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April 26, 1994

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Mr. John Caffrey, Chairman
State Water Resources Control Board
901 P Street
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Sacramento, California 95812-0100

RE: Comments of the Turlock Irrigation District to the State Water Resources Control Board's Notice of Public Workshop for the Review of Standards for the San Francisco Bay/Sacramento – San Joaquin Delta Estuary

Dear Chairman Caffrey:

These comments are submitted on behalf of the Turlock Irrigation District ("District") and are directed to the key issues identified in the State Water Resources Control Board's March 25, 1994, Notice of Public Workshop for the Review of Standards for the San Francisco Bay/Sacramento– San Joaquin Delta Estuary.

1. Which standards should the State Water Board focus on during this triennial review?

The Clean Water Act does not authorize the EPA to promulgate the water quality standards it has proposed for the Bay-Delta. (See Comments of the Office of the Attorney General for the State of California, March 11, 1994.) Furthermore, it appears to us the standards proposed by EPA for water quality in the Bay-Delta were poorly drafted, not supported by scientific evidence, and have the potential to disrupt California's vital water supply system and its economy. Following is a summary of the District's comments to the EPA, a copy of which is attached as Exhibit 1.

Salinity Criteria to Protect Estuarine Habitat in Suisun Bay

The proposed 2 parts per thousand estuarine objective obscures the impacts of export pumping and other factors, such as introduced species. A water quality objective designed to protect a particular habitat should focus on the problems affecting the resources within the habitat, such as the direct and indirect effects of the export pumping on Delta fishery resources, rather than attempting to define the problem as a salinity problem.

Salmon Smolt Survival Indices to Protect Migrating Salmon

The validity of historic estimates of the San Joaquin River salmon smolt survival index is questionable and smolt survival indexes should not be used as a water quality objective, particularly in light of questions raised by the District and other participants about the reliability of those indexes under certain flow and export conditions.

From the standpoint of the Delta, export pumping is the major factor influencing salmon populations.

Criteria to Protect Striped Bass Spawning in the San Joaquin River

There is no justification for striped bass spawning salinity objectives upstream from Prisoner's Point.

The water quality objectives contained in the 1991 Water Quality Control Plan for Salinity appear to be adequate to protect water quality and the beneficial uses of the Bay-Delta Estuary. Accordingly, we believe the focus should be on the 1991 Water Quality Control Plan with such modifications which may be necessary for implementation within the framework of California's water rights laws.

2. What level of protection is required by the California Water Code and the Clean Water Act for protection of public trust uses in the Bay-Delta Estuary?

The EPA draft standards far exceed the targeted level of habitat conditions. EPA claims that its draft criteria are consistent with the Interagency Statement of Principles, dated June 15, 1992, which stated a goal of "restoring habitat conditions to levels which existed during the late 1960's and early 1970's." Numerous parties have pointed out that EPA's use of the 1940-1975 hydrologic period as characteristic of habitat conditions that existed in the late 1960's–early 1970's is incorrect. The period between 1940 and 1975 did not contain any critically dry years. Furthermore, it excluded the historic drought of 1928-1934, as well as the severe drought of 1976-1977 and the recent 1987-1992 drought.

EPA also incorrectly assumed that 1940-1975 was a period of relatively minor development in the Central Valley. Many of the commentators also pointed out that the period 1940 through 1975 saw considerable reservoir development upstream of the Delta by federal, state, and local water agencies. In fact, the capacity of Central Valley reservoir storage grew by approximately 17 million acre-feet during this period (Department of Water Resources Comments on U.S. Environmental Protection Agency Proposed Bay-Delta Standards, March 11, 1994, p. 2).

EPA's use of the 1956-1970 historical reference period on the Sacramento River to develop its salmon smolt survival index for the San Joaquin River is also without justification. As the attached Exhibit 2 points out, the fall run Chinook salmon average escapements for the San Joaquin River basin were actually *lower* during the EPA reference period of 1956-1970 then were average escapements during the more recent period of 1984-1993. The lowest San Joaquin River basin escapement record of 320 spawners occurred in 1963—right in the middle of EPA's historical reference period.

The District believes that the State Board must establish a reasonable baseline against which can be measured both the decline and recovery of Bay-Delta resources. Any level of water quality standards finally adopted should consider how any such standards are to be implemented. In addition the State Board must balance public trust uses with other competing uses important to the welfare of the state as it seeks to establish its own water quality standards pursuant to state law.

3. What are the principal environmental, water supply and economic effects of USEPA's draft standards? Should these standards, or modified versions of these standards, be considered as alternatives in this review?

It is impossible to determine the environmental, water supply and economic effects of EPA's proposed draft standards since they have been prepared without any implementation scheme. Furthermore, it appears the EPA did not consider the impacts of such standards on California's water supply systems and, in general, upon the economy of the state.

The State Board should develop alternative standards that seek to protect the beneficial uses of the Bay-Delta but are reasonable and can be implemented without a major disruption of California's water supply systems and the economy of the state. The State Board should principally address the impacts on the Bay-

Delta uses by the Federal and State export projects and other factors causing deterioration of water quality in the Bay-Delta Estuary.

Of major importance to the State Board should be the manner in which any Bay-Delta standards are to be implemented within the framework of California water rights laws. As between users, the priority system has been the primary mechanism for allocating water for over 100 years. Substantial investment decisions have been made in reliance on this system. Any action by the State Board should be consistent with the priority system.

State law includes protections for the counties of origin (Water Code §§ 10505 and 10505.5) and for the watersheds of origin (Water Code §§ 11460 et seq.). The protections afforded by these statutes limit the water available for export to such water as may be surplus to the needs of the area of origin. Water required for existing upstream beneficial uses and for upstream public trust purposes is not surplus to the areas of origin and takes priority over any water needed by the export projects to meet export public trust responsibilities or export beneficial uses. Non-project water users cannot be required to mitigate the effects of the export projects and thereby support Delta exports.

DATED: April 26, 1994

Respectfully submitted,

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COMMENTS OF THE TURLOCK IRRIGATION AND MODESTO IRRIGATION DISTRICTS TO THE ENVIRONMENTAL PROTECTION AGENCY'S PROPOSED RULE FOR WATER QUALITY STANDARDS FOR SURFACE WATERS OF THE SACRAMENTO RIVER, SAN JOAQUIN RIVER, AND THE SAN FRANCISCO BAY AND DELTA OF THE STATE OF CALIFORNIA

40 CFR Part 131

March 10, 1994

COMMENTS OF THE TURLOCK IRRIGATION AND MODESTO IRRIGATION DISTRICTS TO THE ENVIRONMENTAL PROTECTION AGENCY'S PROPOSED RULE FOR WATER QUALITY STANDARDS FOR SURFACE WATERS OF THE SACRAMENTO RIVER, SAN JOAQUIN RIVER, AND THE SAN FRANCISCO BAY AND DELTA OF THE STATE OF CALIFORNIA

40 CFR Part 131

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1. INTRODUCTION

These comments are submitted on behalf of the Modesto Irrigation District and the Turlock Irrigation District ("MID/TID" or "Districts") and are directed to the proposed water quality standards for waters of the Sacramento and San Joaquin Rivers and San Francisco Bay and Delta described in Volume 59 of the Federal Register beginning at page 810.[1] The proposed criteria could impose significant economic and social costs on California. It is therefore incumbent on EPA to ensure that the criteria it adopts are not only scientifically defensible but strike a reasonable balance between the needs of the environment and the legitimate needs of California's human population. Recognizing the realities of a semi-arid state, California's Constitution prohibits the waste and unreasonable use of water. (Cal. Const., Art. X, sec. 2.) EPA should recognize the same realities and recommend only actions that can achieve a reasonable measure of aquatic resource protection in the most water-efficient manner. As explained below, the Districts do not believe that the proposed criteria meet the state constitutional standard.

At page 821 of the Federal Register, the Environmental Protection Agency (EPA) states that it expects the State Water Resources Control Board (State Board) to implement the proposed salinity criteria "by making appropriate revisions to operational requirements included in water rights permits issued by

[1] Instead of attaching exhibits previously submitted by the Districts and other Bay-Delta participants, the Districts hereby incorporate previous submittals into these comments by reference.

the State Board." Later at page 822, EPA asks the State Board to allocate the burden of meeting the proposed salinity criteria "across the broad range of the state's water users" in order increase the operational flexibility of the water system and to reduce the total burden of meeting the salinity criteria.

As the EPA knows, any decision concerning water allocation is a matter of state water rights. Any State Board implementation order must comply with all relevant provisions of California law, including the California Constitution's prohibition of waste and unreasonable use, water right priorities, and the area of origin and watershed protection principles that have been recognized in California statutes dating back to 1931 and in prior State Board decisions. (See generally United States v. State Water Resources Control Board (1986) 182 Cal. App. 3d 82, 138-139.)

The State Board cannot allow the export of water from the Delta if such exports would deprive the areas, counties, and watersheds of origin of the water of the amounts of water needed for reasonable beneficial uses in those areas. In sum, the State Board may not simply spread the burden uniformly on all Bay-Delta watershed users as EPA has suggested. The State Board must also take into consideration which water users or groups of users are actually impacting the aquatic resources in question.

EPA states at page 823 that "As a part of EPA's coordination process in developing this proposal, the Agency has discussed its proposed criteria at length with the operators of California's major water projects." The proposed criteria will potentially impact all water users, and the Districts urge EPA to establish a procedure that allows participation by all users, not just the federal and state projects.

2. SALINITY CRITERIA TO PROTECT ESTUARINE HABITAT IN SUISUN BAY

2.1. THE PROPOSED SALINITY CRITERIA IGNORES THE EFFECTS OF EXPORT PUMPING

Degradation of the Bay-Delta habitat since the Clean Water Act's (CWA) 1975 reference date can be traced to increased water development and use, to a prolonged drought, and to the introduction of new species. The greatest change in water development conditions affecting the estuary since 1975 has been the increase in Delta exports and related changes in export project reservoir operations and flow regulation. Central Valley Project (CVP) and State Water Project (SWP) exports have impacted the biological resources of the estuary by contributing to an overall reduction in Delta outflow, by changing the volume and direction of flow in Delta channels and by directly entraining fish at the project export pumps. Despite the obvious effects of exports on Delta hydrology and aquatic resources, EPA has chosen to focus only on salinity/outflow conditions. The result of this "habitat-based" approach is that it fails to come to grips with an essential element of the habitat.

Although EPA implicitly rejects the Department of Fish and Game's (DFG) striped bass model incorporating outflow and export relationships in preference to models that rely only on the position of low-salinity habitat in Suisun Bay, the linkage between the impact of Delta exports and the importance of locating the 2 ppt isohaline in Suisun Bay is acknowledged elsewhere in EPA's comments: "Dr. Peter Moyle testified to the State Board that nursery habitat (represented by areas of low salinity) in Suisun Bay is now more important than it was historically due to the high risks of entrainment faced by fishes in the Delta." (59 Fed. Reg. 816.) In other words, under pre-project conditions and probably under conditions of limited export pumping, the Delta itself provided a valuable nursery area. Moyle and the co-authors of a 1992 paper on Delta smelt made a similar point when they wrote:

> Increased diversion of fresh water from the estuary has altered both the location of the mixing zone and the flow patterns through the Delta during much of the year.... During the months when Delta smelt are spawning, the changed flow patterns presumably lead to greater entrainment of spawning adults and newly hatched larvae into water diversions. The combined effects of habitat constriction and fish entrainment provide the most likely explanation of the declines in abundance. (WRINT-USFWS-18, at p. 75.)

Even if outflows and salinity conditions had not changed since EPA's historic reference period, increased exports could still have produced a decline in species like striped bass or Delta smelt that frequent western Delta waters influenced by the pumps. If the point is to protect estuarine resources—as opposed to protecting estuarine salinity—then all of the factors that effect those resources must be taken into consideration in the development of protective criteria.

By contrast, EPA relies on salmon smolt survival models that are in large part export-driven. If the fate of salmon migrating through the Delta is linked to export pumping, what justification exists for "estuarine habitat" protection that fails to consider the impact of export pumping? EPA states that the federal agencies, "recognized the need to take an integrated ecosystem approach to the Bay-Delta rather than a fragmented, species-by-species approach." (59 Fed. Reg. 827.) It appears the approach is still fragmented. EPA needs a unified and comprehensive approach to estuarine protection, rather than one that compartmentalizes protected uses and selectively ignores factors that contribute to the decline of many aquatic resources.

EPA's authority under the CWA extends only to the water quality aspects of aquatic resource problems. That may be the reason why the agency's proposed criteria and supporting documentation attempt to portray the problems, and their solutions, primarily in terms of water quality. However, changes in water quality conditions are only one factor, and not the most important factor causing the decline of aquatic resources in the Delta.

2.2. USE OF 1940 TO 1975 REFERENCE PERIOD IS INAPPROPRIATE

Under the CWA the applicable reference condition for nondegradation criteria are conditions existing on November 28, 1975. EPA correctly concluded that in a complex estuarine setting the use of a single date, or even conditions in a single year, inadequately reflect the range of existing conditions. As an alternative EPA proposes the use of vaguely defined late 1960's–early 1970's conditions. To the extent that the late 1960's–early 1970's generally represent a 1975 level of development for water projects in the Delta watershed, the substitution would be acceptable. However, the period from 1965 to 1975 saw several reservoirs go into operation and export pumping more than double. Given that fact, if the reference period is to be expressed as a number of years, those years should be closely grouped around 1975. EPA rejected the inclusion of 1976 because "the decline of certain aquatic resources was already apparent." That rejection is inappropriate because 1976 simply demonstrates the response of the estuary to mid-1970's levels of development. If conditions several years prior to 1970 can be used as a basis for the definition of 1975-level conditions, then the following year should logically be accorded the same status.

Despite its preference for a late 1960's and early 1970's reference period, EPA has proposed to use a far broader time frame 1940-1975 instead because (1) "this span of years provides the greatest number of examples of each year type during the period after the massive changes in hydrology due to construction of Shasta Dam on the Sacramento River and the Friant Dam on the San Joaquin but before the most dramatic recent declines in fishery abundance" (59 Fed. Reg. 839) and (2) it is a period of "fairly consistent hydrological conditions" (59 Fed. Reg. 820). EPA's reasoning is flawed on both counts.

No period in California water development history saw more dramatic changes than the 1940-75 period. All of the state and federal project reservoirs went into service in those years, with the sole exception of New Melones, a unit of the CVP. Despite implications in the text to the contrary, the early 1940's are not a part of the post-Shasta period. Shasta did not begin operation until 1944, and Friant Dam not until 1947. The first several years of the proposed reference period exemplified true without-project conditions, with high spring outflows, very low summer outflows, and no disturbance of natural Delta nursery areas. Exports from the Delta began in 1950 and quickly reached a level that was maintained until 1968 when the operation of the SWP began. Pre-1968 export levels had little apparent effect on Delta fisheries. The state of water development in 1975, and especially the hydrology of the Delta, bore little resemblance to conditions in 1940 or even in 1965.

Despite the range of water development covered by the extended 1940-75 time span, EPA took comfort in what it appears to believe to be the hydrologic consistency across the period. The table showing the number of days between February and June when the 2 ppt isohaline was west of Chipps Island in dry or below normal years between 1930 and 1989 is said to show "the absence of a strong pattern of decreasing days at Chipps Island over time" (59 Fed. Reg. 840) and thus justified the use of the broader historical period. However, the table in the Federal Register at page 839 showing the average location of the 2 ppt isohaline for both 1940-75 and 1964-75 shows significant differences between the broader period and one closer to the late 1960's–early 1970's target. In fact, habitat conditions were dramatically different in 1975 compared to what they had been 20 or even 10 years earlier, because of export pumping and changes in salinity conditions in Suisun Bay.

EPA has recognized that one of the problems with any set of years between 1940 and 1975 is that there were no critical years in the Sacramento Basin classification, although there were critical water years in the San Joaquin Basin, including a severe drought from 1959 to 1961. The use of extrapolations to fill gaps is hardly satisfactory. The inclusion of 1976 would partially solve the problem, but even with that addition, any period of years grouped closely enough around 1975 to accurately reflect 1975-level conditions might exclude other year types or have too few examples to be meaningful. An alternative to selecting a limited number of actual years would be the use of an operations model such as DWRSIM set to 1975 level-of-development and operated to meet Delta standards in place in 1975. EPA should seriously consider an alternative to a set of actual years.

2.3. SPECIFIC SALINITY CRITERIA ISSUES FOR COMMENTERS TO ADDRESS

Issue 7 (59 Fed. Reg. 840, 841): Proposals to increase outflows in the third year, and perhaps other years, of an extended drought could pose tremendous risks to water users and to the environment. The basic criteria being proposed by EPA will place additional demands on the water supply system in periods of shortage. Additional outflow, over and above the basic requirements, during a prolonged drought would be the equivalent of additional deliveries of stored water and could result in reduced ability to maintain instream flows or Delta outflows in subsequent years. The necessity of prudent reservoir management and maintenance of adequate carryover storage is not recognized by EPA. EPA should avoid setting criteria that could curtail carryover storage and lead to loss of flexibility in project operation during times of critical water shortage.

A better course for coping with severe or extended droughts would be to encourage the development of strategies that would maximize the benefits to be derived from the water available for release through the Delta. For example, coordinated, short-term pulse flows from upstream tributaries could improve salinity conditions while moving juvenile fish through the estuary. Criteria adopted by EPA should be flexible enough to permit the most effective use of the available water resources.

Issue 16 (59 Fed. Reg. 842): In terms of seasonal habitat conditions, EPA must remember that although dams and diversions reduce spring outflows, they also provide additional flows in the drier summer and fall months. These releases benefit upstream fisheries and prevent movement of the low salinity estuarine habitat as far into the Delta as it penetrated prior to the operation of the major projects. Especially in drought years, many streams that would in nature carry little water or no water for several months at a time are maintained as viable habitats by reservoir releases. EPA should recognize the value of releases during the "off-season" when considering what a reasonable level of releases may be in the months of February through June.

2.4. CONCLUSION

The proposed criteria for estuarine habitat protection attempt to protect aquatic resources by controlling only one element of the habitat—salinity—while ignoring other elements, especially the impact of export pumping. This is a critical flaw. EPA should address the full range of habitat issues, and revise its criteria accordingly. The EPA must also develop a credible reference period. In this, as in all other criteria, a reasonable balance must be maintained between environmental and human uses, and between the needs of upstream and estuarine environments.

3. SALMON SMOLT SURVIVAL INDICES TO PROTECT MIGRATING SALMON

3.1. EPA HAS NO AUTHORITY TO ADOPT THE PROPOSED SMOLT SURVIVAL CRITERIA

EPA has proposed salmon smolt survival criteria to protect the Cold Fresh-Water Habitat and Fish Migration designated uses. EPA is attempting to use the salmon smolt survival criteria in lieu of water quality standards, because EPA lacks an adequate basis on which to propose water quality criteria. The State Board, too, recognized that the CWA does not specifically require that a salmon smolt survival standard be established, and that the proposed standards promulgated by EPA substantially exceeded the level of protection required by the CWA. (State Board Preliminary Comments to EPA, November 15, 1993.)

EPA's authority under § 303 of the CWA is limited to setting water quality criteria for navigable waters based upon designated uses of those waters. (CWA

§ 303(c)(2), 33 U.S.C. § 1313 (c)(2).) Water quality "relates to the levels of specific substances present in water, including TDS, various chemicals, and bacteria." (James River Flood Control Ass'n. v. Watt, 553 F. Supp. 1284, 1291 fn. 6, see also CWA § 101(a) & (g), 33 U.S.C. §§ 1251(a) & (g); 40 C.F.R. § 131.11(a).) "Criteria" are defined as the chemical, physical, and biological characteristics of a water body (33 U.S.C. § 1362(18)), which, when attained, protect designated uses (40 C.F.R. § 131.3(b)).

The proposed salmon smolt survival criteria, which assumes a barrier is in place at the head of Old River, consists of an index based upon a statistical relationship between flow in the San Joaquin River at Stockton and exports at the CVP and SWP pumping plants. If the barrier is not in place, the index must be calculated using a different equation that relates smolt survival to San Joaquin River flow at Vernalis and export pumping. The proposed San Joaquin salmon smolt survival criteria can hardly qualify as a water quality criteria as defined by the CWA.

3.2. EPA'S PROPOSED USE OF SAN JOAQUIN RIVER SALMON SMOLT SURVIVAL INDICES IS SERIOUSLY FLAWED

The smolt survival index criteria proposed by EPA are identical to the index values listed under Alternative D on Table 14 of the Fish and Wildlife Services WRINT-USFWS-7. The linkage between Alternative D and the proposed criteria is also readily apparent from the description of USFWS-recommended implementation measures found on page 825 of the Federal Register. The major change in implementation strategies proposed by EPA—keeping Georgiana Slough open—does not effect the San Joaquin River index, so the values in Tables 3 and 4 of the EPA proposal for the San Joaquin River are identical. EPA concludes that, "Based on the USFWS models, these particular measures will achieve the proposed smolt survival indices in Table 3." (59 Fed. Reg. 825) That statement should be compared to the question raised on page 842 of the Federal Register discussion, which reads in part,

> EPA is concerned that there may be implementation scenarios for the two rivers [Sacramento and San Joaquin] that could result in detrimental conditions for migrating smolts even if the proposed index values are achieved. One such possible scenario may occur if the State Board adopts USFWS implementation recommendations on the Sacramento River (adjusted, as described above, to account for Georgiana Slough remaining open), but then operates the San Joaquin River so as to just meet the proposed index values. In this case, our preliminary review indicates that the San Joaquin River index value theoretically might be attained with lower flows than are protective for the salmon resources.

The only variable common to the two rivers is export pumping. It appears that EPA has realized that if the export limits found in USFWS Alternative D are implemented, San Joaquin smolt survival index targets can be achieved at flows significantly lower than the Vernalis flows proposed by USFWS in Alternative D. In other words, the export and San Joaquin flow limits found in Alternative D do not appear to match the smolt survival index values listed for that alternative. The obvious question, then, is how were the San Joaquin index values found in Alternative D, and EPA Tables 3 and 4, calculated? A full explanation of the derivation of the proposed index criteria must be provided.

Based on the issues raised above, it appears that there is inadequate scientific support for the use of salmon smolt survival indices as the basis to protect the Cold Fresh-Water Habitat and Fish Migration designated uses.

3.3. THE HISTORIC REFERENCE PERIOD IS INADEQUATELY DEFINED

3.3.1. Use of 1956-1970 as a reference period is inappropriate

The use of the 1956-70 as a historic reference period does not meet the requirements of the CWA. EPA is not entitled to adjust the temporal context of the antidegradation concept simply because it perceives that the protected uses were already in decline by 1975. As pointed out in these comments, the applicable reference period is 1975, or a period reflective of a 1975 level-of-development.

3.3.2. The historic 1956-1970 smolt survival index may be overestimated

In calculating historic smolt survivals indices, USFWS (and EPA) appear to have used a without-export relationship (Relationship A) prior to operation of the export pumps, and a with-export relationship (Relationship B) for the post-1950 period. The background and derivation of both of these relationships are described in WRINT-USFWS-7, page 49. Relationship B is based on data for the period 1969-87 (except for 1981). Operation of the State Water Project dramatically increased export pumping in 1968 and later years compared to the CVP-only period (1950-67). Relationship B therefore reflects only post-SWP conditions, and it may not be valid outside the range of conditions used to create it.

Attachment 1 compares the smolt survival index as computed using Relationship A to the index computed using Relationship B. Typically, Relationship A (without-export) would be used through 1949, and Relationship B (with-export) would be used thereafter. In this case, indexes were computed using April-May average flow and exports, and the without-export index was computed for the entire period shown (1940-80). After exports began it would be expected that Relationship A would overestimate survival because it fails to take into account a new source of mortality (export pumping). However, the graph shows that Relationship A initially predicted lower survivals than the with-export

Relationship B. This is counter-intuitive because it suggests that the addition of an export term improved survival. The only explanation for this result is that the CVP exports alone had little, if any, impact on smolt survival. By the mid- to late-1960's the two estimates merge and after 1968, exports show their expected depressing effect on smolt survival. This suggests the Relationship B cannot be applied to conditions (such as lower exports) outside the range of conditions upon which it is based, i.e., prior to the time the SWP exported water from the Delta. It also suggests that USFWS may have overestimated smolt survival during much of the 1956-70 period, which was the same period used by EPA as its historical reference period.

3.3.3. The "1940 Level of Development" is an inappropriate comparison and was not developed using sound science

EPA states that "In developing the goals or target index values for its proposal, EPA is relying primarily on the goal of restoring habitat conditions to those existing in the late 1960's and early 1970's." (59 Fed. Reg. 823.) It then refers to Table 2 (59 Fed. Reg. 824) to demonstrate the decline in the fishery resource and support for the proposition that "strict adherence to the late 1960's and early 1970's target is inappropriate ... [because] fisheries, especially on the San Joaquin River, were already somewhat degraded during that historical period." (59 Fed. Reg. 824.) The relative degradation occurring between various periods prior to 1975 is irrelevant under EPA's Clean Water Act authority.

Degradation is apparently measured by the difference between the average smolt survival index for each water year type under a "1940 Level of Development" and the corresponding average index for later historical periods. The smolt survival flow relationship for 1940 level of protection goal for the San Joaquin River was based on the original relationship between escapement in the Tuolumne River only and flow at Tuolumne City for the escapement years 1938-1940, 1942, 1944, and 1945. USFWS then replaced the escapement values on the Y-axis with smolt survival values with a range of 0% to 100% survival corresponding to the range of 1 to maximum escapement. (WRINT-USFWS-7, pp. 49-51.) This methodology was criticized during the Five Agency Chinook Salmon Committee process as being neither sound science nor sound statistics for deriving a 1940 level of protection goal. EPA has apparently adopted the same methodology in developing the proposed rule (59 Fed. Reg. 850).

3.4. *SUBSTANTIAL EFFORTS ARE ALREADY UNDERWAY IN THE SAN JOAQUIN BASIN TO IMPROVE CONDITIONS FOR SALMON AT ALL LIFE STAGES*

3.4.1. The Turlock and Modesto Irrigation Districts have long recognized the need for balance in the use of water resources

After months of negotiations, the Districts and DFG reached an agreement to increase flows on the Tuolumne River below Don Pedro Dam. The agreement is currently undergoing environmental review at the Federal Energy Regulatory Commission. The agreement represents a significant step towards resolving the fishery problems on the San Joaquin River—the significance of the agreement was recognized most recently in the November 1993 draft of The California Water Plan Update which contains the following statement:

> As a result of the Phase I Bay/Delta Hearings in 1987, the State Board asked that local, State, and federal agencies collaborate on mutually acceptable programs to meet the environmental water needs of California. Probably the most successful product of this request is the 1992 agreement among Turlock Irrigation District, Modesto Irrigation District, and DFG.... (DWR, California Water Plan Update, Bulletin 160-93, Vol. 1, p. 227-228.)

The agreement (WRINT-MID/TID-16) is a very significant and innovative one. The agreement incorporates many of the concepts and measures which have been discussed during the Bay-Delta and related processes. For example:

- The agreement incorporates a multi-water year classification system. Water year classifications are based upon inflow into Don Pedro Reservoir because of San Francisco's upstream Hetch Hetchy Project reservoirs and peripheral aqueduct.
- Based upon the principle of equitable sharing of the inflow, 15% to 16% of the current water year's inflow is allocated to minimum instream flows.
- The new minimum instream flows are a significant increase over the current minimum instream flow requirements.
- The spring pulse flow concept under Alternative C of Table 14, Fall-run Salmon Protective Alternatives for Delta, WRINT-USFWS-7, is implemented in the agreement. Tuolumne River pulse flows under the agreement are significantly greater in median dry or better water years than would be required under Alternative C's 14-day pulse flow. (See WRINT-MID/TID-31.)
- DFG is required to appoint a Flow Coordinator. This will hopefully be the first step in eventually having one representative for all State and

Federal fishery agencies to coordinate minimum instream flow schedule changes within the San Joaquin Basin for spring pulse flow and other fishery purposes.

- Both flow and non-flow measures (e.g., spawning gravel rehabilitation) are included in the agreement.
- The agreement focuses on the short term (to June 30, 2002); however, the agreement incorporates concepts and measures which will have long term significance.

Although the agreement was developed nearly a year before the CVP Improvement Act was signed into law, it contains many of the concepts which later appeared in the Federal act including significant increases in instream flows, spring pulse flows to aid salmon outmigration, spawning gravel rehabilitation, and provisions for fish and operational studies.

3.4.2. Other efforts in the San Joaquin River Basin

In the San Joaquin River Basin, the institutional processes are already in place and are moving forward to develop and implement measures to improve San Joaquin Basin fisheries.

The United States Fish and Wildlife Service (USFWS) and DFG have submitted to the United States Bureau of Reclamation (USBR) their recommended new instream flows for the New Melones Project on the Stanislaus River. On the Merced River, the Merced Irrigation District has successfully transferred water during the smolt outmigration period for use by San Joaquin basin wildlife refuges. In addition, the three San Joaquin River tributaries coordinated pulse flow releases in Spring 1993 to enhance conditions for outmigrating salmon smolts.

Construction and operation of Friant Dam on the Upper San Joaquin River has brought about the loss of flows during salmon spawning and spring outmigration and adversely impacted the salmon runs on the other three tributaries. Section 3406(c)(1) of the CVP Improvement Act addressees fish, wildlife, and habitat concerns on the San Joaquin River, including streamflow, channel, riparian habitat, and water quality improvements necessary to sustain naturally reproducing anadromous fisheries from Friant Dam to the river's confluence with the Bay-Delta Estuary. The development of a comprehensive plan, which is required to be completed by September 30, 1996, is a joint effort by USFWS and USBR. The Notice of Intent to prepare an environmental impact statement on the comprehensive plan will be published in April 1994 with public input meetings to follow in May 1994.

3.5. *DIFFERENCES BETWEEN THE SACRAMENTO AND SAN JOAQUIN RIVERS MUST BE RECOGNIZED*

3.5.1. The San Joaquin River Basin is significantly different from the Sacramento River Basin

3.5.1.1. The Significant Differences

During the D-1630 Bay-Delta hearing process most participants recognized that the San Joaquin River Basin is significantly different from the Sacramento River Basin. For example,

- The Sacramento Basin is a rain-fed system, whereas the San Joaquin Basin is a snow-fed system. This results in a significantly different run-off pattern which was recognized when the Water Year Classification Workgroup proposed use of a 40-30-30 water year classification index for the Sacramento Basin and a 60-20-20 index for the San Joaquin Basin. See WRINT-DWR 16.
- The unimpaired and impaired flows for the Sacramento Basin are substantially greater than for the San Joaquin Basin. For example, see Exhibit No. WRINT-MID/TID 38, entitled "Actual Delta Inflow by Tributary Basin, 1956-1970," which shows that during the period 1956 to 1970, the Sacramento Basin contributed 82.6% of the Delta inflow, the East Side Streams, 4.77%, and the San Joaquin Basin, 12.63%.
- A substantial portion of the Sacramento Basin water flows to the Delta for export, whereas most of the San Joaquin Basin water is used upstream within the basin or is diverted around or away from the Delta.
- Some 760,000 AF of Trinity River water is imported annually into the Sacramento River Basin, whereas 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 without first flowing to the Delta. The Sacramento River Basin water which is exported at the Delta for use in the San Joaquin Valley is part of the Delta export problem.

CVP facilities and operations have influenced and impacted in a very pervasive and dominant way fishery habitat conditions in the San Joaquin River Basin by the destruction of salmon runs on the mainstem and alteration of the basin's hydrology. Because of the location of the SWP and CVP export pumps in the South Delta, export operations significantly impact San Joaquin Basin salmon smolt outmigration, whereas, the impacts of export operations on Sacramento Basin salmon smolts vary depending upon the timing of various aspects of export operations (e.g., operation of the Delta Cross-Channel gate).

3.5.1.2.Recognition of Those Differences by the Fishery Agencies

One of the more significant developments during the D-1630 Bay-Delta hearings was that the differences between the two basins are now being officially recognized by the fishery agencies. This was reflected in the fishery agencies' recommendations to the State Board. In WRINT-DFG-30, page 7, DFG stated:

> We recognize these measures for habitat restoration [in the San Joaquin drainage] differ substantially from those proposed for the Sacramento drainage. This is necessitated by the fact that the majority of developed water on the San Joaquin is diverted at or above the lowest dams. Hence, we have suggested very conservative 'freshet' flows that minimize water allocations as an interim and experimental approach in the San Joaquin system.

Dick Daniel, DFG Water Management Coordinator, further clarified WRINT-DFG-30 by stating on August 3, 1992, in response to a cross-examination question that the San Joaquin Basin has been so severely modified by water development projects that DFG was only looking to "maintain" the existing San Joaquin salmon population as opposed to the Sacramento Basin where DFG was looking to "optimize" those salmon populations. (WRINT Hearing Transcript, August 3, 1992, pp. 21-22.)

3.5.2. The San Joaquin River measures under Table 14's Alternative C (WRINT-USFWS-7) meet the 1956-70 smolt survival indices for the San Joaquin River

Significant problems with the derivation of the salmon smolt survival index values in Table 14 of WRINT-USFWS-7 and with the possible overestimation of the 1956-70 San Joaquin River smolt survival indexes have already been noted. However, to the extent that USFWS estimates of historic index values associated with the implementation measures shown on Table 14 are useful for comparative purposes, Tables 13 and 14 of WRINT-USFWS-7 show that the 1956 to 1970 smolt survival index averages would be met under **Alternative C for the San Joaquin Basin** as opposed to Alternative D for the Sacramento Basin.

The Alternative C San Joaquin Basin measures call for a limit on total CVP/SWP exports during the 14-day period April 23 to May 6, a full barrier at the head of Upper Old River, and a 14-day pulse flow during the period April 23 to May 6. (See WRINT Hearing Transcript, Vol. III, July 6, 1992, pp. 90-91.) By way of contrast Alternative D calls for a limit on total CVP/SWP exports during a 30-day period from April 15 to May 15, a full barrier at the head of Upper Old River, and a 30-day pulse flow during the April 15-May 15 period. The following table compares relevant data from WRINT-USFWS-7 Tables 13 and 14:

San Joaquin River	W	AN	BN	D	C	Mean of Five Year Types
1956-70 Historical (Table 13)	.61	.25	.18	.17	.15	.27
Alternative C (Table 14)	.42	.25	.21	.19	.18	.27

The table shows that by USFWS's own estimates a 14-day Vernalis pulse flow with concurrent CVP/SWP export restrictions and an Upper Old River barrier would restore smolt survival rates through the Delta to 1956-1970 historical levels—both having a mean of the five water year types of 0.27. Perhaps more significant is that Alternative C is predicted to produce higher survival rates during critical, dry, and below normal years than during the 1956-70 reference period.

EPA has misinterpreted Table 14 and applied Alternative D to the San Joaquin River in order to achieve a goal of restoring habitat conditions to the late 1960's–early 1970's period. As pointed out above and the testimony provided by USFWS during cross-examination at the State Board's Bay-Delta hearings (WRINT Hearing Transcript, Vol. III, July 6, 1992, pp. 90-91), Alternative C is more appropriate to the San Joaquin River, while Alternative D is more appropriate to the Sacramento River.

3.5.3. Since 1960, San Joaquin Basin salmon populations have followed a cyclical pattern with the all time historic low occurring in 1963

EPA's proposal is aimed "to protect salmon from falling to dangerously low population levels, and more nearly mimic the natural historical response of smolts migrating through the Delta to year-to-year changes in hydrology" (59 Fed. Reg. 824). With its primary focus on Sacramento salmon issues, EPA has failed to properly examine historic salmon escapements in the San Joaquin Basin. An examination of the escapement record would show that since 1956 (the beginning of EPA's reference period) to the present, the San Joaquin Basin salmon runs have crashed following each of the three droughts during that period (1959-61, 1976-77, and 1987-92). For example, after the 1959-61 drought, the total San Joaquin Basin fall-run salmon escapements fell to an all time historic low of 320 spawners in 1963—right in the middle of EPA's 1956-70 reference period. (WRINT-USFWS-7; WRINT-MID-TID-23.) The Basin's escapements did not approach the average 1950's escapements again until the 1969-71 period. In developing the proposed smolt survival criteria, EPA has ignored the historic realities of the 1956-70 period in the San Joaquin Basin and instead has tried to create its own artificial version of history.

3.6. THERE IS NO SCIENTIFIC BASIS FOR A TEMPERATURE CRITERIA FOR SALMON SMOLT SURVIVAL THROUGH THE DELTA

In 1991 the State Board adopted new temperature objectives of 68°F at Freeport and Vernalis from April 1 through June 30 and September 1 through November 30 for the protection of fall-run chinook salmon. EPA disapproved the 68°F objective "because the evidence in the State Board's submittal did not demonstrate that they would be sufficient to protect cold-water habitat for these species.... EPA recommended that the State Board adopt a 65°F criterion, or an alternative that is scientifically defensible." (59 Fed. Reg. 823.) Neither the 68°F objective adopted by the State Board nor the 65°F criteria recommended by EPA is a scientifically defensible temperature criteria for the protection of salmon smolts migrating through the Delta.

3.6.1. Temperature requirements of chinook salmon smolts

There have been a number of scientific studies of the temperature requirements of chinook salmon smolts, dating back at least as far as 1952.[2] These controlled experiments, reported in respected, peer-reviewed, international journals, consistently find 50% survival from 74°F to 77°F, with little or no mortality attributable to temperature below 68°F.

Recent USFWS interpretation trawl-survey data from the Delta[3] appears to conflict with this body of literature. In particular, the smolt survival model of Kjelson et al. predicts 50% survival at only 65°F. However, the Districts' consultants, EA Engineering, Science, and Technology (EA), have demonstrated on numerous occasions[4] that this discrepancy can be attributed almost entirely to

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[2] Brett, J. R. 1952. *Temperature tolerance in young Pacific salmon, genus* <u>Oncorhynchus</u>. J. Fish. Res. Board Can. 9: 265-323; Houston, A. H. 1982. *Thermal effects upon fishes.* Natl. Res. Counc. Can. Assoc. Comm. Sci. Criter. for Environ. Qual. Publ. No. 18566. Ottawa, Ont.

[3] 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 chinook salmon in the Sacramento-San Joaquin Estuary. 1984 Annual Progress Report. U. S. Fish Wildl. Serv., Fisheries Assistance Office, Stockton, CA.; 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.

[4] E.g., Baker, P. F., T. P. Speed, and F. K. Ligon. 1992. *The influence of temperature on the survival of chinook salmon 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.

the decision by USFWS to divide their basic survival estimates by 1.8 before fitting their models.

USFWS has always been careful to describe the results of their analyses as a smolt survival *index*. From this point of view, the 1.8 factor can be regarded as relatively harmless (and perhaps even mathematically convenient). However it is inappropriate to use models based on this factor to set absolute temperature guidelines.

EA has reanalyzed the Chipps Island recoveries of smolts released at Ryde without the 1.8 factor. The details of EA's analysis are given in Attachment 2, which is an article recently accepted for publication by the Canadian Journal of Fisheries and Aquatic Sciences. The smolt survival predicted by the statistical model described in the article is 50% at 73.4°F. This is much closer to the survival one would expect from the published results of laboratory experiments.

EA's modeled survival of salmon smolts is 88% at 68°F and 96% at 65°F. This is a gain of only 8%. Simulation allows us to estimate confidence intervals for all functions of model parameters. Using this method with EA's most conservative model of extra variation, the gain in predicted smolt survival is found to be less than 13% at the 90% confidence level.

EA's analyses are based on the assumption that smolt survival indexes calculated from the Chipps Island trawl data *without* the 1.8 factor can be used directly as estimates of actual survival. This point of view is supported by the following observations:

- To the best of EA's knowledge, no derivation of the 1.8 factor, and no biologically or statistically sound argument that could lead to such a derivation, has ever been published.
- Survival estimates without the 1.8 factor are consistent with survival estimates for the same smolts based on ocean recovery data, and with all the experiments known to EA in the formal scientific literature.
- Survival estimates with the 1.8 factor are very seriously inconsistent with survival estimates for the same smolts based on ocean recovery data, and with all the experiments known to EA in the formal scientific literature.

3.6.2. Effects of high water temperature on migrating chinook salmon smolts in the San Joaquin River

Exhibit WQCP MID/TID-1, presented to the State Board during the Water Quality phase of the Bay-Delta hearings, examines the effects temperatures in the San Joaquin River on outmigrating salmon smolts. A review of the scientific literature by EA showed that laboratory studies indicated that if the salmon smolts were acclimated to warm temperatures they would probably not be adversely affected by short-term exposures to temperatures at least as high as 77°F. EA showed that there is no evidence that high temperatures have adversely affected historical recruitment of two year olds to the ocean fishery or spawning escapement, and they provided field observations that smolts in the San Joaquin River and its tributaries survived temperatures of at least 77°F during downstream migration.

The Districts' consultants concluded that the San Joaquin River population of chinook salmon is the most southerly population, and therefore, could be expected to be the least susceptible to high temperatures. It was recommended that direct tests of temperature tolerance be applied, rather than assuming that existing temperatures are having adverse effects.

3.7. A PERMANENT BARRIER AT THE HEAD OF OLD RIVER SHOULD BE CONSTRUCTED

The Federal Register notes that "[c]onsistent with implementation recommendations of USFWS, NMFS, and DFG, the San Joaquin model assumes that a barrier will be in place at the head of Old River during the peak migration period." (59 Fed. Reg. 823.)

The one physical solution that was widely supported by the participants to the State Board's hearings regarding interim water rights actions to protect the Bay-Delta estuary was the construction of a barrier at the head of Upper Old River during the spring to aid smolt outmigration. The "construction and operation of barriers within the Delta to assist fish in their migration either out of or through the Delta" was recognized by the State Board in its May 8, 1992 Notice of Public Hearing for the above-referenced hearings as a suggested requirement to be placed on the SWP and CVP as a structural option "which the SWP and CVP could undertake in the short-term to reduce their impacts on public trust resources." (Notice, p. 3.) Governor Wilson in his April 6, 1992 water policy statement emphasized the "need to take immediate interim actions in the South Delta that will help restore the environment and improve the water supply," including the construction of flow control barriers, and, concurrently, linking "South Delta facilities to improved, interim standards for protection of fish and wildlife." The Regional Director of the USFWS specifically stated that "there are some largely single purpose fishery facilities that could and should be implemented in the interim" and "A barrier at the head of upper Old River is one such facility." (Policy Statement of Marvin L. Plenert, dated June 22, 1992, at pp. 2-3.) The State Water Contractors included "Install barriers at the head of Old River and other strategic locations within the lower San Joaquin River and Delta to ... improve survival of emigrating chinook salmon and steelhead" in its elements to be included in an interim Bay-Delta management program. (WRINT-SWC-1, Table 1, p. 1.) The installation of a full barrier at the head of Upper Old River barrier was an essential element of all five Alternatives contained in Table 14 of WRINT-USFWS-7. The CVP Improvement Act mandates that such a barrier be built. (CVPIA sec. 3406 (b)(15).)

While acknowledging that a barrier at the head of Old River was recommended by both DFG and USFWS to reduce the mortality attributable to the export pumps of San Joaquin Basin smolts (59 Fed. Reg. 823), the criteria set by the EPA would require the San Joaquin Basin water users to meet the criteria even if the barrier is not constructed. In the absence of a barrier, the San Joaquin Basin spring pulse flow requirement would probably be unreasonably increased in an effort to meet the criteria. Under Article X, section 2 of the California State Constitution, "all uses of water, including public trust uses, must now conform to the standard of reasonable use." (National Audubon Society v. Superior Court (1983) 33 Cal.3d 419, 443.) The use of additional outflow where a physical solution was initially recognized by the State Board, advanced by the Governor, and endorsed by consensus of the Bay-Delta hearing participants would be an unreasonable allocation of water for public trust purposes. A permanent barrier at the head of Old River should be constructed.

3.8. SPECIFIC SALMON SMOLT SURVIVAL CRITERIA ISSUES FOR COMMENTERS TO ADDRESS

Issue 10 (59 Fed. Reg. 841): As shown above, there is no scientific basis for establishment of a temperature criteria for the protection of outmigrating San Joaquin River salmon smolts. Furthermore, testimony in the Bay-Delta hearing clearly showed that the implementation of a temperature criteria using only reservoir releases would be an exercise in futility. The use of a temperature-only criteria would tend to mask the impact of the export pumps and would be less protective than a criteria that included export limitations.

Issue 11 (59 Fed. Reg. 841): Closure of Georgiana Slough could worsen reverse flows in the lower San Joaquin River by reducing the cross-Delta transfer of water. EPA suggests that the reverse flow problem could be reduced if exports were balanced with San Joaquin River flow. In fact, unless exports are reduced to equal the amount of water that can get to the pumps from the San Joaquin River by way of Old River, there are going to be reverse flows someplace in the Delta. A barrier at the head of Old River will increase flows in Middle River at any given level of export. What effects the combination of a Georgiana Slough closure and an Old River barrier would have is unknown, but in that instance exports would have to be balanced to what the pumps could pull from the central Delta if reverse flows further west were to be avoided.

Issue 12 (59 Fed. Reg. 841, 842): If the San Joaquin River smolt survival index criteria reflect assumptions about scientific implementation measures, then any change in the suite of implementation measures must be reflected in the accompanying index values. That is, after all, what EPA did when it changed the Sacramento River index values to show the effect of leaving Georgiana Slough open. The question, and its answers, further supports the statement made above that EPA's use of the smolt survival indexes is fundamentally flawed and must be revised in its entirety.

Issue 13 (59 Fed. Reg. 842): The USFWS index equations can yield high survivals at very low flows given the export limitations proposed by USFWS. This supports the contention that the major factor influencing San Joaquin smolt survival through the Delta is the export pumps and not flow. EPA has no basis for making arbitrary adjustments of index values.

3.9. CONCLUSION

EPA has no legal authority to substitute a smolt survival index criteria for the water quality criteria authorized under the CWA. Notwithstanding that fundamental objection, the derivation of the proposed criteria is flawed and scientifically unsound. There is also no scientific basis for a San Joaquin River temperature criteria for smolt protection. Given the intensive efforts being made by federal, state and local agencies to improve conditions for all life stages of San Joaquin River Basin salmon, we recommend that EPA refrain from adopting any salmon criteria at this time.

4. CRITERIA TO PROTECT STRIPED BASS SPAWNING IN THE SAN JOAQUIN RIVER

4.1. STRIPED BASS DECLINE IS NOT A WATER QUALITY PROBLEM

There is no evidentiary support for the proposed electrical conductivity criteria to protect striped bass spawning upstream of Prisoner's Point in the San Joaquin River. Striped bass are mass, open-water spawners; unlike salmon they do not have any special nesting requirements for spawning. There is no credible evidence to suggest that an inadequate spawning area, in terms of size or location, is a factor that limits the abundance of striped bass.

The decline of the striped bass population has been extensively studied in the past by DFG which came to the following conclusion:

> Substantial effort has gone into evaluating factors responsible for the decline in striped bass abundance. This effort has centered on the concept that for the population to decline, there must be a decrease in its birth and/or increase in its death rates. In brief, our explanation of the striped bass decline is that there has been an increase in death rate (decrease in survival rate) predominantly in the first year of life and caused mainly by increased losses of fish entrained in water exports by the State and Federal Water Projects. This has led to a lower adult striped bass population which is producing fewer eggs (lower birth rate) and that, in turn, is producing fewer young fish and subsequently even fewer adults. (WRINT-DFG-2.)

EPA is attempting to characterize the decline in striped bass populations as a water quality problem, when in fact the problem is the impact of the export pumps.

4.2. SAN JOAQUIN RIVER UPSTREAM FROM PRISONER'S POINT WAS NEVER A SIGNIFICANT SPAWNING AREA

Exhibit WQCP MID/TID 2 submitted to the State Board during hearings on the Water Quality Control Plan surveys the available historical literature on striped bass spawning locations in the Delta and concludes that the primary spawning area was in the western and central Delta, and that the San Joaquin River upstream from Venice Island was never more than a comparatively minor or sporadic spawning location. The current Water Quality Control Plan (91-15WR, May 1991) adequately defines and protects the historic spawning area in the San Joaquin River.

Discussion of the proposed criteria (see 59 Fed. Reg. 827) leaves the impression that striped bass run upstream until they encounter higher salinity. If this were true, most spawning would occur near the upstream limit of acceptable salinity, and in wet years should be expected to occur well upstream from Prisoner's Point. There is no evidence that that has occurred, and there appears to be no clear correlation between salinity at Vernalis and spawning distribution. The persistent pattern of spawning in the western and central Delta makes it problematical whether or not striped bass would migrate further upstream in substantial numbers if the proposed criteria were adopted.

4.3. THE PROPOSED SALINITY CRITERIA EXCEED EPA'S AUTHORITY UNDER THE CLEAN WATER ACT

Salinity levels in the San Joaquin River have been high enough to inhibit striped bass spawning in dry years and many normal years since the 1930's.[5] Despite a long history of elevated salinity, the EPA proposal is conspicuously silent regarding reference period salinity conditions in the San Joaquin River between Vernalis and Prisoner's Point. A review of Vernalis TDS data shows that 0.44 mmhos/cm EC was achieved in only 3 of the 12 years between 1964 and 1975, with the three years being wet years and prior to 1970. Between 1970 and 1975 there were two wet years, two above normal years and one below normal year, but average April/May salinity did not fall below 0.44 mmhos/cm EC in any of them. Due to saline runoff entering the river as it passes through the south Delta, salinity near Stockton would probably be somewhat higher than at Vernalis. The San Joaquin River begins to freshen in the central Delta as it mixes with water from the Mokelumne and Sacramento rivers.

[5] This statement assumes that spawning salinity preferences found in the Federal Register at page 826 are valid. The studies cited may not be sufficient to establish or define a salinity barrier to migration and spawning in the lower San Joaquin River. (See Exhibit WQCP-MID/TID-2.)

EPA is authorized under the CWA to maintain water quality conditions as they existed in 1975. The proposed criteria would substantially exceed that mandate by requiring better conditions than existed in 1975, or would exist at a 1975 level-of-development in all but the wettest year types.

4.4. SPAWNING ABOVE PRISONER'S POINT WOULD SUBJECT STRIPED BASS LARVAE TO INCREASED RISK OF ENTRAINMENT

During the State Board's Bay-Delta hearing process, the DFG did not recommend enlarging the size of the spawning area upstream, in part because it would expose the upstream spawners' eggs to an increased risk from the export pumps. DFG testified during the Water Quality Phase of the Bay-Delta hearings that:

> ...restoration of striped bass depends primarily on management decisions pertaining to areas farther downstream in the Delta and Suisun Bay.... Restoration of bass spawning in the San Joaquin River could be a useful adjunct to measures directed towards rehabilitating downstream areas. By itself, however, we [DFG] believe it would at best provide a small benefit and at worst could be detrimental to bass. Detriment could result from bass eggs and larvae drifting downstream in the San Joaquin River being more vulnerable to diversion at the CVP and SWP export pumps than eggs spawned in the lower San Joaquin River. (Exhibit WQCP-DFG-4, p. 9.)

EPA states that it believes that the State Board can, in developing its implementation measures, address the impact of entrainment at the export pumps. The losses of young striped bass to entrainment at the State and Federal pumping plants needs to be addressed before considering any standards aimed at extending the potential striped bass spawning habitat upstream of its current location.

4.5. STRIPED BASS PREDATION THREATENS ENDANGERED WINTER RUN CHINOOK SALMON

EPA fails to address the impacts that its striped bass spawning criteria could have on endangered winter-run chinook salmon. The final rule determining that the Sacramento River winter-run chinook salmon should be reclassified from threatened to endangered under the Endangered Species Act (ESA) listed striped bass predation as one cause for the decline of the winter-run chinook salmon. (59 Fed. Reg. 440.) The final rule states:

> Several groups raised concerns in 1992 about the possible effects of CDFG's striped bass enhancement and management program on winter-run chinook salmon. NMFS reviewed CDFG's proposed

enhancement program for 1992 and recommended several changes, as well as the implementation of studies designed to assess the magnitude of striped bass predation on winter-run chinook salmon. As a result of these and other concerns, CDFG eventually decided to suspend the planting of hatchery-reared striped bass in Delta waters in 1992. In June 1993, NMFS requested that CDFG delay further release of hatchery fish as part of its striped bass management program, and apply for an ESA section 10 incidental take permit. (59 Fed. Reg. 446.)

While striped bass are still entitled to reasonable protection, EPA should at least acknowledge that a significant improvement in striped bass abundance at this time could be detrimental to winter-run chinook salmon and possible to other species listed under the ESA.

4.6. CONCLUSION

The proposed criteria are unnecessary biologically, unjustified historically from both fishery and water quality perspectives, and could, according to DFG, do more harm than good given the present configuration of the Delta. Because it goes beyond an antidegradation criteria, the proposal exceeds EPA's authority. No further consideration should be given to striped bass spawning salinity criteria upstream of Prisoner's Point.

DATED: March 10, 1994

Respectfully submitted,

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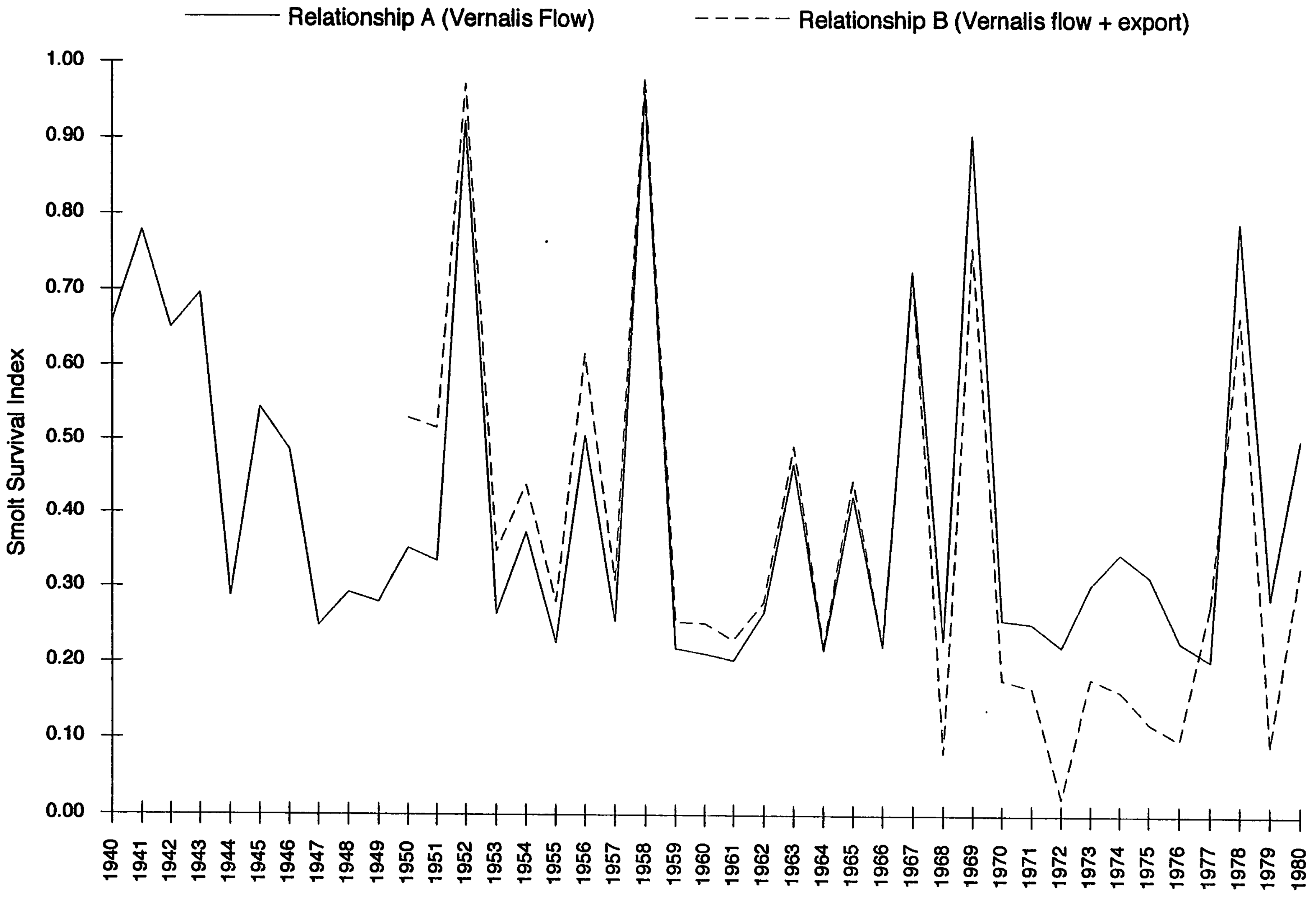
Attachment 1

Comparison of Historic San Joaquin River Salmon Smolt Survival Estimates

(using April-May flow and export data)



3/7/94

Attachment 2

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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3 December 1993 1:19PM

Baker, P. F., T. P. Speed, and F. K. Ligon. 1993. The influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento - San Joaquin River Delta of California. Can. J. Fish. Aquat. Sci.

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 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 midwater 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. Quasilikelihood 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 important implications for the applicability of laboratory findings to natural systems.

Introduction

For many years, the U.S. Fish and Wildlife Service (USFWS) has conducted trawls for chinook salmon (*Oncorhynchus tshawytscha*) smolts at 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 (notably by Stevens et al. 1984; USFWS 1987; Kjelson et al. 1989).

An important part of these data consists of the recoveries of smolts bearing coded-wire tags (CWTs) from a series of releases by USFWS and the California Department of Fish and Game (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 serious 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 present a number of such models for smolt survival as a function of water temperature. We restrict our attention here to 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 careful 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 Sacramento River water temperature at Freeport at the time of release, in degrees centigrade.

The data used in the models are those from the 15 releases at Ryde from 1983 through 1990 that are listed in Table 1. These data were assembled from the USFWS annual reports (USFWS 1983–1992). 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 essentially only one route to Chipps Island, 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).

The trawl effort is defined by USFWS as the fraction of time spent trawling times the ratio of the net cross section to the channel cross section. 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 later in this paper.

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 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

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

This is a generalized linear model with canonical link function, in the terminology of McCullagh and Nelder (1989). The maximum likelihood estimate for (b_1, b_2) is easily found by 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 1. 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 1 near here

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 (c.f. McCullagh and Nelder 1989, §4.5.1). There is an extensive literature on the subject, which basically justifies using the model to estimate parameters like b_1 and b_2, but not to estimate their uncertainty (see references in McCullagh and Nelder 1989; Burnham et al. 1987).

Nonetheless, it is a good idea to determine which of the assumptions in the model are responsible for the poor fit. At the least, we would like to make sure that the general results referred to in the last paragraph actually are applicable here. Even better, if the source of the extra variation can be identified, we can try to incorporate it into the model.

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 easily 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 two-year-olds. By comparing the ocean recovery rates for the Ryde groups with the ocean recovery rates for 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:

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

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.

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. Since 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 2, that the hypothesis $S_{\text{Ocean}} = S_{\text{Trawl}}$ cannot be rejected at the 95% confidence level. We interpret this as evidence that the p_i can be used as estimates of the expected values of the true recovery probabilities. Figure 2 near here

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

THE RELAXED MODEL, QUASILIKELIHOOD, 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. This gives

(2)
$$\pi(m_i|n_i,\phi_i,p_i) = \int_0^1 \binom{n_i}{m_i}(P\phi_i)^{m_i}(1-P\phi_i)^{n_i-m_i} f_i(P)\,dP$$
$$\phi_i = \phi(T_i) = \frac{1}{1+e^{-b_1-b_2T_i}}$$

where f_i is the density for P.

Since 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

(3)
$$E[m_i] = p_i\phi_i n_i$$
$$V[m_i] = E[m_i] + \left(\frac{n_i-1}{n_i}\rho^2 - \frac{1}{n_i}\right)E[m_i]^2$$

(or, more symmetrically, $E[m_i] = E[m_i|P = p_i]$, $\frac{V[m_i]}{E[m_i]^2} = \frac{V[m_i|P=p_i]}{E[m_i|P=p_i]^2} + \frac{n_i-1}{n_i}\rho^2$). 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, which one would expect to inherit some of the properties of a genuine maximum-likelihood estimator. This procedure is called quasilikelihood (McCullagh and Nelder 1989).

For any particular choice of the f_i, the properties of the quasilikelihood estimator can be determined empirically 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 this 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 proceedure 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 $\alpha = -0.1691$. The Pearson chi-square is 13.00 ($p = 0.4478$).

Confidence intervals and bias for b_1, b_2, LT50, and α were estimated by simulation: the model (2) 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 and standard deviation of these data, and some order statistics, are shown in Table 3. 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 23.01 ± 1.08°C and 23.01 ± 0.41°C, respectively. **Table 3 near here**

The results of the simulation are shown more vividly in Figure 3. Here one point has been plotted at random from each of the 5000 fitted survival curves for each model, to give some feeling for the shape of the confidence surfaces. **Figure 3 near here**

The quasilikelihood-generating model

If there were a suitable exponential family distribution having the same mean and variance as (2), 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:

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

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

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

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

and the the quasilikelihood-generating distribution takes the form:

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

where $\gamma_i = -n_i\rho^2$ (so the first case of (4) never arises). These equations are identical to equations (3) and (4) except for obviously negligible terms of order $1/n_i$.

The second (negative binomial) distribution of (6), 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 smolt survival at a given temperature to about 10% at the 95% confidence level (cf. Figure 3).

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: including such sources would probably increase the LT50 associated with the temperature-dependent component of modeled mortality.

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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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	Year of Release	Coded-Wire-Tag Number(s)	Temperature (°C) T_i	Number Released n_i	Number Recovered m_i	Trawl Effort p_i
1	1983	06-62-23	16.1	92 693	95	0.00083324
2	1984	06-42-09, 06-62-29	18.9	59 998	37	0.00088098
3	1985	06-62-35	18.9	107 161	88	0.00106649
4	1986	06-62-48	23.3	101 320	74	0.00112363
5	1987	06-62-55	19.4	51 103	46	0.00105899
6	1987	06-62-58	17.8	51 008	47	0.00107142
7	1988	06-31-01	17.2	52 741	106	0.00213811
8	1988	06-31-02	16.1	53 238	146	0.00214250
9	1988	06-62-63	23.9	53 961	46	0.00213117
10	1988	06-31-03	23.3	53 942	39	0.00212647
11	1989	06-31-12	16.7	51 046	65	0.00107005
12	1989	06-31-07	19.4	50 601	26	0.00107047
13	1989	06-01-14-01-02	22.8	51 134	8	0.00097782
14	1990	06-31-20	20.6	51 878	87	0.00103647
15	1990	06-31-22	18.3	50 837	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.

	b_1	b_2	LT50	α
Fitted	15.56	−0.6765	23.01	−0.1691
Uniform				
mean	18.65 ±0.28	−0.8080 ±0.0121	23.06 ±0.02	−0.2020 ±0.0030
s.d.	10.18 ±0.20	0.4356 ±0.0085	0.57 ±0.01	0.1089 ±0.0021
bias	3.08 ±0.28	−0.1315 ±0.0121	0.05 ±0.02	−0.0329 ±0.0030
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 ±0.14	−0.7291 ±0.0060	23.01 ±0.01	−0.1823 ±0.0015
s.d.	5.06 ±0.10	0.2163 ±0.0042	0.21 ±0.00	0.0541 ±0.0011
bias	1.23 ±0.14	−0.0526 ±0.0060	0.01 ±0.01	−0.0132 ±0.0015
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. Pearson (open circles) and deviance (solid circles) residuals for the fitted base model, plotted against water temperature.

Figure 2. 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 3. 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.

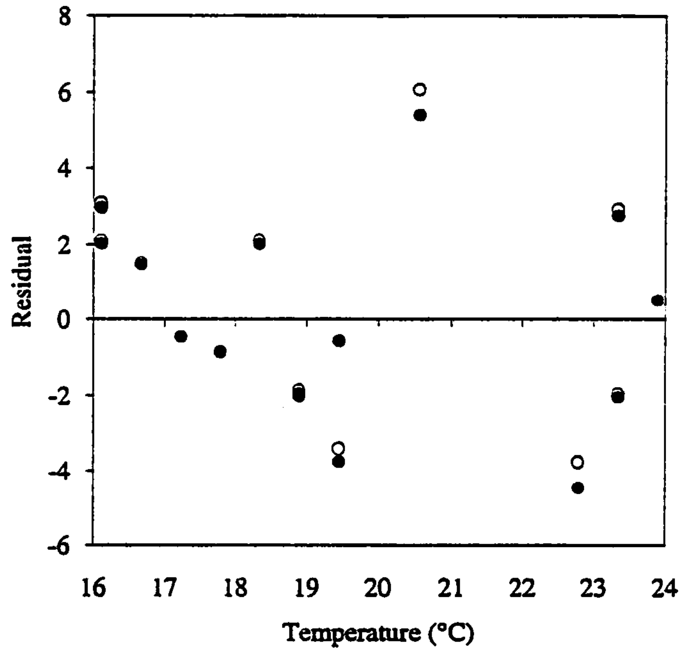


Figure 1

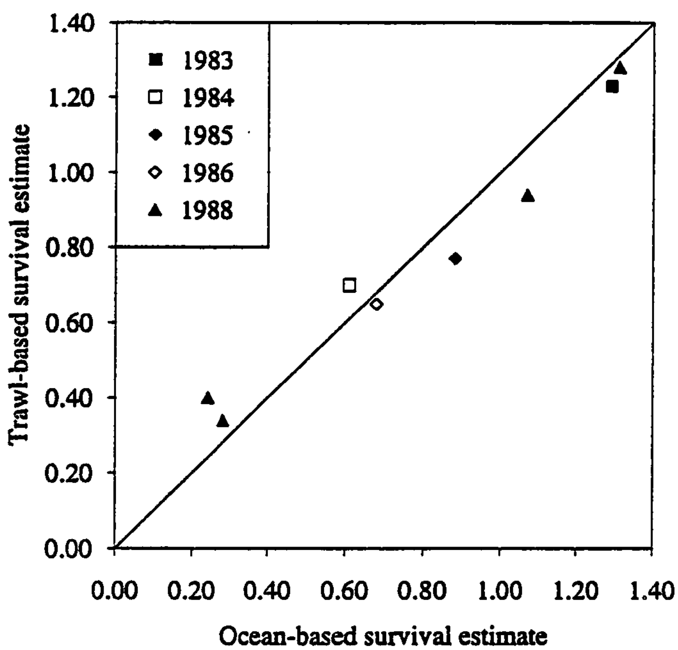


Figure 2

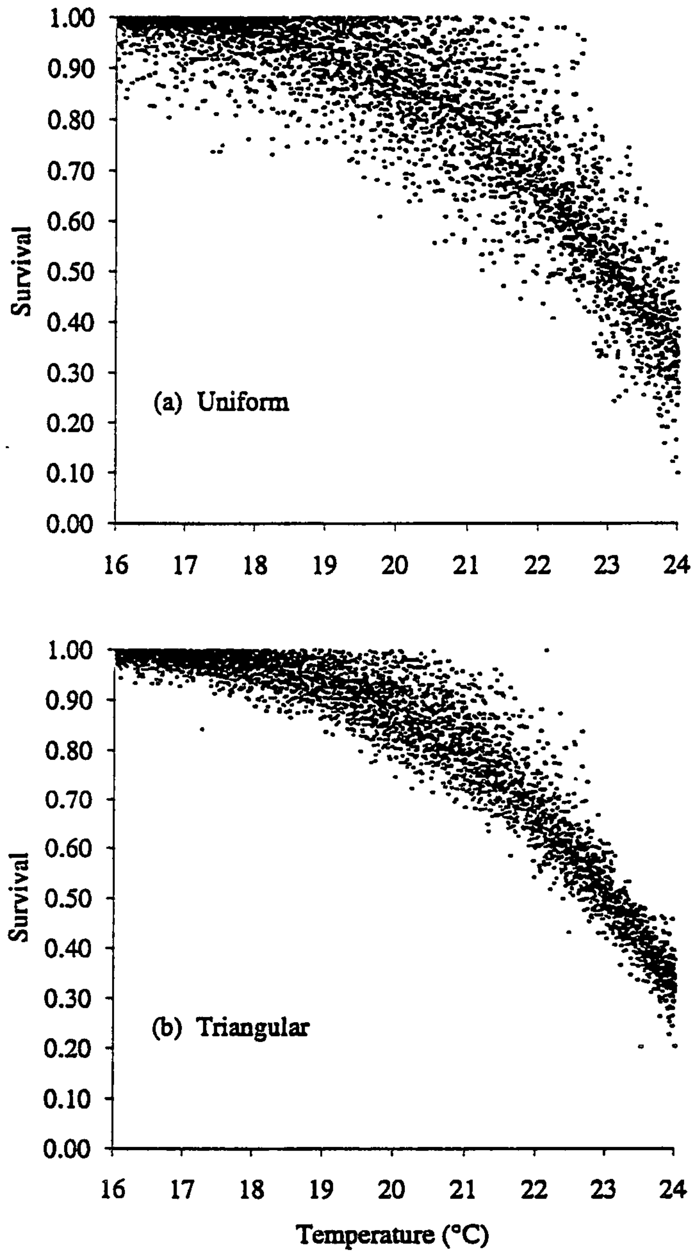
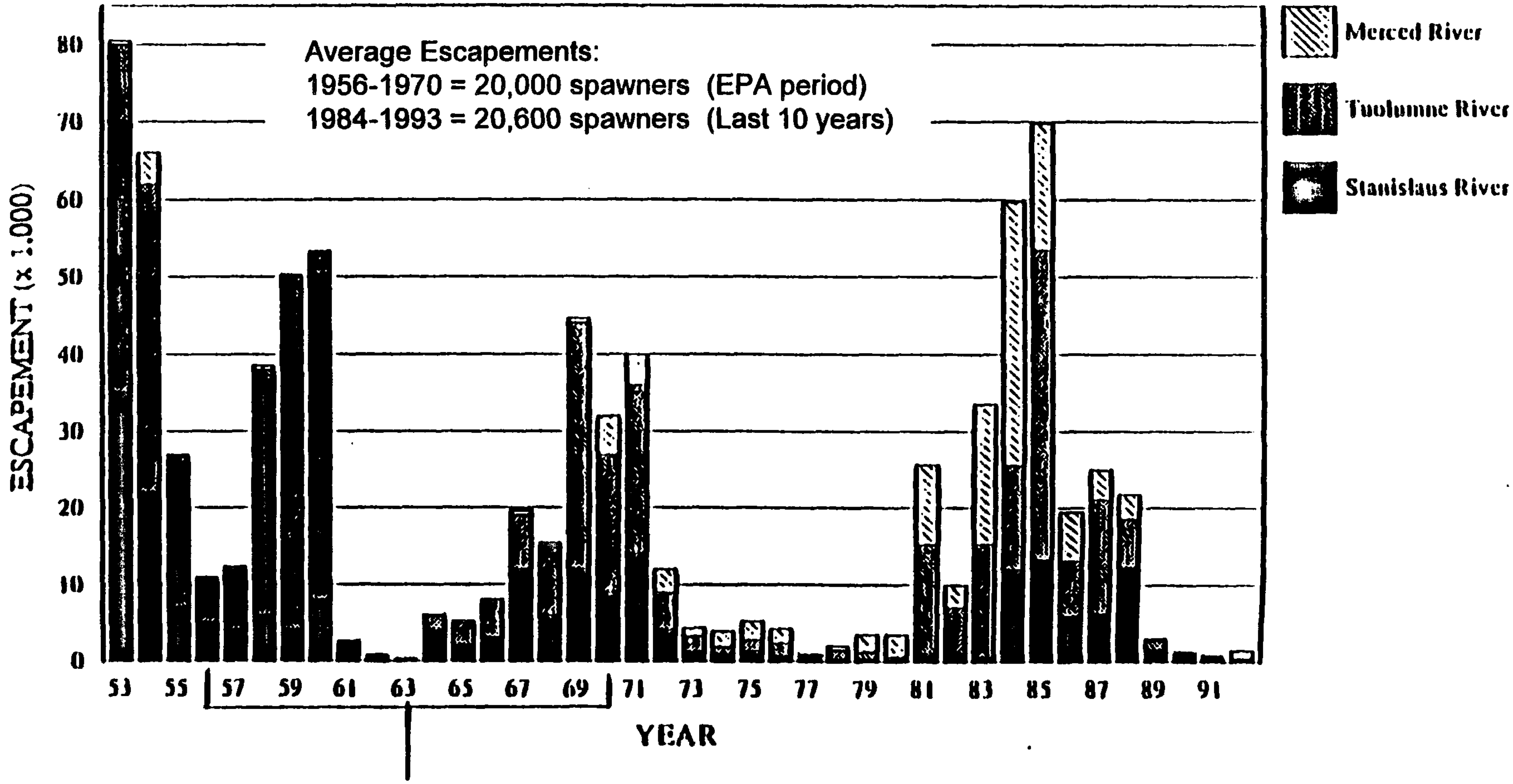

1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Survival
(a) Uniform
16
17
18
19
20
21
22
23
24
(b) Triangular
Temperature (°C)

Figure 3

Fall-Run Chinook Salmon Spawning Escapement
San Joaquin Drainage



Source: Department of Fish and Game, Region 4
Note: 1991 and 1992 are preliminary estimates

Driven by a Sacramento Basin orientation, EPA wants to restore salmon conditions in the Delta to that which existed in 1956-1970 -- the lowest San Joaquin Basin escapement of record of 320 spawners occurred in 1963 right in the middle of that historical period.

Exhibit 2