SJTA-2

SAN JOAQUIN TRIBUTARY AGENCIES
Merced Irrigation District
Modesto Irrigation District
Oakdale Irrigation District
South San Joaquin Irrigation District
Turlock Irrigation District

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March 10, 1995

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

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

Dear Mr. Caffrey:

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

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

SWP and CVP Pumping Impacts

The Draft Plan notes that salmon populations have been severely affected by pumping operations in the Delta and that peak chinook salmon losses occur at the state and federal export pumps in April through June when the fall run smolts are passing through the Delta. In addition, prior testimony by DFG, USFWS, and NMFS left no doubt that the direct and indirect effects of CVP and SWP export pumping operations are responsible for declining populations of anadromous and resident fish. While valid arguments may exist regarding the various analytical tools employed to define and quantify project impacts on specific species, the inescapable fact is that exports, given the present hydraulic configuration of the Delta, significantly impact fisheries through direct entrainment, interference with migration pathways, and elimination of once productive spawning and nursery areas. Export project operations have also altered the natural and historic seasonal pattern of Delta outflows.

The burden of dealing with these project-created impacts cannot be transferred to other entities. The projects alone must be held responsible for flows necessary to permit export pumping, whether those flows are operational carriage water or additional flows to offset and mitigate these project impacts.

Salmon Models

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

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

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

Salinity

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

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

San Joaquin River Flow Standards

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

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

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

Water Supply Impacts

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

State Board prepare an environmental impact report before issuing any order reallocating water to benefit public trust resources in the Bay–Delta estuary.

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

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

Respectfully submitted,

SAN JOAQUIN TRIBUTARY AGENCIES

By Arthur F. Godwin

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Encl.

cc: Paul Elias
Barrett Kehl
Rick Martin
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Comments of the San Joaquin Tributary Agencies on the State Water Resources Control Board Draft Water Quality Control Plan and Environmental Report for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary

March 10, 1995

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COMMENTS OF THE SAN JOAQUIN TRIBUTARY AGENCIES ON THE DRAFT WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Page 13 **Salinity objectives for the lower San Joaquin River are included to protect striped bass spawning habitat.**

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

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

Page 16 **Table 3: San Joaquin River Salinity — San Joaquin River between Jersey Point and Prisoner's Point**

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

Page 17 **Table 3: River Flows — San Joaquin River at Airport Way Bridge, Vernalis**

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

Page 19 **Table 3: Footnotes [15] and [16].**

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

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

Page 21 **San Joaquin Valley Water Year Hydrologic Classification**

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

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

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

Page 25 **During the three-year period, decisions by the Federal Energy Regulatory Commission (FERC) or other regulatory orders may increase flows to the Estuary required of upstream water users. These flows will be considered by the SWRCB in its allocation of responsibility among the water right holders in the watershed during the water right proceeding.**

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

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

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

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

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

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

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

Factors that contribute to the low level dissolved oxygen are not related to the activities of the upstream San Joaquin River basin water users. There should be no obligation placed on these water users to remedy the problems caused by others.

It is important to note that Vernalis flows in the late summer and fall (August-October) have been higher historically than unimpaired flow (see, e.g., Figure V-2 in the Environmental Report.)

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

Page 26 **Implement the recommendations of the SJVDP's 1990 document "A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley" according to the 1991 document.**

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

Page 32 **Evaluate the effectiveness of barriers as a means of improving fish survival in the Delta.**

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

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

Page 33 **Reduce the impact of introduced species on native species in the Estuary.**

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

Page 33 **Improve hatchery programs for species of concern.**

We support the establishment of a salmon hatchery in the Tuolumne River watershed.

Page 34 **Minimize losses of salmon and steelhead to flow fluctuations.**

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

Page 34 **Evaluate alternative water conveyance and storage facilities of the SWP and CVP in the Delta.**

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

Page 35 **Develop an experimental study program on the effects of pulse flows on fish eggs and larvae in the Delta.**

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

Page 36 **Implement temperature control measures to reduce adverse effects on salmon and steelhead.**

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

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

Figure 1 shows the daily average water temperature for water released from New Don Pedro between 1978 and 1993. Except for a few days in 1980 the temperature of the water released from New Don Pedro has ranged from 47°F and 53°F, well below the temperatures needed for chinook salmon.

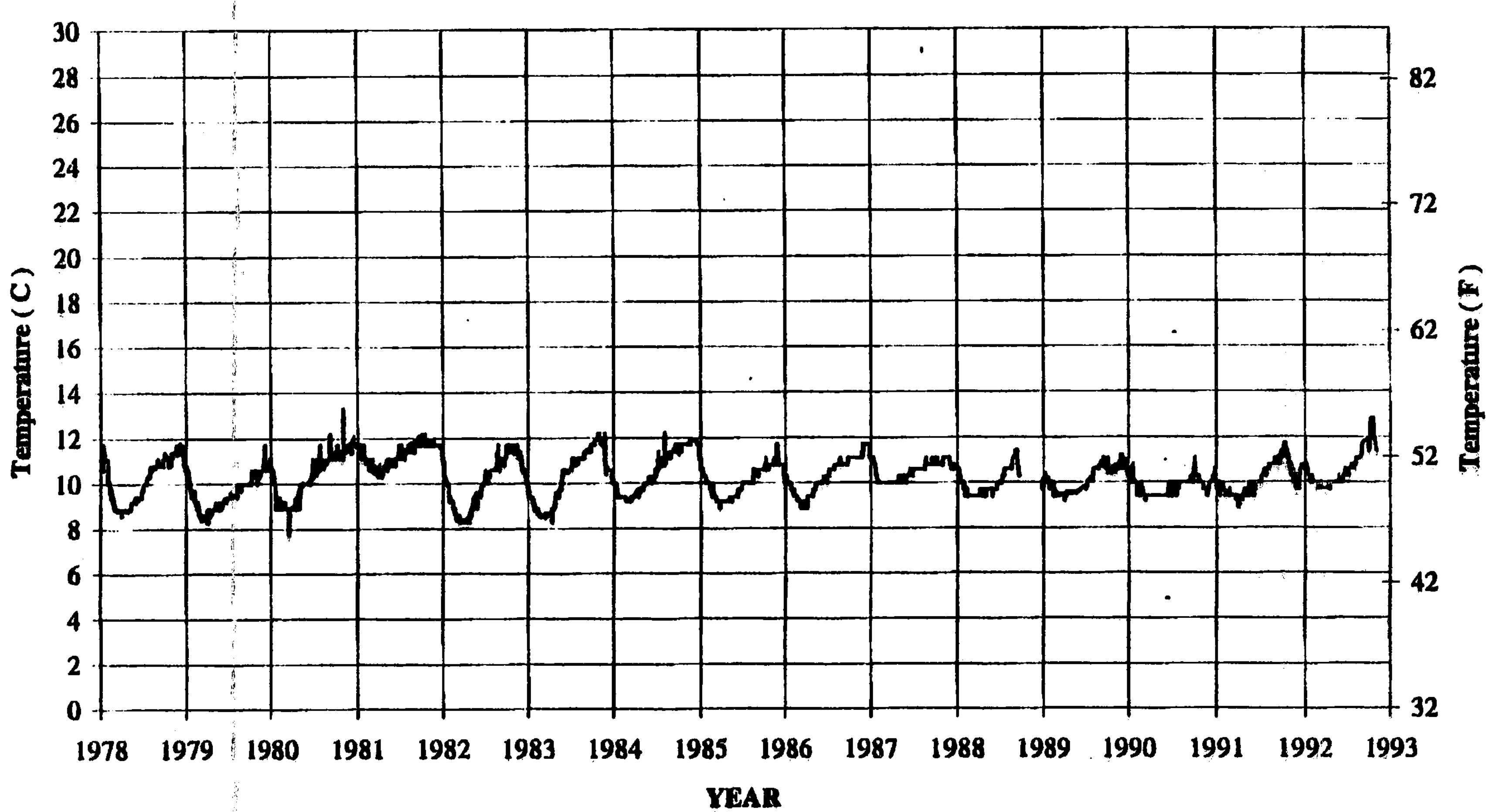

Figure 1. Daily water release temperatures from New Don Pedro Powerhouse 1978-1992. (A single temperature measurement was taken daily at each of three power generating units and averaged for water years 1989-1992. Prior to water year 1989, data were either the average of three power generating units, or from a single representative unit. Data are not available for October, November, and December 1988.)

COMMENTS OF THE SAN JOAQUIN TRIBUTARY AGENCIES ON THE ENVIRONMENTAL REPORT APPENDIX TO THE DRAFT BAY-DELTA WATER QUALITY CONTROL PLAN

Page	Comment
I-4, I-5	**Water Right Holders**

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

I-7 **SWP**

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

I-8 **Decision 990**

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

II-5 **Salinity objectives for the lower San Joaquin River**

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

However, meeting the proposed Prisoner's Point standard under the Draft Plan may not be possible. Although Prisoner's Point is upstream from the mouth of the Mokelumne River, the transfer of water through the central Delta to the export pumps has

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	historically kept salinity below the 0.44 mmhos EC objective. With the Delta Cross Channel closed and exports restricted, water quality in the Prisoner's Point vicinity may reflect saltier San Joaquin River conditions instead of Mokelumne River conditions. This may be particularly true (1) in April and May, outside the pulse flow period, when the San Joaquin River is managed to meet the 0.7 mmhos EC agricultural standard, and (2) during the April 15–May 15 period when exports are restricted to 100% of the San Joaquin River flow at Vernalis, especially without the Old River barrier in place.
II-9	**Table II-3 Footnotes**
	Footnote [10] defines the Eight River Index as the sum of unimpaired runoff for the eight rivers listed, including the Tuolumne and San Joaquin Rivers, as published in DWR Bulletin 120.
	Unimpaired runoff for the Tuolumne River is not the same as runoff into Don Pedro. San Francisco diverts an average of 225,000 AF per year out of the Tuolumne River watershed. If the SWRCB does not require contribution from San Francisco to meet the Bay–Delta standards, then the SWRCB should use inflow into Don Pedro to determine the Tuolumne River portion of San Joaquin Valley Water Year Index.
	Total inflow into Millerton Lake is used to calculate the San Joaquin Valley Water Year Index, yet there is no indication that the San Joaquin River is expected to contribute to the Vernalis flow requirements. It is inconsistent to use the San Joaquin River to calculate the index and not expect some contribution from the upper San Joaquin River. If there are no contributions from the upper San Joaquin River, then the value for the unimpaired inflow into Millerton Lake should be set at zero.
II-12	**San Joaquin Valley Water Year Hydrologic Classification**
	Footnote 2 for Table II-3 should be "Footnote 3".
	As noted above, unimpaired runoff for the Tuolumne River is not the same as runoff into Don Pedro. If the SWRCB does not require contribution from San Francisco to meet the Bay–Delta standards, then the SWRCB should use inflow into Don Pedro to determine the Tuolumne River portion of San Joaquin Valley Water Year Index. If there are no contributions from the upper San Joaquin River, then the value for the unimpaired inflow into Millerton Lake should be set at zero.
II-14	**Footnote [b]**
	See above comments regarding the Eight River Index.
IV-5	**Central Valley Basin Description**
	The description of the aquifer underlying the Central Valley states that "Useable storage capacity in a depth zone of 200 feet below ground surface has been estimated as between 80 and 93 MAF in the San Joaquin River basin...." The SWRCB should understand that there are literally thousands of domestic wells drilled to depths of less than 100 feet—in order to estimate the cost of emptying and filling this underground space, SWRCB will have to analyze cost of deepening all domestic wells to more than 200 feet. In addition there is already an overdraft of 209,000 acre-feet on average in the San Joaquin River Basin. This plan will only make the

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	overdraft worse.

IV-7 **Sacramento Valley—Surface Water Hydrology**

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

IV-24 **San Joaquin River Basin—Surface Water Hydrology**

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

IV-25 **Major Reservoirs in the San Joaquin River Basin**

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

IV-25 **San Joaquin River Basin—Surface Water Quality**

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

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

IV-26 Prior to 1977, the Tuolumne River water quality was heavily influenced by abandoned gas wells that discharged highly saline water into the river. As a result, the Tuolumne River had higher salinity than the other tributaries. The salinity of the Tuolumne River water decreased significantly after the wells were capped in 1977, and water quality has also improved due to the higher flows provided by New Don Pedro for fishery purposes, particularly in the fall months.

IV-28 **San Joaquin River Basin—Land Use and Economy**

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

IV-29 **San Joaquin River Basin—Recreation**

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

Page	Comment

jor tributaries.

V-2 **Water Year Types for the Sacramento and San Joaquin River Basins**

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

V-8 **Inflows to the Delta**

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

V-9 **Figure V-2**

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

V-18 **Reverse Flows**

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

V-19 It is clear that with high Delta flows and no CVP or SWP exports there would be a continuous downstream flow pattern throughout the Delta with the exception of the tidal influence noted above. This indicates that the projects should be responsible for all Bay–Delta standards necessary to maintain exports and protect Delta water quality.

V-58 **Freshwater Fish—White Catfish**

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

Page	Comment
V-62	**Estuarine Fish—Delta Smelt**

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

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

V-67 Estuarine Fish—Longfin Smelt

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

V-73 Anadromous Fish—Chinook Salmon

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

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

V-76 Anadromous Fish—Chinook Salmon—Population Trends

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

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

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

The Environmental Report notes the responsibility and significance that Friant Dam has had in regard to the reduced production and survival of salmon throughout the San Joaquin River system. This fact cannot be ignored when allocating responsibility. Suitable San Joaquin River flows must be provided by the USBR. Alternatives to

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	providing the water from Friant Dam include releases of USBR water through New Melones or transferring water through the Delta Mendota Canal and San Luis Reservoir.
V-80-82	Throughout this section are numerous statements regarding the impacts of the export projects on the San Joaquin River chinook salmon population. The report points out that the salmon populations have been severely affected by pumping operations in the Delta and that peak chinook salmon losses occur at the state and federal export pumps in April to June when the fall run smolts are passing through the Delta. The burden of dealing with these project-created impacts cannot be transferred to other entities. The projects alone must be held responsible for flows necessary to permit export pumping, whether those flows are operational carriage water or additional flows to offset and mitigate these project impacts. The State Board's greatest opportunities during the next three years may be in the creative design of operational parameters that will permit CVP and SWP operators, in consultation with the fishery agencies, to most efficiently manage their integrated export and water supply systems to meet both water user and environmental needs. Additionally, to the extent that dissolved oxygen problems near Stockton are the result of dredging activities and effluent discharges in the Stockton Ship Channel and turning basin. The burden of mitigating these impacts cannot be transferred to other entities. It is true that chinook salmon escapement in the San Joaquin River Basin is correlated with spring flows at Vernalis 2½ years earlier. However, the causes of this correlation require further analysis. For example, in month-by-month comparisons, the strongest correlation by far is between June flow and escapement, although the peak of the smolt outmigration is always in May. The correlation with *July* flow is about as strong as that with May, and stronger than with any other month except June, even though there are never any smolts in the San Joaquin River in July. These observations are difficult to reconcile with the simple cause-and-effect relationship suggested in the text. The poorest correlations of all are for the months of September, October, and November, when the upstream migration of parent spawners takes place. It is therefore ironic that a reference to flow-escapement relations to justify increased spring flow at Vernalis is immediately followed by the claim that increased fall flow would benefit upmigrating adults (p. V-81).
V-90-94	**Striped Bass—Causes of Decline** From a policy standpoint, it is inappropriate to set standards to improve the habitat for an exotic species that is a known threat to the native chinook salmon. This entire section lacks any reference to the lack of spawning habitat as a reason for the decline of striped bass. Despite this, the State Board continues to propose salinity objectives to protect striped bass spawning habitat in the lower San Joaquin River. As pointed out on numerous occasions by the SJTA and the Modesto and Turlock Irrigation Districts there is no reason to adopt a striped bass water quality standard. We believe that (1) there is no real scientific evidence that a salinity barrier to migration exists; (2) even if such a barrier did exist, it would not affect the production of striped bass, because as broadcast spawners, they are not spawning-habitat limited;

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	and (3) if striped bass did spawn farther upstream, the eggs and larvae would be susceptible to increased entrainment at the stated and federal pumping facilities.
V-97	**Freshwater Flows**
	The State Board's authority to impose terms and conditions on permits and licenses for the protection of beneficial uses is not without limits. Certainly the Board has authority to add terms and conditions to a permit upon issuance of a license. Once the license is issued, however, the Board's authority is limited to those situations where it has reserved jurisdiction or it has exercised its authority pursuant to state law and State Board regulations regarding a finding of waste or a specific unreasonable use.
V-98	**Water Temperature**
	Numerous participants have commented in the past on the effects of reservoir releases on downstream temperatures (see e.g., WQCP-CVPWA 204). This led the State Board to conclude in its 1991 Water Quality Control Plan that reservoir releases were not a "controllable factor" for achieving water quality temperature objectives.
	We have continually pointed out that there is no evidence that temperatures in the San Joaquin River affect either salmon recruitment or escapement. Temperature has not been demonstrated as a significant factor in survival of outmigrating juvenile salmon in the San Joaquin River. The San Joaquin River population of chinook salmon is the most southerly population and therefore might be expected to be least susceptible to high temperatures. Figure 1 to SJTA's comments on the Draft Plan is a figure showing the daily average water temperature for water released from New Don Pedro between 1978 and 1993. Except for a few days in 1980 the temperature of the water released from New Don Pedro has ranged from 47°F and 53°F, well below the temperatures needed for chinook salmon.
VI-2	Even though DWRSIM has not incorporated operations criteria for non CVP and SWP reservoirs, operations data for these reservoirs has been provided to the USBR for their SANJASM model.
VI-11	**Salmon Models**
	If the statistical validity of the USFWS model is so criticized, why is the State Board using it for their analysis? The SJTA and others have presented testimony at previous State Board hearings and workshops regarding the suitability and use of the USFWS smolt survival model. As pointed out at the October 13 and October 19, 1994 workshops, the model incorrectly uses and interprets the smolt survival data. As a result, it is inappropriate to use the model for the purpose of determining outflows and for setting policy.
	Included with these comments is a full copy of a paper entitled"Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento-San Joaquin Delta of California." The paper points out that with a correct interpretation of the USFWS data, salmon smolts can survive at temperatures substantially higher than those being recommended by the USFWS. The USFWS analysis indicates that increases in tempera-

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ture between 61 and 72 degrees F will result in a linear increase in smolt mortality. Our analysis indicates that survival is relatively insensitive to temperature until about 70 degrees F.

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

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

VII-4 **Modeling Assumptions—San Joaquin River Flow Requirements**

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

VII-5 **Water Supply Impacts**

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

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	proper time to evaluate the impacts of any proposed allocation scheme is during the water right phase. In addition, CEQA requires that the State Board prepare an environmental impact report before issuing any order reallocating water to benefit public trust resources in the Bay–Delta estuary.
VII-7	**Sacramento River Basin Storage Impact**
	Is the increase in Sacramento River Basin storage a result of reduced exports by the CVP and the SWP, increased export of San Joaquin River flows during the spring and fall, changes in project operations as a result of the winter run biological opinion, or a combination of all three? It bears repeating that the burden of dealing with project-created impacts cannot be transferred to other entities. To the extent that Sacramento River Basin storage is increased as a result of CVP and SWP export of the additional San Joaquin River flows, the projects alone must be held responsible for providing the flows necessary to permit export pumping and additional flows to offset and mitigate project impacts.
VII-10	**San Joaquin River Basin Impact**
	The two alternatives—reducing storage in reservoirs and limiting deliveries to customers—are basically the same alternative. There should be no water supply impacts to anyone other than the CVP and the SWP. As pointed out above, the Draft Plan covers only a three year period, during which time the USBR is required to meet the San Joaquin River flow objectives, in accordance with the biological opinion for Delta smelt. The SWRCB is not even considering allocation of flows at this time—the allocation process will be the subject of a water right proceeding which is scheduled to commence following the adoption of the Draft Plan.
	The San Joaquin River flow requirements are such that the water supply impacts to the San Joaquin River basin are actually greater in wet, above normal and below normal years than the export projects' water supply impacts. The upstream projects cannot be held responsible for providing flow for the benefit of the export projects. The CVP and SWP alone must provide the flows necessary to permit export pumping. The proposed outflows do not serve any habitat or biological purpose so much as they attempt to separate public trust resources from the pumps.
	The most important and efficient way to reduce the amount of water necessary to maintain water quality in the south Delta is to remove the salt discharged to the San Joaquin River. This would leave more water available in New Melones for fish flows and to meet USBR obligations. It is improper and illegal to allocate responsibility for water quality control and excess fish flows to non-CVP and SWP reservoirs.
VII-11	**New Melones Reservoir Carryover Storage and San Joaquin River Flow**
	The term "average annual additional water" is inconsistent between these two sections. Is "average annual additional water" the amount of water needed from New Melones to meet the Vernalis flow requirement under the preferred alternative as compared to the base case or does it refer to the shortage on the San Joaquin River after attempting to meet the San Joaquin River flow requirement from New Melones?
VII-17	**Figure VII-15**
	Figure VII-5 shows San Luis Reservoir will be filled over ½ of the time by the end of

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	March. Some of this water should be dedicated for discharge to the San Joaquin River to meet the current and future federal obligation for fish flows and water quality.
VIII-1	**Environmental Effects of Preferred Alternative**

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

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

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

VIII-6 Delta Exports

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

VIII-9 Salinity (X2 and Vernalis)

Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water. We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by re-

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quiring those discharging water in excess of salinity standards into the river to cease, mitigate or reduce all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying additional on additional fresh water flows to dilute such salt. The only real solution to the San Joaquin Valley salinity problem is to export salt from the valley through an isolated channel.

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

VIII-15 Spring—Delta Outflow

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

VIII-17 Spring—San Joaquin River Flow

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

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

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

2. The preferred alternative fails to include an Old River Barrier despite frequent references in the Environmental report to the benefits of the barrier and despite the fact that the Principles for Agreement on Bay–Delta Standards between the State of California and the Federal Government require the installation of a barrier. According to USFWS smolt survival model results, the preferred alternative would increase the San Joaquin smolt survival index by only 0.01, using the 1984-92 baseline, and only 0.03 using the 1922-92 baseline, over the index resulting from historical flows. The alternative achieves these trivial gains at enormous costs to upstream water users. In

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contrast the same USFWS model predicts increases of 0.16 to 0.20 when the barrier is present. The use of so much water where a physical solution has been endorsed by the signatories to the Principles for Agreement would be a tremendous waste and an unreasonable allocation of water for public trust purposes.

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

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

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

VIII-20 **Summer—Delta Outflow**

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

VIII-22 **Fall—San Joaquin River Flow**

There is no scientific evidence which supports the need for attraction pulse flows in the Tuolumne or Stanislaus Rivers:

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

2. The perceived need for Merced River attraction flows is directly related to the lack of any required fishery flows from the upper San Joaquin. As the uppermost river in the system, the upper San Joaquin River fall flows were a part of the flows which helped guide salmon from all four Basin rivers back to spawn. In the absence of upper San Joaquin River flows, the burden is now being unreasonably placed on the Merced River, as the uppermost river with a salmon run, and on the Tuolumne and Stanislaus Rivers, to mitigate for the lack of flows from the Upper San Joaquin River.

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The lack of a scientific basis is supported by the report which states, in part that"The scientific basis for this standard is largely subjective and based on biological judgment...."

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

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

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

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

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

VIII-29 **Aquatic Resource Model Results—Smolt Survival Models**

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

VIII-30 **Figures VIII-29 and VIII-30**

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

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	crease predicted by the USFWS model.
	If the State Board continues to use the 1984-1992 hydrology as a reference period for its environmental analysis, then the portion of the graph showing the model results under the 1922-1992 hydrology should be eliminated.
VIII-50	**Agricultural Supply**
	The report states that the "SWRCB will address the issue of flow allocation, and its intention to implement the objectives, during the water right phase" If the SWRCB is delaying the issue of flow allocation until the water right phase, why does this report analyze the impacts of the standards based upon some assumed allocation? The process for allocating responsibility for flows is not the subject of the Draft Plan, therefore, impacts from the proposed San Joaquin River flows must be allocated to the CVP and the discussion on flow allocation to the others must be eliminated.
VIII-51	**Effects in Upstream Areas**
	The term "upstream area" is defined as the Sacramento Valley and the eastside San Joaquin Valley. The definition excludes the Friant service area, the San Joaquin River exchange contractors, and others who use the waters of the San Joaquin River. If the State Board insists on including the upstream areas in its analysis of the impacts of the Draft Plan, then it must include all users, not just select groups.
VIII-52	**River Flows**
	According to the report there are no Sacramento River impacts since the required flows are similar to the base flows. For the San Joaquin River, the Vernalis flow requirements result in substantial impacts to San Joaquin River flows. In fact, under current conditions, the proposed standards could not be met even in wet years.
VIII-58	**Land Use**
	The report states that water users in upstream areas will be required to contribute an unknown amount of water to meet Bay–Delta standards. The report then refers the reader to Chapter XII for a quantitative assumption regarding the allocation of water supply impacts in the eastside San Joaquin Valley. Chapter XII has no discussion. There is no explanation of the methods used by the State Board to allocate responsibility among the upstream users. We are left to speculate as to how the State Board may have assigned such responsibility.
VIII-61	**Recreation**
	The report states that reservoir levels are likely to decline, but the impacts cannot be determined because reservoir levels will be dependent upon "management decisions" made by reservoir operators, i.e. reducing storage in reservoirs or limiting deliveries to customers. This lack of analysis merely masks the fact that if upstream areas have to make substantial flow contributions, recreation will be significantly affected.
VIII-63	**Depletion of Ground Water Resources**
	As Table VIII-4 points out, the preferred alternative will only exacerbate the current groundwater overdraft situation in the San Joaquin Valley. We agree that the reduced surface water supplies will probably be replaced with groundwater, where

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	available, and that the overdraft will increase the magnitude of the water supply impact. The discussion of water supply impacts should also state that groundwater overdraft will increase significantly under the preferred alternative.
VIII-75	**Cumulative Impacts**
	This section should also include a discussion of pending FERC decisions on the Mokelumne and Tuolumne Rivers and the pending SWRCB water right decision on the Yuba River.
VIII-77	**Federal ESA**
	The report states that requirements under the federal ESA are not incorporated into the base case analysis. This is inconsistent with the base case assumptions on p. VII-4 which states "The base case for this analysis is D-1485 conditions, modified to account for upstream requirements on the Sacramento River imposed by the NMFS to protect winter-run chinook salmon."
IX-1 to 5	Use of water to dilute the pollution of others is not a listed beneficial use of San Joaquin River water. We believe that the State Board and the Regional Water Quality Control Board must enforce the San Joaquin River water salinity standards by requiring those discharging water not meeting salinity requirements into the river to cease all such discharges. The program of implementation should instead describe the steps that must be taken to reduce the salt load entering the river rather than relying additional on additional fresh water flows to dilute such salt. The only appropriate way to meet the salinity objectives is to reduce, mitigate or eliminate the salt discharges to the San Joaquin River. If the SWRCB continues to require dilution of salts, than those entities responsible for the saline water discharges to the San Joaquin River should provide the water necessary for the dilution of such salts. Sources of water include CVP water stored in San Luis Reservoir and water transfers.
	We support the SWRCB recommendation to the USBR to study the San Luis Drain—the other in basin alternatives do not solve the salt management problem.
IX-5	**Recommendations to Improve Habitat Conditions**
	There needs to be a detailed and open process for prioritizing and funding habitat improvement activities.
IX-9	**The Use of Barriers in the Delta**
	There have been no studies to date regarding the potential effect of the Old River Barrier on Delta smelt. Such reservations are made based on speculation and judgment. Requiring high spring flows without the Old River Barrier would be a waste and unreasonable use of water.
IX-11	**Improve Hatchery Programs for Species of Concern**
	We support the construction of a hatchery on the Tuolumne River.
IX-11	**Flow Fluctuations**
	Ramping rates for the protection of salmon and steelhead are already given due consideration as part of the FERC licensing process. It would be inappropriate for

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	the SWRCB to recommend changes in instream flow requirements in water rights permits on FERC-licensed facilities.
IX-14	**Temperature Control**

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

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

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

XI-1 Description of Alternatives

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

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

XI-5 Fish Migration Criteria (Salmon Smolt Survival Standard)

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

XI-22 Impacts of Alternatives on Aquatic Resources—San Joaquin River Salmon

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

XII-2 Impacts on Agriculture

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

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	proximately 37% of the irrigated acreage.
XII-3	**Water Supplies—Eastside Districts**

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

XII-5 **Water Transfers**

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

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

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

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

4. The SWRCB should streamline the water transfer process.

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

XII-13 **Employment Impacts**

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

XII-15 Does the statement "The accuracy of this information has not been verified by SWRCB staff" mean that the SWRCB staff has verified all the information where this statement is <u>not</u> present?

XII-17 **Impacts on Hydroelectric Power Production**

Does the inclusion of PG&E and SCE in the analysis imply that they will also be re-

Page	Comment
	quired to contribute to Bay–Delta flows? Is the same true for SMUD which does not appear in the analysis? Who will pay for the impacts on hydroelectric purchase agreements?
XII-23	**Benefits**
	The benefits listed in Table XII-7 are highly questionable—most do not apply to the Bay–Delta or to California. If the State Board is not estimating the benefits accruing from its proposal, then what is the purpose for including a table such as this?
XII-24	We agree that the "relationship between smolt survival and the size of the adult population, evidence of a significant positive relationship is lacking."
XIII-35	**Winter-run Chinook Salmon**
	It is stated that the proposed standards, including San Joaquin River pulse flows in April-May and increased base flows from February to June, will benefit winter-run smolts. Additional spring flows on the San Joaquin River have never been identified in any winter-run chinook salmon biological assessment or biological opinion as having a benefit to that species. There is no scientific or biological justification for this statement. The decline of the winter run is strictly related to Sacramento River conditions and export-caused impacts.
XIII-39	**Delta Smelt**
	The upstream projects should not be required to provide increased flows on the San Joaquin River in order to maintain net seaward flows while export project pumping continues. The Delta smelt problem and the causes of its decline are strictly a project–related, export problem.
	In addition the report itself notes that the declines in Delta smelt have been attributed primarily to restricted habitat and increased losses through entrainment by Delta diversions (Environmental Report, p. V-62). The decline in Delta smelt coincides with the increases in the proportion of water diverted since 1984. Prior to 1984, and before the sharp decline in Delta smelt abundance, the entrapment zone was generally located in the western Delta. Since 1984, however, the increased export pumping has shifted the entrapment zone upstream into the Delta river channels. See also Table 2.3 in USFWS, Technical/Agency Draft Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes, December 1994, which evidences the decline in Delta smelt abundance after 1982. The proposed standards will require non-project San Joaquin River flows to offset the impacts of increased export pumping.
	We recommend that if the Old River Barrier is not installed during the spring outmigration period for San Joaquin River chinook salmon, then the SWRCB should require a complete cessation of export pumping for a minimum of four weeks during the April–May period. The precise four weeks should be determined each year by the SJTA and the San Joaquin River Basin Flow Coordinator depending on the time the smolt outmigration takes place.

San Joaquin Tributary Agencies
Additional Material Submitted in Response to State Water Resources Control Board Draft Water Quality Control Plan and Environmental Report for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary[1]

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

2. Figure — Percentages of striped bass eggs between 0 and 8 hours old collected in segments of the Sacramento–San Joaquin Delta and Suisun Bay at different flows for the years 1968-1973, 1975-1977, and 1984-1986.

3. Table — Factors affecting striped bass abundance in the Sacramento-San Joaquin River system. CDFG, 1987.

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

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

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

7. Paterson, A. 1990. Historic spawning locations of striped bass in the Sacramento-San Joaquin Delta. WQCP MID/TID 2.

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

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

10. Baker, P., et al. 1994. Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento-San Joaquin Delta of California.

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

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

[1] These materials were originally submitted by the San Joaquin Tributary Agencies at the State Water Resources Control Board Bay–Delta workshops on October 13, 1994 and October 19, 1994.

The Salinity Barrier and Striped Bass Ecology: an Evaluation[1]

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

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

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

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

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

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

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[1] Prepared by EA Engineering, Science and Technology for San Joaquin Tributary Agencies.

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

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

To conclude, we feel that there is no evidence to support the belief that a salinity barrier restricts striped bass from spawning in the San Joaquin River above Venice Island. In addition, even if such a barrier existed and spawning habitat area was reduced in size, there is no evidence that a reduction in area available for spawning would adversely affect the bass population. We have reviewed almost 400 articles on striped bass ecology and management and have found no evidence of salinity barriers or spawning habitat limitations.

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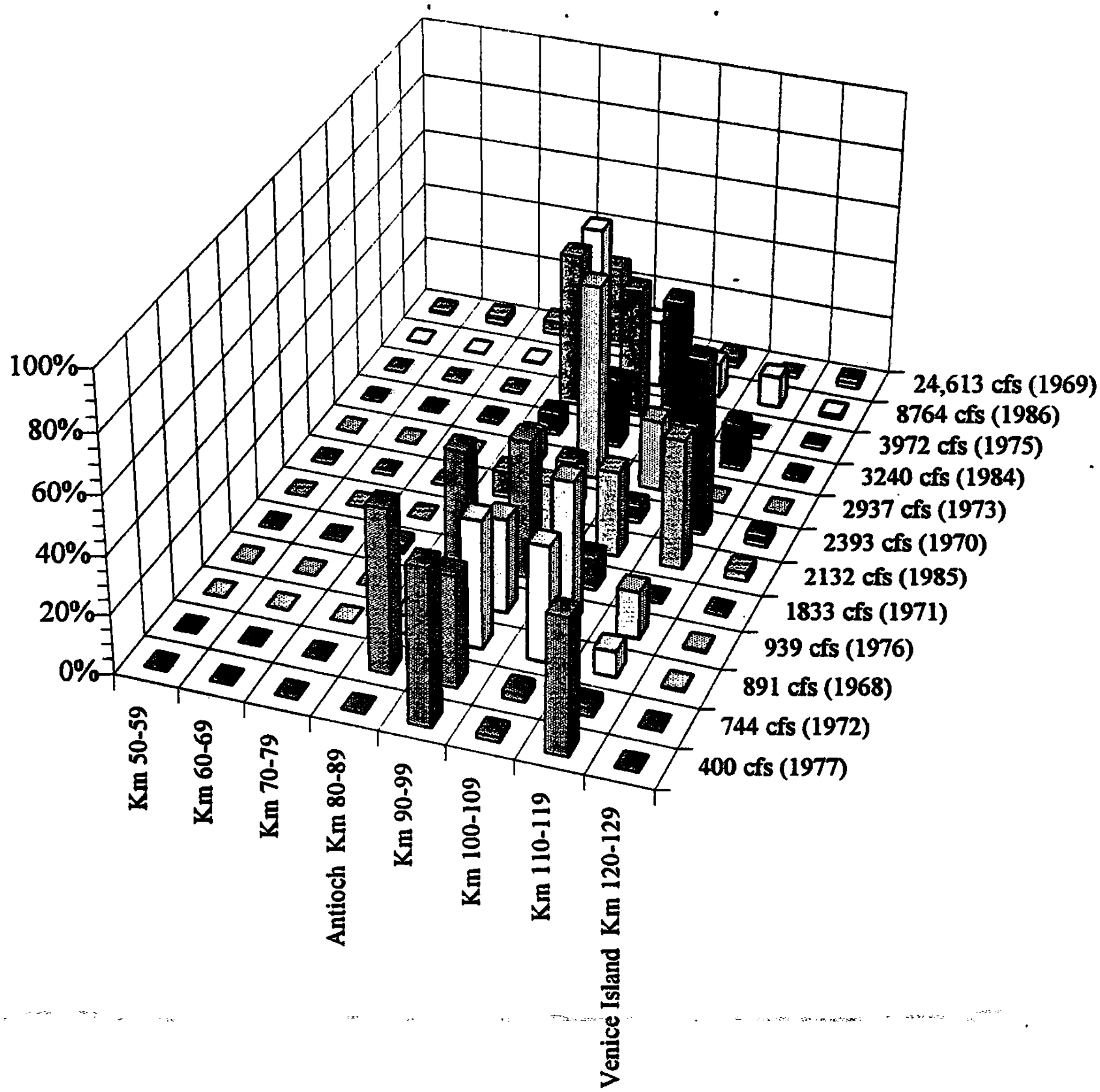


Percentages of striped bass eggs between 0 and 8 hours old collected in segments of the Sacramento-San Joaquin Delta and Suisun Bay at different flows (San Joaquin River mean May flow at Vernalis), for the years 1968-1973, 1975-1977, and 1984-1986. (Km 0 is the Golden Gate.)

Source: California Department of Fish and Game. 1987. Factors affecting striped bass abundance in the Sacramento-San Joaquin river system. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality\Water Rights Hearings Phase I, Exhibit 25. CDFG, Region 4, Fresno.

CDFG, (California Department of Fish and Game). 1987. Factors affecting striped bass abundance in the Sacramento-San Joaquin river system. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality/Water Rights Hearings Phase I, Exhibit 25. CDFG, Region 4, Fresno.

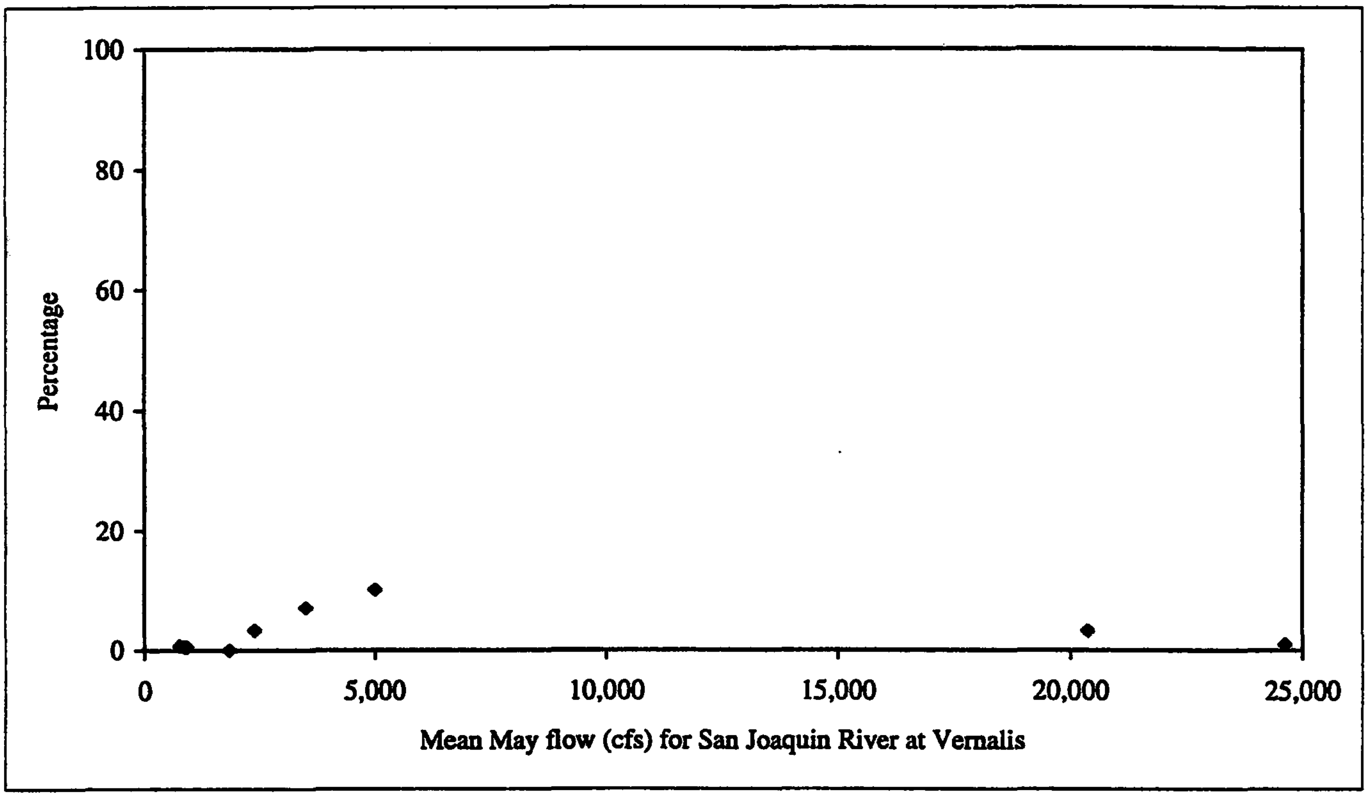
Table 8. Percentages of striped bass eggs between 0 and 8 hours old in 10 km (6.2 mile) segments of the Delta and Suisun Bay. River km (mile) 0 is at the Golden Gate. * = Not Sampled.

Area	River Kilometer (Miles)	1968	1969	1970	1971	1972	1973	1975	1976	1977	1984	1985	1986
Suisun Bay[1]	50-59 (31.1-36.7)	0	0.7	0	0	0	0	0	*	*	0.1	*	0.1
	60-69 (37.3-42.9)	0	2.5	0	0	0	0	0	*	*	0	0	0
	70-79 (43.5-49.1)	0	4.5	0.2	2.3	0	0	0.2	0	0	0.5	0	0.3
San Joaquin River[2] Antioch	80-89 (49.7-55.3)	6.5	27.8	9.0	39.6	55.5	10.0	52.8	1.5	0.1	6.9	0.9	52.2
	90-99 (55.9-61.5)	43.9	13.3	16.6	46.9	37.6	66.2	43.9	32.4	52.8	22.9	20.3	22.8
	100-109 (62.1-67.7)	39.5	3.3	5.0	10.8	2.4	23.9	1.8	49.3	1.6	53.9	29.3	11.8
	110-119 (68.4-73.9)	8.3	0	59.8	0	2.7	0	0.2	16.2	45.5	15.0	44.2	10.7
Venice Island	120-129 (74.6-80.2)	0.5	1.9	3.2	0	0.2	0	0.1	0.6	0.1	0.5	3.0	1.1
Sacramento River[3] Collinsville	80-89 (49.7-55.3)	0	43.5	0.1	0	0	0	0.3	0	0	0.1	0.1	0.2
	90-99 (55.9-61.5)	0.3	2.6	5.3	0.4	1.3	0	0.4	*	0	0.1	2.1	0.9
Rio Vista	100-109 (62.1-67.7)	0.9	0	0.9	0	0.3	0	0.2	*	0	0	0.1	0

1/ Based on sampling of DFG striped bass egg and larvae survey stations from Martinez to Collinsville.

2/ Based on sampling of DFG striped bass egg and larvae survey stations from Broad Slough to Mandeville Cutoff.

3/ Based on sampling of DFG striped bass egg and larvae survey stations from Collinsville to Rio Vista.



Percentage of striped bass eggs collected above Venice Island at various spawning flows, 1966-1972.

TABLE 1. OBSERVATIONS IN LITERATURE OF STRIPED BASS SPAWNING UPSTREAM OF VENICE ISLAND AND/OR STOCKTON

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

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

REFERENCES

Erkkila, L. F., J. W. Moffet, O. B. Cope, B. R. Smith, and R. S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: effects of Tracy Pumping Plant and Delta Cross Channel. Special Scientific Report - Fisheries 56. U. S. Fish and Wildlife Service.

Farley, T. C. 1966. Striped bass, *Roccus saxatilis*, spawning in the Sacramento-San Joaquin River system during 1963 and 1964. Fish Bulletin 136. California Department of Fish and Game.

Paterson, A. M. 1989. Notes on historic spawning locations of striped bass, with emphasis on the San Joaquin River. Revised Draft Report. Prepared for Turlock Irrigation District and Modesto Irrigation District, California.

Turner, J. L. 1976. Striped bass spawning in the Sacramento and San Joaquin rivers in central California from 1963-1972. California Fish and Game 62: 106-118.

USBR and USFWS (U. S. Bureau of Reclamation and U. S. Fish and Wildlife Service). 1957. Fish protection at the Tracy pumping plant, Central Valley Project, California. USBR, Region 2, Sacramento, California and USFWS, Region 1, Portland, Oregon.

Woodhull, C. 1947. Spawning habits of the striped bass (*Roccus saxatilis*) in California waters. California Fish and Game 33: 97-102.

STRIPED BASS BIBLIOGRAPHY

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

Albrecht, A. B. 1964. Some observations on factors associated with survival of striped bass eggs and larvae. California Fish and Game 50: 100-113.

Allen, D. H. 1975. Loss of striped bass (*Morone saxatilis*) eggs and young through small, agricultural diversions in the Sacramento-San Joaquin Delta. Anadromous Fisheries Branch Administrative Report 75-3. California Department of Fish and Game.

Arthur, J. 1982. The striped bass decline as influenced by food supply in the postyolk sac larval life stage. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Arthur, J. 1987a. Phytoplankton, zooplankton, and larval striped bass population dynamics during a regulated flow study in the Sacramento-San Joaquin Delta in 1985. Interagency Ecological Study Program Draft Report. U. S. Bureau of Reclamation, Sacramento, California.

Arthur, J. 1987b. Proposed physical and operational changes to increase survival of larval striped bass and salmon smolts. Internal Report. U. S. Bureau of Reclamation, Sacramento, California.

Arthur, J., and D. Ball. 1978. Entrapment of suspended materials in the San Francisco Bay-Delta Estuary. U. S. Bureau of Reclamation, Sacramento, California.

Arthur, J., and D. Ball. 1980. The significance of the entrapment zone location to the phytoplankton standing crop in the San Francisco Bay-Delta Estuary. U. S. Bureau of Reclamation, Sacramento, California.

Arthur, J., M. Ball, L. Hess, C. Liston, S. Hiebert, and G. Collins. 1991. 1990 Striped bass egg and larvae management studies: San Francisco Bay-Delta Estuary. Executive Summary. U. S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

Arthur, J. F., and M. D. Ball. 1979. Factors influencing the entrapment of suspended material in the San Francisco Bay-Delta Estuary. Pages 143-174 *in* T. J. Conomos, editor. San Francisco Bay: the urbanized estuary. American Association for the Advancement of Science, Pacific Division, San Francisco, California.

Arthur, J. F., H. F. N. Wong, M. D. Ball, and L. J. Hess. 1991. Evaluation of potential striped bass management scenarios by use of a numerical salt transport model. 1990 Striped bass egg and larvae management studies: San Francisco Bay-Delta Estuary. U. S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

Auld, A. H., and J. R. Schubel. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine Coastal Marine Sciences 6: 153-164.

Austin, H. M., and C. R. Hickey, Jr. 1978. Predicting abundance of striped bass, *Morone saxatilis*, in New York waters from modal lengths. Fishery Bulletin 76: 467-473.

Bailey, H. C., D. J. Ostrach, and D. E. Hinton. 1991. Effect of rice irrigation water in Colusa Basin Drain on fertilization success and embryonic development in striped bass. Draft Report, Contract No. 9-169-250-0. Prepared for State Water Resources Control Board, Sacramento, California.

Baracco, A. 1984. A procedure for estimating losses of striped bass and chinook salmon caused by State Water Project water export operations in the south Delta, 1968-1980. Memorandum to Bay-Delta Project Files. California Department of Fish and Game, Bay-Delta Project, Stockton.

Bay on Trial. 1992. Actions louder than words at Fish and Game? 4: 5.

Bayless, J. D. 1967. Striped bass hatching and hybridization experiments. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 21: 233-241.

Beak Consultants. 1989. Summary report of technical studies on the lower Yuba River, California. Yuba River Fisheries Investigations, 1986-88 Draft Final Report. Prepared for California Department of Fish and Game, Sacramento.

Bennett, W. B., D. J. Ostrach, and D. E. Hinton. 1990. The nutritional condition of striped bass larvae from the Sacramento-San Joaquin estuary in 1988: an evaluation of the starvation hypothesis using morphometry and histology. Prepared for the California Department of Water Resources, Sacramento.

Bigelow, H. B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Fish and Wildlife Service Bulletin 53: 1-577.

Bishai, H. M. 1960. The effects of water currents on the survival and distribution of fish larvae. Journal of Conservation 25: 134-146.

Bishai, H. M. 1961. The effect of salinity on the survival and distribution of larval and young fish. Journal of Conservation 26: 166-179.

Blunt, C. E., Jr. 1962. Striped bass. Pages 61-86 *in* Delta Fish and Wildlife Protection Study. Annual Report 1. California Department of Fish and Game.

Boreman, J. 1982. Potential impact of the State/Federal recommendations for striped bass management on the commercial fisheries in Rhode Island. Laboratory Reference Document 82-05. National Marine Fisheries Service, Northeast Fisheries Center, Woodshole, Massachusetts.

Boreman, J. 1983. Simulation of striped bass egg and larva development based on temperature. Transactions of the American Fisheries Society 112: 286-292.

Boreman, J., and H. M. Austin. 1985. Production and harvest of anadromous striped bass stocks along the Atlantic coast. Transactions of the American Fisheries Society 114: 3-7.

Botsford, L. W. 1983. Possible influences of adult striped bass on young-of-the-year modeling results. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Bowker, R. G., D. J. Baumgartner, J. A. Hutcheson, and R. H. Ray. 1969. Striped bass, *Morone saxatilis* (Walbaum). Development of essential requirements for production. U. S. Fish and Wildlife Service, Washington, D.C.

Boynton, W. R., T. T. Polgar, and H. H. Zion. 1981. Importance of juvenile striped bass food habits in the Potomac estuary. Transactions of the American Fisheries Society 110: 56-63.

Breitburg, D. L. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117: 72-77.

Burton, D. T., L. W. Hall Jr., S. L. Margrey, and R. D. Small. 1979. Interactions of chlorine, temperature change, and exposure time on survival of striped bass (*Morone saxatilis*) eggs and prolarvae. Journal of the Fisheries Research Board of Canada 36: 1108-1113.

Cada, G. F. 1990. A review of studies relating to the effects of propeller-type turbine passage on fish early life stages. North American Journal of Fisheries Management 10: 418-426.

Calhoun, A. J. 1946. Observations of the striped bass fishery in the Sacramento Delta during April and May 1946. Inland Fisheries Administrative Report 46-12. California Department of Fish and Game.

Calhoun, A. J. 1949. California striped bass catch records from the party boat fishery: 1938-1948. California Fish and Game 35: 211-253.

Calhoun, A. J. 1952. Annual migrations of California striped bass. California Fish and Game 38: 391-403.

Calhoun, A. J. 1953. Distribution of striped bass fry in relation to major water divisions. California Fish and Game 39: 279-300.

Calhoun, A. J., and C. A. Woodhull. 1948. Progress report on studies of striped bass reproduction in relation to Central Valley Project. California Fish and Game 34: 171-188.

Calhoun, A. J., C. A. Woodhull, and W. C. Johnson. 1950. Striped bass reproduction in the Sacramento River system in 1948. California Fish and Game 36: 135-145.

CDFG (Division of Fish and Game of California). 1935. The commercial fish catch of California for the years 1930-1934, inclusive. Fish Bulletin 44. CDFG, Bureau of Commercial Fisheries.

CDFG. 1937. The commercial fish catch of California for the year 1935. Fish Bulletin 49. CDFG, Bureau of Commercial Fisheries.

CDFG. 1940. The commercial fish catch of California for the years 1936-1939, inclusive. Fish Bulletin 57. CDFG, Bureau of Marine Fisheries.

CDFG. 1942. The commercial fish catch of California for the year 1940. Fish Bulletin 58. CDFG, Bureau of Marine Fisheries.

CDFG. 1944. The commercial fish catch of California for the years 1941 and 1942. Fish Bulletin 59. CDFG, Bureau of Marine Fisheries.

CDFG. 1946. The commercial fish catch of California for the years 1943 and 1944. Fish Bulletin 63. CDFG, Bureau of Marine Fisheries.

CDFG. 1947. The commercial fish catch of California for the years 1945 and 1946. Fish Bulletin 67. CDFG, Bureau of Marine Fisheries.

CDFG. 1949. The commercial fish catch of California for the year 1947 with an historical review 1916-1947. Fish Bulletin 74. CDFG, Bureau of Marine Fisheries.

CDFG. 1951. The commercial fish catch of California for the years 1948-1949 with yield per area of the California sardine fishing grounds 1937-1949. Fish Bulletin 80. CDFG, Bureau of Marine Fisheries.

CDFG (California Department of Fish and Game). 1952. The commercial fish catch of California for the year 1950 with a description of methods used in collecting and compiling the statistics. Fish Bulletin 86. CDFG, Bureau of Marine Fisheries.

CDFG. 1953. The commercial fish catch of California for the year 1951 with an evaluation of the existing anchovy case pack requirements. Fish Bulletin 89. CDFG, Bureau of Marine Fisheries.

CDFG. 1954. The commercial fish catch of California for the year 1952 with proportion of king and silver salmon in California's 1952 landings. Fish Bulletin 95. CDFG, Marine Fisheries Branch.

CDFG. 1976. Report to the State Water Resources Control Board on the impact of water development on fish and wildlife resources in the Sacramento-San Joaquin Estuary. San Francisco Bay/Sacramento-San Joaquin Delta Hearings, CDFG Exhibit 3. CDFG, Bay-Delta Fishery Project, Stockton.

CDFG. 1981. An evaluation of factors affecting abundance of striped bass in the Sacramento-San Joaquin Estuary. Manuscript. CDFG, Stockton.

CDFG. 1982. Relationships between abundance and survival of young striped bass and crustacean zooplankton densities on the striped bass nursery area. Striped Bass Working Group Report. Prepared for the State Water Resources Control Board, Sacramento, California.

CDFG. 1987a. Factors affecting striped bass abundance in the Sacramento-San Joaquin river system. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality/Water Rights Hearings Phase I, Exhibit 25. CDFG, Region 4, Fresno.

CDFG. 1987b. Estimates of fish entrainment losses associated with the State Water Project and Federal Central Valley Project facilities in the south Delta. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Hearings Phase I, Exhibit 17. CDFG, Bay-Delta Project, Stockton.

CDFG. 1988. Striped bass egg and larvae monitoring, and effects of flow regulation on the larval striped bass food chain in the Sacramento-San Joaquin Estuary. Final report to the State Water Resources Control Board.

CDFG. 1989a. Initial elements of the salmon, steelhead trout and anadromous fisheries program: a report submitted to the Legislature. Chapter 1545/88 Report. CDFG, Inland Fisheries Division, Sacramento.

CDFG. 1989b. Striped bass restoration and management plan for the Sacramento-San Joaquin Estuary. Phase I. Draft Report.

CDFG. 1992a. A model for evaluating the impacts of freshwater outflow and export on striped bass in the Sacramento-San Joaquin Estuary. WRINT-DFG-3. State Water Resources Control Board Hearing for setting interim standards for the Delta.

CDFG. 1992b. The basis for the California Department of Fish and Game's position on predatory fish in Clifton Court Forebay. Draft Report.

CDWR (California Department of Water Resources). 1990. Article VII framework agreement. Draft Outline.

CDWR. 1992. Notes of January 8, 1992 Delta Pumping Plant Fish Advisory Committee meeting. Memorandum. CDWR, Central District, Sacramento.

CDWR and CDFG (California Department of Water Resources and California Department of Fish and Game). 1973. Evaluation testing program report for Delta Fish Protective Facility, State Water Facilities, California Aqueduct, North San Joaquin Division. Memorandum Report.

Chadwick, H. K. 1958. A study of the planktonic fish eggs and larvae of the Sacramento-San Joaquin Delta with special reference to the striped bass (*Roccus saxatilis*). Inland Fisheries Administrative Report 58-5. California Department of Fish and Game.

Chadwick, H. K. 1962. Catch records from the striped bass sportfishery in California. California Fish and Game 48: 153-177.

Chadwick, H. K. 1964. Annual abundance of young striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta, California. California Fish and Game 50: 69-99.

Chadwick, H. K. 1966. Variation in the growth of young striped bass (*Roccus saxatilis*) in the Sacramento-San Joaquin system. Inland Fisheries Administrative Report 66-11. California Department of Fish and Game.

Chadwick, H. K. 1967. Recent migrations of the Sacramento-San Joaquin River striped-bass population. Transactions of the American Fisheries Society 96: 327-342.

Chadwick, H. K. 1968. Mortality rates in the California striped bass population. California Fish and Game 54: 228-246.

Chadwick, H. K. 1969. An evaluation of striped bass angling regulations based on an equilibrium yield model. California Fish and Game 55: 12-19.

Chadwick, H. K. 1974. Entrainment and thermal effects on a Mysid shrimp and striped bass in the Sacramento-San Joaquin Delta. *in* L. D. Jensen, editor. Second workshop on entrainment and intake screening. Publication 74-049-00-5. Electrical Power Research Institute, Palo Alto, California.

Chadwick, H. K. 1977. Effects of water development on striped bass. Pages 123-130 *in* Marine Recreational Fisheries 2: Proceedings of the Second Annual Marine Recreational Fisheries Symposium. Sport Fishing Institute.

Chadwick, H. K. 1982. Biological effects of water projects on the Sacramento-San Joaquin estuary. Pages 215-219 *in* W. J. Kockelman, T. J. Conomos and A. E. Leviton, editors. San Francisco Bay: use and protection. Pacific Division, AAAS.

Chadwick, H. K., D. Juliano, C. Seeley, and W. Silvey. 1967. Progress report on the study of dissolved oxygen in the Sacramento-San Joaquin estuary. Annual Report 6. California Department of Fish and Game and California Department of Water Resources.

Chadwick, H. K., and D. E. Stevens. 1971. An evaluation of effects of thermal discharges in the western Sacramento-San Joaquin Delta on striped bass, king salmon, and the opossum shrimp. Anadromous Fisheries Branch Report. California Department of Fish and Game.

Chadwick, H. K., D. E. Stevens, and L. W. Miller. 1977. Some factors regulating the striped bass population in the Sacramento-San Joaquin Estuary, California. Pages 18-35 in W. Van Winkle, editor. Conference on assessing the effects of power-plant induced mortality on fish populations. Pergamon, New York.

Chafee, J. H. 1980. The outlook for striped bass recovery. Pages 5-7 *in* H. Clepper, editor. Marine Recreational Fisheries 5: Proceedings of the Fifth Annual Marine Recreational Fisheries Symposium. Sport Fishing Institute, Washington, D. C.

Cheek, T. E., M. J. Van Den Avyle, and C. C. Coutant. 1985. Influences of water quality on distribution of striped bass in a Tennessee River impoundment. Transactions of the American Fisheries Society 114: 67-76.

Cheek, T. E., M. J. Van Den Avyle, and C. C. Coutant. 1983. Distribution and habitat selection of adult striped bass, *Morone saxatilis* (Walbaum), in Watts Bar Reservoir, Tennessee. ORNL/TM-8447. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Chervenski, J., G. T. Klar, and N. C. Parker. 1989. Predation by striped bass x white bass hybrids on redbelly tilapia and common carp. The Progressive Fish-Culturist 51: 101-103.

Chittenden, M. E., Jr. 1971. Effects of handling and salinity on oxygen requirements of striped bass, *Morone saxatilis*. Journal of the Fisheries Research Board of Canada 28: 1823-1830.

Chittenden, M. E., Jr. 1971. Status of the striped bass, *Morone saxatilis*, in the Delaware River. Chesapeake Science 12: 131-136.

Clark, G. H. 1933. Fluctuations in the abundance of striped bass (*Roccus lineatus*) in California. Fish Bulletin 39. California Department of Fish and Game.

Clark, G. H. 1934. Tagging of striped bass. California Fish and Game 20: 14-19.

Clark, G. H. 1936. A second report on striped bass tagging. California Fish and Game 22: 272-283.

Clark, G. H. 1938. Weight and age determination of striped bass. California Fish and Game 24: 176-177.

Clark, W., and M. Baldrige. 1984. Emergency striped bass research study report for 1982-1983. Report to Congress by the Secretaries of Interior and Commerce, Washington, D. C.

Cohen, J. E., S.W. Christensen, and C. P. Goodyear. 1983. A stochastic age-structured population model of striped bass (*Morone saxatilis*) in the Potomac River. Canadian Journal of Fisheries and Aquatic Sciences 40: 2170-2183.

Cole, J. N. 1984. Fisheries: An offspring of the ice age, the striper may not survive the nuclear age. March issue. Audubon.

Collins, B. W. 1982. Growth of adult striped bass in the Sacramento-San Joaquin Estuary. California Fish and Game 68: 146-159.

Colt, J. 1984. Seasonal changes in dissolved-gas supersaturation in the Sacramento River and possible effects on striped bass. Transactions of the American Fisheries Society 113: 655-665.

Combs, D. L. 1979. Striped bass research study: categorization of spawning areas. Final Report, Job 1 Dingell-Johnson Project F-29-R. Oklahoma Department of Wildlife and Conservation, Oklahoma City.

Combs, D. L., and L. R. Peltz. 1982. Seasonal distribution of striped bass in Keystone Reservoir, Oklahoma. North American Journal of Fisheries Management 2: 66-73.

Cooper, J. C., and T. T. Polgar. 1981. Recognition of year-class dominance in striped bass management. Transactions of the American Fisheries Society 110: 180-187.

Cooper, J. J., and S. Vigg. 1984. Extreme mercury concentrations of a striped bass, *Morone saxatilis*, with a known residence time in Lahontan Reservoir, Nevada. California Fish and Game 70: 190-192.

Cornacchia, J. W., and J. E. Colt. 1984. The effects of dissolved gas supersaturation on larval striped bass *Morone saxatilis* (Walbaum). Journal of Fish Diseases 7: 15-27.

Coughlan, D. J., and J. S. Velte. 1989. Dietary toxicity of selenium-contaminated red shiners to striped bass. Transactions of the American Fisheries Society 118: 400-408.

Coutant, C. C. 1974. Evaluation of entrainment effect. Report No. 15 *in* Second entrainment and impingement workshop, Johns Hopkins University Cooling Water Research Project. Johns Hopkins University, Baltimore, Maryland.

Coutant, C. C. 1977. Compilation of temperature preference data. Journal of the Fisheries Research Board of Canada 34: 739-745.

Coutant, C. C. 1978a. A working hypothesis to explain mortalities of striped bass, *Morone saxatilis* in Cherokee Reservoir. Report ORNL/TM-6534. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Coutant, C. C. 1978b. Emergency striped bass research study report for 1982-1983. Report ORNL/TM-6534. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Coutant, C. C. 1980. Environmental quality for striped bass. Pages 179-187 *in* H. Clepper, editor. Marine Recreational Fisheries 5: Proceedings of the fifth annual marine recreational fisheries symposium. Sports Fishing Institute, Washington, D. C.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114: 31-61.

Coutant, C. C. 1986. Thermal niches of striped bass. Scientific American 255: 98-104.

Coutant, C. C. 1987. Poor reproductive success of striped bass from a reservoir with reduced summer habitat. Transactions of the American Fisheries Society 116: 154-160.

Coutant, C. C. 1990. Temperature-oxygen habitat for freshwater and coastal striped bass in a changing climate. Transactions of the American Fisheries Society 119: 240-253.

Coutant, C. C., and D. L. Benson. 1990. Summer habitat suitability for striped bass in Chesapeake Bay: reflections on a population decline. Transactions of the American Fisheries Society 119: 757-778.

Coutant, C. C., and D. S. Carroll. 1980. Temperatures occupied by ten ultrasonic-tagged striped bass in freshwater lakes. Transactions of the American Fisheries Society 109: 195-202.

Coutant, C. C., and R. J. Kedl. 1975. Survival of larval striped bass exposed to fluid-induced and thermal stresses in a simulated condenser tube. Publication 637. Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, Tennessee.

Coutant, C. C., K. L. Zachman, D. K. Cox, and B. L. Pearman. 1984. Temperature selection by juvenile striped bass in laboratory and field. Transactions of the American Fisheries Society 113: 666-671.

Cox, D. K., and C. C. Coutant. 1981. Growth dynamics of juvenile striped bass as functions of temperature and ration. Transactions of the American Fisheries Society 110: 226-238.

Craig, J. A. 1930. An analysis of catch statistics of the striped bass (*Roccus lineatus*) fishery of California. Fish Bulletin No. 39. California Division of Fish and Game.

Daniel, D. A. 1976. A laboratory study to define the relationship between survival of young striped-bass (*Morone saxatilis*) and their food supply. Anadromous Fisheries Branch, Administrative Report 76-1. California Department of Fish and Game.

Davies, W. D. 1970. The effect of temperature, pH, and total dissolved solids on the survival of immature striped bass, *Morone saxatilis* (Walbaum). Doctoral dissertation. North Carolina State University, Raleigh.

Davies, W. D. 1973. The effects of total dissolved solids, temperature, and pH on the survival of immature striped bass: a response surface experiment. The Progressive Fish-Culturist 35: 157-160.

Davis, K. B., N. C. Parker, and M. A. Suttle. 1982. Plasma corticosteroids and chlorides in striped bass exposed to tricaine methanesulfonate, quinaldine, etomidate, and salt. The Progressive Fish-Culturist 44: 205-207.

Dedini, L. A, L. E. Schemel, and M. A. Tembreull. 1981. Salinity and temperature measurements in San Francisco Bay waters, 1980. Open-File Report 82-125. U. S. Geological Survey, Menlo Park, California.

Delta Fish Facilities Technical Coordinating Committee. 1980. Predation management for the Peripheral Canal Fish Facilities. Working Justification Paper 5. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary (California Department of Water Resources, California Department of Fish and Game, U. S. Bureau of Reclamation, and U. S. Fish and Wildlife Service).

Deppert, D. L., and J. B. Mense. 1980. Effect of striped bass predation on an Oklahoma trout fishery. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 33: 384-392.

Dew, C. B. 1988. Biological characteristics of commercially caught Hudson River striped bass, 1973-1975. North American Journal of Fisheries Management 8: 75-83.

Dey, W. P. 1981. Mortality and growth of young-of-the-year striped bass in the Hudson River estuary. Transactions of the American Fisheries Society 110: 151-157.

Diringer, E. 1989. Farm chemicals linked to striped bass decline. San Francisco Chronicle, 21 December 1989.

Diringer, E. 1990? Herbicide link to decline of bass disputed. San Francisco Chronicle.

Doroshev, S. I. 1970. Biological features of the eggs, larvae and young of the striped bass (*Roccus saxatilis* (Walbaum)) in connection with the problem of its acclimatization in the USSR. Journal of Ichthyology 10: 235-248.

Dovel, W. L., and J. R. Edmunds IV. 1971. Recent changes in striped bass *Morone saxatilis* spawning sites and commercial fishing areas in Upper Chesapeake Bay: possible influencing factors. Chesapeake Science 12: 33-39.

DuBois, R. B., and S. P. Gloss. 1993. Mortality of juvenile American shad and striped bass passed through Ossberger crossflow turbines at a small-scale hydroelectric site. North American Journal of Fisheries Management 13: 178-185.

Dudley, R. G., A. W. Mullis, and J. W. Terrell. 1977. Movements of adult striped bass (*Morone saxatilis*) in the Savannah River, Georgia. Transactions of the American Fisheries Society 106: 314-322.

Dunning, D. J., Q. E. Ross, M. T. Mattson, P. Geoghegan, and J. R. Waldman. 1989. Reducing mortality of striped bass captured in seines and trawls. North American Journal of Fisheries Management 9: 171-176.

Durham, M. 1980. Toxic chemicals may provide clue to mysterious disappearance of striped bass. News Release 14 July. U. S. Fish and Wildlife Service.

Eisler, R. 1970. Factors affecting pesticide-induced toxicity in an estuarine fish. Technical Paper 45.

Eldridge, M. B., B. J. Whipple, and D. Eng. 1980. Endogenous energy sources as factors affecting mortality and development in striped bass (*Morone saxatilis*) eggs and larvae. K. Sherman and R. Lasker, editors. Early life history of fish. Springer-Verlag, New York.

Eldridge, M. B., J. A. Whipple, D. Eng, and M. Bowers. 1978. Laboratory studies on factors affecting mortality in California striped bass (*Morone saxatilis*) eggs and larvae. Proceedings of the 108th annual meeting of the American Fisheries Society.

Eldridge, M. B., J. A. Whipple, D. Eng, M. J. Bowers, and B. M. Jarvis. 1981. Effects of food and feeding factors on laboratory-reared striped bass larvae. Transactions of the American Fisheries Society 110: 111-120.

EPA (Environmental Protection Agency). 1976. Temperature. Pages 218-231 *in* Quality criteria for water. EPA, Washington, D. C.

EPA. 1994a. Water quality standards for surface waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the State of California. Federal Register 59: 810-852.

EPA. 1994b. Water quality standards for surface waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the State of California: notice of availability. Federal Register 59: 44095-44097.

Erkkila, L. F., J. W. Moffet, O. B. Cope, B. R. Smith, and R. S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: effects of Tracy Pumping Plant and Delta Cross Channel. Special Scientific Report - Fisheries 56. U. S. Fish and Wildlife Service.

Faggella, G. A., and B. J. Finlayson. 1987. Hazard assessment of rice herbicides, molinate and thiobencarb, to larval and juvenile striped bass. Environmental Services Division Administrative Report No. 87-2. California Department of Fish and Game.

Farley, T. C. 1966. Striped bass, *Roccus saxatilis*, spawning in the Sacramento-San Joaquin River system during 1963 and 1964. Fish Bulletin 136. California Department of Fish and Game.

FERC (Federal Energy Regulatory Commission). 1992. Proposed modifications to the Lower Mokelumne River Project, California (FERC Project No. 2916-004). Draft Environmental Impact Statement FERC DEIS-0067. FERC, Office of Hydropower Licensing, Washington, D. C.

FERC. 1993. Proposed modifications to the Lower Mokelumne River Project, California: FERC Project No. 2916-004 (Licensee: East Bay Municipal Utility District). Final Environmental Impact Statement. FERC, Division of Project Compliance and Administration, Washington, D. C.

Finlayson, B. J., and G. A. Faggella. 1986. Comparison of laboratory and field observations of fish exposed to the herbicides molinate and thiobencarb. Transactions of the American Fisheries Society 115: 882-890.

Foe, C. 1989. Rice season toxicity monitoring results, plus Appendices A-D. Report. California Regional Water Quality Control Board, Central Valley Region.

Frederiksen, L., and F. E. Borcalli. 1992. Striped bass enhancement and chinook salmon protection. Letter to C. Fullerton, Regional Director, National Marine Fisheries Service, Terminal Island, California. From Borcalli and Associates, Sacramento, California. 3 February.

Freeman, J. 1989. Lull in bay dumping brings back stripers. San Francisco Chronicle, 18 September.

The Fresno Bee. 1992. Killer alga suspected in delta fish deaths. 18 August, A4.

Gall, G. A. E. 1989. California striped bass: conservation management and fishery enhancement. Prepared by Department of Animal Science, University of California, Davis for California Department of Fish and Game.

Geiger, J. G., and N. C. Parker. 1985. Survey of striped bass hatchery management in the southeastern United States. The Progressive Fish-Culturist 47: 1-13.

Gilderhus, P. A., C. A. Lemm, and L. C. Woods III. 1991. Benzocaine as an anesthetic for striped bass. The Progressive Fish-Culturist 53: 105-107.

Goodyear, C. P. 1978. Management problems of migratory stocks of striped bass. Pages 75-84 *in* H. Clepper, editor. Marine Recreational Fisheries 3: Proceedings of the third annual marine recreational fisheries symposium. Sport Fishing Institute.

Goodyear, C. P. 1980. Oscillatory behavior of a striped bass population model controlled by a Ricker function. Transactions of the American Fisheries Society 109: 511-516.

Goodyear, C. P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Transactions of the American Fisheries Society 114: 92-96.

Goodyear, C. P. 1985. Toxic materials, fishing, and environmental variation: simulated effects on striped bass population trends. Transactions of the American Fisheries Society 114: 107-113.

Goodyear, C. P., and S. W. Christensen. 1984. On the ability to detect influence of spawning stock on recruitment. North American Journal of Fisheries Management 4: 186-193.

Goodyear, C. P., J. E. Cohen, and S. W. Christensen. 1985. Maryland striped bass: recruitment declining below replacement. Transactions of the American Fisheries Society 114: 146-151.

Gritz, W. J. 1971. Distribution and food habits of fishes in relation to the thermal plume at Pacific Gas and Electric Company's power plant in the Sacramento-San Joaquin Delta. Anadromous Fisheries Branch Administrative Report 71-14. California Department of Fish and Game.

Hall, F. A., Jr. 1980b. Ultrasonic tracking of striped bass, *Morone saxatilis*, and Sacramento squawfish, *Ptychocheilus grandis*, near fish facilities. Anadromous Fisheries Branch Administrative Report 80-1. California Department of Fish and Game.

Hall, L. W., Jr., D. T. Burton, W. C. Graves, and S. L. Margrey. 1981. Effects of dechlorination on early life stages of striped bass (*Morone saxatilis*). Environmental Science and Technology 15: 573-578.

Hall, L. W., Jr., D. T. Burton, and L. B. Richardson. 1981. Comparison of ozone and chlorine toxicity to the developmental stages of striped bass, *Morone saxatilis*. Canadian Journal of Fisheries and Aquatic Sciences 38: 752-757.

Hall, L. W., Jr., W. S. Hall, S. J. Bushong, and R. L. Herman. 1987. *In situ* striped bass (*Morone saxatilis*) contaminant and water quality studies in the Potomac River. Aquatic Toxicology 10: 73-99.

Hall, L. W., Jr., L. O. Horseman, and S. Zeger. 1984. Effects of organic and inorganic chemical contaminants on fertilization, hatching success, and prolarval survival of striped bass. Archives of Environmental Contamination and Toxicology 13: 723-729.

Hall, L. W., Jr., A. E. Pinkey, and R. L. Herman. 1987. Survival of striped bass larvae and yearlings in relation to contaminants and water quality in the upper Chesapeake Bay. Archives of Environmental Contamination and Toxicology 16: 391-400.

Hall, L. W., Jr., A. E. Pinkey, L. O. Horseman, and S. E. Finger. 1985. Mortality of striped bass larvae in relation to contaminants and water quality in a Chesapeake Bay tributary. Transactions of the American Fisheries Society 114: 861-868.

Hansen, S. R. 1983. Evaluation of the role played by toxic substances in the decline of the striped bass population in the San Francisco Bay-Delta system. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Hanson, C. H. 1983. A conceptual model of mechanisms and factors affecting striped bass year class strength. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Hassler, W. W. 1958. The striped bass in relation to the multiple use of the Roanoke River, North Carolina. Transactions of the 23rd North American Wildlife Conference 378-391.

Hatton, S. R. 1940. Progress report on the Central Valley fisheries investigations, 1939. California Fish and Game 26: 334-373.

Hatton, S. R. 1942. Striped bass spawning areas in California. California Fish and Game 28: 65.

Hedgpeth, J. W., and W. E. Mortensen. 1987. San Francisco Bay estuarine circulation and productivity of the estuary for striped bass and other species. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Hearings, Bay Institute Exhibit 47. The Bay Institute of San Francisco, Sausalito, California.

Heubach, W., R. J. Toth, and A. M. McCready. 1963. Food of young-of-the-year striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin river system. California Fish and Game 49: 224-239.

Hopkins, T. E., and J. J. Cech, Jr. 1992. Physiological effects of capturing striped bass in gill nets and fyke traps. Transactions of the American Fisheries Society 121: 819-822.

Horseman, L. O., and J. Kernehan. 1976. An indexed bibliography of the striped bass (*Morone saxatilis*), 1670-1976. Bulletin 13. Ichthyological Associates, Ithaca, New York.

IESP (Interagency Ecological Studies Program). 1993a. IESP Directors briefing statement: Fish Facilities Program. California Department of Water Resources, California Department of Fish and Game, U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, U. S. Geological Survey, U. S. Army Corps of Engineers, and U. S. Environmental Protection Agency.

IESP. 1993b. IESP Directors briefing statement: Fishery/Water Quality Program. California Department of Water Resources, California Department of Fish and Game, U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, U. S. Geological Survey, U. S. Army Corps of Engineers, and U. S. Environmental Protection Agency.

Jackson, H. W., and R. E. Tiller. 1952. Preliminary observations on spawning potential of striped bass, *Roccus saxatilis* (Walbaum). Publication 93. Chesapeake Biological Laboratory.

Johnson, J. H., A. A. Nigro, and R. Temple. 1992. Evaluating enhancement of striped bass in the context of potential predation on anadromous salmonids in Coos Bay, Oregon. North American Journal of Fisheries Management 12: 103-108.

Johnson, W. C., and A. J. Calhoun. 1952. Food habits of California striped bass. California Fish and Game 38: 531-534.

Jung, M., J. A. Whipple, and M. Moser. 1984. Summary report of the Cooperative Striped Bass Study. Institute for Aquatic Resources, Santa Cruz, California.

Kane, A. S., R. O. Bennett, and E. B. May. 1990. Effect of hardness and salinity on survival of striped bass larvae. North American Journal of Fisheries Management 10: 67-71.

Kano, R. M. 1985a. 1984 Clifton Court Forebay evaluations of predation losses to juvenile chinook salmon and striped bass. Memorandum to Clifton Court Forebay Files. California Department of Fish and Game.

Kano, R. M. 1985b. 1985 Clifton Court Forebay evaluation of predation losses to juvenile chinook salmon. Memorandum to Clifton Court Forebay Files. California Department of Fish and Game.

Kano, R. M. 1986. 1986 Evaluation of Clifton Court Forebay losses to juvenile striped bass. Memorandum to Clifton Court Forebay Predation Files. California Department of Fish and Game.

Kaumeyer, K. R., and E. M. Setzler-Hamilton. 1982. Effects of pollutants and water quality on selected estuarine fish and invertebrates: a review of the literature.

Kelley, D. W. 1966. Ecological studies of the Sacramento-San Joaquin Estuary. Part I. Zooplankton, zoobenthos, and fishes of San Pablo and Suisun Bays, zooplankton and zoobenthos of the Delta. Fish Bulletin 133. California Department of Fish and Game.

Kelley, D. W. 1982. The striped bass decline in the San Francisco Bay-Delta estuary. State Water Resources Control Board, Sacramento, California.

Kellogg, R. L., and J. J. Gift. 1983. Relationship between optimum temperatures for growth and preferred temperatures for the young of four fish species. Transactions of the American Fisheries Society 112: 424-430.

Kelly, R., and H. K. Chadwick. 1971. Some observations on striped bass temperature tolerances. Anadromous Fisheries Branch Administrative Report No. 71-9. California Department of Fish and Game.

Kelly, R. O., J. R. Hair, and D. E. Stevens. 1971. *Neomysis awatchensis* Brant distribution in the Sacramento-San Joaquin Delta with regard to physical parameters at Pittsburg and Collinsville. Anadromous Fisheries Branch Administrative Report No. 71-8. California Department of Fish and Game.

Kjelson, M. A., B. Loudermilk, D. Hood, and P. Brandes. 1990. The influence of San Joaquin River inflow, Central Valley and State Water Project exports and migration route on fall-run chinook smolt survival in the southern Delta during the spring of 1989. Supplemental Annual Progress Report. U. S. Fish and Wildlife Service, Fisheries Assistance Office, Stockton, California with California Department of Fish and Game, Region 4, Fresno.

Klar, G. T., and N. C. Parker. 1986. Marking fingerling striped bass and blue tilapia with coded wire tags and Microtaggants. North American Journal of Fisheries Management 6: 439-444.

Klauda, R. J., W. P. Dey, T. P. Hoff, and J. B. McClaren. 1980. Selected aspects of the biology of Hudson River striped bass and prudent speculation on factors influencing juvenile abundance. H. Clepper, editor. Proceedings of the Fifth Annual Marine Recreational Symposium. Sport Fishing Institute.

Knudsen, D. L., and D. W. Kohlhorst. 1987. Striped bass health monitoring. 1985 Final Report No. 4-090-120-0. Prepared for the California State Water Resources Control Board under Interagency Agreement.

Knutson, A. C., Jr., and J. J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp, *Neomysis mercedis*, in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 112: 476-485.

Kohlenstein, L. C. 1980. Aspects of the population dynamics of striped bass (*Morone saxatilis*) spawning in Maryland tributaries of the Chesapeake Bay. Doctoral dissertation. Johns Hopkins University, Baltimore, Maryland.

Kohlhorst, D. 1983. Comparison of adult striped bass survival rates estimated by several methods. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Kohlhorst, D. 1983. Comparison of natural mortality rates of striped bass tagged in the Sacramento River and in the Delta. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Kohlhorst, D. 1983. Trends in striped bass harvest rates. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Kohlhorst, D. W. 1973. An analysis of the annual striped bass die-off in the Sacramento-San Joaquin estuary. Anadromous Fisheries Branch Administrative Report 73-7. California Department of Fish and Game.

Kohlhorst, D. W. 1975. The striped bass (*Morone saxatilis*) die-off in the Sacramento-San Joaquin estuary in 1973 and a comparison of its characteristics with those of the 1971 and 1972 die-offs. Anadromous Fisheries Branch Administrative Report 74-13. California Department of Fish and Game.

Kohlhorst, D. W., D. E. Stevens, and L. W. Miller. 1991. A means of evaluating impacts of alternative outflow and export criteria on striped bass in the Sacramento-San Joaquin Estuary. Draft Report. California Department of Fish and Game, Bay-Delta and Special Water Projects Division, Stockton.

Koo, T. S. Y. 1970. The striped bass fishery in the Atlantic States. Chesapeake Science 11: 73-93.

Korn, S., and R. Earnest. 1974. Acute toxicity of twenty insecticides to striped bass, *Morone saxatilis*. California Fish and Game 60: 128-131.

Kornegay, J. W., and A. W. Mullis. 1984. Investigations into the decline in egg viability and juvenile survival of Albemarle Sound striped bass (*Morone saxatilis*). Project F-22. North Carolina Wildlife Resources Commission, Federal Aid in Fish Restoration, Raleigh, North Carolina.

Krouse, J. S. 1968. Effects of dissolved oxygen, temperature, and salinity on survival of young striped bass, *Roccus saxatilis* (Walbaum). Master's thesis. University of Maine, Orono.

Lal, K., R. Lasker, and A. Kuljis. 1977. Acclimation and rearing of striped bass larvae in seawater. California Fish and Game 63: 210-218.

Leverone, M. F. 1980. Regional management of striped bass. Pages 165-170 *in* H. Clepper, editor. Marine Recreational Fisheries 5: Proceedings of the fifth annual marine recreational fisheries symposium. Sport Fishing Institute, Washington, D. C.

Lewis, R. M., and R. R. Bonner Jr. 1966. Fecundity of the striped bass, *Roccus saxatilis* (Walbaum). Transactions of the American Fisheries Society 95: 328-331.

Loeber, T. S. 1951. A report of the investigation of the temperature and salinity relationships of striped bass (*Roccus saxatilis*) and salmon (*Oncorhynchus tshawytscha*) in connection with the Reber plan. California Department of Fish and Game, Sacramento.

Logan, P. T. 1985. Environmental variation and striped bass population dynamics: a size dependent mortality model. Estuaries 8: 28-38.

Lollock, D. L. 1964. Investigation of San Francisco Bay fish kills during 1964. Unpublished Inland Fisheries Report. California Department of Fish and Game, Region 3.

Low, A. 1986. 1985 striped bass egg and larva survey in the Sacramento-San Joaquin Estuary. California Department of Fish and Game.

MacFarlane, R. B., and P. E. Benville Jr. 1986. Primary and secondary stress responses of striped bass (*Morone saxatilis*) exposed to benzene. Marine Biology 92: 245-254.

MacFarlane, R. B., and J. A. Whipple. 1982. The striped bass (*Morone saxatilis*) as an indicator of water quality in the San Francisco Bay-Delta system. Pages 81-134 *in* M. J. Herz and S. T. McCreary, editors. State of the Bay. Oceanic Society, San Francisco, California.

Mansueti, R. 1958. Eggs, larvae and young of the striped bass, *Roccus saxatilis*. Contribution 112. Maryland Department of Research and Education, Solomans.

Mansueti, R. J. 1961. Age, growth, and movements of the striped bass, *Roccus saxatilis*, taken in size selective fishing gear in Maryland. Chesapeake Science 2: 9-36.

Mansueti, R. J. 1962. Effects of civilization on striped bass and other estuarine biota in Chesapeake Bay and tributaries. Proceedings of the Gulf and Carribean Fisheries Institute 14: 110-136.

Mansueti, R. J., and E. H. Hollis. 1963. Striped bass in Maryland tidewater. Educational Services Report No. 61. Natural Resources Institute, University of Maryland.

Marine, K. R., and Jr. J. J. Cech. 1994. An investigation of the effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile chinook salmon; implications for management of California's Central Valley salmon stocks. Final Report (preliminary) to the Interagency Ecological Studies Program for San Francisco Bay/Delta and the California Department of Water Resources. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis.

Martin, D. F., D. A. Wright, J. C. Means, and E. M. Setzler-Hamilton. 1985. Importance of food supply to nutritional state of larval striped bass in the Potomac River estuary. Transactions of the American Fisheries Society 114: 137-145.

Matthews, W. J., L. G. Hill, D. R. Edds, and F. P. Gelwick. 1989. Influence of water quality and season on habitat use by striped bass in a large southwestern reservoir. Transactions of the American Fisheries Society 118: 243-250.

May, R. C. 1974. Larval mortality in marine fishes and the critical period concept. Pages 3-19 *in* J. H. S. Blaxter, editor. The early life history of fish. Springer-Verlag, New York.

Mazik, P. M., B. A. Simco, and N. C. Parker. 1991. Influence of water hardness and salts on survival and physiological characteristics of striped bass during and after transport. Transactions of the American Fisheries Society 120: 121-126.

McCloskey, L., and V. Stevens. 1980. Striped bass investigations. Report F-15-R. Kansas Fish and Game Commission.

McGie, A. J., and R. E. Mullen. 1979. Age, growth, and population trends of striped bass, *Morone saxatilis* in Oregon. Information Report Series Fisheries 79-8. Oregon Department of Fish and Wildlife, Charleston.

McGovern, J. C., and J. E. Olney. 1988. Potential predation by fish and invertebrates on early life history stages of striped bass in the Pamunkey River, Virginia. Transactions of the American Fisheries Society 117: 152-161.

Mehrle, P. M., T. A. Haines, S. Hamilton, J. L. Ludke, F. L. Mayer, and M. A. Ribick. 1982. Relationship between body contaminants and bone development in East-Coast striped bass. Transactions of the American Fisheries Society 111: 231-241.

Meldrim, J. W., and J. J. Gift. 1971. Temperature preference, avoidance, and shock experiments with estuarine fish. Bulletin 7. Ichthyological Associates, Ithaca, New York.

Meng, L., and J. J. Orsi. 1991. Selective predation by larval striped bass on native and introduced copepods. Transactions of the American Fisheries Society 120: 187-192.

Merriman, D. 1937. Notes on the life history of the striped bass (*Roccus lineatus*). Copeia 1: 15-36.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic coast. U. S. Fish and Wildlife Service Fishery Bulletin 50: 1-77.

Messersmith, J. 1966. Fishes collected in Carquinez Strait in 1961-1962. California Department of Fish and Game Fishery Bulletin 136: 57-63.

Meyer Resources. 1985. The economic value of striped bass, *Morone saxatilis*, chinook salmon, *Oncorhynchus tshawytscha*, and steelhead trout, *Salmo gairdneri*, of the Sacramento and San Joaquin river systems. Anadromous Fisheries Branch Administrative Report 85-03. California Department of Fish and Game.

Meyerhoff, R. D. 1975. Acute toxicity of benzene, a component of crude oil, to juvenile striped bass (*Morone saxatilis*). Journal of the Fisheries Research Board of Canada 32: 1864-1866.

Middaugh, D. P., J. A. Couch, and A. M. Crane. 1977. Chlorine toxicity to eggs and larvae of five Chesapeake Bay fishes. Chesapeake Science 18: 141-153.

Mihursky, J. A., W. R. Boynton, E. M. Setzler-Hamilton, and K. V. Wood. 1981. Freshwater influences on striped bass population dynamics. Report FWS/OBS-81-04. U. S. Fish and Wildlife Service, Office of Biological Services.

Miller, L. 1983. A partial analysis of trophic relationships between chlorophyll *a*, zooplankton, *Neomysis*, and young striped bass in the Sacramento-San Joaquin Estuary. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Miller, L. 1983. Hypothesis: increased Ordram (molinate) use could account for the decline in abundance of striped bass. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Miller, L. W. 1974. Mortality rates for California striped bass (*Morone saxatilis*) from 1965-1971. California Fish and Game 60: 157-171.

Miller, L. W. 1987. Analysis of larval striped bass food habits in the Sacramento-San Joaquin Estuary - 1986. Draft Manuscript. California Department of Fish and Game, Bay-Delta Fishery Project, Stockton.

Miller, L. W., and R. J. McKechnie. 1969. Trends in the striped bass fishery in the Sacramento-San Joaquin Delta from 1959-1965. Anadromous Fisheries Branch, Administrative Report 69-5. California Department of Fish and Game.

Miller, L. W., and J. J. Orsi. 1969. Growth of striped bass (*Morone saxatilis*) in the Sacramento-San Joaquin estuary from 1961-1965. Anadromous Fisheries Branch, Administrative Report 69-6. California Department of Fish and Game.

Miller, P. E., Jr. 1977. Experimental study and modeling of striped bass egg and larval mortality. Doctoral dissertation. John Hopkins University, Baltimore, Maryland.

Moffett, J. W. 1949. The first four years of king salmon maintenance below Shasta Dam, Sacramento River, California. California Fish and Game

Morgan, A. R., and A. R. Gerlach. 1950. Striped bass studies on Coos Bay in 1949 and 1950. Oregon Fish and Game Commission Contribution 14: 1-31.

Morgan, R. P., II, and R. D. Prince. 1978. Chlorine effects on larval development of striped bass (*Morone saxatilis*), white perch (*M. americana*) and blueback herring (*Alosa aestivalis*). Transactions of the American Fisheries Society 107: 636-641.

Morgan, R. P., II, J. Rasin, Jr., and L. A. Noe. 1983. Sediment effects on eggs and larvae of striped bass and white perch. Transactions of the American Fisheries Society 112: 220-224.

Morgan, R. P., II, V. J. Rasin, Jr., and R. L. Copp. 1981. Temperature and salinity effects on development of striped bass eggs and larvae. Transactions of the American Fisheries Society 110: 95-99.

Morgan, R. P., II, R. E. Ulanowicz, and V. J. Rasin, Jr. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis*, and white perch, *M. americana*. Transactions of the American Fisheries Society 105: 149-154.

Moss, J. L. 1985. Summer selection of thermal refuges by striped bass in Alabama reservoirs and tailwaters. Transactions of the American Fisheries Society 114: 77-83.

Moyle, P. B. 1976. Inland fishes of California. First edition. University of California Press, Berkeley.

Neumann, D. A., J. M. O'Connor, and J. A. Sherk Jr. 1981. Oxygen consumption of white perch (*Morone americana*), striped bass (*Morone saxatilis*), and spot (*Leiostomus xanthurus*). Comparative Biochemical Physiology 69A: 467-478.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231: 567-573.

NMFS, (National Marine Fisheries Service). 1990. Endangered and threatened species; winter-run chinook salmon: proposed rule. Federal Register 55 (54): 10260-10267.

Nolte, C. 1990. Delta bass population at record low. San Francisco Chronicle, 4 August, A1,A20.

O'Neil, R. V., R. H. Gardner, S. W. Christensen, W. Van Winkle, J. H. Carney, and J. B. Mankin. 1981. Some effects of parameter uncertainty in density-independent and density-dependent Leslie models for fish populations. Canadian Journal of Fisheries and Aquatic Sciences 38: 91-100.

Odenweller, D. B. 1990. SWP mitigation loss calculation - 1989. Memorandum to H. K. Chadwick, from California Department of Fish and Game, Bay-Delta Project, Stockton.

Odenweller, D. B., and R. L. Brown. 1982. Delta Fish Facilities Program Report through June 30, 1982. Technical Report 6. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Olney, J. E., J. D. Field, and J. C. McGovern. 1991. Striped bass egg mortality, production, and female biomass in Virginia Rivers, 1980-1989. Transactions of the American Fisheries Society 120: 354-367.

Orsi, J. J. 1971. The 1965-1967 migrations of the Sacramento-San Joaquin estuary striped bass population. California Fish and Game 57: 257-267.

Otwell, W. S., and J. V. Merriner. 1975. Survival and growth of juvenile striped bass, *Morone saxatilis*, in a factorial experiment with temperature, salinity, and age. Transactions of the American Fisheries Society 104: 560-566.

Palawski, D., J. B. Hunn, and F. J. Dwyer. 1985. Sensitivity of young striped bass to organic and inorganic contaminants in fresh and saline waters. Transactions of the American Fisheries Society 114: 748-753.

Paterson, A. M. 1989. Evaluating proposed changes in striped bass spawning standards. Prepared for Turlock Irrigation District and Modesto Irrigation District, California.

Paterson, A. M. 1989. Historical notes on striped bass. Prepared for Turlock Irrigation District and Modesto Irrigation District, California.

Paterson, A. M. 1989. Notes on historic spawning locations of striped bass, with emphasis on the San Joaquin River. Revised Draft Report. Prepared for Turlock Irrigation District and Modesto Irrigation District, California.

Paterson, A. M. 1990. Historic spawning locations of striped bass in the Sacramento-San Joaquin Delta. Draft Report. Turlock Irrigation District and Modesto Irrigation District, California.

Pearson, J. C. 1938. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). Bulletin 28. U. S. Department of Commerce, Bureau of Fisheries.

Persons, W. R., and R. V. Bulkley. 1982. Feeding activity and spawning time of striped bass in the Colorado River inlet, Lake Powell, Utah. North American Journal of Fisheries Management 4: 403-408.

Persons, W. R., R. V. Bulkley, and W. R. Noonam. 1981. Movements and feeding of adult striped bass, Colorado River inlet, 1980-81. Utah Cooperative Fishery Research Unit, Logan.

Petit, C. 1991. Bay going downhill, experts say-bass found with bad livers. San Francisco Chronicle, 31 May, A17.

Pfuderer, H. A., S. S. Talmage, B. N. Collier, W. Van Winkle, Jr., and C. P. Goodyear editors. 1975. Striped bass - a selected, annotated bibliography. Environmental Sciences Division Publication No. 615, Contract W-7405-eng-26. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Pickard, A., A. M. Grover, and F. A. Hall, Jr. 1982. An evaluation of predator composition at three locations on the Sacramento River. Technical Report 2. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Polgar, T. T. 1977. Striped bass ichthyoplankton abundance, mortality, and production estimation for the Potomac River population. Pages 110-126 *in* W. Van Winkle, editor. Conference on assessing the effects of power-plant induced mortality on fish population. Pergamon, New York.

Prager, M. H., J. F. O'Brien, and S. B. Saila. 1987. Using lifetime fecundity to compare management strategies: a case history for striped bass. North American Journal of Fisheries Management 7: 403-409.

Price, K. S., D. A. Flemer, J. L. Taft, G. B. Mackiernan, W. Nehlsen, R. B. Biggs, N. H. Burger, and D. A. Blaylock. 1985. Nutrient enrichment of Chesapeake Bay and its impact on the habitat of striped bass: a speculative hypothesis. Transactions of the American Fisheries Society 114: 97-106.

Radovich, J. 1963. Effect of ocean temperature on the seaward movements of striped bass, *Roccus saxatilis*, on the Pacific Coast. California Fish and Game 49: 191-206.

Radtke, L. D. 1966. Distribution of adult and subadult striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. Bulletin No. 136, pages 15-27. California Department of Fish and Game.

Radtke, L. D., and J. L. Turner. 1967. High concentrations of total dissolved solids block spawning migration of striped bass (*Roccus saxatilis*) in the San Joaquin River, California. Transactions of the American Fisheries Society 96: 405-407.

Rago, P. J., and C. P. Goodyear. 1987. Recruitment mechanisms of striped bass and Atlantic salmon: comparative liabilities of alternative life histories. Pages 402-416 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Cooper, editors. Common strategies of anadromous and catadromous fishes: American Fisheries Society Symposium 1. American Fisheries Society, Bethesda, Maryland.

Raney, E. C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bulletin of the Bingham Oceanographic Collection Yale University 14: 19-45, 64-80.

Raquel, P. F. 1987. Estimated entrainment of striped bass eggs and larvae at State Water Project and Central Valley Project facilities in the Sacramento-San Joaquin Delta 1985 and 1986. Technical Report 13. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Raquel, P. F. 1989. Effects of handling and trucking on chinook salmon, striped bass, American shad, steelhead trout, threadfin shad, and white catfish salvaged at the John E. Skinner Delta Fish Protective Facility. Technical Report 19. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Rast, W., and J. E. Sutton. 1989. Use of stable carbon and nitrogen isotopes to trace the larval striped bass food chain in the Sacramento-San Joaquin estuary, California, April to September 1985. Water Resources Investigations Report 88-4164. U. S. Geological Survey, in cooperation with the State Water Resources Control Board, Sacramento, California.

Rathjen, W. F., and L. C. Miller. 1957. Aspects of the early life history of the striped bass (*Roccus saxatilis*) in the Hudson River. New York Fish and Game Journal 4: 43-60.

Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game, Inland Fisheries Division, Sacramento.

Robinson, J. B. 1960. The age and growth of striped bass (*Roccus saxatilis*) in California. California Fish and Game 46: 279-290.

Rochelle, J. M., and C. C. Coutant. 1973. Temperature sensitive ultrasonic fish tag, Q-5099. Report ORNL/TM 4438. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Rogers, B. A., and D. T. Westin. 1975. A bibliography on the biology of the striped bass, *Morone saxatilis* (Walbaum). Marine Technical Report 37. University of Rhode Island, Kingston.

Rogers, B. A., and D. T. Westin. 1981. Laboratory studies on effects of temperature and delayed initial feeding on development of striped bass larvae. Transactions of the American Fisheries Society 110: 100-110.

Rogers, R. D., and D. E. Stevens. 1971. Distribution of young striped bass (Morone saxatilis) in the Sacramento-San Joaquin Delta at Collinsville and Pittsburg. Anadromous Fisheries Branch Administrative Report 71-12. California Department of Fish and Game.

Rogier, C. G., J. J. Ney, and B. J. Turner. 1985. Electrophoretic analysis of genetic variability in a landlocked striped bass population. Transactions of the American Fisheries Society 114: 244-249.

Rulifson, R. A., and III C. S. Manooch. 1990. Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. North American Journal of Fisheries Management 10: 397-407.

Saiki, M. K., M. R. Jennings, and R. H. Wiedmeyer. 1992. Toxicity of agricultural subsurface drainwater from the San Joaquin Valley, California, to juvenile chinook salmon and striped bass. Transactions of the American Fisheries Society 121: 78-93.

Sakanari, J. A., C. A. Reilly, and M. Moser. 1983. Tubercular lesions in Pacific Coast populations of striped bass. Transactions of the American Fisheries Society 112: 565-566.

San Francisco Chronicle. 1992. State plans fewer bass, more salmon. 30 May 1992, A16.

Sasaki, S. 1966. Distribution of juvenile striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. J. L. Turner and D. W. Kelly, editors. Ecological studies of the Sacramento-San Joaquin Delta, part II. Fish Bulletin 136. California Department of Fish and Game,

Sazaki, M., W. Heubach, and J. E. Skinner. 1972. Some preliminary results on the swimming ability and impingement tolerance of young-of-the-year steelhead trout, king salmon and striped bass. Final Report for Anadromous Fisheries Act Project AFS-13. California Department of Fish and Game.

SBWG (Striped Bass Working Group). 1982. The striped bass decline in the San Francisco Bay-Delta Estuary. Prepared for State Water Resources Control Board, Sacramento, California.

Schaffter, R. G. 1978. An evaluation of juvenile king salmon (*Oncorhynchus tshawytscha*) loss in Clifton Court Forebay. Anadromous Fisheries Branch, Administrative Report 78-21. California Department of Fish and Game.

Schaich, B. A., and C. C. Coutant. 1980. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. Report ORNL/TM-7127. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Schubart, B. J., and T. S. Y. Koo. 1973. Sex differentiation in juvenile striped bass, *Morone saxatilis*. Proceedings of a workshop on egg, larval, and juvenile stages of fish in Atlantic coast estuaries. Middle Atlantic Coastal Fisheries Center, National Oceanic and Atmospheric Administration.

Schubel, J. R., and J. C. S. Wang. 1973. The effects of suspended sediment on the hatching success of *Perca flavescens* (yellow perch), *Morone americana* (white perch), *Morone saxatilis* (striped bass), and *Alosa psuedoharengus* (alewife) eggs. Special Report 30, Reference 73-3. Johns Hopkins University, Chesapeake Bay Institute, Baltimore, Maryland.

Scofield, E. C. 1931. The striped bass of California (*Roccus lineatus)*. Fish Bulletin 29. California Division of Fish and Game.

Scofield, N. B. 1910. Notes on the striped bass in California. Pages 104-109 *in* 21st Biennial Report, Board of Fish and Game Commissioners of California for 1909-1910, Sacramento.

Scofield, N. B., and H. C. Bryant. 1926. The striped bass in California. California Fish and Game 12: 52-74.

Secor, D. H., M. G. White, and J. M. Dean. 1991. Immersion marking of larval and juvenile hatchery-produced striped bass with oxytetracycline. Transactions of the American Fisheries Society 120: 261-266.

Setzler-Hamilton, E. M., W. R. Boynton, J. A. Mihursky, T. T. Polgar, and K. V. Wood. 1981. Spatial and temporal distribution of striped bass eggs, larvae, and juveniles in the Potomac estuary. Transactions of the American Fisheries Society 110: 121-136.

Setzler-Hamilton, E. M., W. R. Boynton, K. V. Wood, H. H. Zion, and L. Lubbers. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). Technical Report 433. National Marine Fisheries Service.

Setzler-Hamilton, E. M., J. A. Mihursky, W. R. Boynton, K. V. Wood, G. E. Drewry, and T. T. Polgar. 1980. Striped bass spawning and egg and larval stages. Pages 89-99 *in* H. Clepper, editor. Marine Recreational Fisheries 5: Proceedings of the fifth annual marine recreational fisheries symposium. Sport Fishing Institute, Washington, D. C.

Setzler-Hamilton, E. M., D. A. Wright, F. D. Martin, C. V. Millsaps, and S. I. Whitlow. 1987. Analysis of nutritional condition and its use in predicting striped bass recruitment: field studies. American Fisheries Society Symposium 2: 115-128.

Shannon, E. H., and W. B. Smith. 1967. Preliminary observations of the effect of temperature on striped bass eggs and sac fry. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 21: 257-260.

Shapovalov, L. 1936. Food of the striped bass. California Fish and Game 22: 261-271.

Silvey, W. D., and G. A. Irvwin. 1969. Relation of water quality to striped bass mortalities in the Carquinez Strait of California. Open-File Report 3016-01. U. S. Geological Survey, Water Resources Division, Menlo Park, California.

Sitts, R. M. 1983a. Entrainment impacts on young striped bass of combined operation of southern Delta export facilities over the years 1959-1981. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M. 1983b. Increased secondary waste treatment as the cause of the striped bass decline. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M. 1983c. Monthly flows in the Delta as indicators of residence time, a potential cause of the striped bass decline. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M. 1983d. Recommended courses of Board action to fight the decline in striped bass. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M. 1983e. Striped bass entrainment at Delta water diversion intakes. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M., and C. H. Hanson. 1983a. Conclusions and recommendations on entrainment and point-source organic wastes. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Sitts, R. M., and C. H. Hanson. 1983b. Entrainment and the loss of small bass by diversions. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Skinner, J. E. 1974. A functional evaluation of a large louver screen installation and fish facilities research on California water diversion projects. L. D. Jensen, editor. Proceedings of the second entrainment and intake screening workshop. The Johns Hopkins University Cooling Water Research Project, Report Number 15. Johns Hopkins University, Baltimore, Maryland.

Smith, R. E., and R. J. Kernehan. 1981. Predation by the free-living copepod, *Cyclops bicuspidatus thomasi*, on larvae of the striped bass and white perch. Estuaries 4: 81-83.

Sommani, P. 1972. A study on the population dynamics of striped bass *Morone saxatilis* (Walbaum) in the San Francisco Bay estuary. Doctoral dissertation. University of Washington, Seattle.

Spaar, S. 1988. Estimated entrainment of striped bass eggs and larvae at the State Water and Central Valley Project facilities in the Sacramento-San Joaquin Delta, 1988. Special Report. California Department of Water Resources, Sacramento.

Sport Fishing Institute. 1980. Striped bass temperature preference. Bulletin No. 315.

Stern, E. M., and W. B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Literature review. Technical Report D-78-21. U. S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Stevens, D. 1983a. Decline in striped bass due to competition from threadfin shad? Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Stevens, D. 1983b. Increased predation responsible for decline in young striped bass? Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Stevens, D. 1983c. Recent trends in water transparency in the Sacramento-San Joaquin Delta. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Stevens, D. 1983d. Relationships between abundance and survival of young striped bass and crustacean zooplankton densities in the striped bass nursery area. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Stevens, D. E. 1967. Food habits of striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. Pages 68-96 *in* J. L. Turner and D. W. Kelley, editors. Ecological studies of the Sacramento-San Joaquin Delta, Part II. Fish Bulletin 136. California Department of Fish and Game.

Stevens, D. E. 1977. Striped bass (*Morone saxatilis*) monitoring techniques in the Sacramento-San Joaquin Estuary. Pages 68-96 in W. Van Winkle, editor. Proceedings of the conference on assessing the effects of power-plant induced mortality on fish populations. Pergamon, New York.

Stevens, D. E. 1977. Striped bass (*Morone saxatilis*) year class strength in relation to river flow in the Sacramento-San Joaquin estuary, California. Transactions of the American Fisheries Society 106: 34-42.

Stevens, D. E. 1980. Factors affecting the striped bass fisheries of the West Coast. Pages 15-28 *in* H. Clepper, editor. Marine Recreational Fisheries 5: Proceedings of the fifth annual marine recreational fisheries symposium. Sport Fishing Institute, Washington, D.C.

Stevens, D. E., H. K. Chadwick, and R. E. Painter. 1987. American shad and striped bass in California's Sacramento-San Joaquin river system. Pages 66-78 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Cooper, editors. Common strategies of anadromous and catadromous fishes: American Fisheries Society Symposium 1. American Fisheries Society, Bethesda, Maryland.

Stevens, D. E., and B. J. Finlayson. 1978. Mortality of young striped bass entrained at two power plants in the Sacramento-San Joaquin Delta, California. Pages 57-69 *in* L. D. Jensen, editor. Fourth national workshop on entrainment and impingement. EA Communications, Melville, New York.

Stevens, D. E., M. A. Kjelson, and P. L. Brandes. n. d. An evaluation of the relationship between survival of chinook salmon smolts and river flow in the Sacramento-San Joaquin Delta. Unknown report, Appendix A. California Department of Fish and Game.

Stevens, D. E., D. W. Kohlhorst, L. W. Miller, and D. W. Kelley. 1985. The decline of striped bass in the Sacramento-San Joaquin estuary, California. Transactions of the American Fisheries Society 114: 12-30.

SWC (State Water Contractors). 1991. Sacramento-San Joaquin striped bass: development and evaluation of protection alternatives. San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality/Water Rights Hearings, Environmental Impact Report Scoping Phase Exhibit 706. SWC, Sacramento, California.

SWRCB (State Water Resources Control Board). 1980. First Progress Report on the Cooperative Striped Bass Study (COSBS). Special Projects Report 8010-1. SWRCB, Sacramento, California.

SWRCB. 1981. Second Progress Report on the Cooperative Striped Bass Study (COSBS). Special Projects Report. SWRCB, Sacramento, California.

SWRCB. 1985. Acute toxicity of rice herbicides to *Neomysis mercedis*; chronic toxicity of rice herbicides to *Neomysis mercedis*. International Project No. LSU-7578. Stanford Research Institute, Menlo Park, California.

SWRCB. 1987. Regulation of agricultural drainage to the San Joaquin River. Draft Technical Committee Report, Order No. WQ85-1. SWRCB, Sacramento, California.

SWRCB. 1991. Water quality control plan for salinity: San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Report 91-15 WR. SWRCB, Bay-Delta Section Division of Water Rights, Sacramento, California.

SWRCB. 1992. Decision establishing terms and conditions for interim protection of public trust uses of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Draft Water Right Decision 1630. SWRCB, Sacramento, California.

SWRCB. 1993. Decision establishing terms and conditions for interim protection of public trust uses of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Draft Water Right Decision 1630. SWRCB, Sacramento, California.

Tagatz, M. E. 1961. Tolerance of striped bass and American shad to changes in temperature and salinity. Special Scientific Report - Fisheries 388. U. S. Fish and Wildlife Service.

Talbot, G. B. 1966. Estuarine environmental requirements and limiting factors for striped bass. Special Publication 3: 37-49. American Fisheries Society, Bethesda, Maryland.

Talbot, G. E. 1967. Teratological notes on striped bass (*Roccus saxatilis*) of San Francisco Bay. Copeia 1967: 459-461.

Thomas, J. L. 1967. The diet of juvenile and adult striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin river system. California Fish and Game 53: 49-62.

Thompson, K. W., L. A. Knight, Jr., and N. C. Parker. 1986. Color-coded flourescent plastic chips for marking small fishes. Copeia 1986: 544-546.

Tresselt, E. F. 1952. Spawning grounds of the striped bass or rock, *Roccus saxatilis* (Walbaum), in Virginia. Bulletin of the Bingham Oceanographic Collection 14: 98-110.

Tsai, C.-F., M. Wiley, and A.-L. Chai. 1991. Rise and fall of the Potomac River striped bass stock: a hypothesis of the role of sewage. Transactions of the American Fisheries Society 120: 1-22.

Ture, M. 1985. The case of the vanishing striper. The East Bay Express, 22 November 1985, 1-16.

Turner, J. 1990. Observations on the time, location, and possible factors determining the size of the young bass index in the Sacramento-San Joaquin Estuary. Draft Report for the Food Chain Committee. U. S. Bureau of Reclamation.

Turner, J., and D. Kelley. 1966. Ecological studies of the Sacramento-San Joaquin Delta. Part II. Fish Bulletin 136. California Department of Fish and Game.

Turner, J. L. 1976. Striped bass spawning in the Sacramento and San Joaquin rivers in central California from 1963-1972. California Fish and Game 62: 106-118.

Turner, J. L. 1983. Chlorophyll *a* and *Neomysis* concentration in the Suisun Bay/Delta from 1970 to 1980. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Turner, J. L. 1983. Possible sudden decline in adult striped bass population of the Delta-San Francisco Bay Estuary based on Petersen tagging results. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Turner, J. L., and H. K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 101: 422-452.

Turner, J. L., and T. C. Farley. 1971. Effects of temperature, salinity, and dissolved oxygen on the survival of striped bass eggs and larvae. California Fish and Game 57: 268-273.

Ulanowicz, R. E., and T. T. Polgar. 1980. Influences of anadromous spawning behavior and optimal environmental conditions upon striped bass (*Morone saxatilis*) year-class success. Canadian Journal of Fisheries and Aquatic Sciences 37: 143-154.

Uphoff, J. H., Jr. 1989. Environmental effects on survival of eggs, larvae, and juveniles of striped bass in the Choptank River, Maryland. Transactions of the American Fisheries Society 118: 251-263.

Urquhart, K., and D. Knudsen. 1987. Striped bass health monitoring. Final Report for Interagency Agreement 6-170-300-0. California Department of Fish and Game.

USBR (U. S. Bureau of Reclamation). 1983. Predation of anadromous fish in the Sacramento River, California. Central Valley Fish and Wildlife Management Study. Special Report. USBR, Mid-Pacific Region, Sacramento, California.

USBR. 1990. Continuous monitoring of striped bass eggs and larvae in the San Francisco Bay-Delta Estuary: a potential management tool. Report MP-780, ENV-4.0. USBR, Mid-Pacific Region, Sacramento, California.

USBR. 1992. Agreement between U. S. Bureau of Reclamation and the California Department of Fish and Game to reduce and offset direct fish losses associated with the operation of the Tracy Pumping Plant and the Tracy Fish Collection Facility. WRINT-USBR-Exhibit No. 32.

USBR and USFWS (U. S. Bureau of Reclamation and U. S. Fish and Wildlife Service). 1957. Fish protection at the Tracy pumping plant, Central Valley Project, California. USBR, Region 2, Sacramento, California and USFWS, Region 1, Portland, Oregon.

USFWS (U. S. Fish and Wildlife Service). 1982. Regional Resource Plan, Region 1. Volume IV - Fishery resources section. USFWS, Region 1, Portland, Oregon.

USFWS. 1993. Central Valley Project Improvement Act: plan of action for the Central Valley anadromous fish restoration program. Draft Report. USFWS, Sacramento, California.

USFWS and NOAA (U. S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration). 1984. Emergency striped bass research study, report for 1982-1983. USFWS and NOAA, Washington, D.C.

Vladykov, V. D. 1952. Studies of the striped bass, *Roccus saxatilis* (Walbaum) with special reference to the Chesapeake Bay region during 1936-1938. Bulletin of the Bingham Oceanographic Collection, Yale University 14: 132-177.

von Geldern, C., and D. F. Mitchell. 1975. Largemouth bass and threadfin shad in California. Pages 436-449 *in* R. H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, D. C.

Waddle, H. R., C. C. Coutant, and J. H. Wilson. 1980. Summer habitat selection by striped bass, *Morone saxatilis*, in Cherokee Reservoir, Tennessee, 1977. Report ORNL/TM-6927. Oak Ridge National Laboratory, Oak Ridge, Tennesee.

Welborn, T. L., Jr. 1971. Toxicity of some compounds to striped bass fingerlings. The Progressive Fish-Culturist 33: 32-36.

Westin, D. T., C. E. Olney, and B. A. Rogers. 1983. Effects of parental and dietary PCBs on survival, growth, and body burdens of larval striped bass. Bulletin of Environmental Contamination and Toxicology 30: 50-57.

Westin, D. T., C. E. Olney, and B. A. Rogers. 1985. Effects of parental and dietary organochlorines on survival and body burdens of striped bass larvae. Transactions of the American Fisheries Society 114: 125-136.

Westin, D. T., and B. A. Rogers. 1978. Synopsis of biological data on the striped bass, *Morone saxatilis* (Walbaum) 1972. Marine Technical Report 67. University of Rhode Island, Kingston.

Whipple, J., M. Eldridge, P. Benville, M. Bowers, B. Jarvis, and N. Stapp. 1980. The effect of inherent parental factors on gamete condition and viability in striped bass *Morone saxatilis*. *In*. K. Sherman and R. Lasker, editors. Early life history of fish. Springer-Verlag, New York.

Whipple, J. A. 1979. The impact of estuarine degradation and chronic pollution on populations of anadromous striped bass *Morone saxatilis* in San Francisco Bay-Delta, California. Project Summary. National Marine Fisheries Service, Tiburon Laboratory, Tiburon, California.

Whipple, J. A. 1982. Impacts of pollutants on striped bass in the San Francisco Bay-Delta, California. Project Summary. National Marine Fisheries Service, Tiburon Laboratory, Tiburon, California.

Whipple, J. A., D. G. Crosby, and M. Jung. 1983. Third Progress Report: Cooperative Striped Bass Study. Special Projects Report 83-3SP. State Water Resources Control Board, Sacramento, California.

White, J. R. 1986. The striped bass sport fishery in the Sacramento-San Joaquin Estuary, 1969-1979. California Fish and Game 72: 17-37.

Wirgin, I. I., C. Grunwald, S. J. Garte, and C. Mesing. 1991. Use of DNA fingerprinting in the identification and management of a striped bass population in the southeastern United States. Transactions of the American Fisheries Society 120: 273-282.

Woiwode, J. G., and I. R. Adelman. 1991. Effects of temperature, photoperiod, and ration size on growth of hybrid striped bass x white bass. Transactions of the American Fisheries Society 120: 217-229.

Woodhull, C. 1947. Spawning habits of the striped bass (*Roccus saxatilis*) in California waters. California Fish and Game 33: 97-102.

Wooley, C. M., and E. J. Crateau. 1983. Biology, population estimates, and movement of native and introduced striped bass, Apalachicola River, Florida. North American Journal of Fisheries Management 3: 383-394.

Wright, D. A., and F. D. Martin. 1985. The effect of starvation on RNA:DNA ratios and growth of larval striped bass, *Morone saxatilis*. Journal of Fish Biology 27: 479-485.

Yocom, T. G., and R. S. C. Wolcott, Jr. 1983. The condition of adult striped bass in the Bay-Delta Estuary. Working Paper. Striped Bass Working Group, State Water Resources Control Board, Sacramento, California.

Zale, A. V., J. D. Weichman, R. L. Lochmiller, and J. Burroughs. 1990. Limnological conditions associated with summer mortality of striped bass in Keystone Reservoir, Oklahoma. Transactions of the American Fisheries Society 119: 72-76.

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

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February 13, 1990

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

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

> Captain Lambson, in company with our Chief Deputy, made an extended trip through those sections from which the largest number of spawning fish are shipped to market. Several points near the mouth of the San Joaquin and Sacramento rivers were inspected, and Bouldin Island in San Joaquin

> County has been selected as the best point at which to establish an experiment station. In the month of May the spawning fish are captured there in large numbers. (Ca. Bd. of Fish Commissioners, 1907, p. 41)

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

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

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

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

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

A major striped bass research project was begun by Eugene C. Scofield in

1925, with the results published as Fish Bulletin No. 29 in 1931. Scofield described the Delta islands and explained how they were sometimes flooded. Based on his research he concluded that,

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

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

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

Striped bass spawning could be indicated by the presence of ripe fish, floating eggs or the appearance of a spawning activity known as a "rock fight" in which the fish would appear at the surface agitated and splashing. The latter activity formed the basis of reports that on May 11, 1943 bass were spawning at the mouth of Middle River and in the lower five miles of the Mokelumne River. On May 5, 1944 wardens observed spawning at Fisherman's Cut. On May 6, 1946 a rock fight was observed near Venice Island in the Mandeville Reach of the San Joaquin River. (Woodhull, 1947, pp. 98-99)

Reports of "rock fights" were, like previous indications of spawning location, restricted mainly to the western and central portion of the Delta and the Mokelumne River. However it was believed that striped bass spawned much farther up the San Joaquin River. Woodhull reported that fish in spawning condition had been found as far upstream as the town of Patterson and that he himself had found ripe bass at San Joaquin City [near Durham Ferry Bridge] in April 1946. (Woodhull, 1947, pp. 98-99) A 1948 progress report on striped bass studies said:

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

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

In 1948, two-thirds of the eggs collected were taken in a single sample at the station on Middle River above Empire Cut. The remaining eggs were widely distributed in the San Joaquin Delta, with very few at the Sacramento or Mokelumne sites. The main stem of the San Joaquin River above Venice Island accounted for about ten percent of the eggs collected that year, but no eggs were collected between Venice Island and Stockton. (Erkkila, et.al., l950, p. 64)

The distribution of eggs was different in l949. Almost half the eggs came from the Antioch Bridge station and over two-thirds were collected between that site and San Andreas Landing. As in the previous year, less than ten percent of the total came from the San Joaquin River above Venice Island and only a single egg was taken between Venice Island and Stockton. (Erkkila, et.al., l950, p. 70) The study report concluded:

> Assuming that the number of eggs recovered from week to week in the San Joaquin Delta is an index of spawning intensity, it is evident that the initial spawning was heaviest in the southern and central portion of the Delta, with a gradual shift to the western or lower San Joaquin River portion. Very few eggs were taken at stations located in Sacramento and Mokelumne Rivers. As in l948, the most productive area was the San Joaquin River from the mouth of Old River to Antioch. (Erkkila, 1950, p. 25)

On the basis of later studies (see Radtke and Turner, l967), it has been assumed that striped bass do not prefer to migrate through salinities higher than 350 mg/l or spawn in salinities higher than l80 mg/l TDS. Monthly average TDS at Vernalis was lower than 350 mg/l in April and under l80 mg/l during May in both l948 and l949. (SDWA, l987)

Confirmation of the pattern of spawning locations came from the recoveries of tagged striped bass in l950-5l. Reporting on "Annual Migrations of California Striped Bass" in l952, A.J. Calhoun noted that his Figure 6, "Recoveries During April," was "of particular interest because it illustrates the spreading out of the striped bass into the remoter sections of the Delta and its tributary rivers to spawn." (Calhoun, l952, p. 394) Several tagged fish were recovered near Antioch Bridge and Big Break and the largest group appeared to be from Three Mile Slough to Venice Island. Several more fish were collected in the main river and Middle River around Medford and McDonald Islands and some south of Franks Tract in Old River. The scale of the map makes further identification difficult, but it appears to confirm that spawning was centered in the western and central Delta from Venice Island to Anitoch and a short distance up Middle River and Old River. Figure 7, showing recoveries from May l to June l5 showed almost all the fish scattered in the main channel from Venice Island to Suisun Bay.

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

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

The hypothesis that salinity could block spawning migrations was further investigated in 1966 in the San Joaquin River from Venice Island to near Stockton. This was an area where substantial spawning had never been reported. The authors themselves admitted that, "In the past, very little spawning has occurred in our study area" and "the run of striped bass above Stockton is small even under ideal conditions." (Radtke and Turner, 1967, pp. 406-407) Five stations were monitored from March 21 to May 31, although few bass were caught before mid-April. Bass were found in the greatest abundance at salinities from 250 to 300 ppm TDS and never above 350 ppm TDS. Eggs were found in salinities under 150 ppm TDS, apparently confirming the earlier conclusion that no serious spawning took place above 180 ppm TDS. (Radke and Turner, 1967) This study became the basis for subsequent descriptions of striped bass spawning preferences. (for example see Ca. Dept.

of Fish and Game, I987, p. 44)

While the limits of spawning salinity were presumably established in I967, bass have been known to spawn in higher salinities since that time. "In I968, substantial spawning occurred in salinities up to 600 mg/l TDS." (Ca. Dept. of Fish and Game, I972, p. 36) Another dry year occurred in I972, with similar results:

> In I968 and even more so in I972, salinities increased in the western part of the spawning area but bass still spawned in essentially the same place. Thus in I972, approximately 45% of the eggs taken in our sampling were collected at salinities between 500 and I,000 mg/l TDS and another 25% at salinities between I,000 and I,500 mg/l TDS. The proportion of dead eggs in our samples was essentially equal in all salinities, suggesting that salinity did not affect the survival of eggs. While these results indicate less dependence on salinity than initially thought, they are not sufficient to evaluate the effects of consistent salinity intrusion of the magnitude experienced during spawning in I972. (Ca. Depts. of Fish and Game and Water Resources, et. al., I973, p. 9)

Considerable data was collected between I963 and I972 showing the location of spawning and the percentage of eggs spawned in various salinities. On the average, from I966 to I972, about two-thirds of the spawning occurred in the ten-mile stretch of the river upstream from Antioch in the western Delta. Over I2 percent was downstream from Antioch with the remainder from about False River to Venice Island. (Turner, I976, p. II3) As noted above, there was a tendency to return to the same spawning area even in the face of less-than-ideal salinity conditions. Although there was evidence that in some years spawning could occur farther upstream, DFG collected eggs only between Martinez and the Venice Island area. This sampling program was continued, with subsequent years showing results similar to those reported in Turner's I976 report. (see Ca. Dept. of Fish and Game, I987, pp. 44-46)

CONCLUSION

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

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

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

REFERENCES

Calhoun, A.J., 1952, Annual Migrations of California Striped Bass. California Fish and Game 38: 391-403

Calhoun, A.J. and C.A. Woodhull. 1948. Progress Report on Studies of Striped Bass Reproduction in Relation to the Central Valley Project. California Fish and Game 34: 171-188

California Board of Fish Commissioners, 1907, Nineteenth Biennial Report

California Department of Fish and Game. 1972. Ecological Studies of the Sacramento-San Joaquin Estuary: A Decenniel Report, 1961-71 (J.E. Skinner, comp.). Delta Fish and Wildlife Protection Study, Report No. 8.

California Department of Fish and Game. 1987. Factors Affecting Striped Bass Abundance in the Sacramento-San Joaquin River System. Bay-Delta Hearings Exhibit 25

California Departments of Fish and Game and Water Resources, U.S. Bureaus of Sport Fisheries and Wildlife and Reclamation. 1973. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Second Annual Report.

Chadwick, H.K. 1967. Recent Migrations of the Sacramento-San Joaquin River Striped Bass Population. Transactions of the American Fisheries Society 96: 327-342.

Erkkila, L.F., J.W. Moffett, O.B. Cope, B.R. Smith, and R.S. Nielson. 1950. Sacramento-San Joaquin Delta Fishery Resources: Effects of Tracy Pumping Plant and Delta Cross Channel. U.S. Fish and Wildlife Service, Special Scientific Report, Fisheries No. 56. 109 pp.

Farley, T.C. 1966. Striped Bass, Roccus Saxatilis, Spawning in the Sacramento-San Joaquin River Systems during 1963-1964. in Ecological Studies of the Sacramento-San Joaquin Delta, Part II (J.L. Turner and D.W. Kelley, comp.), pp. 28-43. California Department of Fish and Game Bull. 136.

Hatton, S.R. 1940. Progress Report on the Central Valley Fisheries Investigations, 1939. California Fish and Game 26: 334-373

Hatton, S.R. 1942. Striped Bass Spawning Areas in California. California Fish and Game, 28: 65.

Radtke, L.D. and J.L. Turner. 1967. High Concentrations of Total Dissolved Solids Block Spawning Migration of Striped Bass (Roccus Saxatilis) in the San Joaquin River, California. Transactions of the American Fisheries Society 96: 405-407.

Scofield, E.C. 1931. The Striped Bass of California (Roccus Lineatus). California Division of Fish and Game, Fish Bulletin No. 29.

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

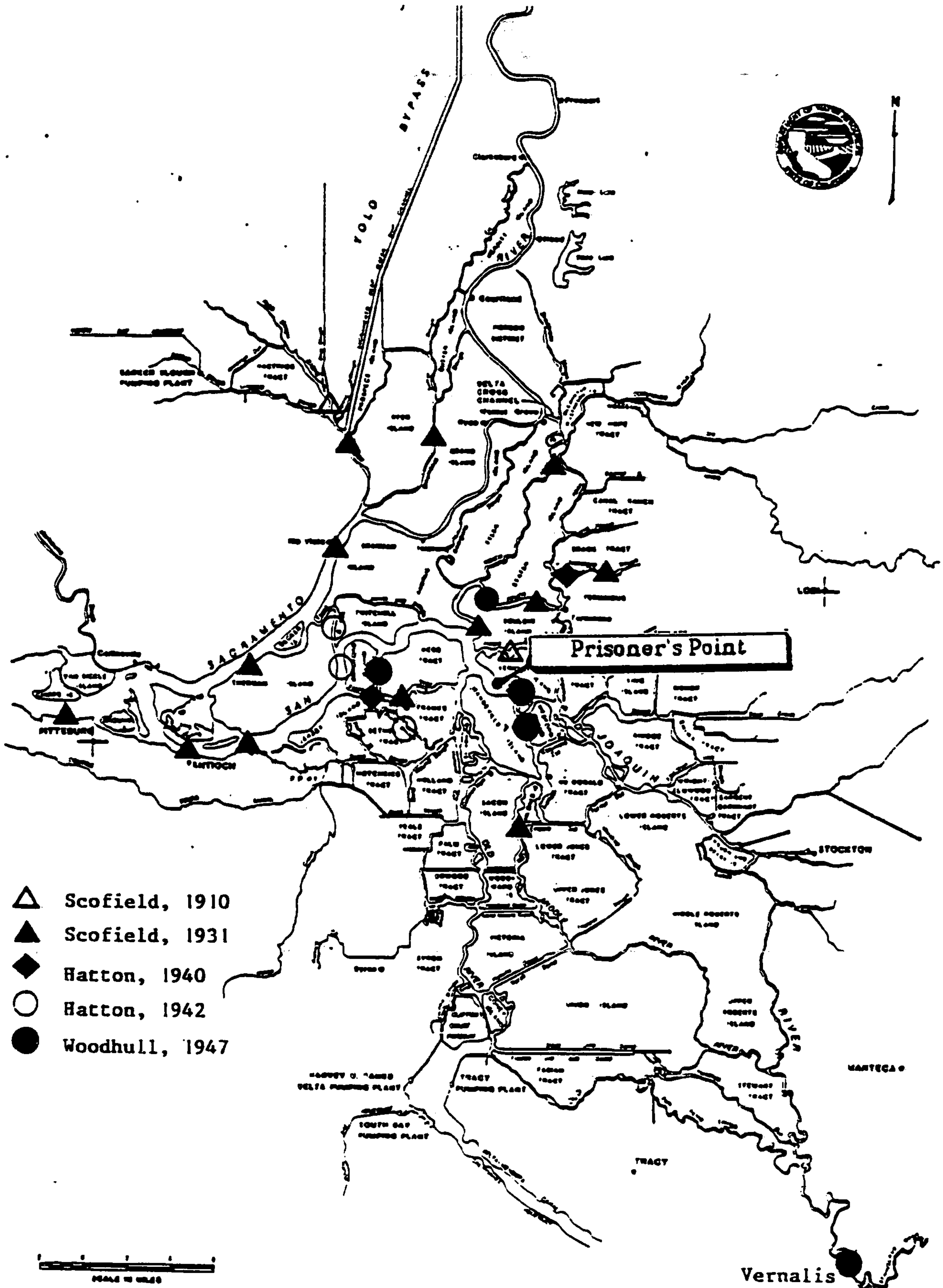
Scofield, N.B. and H.C. Bryant. 1926. The Striped Bass in California. California Fish and Game 12: 55-74.

South Delta Water Agency, 1987, Exhibit 40, "Mean Monthly Total Dissolved Solids, Mg/Liter, San Joaquin River at Vernalis, 1930-1986"

Turner, Jerry L. 1976. Striped Bass Spawning in the Sacramento and San Joaquin Rivers in Central California from 1963 to 1972. California Fish and Game 62: 106-118.

Woodhull, C.A. 1947. Spawning Habits of the Striped Bass (Roccus Sacatilis) in California Waters. California Fish and Game 33: 97-102.

REPORTED STRIPED BASS SPAWNING LOCATIONS IN THE SACRAMENTO-SAN JOAQUIN DELTA, 1903-1946



Base Map by DWR

MIGRATORY RESPONSE OF JUVENILE CHINOOK TO PULSES IN FLOW

Comments by *Steven P. Cramer*

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

1. Overview

2. Stanislaus Experience
   - Description of Sampling
     - Rotary-Screw Trap, April 21 - June 29, 1993 near Oakdale
   - Flows
     - Regulated pulses of 1,500 for 17 and 13 days
     - Earlier flow spikes before sampling began
   - Juvenile Chinook catches
     - Efficiency was 1/2 of percentage flow sampled
     - Expanded catches peaked first day of 1500 cfs
   - Conclusions
     - Some juvenile chinook were stimulated to migrate almost immediately by increased flows, but sustained high flows did little to stimulate migration after the initial migration spike. There was no indication that the sustained high flows "flushed" juvenile chinook out of the river. Mean lengths of fish captured throughout the season indicated that chinook were stimulated to migrate as they reach a threshold size.
   - Observations Consistent with Other Rivers
   - Final Report Complete by mid November

3. Recommendations

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

> *"Flow-induced stimulation of passage is especially pronounced when it occurs on the heels of a number of days of declining flows. Interestingly, the peak of the migratory response to increased flows usually occurs before the discharge peak."*
>
> *"Inspection of daily passage and flow data has revealed that consecutive days of declining, or even stable, flows are usually associated with declining outmigration rates. It should be noted that descending flows stall passage, even when absolute discharge during the decline remains relatively high. During such periods, smolts accumulate somewhere between Sunnyside and Prosser dams, and are subject to longer periods of vulnerability to predators."*
>
> *"Stalled migrations are stimulated by rapid increases in flow. The increase need not be especially large, but should be abrupt; gradual increases do not evoke a sharp response in passage. An analysis of natural flow pulses gauged below Sunnyside Dam indicates the "minimal stimulated pulse" should be about 20% of the pre-pulse "base flow," and that the pulse should occur over no more that two days."*

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

The relatively slow change in the mean lengths of chinook we captured is consistent with the widely observed phenomena that juvenile chinook are stimulated to migrate as they reach a threshold size (Figure 9). Smolting generally occurs when juvenile chinook are 80 to 100 mm long. The outmigration of fish when they reach this size range continuously removes the largest fish in the population and causes the mean length of the population to increase slower than the actual growth rate.

These findings indicate that the response of juvenile chinook to pulses in flow is modulated by their own physiological readiness to migrate. The physiological process of smolting in juvenile chinook peaks at a consistent time of year for the population as a whole, but there can be several months of variation between individuals in the time that they reach physiological readiness to migrate. We conclude that individual fish which are physiologically ready to migrate will respond to the stimulus of a sharp increase in flow, while the remainder of the population will not. This being the case, periodic pulses in flow, perhaps two weeks apart, which allowed time between flow pulses for additional fish to reach physiological readiness to migrate, should be more effective at stimulating outmigration than a constant high flow. However, it remains to be determined what level of increased survival of smolts would be achieved by such a scenario.

RECOMMENDATIONS

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

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

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

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

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

REFERENCES

Cramer, Steven P.,Satterwaite, T., Boyce, R., and McPherson, B. 1985. Impacts of Lost Creek Dam on the biology of anadromous salmonids in the Rogue River. Submitted to U.S. Army Corps of Engineers.

Fast, D., Huble, J., Kohn, M., and Watson, B. 1991. Yakima river spring chinook enhancement study. Yakima Indian Nation Fisheries Resource Management, Final Report, May 1991. Prepared for U.S. Department of Energy, Bonneville Power Administration. Project No. 82-16.

EFFECTS OF PULSE FLOWS ON JUVENILE CHINOOK MIGRATION IN THE STANISLAUS RIVER

DRAFT REPORT

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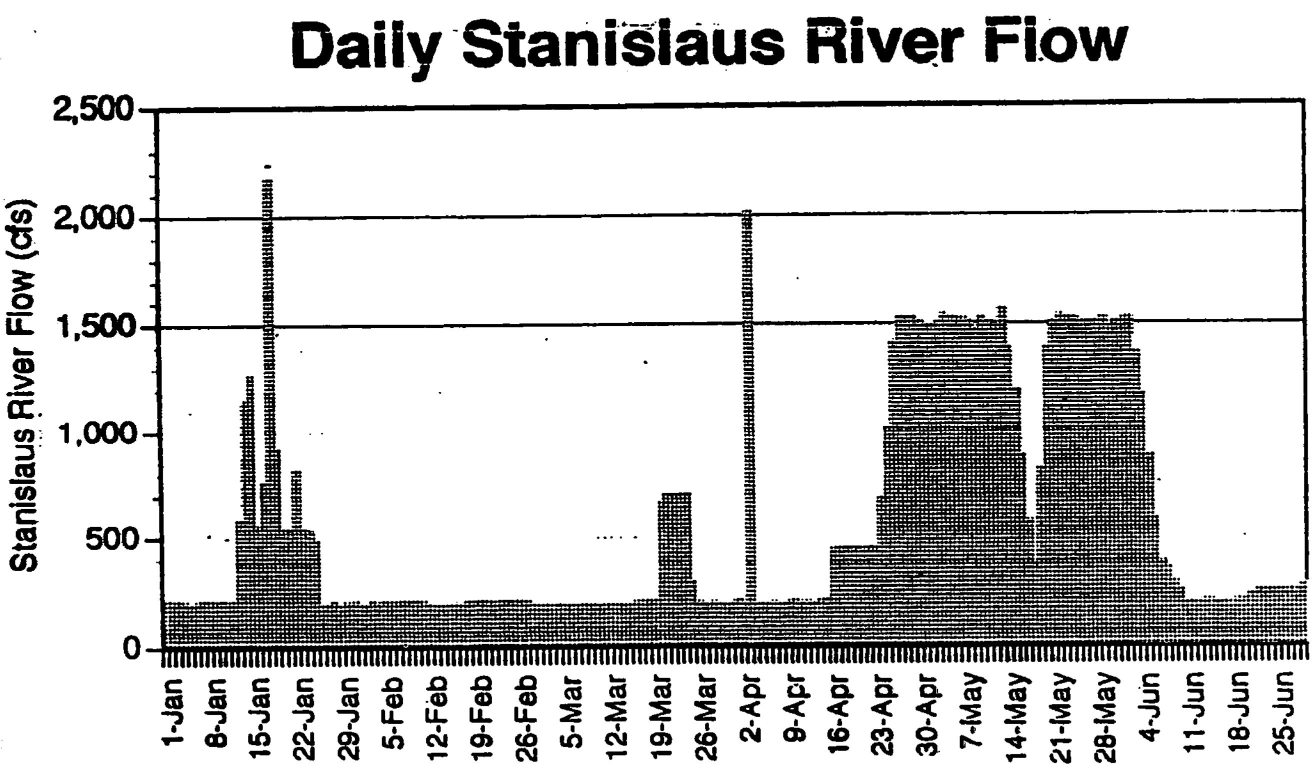


Figure 8. **Graph of daily Stanislaus River flow showing periods of high flow when we were not sampling.** High flows in March and early April may have moved many juveniles downstream.

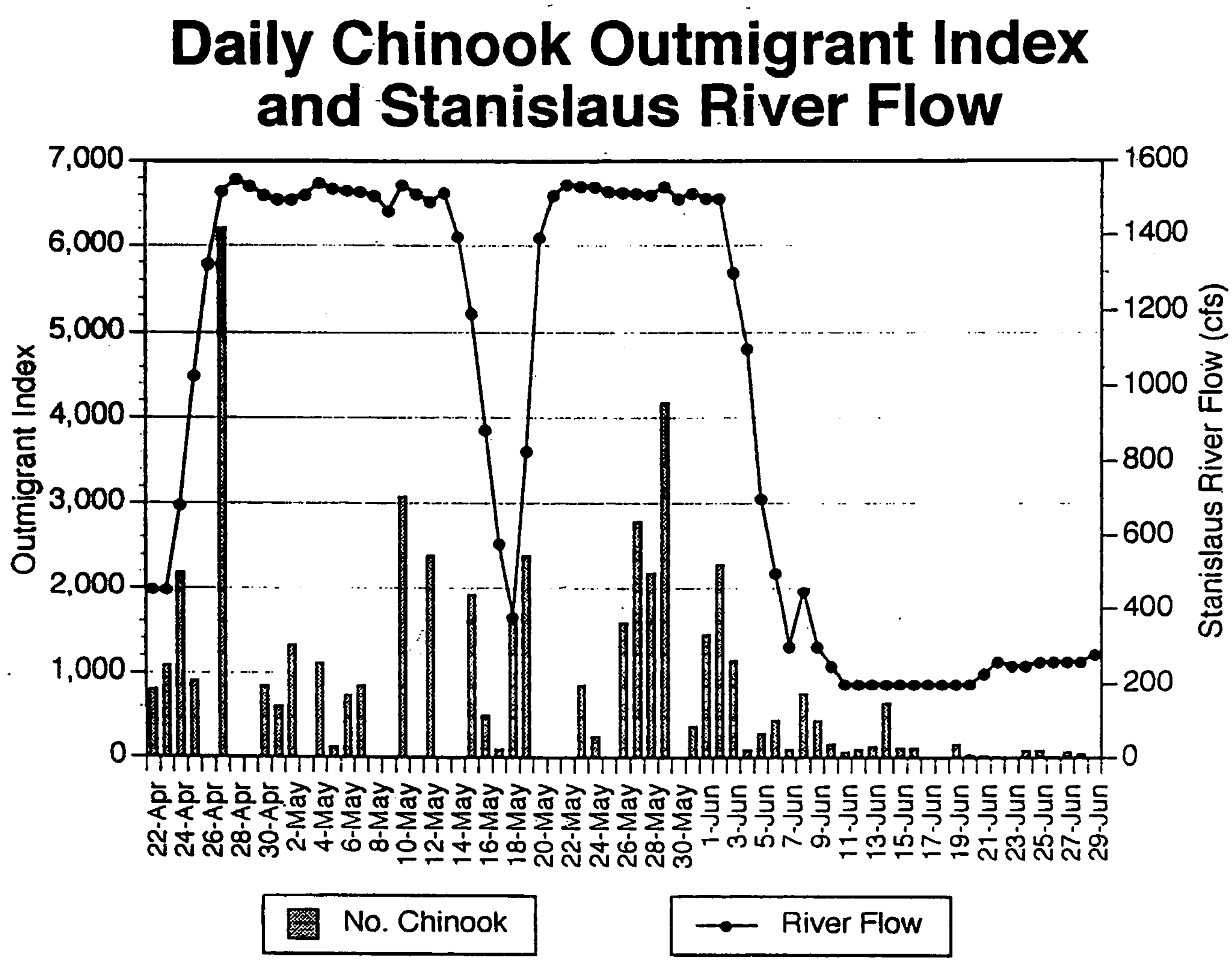


Figure 7. Daily chinook outmigrant index and Stanislaus River flow.

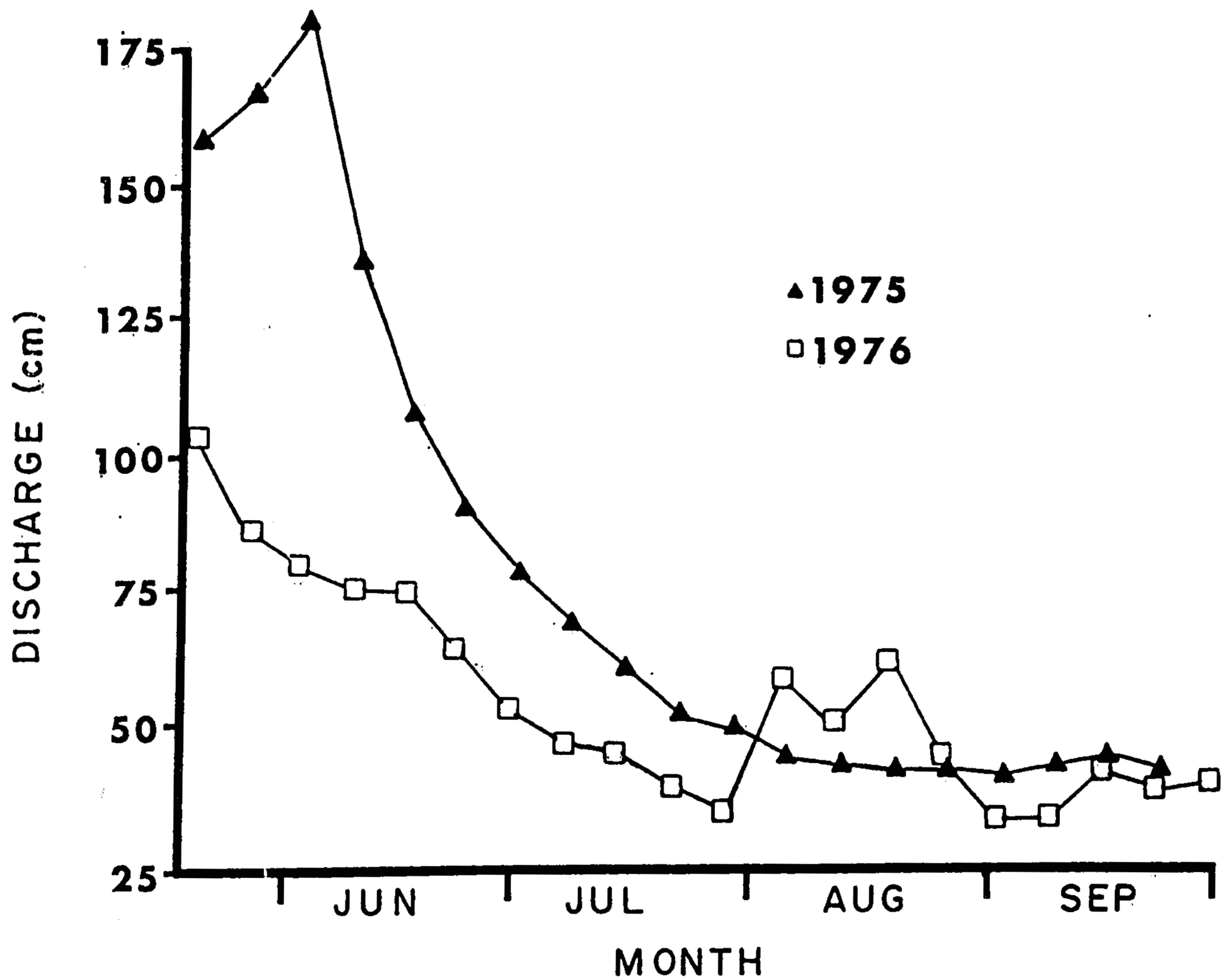


Fig. 17. Average weekly flow in the Rogue River at Grants Pass (km 166) during the summers of 1975 and 1976.

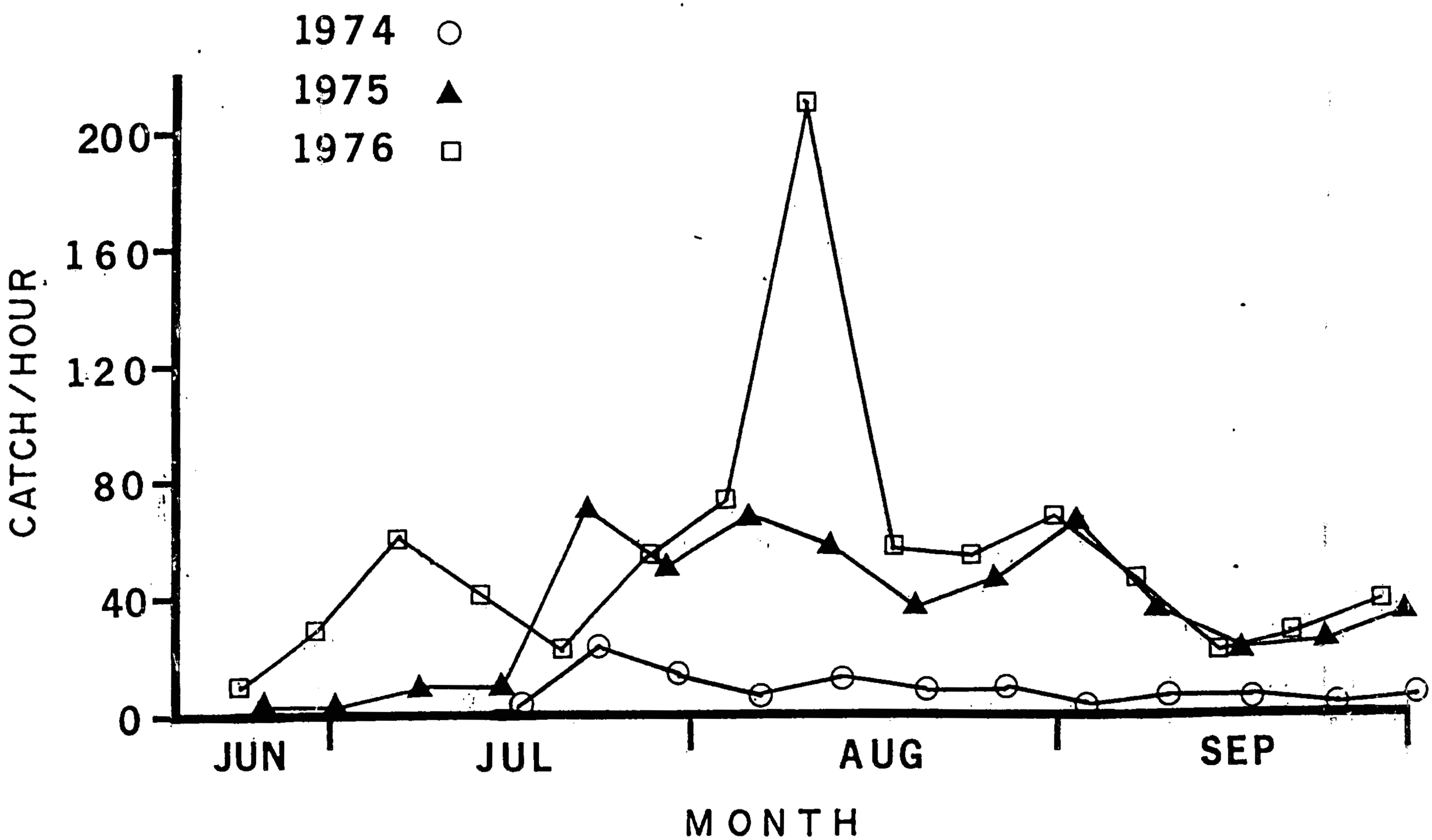
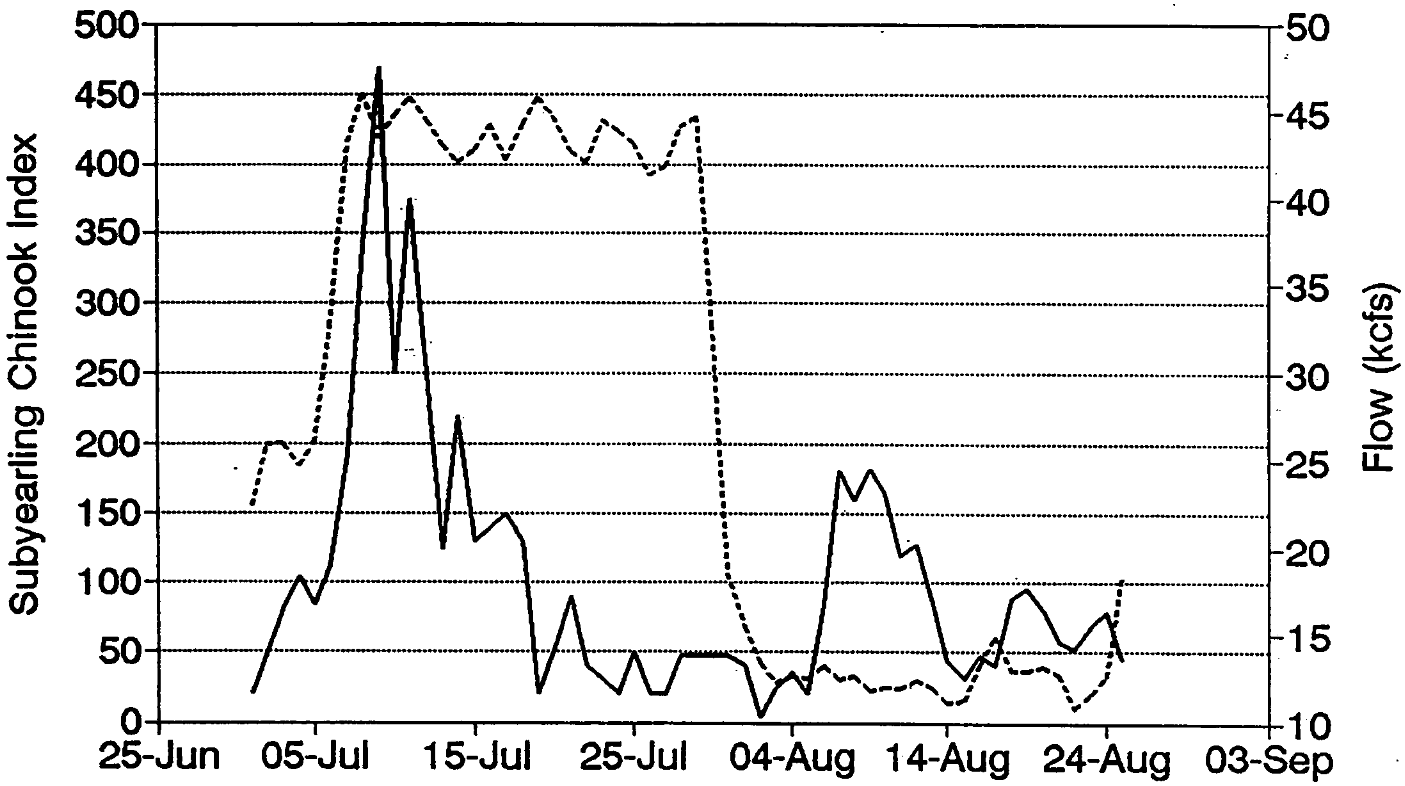


Fig. 18. Weekly catch/trap hour of juvenile chinook salmon at Savage Rapids in 1974, 1975 and 1976.

Subyearling Chinook Passage

Lower Granite Dam - 1994



Fish .... Flow

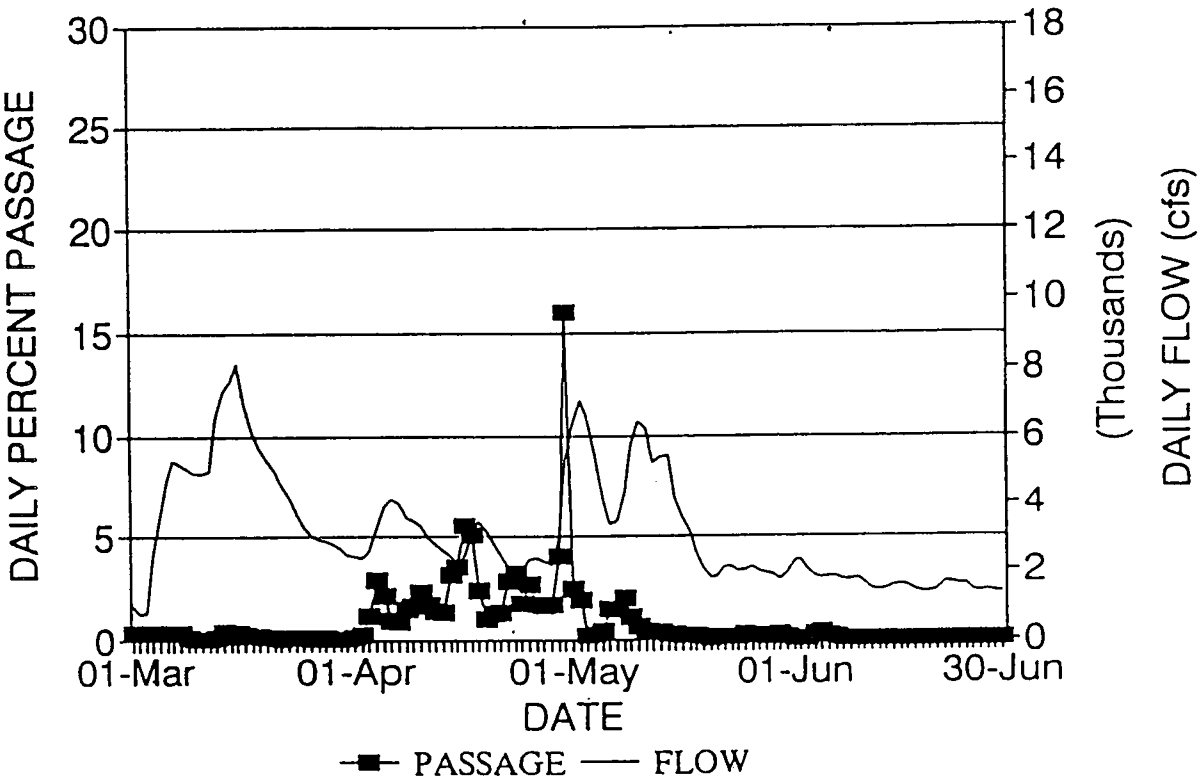


Figure 44. Daily passage of wild spring chinook smolts at Prosser Dam and daily mean flows at Prosser Dam, 1987.

Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento - San Joaquin River Delta of California

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

INTRODUCTION

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

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

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

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

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

DATA

In this paper, r denotes the number of smolt release groups. For the ith release, $1 \leq i \leq r$, n_i is the number of smolts released, m_i is the number of smolts recovered, p_i is the trawl effort, and T_i is the water temperature at Ryde at the time of release, in degrees centigrade.

The data used in the models are those from the 15 releases in the lower Sacramento River at Ryde from 1983 through 1990 that are listed in Table 1. These data were assembled from (USFWS 1983–1992) and (Johnson and Longwill 1991). The smolts were all fall-run chinook salmon, reared at the Feather River Hatchery and released at Ryde in May or June. The average weight of these smolts ranged in different years from 5.15 g to 9.40 g. Peak trawl recoveries at Chipps Island ranged from two to five days after release at Chipps Island. Table 1 near here

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

Figure 1 shows the region of the Delta under discussion. Figure 1 near here

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

THE BASE MODEL

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

This corresponds to the likelihood function

$$L = \prod_{1}^{r} \pi_i$$

where

$$\begin{aligned} \pi_i &= \pi(m_i|n_i, \phi_i, p_i) = \binom{n_i}{m_i} (p_i\phi_i)^{m_i} (1 - p_i\phi_i)^{n_i - m_i} \\ \phi_i &= \phi(T_i) = \frac{1}{1 + e^{-b_1 - b_2 T_i}} \end{aligned} \tag{1}$$

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

$$\begin{aligned} E[m_i] &= p_i\phi_i n_i \\ V[m_i] &= E[m_i] - \frac{1}{n_i} E[m_i]^2 \end{aligned} \tag{2}$$

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

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

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

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

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

Table 2 near here

Figure 2 near here

Overdispersion

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

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

$$\begin{aligned} E[m_i] &= p_i \phi_i n_i \\ V[m_i] &= \sigma^2 (E[m_i] - \frac{1}{n_i} E[m_i]^2) \end{aligned} \tag{3}$$

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

The main criticism one can make of this procedure is that it seems rather arbitrary. If a model does not fit the data, the model assumptions are inadequate in some way, and should at least be re-examined. After all, the fitted values of the model parameters will not be meaningful if the model itself has no relation to reality, regardless of how we assign confidence levels.

In fact, there is an extensive literature on the subject, which basically justifies using the unadorned model to estimate parameters like b_1 and b_2, and dealing with overdispersion as indicated above (see references in McCullagh and Nelder 1989; Burnham et al. 1987). Nevertheless, we prefer to tailor our approach to the specifics of our situation.

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

Furthermore, the data from some of the individual releases clearly point to errors in the capture probability estimates. In the first of the two 1990 releases, 51 878 smolts were released, of which 87 were recovered; even if the survival were 100%, the probability of recovering as many as 87 smolts, assuming that the probability of capture was really 0.001036, would be on the order of 10^{-5}.

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

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

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

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

$$S_{\text{Trawl}} = \frac{m_i}{n_i p_i}$$

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

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

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

THE RELAXED MODEL, THE QUASILIKELIHOOD ESTIMATOR, AND SIMULATION

We modify the base model (1) to allow for uncertainty in the capture probabilities by assuming that the capture probability P in the ith release is itself a random variable with mean p_i and variance $\rho^2 p_i^2$. Here ρ^2 is taken to be the same for all release groups. (Because the capture probabilities are necessarily non-negative, and we expect the errors in the p_i

to be large, a multiplicative error structure seems called for; this leads to the assumption that the coefficient of variation, rather than the variance itself, is constant from release to release). This gives

$$
\begin{aligned}
\pi(m_i|n_i,\phi_i,p_i) &= \int_0^1 \binom{n_i}{m_i}(P\phi_i)^{m_i}(1-P\phi_i)^{n_i-m_i} f_i(P)\,dP \\
\phi_i = \phi(T_i) &= \frac{1}{1+e^{-b_1-b_2T_i}}
\end{aligned} \tag{4}
$$

where f_i is the density for P. We will call this the *relaxed model.*

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

$$
\begin{aligned}
E[m_i] &= p_i\phi_i n_i \\
V[m_i] &= E[m_i] + (\frac{n_i-1}{n_i}\rho^2 - \frac{1}{n_i})E[m_i]^2
\end{aligned} \tag{5}
$$

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

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

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

We will consider two simple examples: the uniform distribution

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

and the triangular distribution

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

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

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

For the data in Table 1, the fitting procedure described above produced the estimate $\rho^2 = 0.1503$. This value for ρ^2 seems plausible to us. It is close to the ρ^2 for the maximally broad triangular distribution, and comfortably within the range of ρ^2 values that are consistent with the derivation of the model.

For this value of ρ^2, the fitted parameters are $b_1 = 15.56$, $b_2 = -0.6765$, so that LT50 = 23.01 and $\alpha = -0.1691$.

Confidence intervals and bias for b_1, b_2, LT50, and α were estimated by simulation: the model (4) was used with both the uniform and triangular distributions for f_i to generate 5000 data sets each, assuming the values for ρ^2, b_1, and b_2 given above. Each simulated data set was fitted to the model (holding ρ^2 constant), yielding 10 000 pairs (b_{1k}, b_{2k}).

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

Table 3 near here

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

Figure 4 near here

The quasilikelihood-generating model

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

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

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

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

$$(6) \quad \pi(m_i|n_i,\phi_i,p_i) = \begin{cases} \binom{n_i/\gamma_i}{m_i}(\gamma_i p_i\phi_i)^{m_i}(1-\gamma_i p_i\phi_i)^{n_i/\gamma_i - m_i}, & \text{for } 0 < \gamma_i < 1 \\ \frac{(p_i\phi_i n_i)^{m_i}}{m_i!}e^{-p_i\phi_i n_i}, & \text{for } \gamma_i = 0 \\ \binom{-n_i/\gamma_i + m_i - 1}{m_i}(-\gamma_i p_i\phi_i)^{m_i}(1-\gamma_i p_i\phi_i)^{n_i/\gamma_i - m_i}, & \text{for } \gamma_i < 0 \end{cases}$$

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

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

Because the number of smolts in each release ($\approx 10^4, 10^5$) is very much larger than the typical number recovered ($\approx 10^1, 10^2$), it would have been quite reasonable to model the underlying survival-capture process as a Poisson process. After all, the binomial model is also only an approximation (for example, smolts from one release are actually recovered over several trawls), and it would be difficult to argue convincingly that it is a better one than the Poisson in this case. If we imitate the development of the previous section, beginning from the Poisson model, things work out pretty much as before. The mean and variance functions of the "relaxed" model become

$$
\begin{aligned}
E[m_i] &= p_i\phi_i n_i \\
V[m_i] &= E[m_i] + \rho^2 E[m_i]^2
\end{aligned}
\tag{7}
$$

and the quasilikelihood-generating distribution takes the form:

$$
\pi(m_i|n_i,\phi_i,p_i) = \begin{cases} \frac{(p_i\phi_i n_i)^{m_i}}{m_i!}e^{-p_i\phi_i n_i}, & \text{for } \gamma_i = 0 \\ \binom{-n_i/\gamma_i+m_i-1}{m_i}(-\gamma_i p_i\phi_i)^{m_i}(1-\gamma_i p_i\phi_i)^{n_i/\gamma_i-m_i}, & \text{for } \gamma_i < 0 \end{cases}
\tag{8}
$$

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

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

Discussion

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

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

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

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

	Brett (1952)				Fitted
Acclimation (°C)	10	15	20	24	—
UILT	24.3 ± 0.1	25.0 ± 0.1	25.1 ± 0.1	25.1 ± 0.1	23.01 ± 1.08

We regard this as a reasonable agreement.

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

	Houston (1982)						Fitted
Acclimation (°C)	10	10	11	13	18	20	—
10% Loss	22.9	20.5	23.0	19.5	20.0	23.8	19.76
50% Loss	—	—	23.5	—	—	24.7	23.01
90% Loss	24.5	23.5	23.8	23.0	23.5	24.8	26.26

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

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

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

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References

Baker, P. F., T. P. Speed, and F. K. Ligon. 1992. The influence of temperature on the survival of chinook salmon smolts migrating through the Sacramento - San Joaquin Delta. San Francisco Bay/Sacramento - San Joaquin Delta Estuary Hearings Exhibit No. WRINT-MID/TID 32. Prepared for Turlock Irrigation District and Modesto Irrigation District, CA by EA Engineering, Science, and Technology, 3468 Mt. Diablo Blvd., Suite B100, Lafayette, CA 94549.

Brett, J. R.. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Board Can. 9: 265-323.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release- recapture. Am. Fish. Soc. Monogr. 5. American Fisheries Society. Bethesda, MD. 437 p.

Houston, A. H.. 1982. Thermal effects upon fishes. Natl. Res. Counc. Can. Assoc. Comm. Sci. Criter. for Environ. Qual. Publ. No. 18566. Ottawa, Ont.

Kilgour, D. M., and R. W. McCauley. 1986. Reconciling the two methods of measuring upper lethal temperature in fishes. Environ. Biol. Fishes 17: 281-290.

Kjelson, M. A., S. Greene, and P. L. Brandes. 1989. A model for estimating mortality and survival of fall-run chinook salmon smolts in the Sacramento River Delta between Sacramento and Chipps Island. San Francisco Bay/Sacramento - San Joaquin Delta, Water Quality Control Plan Hearings, WQCP-USFWS Exhibit 1. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

McCullagh, P., and J. A. Nelder. 1989. Generalized linear models. 2nd ed. Chapman and Hall. New York, NY. 511 p.

Johnson, J. Kenneth, and James R. Longwill. 1991. Pacific salmonid coded wire tag releases through 1990. Regional Mark Processing Center, Pacific States Marine Fisheries Commission, 2501 S.W. First Avenue, Suite 200, Portland, Oregon, 97201–4752.

Stevens, D. E., M. A. Kjelson, and P. L. Brandes. 1984. An evaluation of the relationship between survival of chinook salmon smolts and river flow in the Sacramento- San Joaquin Delta. Appendix A in Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1984 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

U. S. FISH AND WILDLIFE SERVICE. 1983. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1983 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1984. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1984 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1985. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1985 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1986. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1986 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1987. The needs of chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary. San Francisco Bay/Sacramento- San Joaquin Delta, Phase I Hearings, U. S. Fish. Wildl. Serv. Exhibit 31. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1988. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1988 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1989. Survival and productivity of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1989 Annual Progress Report. U. S. Fish. Wildl. Serv., Fisheries Assistance Office, Stockton, CA.

1990. Abundance and survival of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1990 Annual Progress Report. U. S. Fish. Wildl. Serv., Sacramento- San Joaquin Estuary Fishery Resource Office, Stockton, CA.

1992. Abundance and survival of juvenile chinook salmon in the Sacramento- San Joaquin Estuary. 1991 Annual Progress Report. U. S. Fish. Wildl. Serv., Sacramento-San Joaquin Estuary Fishery Resource Office, Stockton, CA.

1992. Measures to improve the protection of chinook salmon in the Sacramento/San Joauqin River Delta. San Francisco Bay/Sacramento - San Joaquin Delta Estuary Hearings Exhibit No. WRINT-USFWS 7.

WILLIAMS, D. A. 1982. Extra-binomial variation in logistic linear models. Appl. Statist. 31: 144-148.

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

i	Coded-Wire-Tag Number(s)	Date of Release	Average Weight(g)	Temperature (°C) T_i	Number Released n_i	Number Recovered m_i	Trawl Effort p_i
1	06-62-23	5/20/83	5.89	16.1	92693	95	0.00083324
2	06-42-09 06-62-29	6/13/84	5.15	18.9	59998	37	0.00088098
3	06-62-35	5/11/85	5.82	18.9	107161	88	0.00106649
4	06-62-48	5/30/86	5.34	23.3	101320	74	0.00112363
5	06-62-55	4/29/87	5.79	19.4	51103	46	0.00105899
6	06-62-58	5/2/87	6.21	17.8	51008	47	0.00107142
7	06-31-01	5/3/88	8.40	17.2	52741	106	0.00213811
8	06-31-02	5/6/88	8.56	16.1	53238	146	0.00214250
9	06-62-63	6/22/88	8.25	23.9	53961	46	0.00213117
10	06-31-03	6/25/88	8.72	23.3	53942	39	0.00212647
11	06-31-12	5/3/89	7.00	16.7	51046	65	0.00107005
12	06-31-07	6/2/89	9.40	19.4	50601	26	0.00107047
13	06-01-14-01-02	6/16/89	7.83	22.8	51134	8	0.00097782
14	06-31-20	5/9/90	5.04	20.6	51878	87	0.00103647
15	06-31-22	5/31/90	6.87	18.3	50837	67	0.00105773

Table 2. Comparison of the trawl recoveries predicted by the fitted base model for the Ryde release groups with the corresponding actual trawl recoveries.

i	Expected Recoveries	Actual Recoveries	Pearson Residuals	Deviance Residuals
1	77	95	2.10	2.02
2	50	37	-1.86	-1.95
3	108	88	-1.96	-2.03
4	53	74	2.91	2.74
5	50	46	-0.58	-0.59
6	53	47	-0.86	-0.88
7	111	106	-0.46	-0.46
8	113	146	3.09	2.96
9	43	46	0.50	0.50
10	53	39	-1.95	-2.05
11	54	65	1.50	1.45
12	50	26	-3.41	-3.76
13	28	8	-3.78	-4.46
14	46	87	6.07	5.39
15	52	67	2.11	2.01

Table 3. Statistical properties of the quasilikelihood estimators, determined by simulation with respect to two models of capture probability.

	Canonical parameters		Natural parameters	
	b_1	b_2	LT50	α
Fitted	15.56	−0.6765	23.01	−0.1691
Uniform				
mean	18.65	−0.8080	23.06	−0.2020
s.d.	10.18	0.4356	0.57	0.1089
bias	3.08	−0.1315	0.05	−0.0329
P1	5.72	−2.6166	21.64	−0.6542
P2.5	7.40	−2.0770	21.95	−0.5193
Q1	13.09	−0.8957	22.85	−0.2239
median	15.80	−0.6880	23.03	−0.1720
Q3	20.70	−0.5722	23.26	−0.1430
P97.5	47.97	−0.3168	24.10	−0.0792
P99	60.60	−0.2352	24.63	−0.0588
Triangular				
mean	16.80	−0.7291	23.01	−0.1823
s.d.	5.06	0.2163	0.21	0.0541
bias	1.23	−0.0526	0.01	−0.0132
P1	10.09	−1.5716	22.47	−0.3929
P2.5	10.75	−1.3101	22.57	−0.3275
Q1	13.62	−0.8028	22.88	−0.2007
median	15.62	−0.6810	23.02	−0.1703
Q3	18.54	−0.5941	23.16	−0.1485
P97.5	30.32	−0.4690	23.40	−0.1172
P99	36.23	−0.4414	23.48	−0.1103

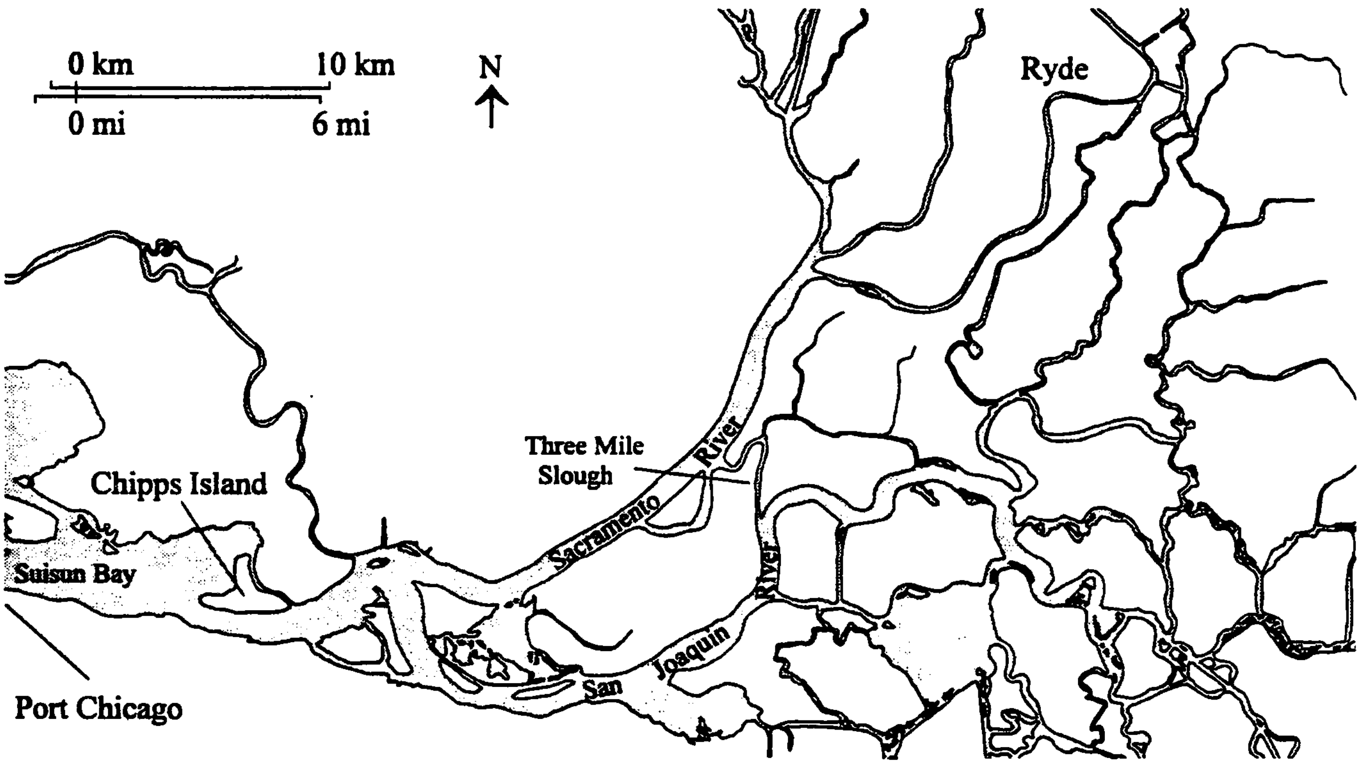
Figure 1. North-Central Region of the Sacramento - San Joaquin Delta.

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

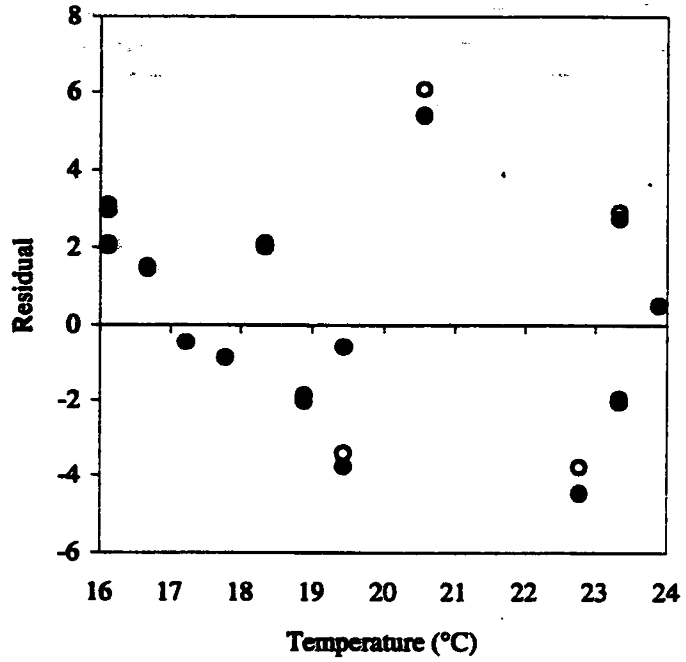
Figure 3. Two methods of estimating smolt survival from Ryde to Chipps Island. The diagonal line Trawl-based survival = Ocean-based survival is provided for reference.

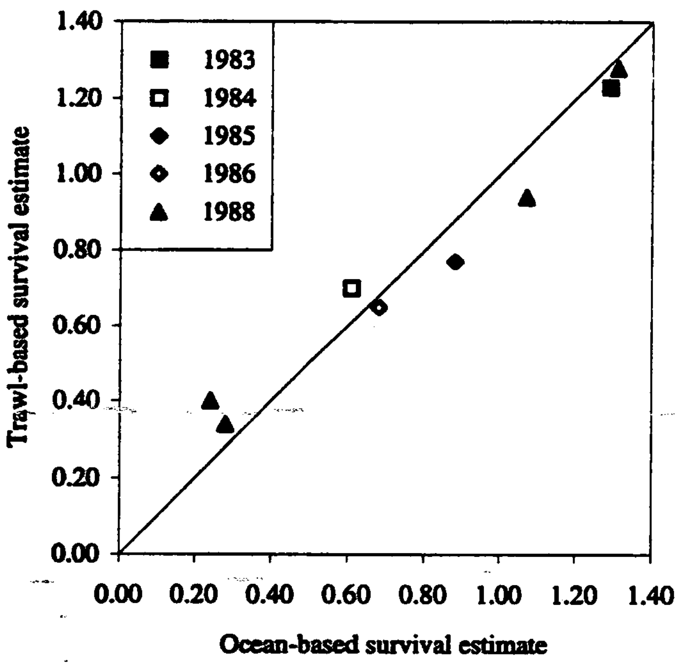
Figure 4. Distributions of quasilikelihood estimates of smolt survival from Ryde to Chipps Island, for the fitted model, assuming that the probabity of capture is drawn from (a) the uniform distribution and (b) the triangular distribution.

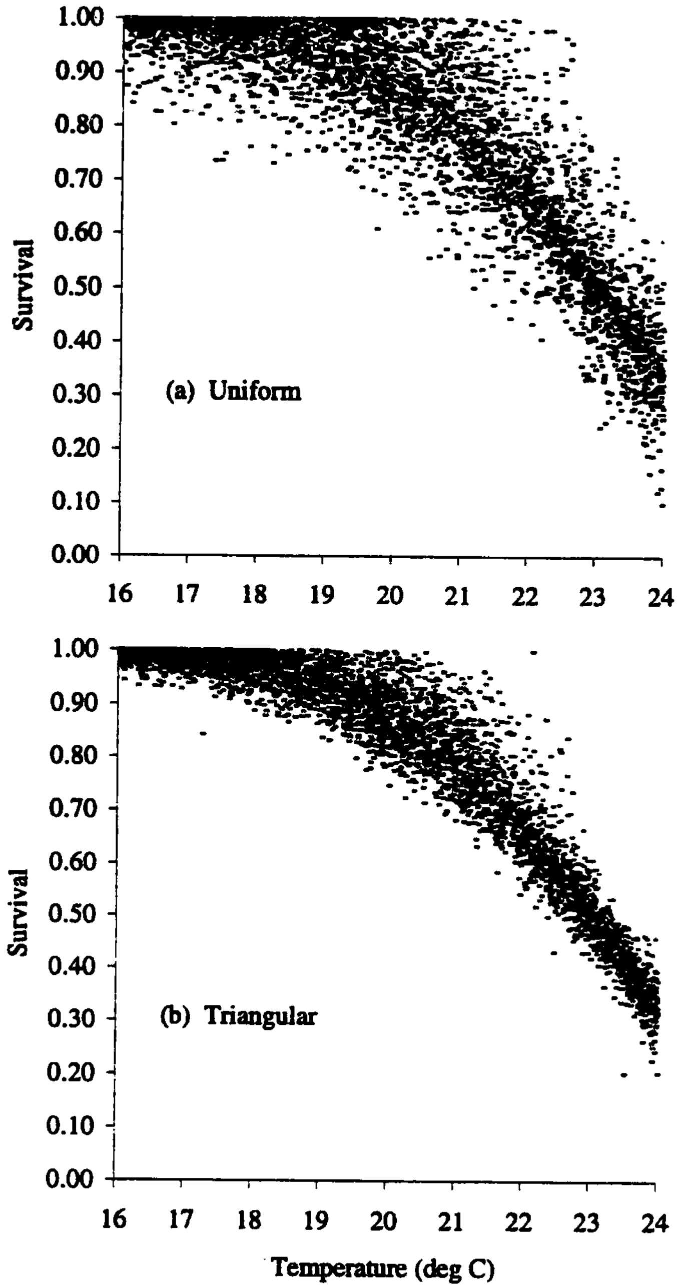
Figure 1



0 km
10 km
0 mi
6 mi
N
Ryde
Three Mile Slough
Chipps Island
Sacramento River
Suisun Bay
San Joaquin River
Port Chicago


8
6
4
2
0
-2
-4
-6
Residual
16
17
18
19
20
21
22
23
24
Temperature (°C)


1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Trawl-based survival estimate
1983
1984
1985
1986
1988
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Ocean-based survival estimate



1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Survival
(a) Uniform
16
17
18
19
20
21
22
23
24
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Survival
(b) Triangular
16
17
18
19
20
21
22
23
24
Temperature (deg C)

MODELED SAN JOAQUIN CHINOOK SALMON ESCAPEMENT UNDER SELECTED PULSE FLOW ALTERNATIVES

EACH for Windows 8.5.3, runs of 11 October 1994

Percentage Increase over Modeled Historical Escapement

	With Old River Barrier			Without Old River Barrier		
	DFG	JP	SJT	DFG	JP	SJT
1982	812	688	494	201	153	67
1983	547	489	488	117	91	61
1984	518	460	542	111	81	73
1985	450	349	457	89	45	60
1986	392	238	289	86	23	40
1987	293	202	222	60	21	25
1988	200	144	196	24	-1	15
1989	217	180	201	34	14	20
1990	305	311	231	75	72	36
1991	375	372	262	106	100	50
1982–1991	*394*	*315*	*360*	*81*	*45*	*45*

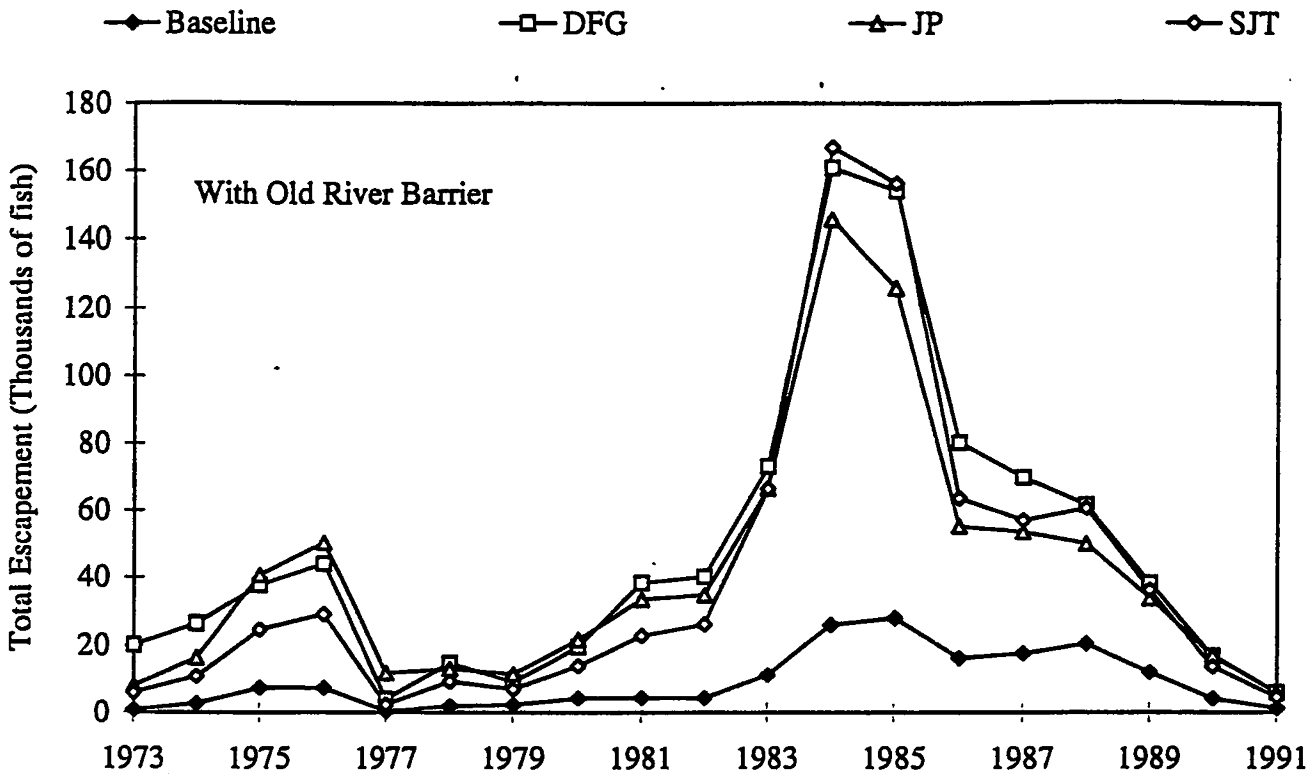
DFG: SWRCB Alternative 4.

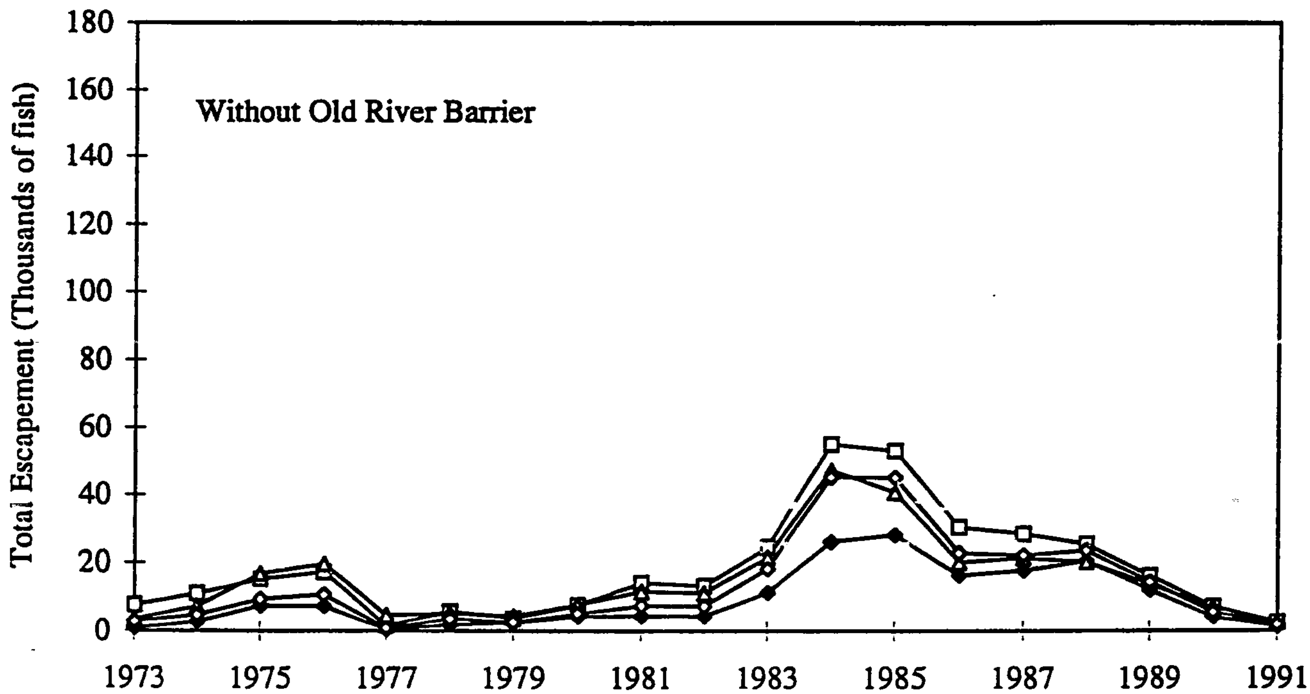
JP: Water Users Joint Proposal.

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

MODELED SAN JOAQUIN CHINOOK SALMON ESCAPEMENT
UNDER SELECTED PULSE FLOW ALTERNATIVES

EACH for Windows 8.5.3, runs of 11 October 1994





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