effort to reduce cumulative fisheries losses. The feasibility analysis should include consideration of potential water transfers as another option for managing diversion operations during time periods when potential fisheries impacts are lowest.

BIOLOGICAL BENEFITS: The potential biological benefits associated with operational modifications to the SWP and CVP diversions through coordinated operations based on real-time biological data will be assessed as part of the first phase evaluation of this proposal. The potential magnitude of biological benefits will be determined based on seasonal flexibility in the operation of the two projects to respond to variations in the densities of organisms susceptible to entrainment losses at the two diversion locations. Potential biological benefits associated with this short-term management action will vary between species and between years.

RECOMMENDED ACTION: Design and construct the structural temperature control device at Shasta Dam and develop and implement modifications in CVP operations, if needed, to allow for control of water temperatures sufficient to protect salmon.

BASIS FOR THE RECOMMENDATION: Water temperature is a key factor influencing spawning, egg incubation, and juvenile rearing of chinook salmon and steelhead in the upper Sacramento River. Water temperatures are particularly important for successful spawning and egg incubation. Seasonal changes in ambient air temperature and the temperature of water released from Shasta Dam are the two most important factors influencing water temperature within the spawning and rearing area for chinook salmon, including winter-run, within the upper Sacramento reach. Vertical stratification in water temperatures within Shasta Reservoir offers the opportunity for releases of relatively cold water during the late spring, summer, and fall when water temperatures within the upper Sacramento River may otherwise be elevated to levels which are detrimental to growth and survival of various lifestages of both chinook salmon and steelhead. The current design of water release structures at Shasta Dam, however, does not allow for the withdrawal of water from selected locations within the water column to take advantage of vertical stratification in water temperatures while continuing to operate the hydroelectric generating facility. Water released from the lower strata, for example, to achieve cooler temperatures during the summer bypasses the hydroelectric generator.

Proposals have been developed for the design and construction of a temperature control device to be retrofitted to Shasta Dam and the hydroelectric generator which would permit the selective withdrawal of water from various locations within the water column while continuing to generate hydroelectric power. The temperature control structure provides operational flexibility in achieving specified release temperatures from the cold water pool within Shasta Reservoir for downstream fisheries while continuing to generate hydroelectric power. The temperature control structure would provide biological benefits contributing to improved survival for all races of chinook salmon, including winter-run, which spawn and utilize the upper Sacramento River for rearing. The temperature control structure for Shasta Dam, although providing both biological and power generation benefits, represents a substantial capital investment.

RECOMMENDED ACTION: Rehabilitate and expand the Coleman National Fish Hatchery.

BASIS FOR THE RECOMMENDATION: The Coleman National Fish Hatchery, operated by the U.S. Fish and Wildlife Service on Battle Creek, a tributary to the upper Sacramento River, produces a substantial number of juvenile chinook salmon each year. The production of fall-run juvenile chinook salmon in the hatchery has contributed to ocean adult stocks and associated commercial and recreational fisheries. The Coleman Hatchery is also a significant factor contributing to the maintenance of the fall-run chinook salmon population produced within the upper Sacramento River. During the past several years, the U.S. Fish and Wildlife Service has also experimented with hatchery propagation for winter-run chinook salmon.

The Coleman Hatchery, through years of operation and production, requires increasing levels of maintenance and repair. As a key element in the production and maintenance of chinook salmon stocks on the Sacramento River the Coleman National Fish Hatchery should be extensively rehabilitated and expanded to support both salmon and steelhead production. Rehabilitation and expansion of the hatchery facility would improve production capability and efficiency in the operations of the hatchery.

RECOMMENDED ACTION: Eliminate, to the extent practical, losses of salmon and steelhead resulting from flow fluctuations caused by operation of upstream impoundments.

BASIS FOR THE RECOMMENDATION: Flow fluctuations within the upper Sacramento River and major tributaries including the American River, Feather River, and Yuba River, may result in dewatering of salmon and steelhead redds (incubating eggs) and stranding of fry within side channels and shallow backwaters which are isolated from the main river channel when flows are reduced. Similar concerns regarding dewatering and stranding as a consequence of flow fluctuations also exist on the San Joaquin River and its major tributaries. Rapid reductions in flows in those areas utilized by chinook salmon and steelhead for spawning and juvenile rearing have resulted in documented fish mortalities. The potential adverse impacts associated with rapid reductions in flow on various lifestages of chinook salmon and steelhead vary depending on the season and occurrence of susceptible lifestages of both salmon and steelhead, the magnitude of reduction in flow, the rate at which the flow is reduced (ramping rate), and the topographic characteristics of the river channel. Flow fluctuations resulting from uncontrolled storm activity, in many cases cannot be avoided. Flow fluctuations, however, associated with scheduled releases from upstream impoundments can be managed to reduce potential adverse impacts on downstream fisheries. Operational criteria to minimize adverse fishery impacts resulting from flow fluctuations, to the extent possible, should be developed and implemented. Operational criteria would include consideration of both the magnitude of flow reductions and appropriate ramping rates. Development of operational criteria must recognize and acknowledge flexibility required for flood control operations.

RECOMMENDED ACTION: Expand gravel replenishment and maintenance programs for purposes of improving the availability and quantity of salmonid spawning habitat.

BASIS FOR THE RECOMMENDATION: The construction and operation of dams and impoundments on the Sacramento and San Joaquin rivers and their major tributaries blocked the movement of gravel eroding from upstream areas. The reduction in gravel recruitment below dams has resulted in a reduction in availability and quality of gravel areas suitable for successful spawning by chinook salmon and steelhead. In addition to a change in the size distribution of potential spawning gravels below dams changes in the hydraulic characteristics resulting from impoundment operations have contributed to increased sediment deposition resulting, in part, from reduced scouring by high-flow events, and cementation and armoring of gravels which may significantly reduce their suitability for spawning.

As a consequence of reductions in gravel recruitment and the quality of spawning gravels, the spawning habitat located below dams on both the Sacramento and San Joaquin river systems has deteriorated. Deteriorations in the quantity and quality of available spawning habitat contributes to a reduction in the reproductive success and subsequent yearclass strength (juvenile production) for both salmon and steelhead. Programs have been implemented in an effort to restore spawning gravels and improve spawning habitat on the upper Sacramento River, the Mokelumne River, and others. The gravel replacement and improvement programs on both the Sacramento and San Joaquin river systems should be expanded to provide improved habitat conditions for in-river production of both salmon and steelhead.

RECOMMENDED ACTION: Implement a program to improve fish screening and diversion bypasses, fish passage, etc. along the tributaries to the Bay-Delta estuary.

BASIS FOR THE RECOMMENDATION: A number of water diversions exist on both the Sacramento and San Joaquin river systems where juvenile chinook salmon, steelhead, and other fish species are susceptible to entrainment and impingement losses. A large number of these intake and diversion facilities have no fish screen or protection facilities. A number of diversion intakes are equipped with intake screens that, as a result of design, operations, or maintenance, have varying levels of efficiency in providing fish protection. In addition to concerns regarding intake screening, a number of diversions have fish bypass facilities which have not proven to be effective. Predation associated with a number of these intakes is another factor contributing to the losses of juvenile chinook salmon and other species. The design and operations of fish passage facilities, including both fish ladders for upstream migration of adult chinook salmon and steelhead and for the passage of downstream migrants, has also been identified as an area of concern which may adversely impact the migration of anadromous species within the Sacramento and San Joaquin river systems.

The California Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, State Board, FERC, and other agencies are actively involved in identifying opportunities to improve the operations and performance of intake screens, bypass facilities, and fish ladders and passage facilities at a number of locations throughout the Sacramento - San Joaquin system. Additional emphasis should be placed on identifying opportunities to reduce fish mortality through the installation, operations, and maintenance of intake screens and passage facilities designed to reduce mortality to both juvenile and adult fish. The State Water Contractors support the efforts to improve the performance of all water diversions, including the CVP and SWP facilities as discussed above.

RECOMMENDED ACTION: Plan and construct a fish hatchery at Keswick Dam on the Sacramento River for winter-run and other races of salmon.

BASIS FOR THE RECOMMENDATION: To date, hatchery facilities on the Sacramento River system have largely focused on the production of fall-run chinook salmon and steelhead. Recently the Coleman National Fish Hatchery began an experimental program for producing winter-run chinook salmon in an effort to provide additional support in maintaining and enhancing the stock. Winter-run chinook salmon and other races of salmon and steelhead which utilize the upper Sacramento River as spawning and rearing areas have been blocked from up-river habitat areas by construction of Shasta and Keswick dams. Data collected on the trends in abundance for various salmon races produced within the upper Sacramento River reflect substantial reductions in the abundance and in-river production of these stocks. In an effort to provide mitigation for habitat loss and additional support for the maintenance and enhancement of various salmon races from the upper Sacramento River it is recommended that a salmonid hatchery be designed and constructed in the area adjacent to the Keswick Dam for production of spring-run, winter-run, and other races of salmon. The Keswick Hatchery would complement and augment the production of fall-run chinook salmon and steelhead at the Coleman National Fish Hatchery and other hatcheries on tributaries to the Sacramento River.

RECOMMENDED ACTION: Plan and construct a salmon and steelhead hatchery within the San Joaquin River system.

BASIS FOR THE RECOMMENDATION: Salmon and steelhead stocks produced within the San Joaquin River drainage have experienced, particularly in recent years, substantial declines in abundance. A number of factors, including, but not limited to, instream flow conditions, habitat quality, mortality at water diversion locations, operation of impoundments, exposure to elevated water temperatures during spawning, egg incubation, and juvenile rearing and emigration, and other factors have contributed to the overall trend in declining fish stock abundance. One component in the development of the long-term comprehensive management program for improving conditions for salmon and steelhead within the San Joaquin River drainage should be the design and construction of hatchery facilities to provide mitigation for unavoidable losses and provide additional support in the maintenance and enhancement of salmonid stocks. A salmon and steelhead hatchery on the San Joaquin River drainage would contribute to increased stock stability, particularly during years of low flow when in-river production is reduced.

The salmon and steelhead hatchery should be designed and managed specifically to rebuild the San Joaquin River stocks. Hatchery management should focus on the production and release of yearling chinook salmon and steelhead to improve survival and release strategies which minimize subsequent straying of adults. The hatchery management practices should recognize and address concerns regarding the genetic integrity of the runs, the seasonal timing, and the balance between hatchery production and in-river production within various San Joaquin River tributaries. The ultimate goal of the hatchery program would be to contribute to a rebuilding and maintenance of the San Joaquin River stocks during the period of implementation of the comprehensive management program for improving overall habitat conditions for instream production within the drainage.

RECOMMENDED ACTION: Negotiate and execute an agreement which, when implemented, will fully mitigate the fishery impacts associated with direct entrainment losses resulting from CVP and Contra Costa Canal pumping operations.

BASIS FOR THE RECOMMENDATION: Juvenile chinook salmon, steelhead, striped bass, and other fish species are lost as a direct result of entrainment, collection, handling, and predation losses at the CVP water diversion intake. Fish losses also occur as a direct consequence of diversion by the Contra Costa Water District at the Rock Slough intake to the Contra Costa Canal. Aggressive efforts should be implemented at both water diversion facilities to minimize, to the extent practical, direct diversion losses for various fish and macroinvertebrate species. Unavoidable losses resulting from direct diversion effects should be mitigated.

Agreements have been established for the mitigation of fisheries losses as a direct result of operations at the State Water Project facility and at the Pacific Gas & Electric Company power plants located at Pittsburg and Antioch. The mitigation agreement developed between the Department of Water Resources and Department of Fish and Game for direct losses at the SWP intake provides for a system of monitoring and accounting for the losses of various target fish species and appropriate levels of mitigation through a combination of hatchery production and habitat improvement projects. The agreement between the California Department of Fish and Game and Pacific Gas & Electric Company provides for the production of striped bass in hatchery facilities for release into the Bay-Delta system. These existing mitigation agreements provide a framework and precedent for the development of mitigation agreements which will fully mitigate the fisheries impacts associated with the direct entrainment losses resulting from CVP and Contra Costa Canal pumping operations. Mitigation for these losses will contribute directly to the support and maintenance of various Bay-Delta fish species during the interim period while a comprehensive long-term management plan which is designed, in part, to minimize adverse fisheries losses can be developed and implemented.

EVALUATIONS AND STUDIES IN SUPPORT OF DEVELOPING A COMPREHENSIVE LONG-TERM MANAGEMENT PROGRAM

The ultimate goal is to develop and implement a comprehensive program of long-term actions which will achieve and sustain the goals and objectives of the fisheries management program. Actions taken on a short-term basis should complement and be consistent with achieving the long-term program goals including the quantitative evaluation of biological benefits associated with various alternative program actions. The comprehensive long-term program would be developed to improve habitat conditions and reduce sources of mortality, such as those occurring as a result of diversion of fish at the Delta Cross-channel or direct entrainment losses at the SWP and CVP intakes, upstream and within the Delta environment.

The interim program should include several short-term actions designed to provide scientific information for use in evaluating various alternative long-term management plan alternatives and developing a long-term program of implementation. Specific elements to be included in the short-term actions designed to provide inputs to the development of the comprehensive long-term management program are outlined below:

RECOMMENDED ACTION: Evaluate the operational and biological benefits, design criteria, and costs associated with various alternative water conveyance and storage facilities including relocation of the SWP and/or CVP diversions.

BASIS FOR THE RECOMMENDATION: Several alternative intake structure locations, water conveyance facilities, and other major water project facilities have been identified in an effort to reduce water-project system impacts on Bay-Delta fisheries populations while continuing to meet water-supply demands. Several of these alternative proposals include construction of a water diversion intake, equipped with state-of-the-art fish screens, to be located on the Sacramento River in an effort to reduce diversion losses occurring within the Delta, isolated transfer and through-Delta water conveyance options, and various storage options within and south of the Delta. Each alternative offers strengths and weaknesses in reducing impacts of water project operations on Bay-Delta fisheries populations and Delta aquatic habitats. The alternatives also include various operational constraints, water project yield, and capital and annual costs which need to be evaluated on a comparative basis. In addition to evaluating potential impacts and biological benefits associated with alternative facilities the development of operational criteria is a major factor in the evaluation of potential long-term management alternatives. Development of a comprehensive long-term management plan, which is planned to occur over the next three years, will require that these options and alternatives be developed to include detailed information on actual facility design and operations.

BIOLOGICAL BENEFITS: As identified in the previous sections, there currently exist a number of factors within the Bay-Delta system which adversely impact fisheries populations and their aquatic habitat. The evaluation of long-term facility alternatives should focus on achieving a broad-set of biological goals for the Bay-Delta system while balancing competing water needs. A comprehensive long-term program should accomplish the goals of reducing entrainment losses, improving hydraulic conditions within the Delta, reducing mortality and improving overall habitat conditions as discussed above. Information collected from historical biological surveys, in combination with specific data collected as part of the short-term (interim) program of actions will provide the scientific basis for the assessment and evaluation of potential biological benefits and operational scenarios for the various water project alternatives being considered. The biological benefits to be accomplished through this process should result in the maintenance of population abundance and aquatic habitat conditions comparable to those occuring during the mid-1970's.

RECOMMENDED ACTION: Evaluate potential options for improving fisheries habitat conditions within the Delta including seasonal reductions in channel velocities, developing areas of greater riparian and emergent vegetation, shoal and shallow water areas for juvenile rearing habitat, etc.

BIOLOGICAL BASIS: As a result of land use practices, island reclamation, channelization and levy construction, changes in Delta hydrology, and other factors the characteristics of the Delta environment as aquatic habitat has been substantially altered. Dredging and channelization have reduced the availability of shallow water habitat, with emergent and riparian vegetation, which is utilized as habitat by many lifestages and species of fish and invertebrates inhabiting the Bay-Delta system. Changes in Delta hydrology, in part resulting from flow regulation upstream and diversions from within the Delta, have influenced both seasonal and geographic hydrologic patterns (cross-Delta flows, reverse flows, etc.) and contributed to increased channel velocities in many areas, which influence the geographic distribution of planktonic larval fish and the suitability of many areas as habitat for both juvenile and adult fish. Significant changes which have occurred historically to the Delta environment have impacted the carrying capacity of the Delta aquatic habitat in terms of both production and survival for resident and migratory fish species, phytoplankton, and invertebrates.

One of the long-term goals for the Bay-Delta system should be an improvement in the availability and quality of aquatic habitat for fish and other aquatic organisms. Opportunities exist to improve aquatic habitat conditions, on a long-term basis, through management and habitat improvement projects within existing areas such as Suisun Marsh and within flooded island areas such as Sherman Lake, Big Break, and Frank's Tract. A number of additional opportunities to improve habitat conditions for aquatic organisms exist within the Bay-Delta system and upstream tributaries which need to be identified and evaluated as part of the foundation for developing the comprehensive long-term management program. Opportunities to develop, improve availability, and improve the quality of aquatic habitats within the Delta system and tributaries will form an integral part of the evaluation of long-term planning alternatives, including isolated water conveyance facilities which would relocate the major diversion points from the south Delta, thereby substantially increasing the opportunities for habitat improvement within the Delta system.

It is recommended that a team of scientists and engineers with expertise in hydrology, fisheries, and aquatic and terrestrial vegetation be given responsibility to technically evaluate a range of options for habitat improvements within and upstream of the Delta. The evaluation of potential habitat improvement projects should be completed within two years and should include a set of specific proposals, including estimated capital and annual maintenance costs, for habitat improvement projects to be considered in developing the comprehensive long-term program of actions.

BIOLOGICAL BENEFITS: The evaluation of potential habitat improvement projects within the Bay-Delta environment will not result in any short-term direct biological benefit. The biological benefits to be derived from this program will result from a program of implementation to be performed in concert with other comprehensive long-term management actions.

RECOMMENDED ACTION: Develop water budget management scenarios, reflecting interannual and seasonal availability and demand in water supply, to reduce direct and indirect mortality associated with cross-Delta flows, reverse flow within the lower San Joaquin River, and the balance between freshwater inflow and exports (percent diverted) during periods of greatest susceptibility of various fish species and life stages to diversion losses.

BASIS FOR THE RECOMMENDATION: Freshwater inflow to the Delta, freshwater outflow, and the percentage of water diverted from the Delta are important factors influencing habitat quality and the susceptibility of various fish species and lifestages to direct entrainment losses. The development of a water budget, which includes consideration of both fisheries and water supply demands, includes both short-term and long-term elements. On a short-term basis efforts are continuing to develop and expand the State Water Bank and other projects which increase the availability of freshwater supplies within the Delta. A portion of this increased water supply should be allocated specifically for instream benefits to fish populations inhabiting the Bay-Delta system. The water supply allocated to Delta fisheries through this process each year in coordination with an interdisciplinary team. The interdisciplinary team would have the authority to specify the timing and magnitude of water releases, including the carryover of water supplies from one year to the next, within the total volume allocated for fisheries enhancement each year. The water allocation would vary between years based on volumes available through the waterbank and other projects.

An interdisciplinary team of engineers, hydrologists, fisheries biologists, and water quality specialists should be assembled and given responsibility to develop a series of water budget scenarios which include consideration of both environmental and water supply demand, for use as technical input in the development of a comprehensive long-term management plan for the Bay-Delta system. Technical information needs to be developed, to the extent possible, on such factors as Sacramento River flow and Delta outflow requirements for fisheries purposes under various operational scenarios for both isolated transfer facilities and through-Delta transfer and conveyance facility alternatives. Much of the early development of the long-term water budget and management scenarios has been initiated through efforts to develop alternative flow and operational scenarios for the State Board scoping process and discussions associated with the State Water Contractors sponsored matrix meetings on the design and operation of alternative water conveyance facilities. The information developed through these processes, and the identification of areas of biological uncertainty, will provide necessary scientific and technical input to the assessment of various alternatives and the formulation of a comprehensive long-term management program for the Bay-Delta system.

BIOLOGICAL BENEFITS: Potential biological benefits associated with the development of water budget management scenarios cannot be quantified given the information currently available. Quantities of water available for allocation to fisheries protection and enhancement is anticipated to vary substantially between years. The biological benefits to be derived from the allocation of these water supplies each year will also vary depending on the magnitude of the volume of water available to provide benefits to various fish species. In association with the annual water supply allocations a monitoring program should be developed to provide, to the extent possible, quantitative information useful in evaluating biological benefits associated with development of the comprehensive long-term management plan.

The development of water budget allocations, additional water conveyance facilities, etc. for the comprehensive long-term management plan should focus on achieving a level of biological protection comparable to conditions during the 1970 period of development. Biological benefits to be achieved on the long-term program, through combined implementation of water budget allocations and the addition of various water development-storage facilities should include substantial improvements in the survival of juvenile chinook salmon and steelhead emigrating from the Sacramento and San Joaquin rivers, substantial improvements in the survival and abundance of striped bass and other resident fish and invertebrate species, and substantial improvements in the availability and quality of aquatic habitats within the Bay-Delta system.

RECOMMENDED ACTION: Develop an experimental study program to provide short-term seasonal increases in outflow to promote the downstream transport and location of larval fish populations within areas of Suisun Bay to reduce susceptibility to entrainment losses at the SWP and CVP intakes and agricultural and municipal diversions within the Delta.

BASIS FOR THE RECOMMENDATION: The geographic distribution of many planktonic fish eggs and larvae is influenced by the magnitude of freshwater outflow passing through the Delta. The larval stages of many of these species, including striped bass, occur in the Delta during a relatively short period of time in the spring (April - June). During periods of high spring freshwater outflow the planktonic larval stages of these fish species are distributed downstream in Suisun Bay where their susceptibility to entrainment losses at the SWP and CVP diversions and at other diversion points within the Delta (Figure 2) is reduced. During years when spring outflow is low, a larger percentage of the planktonic larval fish are located within the Delta where they are susceptible to entrainment losses and higher mortality rates. An interim management plan is proposed in which experimental short-term increases in freshwater outflow are used to transport planktonic organisms downstream into Suisun Bay in an effort to improve survival and reduce entrainment losses. The magnitude and duration of increased outflows necessary to redistribute a substantial proportion of fish eggs and larvae during the spring into downstream areas has not been quantified. Furthermore, concern exists that potential biological benefits associated with short-term increased outflows will be reduced substantially when outflows are reduced to lower levels and larval fish may be drawn back into interior Delta areas where entrainment susceptibility is increased.

It is recommended that an experimental program be implemented as part of the interim program of actions to investigate and evaluate biological benefits associated with short-term increases in freshwater outflow to redistribute planktonic fish eggs and larvae in Suisun Bay. The recommended program would be conducted during selected years based on availability of water supplies. The period of increased outflow would be coordinated with short-term pulsed flow levels on both the Sacramento and San Joaquin Rivers based on results of real-time biological monitoring. A biological monitoring program to assess, in detail, changes in the geographic distribution and densities of fish eggs and larvae for various species, including changes in the susceptibility to entrainment at various water diversion points within the Delta, is an integral part of the proposed experimental management program. Results of the experimental program will provide a basis for evaluating potential biological benefits of the proposed management scenario and serve as technical input into the development of a comprehensive long-term management plan.

BIOLOGICAL BENEFITS: Potential biological benefits resulting from increases in freshwater outflow designed to promote the downstream transport and distribution of fish eggs and larvae within Suisun Bay cannot be quantified using existing data. The proposed management action has the potential to contribute to reduced entrainment losses. The proposed test will be designed and implemented to include a detailed assessment of the biological benefits (e.g., reduced susceptibility of fish eggs and larvae to entrainment losses and redistribution of organisms within Suisun Bay). The experimental program will provide the necessary technical and scientific basis for evaluating the potential benefits and costs associated with the proposed management scenario for consideration in developing the comprehensive long-term management program.

RECOMMENDED ACTION: Evaluate the types of chemicals, application rates, acute and chronic toxicity, and timing of agricultural, industrial, and urban discharges into the upper Sacramento River, San Joaquin River system, and Delta during spawning periods for striped bass, American shad, and other fish species (several of these evaluations are under way).

BASIS FOR THE RECOMMENDATION: Areas of the Sacramento - San Joaquin Delta and upstream tributaries utilized as spawning and rearing areas for a large number of resident and migratory fish and invertebrate species receive point and non-point source agricultural, industrial, and municipal discharges. For example, pesticides and herbicides used in the production of rice and other crops are discharged into the upper Sacramento River (e.g., the Colusa Basin Drain) at a time which overlaps with the spawning of striped bass. Agricultural chemicals are also discharged as part of return flows from agricultural areas located adjacent to the San Joaquin River and its tributaries and from reclaimed Delta islands. Point source discharges of municipal sewage effluent occur within the Sacramento and San Joaquin River systems at a number of municipalities including Redding, Sacramento, Stockton, and Contra Costa County communities. Non-point source discharges, primarily associated with stormwater runoff, occur throughout the drainage system. Industrial point-source discharges such as those associated with petroleum refining also occur throughout the Bay-Delta system.

Kelley *et al.* (1982), Cashman *et al.* (1992), Bailey (1992) and other investigators have hypothesized that pollutant discharges may be a significant factor influencing the survival, growth, and reproduction of striped bass, chinook salmon, and other Bay-Delta fish and invertebrate populations. During the past 10 years the State Water Resources Control Board, Regional Water Quality Control Boards, U.S. Bureau of Reclamation, Department of Water Resources, Department of Fish and Game, EPA, USGS, and others have conducted extensive water quality monitoring programs designed to document and characterize ambient water quality conditions and various sources of potential pollution. Results of these water quality monitoring programs have shown the seasonal occurrence of elevated concentrations of various pollutants which have the potential to adversely impact Bay-Delta phytoplankton, zooplankton, and fish populations. For example, these water quality monitoring programs have shown the presence of elevated concentrations of agricultural chemicals (pesticides and herbicides) in areas of the Sacramento River adjacent to the Colusa Basin Drain and within the San Joaquin River associated with the discharges from agricultural return flows. The Regional Water Quality Control Boards, under the authority of the Clean Water Act as part of the NPDES permitting process, also collects an extensive amount of information on water quality as part of the point-source discharge self-monitoring program.

As a complement to the water quality monitoring programs, several laboratory and field-based toxicological investigations have been performed. Investigations performed by Chris Foe for the Central Valley Regional Water Quality Control Board during the late-1980's demonstrated toxicity of water discharged from rice fields into the upper Sacramento River to larval striped bass and the cladoceran *Ceriodaphnia dubia*. Results of these toxicity studies complement the field observations of periodic fish kills occurring within the Colusa Basin Drain and associated with other agricultural discharges within the upper Sacramento River. Results of *Ceriodaphnia* toxicity studies within the Sacramento River demonstrated the presence of acute toxicity within agricultural drains discharging into the upper Sacramento River and as far as 75 miles downstream of the Colusa Basin Drain (Foe and Connor 1989). Studies performed on rice field drainage by the U.S. EPA indicated that the primary causes of toxicity to *Ceriodaphnia* were associated with the agricultural chemicals carbofuran and methyl parathion (Norberg - King *et al.* 1991). Results of a similar series of toxicity tests demonstrated significant levels of acute mortality to *Ceriodaphnia* when exposed to agricultural drainage waters within the lower San Joaquin River.

An extensive set of laboratory toxicity studies were performed during 1989-91 on striped bass eggs and larvae and *Mysid* shrimp (Bailey 1992) to provide further information on the toxicity of agricultural discharges into the upper Sacramento River. Agricultural discharges associated with rice production occur during the spring (April and May) coincident with the seasonal timing of striped bass spawning in the upper Sacramento River. Results of toxicity tests performed in 1989 and 1990 demonstrated that exposure of larval striped bass to agricultural return flows resulted in significant levels of acute mortality (Figure 5). For example, striped bass larvae exposed to agricultural drainage water exhibited an average 84% mortality in 1990 compared with an average of 20% mortality in control groups (Bailey 1992). Toxicity was also demonstrated to striped bass eggs in the 1990 tests.

The Central Valley Regional Water Quality Control Board and Department of Food and Agriculture mandated modified chemical management for the application of agricultural chemicals used in rice production, retention times, and return-flow discharges to the upper Sacramento River. These changes in chemical management resulted in a substantial reduction in the acute toxicity of agricultural return flows as indicated by results of the striped bass and *Mysid* toxicity studies completed in 1991 (Figures 5 and 6). Results of these laboratory bioassays have shown that agricultural return flows resulted in acute toxicity to striped bass eggs and larvae and invertebrates and that modifications to chemical management practices contributed to a substantial reduction in toxicity in 1991.

Findings of the laboratory-based toxicity studies using striped bass larvae are consistent with preliminary observations from histological examination of striped bass larvae collected within the Delta. Investigators from the University of California at Davis (D. Hinton *et al.*) have performed histological examinations of the cellular structure of

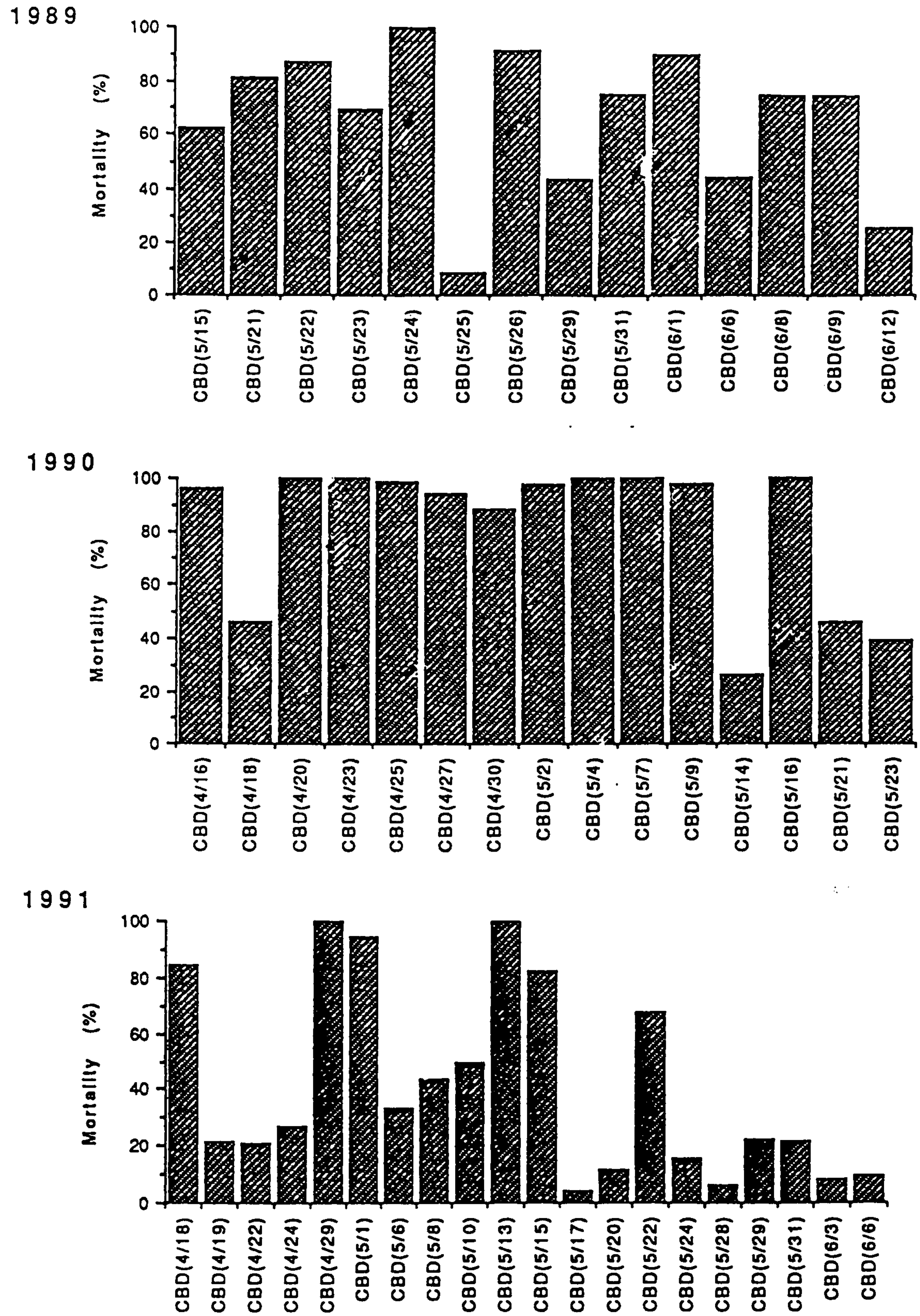

Figure 5. Acute toxicity of Colusa Basin Drain effluent to striped bass larvae, 1989-1991. (Source: Bailey 1992).

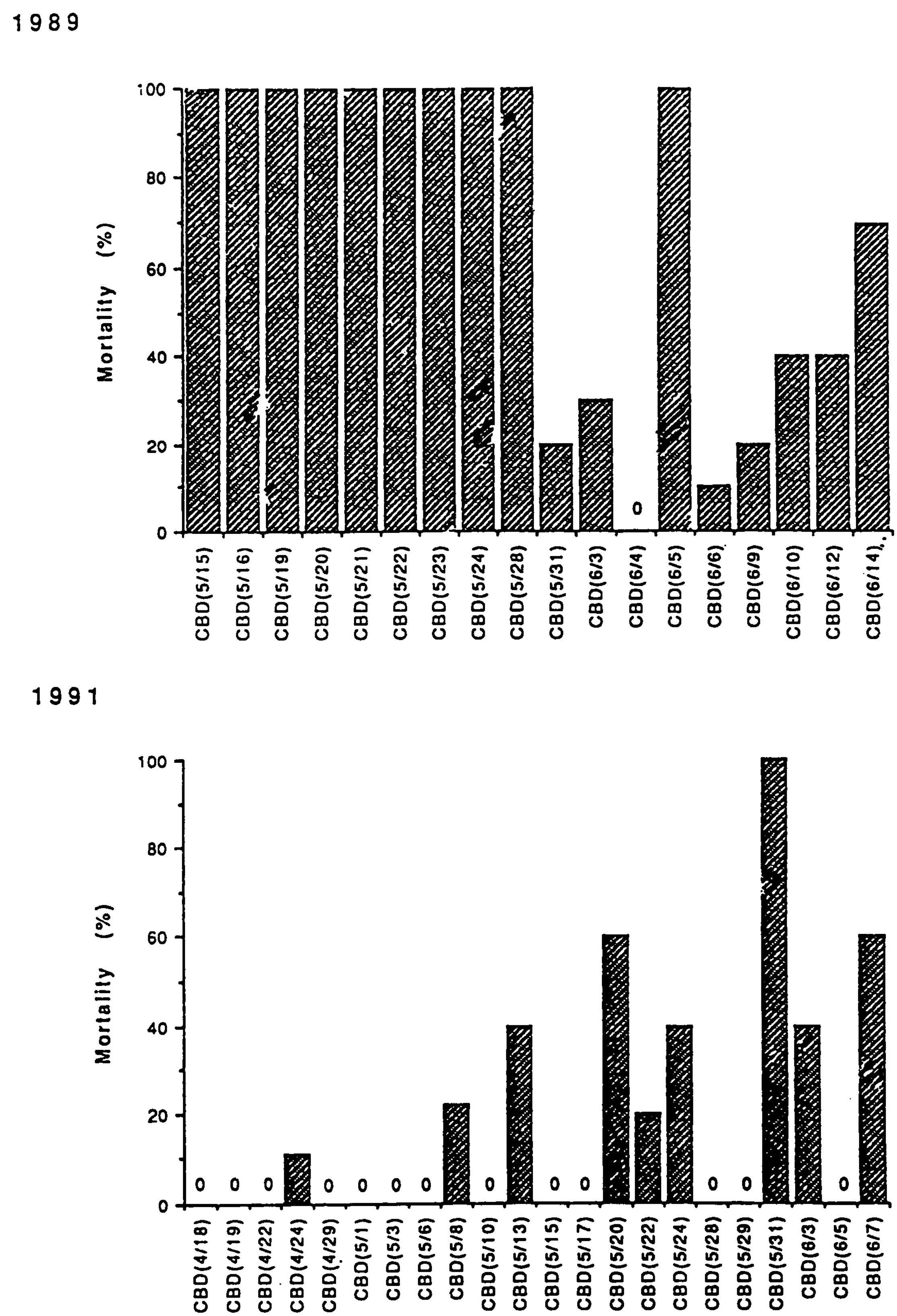

Figure 6. Acute toxicity of Colusa Basin Drain effluent to mysid shrimp (*Neomysis mercedis*), 1989, 1991. (Source: Bailey 1992).

various organs of striped bass larvae and early juveniles collected in the CDFandG fisheries sampling programs within the lower San Joaquin River, Sacramento River, and Delta. Results of these histological examinations have shown evidence of liver necrosis and other cellular damage symptomatic of exposure to toxic chemicals.

Investigators from the University of California at Berkeley, U.C. Davis, and San Francisco State University have conducted autopsies and histological tissue examinations of adult striped bass collected within the Bay-Delta system. During the late spring and summer dead and dying adult striped bass have been observed over a number of years in areas adjacent to the Carquinez Straits. Moribund striped bass collected in 1985 showed evidence of chronic liver dysfunction (pathology). In a follow-up study conducted in 1987 researchers investigated chemical contaminants found within the livers of moribund and healthy striped bass. Results of chemical analysis of liver tissue showed that moribund striped bass had substantially higher concentrations of a variety of chemical contaminants including hydrocarbons, agricultural herbicides, and petroleum-based constituents when compared with healthy striped bass (Cashman et al. 1992). Chemical contaminants contained within striped bass livers were characteristic of industrial, agricultural, and urban chemical discharges. Chemical body burden, as evidenced by elevated concentrations of chemical constituents within livers of moribund striped bass, represent a factor which may directly and indirectly influence mortality of the Bay-Delta adult striped bass population. Unfortunately, no comparative chemical data exists for earlier periods (e.g., the 1950's, 60's, and 70's) when adult striped bass dieoffs were also observed to occur within the Bay-Delta system.

The information available from both laboratory and field studies, in addition to water quality monitoring data, supports the hypothesis that pollutant discharges associated with agricultural, industrial, and urban development are a factor influencing the health and survival of Bay-Delta fisheries populations. The State Water Contractors support the continued investigation of water quality conditions and toxicological studies of various point- and non-point source discharges into Bay-Delta waters. The investigations of agricultural discharges in the upper Sacramento River associated with rice production (e.g., Colusa Basin Drain, etc.) which documented toxicity of the drainage which was then used in the development of a chemical management program resulting in a substantial reduction in the toxicity of agricultural drainage reflects the appropriate process for reducing the volume and toxicity of discharges into Bay-Delta waters. The State Water Resources Control Board should provide continued support for these investigations. Toxicity of point-source discharges should be controlled at the source, in accordance with the State Board Pollutant Policy, and not through increases in outflow to provide dilution water.

BIOLOGICAL BENEFITS: Although a growing body of scientific information exists on the potential toxicity of various sources of pollutant discharges to the Bay-Delta system the significance of pollutant discharges on the population dynamics (growth, survival, reproduction, etc.) of various fish and invertebrate populations cannot be quantified. Although population impacts cannot be quantified there is sufficient information available to conclude that reductions in the volume and toxicity of point- and non-point source chemical discharges into the Bay-Delta system will contribute to improved conditions for aquatic organisms.

RECOMMENDED ACTION: Evaluate alternative methods and facilities for agricultural, municipal, and industrial wastewater treatment (toxicity and volume reduction) and disposal.

BASIS FOR THE RECOMMENDATION: As discussed above, scientific data is being compiled which demonstrate acute and chronic effects on striped bass and other aquatic organisms as a result of exposure to various chemical contaminants discharged into Bay-Delta waters. Exposure of aquatic organisms to elevated concentrations of chemicals associated with agricultural, industrial, and urban discharges has the potential to contribute to acute toxicity, chronic liver dysfunction, increased physiological stress, reduced growth rates, and increased mortality. The scientific studies and management actions implemented to reduce the toxicity of agricultural return flows associated with rice production in the upper Sacramento River demonstrate the ability to identify specific problems and implement management actions which contribute directly to reductions in potentially adverse chemical discharges. An aggressive program by the Central Valley Regional Water Quality Control Board and State Water Resources Control Board to reduce the volume and toxicity of point-source discharges such as those occurring as a result of agricultural return flows should be implemented. Implementation of additional treatment facilities, including consideration of the consolidation of a number of individual discharges to promote more cost-effective and efficient wastewater treatment prior to discharge, should be developed as part of the foundation for the comprehensive long-term management plan for the Bay-Delta system.

BIOLOGICAL BENEFITS: Benefits to be derived from the identification and implementation of alternative methods for reducing the volume and toxicity of chemical discharges into the Bay-Delta system cannot be quantified. Reductions in the density, abundance, and biomass of a broad spectrum of organisms including phytoplankton, zooplankton, and fish populations throughout the Bay-Delta system supports the development of management actions designed to improve water quality and habitat conditions for these populations. An aggressive program to reduce the cumulative impacts associated with chemical discharges will contribute to improved conditions and protection for aquatic populations. Potential biological benefits associated with short- and long-term management actions need to be evaluated in context with the wide variety of factors (including pollutant discharges) influencing the population dynamics and overall health and condition of Bay-Delta aquatic resources and their supporting habitat.

CONCLUSIONS

The State Water Contractors have developed recommendations for a series of short-term actions which can be implemented on an interim basis. The program of interim actions will provide additional protection for Bay-Delta aquatic resources while a comprehensive long-term management plan is being developed and implemented. The interim program of actions is consistent with, and will complement, the fisheries management goals to be accomplished through the comprehensive management plan. The interim program includes multifaceted actions designed to provide protections and improved conditions both within the Delta and in upstream tributary areas. The interim actions and development of a long-term comprehensive management program, reflect the need for a balanced approach which includes consideration of habitat improvement for aquatic resources, reductions in a variety of sources of mortality to juvenile and adult fish, and the role of hatchery production in the mitigation for unavoidable losses and in providing maintenance and support for various fish populations in low-flow years when in-river production is reduced.

The interim program of recommended actions has been developed, within constraints imposed by the existing facilities and competing demands for available water supplies, to reduce mortality and maintain fisheries populations during the interim period of development of the comprehensive long-term management program. The available scientific data, however, is insufficient to allow quantification of the biological benefits resulting from many of the recommended interim actions. Although the biological benefits of these recommended actions cannot be quantified with confidence, available scientific information clearly demonstrates that the recommended actions <u>will</u> contribute directly to increased survival and abundance of fish and macroinvertebrate populations inhabiting the Bay-Delta system and upstream tributaries. The interim program also includes recommendations for data collection and evaluation designed specifically to quantify biological benefits and support the development of a long-term comprehensive management plan.

The recommended program of interim actions represents a significant first step which can be taken in the near-term to improve conditions for fish and aquatic resources within the Bay-Delta system. Some, but not all, of these interim actions are within the State Board's jurisdiction. The State Water Contractors recommend that the board, through adoption of water rights terms and conditions, act in those areas where it has authority and jurisdiction. As to other actions, the State Board can assist other agencies by recommending that certain interim actions be adopted as part of an overall program to provide short-term interim improvements in the conditions for Bay-Delta aquatic resources.

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