SJC-387

# United States Department of the Interior

# Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding To Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources

February 12th, 2010

## Approach/Outline

# I. Summary

### *a. Introduction*

The U.S. Department of the Interior (Interior) submits this written summary and witness testimony on behalf of both the Fish and Wildlife Service (Service) and the Bureau of Reclamation (Reclamation), pursuant to the State Water Resources Control Board's (Board) Public Notice and Revised Notice: Public Informational Proceeding to Develop Delta Flow Criteria Necessary to Protect Public Trust Resources. The summary and witness testimony will address the questions set forth on page 10 of the Public Notice, and related topics.

In 2008 and 2009 Reclamation concluded consultations regarding the effects of continued long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) with the Service and the National Marine Fisheries Service (NMFS), respectively, pursuant to Section 7 of the Endangered Species Act (ESA). Those consultations focused on the effects of CVP and SWP operations on federally listed aquatic species and their designated critical habitats. While those consultations utilized the best scientific and commercial data available and therefore may provide useful information for the Board proceeding here, by law, the Biological Opinions focus on the questions of whether a proposed action jeopardizes the continued existence of a species or adversely modifies or destroys designated critical habitat, and if it does, whether there are any alternatives to the action that avoid jeopardizing listed species or adversely modifying or destroying designated critical habitat. Per Senate Bill 1 of the 2009-2010 Seventh Extraordinary Session (S.B. 1), our biological witnesseses for this process have focused not on jeopardy or adverse modification standards, but are rather focused on providing the best available scientific information regarding flow criteria in the context of protecting and restoring a healthy Sacramento-San Joaquin Delta ecosystem on a sustainable basis, and identifying biological objectives for the species of concern dependent on the Delta.

At the end of this proceeding we believe the Board should have three primary products: defined ecosystem goals (using specific biological/physical indicators to track progress), Delta flow criteria that were developed to meet the defined ecosystem goals, considering watershed hydrology, and a process to adaptively manage flow criteria to meet the ecosystem goals. The flow criteria that the Board adopts should be viewed as a starting point that will be monitored, evaluated and adaptively managed to meet the ecosystem goals. We stand ready to work with Department of Fish and Game and NMFS to assist the Board in developing Delta flow criteria and quantifiable biological objectives for aquatic and terrestrial species of concern dependent on the Delta.

### *b. Background*

As the Board is aware, the challenges in restoring the Delta are contentious, complicated and have hit the headlines in not only California, but the entire nation. Data from the Delta ecosystem suggests that what we are doing now is not adequate to protect and restore the Delta on a sustainable basis. Changes in Delta flows have caused changes in the physical habitat components of the system, which has contributed to the decline of the Delta ecosystem. Fish populations dependent on the Delta have declined across the board, with some species on the brink of extinction. Food web dynamics have undergone significant changes in both abundance and composition.

Salmon populations in the Central Valley are in serious decline, with the adult escapement of Chinook salmon in 2008 estimated to be approximately 10% of the escapement in 2003 (CDFG GrandTab, 2009). Of the four races of Chinook salmon, two are listed under the Endangered Species Act (ESA) (winter run and spring run) and fall run Chinook salmon are at historical lows. Central Valley steelhead (threatened) are also in serious decline. Preliminary adult escapement estimates for the fall of 2009 show little improvement.

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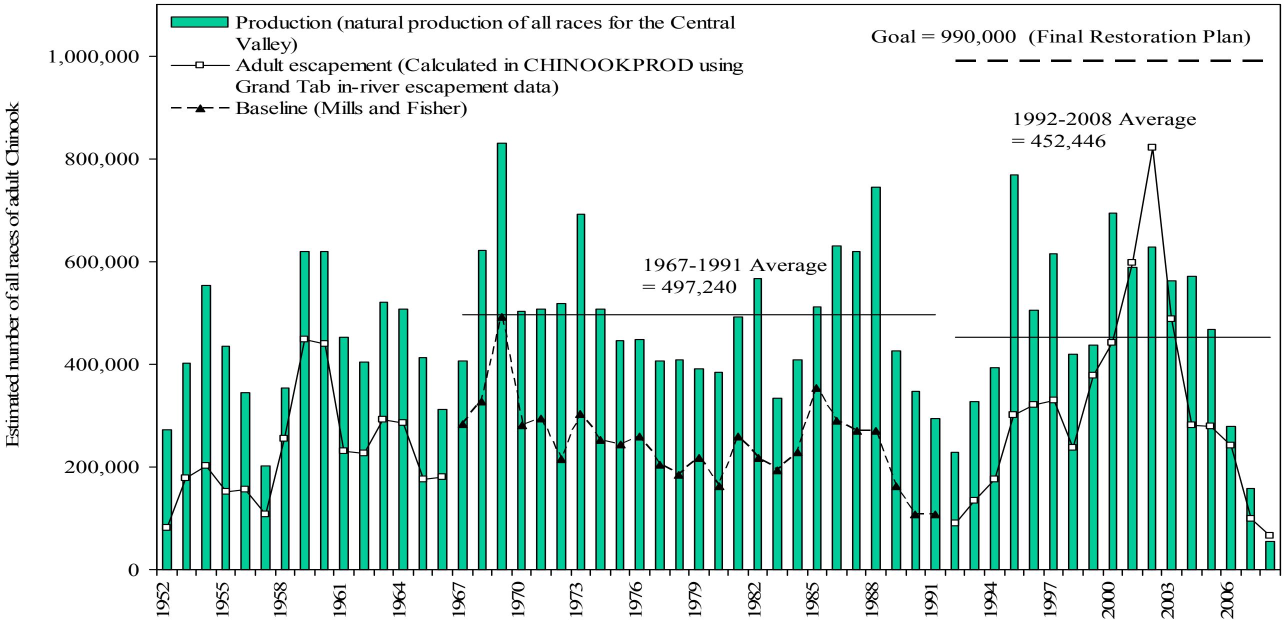


Figure 1. Estimated yearly natural production and in-river escapement of all races of adult Chinook Salmon in the Central Valley rivers and streams. 1952 - 1966 and 1992 - 2008 numbers are calculated in CHINOOKPROD using CDFG Grand Tab in-river escapement data (February 18, 2009). Baseline numbers (1967 - 1991) are from Mills and Fisher (CDFG, 1994).

In addition, the large scale pelagic organism decline (POD) in the Sacramento-San Joaquin Delta has not reversed its trend, although ESA/CESA protective actions are now being taken to alleviate some of the key hydrologic drivers contributing to the decline of delta smelt and longfin smelt. Note that the 2009 fall mid-water trawl index for Delta smelt is the absolute lowest on record (17) and the longfin smelt index was the second lowest on record (65).

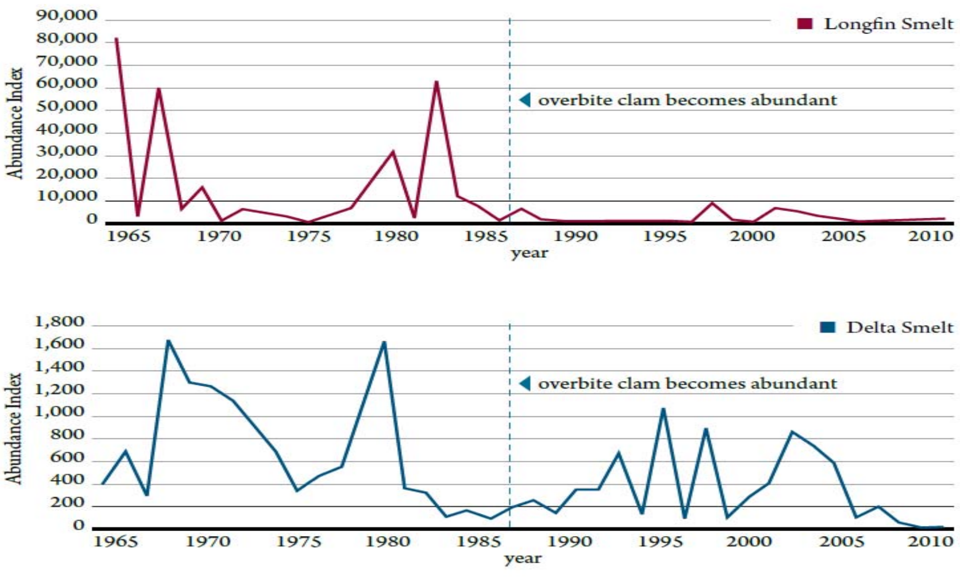
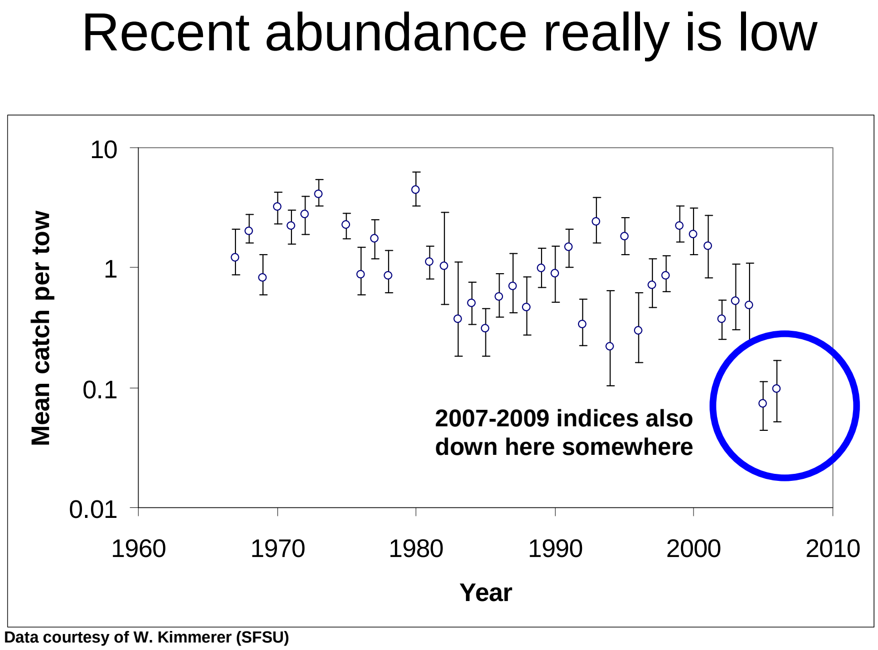


Figure 2. Changes in abundance indices for longfin smelt, Delta smelt, and striped bass over time in the Delta. (Source: Fall Midwater Trawl Survey 2008) copied from Calfed 2008. The state of Bay Delta Science. Calfed Science Program. Sacramento, CA.



Recent abundance really is low

2007-2009 indices also down here somewhere

Data courtesy of W. Kimmerer (SFSU)

Figure 3. Mean Catch per tow . Nobrega January 2010 Presentation NAS.

Flow in the Delta is one of the most important components of ecosystem function. Timing, magnitude and variability of flow are the primary drivers of physical habitat conditions including: turbidity, temperature, particle residence time, nutrient loading, etc. These physical habitat conditions created by flow are part of what drives ecosystem function and define the key attributes comprising ultimate habitat utility and quality for resident and migratory fish species. It is technically very difficult to define the optimal timing, magnitude, and volume of flows required to provide sufficient habitat quantity and quality to protect our trust aquatic species. However; it is generally logical to presume that flow conditions more similar to natural flows will provide beneficial flow conditions and improved habitat for native species; while the further flow conditions are from what naturally occurs, the less adequate habitat conditions are for our native species.   Figure 4 below presents a basic conceptual model linking the various drivers of fish populations in the estuary.

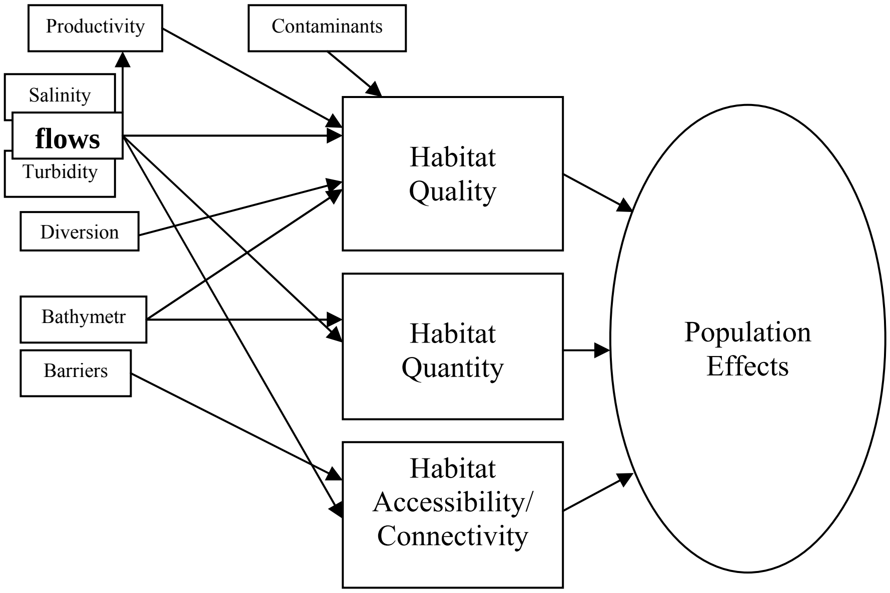


Figure 4. Conceptual model of various drivers of fish populations in the Delta estuary

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The 1996 U.S. Fish and Wildlife Service Delta Native Fish Recovery Plan states: “Flow patterns in Delta channels are the principal element used to describe habitat conditions because most channels have been dredged and shallow areas have been separated from the river by an extensive series of levees. Thus, little connection to shallow wetland habitats and little diversity in salinity or depth remain. The flow patterns are determined largely by the interactions of freshwater inflow, tidal action, and water diversion.” Figure 5 below depicts the conceptual relationship linking the physical ecosystem attributes to higher level scales of resolution or attributes such as population abundance.

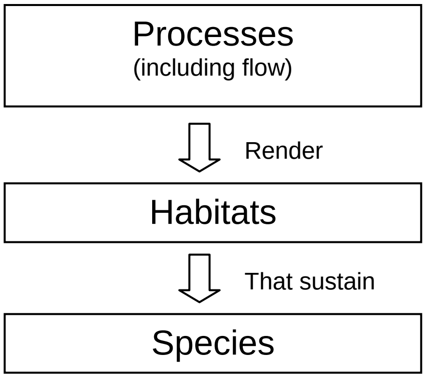


Figure 5. Conceptual relationship of processes and species.

This Board proceeding is an opportunity to review where we are, and chart a new course to achieve a healthy Delta ecosystem to protect aquatic resources. These flows will also contribute towards other goals that the Board and resource agencies have including: the anadromous fish doubling goals, recovery of threatened and endangered species, reducing and or eliminating non-native species, and contributing to a healthy commercial fishery.

Clearly articulating the ecological and biological goals should be the starting point in the Board’s process of developing Delta flow criteria. The goals of the 1996 U.S. Fish and Wildlife Service Delta Native Fish Recovery Plan include: “to establish self-sustaining populations of the species of concern that will persist indefinitely. For Chinook salmon, green sturgeon, and splittail, the goals include having large enough populations so that a limited harvest can once again be sustained. The basic strategy for recovery is to manage the estuary in such a way that it is better habitat for aquatic life in general and for the fish species of concern in particular. Restoration of the Delta ecosystem should also include efforts to reestablish the extirpated Sacramento perch.”

One goal of the Central Valley Project Improvement Act (CVPIA) is to: “ensure that…natural production of anadromous fish in Central Valley Rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967 – 1991.” The Board’s Water Quality Control Plan (WQCP) has a narrative salmon protection objective with a similar doubling goal: “Water quality conditions shall be maintained together with other measures in the watershed, sufficient to achieve a doubling of natural production of Chinook salmon from the average production of 1967 – 1991, consistent with the provisions of State and Federal law.”

### *c. Limitations of this proceeding*

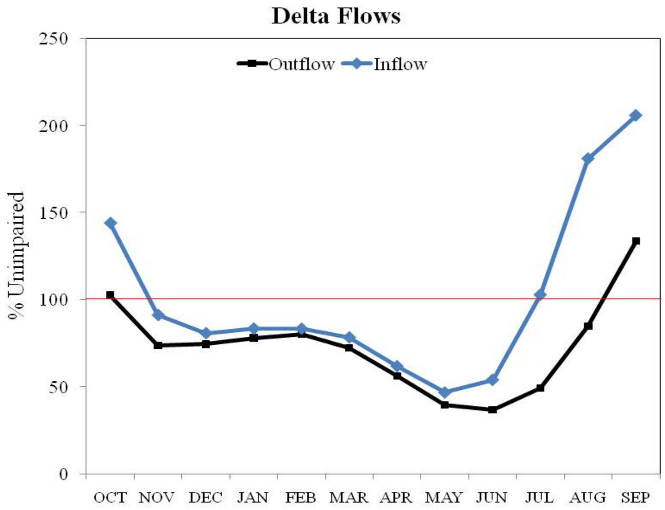
Interior commends the Board for taking on this difficult task of reviewing Delta outflow criteria; however, this process has several limitations. While the timeline in this informational proceeding is short, Interior encourages the Board to not defer these important decisions on Delta flows. The scope of this process has been limited to Delta flow criteria; however, Delta flow is just one of the important factors contributing to the health of the ecosystem. We appreciate that the Board (in its revised notice on January 29, 2010) broadened the scope of the informational proceeding to include information regarding other stressors that affect the Delta ecosystem along with the topics of hydrology and hydrodynamics.

The approach taken in this process focused on flows. It's important that this process should start by defining ecosystem goals and specific biological and physical process objectives to model what flows are necessary to meet those objectives. Once ecosystem goals are defined the Board should consider broadening the scope to address all components that affect the stated ecosystem goals and identify a suite of management actions to attain the stated ecosystem goals that would include flow, but not limited to flow. Some of these other stressors are also under the purview of the Board's regulatory domain, and this governance structure will be critical to successfully integrating and adaptively managing the estuary to maintain habitat conditions required for native fish recovery. An adaptive management process and appropriate monitoring program should be created to provide the framework for meeting the ecosystem goals. We encourage the Board to facilitate this process of developing Delta flow criteria consistent with the timeframes set forth in S.B. 1 and will work with the Board to achieve that end.

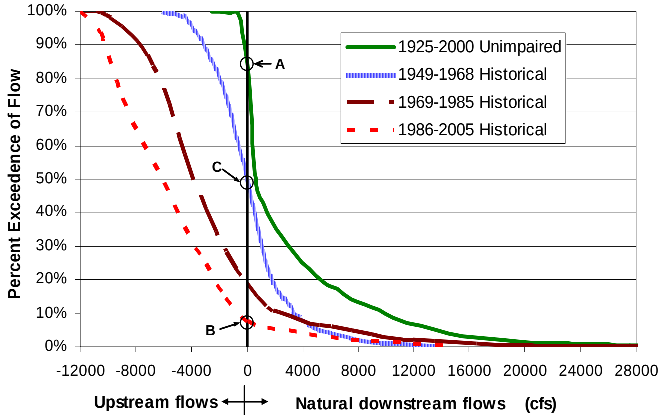
This process should also give consideration to not only the source of the flows, but the balancing of flow needs for aquatic resources in the Delta and flow needs upstream in the rivers. When considering the needs of anadromous fish, for example, the conditions in the Delta are important and the conditions upstream (such as temperature) are important and both affect fish populations at different life stages.

### *d. Delta flow criteria and biological objectives*

The Delta ecosystem evolved and adapted to natural flows, conditions, variability, and resulting habitat. The annual dry season is typically during the late spring through early fall, and variable wet season during the winter through spring months. Given our understanding of the evolution of the Delta ecosystem, consideration to the timing, magnitude and variability of unimpaired flow can be used to guide what conditions species within the ecosystem have evolved and adapted under.



- Annual Delta Inflow reduced 22% from unimpaired conditions
- Winter / early spring inflows shifted to summer / early fall
- Annual Delta Outflow reduced 34% from unimpaired conditions
- Winter / early spring outflows shifted to summer / early fall
- Reverse flows, i.e. OMR flows shifting to more negative (upstream)



- Unimpaired OMR estimates positive approximately 85% of the time

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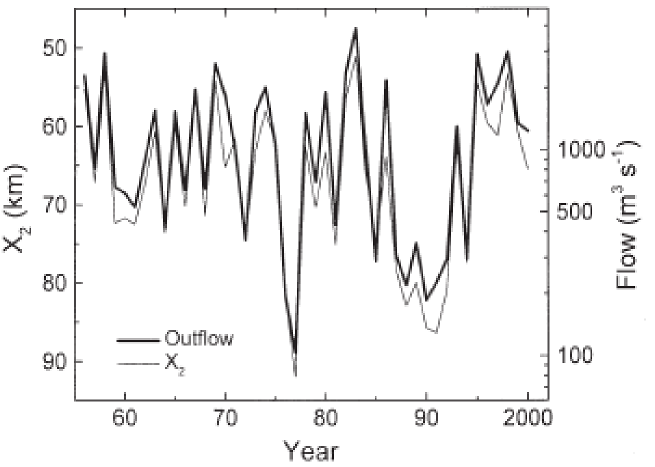
- Current operations result in negative OMR flows greater than 90% of the time



- Historical X2 position highly correlated with historical Delta outflow
- X2 position inversely related to outflow with a time lag of about two weeks
- X2 variability reduction from unimpaired conditions

Figure 6. Changes to Delta Hydrology and hydrodynamics. See expert testimony of Craig Anderson for more information.

**Delta Outflow:**

Inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration of Delta fish. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components (USFWS 2008). Delta smelt critical habitat consists of four primary constituent elements: physical habitat, water, river flow and salinity, and flow is a constituent of each of these.

The scientific information that we reviewed indicates that generally fish abundance is higher when suitable habitat is available, and suitable habitat is related to X2 among other variables. The Delta native fish have declined as habitat suitability has declined. Delta flow is a component of habitat suitability.

When X2 is in the relatively shallow waters of Suisun Bay at particular times of the year, phytoplankton growth rates are higher, productivity is maximized and fish rearing is supported. Having X2 further westward also may reduce entrainment of estuarine species into the State and Federal export facilities.

The strategic placement of X2 is intended to have two benefits for delta smelt (1) improvement of environmental quality and (2) minimization of entrainment into the SWP and the CVP (Project) export facilities. While reverse flows or OMR are the proximal mechanism of entrainment, X2 is a distal mechanism. For example, if X2 is relatively seaward, then larval and juvenile delta smelt would be expected to be distributed such that they would be less likely to be entrained (Dege and Brown 2004; Kimmerer 2008), but if X2 is upstream, then the distribution of delta smelt is relatively nearer to the export facilities and the risk of entrainment may be greater (Kimmerer 2008). Prior to when adult delta smelt migrate upstream, X2 explains intra-annual salvage patterns, presumably because they have a shorter distance to enter the footprint of the exports once migration occurs (Grimaldo et al. 2009). However, X2 only matters in this case when Old and Middle River flows are negative. Kimmerer and Nobriga (2008) used Particle Model Tracking to show that it only takes a few tidal cycles for particles modeled with surfing behavior to move within the footprint of the exports during high outflow periods. (Bennett 2006; Feyrer, et al. 2007; Kimmerer, et al. 2009).

The most recent period of relatively robust annual abundance numbers for several species of concern should be used to guide the development of Delta flow criteria needed to protect the public trust resources.

### Reverse Flow:

Old and Middle River flow is a hydrodynamic metric used to examine the SWP and CVP export affects on entrainment of fishes because it best characterizes the “footprint” of the exports as it extends into the Delta, integrating for river inflows, barrier operations, and exports (Arthur et al. 1996; Monsen et al. 2007). When exports are greater than San Joaquin river inflow, combined Old and Middle river net flows move upstream (i.e., negative or reverse) towards the SWP and CVP. Recent studies show that entrainment of delta smelt and other pelagic species increases as OMR flows become more negative (Grimaldo et al. 2009; Kimmerer 2008). Kimmerer (2008) found that entrainment losses increased as OMR flows became more negative, with as much 50 % reduction in the delta smelt population during some high export years.

Indirect and direct mortality of juvenile salmonids increases as OMR flows become more negative as well. For example, not only does juvenile salmonid entrainment increase as OMR flows become more negative, but so does their residence time which results in greater losses due to predation. To address the biological objective of increased survival of emigrating salmonid smolts, the AFRP identified the importance of maintaining positive QWEST flows (AFRP Working Paper, 1995). It’s important to note, that in 1992, the Board also acknowledged the importance of maintaining positive QWEST flows, in order to protect and stop the decline of the public trust resources in the Delta, and included a new standard (requirement) that “there shall be no reverse flow for all year types on a 14-day running average in the western Delta… between February 1 and June 30.” OMR flows and Qwest are highly correlated variables, since both represent net flow of Delta interior hydrodynamics.

In trying to evaluate the mechanism(s) for increased winter-time salvage of four primary fishes, including delta smelt, pelagic organism decline (POD) studies identified three key observations (IEP 2005). First, there was an increase in exports during winter as compared to previous years (Figure 16). Second, the San Joaquin River inflow decreased as a fraction of total inflow around 2000, while Sacramento River increased (Figure 17). Finally, there was an increase in the duration of the operation of barriers placed into south Delta channels during some months. These changes may have contributed to a shift in Delta hydrodynamics that led to record-high entrainment levels of delta smelt during a period when their population abundance plummeted to record-low levels (POD Report 2007).

Based on the most recent scientific information, maintenance of Old and Middle River flows at levels that do not result in significant entrainment losses of federally listed species during winter and spring periods when they most vulnerable to exports is important.

### Floodplain Inundation:

Seasonal floodplain inundation has a positive effect on growth rates and on the apparent survival of juvenile Chinook salmon in the Central Valley. The restoration of floodplains and other off channel habitat is potentially important for increasing production of juvenile salmonids in California’s Central Valley. The biological objectives of seasonal floodplain inundation would be to provide off channel areas conducive to salmonid rearing and growth, as well as for other native species such as splittail.

Successful spawning and recruitment of splittail is highly dependent upon the availability of floodplain habitat for spawning and rearing.

The body of evidence indicates that frequent floodplain inundation will provide benefits to numerous native species with respects to abundance (Sommer et al. 1997) and growth rates (Sommer et al. 2001). Efforts to increase floodplain inundation through wier modification and increased outflows will provide benefits to native species consistent with protecting aquatic resources in the Delta.

### Delta Inflow:

Delta inflow and outflow are important for Chinook salmon in the Delta. Freshwater inflow is an important cue for upstream migration of adult salmon and directly affects the abundance and survival of juveniles moving downstream through the Delta. Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs (USFWS, 1987, pages 35 and 36). Survival through the Delta for juvenile fall run Chinook salmon originating from the San Joaquin basin has also been shown to increase with increased Delta inflows at Vernalis. In addition to juvenile salmon survival being higher with higher flows, the abundance of juvenile salmon leaving the Delta is also higher with greater river flow. USFWS has developed estimates of flows needed at Vernalis to achieve doubling in predicted Chinook salmon production for the basin, and help protect public trust resources.

Providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing and magnitude of flow needed for the Delta ecosystem. Scientific information in current and past SWRCB exhibits, scientific publications and models may be helpful to determine the volume, quantity and timing of water needed for the Delta ecosystem.

In summary, based on the scientific information we reviewed, we believe consideration of all aspects of Delta flow criteria, including timing, magnitude, and variability of; outflow, reverse flows, floodplain inundation, inflow and hydrology are important for this Board process. The natural hydrograph can be useful in guiding flow decisions, as the conditions created by a natural hydrograph are what the species evolved and adapted to.

### *e. Uncertainty and the importance of adaptive management*

Biological resource management decisions are always made with varying degrees of scientific certainty. The uncertainty with Delta flow criteria can be separated into categories: uncertainty in prescribing adequate flow criteria, and uncertainty in the affects of changing conditions. In a system as complex as the Delta, it is impossible to gather enough data to describe key processes, evaluate important variables, and predict results of management actions with absolute certainty. Analyses are subject to different interpretations by interest groups, and professional judgment plays a role in management decisions and this process will likely be no different.

By acknowledging varying degrees of scientific certainty in making decisions, biological resource managers engage in risk assessment. Anyone making a decision must balance the certainty of a predicted effect of a management action with the need to act. An example is the certainty of effects resulting from acting to recover delta smelt compared to the probable results of not acting, which are continued decline and possible extinction of the species. Adaptive management involves, a thoughtful approach to document, articulate, and manage uncertainty. It also likely requires accepting some degree of uncertainty and proactively approaching management decisions so that “learning by doing” is possible.

Interior has gone through a process using indicators of ecosystem health to develop Delta flow criteria, however; they are an oversimplification of a very complex ecosystem. The flows that the Board adopts should be viewed as a starting point that will be adjusted to meet specific ecosystem goals.

Appropriate, focused monitoring to evaluate the ecosystem response is critical in understanding the effectiveness of the flows in protecting the public trust resources. Setting ecosystem goals (tracked through indicator species and/or physical habitat targets) are a way to track the effectiveness of flow conditions. If the ecosystem goals are not attained the resources agencies can work with the Board to adaptively manage the flows to accomplish the defined ecosystem goals.

### *f. Alternative process the Board should consider to develop Delta flow criteria*

Interior is interested in working with the Board to approach this process as a blueprint for the Delta ecosystem restoration. It should be a carefully planned process including all stressors to meet the defined ecosystem goals. Recovery plans serve as a road map for species recovery – they lay out where we need to go and how best to get there. The Delta recovery planning process must include the watersheds upstream to create an integrated management plan for the entire San Joaquin/Sacramento basin. Goals of the basin need to be stated upfront and a process, working with stakeholders, to achieve those goals, should be developed. Goals developed in other processes (e.g. Calfed Ecosystem Restoration Program) to address Delta ecosystem needs may help guide this process.

Some key concepts the Board should consider:

- Define ecosystem goals
- Use biological and physical indicators to track progress towards ecosystem goals
- Consider all stressors
- Approach as a basin plan that includes upstream watersheds
- Develop an adaptive management approach to learn and optimize performance of management actions in meeting ecosystem goals
- Consider the Delta flow criteria as a starting point that will be adapted to meet ecosystem goals

### *g. Board questions from the 12/15/09 notice*

1. What key information, in particular scientific information or portions of scientific information, should the State Water Board rely upon when determining the volume, quantity, and timing of water needed for the Delta ecosystem pursuant to the board's public trust obligations? For large reports or documents, what pages or chapters should be considered? What does this scientific information indicate regarding the minimum and maximum volume, quality, and timing of flows needed under the existing physical conditions, various hydrologic conditions, and biological conditions? With respect to biological conditions, what does the scientific information indicate regarding appropriateness of flow to control non-native species? What is the level of scientific certainty regarding the foregoing information?

Much of the key information the Board should consider from Interior has been discussed throughout this report, and is included in our citations throughout this document. Generally, the scientific experts have referred to specific references and pages or chapters to be considered by the Board. Much of what this scientific information indicates regarding the Delta flow criteria needed for restoring the Delta ecosystem and recovering fisheries is summarized in Section III Summary of Delta flow criteria and biological objectives.

In general, the Board should rely on scientific information in current and past Board exhibits, scientific publications, the unimpaired hydrograph, and models to help determine the volume, quantity and timing of water needed for the Delta ecosystem pursuant to the Board's public trust obligations. Uncertainty should not limit the Board's considerations of Delta flow criteria, and can be addressed by monitoring, evaluation, and an adaptive management program to accomplish ecosystem goals, and the ultimate goal of protecting public trust resources.

Some of the key information that Interior relied upon includes:

USFWS 1987, USFWS 1992, AFRP Working Paper 1995, AFRP Restoration Plan 2001, Delta Native Fishes Recovery Plan, 1996, POD Report, 2007, the Long Term CVP and SWP Operations Biological Opinions, 2008 and 2009, the NMFS salmonid Recovery Plan, 2009, UC Davis preliminary draft report “On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta”, 2010.

For example, the UC Davis preliminary draft report “On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta” provides modeling results indicating that OMR flows were positive approximately 50% of the time during the early water development (1949 – 1968) period. The model results indicate that OMR flows were positive less than 10% of the time during the 1986 – 2005 period, coincident with the decline of the delta smelt.

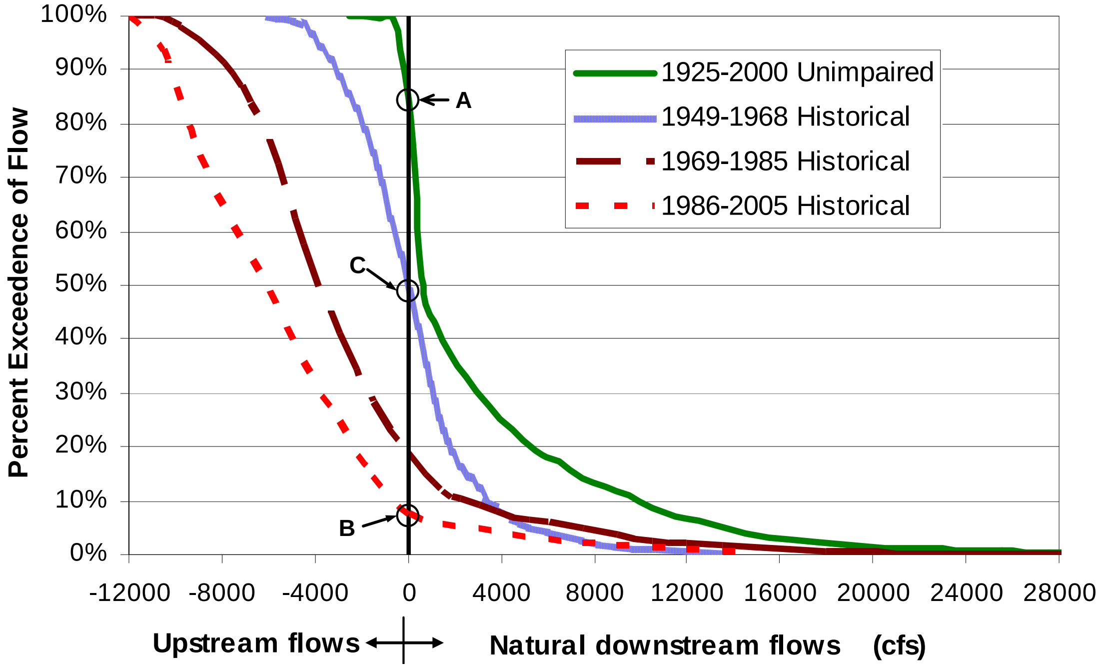


Figure 7. Cumulative probability distribution of sum of flows (cfs) in Old and Middle River resulting from pumping through the Delta showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line). Fleenor et al., 2010.

It’s important to note that the 1995 Anadromous Fish Restoration Plan identified the Delta as the highest priority watershed for achieving the anadromous fish doubling goals, and the AFRP 1995 working paper included Delta flow criteria needed to achieve the doubling of anadromous fish. I-IV-39 and 3-Xe- of the working paper, includes a Delta flow objective to maintain positive QWEST flows from Oct 1 through June 30 to address the biological objective of increased survival of emigrating salmonid smolts.

Maintaining a positive QWEST flow would increase the survival of smolts migrating down the mainstem rivers, decrease the number diverted into the Central Delta, increase the survival of smolts diverted into the Central Delta, and provide attraction flows for the San Joaquin Basin adults (October-December), and protect other public trust resources in the Delta. This is largely consistent with the Board’s draft D-1630 issued in 1992 which includes a Delta flow standard of no reverse flow from February 1 through June 30 (Draft D-1630, pg 31, and pages 46-47).

In general, the scientific information indicates that the current minimum Delta flow criteria are not adequate to protect the aquatic resources and restore the Delta ecosystem.

2. What methodology should the State Water Board use to develop flow criteria for the Delta? What does that methodology indicate the needed minimum and maximum volume, quality, and timing of flows are for different hydrologic conditions under the current physical conditions of the Delta?

We believe an appropriate methodology to develop Delta flow criteria would include a combination of: the best available science concerning flow and relationships with indicator species, the best available science concerning flow and relationships with physical processes (eg geomorphic, hydrodynamic, etc), utilizing biological and physical modeling to inform the process, statistical analysis of all of the above, and using the natural/unimpaired hydrographs to help guide the process. Defining ecosystem goals is an important first step in developing flow criteria is to define ecosystem goals. Flow criteria are a tool that can be used to help meet ecosystem goals. With the help of the resource agencies, we encourage the Board to develop Delta flow criteria that are viewed as a starting point to meet the defined ecosystem goals. In addition to the flow criteria, the Board should consider developing a process to adaptively manage and learn from the flows to accomplish the ecosystem goals as efficiently and effectively as possible.

For example, the UC Davis preliminary draft report "On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta", 2010 "…explores approaches for establishing freshwater flow prescriptions for desirable fishes in the new Sacramento-San Joaquin Delta…" This draft report examines "...four approaches for prescribing environmental flows for the Sacramento-San Joaquin Delta: (1) unimpaired (quasi-natural) inflows, (2) historical impaired inflows that supported more desirable ecological conditions, (3) statistical relationships between flow and native species abundance, and (4) the appropriate accumulation of flows estimated to provide specific ecological functions for desirable species and ecosystem attributes based on available literature…Each approach explored provides a useful perspective on environmental flows for the Delta, and will require further examination and development…"

3. When determining Delta outflows necessary to protect public trust resources, how important is the source of those flows? How should the State Water Board address this issue when developing Delta outflow criteria?

We believe the source of flows is very important to determine Delta outflows. To ensure adequate Delta flow criteria, there must be adequate Delta inflow and outflow. This includes contributions from the Sacramento and San Joaquin Rivers and their tributaries. As stated in previous Board workshops, managing the San Joaquin system for flows only at Vernalis has not been effective in improving fish populations on the San Joaquin and its tributaries. The Board should consider utilizing a percentage of flows from the San Joaquin tributaries (Stanislaus, Tuolumne, and Merced Rivers). Freshwater inflows provide important olfactory cues for upstream migration, and adequate emigration flows for juvenile salmonids improve their survival when moving downstream through the Delta. Providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing and magnitude of water needed for the Delta ecosystem.

Providing Delta inflows from multiple systems would help provide adult salmonids with the olfactory cues they need to successfully navigate through the Delta back to their natal streams, and would provide concurrent instream benefits in terms of habitat and temperature. Outmigrating smolts would benefit from higher instream flows in the spring months, and having a more balanced and diverse set of inflow sources could improve survival through the interior Delta where survival rates are low. Having multiple sources of inflow also provides benefits to more riparian communities by improving their habitat.

The historical hydrograph can be useful in guiding the timing and magnitude of flows to attain broad ecological benefits to native species.

4. How should the State Water Board address scientific uncertainty when developing the Delta outflow criteria? Specifically, what kind of adaptive management, monitoring, and special studies programs should the State Water Board consider as part of the Delta outflow criteria, if any?

Biological resource management decisions are always made with varying degrees of scientific certainty. By acknowledging varying degrees of scientific certainty in making decisions, biological resource managers engage in risk assessment. Anyone making a decision must balance the certainty of a predicted effect of a management action with the need to act. An example is the certainty of effects resulting from acting to recover Delta smelt compared to the probable results of not acting, which are continued decline and possible extinction of the species.

The Delta flow criteria the Board identifies may be viewed as a starting point that will be adjusted to meet specific ecosystem and biological goals. Appropriate, focused monitoring to evaluate the success of management actions to achieve ecosystem and biologic objectives is critical in understanding the effectiveness of the flows in protecting the public trust resources. We encourage the Board to set ecosystem goals (tracked through biological and physical indicators) to track the effectiveness of flow conditions. If the ecosystem goals are not attained, the Board, with the assistance of resource agencies, flows may be adaptively managed to accomplish the defined ecosystem goals. See Section IV below for more information on adaptive management and monitoring.

5. What can the State Water Board reasonably be expected to accomplish with respect to flow criteria within the nine months following enactment of SB 1? What issues should the State Water Board focus on in order to develop meaningful criteria during this short period of time?

Review of the existing water quality objectives and use of the best available science should be employed to develop flow criteria for the Delta ecosystem. We encourage the Board to facilitate this process of developing Delta flow criteria in order to meet the timelines included in SB 1, and based on the best available science, the Service will continue to work with DFG and NMFS, and will assist the Board to develop Delta flow criteria and quantifiable biological objectives for aquatic and terrestrial species of concern dependent on the Delta.

At the end of this proceeding we foresee the Board having three primary products: defined ecosystem goals (using specific biological and physical indicators to track success of flow standards), Delta flow criteria that were developed to meet the defined ecosystem goals, and a process to adaptively manage flows to meet the ecosystem and biological goals. The flow criteria that the Board adopts should be viewed as a starting point that will be monitored, evaluated and adaptively managed to meet the ecosystem goals.

## II. Scientific information used to determine flow criteria

Department of the Interior staff used the best available science to formulate flow criteria intended to protect the public trust resources in the Delta. Interior experts with experience in fisheries, food web, water quality, and non-native species assembled the best available publications, white papers, journal articles, etc to formulate flow criteria.

### *a. Hydrology and hydrodynamics*

i. Expert testimony: Ron Milligan, Paul Fujitani

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Hydrology and Hydrodynamics

Scientific information that examines potential relationships of changes to the unimpaired hydrology and hydrodynamic environment of the delta to estuary health dynamics may be useful to the Board in this process. This information may help to gain a conceptual understanding of fishery needs and potential management frameworks to address complex biological and management considerations. The expert panel members will discuss historic and unimpaired hydrology foundation information to help illustrate how hydrologic or hydrodynamic changes or impaired patterns have influenced aspects of today's ecosystem dynamics.

Unimpaired flows are also the foundation for how the major water facilities in the Central Valley utilize the natural water supply and provide for multiple beneficial uses, including consumptive uses, fishery protection and drought protection. Unimpaired flows represent the quantities and timing of natural hydrologic processes that influence all water management principles. Therefore, in recognition that water facilities impair natural hydrologic and hydrodynamic processes, tradeoff considerations are inevitable. Reclamation personnel are available to help address water management process questions the Board may have in recognition of the complimentary information nature to the expert panel discussion.

ii. Expert testimony: Craig Anderson

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Key points

- Annual Delta inflow has been reduced by 22% from unimpaired conditions (1956-2003) with a shift of a portion of winter/ early spring inflows to summer / early fall.
- Annual Delta outflow has been reduced by 34% from unimpaired conditions (1956-2003) with a shift of a portion of winter/ early spring outflows to summer / early fall.
- Flow characteristics in Old and Middle Rivers have been altered from natural or unimpaired conditions. Flows have shifted in a more upstream direction (increased magnitude and duration of negative flows) under the regulated hydrologic regime compared to unimpaired estimates that indicate positive (downstream) flows approximately 85% of the time.
- The historical position of the X2 Delta salinity metric is highly correlated with historical Delta outflow. Under the regulated flow regime, X2 has shifted upstream in conjunction with reduced Delta outflows, and the upstream shift has increased over time. Historically, X2 exhibited a wide seasonal range following unimpaired inflows. Compared to pre-dam conditions, however, seasonal variation in X2 range has been reduced by nearly 40%.

The hydrologic regime of the Delta has been altered by large scale human impacts including water impoundment behind both minor and major dams and associated water diversions out of the Delta (Kimmerer, 2002a; Knowles, 2002; Kimmerer, 2004; Moyle and Bennett, 2008; Fleenor et al., 2010). These impacts have, in turn, greatly affected the environmental conditions that native fish populations depend on. In order to better integrate the complex linkages between overall Delta fish populations condition, specific life history strategies, and the physical environments that Delta fishes inhabit, it is necessary to first understand the underlying hydrologic and fluvial processes that govern riverine and estuarine morphology in the Delta and provide essential habitat for key aquatic species.

Long-term flow records and unimpaired flow estimates in the Delta have been analyzed and described in multiple reports and manuscripts, including CDWR (1999), Kimmerer (2002b), CDWR (2007), Enright and Culbertson (2009), and Fleenor et al. (2010). I have utilized components of these reports and additional data analyses to provide a basic overview of the fundamental components of the natural and regulated flow regimes in the Delta. It is important to note that there is significant uncertainty associated with scientific knowledge related to the hydrology and hydrodynamics of the Delta ecosystem, and that this overview merely strives to summarize the current scientific understanding of flow related phenomena. The remainder of this testimony is organized by four major flow components; Delta inflow and outflow are considered as gross hydrological components and refer to the volume and timing of freshwater flows, and reverse flows and X2 position are considered as hydrodynamic components and refer to negative or upstream flows in Old and Middle Rivers and the geographical position of the commonly utilized in-Delta salinity standard, respectively. Within each component, summaries are provided that describe the alteration of flow conditions over time by comparing unimpaired and regulated flows, where appropriate, and linking those changes to overall fisheries health and abundance in the Delta ecosystem.

## Unimpaired Flow

The natural, or unimpaired, flow represents approximated inflows and outflows that would occur in the absence of storage facilities and diversions both upstream of the Delta and within the Delta. Unimpaired flows for the major Delta tributaries and Delta outflows have been estimated for the 1921 – 2003 period by the California Department of Water Resources (CDWR, 2007). These flow estimates are unlikely to capture the effects of longer attenuation of spring flows by upstream marshlands and floodplains or evapotranspiration and stream – aquifer interactions which were prominent features of the pre-development hydrology (Fleenor et al., 2010). However, the estimates do provide a reasonable approximation of pre-development conditions and can serve as a valuable baseline for temporal comparisons.

## Delta Inflow

Unimpaired Delta inflow records indicate considerable seasonal and inter-annual variability both in timing and magnitude (Knowles, 2002). Both the Sacramento and San Joaquin Rivers were characterized by high winter flows, spring snowmelt floods, and relatively low summer flows. The lesser Delta tributaries, also referred to as the Eastside streams, provided substantially less inflow to the Delta and were influenced more by winter rainfall events due to their lower elevation catchments and, often times going extremely low in the summer months. Upstream diversions and storage facilities have greatly altered the seasonal inflow patterns in the Delta (Kimmerer, 2004).

Moyle and Bennett (2008) and Fleenor et al. (2010) divide the 1949 – 2005 time period into three discrete categories reflecting the relative health and abundance of native Delta fish populations: 1949 – 1968, 1969 – 1985 and 1986 – 2005. The early 20-year period represents a time when fish were known to be doing better, and the last 20-year time frame when fish were doing worse. The middle 17 years represents a transitional water export period and contains extreme wet and dry periods. Contrasting Delta inflows from these three periods with unimpaired flows shows substantial changes in the volume and timing of freshwater inflows into the Delta from the Sacramento and San Joaquin basins (Figures 1 and 2). Upstream storage and diversions in both basins have shifted a portion of peak winter/spring inflows to enhanced summer and early fall inflows. Sacramento River annual inflows into the Delta from 1949 – 1968 were reduced by 23% from unimpaired conditions, while 1986 – 2005 flows were reduced by 26% annually and by 30% and 39%, respectively, during early winter and spring flow periods. San Joaquin River annual flows into the Delta were reduced from unimpaired conditions by 57% for 1949-1968 and 55% for 1986 – 2005, with 68% and 67% reductions, respectively, during early winter and spring flow periods.

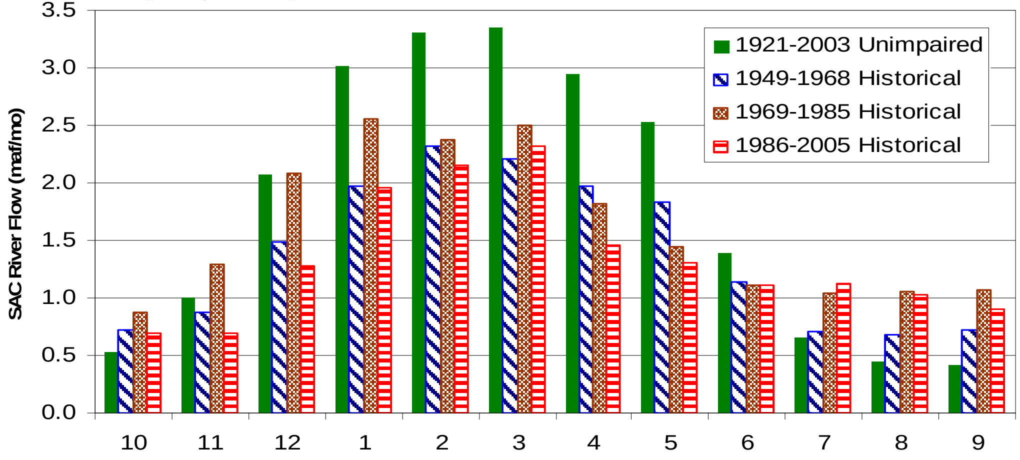

Figure 8. Changes over time to monthly average Sacramento Valley outflows (maf/mo) compared to the unimpaired record. Fleenor et al., 2010.

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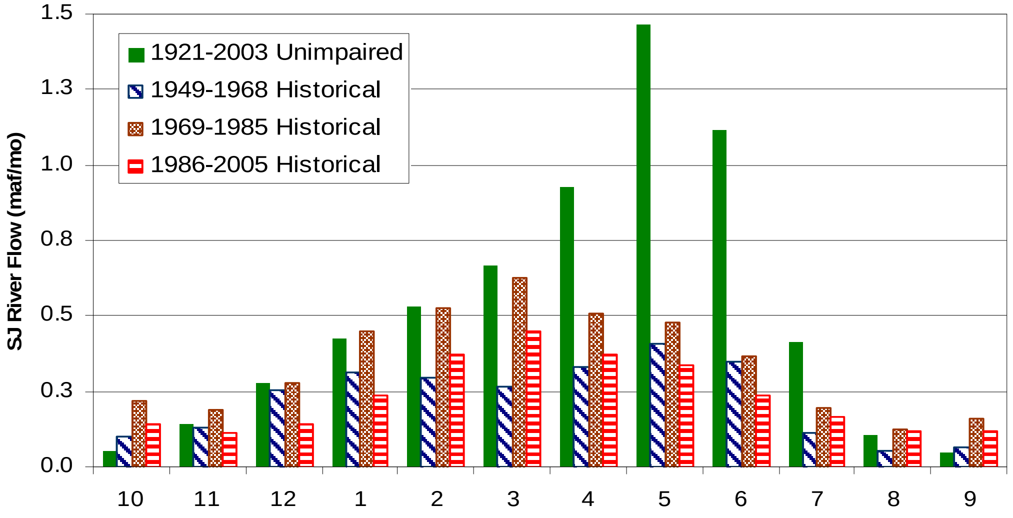

Figure 9. Changes over time to monthly average San Joaquin Valley outflows (maf/mo) compared to the unimpaired record. Fleenor et al., 2010.

Delta Outflow

Net Delta outflow is influenced by a variety of factors including Delta inflow, upstream storage and diversions, Delta consumptive use, and in-Delta diversions and exports (CDWR, 1999; Knowles, 2002; Kimmerer, 2004; Fleenor et al., 2010; and Moyle et al., 2010). Figure 9 shows the long-term reduction in annual Delta outflow as a percentage of unimpaired outflow.

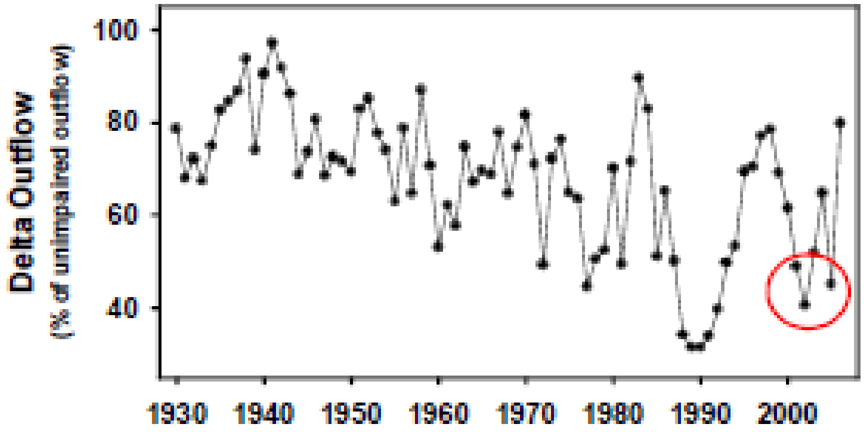

Figure 10. Delta outflow as a percentage of unimpaired outflow (1930-2005). Annual outflow reduced by more than 50% in 2001, 2002, and 2005. Bay Institute, 2007.

The relative contributions to the reduction in Delta outflow are shown in Figure 10, comparing unimpaired outflows to the three time periods from Moyle and Bennett (2008) and Fleenor et al. (2010). It is important to note that the total volume of water potentially available as Delta inflow

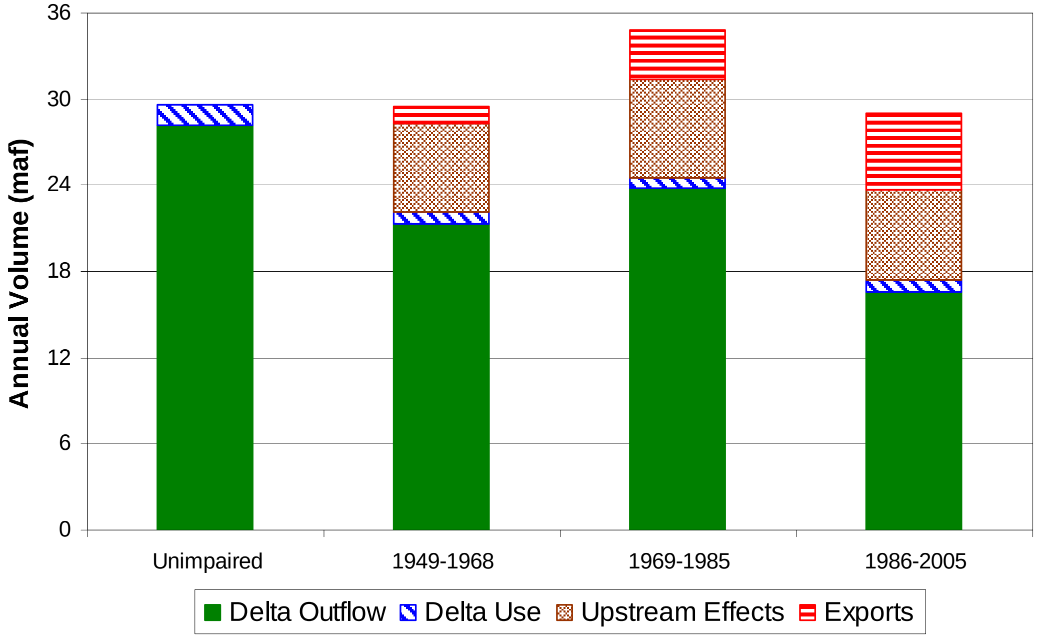

Figure 11. Comparison of annual water use during the three study periods (maf/year) compared to the Unimpaired flows from 1921-2003. Unimpaired data from DWR (2007) and other from Dayflow web site (Neglects upstream groundwater withdrawals). Fleenor et al., 2010.

did not vary substantially between the three periods or the longer unimpaired period and was actually greatest during the wetter 1969-1985 period. The largest change from the 1949-1968 historical period and the 1986-2005 historical period is the increase in exports that reduce net Delta outflow. Exports increased from 0.9 maf during the earlier period (1.4 maf annual average over the 13 years of actual export) to 5.1 maf over the 1986-2005 period.

## Reverse Flows

Numerous studies have developed statistical relationships between Old and Middle River (OMR) flows and various biological parameters (e.g. Kimmerer, 2008; Grimaldo et al., 2009). Similarly, numerous hydrodynamic models have been utilized to simulate OMR flows and related fish entrainment indices (e.g. DRMS, 2007; Fleenor et al., 2008; CDWR, 2009). Unimpaired OMR flow records, however, are not readily available. For the purposes of comparing unimpaired OMR flow estimates to regulated OMR flows, I rely on the simulation results developed by DRMS (2007) and Fleenor (2008) as reported in Fleenor et al. (2010). As with any model, broad assumptions and generalizations are implemented, and there is uncertainty associated with the modeling results.

Hydrodynamic simulations were made for the Delta using the RMA tidally averaged model for unimpaired, 1949-1968, 1969-1985, and 1986-2005 boundary conditions. The unimpaired flow simulations omit all gates and barrier controls while the historical data included all gates and barriers as operated. Model results indicated that continuing exports through the Delta results in reverse OMR flow conditions more than 91% of the time for the 1986 – 2005 period (Figure 5, Point B). With the deeper, wider channels of post-development, and with unimpaired conditions and no through-Delta pumping, there was a net outflow in Old and Middle rivers at least 85% of the time (Figure 5, Point A). For unimpaired flows without the increased conveyance of additional channels, and particularly the dredged Stockton Deep Water Ship Channel, more frequent positive flows would likely have occurred, although tidal energy into these channels would increase. The increased conveyance of the Stockton Deep Water Ship Channel would encourage San Joaquin River flows to take the easier path. The historical periods represent gradually increasing levels of through-Delta pumping. Early in water development, 1969 – 1985, positive outflows were reduced to 50% (Figure 5, Point C) of the time, and in recent years, 1986 –

2005 (pre-Wanger decision), positive flows occur less than 10% of the time. The model also estimates that during the intermediate period, 1969 – 1985, negative flows in Old and Middle rivers did not exceed -2,000 and -4,000 cfs for 81% and 92% of the time, respectively.

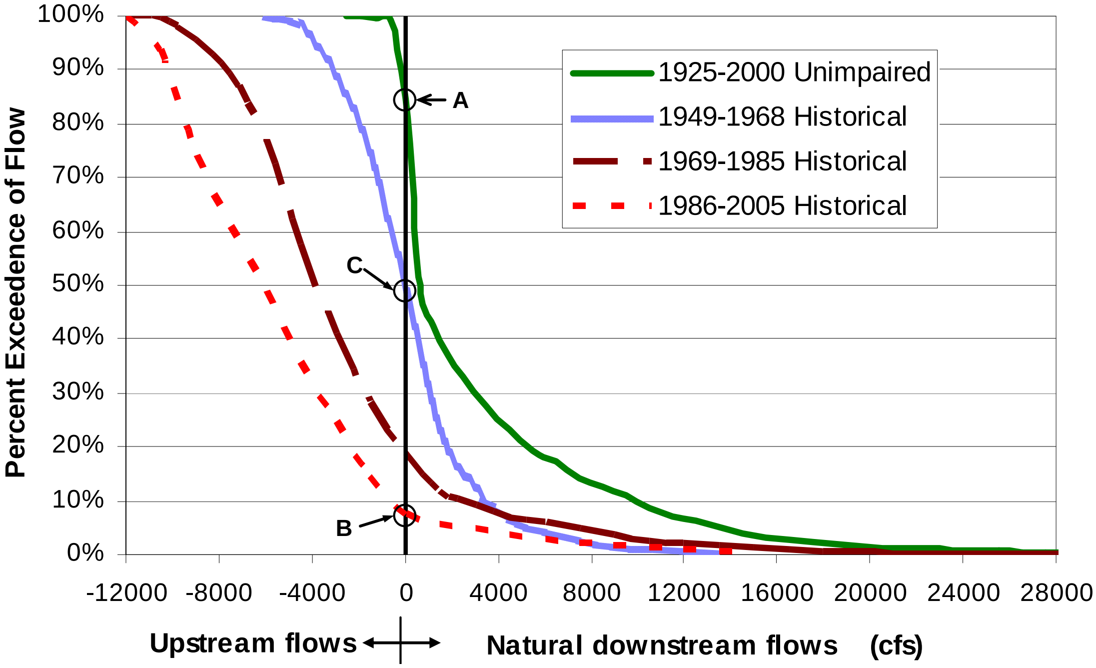

Figure 12. Cumulative probability distribution of sum of flows (cfs) in Old and Middle River resulting from pumping through the Delta showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line). Fleenor et al., 2010.

## X2 Position

X2 is defined as the distance from the mouth at the Golden Gate up the axis of the estuary to where tidally-averaged bottom salinity is 2 practical salinity units (Jassby et al., 1995) and is included as a set of salinity requirements in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB, 1995; SWRCB, 2000; SWRCB, 2006). The X2 objectives are designed to restore a more natural hydrograph and salinity pattern by requiring maintenance of the low salinity zone at a specified point and duration based on unimpaired flow conditions (SWRCB, 2009).

The relationships between Delta outflow and several measures of the health of Bay-Delta estuary have been known for some time (Jassby et al., 1995). Kimmerer et al. (2009) determined that updated abundance-X2 relationships were similar to those previously reported and are seen in a wide variety of estuarine fish species. Additionally, Moyle et al. (2010) hypothesize that a Delta with greater habitat variability, variability in tidal and riverine flows, variability in water chemistry (especially salinity), over multiple scales of time and space, would likely support greater populations of desirable fish species (SWRCB, 2009).

Delta outflows, and therefore Bay inflows, and X2 position are highly correlated (Jassby et al., 1995; Kimmerer, 2002a) (Figure 6). Since the construction and operation of major Central Valley impoundment and diversion structures and rapid population growth and land use changes in California, both Delta outflows and the X2 position have been altered (Kimmerer, 2002b; Kimmerer, 2009; Fleenor et al., 2010; and Moyle et al., 2010). The Bay Institute (2003) developed the San Francisco Bay Freshwater Inflow Index which consists of six indicators to measure the amounts and degree of alteration of freshwater inflows into San Francisco Bay using unimpaired and pre-dam estimates as baselines for comparison. Three of these indicators utilize X2 position to characterize these changes over time.

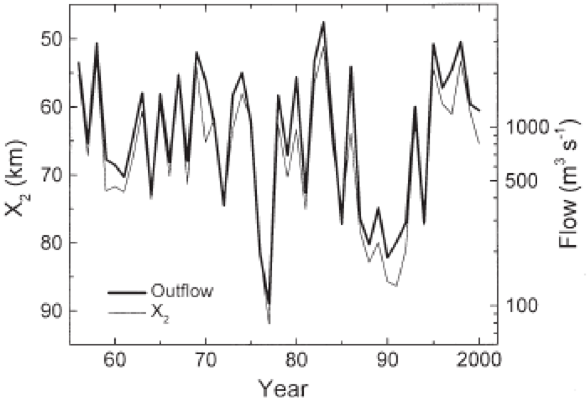

Figure 13. Time series of X2 (distance up the axis of the estuary to the 2 psu isohaline, thin line, left axis, scale reversed) and flow (heavy line, right axis, log scale), annual averages for January to June. Flow data from the California Department of Water Resources; X2 calculated as in Jassby et al., 1995. From Kimmerer (2002a).

The first indicator is the spring X2 position as a function of Delta inflows. Spring inflows have historically been highly variable as a result of the natural hydrologic regime and management operations that store and divert water upstream of the Delta. Prior to the 1970s, spring X2 values rarely exceeded 75 km from the Golden Gate (Figure 7). Since the 1970s,

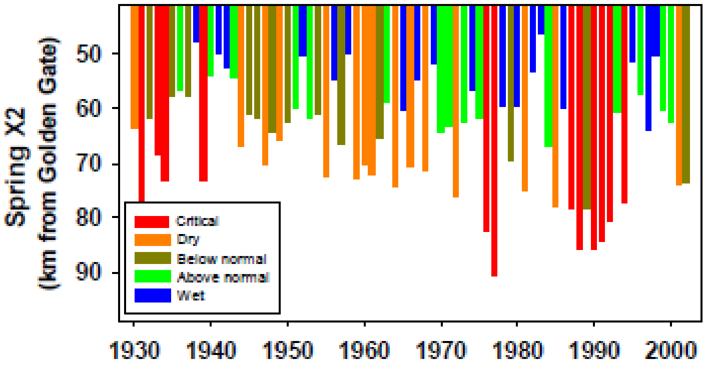

Figure 14. Spring X2 (km from Golden Gate), 1930-2002. Each bar is a single year and, for the year, unimpaired water year type is represented with the different colors. From Bay Institute (2003).

spring X2 has been shifted upstream as far as 90 km. The second indicator, Change in spring inflows, compares the actual amount of Delta outflow (February 1 – June 30) to the amount that would have flowed into the Bay under unimpaired conditions. Delta outflow is characterized by X2 and the change was expressed as the movement of the X2 position upstream. The results indicate that reductions in spring flows have shifted X2 upstream, and upstream movement has increased over time (Figure 8). Between 1940 and 1989, spring X2 significantly increased, shifting as much as 20 km upstream of its predicted (from pre-dam) position. Overall, the greatest shifts have occurred in critically dry water years, but substantial upstream movement occurs in all year types. Similar results have been found through modeling studies conducted by the USFWS (2008) and Fleenor et al. (2010) (Figure 9).

The third indicator, seasonal variation, characterizes the maximum within-year variation

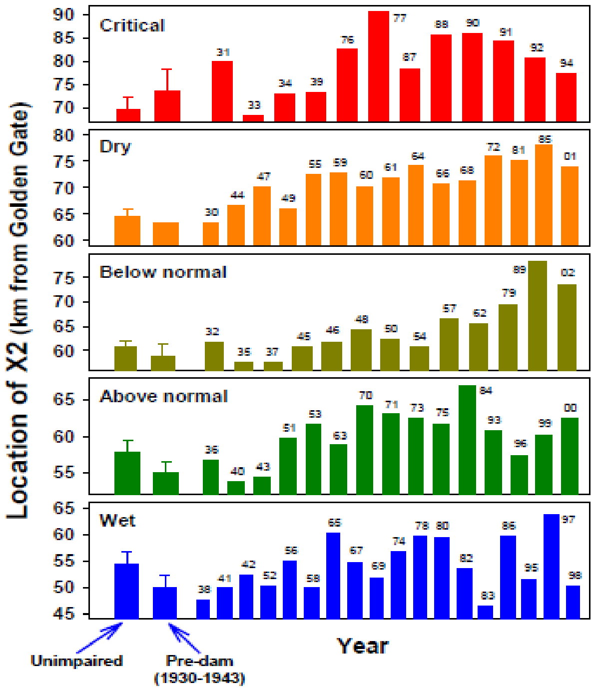

Figure 15. Location of spring X2 (km from Golden Gate) in each water year type, 1930-2002. Mean (+1SD) unimpaired X2 and mean pre-dam X2 (mean+1SD) are also shown for each year type. The number above each bar is the year (shown as last two digits). From Bay Institute (2003).

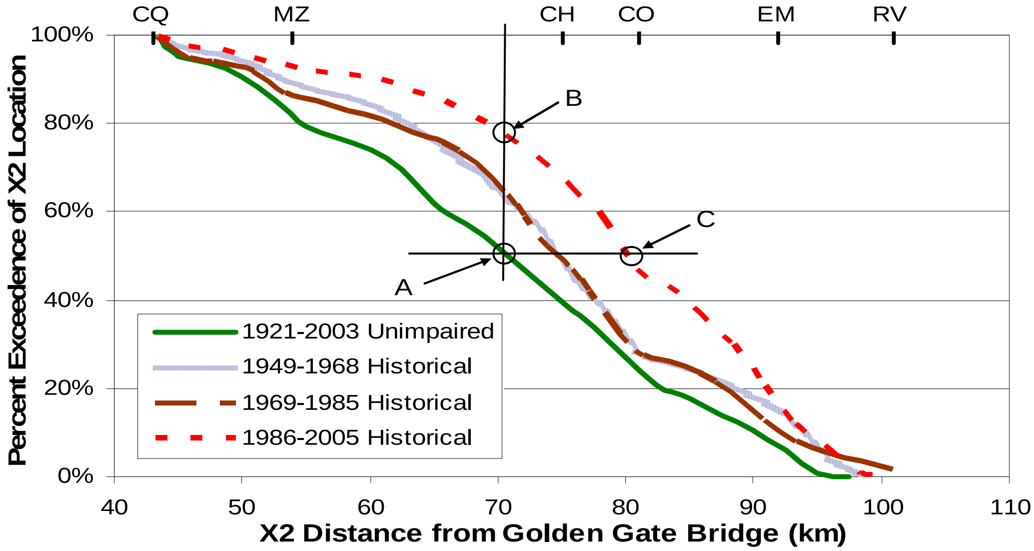

Figure 16. Cumulative probability distributions of daily X2 locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line), illustrating progressive reduction in salinity variability from unimpaired conditions. X2 is the location of the 2 ppt salinity region of the estuary in kilometers from the Golden Gate Bridge. Paired letters indicate geographical landmarks. CQ, Carquinez Bridge; MZ, Martinez Bridge; CH, Chipps Island; CO, Collinsville; EM, Emmaton; and RV, Rio Vista. From Fleenor et al. (2010).

of freshwater inflow to the Bay and was calculated as the difference between maximum and minimum X2 location. Compared to pre-dam conditions, seasonal variation in inflows have been reduced by nearly 40%, to an average of 33 km. Reductions in seasonal flow variations resulted from increases in late summer and fall inflows to the Bay (Figure 16).

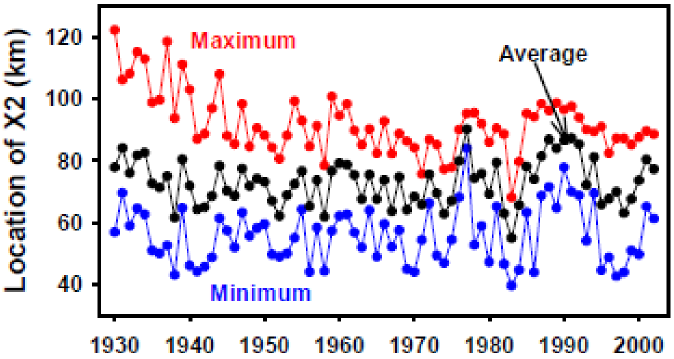

Figure 17. Maximum, minimum daily X2 locations and average annual X2 location, 1930-2002. From Bay Institute (2003).

Fall X2 also has important biological significance for species like the Delta Smelt (Feyrer et al., 2007). During fall, delta smelt are typically fully distributed in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. The amount of suitable abiotic habitat available for delta smelt, measured as hectares of surface area, is negatively related to X2 (USFWS, 2008). The average X2 during fall has exhibited a long-term increasing trend (movement further upstream), which has resulted in a corresponding reduction the amount and location of suitable abiotic habitat. X2 postion (Figure 18) during fall in the years following the Pelagic Organism Decline (2000-2005) was several km upstream compared to that for the pre-pod years (1995-1999). This suggests that operations in the Delta have exported more water relative to inflow, which has had a negative effect on X2 by moving it upstream.

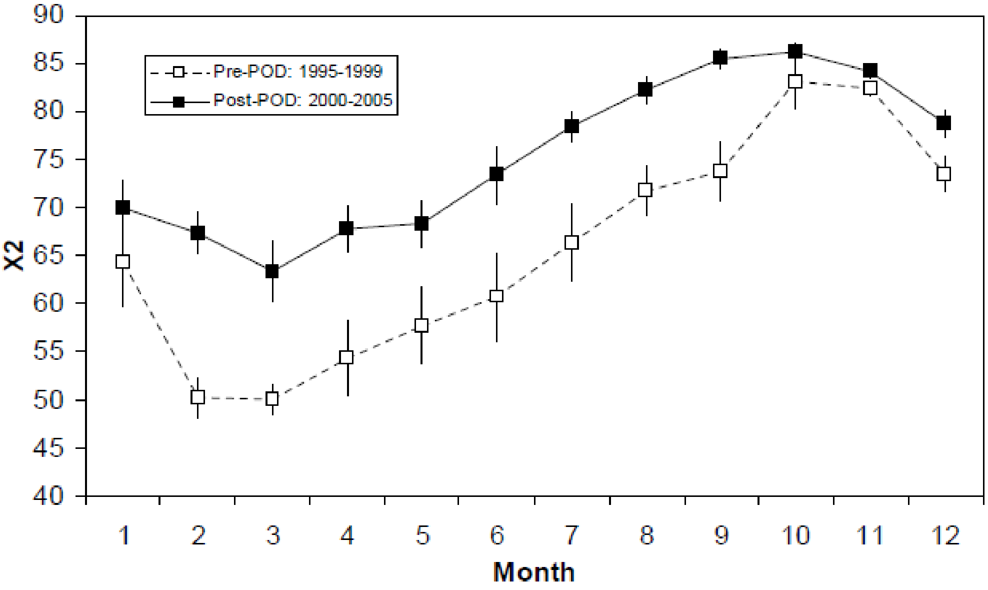

Figure 18. X2 in years preceding and immediately following the Pelagic Organism Decline. From USFWS (2008).

### b. *Anadromous Fish*

i. Expert testimony: Pat Brandes

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## Effects of Delta Inflow and Outflow on Chinook Salmon

**Key Points:**

1. Delta inflow and outflow are important for Chinook salmon in the Delta. Freshwater inflow is an important cue for upstream migration of adult salmon and directly affects the abundance and survival of juveniles moving downstream through the Delta.

2. The Board should rely on scientific information in current and past Board exhibits, scientific publications and models to help determine the volume, quantity and timing of water needed for the Delta ecosystem pursuant to the Board's public trust obligations.

3. Consistent with its narrative salmon doubling objective, the Board should adopt biological goals of doubling smolt survival through the Delta from what it was between 1967-1991 for consistency with the goals of the Central Valley Project Improvement Act and the Anadromous Fish Restoration Program.

4. The Anadromous Fish Restoration Program has developed estimates of flow levels needed at Vernalis to achieve a 53% increase and a doubling (USFWS, 2005, pages 9 and 10) in predicted Chinook salmon production for the basin, and help protect public trust resources in the Delta.

5. Providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing of water needed for the Delta ecosystem.

6. Uncertainty should not limit the Board's actions to protect the public trust resources.

Delta inflow and outflow are important for Chinook salmon in the Delta. Freshwater flow is an important cue for upstream migration of adult salmon and directly affects the abundance and survival of juveniles moving downstream through the Delta. Increasing juvenile salmon survival rates through the Delta will be a critical step toward restoring and doubling natural salmon production in the Central Valley.

The Board should rely on scientific information in current and past Board exhibits, as well as scientific publications and models to help determine the volume, quantity and timing of water needed for the Delta ecosystem pursuant to the board's public trust obligations. In our Exhibit 31 (USFWS, 1987), we presented evidence that habitat alterations in the Delta limit salmon production primarily through reduced survival during the outmigrant (smolt) stage. Smolt mortality in the Delta will impact resulting adult salmon population levels, although other factors that influence abundance both upstream and in the ocean make the impact difficult to quantify for naturally spawned salmon.

Prior to the establishment of Delta flow criteria, the Board should develop biological objectives that are clear, measurable, achievable, and time-based. The present narrative salmon objective of "contributing to doubling" is not specific enough to evaluate success of flow standards. In our Exhibit 31 (USFWS,1987) we modeled how smolt survival has changed from an average of 0.76 with unimpaired Delta outflow to 0.46 under the 1990 level of development (page 60). In our Exhibit 7 (USFWS,1992) we further showed the differences in modeled survival from various historical periods and how survival through the Delta has decreased through time (page 47). We recommend the Board adopt biological goals of doubling smolt survival through the Delta from what it was between 1967-1991 for consistency with the goals of the Central Valley Project Improvement Act. As a minimum, specific biological objectives should be established to achieve improvement in juvenile salmonid survival through the Delta for the recovery of Central Valley Chinook salmon and steelhead to long-term self-sustaining levels. In addition, biological objectives should be adopted that provide attraction flows for the successful upstream migration of adults.

Lower survival in the Delta of marked juvenile fall run salmon is associated with decreases in the magnitude of flow through the estuary, increases in water temperature, and the proportion of flow diverted through the Delta Cross Channel and Georgiana Slough in the Delta. The survival of marked hatchery smolts through the Delta between Sacramento and Suisun Bay was found to be positively correlated to flow and negatively correlated to water temperature (USFWS, 1987). Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs (USFWS, 1987, pages 35 and 36). Smolt survival was also found to be highest when water temperatures were below 66 F (USFWS, 1987). Similar relationships showing the benefit of increased flows to juvenile salmon survival for marked smolts released near Sacramento were reported in previous USFWS publications ( Kjelson et al., 1981, Kjelson et al., 1982). Kjelson and Brandes (1989) also updated these findings and relationships.

Between 1997 and 2008, several statistical models were developed with the USFWS juvenile salmon mark and recapture data (Newman and Rice, 1997, Newman, 2002, Newman, 2003 and Newman, 2008). These models use flow, inflow/exports, water temperature and the position of the Delta Cross Channel gates, in addition to other variables, to explain the variability in juvenile salmon survival for marked smolts migrating through the north Delta. These models are tools that can be used by the Board to help in determining the relative increase in smolt survival for any proposed incremental changes to flow standards in the Delta.

In recent years, studies have been conducted using acoustically tagged late-fall yearlings to determine the effects of the Delta Cross Channel on juvenile salmon survival through the Delta during the winter months (Perry and Skalski, 2008 and Perry and Skalski, 2009 and Perry et al., 2010 in press). The acoustic tag methodology provides information on juvenile salmon survival among reaches in the Delta and how juvenile salmon split at the various river junctions. The data from these and other studies have been used to develop a model that predicts the probability of an individual fish being diverted into the Delta Cross Channel or Georgiana Slough based on the flow in the Sacramento River and upstream flow into the Delta Cross Channel and Georgiana Slough, due to flood tides (Perry, in preparation). Perry has found that increasing Sacramento River flow decreases the probability that juvenile salmon are diverted into Georgiana Slough and the Delta Cross Channel (Perry, in preparation). Closing the Delta Cross Channel and increasing the flow on the Sacramento River to levels where there is no upstream flow from the Sacramento River entering Georgiana Slough on the flood tide during the juvenile salmon migration (November to June). Reducing the number of fish that enter the interior Delta will improve survival as it is an area where survival has been shown to be less than on the mainstem Sacramento River. To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of approximately 17,000 cfs at Freeport are needed (R. del Rosario, personal communication).

Survival through the Delta for juvenile fall run salmon originating from the San Joaquin basin has also been shown to increase with increased Delta inflows at Vernalis (Newman, 2008). Smolt survival and resulting adult production is most favorable in wet years (Kjelson and Brandes, 1989, SJRGA, 2007). In Bayesian hierarchical model fitting of data from the Vernalis Adaptive Management Plan (VAMP) studies, two conclusions were consistent: flow is positively associated with the probability of survival from Dos Reis to Jersey Point and that survival is greater for juvenile salmon migrating between Dos Reis and Jersey Point than for juvenile salmon migrating down Old River to Jersey Point (Newman, 2008). The conclusion that survival is higher between Dos Reis and Jersey Point than for smolts migrating through Old River was further supported by the results of the 2008 VAMP acoustic tag study (USGS, 2009). It should be noted that the full barrier at the head of Old River resulted in increased flows at Dos Reis but the non-physical barrier deployed in 2009 at the head of Old River would not increase the flows at Dos Reis.

In a previous Board exhibit (USFWS, 1992), we showed a positive relationship between temperature corrected juvenile salmon survival indices and flow at Jersey Point for marked fish released at Jersey Point (QWEST) (USFWS, 1992, page 21). In addition, the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30. Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this type of action to assure the contribution of downstream flow from the San Joaquin basin to Delta outflow for the protection juvenile and adult salmonids migrating from the San Joaquin basin.

The Anadromous Fish Restoration Program has developed estimates of flow levels needed at Vernalis to achieve a 53% increase (page 9) and a doubling (page 10) in predicted Chinook salmon production for the basin (USFWS, 2005). These Vernalis flow criteria vary by water year type and by month between February and May. We recommend these flows as starting point for establishing minimum and maximum volume of flow for increasing juvenile salmon and steelhead survival in the San Joaquin basin.

In addition to juvenile salmon survival being higher with higher flows, the abundance of juvenile salmon leaving the Delta is also higher with greater river flow. The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista (USFWS, 1987, Brandes and McLain, 2001, Brandes et al., 2006. The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20,000 cfs which is also the level where we have observed maximum survival in the past (USFWS, 1987).

The flow needs for upstream migration through the Delta for adult salmon is based on sonic tag studies conducted on fall-run fish from 1964 to 1967 (Hallock et al., 1970). Hallock et al., (1970) found that the presence of Sacramento River water in the central and south Delta channels causes migration delays for salmon from both the Sacramento and San Joaquin River basins (Hallock et al, 1970 as summarized in USFWS, 1987). Reverse flows in the lower San Joaquin River also hamper or at least delay migration (Hallock et al., 1970 as summarized in USFWS, 1987). In addition, Hallock et al, (1970) found that low dissolved oxygen concentrations of less than 5 mg/l in the San Joaquin River near Stockton was a barrier to adult migration. USFWS (2005) recommended that 1000 cfs pulse flow be released for 10 days in mid-October from each of the three San Joaquin River tributaries (page 12) to increase Vernalis flows to maintain high levels of gamete viability and to minimize straying during periods of high exports.

These relationships indicate that increased flow during the smolt migration stage increases the abundance and survival of juvenile salmon migrating through the Delta, with maximum survival and abundance observed at flows above 20,000 cfs at Rio Vista. Similarly, maximum adult escapement in the San Joaquin basin is achieved with flows of about 30,000 cfs at Vernalis during the smolt migration period (April 15 and June 15) suggesting similar responses to flow in the Delta for juvenile salmon from both the Sacramento and San Joaquin Rivers. Furthermore, to reduce any delays in adult upstream migration, Delta outflow should incorporate flows from both the Sacramento and San Joaquin Rivers.

We hypothesize that providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing of water needed for the Delta ecosystem. Propst and Gido (2004) support this hypothesis and suggest that manipulating spring discharge to mimic a natural flow regime enhances native fish recruitment (Propst and Gido, 2004 and Marchetti and Moyle, 2001). Thus the timing of flows should mimic the natural flow hydrograph and cover the peak migration period of the various races of juvenile salmon and steelhead migrating through the Delta (November through June on the Sacramento River and February through June on the San Joaquin River).

Although Propst and Gido, (2004) found nonnative fish density in the fall was negatively related to spring discharge, and that the abundance of western mosquito fish (Gambusia affinis) in particular, was significantly lower with higher spring flow, they concluded that mimicking a natural flow regime may not substantially suppress non-native fish production (Propst and Gido, 2004). Marchetti and Moyle (2001) did find evidence that natural flow regimes changed habitat conditions to benefit native fishes and flushed some nonnative fish from Putah Creek.

Why survival is greater at higher flows is hypothesized to be due to lower temperatures, lower proportion of flow diverted into the interior Delta, reduced entrainment at agricultural pumps and project export facilities, lower predation and disease, elimination of reverse flows in the lower San Joaquin River, and increased availability of rearing habitat in Yolo Bypass and floodplains. The models we have identified attempt to decouple the effect of flow from other variables, although in many cases they cannot be separated because variables are not truly independent of one another. While there is uncertainty in the biological response to increases in flow in the Delta, the benefits of higher flow in the Delta during the juvenile outmigration period appears to be supported by several pieces of evidence. However, there is still uncertainty that juvenile salmon survival and abundance will respond to flows in the future as they have in the past.

Climate change has the potential to significantly impact juvenile salmon survival through the Delta by reducing flows and increasing water temperatures during the spring. High water temperature has consistently been one of the most important variables in predicting salmon survival in models of fall run smolt survival for smolts originating from the Sacramento basin. The potential impacts of climate change to the timing, magnitude and duration of flows in the Delta and water temperature need to be incorporated into any flow criteria designed to protect the public trust resources. Climate change will also add to the uncertainty of the biological response to flows in the Delta.

Uncertainty should not limit the Board's actions to protect the public trust resources, because there will always be uncertainty in how the Delta ecosystem will respond to flow. "Because of natural variation, resource systems often are extraordinarily difficult to control with management actions, and "cause and effect" relations are usually unclear and difficult to recognize" (page 28, Williams et al., 2007). One way to address uncertainty in the system response to flow standards is specifically targeted monitoring, such as survival monitoring using acoustic tag methodology, to determine if the biological responses to flow standards achieve the desired biological objectives. Model predictions can be compared to monitoring data to help support or refute hypotheses or differentiate between competing hypotheses for assessing success. In addition to monitoring, continuing to invest in research to understand the mechanisms behind the relationships of flow to abundance and survival and the other factors that affect abundance and survival is also important for informing changes to flow standards if biological objectives are not initially achieved. These are important steps in the process of a passive adaptive management program (Williams et al., 2007). While beneficial, the limitations of this type of approach need to be understood by all the parties, as the rate of learning using this passive adaptive management approach is likely to be less than a more active adaptive management approach (Williams et al., 2007). An active management approach focuses both on learning and achieving management objectives. This approach may not be possible for the Board as it takes a commitment for "management by experiment" and the ability to regularly and quickly change flow standards as monitoring informs management. For more information on active adaptive management we encourage the Board to review the U.S Department of Interior's Technical guide on the process and components for successful adaptive management (Williams, et al., 2007).

ii. Expert testimony: Nick Hindman

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## Effects of Floodplain Inundation on Juvenile Chinook Salmon

Key Points:

- Seasonal floodplain inundation has a positive effect on growth rates and on the apparent survival of juvenile Chinook salmon in the Central Valley.
- Restoration of floodplains and other off channel habitat is potentially important for increasing production of juvenile salmonids in California's Central Valley.
- The biological objectives of seasonal floodplain inundation would be to provide off channel areas conducive to juvenile salmonid rearing and growth, which should improve survival through the Delta and to the ocean.
- The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows needed to restore the Delta ecosystem pursuant to the Board's public trust responsibilities.

Recent studies indicate that seasonal floodplain inundation has a positive effect on the growth and apparent survival of juvenile Chinook salmon in the Central Valley. Results of a study conducted in 1998-1999 (Sommer et.al, 2001) on juvenile salmon in the Yolo Bypass show increased growth rates and higher apparent downstream survival of fish rearing and feeding in the bypass compared to juvenile salmon that remain in the mainstem Sacramento River.

The increased growth rates in the Yolo Bypass may be attributable to higher densities of preferred prey species (e.g. Diptera spp.) and higher water temperatures.

Survival indices to Chipp's Island for coded-wire tagged (CWT) salmon released in the Bypass were higher than survival indices for CWT salmon released in the mainstem Sacramento River, although the differences were not statistically significant. This may be due to the small number of recoveries made at Chipp's Island.

The author's hypothesis that floodplain rearing improves survival is supported by their growth data and bioenergetic modeling. "Faster growth rates reflect improved habitat conditions, which would be expected to lead to improved survival, both during migration and later in the ocean." There may be several factors involved, including; a larger and more diverse area to feed and rear, reduced competition for food and space, lower water velocities, more cover from predatory fish, and emigration at a larger size.

A separate study was conducted by Jeffres et al. on the Cosumnes River in 2004 and 2005. The researchers placed hatchery fall-run Chinook in enclosures in different habitats (mainstem Cosumnes River above the floodplain, on ephemerally submerged floodplain, in ponds on the floodplain, and in the tidally-influenced mainstem Cosumnes below the floodplain).

The results of the Jeffres et al. study indicate that juvenile Chinook salmon placed in ephemeral floodplain habitats grew larger than fish placed in the intertidal river site below the floodplain. The authors hypothesize that along with increased temperature and productivity, ephemeral floodplain is also important to increased growth of juvenile salmon throughout a variety of flow conditions. In addition, they cite a separate study conducted on the Cosumnes River and floodplain by Grosholz and Gallo (2006) which found that zooplankton biomass was 10 – 100 times greater in floodplain sites than in river sites.

The authors make a compelling argument that in the absence of ephemeral floodplains and other off channel habitats, juvenile salmon are frequently displaced downstream to intertidal areas during high water events, and that the intertidal river channels are less favorable habitat. Their conclusion is that restoration of floodplains and other off channel habitat is potentially important for increasing production of juvenile salmonids in California's Central Valley.

The biological objectives of seasonal floodplain inundation would be to provide off channel areas conducive to juvenile salmonid rearing and growth, which should improve survival through the Delta and to the ocean. Larger outmigrating smolts should also have higher rates of ocean survival (Healey, 1982)(Parker, 1971) and produce more returning adults two to four years later. However, Sommer et al., (2005) also conclude that areas with engineered water control structures had comparatively high rates of stranding – thus impact of flooding on the survival of juvenile salmon needs to be continually evaluated to assure losses do not overshadow the benefits of increased flooding in the floodplains. Floodplain restoration projects should be designed to drain completely minimizing the formation of ponds and the occurrence of fish stranding (Jones and Stokes, 1999).

While there is uncertainty in the biological response to more frequent floodplain inundation in the Delta, the benefits during the juvenile outmigration period appear to be supported by several pieces of evidence. However, there is still uncertainty that juvenile salmon survival and abundance will respond to floodplain inundation in the future as they have in the past.

Controlled floodplain inundation events should be allowed to occur more frequently and be considered an experimental pilot project in which key indicators (salmonid growth and survival using coded-wire tags and acoustic tags) are monitored across several years in order to ascertain whether floodplain inundation is an effective tool for improving overall salmonid production. If the results are positive it may be feasible to make physical alterations to certain structures (i.e., the Fremont Weir at the head of Yolo Bypass) to enable controlled events to happen more frequently. We should also consider conducting studies similar to Sommer at al. (2001) in Sutter Bypass, where floodplain inundation can occur at lower Sacramento River flows.

In addition to monitoring, continuing to invest in research to understand the mechanisms behind the relationships of floodplain inundation to growth and survival is important if objectives are not achieved during the experimental phase. The rate of learning using a passive adaptive management approach is likely to be less than a more active adaptive management approach (Williams et al., 2007).

The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows needed to restore the Delta ecosystem pursuant to the Board's public trust responsibilities.

### iii. Expert testimony: John Hannon

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**Key Points**

- Delta habitats for salmonids have been highly altered and simplified resulting in an inhospitable passage route to the ocean much of the time. Flows can be used to access better habitat and assist in transiting degraded habitats.

- Variation in flows is important to anadromous species.

- Increasing diversity in life history types of salmonids can provide insurance against specific stressors such as varying ocean food abundance, precipitation/flow patterns, (maybe not predation though).
- Different life history strategies benefit in different water year types.
- Delta habitats are an extension of riverine habitats for salmonids out to the saltwater interface, wherever it may be.
- Survival through the delta, which is affected by flow, is likely a major factor limiting naturally produced salmonid populations relative to historic levels.
- Delta flow prescriptions should take into account upstream fishery needs.

Flow and water temperature are important in retaining different life history strategies in Chinook salmon populations in different year types. The salmon "season" is extended when flows are higher. A portion of the Chinook salmon population migrates downstream within a few days of leaving the gravel. Higher flows during emigration provide two benefits. 1) For those salmon that stay in the upstream rivers and rear, the amount of higher quality edge habitat (generally inundated areas with vegetation) in the river increases. In addition, food production in those inundated areas increases. 2) For those salmon that emigrate, the flows provide enhanced opportunities for transport downstream and to the ocean and increase rearing habitat availability along the way. An important question for Central Valley Chinook salmon management is to what extent do fish that leave the rivers as fry (less than about 40-50 mm) contribute to adult populations. The predominance of the early emigrating life history type of individuals evolved when rearing habitats is in the delta were abundant. The individuals using a strategy of early emigration from the upstream higher gradient reaches down into the flatter delta habitats were likely highly successful at surviving to the ocean and ultimately back to freshwater to reproduce. This strategy is likely less successful today, except in those years with higher delta through-flow. I say delta through-flow because most relationships between salmon survival and abundance have been developed using the flows coming down from the upstream rivers and entering the delta, rather than as delta outflow. Delta outflow needs appears to be the focus of this process. To a Chinook salmon or steelhead moving downstream the delta channels are simply an extension of the riverine habitats until they reach the saltwater interface. These channels have become more like canals than rivers and contain limited habitat favorable to salmonid survival.

Those fry that remain upstream in the rivers account for well less than half of the total number of fry produced (based on screw trap data from upper Sacramento, American, Stanislaus, and Clear Creek and Williams (2006)). During higher flow years more fry tend to remain longer in the upstream habitats resulting in more rearing parr upstream, but more fry also emigrate downstream early in those years, the result of overall higher survival. Those early emigrants seem to survive better to the delta in wet years. Their survival through the delta is more uncertain. Both strategies seem to be important to manage for, but we have focused management on the larger emigrants that rear upstream longer. For these larger fish a quick passage through the estuary to the ocean, given the degraded lower river and delta habitat, would probably provide the most survival benefit. We may be able to provide for a quicker passage using managed pulse flows.

Delta inflow and outflow at the flow levels that are most meaningful to producing differences in salmon survival are correlated, i.e. a lower proportion of delta inflow can be diverted at higher flows. Consumptive uses in the delta increase the difference between delta inflow and outflow. Direct take of salmonids at the south delta export pumps is most important for salmon and steelhead from the San Joaquin River and eastside tributaries. The Delta exports, to the extent that they modify the tidally dominated flows in the channels with salmonids present, can provide a false "attraction" to emigrating salmonids. This occurs when downstream, in the point of view of the fish, becomes somewhere other than the ocean. This false attraction can result in reduced emigration survival through an increase in the proportion of fish being entrained. The influence of exports on potential entrainment has been developed primarily in relation to delta smelt but probably holds for the anadromous species during the times they inhabit the delta. More important than the direct entrainment effects may be the effects of juvenile salmon spending more time in the intertidal zone of channelized habitat where predation by striped bass is high (VAMP studies). This may be a consequence of steady flows, particularly during dryer periods.

### Variation in flows is important to anadromous species

Water is such a limited resource that we will likely need to explore ways to provide the most ecosystem benefits we can with what is available. Salmonids respond behaviorally to variations in flow. Juvenile salmonid monitoring shows that peaks in emigration occur during the rising limb of the hydrograph. Once an initial pulse of fish passes monitoring points fish numbers tend to decline as the hydrograph remains steady (as from a controlled reservoir release) and the "ready to emigrate" supply of fish is depleted. When the flow subsequently decreases another peak in passage often occurs during the period of changing flow rate (Stanislaus River rotary screw trap data). Juvenile passage at lower mainstem Sacramento River locations occurs primarily during precipitation induced higher flow pulses. A pulse of about a 40% increase in flow at Wilkins Slough appears to be enough to trigger emigration past Knights Landing (DFG Knights Landing rotary screw trap data) and to the delta (lower Sacramento seine and trawl survey data). The same type of monitoring data is not as available in the delta but it is reasonable to assume that high flow pulses result in increased passage through the delta to the ocean (and past the predators in the confined channelized areas). Once in the ocean, juvenile salmon experience a great increase in growth (McFarlane and Norton 2002). Shorter flow pulses may be most useful to larger juveniles in cueing emigration to the ocean. The usefulness of short pulses for fry needs to be studied more.Rapid marine growth did not appear to occur in recent years when poor ocean conditions (reduced upwelling) were the short term cause of the crash of fall-run Chinook (Lindley et.al. 2009). We can only hope that this larger than normal drop in production is a temporary phenomenon. Based on past variation in ocean productivity marine survival should improve. We can plan for future crashes by attempting to increase diversity in salmon stocks. One way to work towards increased life history diversity is by providing diversity in flows to produce a range of emigration timings. The listed runs (winter Chinook, spring Chinook, steelhead) did not recently decline to the extent of the fall-run decline. The listed Chinook runs are not as influenced by hatchery releases. Naturally produced Chinook stocks have more variability in freshwater emigration timing and timing of ocean entry. The Central Valley fall-run Chinook stock appears to be dominated by hatchery fish (Barnett-Johnson et.al. 2007), the majority of which are released downstream of Carquinez Strait, all at about the same time and at about the same size (May-June and 65 – 95 mm). Providing for pulses of emigration through the delta by providing variation in flows to mimic the natural hydrograph could diversify ocean entry size and timing so that in many years at least some portion of the fish arrive in saltwater during periods favoring rapid growth and survival.

Central Valley steelhead have a similar status with the anadromous form of the species dominated by hatchery produced fish released when ready to emigrate. Resident populations on many streams (including Sacramento River, Stanislaus River, Clear Creek, Mokelumne River, Calaveras River, Tuolumne River, Merced River ) maintain high abundances near the dams where cool and relatively constant releases are maintained year round. Variability in releases achieved through variable delta flows may entice more of these residents to emigrate. Abundance of salmonids in the delta tends to be higher and they are present longer during higher flow periods, presumably because the habitat is more suitable. The downside to providing shorter duration flow pulses may be that some fish are "stranded" in the inhospitable parts of the delta when flows subside. An adaptive management/monitoring need would be an evaluation of survival and growth of naturally produced emigrants during variable versus steady delta outflow and inflow.

Adult Chinook salmon, steelhead, and sturgeon are cued to migrate upstream on rapidly increasing limbs of the hydrograph. While variation in flow provided with higher flow pulses triggers increased upstream migration in adults, it is probably not as important to adults as to juvenile migrants in ultimate survival. Adults generally manage to migrate successfully back to their natal tributary as long as there is a flow from their river of origin reaching the delta and no passage barriers are in the way. A passage barrier that flow standards could address is low dissolved oxygen in the San Joaquin River. Flow pulses from the San Joaquin and eastside tributaries may be needed so that some water from each of those areas reaches the lower delta to provide a homing mechanism for returning adults. In addition to upstream migratory cues, post-spawn green sturgeon have been observed to hold in the Sacramento River near their spawning areas until an increased flow pulse occurs. With the pulse they immediately migrated back downstream (USBR sturgeon tracking data).

### Consideration of Upstream Fishery Needs

Delta flow prescriptions should take into account upstream fishery needs. There are at least two upstream considerations that need to be taken into account in delta flow standards.

1) A temporarily increased outflow requirement of a set constant minimum rate for an extended time (more than about two days) during salmonid spawning periods can cause stranding of a significant proportion of redds. Steelhead and Chinook salmon will quickly spawn in newly wetted areas when constant flows of a higher magnitude are provided for a period of time. When the flows are subsequently reduced, redds are dewatered. This has been documented for steelhead and Chinook in the American River. This can probably be ameliorated by providing more of a pulse flow situation than extended steady flows (or very long extended high flows).

2) Delta flow requirements in late spring can have an adverse effect on over-summer water temperatures due to a reduction in the coldwater pool to meet the delta flow standards. This may be a wise tradeoff in consideration of overall ecosystem needs, but it needs to be considered. This affects primarily winter Chinook egg survival in the Sacramento River and juvenile steelhead rearing in the American River (both species with habitat areas transposed downstream from where they originated). These effects can likely be reduced by changing reservoir release patterns during the summer.

In addition to the above considerations, inundation of vegetated areas adjacent to stream channels and in the flood bypasses provides for an expansion in juvenile Chinook salmon rearing habitat area. Moderately high Sacramento River flows (above about 25,000 cfs) begin to inundate the Sutter bypass. This increases rearing habitat for salmonids coming down from the upper Sacramento River by approximately 45 linear miles of three new Sacramento Rivers worth of shallow habitat with dense woody vegetation on each of six new “river edges”. The new river edges are provided by two perennially wetted channels bordering the bypass with a 1 km wide variably vegetated area in the middle. Higher flows (above about 56,000 cfs down the Sacramento and lower Sutter bypass combined) will also inundate Yolo Bypass and provide another large increase in habitat (Sommer et. al. 2005). It is uncertain whether; flow management to increase Yolo Bypass inundation frequency and duration at lower flows may not result in the same type of benefits to the juvenile salmon population as has been observed during flood flows.

### *c. Pelagic Fish*

i. Expert testimony: Victoria Poage

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Key points:

- Inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration of Delta fish.

- Delta smelt critical habitat consists of four primary constituent elements: physical habitat, water, river flow and salinity and flow is a constituent of each of these.
- Past observations indicate that adult delta smelt begin moving up the Estuary to their presumed spawning areas when winter flows on the Sacramento River exceed about 25,000 cfs.
- The location of X2, scaled as distance in kilometers from the Golden Gate Bridge, is a physical attribute of the Bay-Delta Estuary that is used as a habitat indicator.
- Placing X2 in the relatively shallow waters of Suisun Bay at particular times of the year, where phytoplankton growth rates are higher, is intended to maximize productivity and support fish rearing.
- The strategic placement of X2 is intended to have two benefits for delta smelt: (1) improvement of environmental quality, and (2) minimization of entrainment into the State and Federal export facilities.
- Improved flow conditions associated with moving X2 westward may maintain the nutrient input that supports primary productivity and the turbidity that delta smelt need to successfully forage and elude predators.
- Fall X2: Moving X2 westward in the fall therefore reduces the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities.
- Successful spawning and recruitment of splittail is highly dependent upon the availability of floodplain habitat for spawning and rearing.

<u>Delta Smelt:</u> Inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Delta must provide suitable habitat all year, every year. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components (USFWS 2008). The Service designated critical habitat for delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by this designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994). Delta smelt critical habitat consists of four primary constituent elements (PCEs): physical habitat, water, river flow and salinity. Flow is in turn a constituent of each of these, as it influences spawning substrate, water quality (including temperature, turbidity and food availability), transport (both up and down the Estuary, and including entrainment in water diversions), and the location of the low-salinity zone (LSZ), indexed by the two-parts-per-thousand salinity isohaline, or "$X_2$." <u>Physical Habitat</u>: Flows must be sufficient to keep spawning substrates clear of sediment and prevent colonization by submerged aquatic vegetation such as the non-native invasive *Egeria densa*. In the Delta, *E. densa* displaces native plants, blocks photosynthesis, and causes sediment to settle, increasing water clarity. *E. densa* occupies approximately 12 percent of the Delta and spreads at a rate of about 100 acres per year, growing more quickly in drier years (DWR 2010). <u>Water</u>: Flows must be sufficient to provide appropriate temperatures for various life stages, turbidity for cover and feeding, and to dilute contaminants. A Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. The Delta is listed by the USEPA as impaired by a variety of substances; TMDL have been developed or are in development to address these contaminants (USEPA 2010; Central Valley Regional Water Quality Control Board 2006). Existing TMDLs should be implemented and TMDLs currently in development should be expedited to the extent practicable, to ensure that contaminant loads are balanced with Delta inflow and outflow. <u>River Flow</u>: Flows must be sufficient to facilitate the migration of adults and juveniles and avoid entrainment into water diversions. Past observations indicate that adult delta smelt begin moving up the Estuary to their presumed spawning areas when winter flows on the Sacramento River exceed about 25,000 cfs (DSWG 2006). To avoid or minimize entrainment, reverse flows due to water diversions from the Delta must be no more severe than those prescribed by the Service (USFWS 2008). <u>Salinity</u>: The LSZ is where fresh water

transitions into brackish water, and is an indicator of habitat suitability for many organisms in the San Francisco Estuary (Jassby et al., 1995).
The LSZ expands and moves downstream when river flows are high, and contracts and moves upstream when river flows are low.

Longfin Smelt: Flows that meet the needs of delta smelt will generally meet the needs of longfin smelt as well. However, longfin smelt spawn earlier than do delta smelt, and while they may be subject to entrainment into water diversions earlier in the year, it is not likely as great a threat to longfin as it is to delta smelt. A portion of the population also may exhibit an anadromous life history, ranging to nearshore marine areas and the Gulf of the Farallones.

Sacramento Splittail: Successful spawning and recruitment of splittail is highly dependent upon the availability of floodplain habitat for spawning and rearing (Feyrer et al. 2006; Moyle et al. 2004). The Yolo Bypass floods via the Fremont Weir when flows on the Sacramento River exceed about 70,000 cfs, which it currently does in about 60% of years (Fyerer et al 2006). Flows on the Sacramento River must therefore exceed 70,000 cfs in at least six out of ten years.

| Delta Smelt | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| Physical Habitat | clean spawning substrate | clean spawning substrate | | |
| Water | ≤ $12^0$C; turbidity ≥12 NTU | 12 – $18^0$C; turbidity ≥25 NTU | ≤ $25^0$C; turbidity ≥12 NTU | ≤ $25^0$C; turbidity ≥12 NTU |
| River Flow | Sac River ≥ 25,000 cfs (pulse); limit reverse flows | limit reverse flows | limit reverse flows | |
| Salinity | <2 ppt | <2 ppt | <3 ppt | 0.5 – 6 ppt |

Water quality
Water of suitable quality is needed for all life stages of Delta fishes and other organisms. Pelagic habitat in the Delta has been highly altered and degraded by many factors. The historic Delta consisted primarily of tidal freshwater marshes, tributary river channels and their associated floodplains, and sloughs. The current Delta has little (<1 percent) of its historic intertidal marsh habitat, its patterns of sloughs and channels have been modified, changing its hydrodynamic characteristics, and the pattern and quantity of inflow to, through, and out of the Estuary has been altered (USFWS 2008).

Location of X2
The location of the near-bottom two-parts-per-thousand (2 ppt) isohaline, denoted as $X_2$ and scaled as distance in kilometers from the Golden Gate Bridge, is a physical attribute of the San Francisco Estuary that is used as a habitat indicator and, by extension, as a regulatory variable. $X_2$ is particularly well-suited to these roles, as it is easily measured, ecologically significant and integrates a variety of important properties and processes. Further, the position of $X_2$ depends primarily upon freshwater inflow, and can be managed by adjusting water project exports (Jassby et al.1995). $X_2$ also approximates the boundary between stratified downstream reaches where density differences drive net upstream flows in the bottom layers, and unstratified upstream reaches where net flow is seaward (Kimmerer and Bennett 2005; Jassby et al. 1995; Arthur and Ball 1979). Thus $X_2$ often occurs near the estuarine turbidity maximum (ETM), where turbidity may be two to forty times greater than in upstream or downstream areas. Particle suspension is related to physical factors such as the riverine sediment load; flocculation, aggregation and settling rates of particles; tidal and wind-induced resuspension; bathymetry; dredging; and seasonal growth of biota. Flow regulation has resulted in an overall decrease in

riverine sediment load, as sediment is lost to upstream reservoirs. The same circulation patterns that drive the accumulation of particles in the low-salinity zone also appear to influence the distribution of organisms from plankton to larval fishes (Cloern et al. 1983; Arthur and Ball 1979). If $X_2$ is located in upstream river channels, phytoplankton may receive too little light to form blooms. Placing $X_2$ in the relatively shallow waters of Suisun Bay at particular times of the year, where phytoplankton growth rates are higher, is intended to maximize productivity and support fish rearing (Cloern et al. 1983; Arthur and Ball 1979).
Whether considered a surrogate variable for freshwater flow or an indicator of habitat conditions, changing the location of $X_2$ changes physical conditions in the upper estuary (Kimmerer 2004). It is well-known that freshwater flow in the estuary is highly variable, both within and among years (Kimmerer 2004; Jassby et al. 1995; Arthur and Ball 1979; others). Even so, the estuary has a strong and relatively consistent response to freshwater flow. Most of the variability is due to precipitation, most of which comes in the winter months, resulting in a pattern of storage in winter-spring and release in summer-fall (Kimmerer 2004). Delta outflow is determined by inflow and water project exports, and $X_2$ is closely and inversely related to Delta outflow, with a time lag of about two weeks (Kimmerer 2004; Monismith et al 2002).

Delta Smelt: The strategic placement of X2 is intended to have two benefits for delta smelt (1) improvement of environmental quality and (2) minimization of entrainment into the SWP and the CVP (Project) export facilities. While reverse flows or OMR are the proximal mechanism of entrainment, X2 is a distal mechanism. For example, if X2 is relatively seaward, then larval and juvenile delta smelt would be expected to be distributed such that they would be less likely to be entrained (Dege and Brown 2004; Kimmerer 2008), but if X2 is upstream, then the distribution of delta smelt is relatively nearer to the export facilities and the risk of entrainment may be greater (Kimmerer 2008). Prior to when adult delta smelt migrate upstream, X2 explains intra-annual salvage patterns, presumably because they have a shorter distance to enter the footprint of the exports once migration occurs (Grimaldo et al. 2009). However, X2 only matters in this case when Old and Middle River flows are negative. Kimmerer and Nobriga (2008) used Particle Model Tracking to show that it only takes a few tidal cycles for particles modeled with surfing behavior to move within the footprint of the exports during high outflow periods. Temperature, turbidity and specific conductance (a surrogate for salinity) have been used as variables to describe favorable environmental conditions in the Delta; as such, they have been shown to be statistically significant predictors of fish occurrence (Feyrer et al. 2007). Long-term trend analysis has shown that environmental quality has declined across a broad geographical range, but most dramatically in the western, eastern and southern regions of the Delta, leaving only a relatively restricted area around the confluence of the Sacramento and San Joaquin Rivers with the least habitat alteration, compared to the rest of the upper estuary. This reduced condition may contribute to the observed decline in delta smelt abundance by shrinking suitable physical habitat and by altering feeding conditions (availability of prey and efficiency of feeding). Improved flow conditions associated with moving $X_2$ westward may maintain the nutrient input that supports primary productivity (Jassby 2008; Cloern 2007) and the turbidity that delta smelt need to successfully forage and, in turn, to elude predators. Recent modeling indicates that the risk of entrainment is related to location and to hydrology (Kimmerer and Nobriga 2008; Culberson et al 2004). In the fall, delta smelt tend to occur in the low-salinity zone or just seaward of $X_2$, and as they mature, move into freshwater to spawn. Moving $X_2$ westward in the fall therefore reduces the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project facilities.

Salinity

An "estuary" is defined as an area of fresh and saltwater mixing. Operations of the state and federal water projects, including reservoir operations and water diversions, likely represent the single largest factor affecting salinity in the Delta (USFWS 2008). While tides, climate and annual hydrologic cycles, are also important, freshwater inflow is the primary determinant of the extent of salt water penetration (Kimmerer 2004). Different life stages of delta smelt, longfin smelt and other species may require different salinity conditions. Salinity may create a barrier to the movement of organisms, including invasive species. Salinity in the Delta is highly variable both within and among years. Prior to the construction of Shasta Dam in 1943, salinity could intrude as far as Stockton on the San Joaquin and Courtland on the Sacramento River. However, since 1943 salinity has rarely intruded past False River on the San Joaquin or Decker Island on the Sacramento River (DWR 1995).

Non native/invasive/exotic species
Feyrer (2004) found that the abundance of native and non-native fish species clustered around gradients of water temperature and river flow; native species were generally associated with the cooler waters and higher flows of the early season, while non-natives were generally associated with the warmer temperatures and lesser flows of the later season. Similarly, Brown and Ford (2002) found that flow regime was an important factor in successful reproduction, and suggested that manipulation of flow could be a powerful tool in managing the fish assemblages of regulated rivers.

ii. Expert testimony: Lenny Grimaldo

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Key points:

1) Old and Middle river (OMR) flow is a hydrodynamic metric that best characterizes SWP and CVP exports affects on entrainment of delta smelt and other pelagic fishes in the estuary.

2) Entrainment and estimated population losses of delta smelt increase as net OMR flows become more negative (i.e., reverse flow).

3) Entrainment affects of the SWP and CVP on delta smelt and other pelagic fishes can be minimized if OMR flows are managed to less negative levels during critical spawning and rearing periods.

Background-OMR flow is a hydrodynamic metric that has been used to determine entrainment affects on delta smelt and other fishes because these daily net flows reasonably measure the pull or "footprint" of the CVP and SWP exports. Old and Middle river flows integrate a complex set of factors, including flows from the large and small tributaries, daily and neap–spring tidal variation, local agricultural diversions, and wind (Arthur et al. 1996; Monsen et al. 2007). When combined exports are greater than San Joaquin river inflow, combined OMR flows move upstream (i.e., negative or reverse) towards the SWP and CVP.
Significance-Recent studies show that entrainment of delta smelt and other pelagic species increases as OMR flows become more negative (Grimaldo et al. 2009; Kimmerer 2008). Kimmerer (2008) calculated that entrainment losses can result in substantial population losses (up to 50 %) in adult and juvenile life stages and that these losses increased as OMR flows became more negative. Because delta smelt are at record-low abundances, minimizing entrainment of delta smelt through management of OMR flows remains a desirable goal of public trust resources consistent with conservation measures detailed in the USFWS Biological Opinion (2008). Here, I discuss how entrainment affects can be minimized for adult and juvenile delta smelt life stages given careful consideration of life history traits that increase or decrease entrainment risks.

Adults: Entrainment of adult delta smelt soon follows the first substantial precipitation event ("first flush") in the estuary as they begin their migration into the tidal freshwater areas of the Delta from the lower estuary (Grimaldo et al. 2009). The mechanisms that trigger migration during these first flush events are unknown; however increased outflow and turbidity are statistical predictors of when smelt will begin their migration upstream. Adult entrainment patterns distinctly unimodal, suggesting that migration behavior is not intermittent or random, but rather a large population-level event. Evidence provided by Grimaldo et al. (2009) suggests that entrainment during these first flush periods could be reduced if export reductions were made at the onset of first flush periods. The USFWS Biological Opinion (2008) identifies turbidity criteria for which to trigger first flush export reductions, but total Delta outflow (> 25,000 cfs) could serve as an alternate or additional trigger since given it is highly correlated with turbidity (Grimaldo et al. 2009). Additional protection for adult smelt can be achieved in the winter period (Dec-Mar) by managing OMR flows to thresholds at which entrainment or population losses increase rapidly. The USFWS Biological Opinion (2008) identified the lower OMR threshold as -5000 cfs based on observed OMR-salvage relationships from a longer data period (see Figure B-13, USFWS 2008) and more data summarized over a more recent period (Grimaldo et al. 2009). The -5000 cfs OMR threshold is appropriate because it is the level where population losses consistently exceed 10 % (see Figure E-4, USFWS 2008). Note, attempts have been made to examine adult delta smelt salvage-OMR relationships at monthly intervals by year, but this method produces a distorted result (i.e., predicts a lower OMR threshold) because it does take into account the variable timing of smelt migration from year to year. Finally, it is important to note that adult delta smelt entrainment varies according to their distribution after their migration upstream. The population is at higher entrainment risk if the majority of the population migrates into the south Delta, which may require OMR flows to be more positive than -5000 cfs to reduce high entrainment. Conversely, if the majority of the population migrates up the lower Sacramento River or north Delta, a smaller entrainment risk is presumed, which would allow for OMR flow to max at the -5000 cfs for an extended period of time or until conditions warrant a more protective OMR flow.

Juveniles: There is no statistically evident relationship between annual salvage of juvenile delta smelt and OMR flow. In part, this is because an unknown number of larval and juvenile can be entrained at the SWP and CVP but go unaccounted since larvae less than 20 mm standard length are not counted at the salvage facilities and because of poor louver efficiency for juvenile life stages. However, Kimmerer (2008) found a relationship between estimated entrainment of larval and juvenile delta smelt and OMR flow by calculating losses due to mortality, louver efficiency, and distribution from the CDFG 20 mm surveys. From these entrainment estimates, population losses accounted for up to 50 % of the total juvenile population. Based on these findings, the USFWS Biological Opinion identified -5000 cfs as the lower threshold for OMR flows based on relationship between entrainment losses plotted by OMR flow (see figure E-7, USFWS 2008). Similar to adults, the lower threshold is more protective when juveniles are distributed in Sacramento river or north Delta, but more positive OMR flows may be necessary when the majority of juveniles are distributed in the interior Delta. During extreme wet years or periods of positive OMR flow, entrainment losses are zero or very small because the centriod of the larval population shifts downstream out of the entrainment footprint of the exports (Dege and Brown 2004). Once physical habitat degrades and smelt grow to sizes that allow them to swim against net current (behaviorally using tides or physically), juvenile smelt will move back downstream to Suisun Bay (Nobriga et al. 2007; Kimmerer 2008). This downstream movement typically begins in May and June, and by July, salvage and entrainment ceases altogether (Kimmerer 2008).

Summary- Old and Middle river flows affect the entrainment dynamics of delta smelt (Kimmerer 2008; Grimaldo et al. 2009). However, entrainment affects can be reduced if OMR flow reductions are timed when delta smelt are in the footprint of the exports. Management of OMR flows for delta smelt will provide benefits (i.e., reduced entrainment risks) for longfin smelt (Grimaldo et al. 2009) and Chinook salmon (NMFS 2008).

### *d. Other Stressors*

i. Expert testimony: Steve Culberson

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Key points:

1) There is a geomorphological context within which any flow must be considered. Restoration of full historical flow patterns will not be fully successful unless the appropriate changes to Delta geomorphology are also concurrently made.
2) Looking at pre-management hydrologic dynamics in controlling ecological processes, species adaptation, and ecosystem function in streams and rivers is useful in guiding current flow criteria.
3) Returning "historical" outflows to the Delta and its tributaries may provide one mechanism for reversing the spread of nuisance submerged aquatic vegetation.
4) If there is any value in letting the historical ecological record speak for itself, the last period of relatively robust annual abundance numbers for several species of concern was the 1970's. Perhaps as a starting point the inflow and export quantities of that period can be used to guide Delta flow criteria.

## Introduction

It is important to recognize and continually acknowledge that description of flows are useful as a simplified, convenient mathematical/physical description of what is otherwise a complex mosaic of bio/physical organism requirements through time – a life-space, if you will. "450 cfs," or "a million acre-feet" is not an adequate characterization of habitat for any organism, and therefore is inadequate for provisioning "how much water fish need." Aquatic habitat can be partially described using flow descriptions, but most of what an aquatic organism actually experiences and lives within is ill-suited to mere velocity, volumetric, or quantitative characterization. Flow descriptions largely serve construction, extraction, and conveyance functions, and do so with fair prediction, accuracy, and adequacy. However, these characterizations are inadequate for describing habitat. For example, imagine describing human living conditions in any given neighborhood using quantification of available oxygen or oxygen concentration – certainly this description might be necessary as part of a description of terrestrial habitat attributes, but it falls short of adequately specifying living conditions for human beings (or any other terrestrial organism).

As an indicator of the status of a river reach, water course, or reservoir capacity, however, humans necessarily resort to flows and capacities in order to inventory what relative or absolute amount of water the storage or conveyance system "contains" at a given moment or season.

To the extent that an upper river reach conveys "a flow," much like a trapezoidal weir, then we might allow ourselves to consider flows as a characteristic of conveyance – useful for providing emigration/immigration pathways for anadromous species, and perhaps considering motive force for movement of various constituents and washing over redds or eggs. But these characteristics are a minor fraction of what aquatic habitat actually "provides" for the "in-residing" aquatic species – particularly within a "landscape" as varied and complex as a tidal estuary. How does a prescribed flow relate (or even co-relate) to warm, quiescent, semi-saline, opaque patch of habitat within which successful foraging, mating, oviposition, or predator avoidance might successfully occur? What portion of food availability, cover, osmoregulation, endocrine detection, and homeostasis does any flow criteria really characterize? Particularly within the Delta, the question should really be posed in non-flow terms: what habitat characteristics do species of concern need within the Delta that influences their near and long-term persistence? Of these, are there any that are "flow-based" (NB: flow-based *does not* mean "flow related"). Remember as well, that the tidal portion of the estuarine aquatic environment is overwhelming by comparison – even in rare, strong wintertime flood events (say 100,000 cfs outflows on the Sacramento River) the tidal flows are five to ten times as large (500,000 cfs or more at Chipps Island). It is wise, too, to remember that estuarine aquatic species are adapted to estuarine aquatic environments – by definition tidal, variable in multiple dimensions and constituents, unpredictable, connected to floodplains, and punctuated by occasional catastrophic droughts and outflows (Healey et al., 2008).

**Aquatic Habitat**

Sufficient thinking on the topic of environmental flows within rivers has led to international attention to this issue and related research (see, for example, Wolanski, 2007). A related recent article on riverine flow is germane enough to quote here extensively (Poff, 2009):

> *In the 1980s, a new way of thinking about environmental sustainability arose. Academic ecologists began to formalize their understanding of how temporal fluctuations in environmental conditions act to rejuvenate and maintain habitat quality and overall ecosystem health. Even for single species, the notion of a specific flow "preference" gave way to the realization that dynamic variation in flow is often needed to ensure the species' long-term health. For example, flushing flows below dams can certainly cause some mortality to fish; however, they also cleanse gravel beds, rejuvenate spawning and foraging habitat, and may reconnect channel to floodplain habitats, all longer-term benefits. This more holistic understanding of ecosystem health established the foundation for a paradigm shift in ecosystem management away from single species with static habitat requirements to whole ecosystems in which the assemblage of species – many having different flow "preferences" – could be sustained by a dynamic flow regime.*
>
> *This new paradigm in river systems was articulated in the principle of the "natural flow regime" (Poff et al. 1997). Basically, this perspective emphasizes the importance of recent historical (pre-management) hydrologic dynamics in controlling ecological processes, species adaptation, and ecosystem function in streams and rivers. The key elements of this concept are that the variation in flows is essential to sustain the ecosystem (and associated biodiversity) and that the pattern of variation typical of any river is defined by the climatic, geologic, and land cover controls on precipitation and runoff. Because these controlling factors vary geographically, natural flow regimes do so as well. An extensive literature has now accumulated to document how alteration of natural flow regimes has greatly modified ecological function and ecosystem state in streams and rivers throughout the world (Bunn and Arthington 2002; Postel and Richter 2003; Poff and Zimmerman 2009).*

And further (Poff, 2009):

> *From a management perspective, the critical question is "how much natural" is enough to attain self-sustaining riverine ecosystems, and can this level be achieved broadly? While scientists have much to offer here in defining the requirements for ecosystem resilience and health, the answers to the question of "how much natural" are ultimately based as much on social preferences as they are on scientific understanding. Society must collectively decide on the desired state of our aquatic and riparian ecosystems and the value of natural biodiversity and natural goods and services these systems provide – scientists can then provide the knowledge and tools to achieve this state (Poff et al. 2003) [emphases added].*

The CALFED Science Program Lead Scientist further articulates many of the more broad scale issues with respect to environmental management and understanding with a *Delta Ecosystem Context Memo* delivered to the Delta Vision Blue Ribbon Panel. The following appears to be of use in this current context (Healey, 2007):

> **Principle 10:** The Delta/estuary is a mosaic of terrestrial and aquatic ecosystems that interact in important ways (e.g., they exchange materials, energy and species). The size, shape, arrangement, and connections among ecosystem patches is critical to the way the Delta/estuary functions. The Delta/estuary itself is an ecosystem patch within the larger ecosystem mosaic of the Central Valley, Sierra and Coastal mountains and the coastal ocean. This concept of ecosystems as a mosaic of patches nested within larger patches has important implications for the way humans manage and interact with the landscape. Human activity changes patch character (marshes are converted to farm land, farm land to urban land), patch size (small farm patches are combined to form large farm patches, urban lands expand, roads and other transportation corridors fragment large patches into smaller patches, etc.), patch connectivity (formerly contiguous patches are separated by a new patch type, formerly isolated patches are

connected, etc.) and physical and chemical dynamics within and between patches (discharge of contaminants, organic and inorganic nutrients, etc.).

> ***Main Policy Implication:*** Management plans and decisions need to be informed by a landscape perspective that recognizes the interrelationship among patterns of land and water use, patch size, location and connectivity, and species success. The landscape perspective needs to be developed at several physical and temporal scales (e.g., patches within the delta, delta within the valley and temporal scales of patch dynamics and evolution). Achieving a sustainable balance of ecosystem services and biodiversity conservation in the Delta is likely to involve allocating considerably more land and water to support natural and semi-natural systems than is presently the norm.

An underlying theme of any discussion regarding Delta flow criteria must be taken in context, for the reasons outlined above. What is also noteworthy is the basic realization that we do not understand Delta ecosystem form and function well enough to provide "assurances" about fixes to what we believe is broken. Reintroducing proper environmental flows will only be one aspect of a Delta solution. Whether fish stocks in the Delta return to their historical abundances will depend on myriad ecosystem elements and their interactions, over most of which water resource managers have limited or no control.

## Other Stressors

The Interagency Ecological Program Pelagic Organism Decline Management Team (IEP POD MT) has published a conceptual model that includes several categories of "stressors" that affect Delta pelagic organism abundance, including physical and chemical habitat (Sommer et al., 2007). The model includes "top-down," "bottom-up," and "habitat" categories of stressors contributing to detected abundance, acknowledging that some of these factors are linked to outflow in some way in some seasons or years. The emphasis, however, is upon the multiplicity of factors and interactions that affect fish abundance and mortality. While there is evidence of one or few factors playing an inordinately strong role in one given season or year or few years, the IEP POD MT would be quick to point out that no single factors or set of factors has been shown to be "the cause" of any decline throughout the history of estuarine pelagic organism monitoring (roughly 1970 to date) – nor, in fact, in a complex environment like the San Francisco Estuary would this be expected to be the case. Over the course of the monitoring program, however, there has been a distinct trend toward larger and larger volumes of water export from the system, from less than $200m^3/s$ before 1970 to more than $900m^3/s$ in the mid 2000s (Sommer et al., 2007). As explained, this systemic change may have multiple causative actions across one or more stressor categories, even where demonstration of exact causal chains is lacking (see also Feyrer et al., 2007; Nobriga et al., 2008; and Grimaldo, et al., 2009).

As an example of a system-wide impact of increasing exports/decreasing outflows one can consider the establishment and increasing spread of submerged aquatic vegetation (SAV) within the Delta. SAV typically establishes and spreads in areas of reduced water velocities; conversely, where there is sufficient flow (volume and velocity), this vegetation is largely absent. IEP POD and related research and monitoring has identified the spread of SAV as having several potential impacts within the Estuary – SAV introduces habitat for "lurk and wait" predators (Brown and Michniuk, 2007); SAV has been shown to cause local and regional declines in water column suspended sediment concentration by increasing local sedimentation rates (Findlay et al., 2006); SAV can clog local sloughs and bays, reducing access for recreational boating and increasing the need for applications of aquatic herbicides (CA Department of Boating and Waterways, 2010). Returning "historical" outflows to the Delta and its tributaries may provide one mechanism for reversing the spread of nuisance submerged aquatic vegetation.

A particular emphasis on the importance of landforms and geomorphology by Atwater and colleagues (Atwater et al., 1979) has led to a growing understanding that the hydrogeomorphology of the Delta and Estuary play an important role in transforming available flow into a mosaic of habitats and alternative hydraulic residences, many of which are conceptually linked to critical habitat of species of concern (Enright and Burau, personal communication; Feyrer et al., in press; Nobriga at al., 2005; Bunn and Arthington, 2002; Atwater et al., 1979). It is quite likely that recent management activities in the Delta (1850-present) has led to a "short-circuiting" of tidal and residual flow patterns among and between tidal habitats and sloughs in the Estuary, with concomitant impacts on habitat variability and refuge space for native Delta organisms. The growing consensus is that management in the Delta has led to a homogenization of available aquatic habitat and the reduction in variability thought to be important to resident native species (Moyle et al., in preparation; Poff, 2009; Healey et al., 2008; Cloern, 2007).

Delta hydrologic geometry now contains a fraction of the complexity and distribution of what it was during the evolution and historic periods of abundance of species like Delta smelt (Atwater et al., 1979; Enright and Burau, personal communication; Figure 1.). As a consequence of this geomorphologic simplification, flow "reestablishment" will be part of a solution for increasing smelt habitat availability but will be *insufficient in and of itself.* Some stakeholders may argue that recent increases to "environmental flows," however unspecified, have not led to increases in Delta smelt abundance – but this is not sufficient evidence to conclude therefore that increased flows are not necessary for smelt recovery – only that they are not going to be effective when removed from their environmental, ecological, and evolutionary contexts (Moyle et al., in preparation). This is why any potential flow criteria must be made conditional upon appropriate concurrent habitat conservation and restoration requirements. Either without the other would not be expected to yield improvements in native species habitats or recovery.

### Flows as Indexed Using x2

Several authors have explored the effect on fish abundance of flows into the Estuary as indexed by X2 (Grimaldo et al., 2009; Nobriga et al., 2008; Kimmerer et al., 2008; Feyrer et al., 2007; Nobriga et al., 2005; Kimmerer, 2002). By definition X2 does not account for variable sources of Delta inflow which may affect various fishes or life stages differentially and through multiple mechanisms (San Joaquin River contaminant loads, for example). The search for explicit mechanism of causality between flow and abundance continues, but candidates have included increasing habitat, nutrient additions, dilution of contaminants, variable salinity field location, reduced temperature, and increased turbidity. In all likelihood flows equate to changes in several (various) ecological attributes, particularly when considered across different years and variable underlying hydrologic conditions (drought-clustered years, or wetter years, for example). X2 may also be indexing a particularly nutrient- or food-rich area of the Estuary where a relative majority of fish are found at certain times of year.

In overview it is reasonable to conclude that: 1) X2 locations reflective of historical outflow periods (1970s) when estuarine resources were at higher abundances than during the POD years (2000-present) would be expected *ceteris paribus* to result in greater abundance of estuarine fishes *provided that* other ecological functions and habitats could be returned to the Estuary concurrently; 2) location of X2 has been useful for identifying past regions of productivity/mixing/abundance but not for establishing a mechanistic relation explicitly linking flows to abundance (i.e. X2 location does not equal fish abundance, though it may have been correlated historically); 3) location of X2 may be *necessary* for specifying minimum riverine outflow, but has not been shown to be sufficient for species persistence, and; 4) X2 bears a logical relationship to changes in physical habitat space within the Estuary (Suisun Bay versus the confluence area, for example), but it has been difficult to prove much mechanistic causation leading directly or indirectly to aquatic organism abundance. It must be said, that failure to find such linkages (or failure to adequately search for them) does not mean that such links do not exist.

Kimmerer (2002 – Table 1) provides a detailed assessment of how changes in freshwater flow might be expected (or have been shown) to affect the biota of the Estuary. As a geomorphologist, I would also argue that much can be modified with concurrent reestablishment of historic channel network geometry that, via conceptual models, will lead to benefits for Delta resident species. In terms of evaluating the effectiveness of such manipulations, however, I would offer that we will fall far short of our "adaptive management" ambitions unless we make a commitment to process-based ecosystem science, experimentation, analysis, and integration.

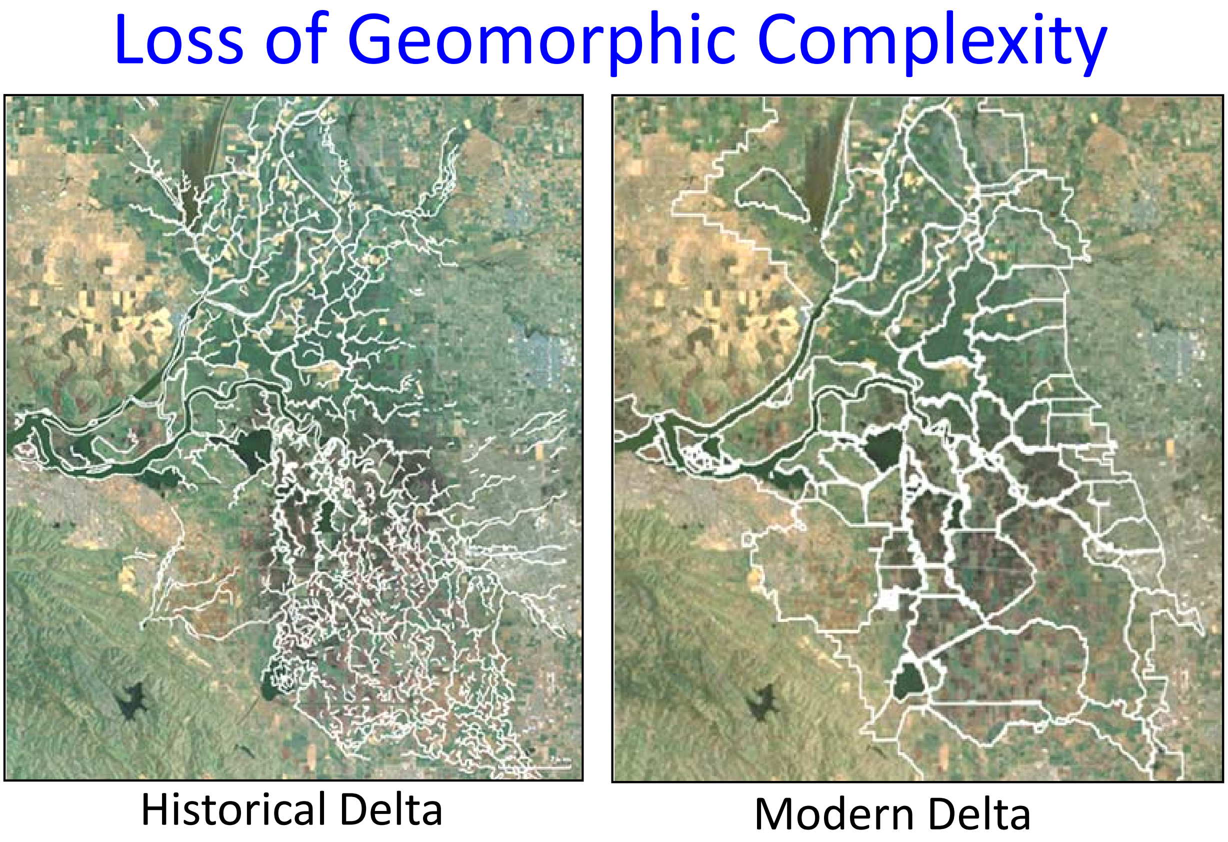

Figure 18. Comparison of Historical and Modern Delta channel networks (Enright, after Atwater).

ii. Expert testimony: James Haas

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Key Points:

- Years of research have generated a large database of contaminants and contaminant effects in the Delta
- The data have not been integrated into a model of contaminant fate and effects that informs decision-making
- Existing models and monitoring programs should be evaluated and coordinated to maximize benefits to managers

Although much work has been done on contaminant fate and effects in the San Francisco Bay-Delta and its major tributaries, the volume of material has not been integrated in a way that readily informs management actions. Werner *et al*. (2008) presented a conceptual model for evaluating pesticide effects on aquatic organisms in the delta; this document potentially provides framework for developing a more comprehensive model of contaminant fate and effects to include inputs from the major tributaries. The Sacramento River Watershed Program (2008), for example, implemented a multi-year monitoring program that evaluated flow, precipitation, land use, chemical use, water physiochemical parameters, toxicity testing, and fish bioaccumulation. Such programs conducted concurrently in each of the major tributaries could provide inputs to an integrated fate and effects model for the delta.

From a human health and ecological perspective, it would not be necessary to analyze for every constituent. A monitoring program could focus on specifically on mercury, nutrients and ammonia, herbicides and pesticides used in large quantities, selenium, urban runoff, and legacy organochlorines such as DDT and PCBs that are still a concern from a fish-consumption perspective.

Along with the elements discussed in SRWP (2008), which included standardized locations and methods, site-specific fish and invertebrate population status and community indices should be added; over time it might be possible to parameterize the conceptual model to incorporate empirical data from the major tributaries and evaluate likely responses of aquatic biota in the delta to changes in contaminant exposure from manipulating other components of the system. While such an approach would be expensive and time consuming, it has potentially significant benefits from an adaptive management perspective.

## III. Summary of Delta flow criteria and biological objectives: Expert testimony: Roger Guinee

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### a. Delta outflow

Key Points:

1. Fish abundance is higher when suitable habitat is available, suitable habitat is related to X2 among other variables, and native fish have declined as habitat suitability has declined.

2. Inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration of Delta fish.

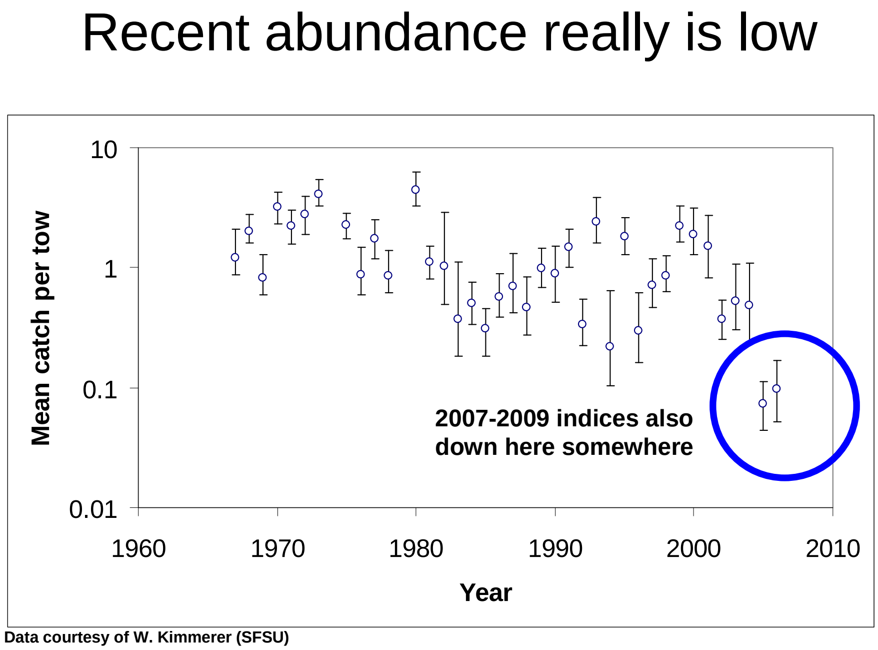
3. When X2 is in the relatively shallow waters of Suisun Bay at particular times of the year, phytoplankton growth rates are higher, productivity is maximized, and fish rearing is supported. Having X2 further westward also may reduce the potential entrainment of estuarine species into the State and Federal export facilities.

4. Moving X2 westward in the fall increases the quality and quantity of habitat for smelt.

5. The most recent period of relatively robust annual abundance numbers for several species of concern should be used to guide the development of Delta flow criteria needed to protect the public trust resources.

6. Restoration of full historical flow patterns will not be fully successful unless the appropriate changes to Delta geomorphology are also concurrently made.

The scientific information that we reviewed indicates that generally fish abundance is higher when suitable habitat is available, and suitable habitat is related to X2 among other variables. The Delta native fish have declined as habitat suitability has declined. Delta flow is a component of habitat suitability, as well as sediment concentration, food supply, and acreage of open-water and hydraulically connected land-water interface.



Recent abundance really is low

2007-2009 indices also down here somewhere

Data courtesy of W. Kimmerer (SFSU)

Figure 19. From presentation to Nat. Acad. of Sciences (Herbold, B. and M. Nobriga, January, 2010)

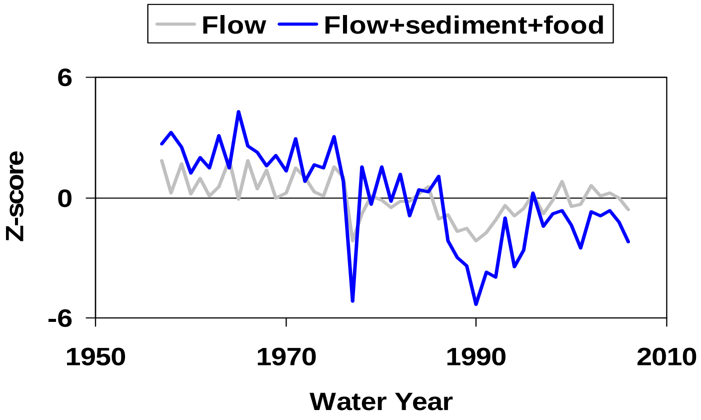


Figure 20. The composite Z score shows habitat has declined. From presentation to Nat. Acad. of Sciences (Herbold, B. and M. Nobriga, January, 2010)

Inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration of Delta fish. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components (USFWS 2008).

Delta smelt critical habitat consists of four primary constituent elements: physical habitat, water, river flow and salinity. Flow is a constituent of each of these, as it influences spawning substrate, water quality (including temperature, turbidity and food availability), transport (both up and down the Estuary, and including entrainment in water diversions), and the location of the low-salinity zone (LSZ) indexed by the two-parts-per-thousand salinity isohaline, or "X2". Flow must be sufficient to keep spawning substrates clear of sediment and prevent colonization by submerged aquatic vegetation. Flow must be sufficient to provide appropriate temperatures for various life stages, turbidity for cover and feeding, and to dilute contaminants. Flows must be sufficient to facilitate the migration of adults and juveniles and avoid entrainment into water diversions. Past observations indicate that adult delta smelt begin moving up the Estuary to their presumed spawning areas when winter flows on the Sacramento River exceed about 25,000 cfs (DSWG 2006).

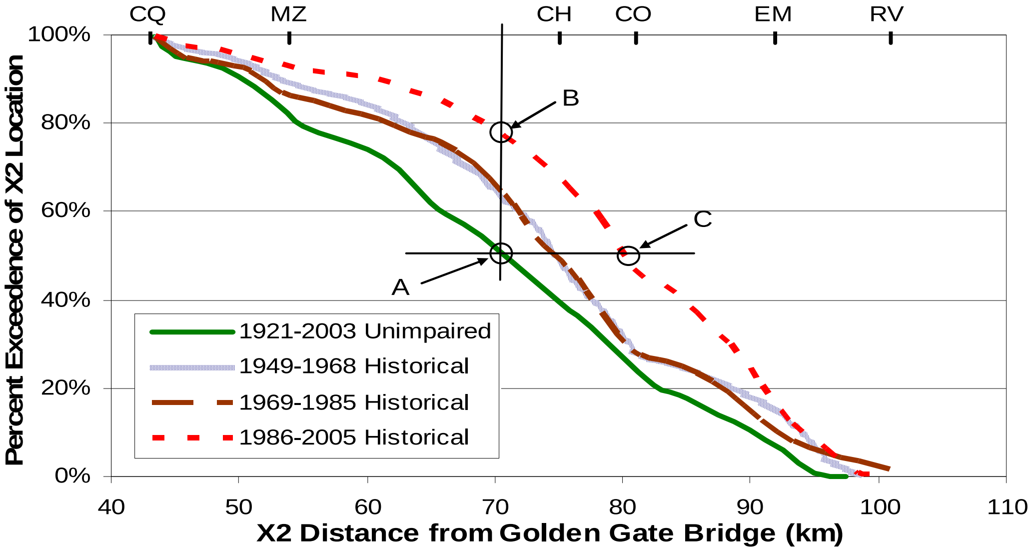


Figure 21. Cumulative probability distributions of daily X2 locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line), illustrating progressive reduction in salinity variability from unimpaired conditions. X2 is the location of the 2 ppt salinity region of the estuary in kilometers from the Golden Gate Bridge. Paired letters indicate geographical landmarks. CQ, Carquinez Bridge; MZ, Martinez Bridge; CH, Chipps Island; CO, Collinsville; EM, Emmaton; and RV, Rio Vista. From Fleenor et al. (2010).

The LSZ is where fresh water transitions into brackish water, and is an indicator of habitat suitability for many organisms in the San Francisco Estuary (Jassby, et al., 1995). The LSZ expands and moves downstream when river flows are high, and contracts and moves upstream when river flows are low. The location of X2, scaled as distance in kilometers from the Golden Gate Bridge, is a physical attribute of the Bay-Delta Estuary that is used as a habitat indicator. X2 is easily measured, ecologically significant and integrates a variety of important properties and processes. Further, the position of X2 depends primarily upon freshwater inflow, and can be managed by adjusting water project exports (Jassby, et al. 1995).

Placing X2 in the relatively shallow waters of Suisun Bay at particular times of the year, where phytoplankton growth rates are higher, is intended to maximize productivity and support fish rearing (Cloern, et al. 1983; Arthur and Ball, 1979). Whether considered a surrogate variable for freshwater flow or an indicator of habitat conditions, changing the location of X2 changes physical condtions in the upper estuary (Kimmerer, 2004). Delta outflow is determined by inflow and water project exports, and X2 is closely and inversely related to Delta outflow (Kimmerer 2004; Monismith, et al. 2002).

The strategic placement of X2 is intended to have two benefits for delta smelt (1) improvement of environmental quality and (2) minimization of entrainment into the SWP and the CVP (Project) export facilities. While reverse flows or OMR are the proximal mechanism of entrainment, X2 is a distal mechanism. For example, if X2 is relatively seaward, then larval and juvenile delta smelt would be expected to be distributed such that they would be less likely to be entrained (Dege and Brown 2004; Kimmerer 2008), but if X2 is upstream, then the distribution of delta smelt is relatively nearer to the export facilities and the risk of entrainment may be greater (Kimmerer 2008). Prior to when adult delta smelt migrate upstream, X2 explains intra-annual salvage patterns, presumably because they have a shorter distance to enter the footprint of the exports once migration occurs (Grimaldo et al. 2009). However, X2 only matters in this case when Old and Middle River flows are negative. Kimmerer and Nobriga (2008) used Particle Model Tracking to show that it

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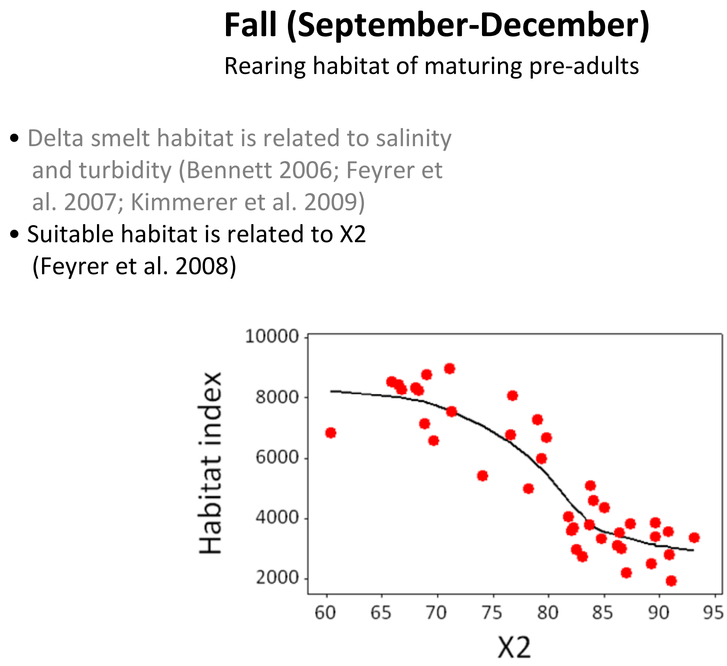
only takes a few tidal cycles for particles modeled with surfing behavior to move within the footprint of the exports during high outflow periods. (Bennett 2006; Feyrer, et al. 2007; Kimmerer, et al. 2009).



**Fall (September-December)**

Rearing habitat of maturing pre-adults

- Delta smelt habitat is related to salinity and turbidity (Bennett 2006; Feyrer et al. 2007; Kimmerer et al. 2009)
- Suitable habitat is related to X2 (Feyrer et al. 2008)

Figure 22. From OCAP Technical Support Team Presentation to Nat. Acad. of Sciences (F. Feyrer, January, 2010)

In the fall, delta smelt tend to occur in the low-salinity zone or just seaward of X2, and as they mature, move into freshwater to spawn. Moving X2 westward in the fall increases the quality and quantity of habitat for smelt and may reduce the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities. The effects of modeled CVP/SWP operations (USFWS 2008) have indicated that X2 shifts upstream, resulting in reduced habitat space and loss of variability in September through December.

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## Fall (September-December)

Rearing habitat of maturing pre-adults

- Effects of modeled CVP/SWP operations (FWS 2008):
  - A) X2 shift upstream
  - B) Habitat space reduced

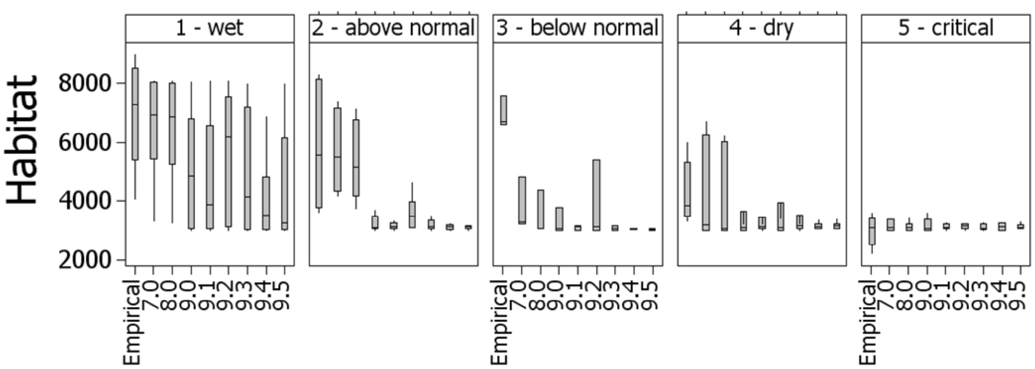


Figure 23. From OCAP Technical Support Team Presentation to Nat. Acad. of Sciences (F. Feyrer, January, 2010)

Over the long-term, the amount of suitable abiotic habitat for delta smelt during fall has decreased anywhere from 28 percent to 78 percent, depending on the specific habitat definitions that are considered (Feyrer et al. 2008). Operations of the State and Federal water projects, including reservoir operations and water diversions, likely represent the single largest factor affecting salinity in the Delta (USFWS 2008). While tides, climate and annual hydrologic cycles, are also important, freshwater inflow is the primary determinant of the extent of salt water penetration (Kimmerer 2004). Different life stages of delta smelt, longfin smelt and other species may require different salinity conditions.

The average X2 during fall has exhibited a long-term increasing trend (movement further upstream), which has resulted in a corresponding reduction in the amount and location of suitable abiotic habitat. X2 postion (Fig 11) during fall in the years following the Pelagic Organism Decline (POD) (2000-2005) was several kilometers upstream compared to that for the pre-POD years (1995-1999). This suggests that operations in the Delta have exported more water relative to inflow, which has had a negative effect on X2 by moving it upstream.

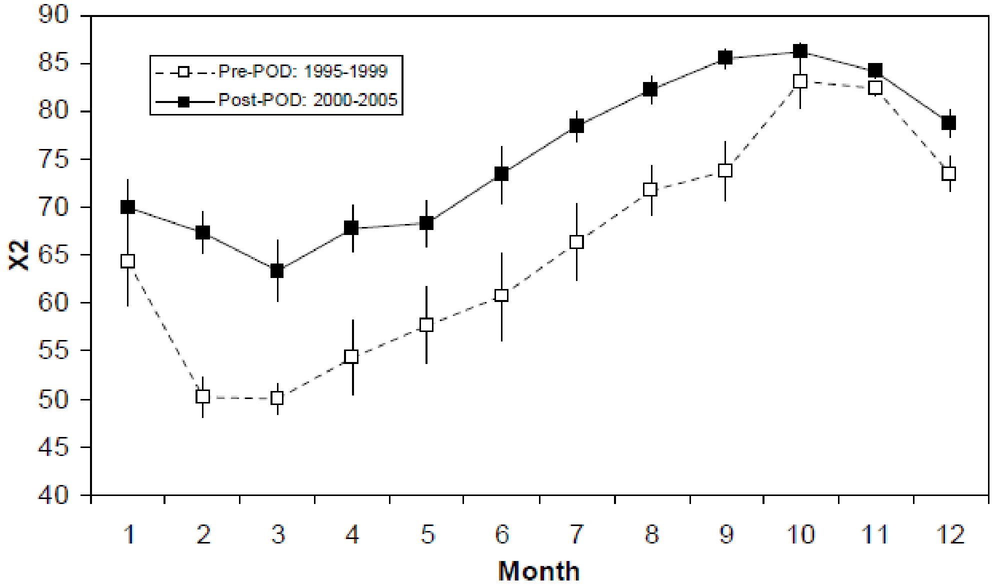


Figure 24. X2 in years preceding and immediately following the Pelagic Organism Decline. From USFWS (2008).

In summary, the scientific information that we reviewed indicates that generally fish abundance is higher when suitable habitat is available, suitable habitat is related to X2 among other variables, and native fish have declined as habitat suitability has declined. It's important that inflow to the Delta and outflow to the Bay must be sufficient to support successful spawning, larval and juvenile transport, rearing, and adult migration of Delta fish. Placing X2 in the relatively shallow waters of Suisun Bay at particular times of the year, where phytoplankton growth rates are higher, is intended to maximize productivity, support fish rearing, and may reduce the potential entrainment of estuarine species into the State and Federal export facilities. Moving X2 westward in the fall increases the quality and quantity of habitat for smelt and may reduce the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities.

Consequently, to protect the public trust resources in the Delta, Delta flow criteria are needed that provide increased freshwater flows passing through the Delta to improve in-Delta habitat, provide transport and attractant flows for anadromous and native fishes, and produce outflows that mix with saltwater and provide suitable rearing habitat in Suisun Bay. Increased Delta inflows are needed to improve the quality and availability of habitat within the Delta. It's important to provide transport inflows and outflows for larval and juvenile dispersal from the Sacramento River as well as the San Joaquin River. Historically, storm events and run-off from snowmelt provided transport flows that moved larval and juvenile fish to downstream rearing areas and outmigrating anadromous fish to the ocean. Increased Delta outflows also improve the quality and availability of habitat within Suisun Bay (The Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes,1996).

The most recent period of relatively robust annual abundance numbers for several species of concern was the 1970's. As a starting point the inflow and export quantities of that period is useful to guide the development of Delta flow criteria needed to protect the public trust resources. The period of 1969 – 1985, in Figures 1, 2, 4 below and Figure 9 above, represents the hydrologic conditions (Delta inflow, Delta outflow, etc.) during this period of relatively robust annual abundance numbers for several species of concern. Historical flows under which native fish were more successful should have greater relevance for establishing fish flows for the current highly altered Delta (Fleenor, et al 2010). In the absence of more direct causal relationships, empirical evidence should be used until more specific processes can be quantified. Flow prescriptions for the future will need to respond to further changes in the Delta's biological composition (Fleenor, et al 2010).

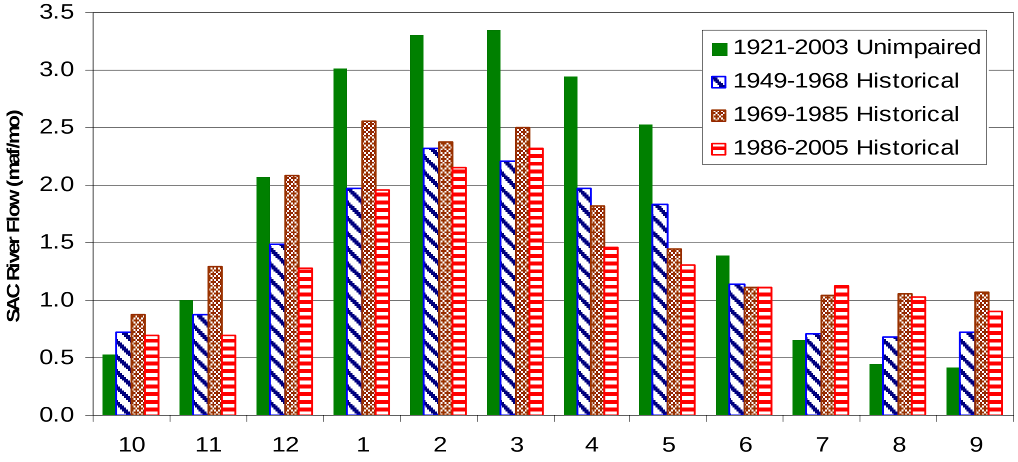


Figure 25. Changes over time to monthly average Sacramento Valley outflows (maf/mo) compared to the unimpaired record. Fleenor et al., 2010.

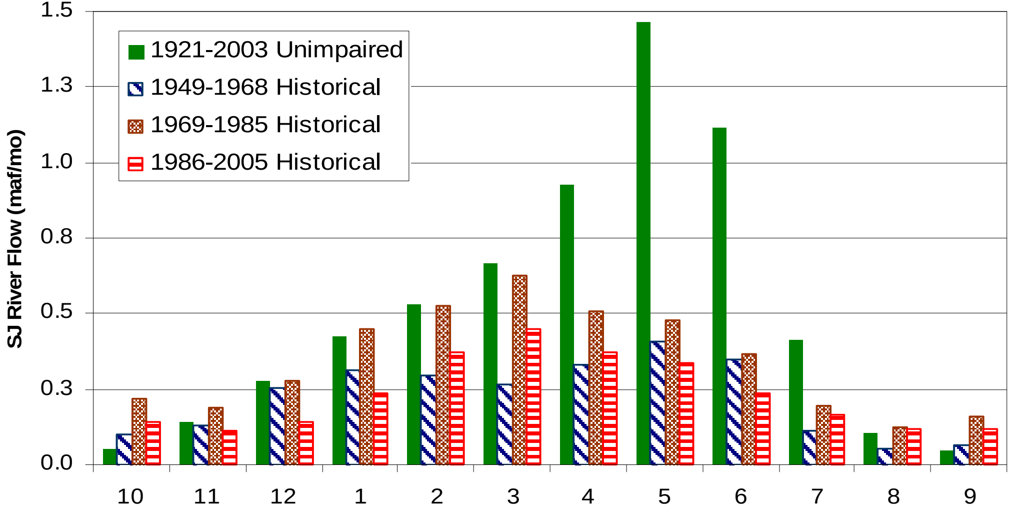


Figure 26. Changes over time to monthly average San Joaquin Valley outflows (maf/mo) compared to the unimpaired record. Fleenor et al., 2010.

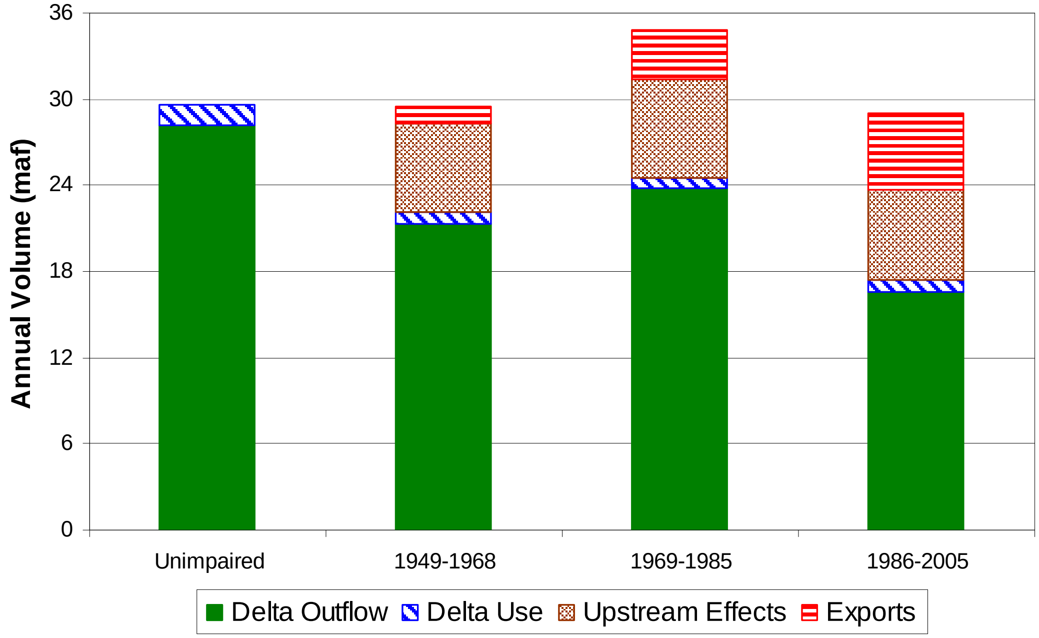


Figure 27. Comparison of annual water use during the three study periods (maf/year) compared to the Unimpaired flows from 1921-2003. Unimpaired data from DWR (2007) and other from Dayflow web site (Neglects upstream groundwater withdrawals). Fleenor et al., 2010.

Finally, there is a geomorphological context within which any flow must be considered. Restoration of full historical flow patterns will not be fully successful unless the appropriate changes to Delta geomorphology are also concurrently made. Reintroducing environmental flows needed for public trust resources will be one important aspect of a healthy Delta ecosystem. There are several categories of "stressors" that affect Delta pelagic organism abundance, including physical and chemical habitat, that must also be addressed.

### b. Reverse flow

Key Points:

1. There is an inverse relationship between net Old and Middle rivers flow and winter salvage of delta smelt and other pelagic fishes at the SWP and CVP.

2. In trying to evaluate the mechanism(s) for increased winter-time salvage of four primary fishes, the key observations in the pelagic organism decline (POD) studies led to a hypothesis that the hydrodynamic change in the Delta could be indexed using net flows through Old and Middle rivers.

3. Juvenile salmonids are also impacted by reverse flows in the Delta, so in 1995 USFWS identified the importance of maintaining positive QWEST flows,

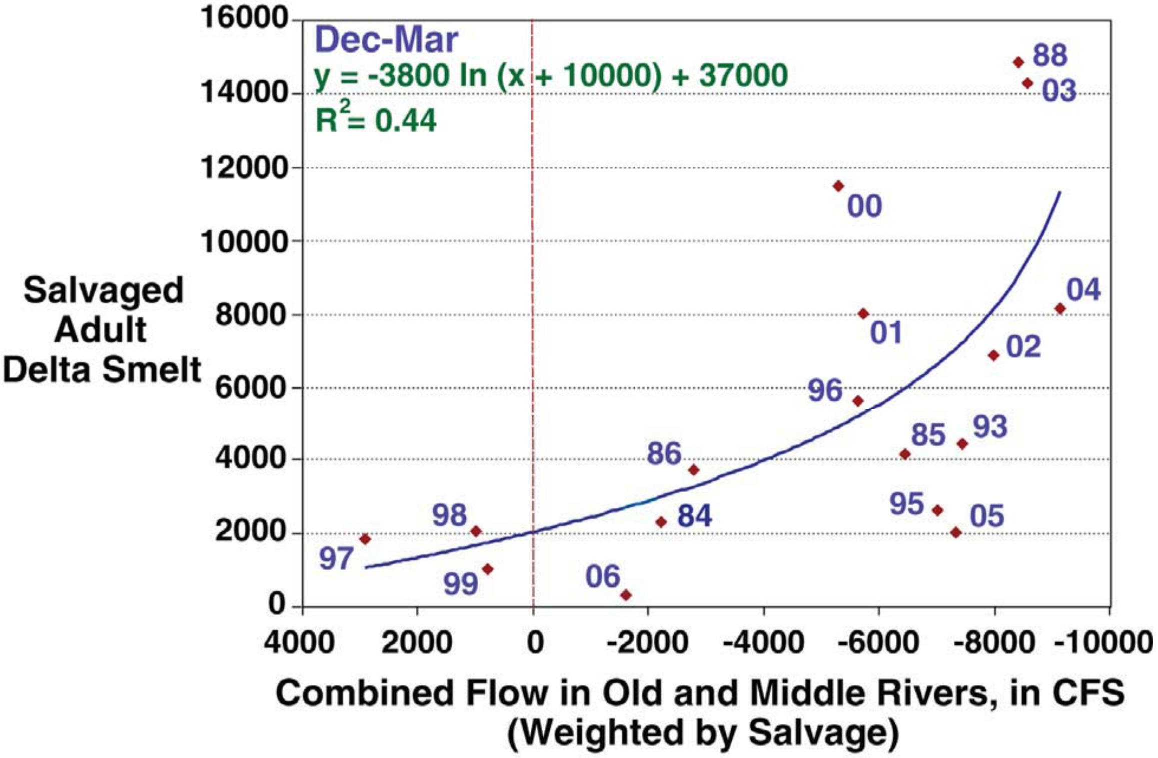
4. In 1992 the Board acknowledged the importance of maintaining positive QWEST flows, in order to protect and stop the decline of the public trust resources in the Delta.

5. It's important that the Board consider developing reverse flow criteria that would maintain the Old and Middle river flow positive during key months (January through June) of the year to protect important public trust resources in the Delta.

There is an inverse relationship between net Old and Middle rivers (OMR) flow and winter salvage of delta smelt and other pelagic fishes at the SWP and CVP. In general, negative OMR is associated with some degree of entrainment, while positive OMR is usually associated with no, or very low, entrainment. Changes to delta smelt larval and juvenile transport attributable to the SWP and CVP include water diversions that create net reverse flows in the Delta that entrain delta smelt.

In trying to evaluate the mechanism(s) for increased winter-time salvage of four primary fishes, including delta smelt, pelagic organism decline (POD) studies by USGS made three key observations (IEP 2005). First, there was an increase in exports during winter as compared to previous years (Figure 16 in POD Report, 20007). Second, the San Joaquin River inflow decreased as a fraction of total inflow around 2000, while Sacramento River increased (Figure 17 in POD Report, 2007). Finally, there was an increase in the duration of the operation of barriers placed into south Delta channels during some months. These changes may have contributed to a shift in Delta hydrodynamics that increased fish entrainment (POD Report 2007).

These observations led to a hypothesis that the hydrodynamic change could be indexed using net flows through Old and Middle rivers, which integrate changes in inflow, exports, and barrier operations (Arthur, et al. 1996; Monsen et al. 2007). An initial analysis revealed that there was a significant inverse relationship between net Old and Middle rivers flow and winter salvage of delta smelt at the SWP and CVP (P. Smith, unpublished) (POD Report 2007).



Note: Data shown are for the period 1984-2007, excluding years 1987, 1989-92, 1994, and 2007 that had low (<12ntu) average water turbidity during Jan-Feb at Clifton Court Forebay.

Figure 28 – Relationship for the total number of adult delta smelt salvaged at the State and Federal fish facilities in the south Delta during the winter months of December through March with the combined, tidally averaged flow in Old and Middle Rivers near Bacon Island (*AVG_OMR).*

These analyses were subsequently updated and extended to other pelagic fishes (L. Grimaldo, in preparation) (POD Report 2007). The general pattern is that POD species salvage is low when Old and Middle river flow are positive (POD Report 2007). Winter (Dec – Mar) salvage patterns of migratory and spawning adult delta smelt reflect Old and Middle River flow (Kimmerer 2008; Grimaldo, et al. 2009)

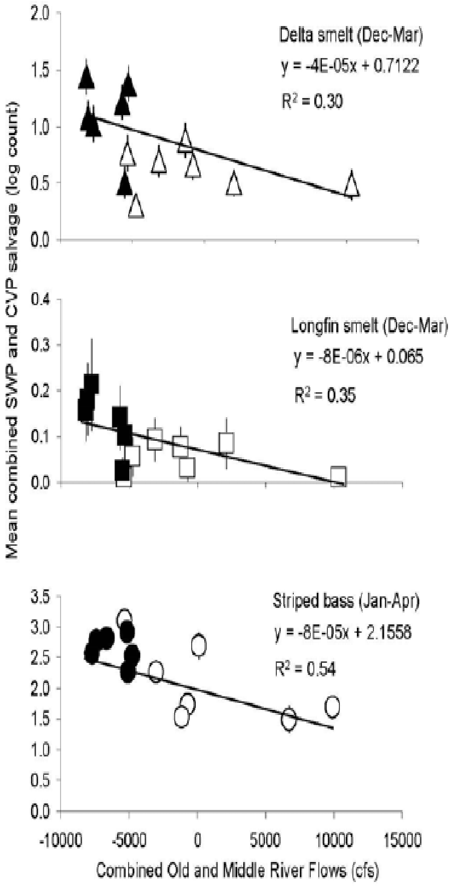


Figure 29. Relationship of mean combined salvage of delta smelt, longfin smelt, and striped bass at the State Water Project (SWP) and Central Valley Project (CVP) to combined Old and Middle rivers flow (cubic feet per second). Open symbols denote pre-POD years (1993-1999) and fille symbols represent post-POD years (2000-2005)(Grimaldo et al. In prep.)

In a recent draft report, model results were compiled to show the frequency of summed flows in Old and Middle Rivers (OMR), showing the effects of through-Delta pumping for three impaired periods compared to unimpaired results (Fleenor, et al. 2010, Fig 9).

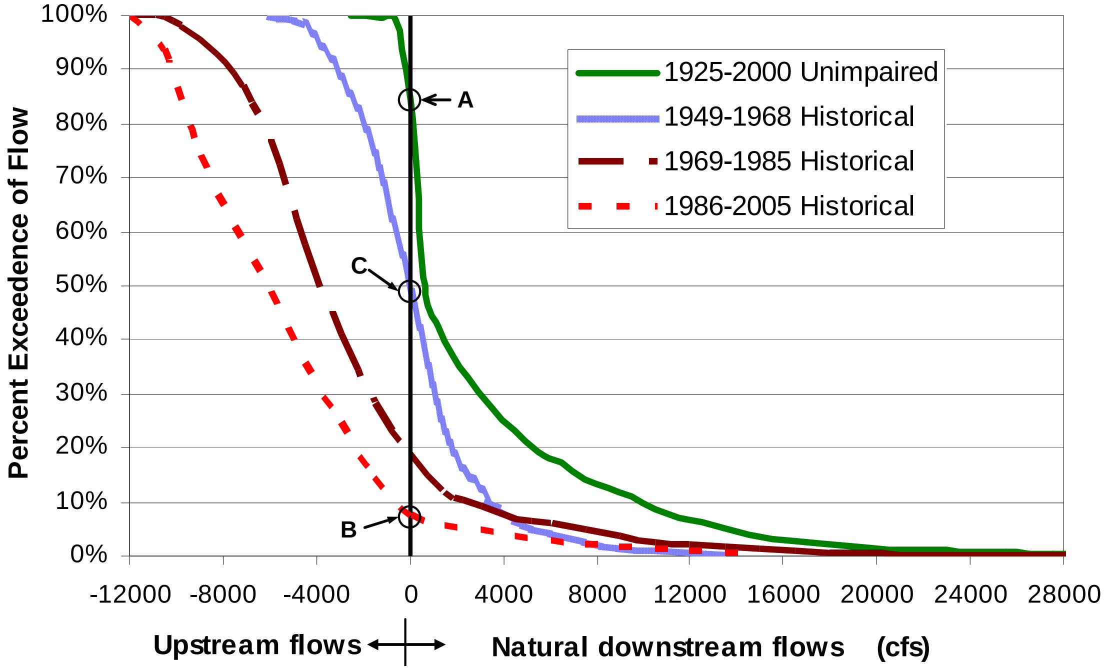


Figure 30. Middle and Old River frequency effects from pumping through the Delta (cfs) locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line).

The graph indicates that OMR flows were positive less than 10% of the time during the 1986 – 2005 period compared to being positive at least 85% of the time in the 1925 – 2000 unimpaired period. During the 1969 – 1985 period, the OMR flows were positive approximately 20% of the time, and during the 1949 – 1968 period, the OMR flows were positive approximately 50% of the time.

During the development of the USFWS "Anadromous Fish Restoration Plan," the Delta was identified as the watershed of highest priority for restoration and doubling of anadromous fish populations, because it is highly degraded, many anadromous fish rear in the Delta, and all anadromous fish in the Central Valley must pass through it as both juveniles and adults (AFRP Final Restoration Plan, 1995, page 17 ). One of the key limiting factors for Chinook salmon and steelhead that the AFRP identified was relatively high juvenile mortality in the central and south Delta, presumably resulting from the inability of juveniles to "find" their way to the ocean as a result of net reverse flows and complex channel configuration, among other things. (AFRP Working Paper, 1995, page 3-Xe-7). To address the biological objective of increased survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (October – December), the AFRP identified the importance of maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, from October 1 through June 30 of all years (AFRP Working Paper, 1995, page 3-Xe-19).

In 1992 the Board acknowledged the importance of maintaining positive QWEST flows, in order to protect and stop the decline of the public trust resources in the Delta (BOARD, Draft Water Right Decision 1630, 1992, pages 44-45). The Board (page 31) agreed that "net reverse flows caused by export pumping are adverse to fishery resources because they pull water and young fish of various species from the western Delta into the central Delta", and cited several exhibits, including WRINT-USFWS – 8, WRINT – USFWS – 11 and WRINT - USFWS – 7. Furthermore, the Board (page 41-42) indicated that "reverse flows should not occur in the San Joaquin and Sacramento Rivers during the delta smelt spawning period in order to transport the larvae to appropriate habitat and to keep them there" citing WRINT-USFWS-19. Consequently, Draft D-1630, included a new standard (requirement) that "there shall be no reverse flow for all year types on a 14-day running average in the western Delta… between February 1 and June 30." (SWRCB, Draft Water Right Decision 1630, 1992, pages 46 - 47).

In summary, there is an inverse relationship between net Old and Middle rivers flow and winter salvage of delta smelt and other pelagic fishes at the SWP and CVP. In trying to evaluate the mechanism(s) for increased winter-time salvage of four primary fishes, the key observations in the pelagic organism decline (POD) studies led to a hypothesis that the hydrodynamic change in the Delta could be indexed using net flows through Old and Middle rivers. Juvenile salmonids are also impacted by reverse flows in the Delta, so in 1995 the USFWS "Anadromous Fish Restoration Plan" identified the importance of maintaining positive QWEST flows. In 1992 the Board acknowledged the importance of maintaining positive QWEST flows, in order to protect and stop the decline of the public trust resources in the Delta. Based on the scientific information we reviewed, the Board should develop reverse flow criteria that would maintain the Old and Middle river flow positive during key months (January through June) of the year to protect important public trust resources in the Delta.

### c. Floodplain inundation/bypass flow

Key Points:

1. Seasonal floodplain inundation has a positive effect on growth rates and on the apparent survival of juvenile Chinook salmon in the Central Valley.

2. Successful spawning and recruitment of splittail is highly dependent upon the availability of floodplain habitat for spawning and rearing.

3. The scientific information indicates that frequent floodplain inundation (especially Yolo Bypass flows) will provide benefits to numerous native species with respect to abundance and growth rates.

Seasonal floodplain inundation has a positive effect on growth rates and on the apparent survival of juvenile Chinook salmon in the Central Valley. The restoration of floodplains and other off channel habitat is potentially important for increasing production of juvenile salmonids in California's Central Valley. The biological objectives of seasonal floodplain inundation would be to provide off channel areas conducive to juvenile salmonid rearing and growth, which should improve survival through the Delta and to the ocean. Also, successful spawning and recruitment of splittail is highly dependent upon the availability of floodplain habitat for spawning and rearing (Feyrer, et al. 2006; Moyle, et al. 2004).

The scientific information indicates that frequent floodplain inundation (especially Yolo Bypass flows) will provide benefits to numerous native species with respect to abundance and growth rates. Efforts to increase floodplain inundation through weir modification and increased outflows will provide benefits consistent with protecting public trust resources in the Delta. The Yolo Bypass floods via the Fremont Weir when flows on the Sacramento River exceed approximately 70,000 cfs, which it currently does in about 60% of years (Feyrer, et al. 2006). Flows on the Sacramento River should therefore exceed 70,000 cfs in at least six out of ten years. Recent historical floodplain inundation events are shown in Figure 4 (Sommer et al., 2001).

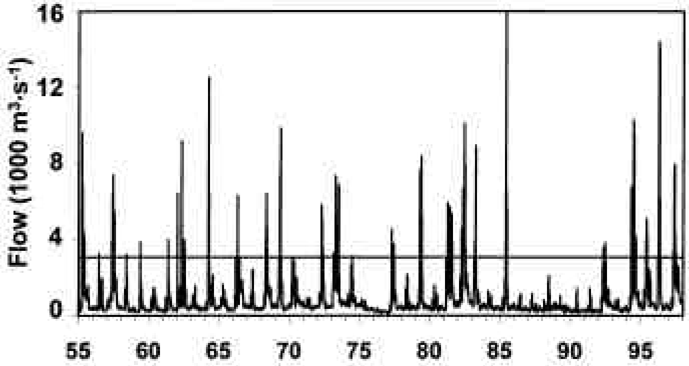


**Figure 31.** Total daily Sacramento Basin flow (m$_3$/s) during 1956–1998. The horizontal line at 3,100 m$_3$/s indicates The channel design capacity of the Sacramento River below Sacramento.

### d. Delta inflow

Key Points:

1. The timing of high freshwater inflow is an important cue for migration of: adults upstream to spawning grounds and juveniles downstream to feeding and rearing grounds.

2. Juvenile fall run Chinook salmon survival increases with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs

3. Survival through the Delta for juvenile fall run Chinook salmon originating from the San Joaquin basin has increases with increased Delta inflows at Vernalis.

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4. USFWS developed estimates of flow levels needed at Vernalis to achieve doubling (USFWS, 2005, pages 9 and 10) in predicted Chinook salmon production for the basin, and help protect public trust resources in the Delta.

5. The Board should adopt biological goals of doubling smolt survival through the Delta from what it was from 1967-1991 for consistency with the goals of the Central Valley Project Improvement Act.

6. Providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the magnitude and timing of flow needed for the Delta ecosystem.

Past observations indicate that adult delta smelt begin moving up the Estuary to their presumed spawning areas when winter flows on the Sacramento River exceed about 25,000 cfs. Freshwater flow is also an important cue for upstream migration of adult salmonids to their spawning grounds.

Juvenile salmon also respond to flow events in the spring and spikes in outmigration often coincide with increased flow, as shown in the Mossdale trawl data (DFG 2009).

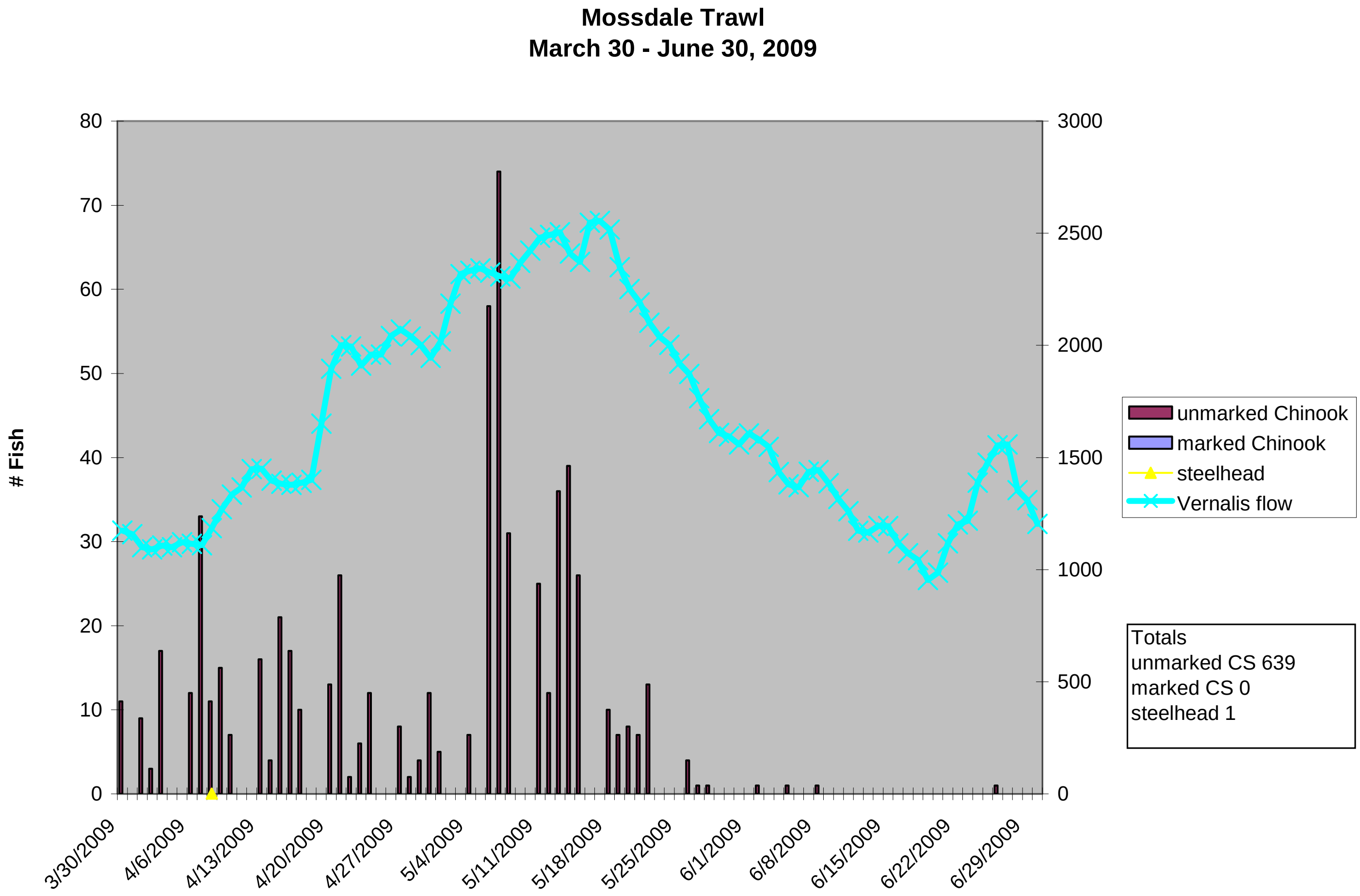


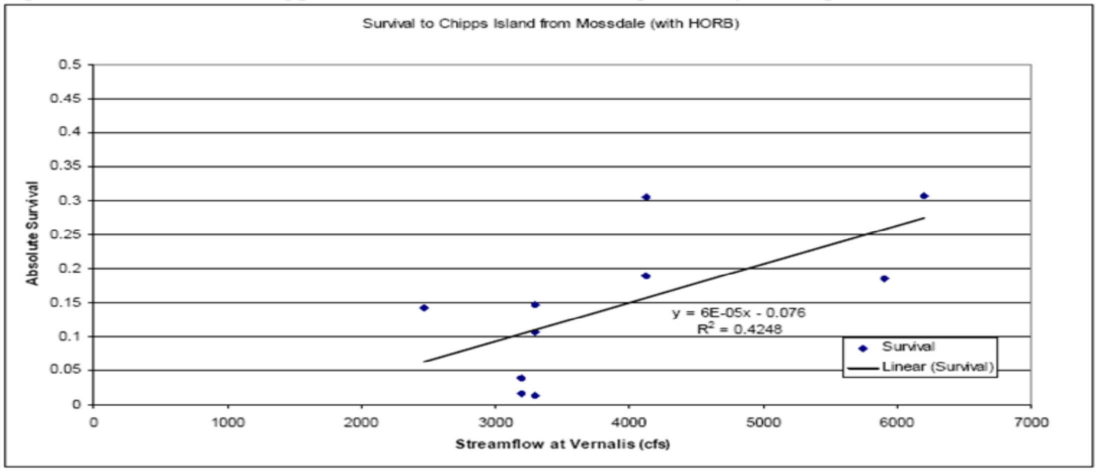
Figure 32. Mossdale trawl data (DFG 2009).

Freshwater inflow has been shown to directly affect the abundance and survival of juveniles moving downstream through the Delta. Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs (USFWS, 1987, pages 35 and 36). Survival through the Delta for juvenile fall run Chinook salmon originating from the San Joaquin basin has also been shown to increase with increased Delta inflows at Vernalis. In addition to juvenile salmon survival being higher with higher flows, the abundance of juvenile salmon leaving the Delta is also higher with greater river flow.

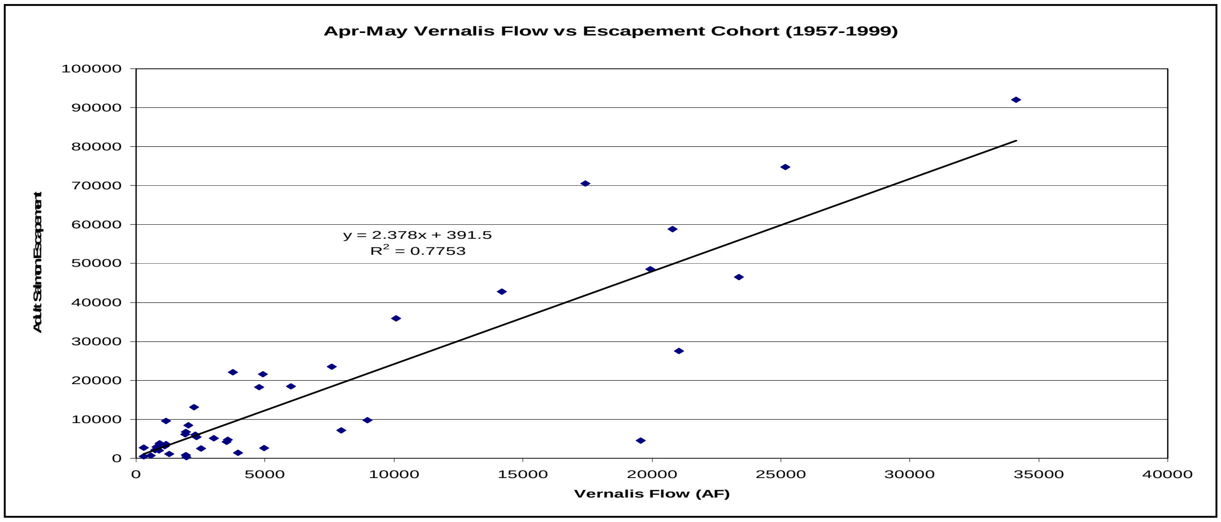
(Fig. 33. DFG-EXH-09 to SWRCB, 2005).

# Mossdale to Chipp’s Smolt Survival

**Figure 4. Mossdale to Chipp’s Island Flow vs. Survival Regression (*y intercept <0*)**



DFG has also shown a strong correlation between spring flows at Vernalis and adult Chinook escapement 2.5 years later (DFG-EXH-09 to SWRCB, 2005).



Consistent with its narrative salmon doubling objective, the Board should adopt biological goals of doubling smolt survival through the Delta from what it was between 1967-1991 for consistency with the goals of the Central Valley Project Improvement Act and USFWS. USFWS has developed estimates of flow levels needed at Vernalis to achieve doubling (USFWS, 2005, pages 9 and 10) in predicted Chinook salmon production for the basin, and help protect public trust resources in the Delta. Based on the scientific information that we reviewed, the Board should consider the Vernalis flows contained in USFWS (2005) and DFG’s San Joaquin Escapement Model as a starting point for establishing flow for the protection of salmon and steelhead migrating from the San Joaquin basin. It's interesting to note that the Vernalis flows in the AFRP report and the Vernalis flows in the DFG submittal are relatively similar regarding magnitude and duration. Where there may be some minor differences, the Service will work cooperatively with DFG to identify, describe and reconcile the Vernalis flow criteria. Managing the San Joaquin system for flows only at Vernalis has not been effective in improving fish populations on the San Joaquin and its tributaries. It's important to utilize a percentage of flows from each of the San Joaquin tributaries (Stanislaus, Tuolumne, and Merced rivers). Providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing and magnitude of water needed for the Delta ecosystem.

The Board should rely on scientific information in current and past Board exhibits, scientific publications, the unimpaired hydrograph, and models to help determine the volume, quantity and timing of water needed for the Delta ecosystem pursuant to the Board's public trust obligations. Uncertainty should not limit the Board's actions to protect the public trust resources, and can be addressed by monitoring, evaluation, and an adaptive management program to accomplish ecosystem goals, and the ultimate goal of protecting public trust resources.

In summary, Delta inflow and outflow are important for Chinook salmon in the Delta. Freshwater inflow is an important cue for upstream migration of adult salmon and directly affects the abundance and survival of juveniles moving downstream through the Delta. Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs (USFWS, 1987, pages 35 and 36), and survival through the Delta for juvenile fall run Chinook salmon originating from the San Joaquin basin has also been shown to increase with increased Delta inflows at Vernalis. USFWS developed estimates of flow levels needed at Vernalis to achieve doubling (USFWS, 2005, pages 9 and 10) in predicted Chinook salmon production for the basin, and help protect public trust resources in the Delta. Consistent with its narrative salmon doubling objective, the Board should adopt biological goals of doubling smolt survival through the Delta from what it was between 1967-1991 for consistency with the goals of the Central Valley Project Improvement Act. Finally, providing flows that mimic the natural hydrograph will benefit the native fishes in the Delta and should be used in determining the timing and magnitude of water needed for the Delta ecosystem.

### e. Other stressors

Key points:

1. Flow can be used as a management tool in reducing populations of non native species

2. Large quantities of data on contaminants have been collected, but has not been integrated into a model of contaminant fate and effects that informs decision-making

3. The presence of toxic chemicals in the Delta is a concern. Organisms can often be affected by very low concentrations of certain toxic contaminants. The synergistic effects of mixtures can magnify the impacts.

4. Many aspects of water quality (dissolved oxygen, temperature, particle residence time, etc.) are affected by flow and can be managed to provide conditions to help protect public trust resources

5. Entrainment at the CVP and SWP facilities can have significant population level effects on Delta fish species

6. Entrainment can be reduced by managing reverse flows and the location of X2. Reverse flow prescriptions can be found in USFWS 2008.

7. Changes to tidal and residual flow patterns in the Delta have reduced habitat variability thought to be important to resident native species

8. Delta hydrologic geometry has been reduced and should be restored with changes to flow and physical restoration to realize the benefits

Feyrer (2004) found that the abundance of native and non-native fish species clustered around gradients of water temperature and river flow; native species were generally associated with the cooler waters and higher flows of the early season, while non-natives were generally associated with the warmer temperatures and lesser flows of the later season. Similarly, Brown and Ford (2002) found that flow regime was an important factor in successful reproduction, and suggested that manipulation of flow could be a powerful tool in managing the fish assemblages of regulated rivers.

An example of a system-wide impact of changes to flow is the establishment and increasing spread of submerged aquatic vegetation (SAV) within the Delta. SAV typically establishes and spreads in areas of reduced water velocities; conversely, where there is sufficient flow (volume and velocity), this vegetation is largely absent. IEP POD and related research and monitoring has identified the spread of SAV as having several potential impacts within the Estuary – SAV introduces habitat for “lurk and wait” predators (Brown and Michniuk, 2007); SAV has been shown to cause local and regional declines in water column suspended sediment concentration by increasing local sedimentation rates (Findlay et al., 2006); SAV can clog local sloughs and bays, reducing access for recreational boating and increasing the need for applications of aquatic herbicides (CA Department of Boating and Waterways, 2010). Returning “historical” outflows to the Delta and its tributaries may provide one mechanism for reversing the spread of nuisance submerged aquatic vegetation.

The presence of toxic chemicals in the Delta is a concern. Organisms can often be affected by very low concentrations of certain toxic contaminants. The synergistic effects of contaminant mixtures can magnify the impacts. Years of research have generated a large database of contaminants and contaminant effects in the Delta; however, the data have not been integrated into a model of contaminant fate and effects that informs decision-making. The Board should evaluate existing models and monitoring programs to develop a comprehensive strategy to monitor and reduce the affects of contaminants in the Delta ecosystem.

Many aspects of water quality (dissolved oxygen, temperature, particle residence time, etc.) are affected by flow and can be managed to provide conditions to help protect public trust resources. Hallock et al, (1970) found that low dissolved oxygen concentrations of less than 5 mg/l in the San Joaquin River near Stockton was a barrier to adult migration. Lower survival in the Delta of marked juvenile fall run salmon is associated with decreases in the magnitude of flow through the estuary, increases in water temperature, and the proportion of flow diverted through the Delta Cross Channel and Georgiana Slough in the Delta. The survival of marked hatchery smolts through the Delta between Sacramento and Suisun Bay was found to be positively correlated to flow and negatively correlated to water temperature (USFWS, 1987). High water temperature has consistently been one of the most important variables in predicting salmon survival in models of fall run smolt survival for smolts originating from the Sacramento basin.

Entrainment at the CVP and SWP facilities can have significant population level effects on Delta fish species. In the fall, delta smelt tend to occur in the low-salinity zone or just seaward of X2, and as they mature, move into freshwater to spawn. Moving X2 westward in the fall therefore reduces the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities. Why survival is greater at higher flows is hypothesized to be due to lower temperatures, lower proportion of flow diverted into the interior Delta, reduced entrainment at agricultural pumps and project export facilities, lower predation and disease, elimination of reverse flows in the lower San Joaquin River, and increased availability of rearing habitat in Yolo Bypass and floodplains. To avoid or minimize entrainment, reverse flows due to water diversions from the Delta must be no more severe than those prescribed by the Service (USFWS 2008).

A particular emphasis on the importance of landforms and geomorphology by Atwater and colleagues (Atwater et al., 1979) has led to a growing understanding that the hydrogeomorphology of the Delta and Estuary play an important role in transforming available flow into a mosaic of habitats and alternative hydraulic residences, many of which are conceptually linked to critical habitat of species of concern (Enright and Burau, personal communication; Feyrer et al., in press; Nobriga at al., 2005; Bunn and Arthington, 2002; Atwater et al., 1979). It is quite likely that recent management activities in the Delta (1850-present) has led to a "short-circuiting" of tidal and residual flow patterns among and between tidal habitats and sloughs in the Estuary, with concomitant impacts on habitat variability and refuge space for native Delta organisms. The growing consensus is that management in the Delta has led to a homogenization of available aquatic habitat and the reduction in variability thought to be important to resident native species (Moyle et al., in preparation; Poff, 2009; Healey et al., 2008; Cloern, 2007).

Delta hydrologic geometry now contains a fraction of the complexity and distribution of what it was during the evolution and historic periods of abundance of species like Delta smelt (Atwater et al., 1979; Enright and Burau, personal communication; Figure 1.). As a consequence of this geomorphologic simplification, flow "reestablishment" will be part of a solution for increasing smelt habitat availability but will be *insufficient in and of itself.* Some stakeholders may argue that recent increases to "environmental flows," however unspecified, have not led to increases in Delta smelt abundance – but this is not sufficient evidence to conclude therefore that increased flows are not necessary for smelt recovery – only that they are not going to be effective when removed from their environmental, ecological, and evolutionary contexts (Moyle et al., in preparation). This is why any potential flow criteria must be made conditional upon appropriate concurrent habitat conservation and restoration requirements. Either without the other would not be expected to yield improvements in native species habitats or recovery.

In summary other stressors can have significant population level affects on the public trust resources. The Board should utilize conceptual models and mathematical models to hypothesize the relative affects and the potential synergistic impacts of all the priority stressors in the Delta ecosystem. Uncertainty should not limit the Board's actions; the Board should work with all the appropriate regulatory agencies to affectively reduce and mitigate the affects of all stressors on the ecosystem. Management actions taken to reduce impacts of stressors should be implemented in an adaptive management framework to effectively and efficiently accomplish ecosystem goals.

## IV. The adaptive management approach: Expert testimony: Dan Cox

The National Resource Council described adaptive management in their assessment of the restoration program in the Grand Canyon as: “an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to specific management actions."

The importance of an adaptive management approach and supporting monitoring cannot be overstated. The Board should not adopt flow criteria without; first stating what they are intended to achieve (ecosystem goals) and second giving thought about how to modify the flows to meet stated ecosystem goals. Monitoring and the use of mathematical models can be utilized to inform the adaptive management process and optimize the effectiveness of management actions.

Much of the monitoring that would be required to track progress in meeting ecosystem goals is already occurring. Modifications to the monitoring needed to address ecosystem goals could include; increase of sample size, increase monitoring stations, and new monitoring. Analyzing the data and incorporating into the mathematical models is essential in utilizing the monitoring data. Existing models will need to be adjusted to take advantage of improved resolution of monitoring data. New models will be useful to address the new information needs, including comprehensive models that integrate the biological and physical models (similar to the Sacramento Ecological Flows Tool under development by The Nature Conservancy).

The Department of Interior adaptive management technical guide states: “Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a ‘trial and error’ process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.”

The National Resource Council identified 8 key components of adaptive management in their assessment of the program in the Grand Canyon: “The key components of this and other working definitions include: (1) commitment to ongoing management adjustments based, in part, upon scientific experimentation, (2) shift from "trial and error" to formal experimentation with management actions and alternatives, (3) shift from fragmented scientific investigations to integrated ecosystem science, (4) explicit attention to scientific uncertainties in ecosystem processes and effects of management alternatives, (5) formal experimental design and hypothesis-testing to reduce those uncertainties and help guide management adjustments, (6) careful monitoring of ecological and social effects and of responses to management operations, (7) analysis of experimental outcomes in ways that guide future management decisions, and (8) close collaboration among stakeholders, managers, and scientists in all phases of these processes.”

An adaptive management approach the Board should consider:

1a. Set ecosystem goals that describe the desired condition of the Delta
1b. Identify specific biological and physical indicators to track progress towards stated ecosystem goals
1c. Monitor biological/physical indicators to establish baseline
2. Assess the problem

3. Use models and available data to develop hypotheses and select a suite of management actions to meet biological objectives and accomplish ecosystem goals
4. Implement management actions to accomplish ecosystem goals utilizing a formal experimental approach
5. Monitor response of specific biological indicators to management action
6. Evaluate the result of the management action- how effective was the action in reach goals?
7. Use what was learned to adapt management actions to improve efficiency and effectiveness in meeting goals

1a. Set ecosystem goals that describe the desired condition of the Delta

Consider starting with the Calfed Ecosystem Restoration Goals (or similar) and scale down to appropriate level. The Calfed Ecosystem Restoration Program enumerated six program goals the Board should consider:

- Achieve recovery of at risk native species dependent on the Delta and Suisun Bay as a first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed
- Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in was that favor native members of these communities
- Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals
- Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting biotic communities, ecological processes, recreation, scientific research and aesthetics
- Prevent the establishment of additional nonnative invasive species and reduce the negative ecological and economic impacts of established nonnative species in the Bay-Delta estuary and its watershed
- Improve and/or maintain water and sediment quality conditions that fully support healthy and divers aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people

1b. Identify biological and physical indicators to track progress towards stated ecosystem goals

Consult the experts on the Delta ecosystem to identify a suite of species and physical parameters that are good indicators of the health of the ecosystem. Consider species and physical parameters that are sensitive to particular aspects of the health of the ecosystem. Some indicators to consider include: survivorship of emigrating salmonid smolts; Delta smelt distribution and abundance; longfin smelt distribution and abundance; distribution and abundance of other indicator species; phytoplankton and zooplankton abundance, composition, temporal dynamics, and distribution; turbidity distribution and magnitude of load; nonnative species abundance and distribution; position of X2; transport flows; temperature at locations throughout the Delta; salinity timing, magnitude, and variability; and utilize biomarkers in select species to track exposure to contaminants, and physiological condition of individuals.

1c. Monitor biological/physical indicators to establish baseline

Conduct appropriate level of biological and physical monitoring to establish baseline conditions. Much of the necessary monitoring may already be occurring and would not need modification, however some new monitoring will be needed and increased effort will likely be required for certain ongoing monitoring.

2. Assess the problem

This could be considered both a scoping issue (defining the problem within the context of the system and its' operational constraints) and a vulnerability assessment. Assessing the threats in a comprehensive systematic way will make decisions about prioritizing management actions possible at varying scales. A vulnerability or threats assessment would be useful at the ecosystem level to give the big picture context, and would be useful at the individual species level to focus on specific threats that are not covered by the ecosystem analysis. A threats assessment includes (1) identifying threats and their sources, (2) determining the effects of threats, and (3) ranking each threat based on relative effects.

3. Use models and available data to develop hypotheses and select a suite of management actions to meet biological objectives and accomplish ecosystem goals

Consult the experts on the Delta ecosystem and identify a suite of management options to accomplish ecosystem goals. Utilize a decision support process informed by mathematical models, conceptual models, and data to select the most appropriate management actions to accomplish ecosystem goals. Use of conceptual models such as DRERIP can be beneficial in providing the context and framework to help guide decision-making. Costs, benefits, uncertainty, and risk will all factor into selection of the suite of management actions considered for implementation.

4. Implement management actions to accomplish ecosystem goals utilizing a formal experimental approach

Working within resource constraints, implement the priority management actions to accomplish ecosystem and biological goals. Some of the priority management actions that should be considered with respect to flow are: pulse flows, align timing of flows to align more closely with the natural hydrograph, changed frequency of reverse flows to align with natural conditions, increased variability of salinity, and reconnecting with the floodplains.

5. Monitor response of biological indicators to management action

Develop monitoring that explicitly is designed to measure the success or failure of management actions to achieve specific ecosystem and biological objectives. In situations with high risk or high uncertainty, monitoring will have to be conducted and assessed frequently to adjust actions to maximize efficiency and avoid irreversible or catastrophic failures caused by the action.

6. Evaluate the result of the management action- how effective was the action in reaching goals?

The data collected from the monitoring will need to be assessed to determine if the objectives were achieved. The core question is how effective was the management action in achieving the ecosystem goals? Comparison of indicators pre and post implementation of management action will give a good indication of how effective the management action was. The level of response of the indicator to the management action should be fed into mathematical models for use in future predictive scenario exercises.

7. Use what was learned to adapt management actions to improve efficiency and effectiveness in meeting goals

Utilize data and models from past management actions to form the basis for future management actions. Use what was learned to modify models, adapt management actions, and propose alternative management actions to achieve ecological and biological goals. In the long-term this process will inform management actions to improve efficiency and effectiveness in meeting ecosystem goals.

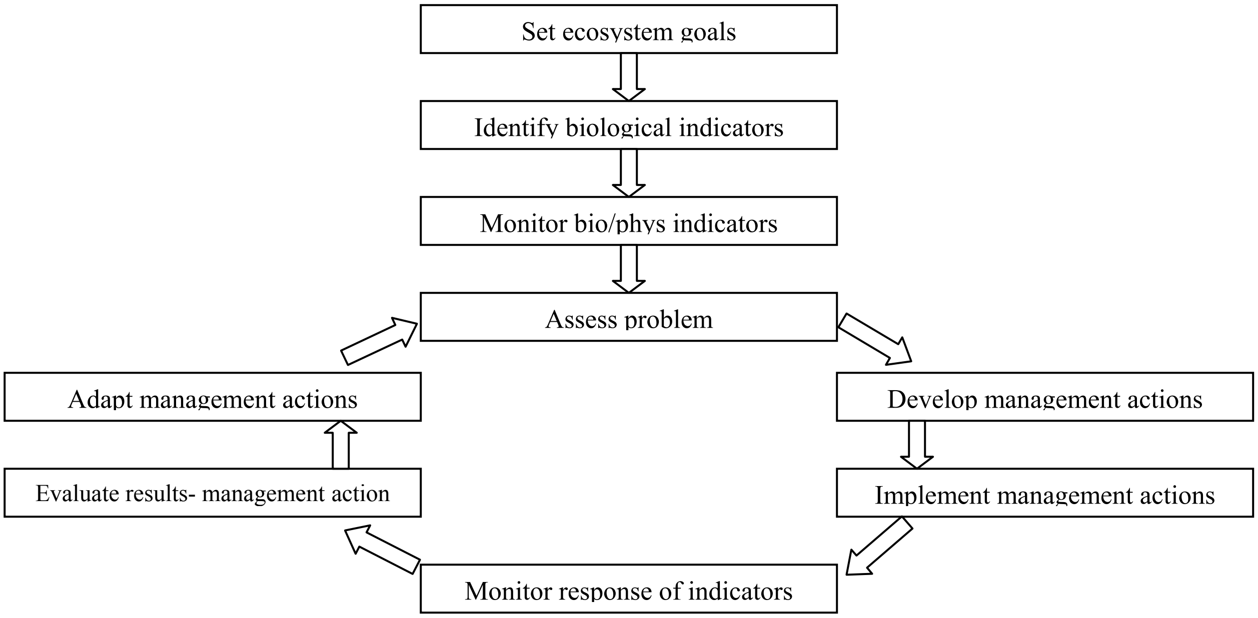


Figure 34. An adaptive management feedback loop

**From the DOI Adaptive Management Guide:**

***Embracing uncertainty***

Making a sequence of good management decisions is more difficult in the presence of uncertainty, an inherent and pervasive feature of managing ecological systems (16,17). Uncertainties arise with incomplete control of management actions, errors in measurement and sampling variation, environmental variability, and an incomplete understanding of system dynamics (see Section 5.2). These uncertainties potentially degrade management performance and contribute to acrimony in the decision making process.

Perhaps not surprisingly, managers have sometimes been reluctant to acknowledge uncertainty in environmental assessments and management strategies (18). Often there is a perception that asserting certainty as to management impacts is more convincing, and acknowledging uncertainty increases the likelihood that recommended actions will be ignored. Acknowledgement of uncertain management outcomes is sometimes seen as an invitation for confrontation among different interest groups, resulting in an inability to reach timely agreement on a proposed action.

Adaptive management forces stakeholders to confront unresolved uncertainties that can significantly influence management performance. An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time.

Adaptive management requires stated management objectives to guide decisions about what to try, and explicit assumptions about expected outcomes to compare against actual outcomes. It is important to know what the available management options and alternative assumptions are, in case the action that is tried does not work as expected. The linkages among management objectives, learning about the system, and adjusting direction based on what is learned distinguish adaptive management from a simple trial and error process. In essence, adaptive management will be seen to be learning by doing, and adapting based on what is learned.

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Electronic copies of many of the citations below have been provided on the CD. If the Board needs assistance acquiring referenced documents please let us know.

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**Other Stressors: Steve Culberson (USFWS)**

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Feyrer, F., Nobriga, M.L., and Sommer, T.R. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences, 64:723-734.

Findlay, S.E.G., Nieder, W.C., Blair, E. A., and Fischer, D.T. 2006. Multi-scale controls on water quality effects of submerged aquatic vegetation in the tidal freshwater Hudson River. Ecosystems, 9:84-96.

Grimaldo, L.F., and 7 others. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? North American Journal of Fisheries Management, 29:1253-1270; doi: 10.1577/M08-062.1

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Kimmerer, W.J., 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries, 25(6B):1275-1290.

Kimmerer, W.J., Gross, E.S., and MacWilliams, M.L. 2008. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts; doi:10.1007/s12237-008-9124-x.

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Nobriga, M.L., Sommer, T.R., Feyrer, F., and Fleming, K. 2008. Long-term trends in summertime habitat suitability for Delta smelt (Hypomesus transpacificus). San Francisco Estuary and Watershed Science. Vol. 6, Issue 1 (February), Article 1.

Nobriga, M.L., Feyrer, F., Baxter, R.D., and Chotkowski, M. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. Estuaries, 28(5)776-785.

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## Other Stressors: James Haas (USFWS)

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Werner I, Anderson S, Larsen K, and Oram J. 2008. Chemical stressors conceptual model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

## Section III Summary of Delta flow criteria and biological objectives: Roger Guinee (USFWS)

Presentation to National Academy of Sciences (Herbold, B. and M. Nobriga, January, 2010)

Fleenor, W. E., W. A. Bennett, P. B. Moyle, and J. R. Lund. 2010. On developing prescriptions for freshwater flows to sustain desirable fishes in the Sacramento-San Joaquin Delta. Report submitted to the California State Water Resources Control Board, 43 pp.

From OCAP Technical Support Team Presentation to Nat. Acad. of Sciences (F. Feyrer, January, 2010)

Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP). US Fish and Wildlife Service. 2008.

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(Grimaldo et al. In prep.)

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

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## <u>**Section IV. The Adaptive Management Approach** Dan Cox (USFWS)</u>

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# WITNESS IDENTIFICATION LIST (Revised January 29, 2010)

**(Due 12 Noon, Tuesday, February 16, 2010)**
**Delta Flow Criteria Informational Proceeding**
**Scheduled to Commence**
**Monday, March 22, 2010**

Department of the Interior plans to call the following witnesses:

| (name of individual participant or group of participants) **NAME** | **PROPOSES PARTICIPATION ON THE FOLLOWING PANEL(S) note panel number)** | **WILL THE WITNESS SUBMIT TESTIMONY (no if only responding to questions)** |
|---|---|---|
| Craig Anderson, Ron Milligan, Roger Guinee | **Hydrology** | **Yes** |
| Craig Anderson, Paul Fujitani, Roger Guinee | **Hydrodynamics** | **Yes** |
| Victoria Poage, Lenny Grimaldo, Roger Guinee | **Pelagic Fish** | **Yes** |
| Pat Brandes, Nick Hindman, John Hannon, Roger Guinee | **Anadromous Fish** | **Yes** |
| Steve Culberson, James Haas, Erwin Van Nieuwenhuyse, Dan Cox | **Other Stressors** | **Yes** |
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# Expert Statements of Qualifications

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**Craig Anderson**
I have a B.S. in Geography, specializing in Hydrology and Geographical Information Systems, from the University of Colorado-Boulder. I have a M.S. in Geography, specializing in Hydrology and Hydrologic Modeling, from the University of Colorado-Boulder.

In my position with FWS, I serve as a senior level hydrologist focusing on environmental water operations, hydro-ecological modeling, water accounting and flow management in support of BDFWO programs including the Central Valley Project Improvement Act (CVPIA), the Bay Delta Conservation Plan (BDCP), and the Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan (OCAP). Prior to working for the FWS, I was a hydrologist with NOAA's National Marine Fisheries Service, Habitat Conservation Division in Sacramento, California. In that position, my regular duties included hydro-ecological data analysis, field data collection, and model evaluation, development, and implementation in support of Federal Energy Regulatory Commission hydroelectric project relicensing proceedings, Endangered Species Act consultations, Magnuson-Stevens Act consultations, California Environmental Quality Act and National Environmental Policy Act processes, and Clean Water Act certifications. These activities required a working knowledge of several of California's largest and most complex water projects and planning efforts including the CVP/SWP, the BDCP, and the San Joaquin River Restoration Program. Prior to working for NMFS, I was a research hydrologist with the United States Geological Survey Grand Canyon Monitoring and Research Center in Flagstaff, AZ. There, my research activities pertained to ecological investigations focused on aquatic food web and fisheries responses to releases from Glen Canyon Dam on the Colorado River in support of ESA consultations and NEPA activities. I was responsible for monitoring and modeling water quality constituents, operational scenarios, and geomorphic change on Lake Powell, the Colorado River below Glen Canyon Dam, and Lake Mead. In this capacity, I routinely interfaced with fisheries biologists, stream ecologists, sediment scientists, and others to facilitate interdisciplinary research and provide management recommendations.

The purpose of my testimony is to provide an overview of the hydrology and hydrodynamics of the Sacramento-San Joaquin Delta (Delta) and the alteration of flow characteristics over time. This testimony relates to the key issue outlined by the California State Water Resources Control Board (Board) in the Notice of Public Informational Proceeding and Pre-Proceeding Conference issued December 15, 2009: what volume, quality, and timing of Delta outflows are necessary for the Delta ecosystem under different hydrologic conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. This testimony will provide background information on the magnitude, frequency, duration, and timing of important Delta hydrograph components, which are directly linked to the flow-habitat relationships for various life stages of pelagic and anadromous fishes and related food web interactions, including Delta inflow, Delta outflow, reverse flows, and Delta salinity.

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Pat Brandes

|  |  |
|---|---|
| Name: | Patricia Little Brandes |
| Address: | U.S. Fish and Wildlife Service<br>4001 N. Wilson Way<br>Stockton, CA 95205 |
| Position: | Fish Biologist, Stockton<br>Fish and Wildlife Office |

Education: B.S. Fisheries
Michigan State University, Lansing, MI – 1982

Employment: U.S. Fish and Wildlife Service, 1981 to Present

Jordan River National Fish Hatchery, Elmira, MI
Fishery Biologist Trainee – March, 1981 – Dec. 1981

Senecaville National Fish Hatchery, Senecaville, Ohio Fishery Biologist – April, 1982 – May, 1983

Stockton Fish and Wildlife Office, Stockton, CA
Fish Biologist – August, 1983 to Present Responsibilities: Responsible for designing and managing field studies, analyzing data and reporting on the abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin Delta.

Professional Organizations: Member of the American Fisheries Society
Certified Fishereies Professional: 1992 to present

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Dan Cox
USFWS Biologist
dan_cox@fws.gov
Office: (916) 414-6539

2800 Cottage Way w-2605
Sacramento, Ca
95825

## EDUCATION

B.S. Ecology and Evolutionary Biology: University of California at Santa Barbara

## BIOLOGICAL EMPLOYMENT HISTORY

**United States Fish and Wildlife Service** Biologist (GS 12) 3/08-present
Water operations division biologist primarily working on Salmonid and water issues

**Arizona Game and Fish Department**
Wildlife Specialist II 12/04-3/08
Statewide project lead for conservation of Arizona's mollusks, crustaceans, and the Sonoran tiger salamander.
Wildlife Technician 5/02-12/05
Amphibian and reptile conservation implementation.

**Hunt & Associates Environmental Consulting** 6/01-12/01
Construction monitoring projects including: primary monitor in charge of overseeing a stream restoration/renovation project, and overseeing the capping of a toxic waste site.

**UC Santa Barbara** 3/00-10/01
Lab assistant II- William Murdoch's laboratory- biological control agents and predator prey cycles

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Steven D. Culberson
**US Fish and Wildlife Service**
**Bay-Delta Fish and Wildlife Office**
**650 Capitol Mall, 5th Floor**
**Sacramento, CA 95814**
**(916) 930-5630**
**steven_culberson@fws.gov**

**Education**
Ph.D. Ecology (Tidal Marsh Geomorphology) University of California at Davis
M.S. International Agricultural Development (Aquacultural Engineering) Univ. of California at Davis
B.A. Biology (History, Creative Writing) Oberlin College, Oberlin, Ohio

**Positions and Employment**
Natural Resources Planner, U.S. Fish and Wildlife Service, 2009 to date; Staff Environmental Scientist, California Bay-Delta Authority/CALFED Science Program, 2005 to 2009; Staff Environmental Scientist, California Department of Water Resources, 2004 to 2005; Environmental Scientist, California Department of Water Resources, 2001 to 2004; Trainee, California Sea Grant Program, UC Davis, 1998 to 2001; Intern, California State Water Resources Control Board, Sacramento, 1996-1998; Teaching Assistant, Department of Agronomy and Range Science, 1998; Teaching Assistant, Ecology Graduate Group, 1995-1997; Research Fellow, Ecology Graduate Group, UC Davis, 1993-1996; Research Assistant, Department of Biological and Agricultural Engineering, UC Davis, 1990 to 1993; Natural Resources Observer, National Marine Fisheries Service, 1990; Program Coordinator, Ministry of Water and Forestry, Gabon, 1988-1989; Regional Coordinator/Technical Consultant, Ministry of Agriculture, Zaire, 1987-1988; Extension Agent, Projet Pisciculture Familiale, Zaire, 1985-87; Laboratory Assistant, Oberlin College, 1984.

**Awards and Honors**
CDWR Unit Citation, Interagency Ecological Program Pelagic Organism Decline Management Team, 2007
Professional Wetland Scientist Certification, 2003
California Sea Grant College Program Trainee, 1998 to 2001
Jastro-Shields Graduate Research Scholar, 1996 to 1998
Graduate Group in Ecology Research Fellow, 1993 to 1996
American Academy of Poetry Honorable Mention Award Winner, 1984

**Societies and Memberships (current)**
Coastal and Estuarine Research Federation
American Institute of Biological Sciences
Ecological Society of America
California Water and Environmental Modeling Forum Steering Committee
National Center for Ecological Analysis and Synthesis (Pelagic System Dynamics Working Group)
American Geophysical Union
American Association for the Advancement of Science

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Paul Fujitani
Central Valley Operations Office
Bureau of Reclamation
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Sacramento, CA 95821

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Paul Fujitani is the Chief, Water Operations Division in the Central Valley Operations Office (CVO) for the U.S. Bureau of Reclamation (Reclamation) in Sacramento, California. He began working for Reclamation in 1979. Since 1989 he has worked in CVO, first as a hydraulic engineer, then, beginning in 2000, as Chief of the Water Operations Division. Paul has also worked as a project manager for a private consultant and the US Army Corps of Engineers from 1986 to 1989.

Paul has a Bachelor of Science Degree in Civil Engineering from the University of California, Davis, and is a registered Civil Engineer by the State of California.

Paul supervises staff in the daily multi-purpose water operations of the Central Valley Project (CVP). These water operations include preparing water operation forecasts of the CVP, determining water supply allocations, determining river releases and flood control operations, determining CVP exports from the Delta, coordinating CVP water operations with the state Department of Water Resources and State Water Project, and ensuring that the CVP water operations comply with the various laws, standards, regulations, and water rights permits.

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Lenny Grimaldo

U.S. Bureau of Reclamation,
Applied Science Branch
2800 Cottage Way
Sacramento, CA 95825
Phone: (916) 978-5125
e-mail: lgrimaldo@usbr.gov

**Education:**

| | |
|---|---|
| 1992 - 1996 | B.S., Wildlife and Fisheries Biology, University of California, Davis, California. |
| 1999 - 2004 | M.S., Marine Biology, San Francisco State University, San Francisco, California. |
| 2002 - 2009 | Ph.D., Ecology, University of California, Davis, California |

**Research Experience:**

| | |
|---|---|
| Sept.2008<br>Present- | Fish biologist (GS-12), United States Bureau of Reclamation, Sacramento, California. I am responsible for design, implementation, and interpretation of ecological studies associated with environmental impacts or research of the Sacramento-San Joaquin Delta. I write proposals and conduct research on food webs, larval fish dynamics, and ecology of fishes in the estuary. I am on the Interagency Ecological Program (IEP) Management team. In this role, I provide technical review and advice on best management practices of natives fishes in the Delta. I also organize public workshops for the IEP. I am responsible for analyzing the environmental impacts of various projects in the estuary, including those related to the Bay Delta Conservation Plan (BDCP), 2-gates demonstration project, and exports from the State Water Project (SWP) and Central Valley Project (CVP). I publish research in peer-review journals and present research at local and national conferences. |

I am member of the Delta Smelt Workgroup Team. In this role, I review and analyze data in support of recommendations to the USFWS on smelt protection from the SWP and CVP. I provide management with updates on the status of research and monitoring results on regular intervals.

| | |
|---|---|
| July 1997-<br>August 2008 | Environmental Scientist, California Department of Water Resources (CDWR), Aquatic Ecology Section, Sacramento, California. Lead scientist for several research projects in the Delta; including studies related to food webs, restoration, entrainment impacts, and general life history of fishes. Worked closely with staff from CALFED, universities, stakeholders, state and federal agencies. Presented research at several national conferences. Published research in technical and peer-reviewed journals. Served on the Delta Smelt Workgroup Team. Supervised and mentored technical staff in field research methods. |
| Jan. 2000- | Environmental Scientist-Delta Science Assistant Coordinator, CALFED Bay-Delta July 2001 Program (on loan from DWR). I was responsible for reviewing and coordinating CALFED-funded science activities in the Delta. I organized and participated in the scientific review of the Delta Cross Channel studies and the Environmental Water Account. I developed plans for incorporating science into restoration activities supported by the CALFED program. I also provided ecological expertise to the CALFED Science Chief, Sam Louma. |
| Oct. 1995 -<br>June 1997 | Fish and Wildlife Scientific Aid, DWR, Sacramento, California<br>I assisted in the field collection of fishes and invertebrates from the Delta. I assisted in the data analysis and report writing for several technical reports. |
| March 1994-<br>May 1997 | Fish and Wildlife Scientific Aid, California Department of Fish and Game, Stockton, California. I assisted in the field collection of fishes and invertebrates from the San Francisco Estuary. I assisted in the data analysis and report writing for several technical reports. Conducted fish identification classes. |
| 1995 - 1996 | Independent Research Project, Dept. of Wildlife and Fisheries Biology, University of California, Davis, California. I conducted a survey of fishes from Putah Creek California. |

**Professional Societies:**

American Fisheries Society
Estuarine Research Federation
California Estuarine Research Society

**Professional Service:**

Committee Chair, 2007 Annual Meeting, California-Nevada Chapter, American Fisheries Society
Referee for various journals including: CALFED Estuarine Watershed Science and Global Ecology and Biogeography

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Roger Guinee

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(916) 414-6537

EDUCATION

Bachelor of Science Degree from Humboldt State University with a major in "Wildlife Management" and a minor in "Biology", December 1975.

EXPERIENCE

I began working for the U.S. Fish and Wildlife Service in 1977. Since 1993, I have been involved in the planning and implementation of the Central Valley Project Improvement Act (CVPIA). My responsibilities included management of the 800,000 AF of B2 water and the acquisition of water pursuant to the B3 Water Acquisition Program for anadromous fish restoration purposes and the protection of federally listed delta smelt.

During this time I worked in coordination with the Anadromous Fish Restoration Program (AFRP), DFG, NMFS and other biologists to help develop the flow objectives and restoration measures identified in the AFRP Working Paper (1995) and AFRP Restoration Plan (2001) which contribute to salmon and steelhead restoration on the Central Valley rivers and streams.

After the CalFed Record of Decision in 2000, I participated on the planning and implementation of the Calfed Environmental Water Account (EWA) intended to protect listed aquatic species. The EWA was implemented in coordination with DFG, NMFS, DWR and USBR.

Currently, I am the Water Operations Division Chief for the Service's Bay-Delta Fish and Wildlife Office. I'm responsible for supervising the staff that work on the environmental water programs authorized by the CVPIA, and related environmental water issues. I provide technical and policy guidance to staff, management and other offices and divisions within the Service. Again, the environmental water programs are intended to help protect delta smelt and restore anadromous fish.

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James Haas

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Environmental Contaminants Coordinator
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Jim has a B.S. in Wildlife and Fishery Resources from the University of Idaho, an M.A. in Biology (Ecology and Systematics) from San Francisco State University, and a Ph.D. in Ecology (Ecotoxicology Area of Emphasis) from the University of California Davis.

Jim has served as the Environmental Contaminants Coordinator for the Pacific Southwest Region, U.S. Fish and Wildlife Service, since 2003. Prior to that time, he served as a senior environmental contaminants biologist in the Sacramento Fish and Wildlife Office, working primarily on natural resource damage assessment and restoration in oil spill and CERCLA cases, ecological risk assessments for CERCLA sites, and other contaminants-related activities.

Before coming to the Service in 1992, Jim worked for the Department of the Navy as the Environmental Coordinator at Naval Air Station Moffett Field. He also served as a Navy officer for 11 years and recently retired from the Navy Reserve with a total of 30 years service.

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John Hannon
Fisheries Biologist
US Bureau of Reclamation
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916-978-5524

Education: BS, Aquatic Ecology, Iowa State University, 1990
work history (include dates, title, major duties)

Fisheries Biologist, US Bureau of Reclamation, Sacramento, CA. 2001 – present
Salmonid expert for ESA consultations on CVP and SWP operations: 2002, 2004, and 2008
Developed and implemented steelhead redd survey protocol
Program Manager for CVPIA Spawning Gravel program – Designed and implemented salmonid habitat restoration projects
Conduct juvenile salmonid habitat use monitoring in American, Stanislaus, and Trinity Rivers.

Fisheries Biologist, Tongass National Forest, Craig, Alaska. 1990 – 2001.
Designed and implemented juvenile salmonid habitat and population monitoring program.
Designed and implemented steelhead escapement monitoring program.
Identified and implemented two fish passage projects.
Conducted long term evaluation of salmonid response to a major fishpass project.
Responsible for stream habitat protection during large scale timber harvests.
Conducted stream improvement projects (woody debris placement, riparian thinning, culvert fish passage upgrades)
Taught stream survey techniques, water resource reconnaissance, aerial photo interpretation, field navigation, and boating procedures to seasonal and professional employees each year.

Commercial Diver, Prince of Wales Island Alaska, 1994 – 2004
Participated in yearly sea cucumber dive fishery

Salmon and Halibut Charter Boat Operator, Craig, Alaska, 1997 – 2000

Fisheries Biologist, Chequamegon National Forest, Hayward, WI, 1990
Surveyed fish populations, evaluated a lake aeration project, conducted trout stream habitat improvement project (brush bundles)

Fisheries Co-op student, Chequamegon National Forest, Park Falls, WI 1988 – 1989
Assembled trout stream inventory database; sampled fish assemblages, water quality, and habitat in streams and lakes; cruised and marked timber

Walleye Culture Technician, Iowa State University, 1987 – 1990
Maintained walleye culture research projects in a lab.

Fish Hatchery Assistant, Wyoming Trout Ranch, Cody, Wyoming, 1987
Raised Yellowstone cutthroat and rainbow trout in a private trout hatchery.

Fish Hatchery Assistant, Schweitzer Fisheries, Bedford, Iowa, 1984 – 1986

Assisted in development of walleye culture methods using artificial feeds in cooperation with Iowa State University.

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Nick Hindman
Fish Biologist
US Fish and Wildlife Service
2800 Cottage Way
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Education: B.S. Fisheries Resources, 1981
University of Idaho, Moscow, ID

Employment: Maryland Dept of Natural Resources
Natural Resources Biologist III, 1986-1989
Annapolis, MD

Washington State Dept of Wildlife
Fish Biologist, 1989-1991
Ellensburg, WA

National Marine Fisheries Service
Fish Biologist, 1991-2001
Dutch Harbor, AK

Western Area Power Administration
Fish Biologist, 2001-2002
Folsom, CA

US Fish and Wildlife Service
Fish Biologist, 2002 to present
Sacramento, CA
Current duties: Responsible for CVPIA environmental water planning and implementation

Professional Organizations: Member of the American Fisheries Society

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Victoria Poage,
Delta Native Fishes Recovery Coordinator
U.S. Fish and Wildlife Service
Bay-Delta Fish and Wildlife Office
650 Capitol Mall, Fifth Floor
Sacramento, CA 95814
916-930-5641
Education:
BS in Fishery Science, University of Washington, Seattle, WA, 1984
MS in Biology, Minnesota State University, Mankato, MN 1998

Employment History:
National Marine Fisheries Service, 1984 - 1990; Fishery Biologist
Washington Department of Fisheries, 1991 (temporary); Biological Technician
Minnesota Department of Natural Resources, 1995-1998; Fisheries Specialist

Minnesota Department of Natural Resources, 1998-2002; Regional Environmental Assessment Ecologist
U.S. Fish and Wildlife Service, 2002-present; Senior Biologist

Professional Organizations: Member of the American Fisheries Society

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Erwin Van Nieuniewenhuyse

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Chief, Applied Science Branch
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Sacramento, CA 95825
Phone/fax: 916-978-5213/5055

**Education**

University of Missouri-Columbia, Columbia, Missouri
(Ph.D., Limnology, 1993)

University of Alaska-Fairbanks, Fairbanks, Alaska
(M.S., Fisheries Science, 1983)

Michigan State University, East Lansing, Michigan
(B.S., Zoology, 1976)

**Recent work history**

2008 to present: Supervisory Biologist, United States Department of Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento, California. In this position, I serve as Chief of the Applied Science Branch of the Environmental Affairs Division and as a senior limnologist and fisheries scientist for the Region. I supervise five professional employees (two GS-13 and three GS-12) and one wage-grade employee. I also coordinate the Interagency Ecological Program and manage some $17,000,000 in contracts, grants and cooperative agreements with a variety of partners including, the U.S. Geological Survey, U.S. Fish and Wildlife Service, California Department of Water Resources, California Department of Fish and Game, and the University of California.

2001 - 2007: Fisheries Biologist, United States Department of Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

1998 – 2001: Fisheries Biologist, United States Department of Interior, Fish and Wildlife Service Anadromous Fish Restoration Program, Stockton, California.

1995 – 1998: Fisheries Biologist, Jones and Stokes Associates, Sacramento, California.

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Ron Milligan: Central Valley Project (CVP) Operations Manager 2004-present.

**SJC-387**

I have a bachelor's degree with honors in civil engineering from California State University, Sacramento, and I direct the functions of Reclamation's Central Valley Operations Office which includes operations forecasting; water supply allocation; river releases and flood control operations; and control and scheduling of power generation. My office coordinates the real-time system operations of the major CVP facilities. I also co-chair the Water Operations Management Team.

I have worked with Reclamation since November 1999. During this time, I have also served as the Mid-Pacific Region's Deputy Planning Officer and was active in CALFED implementation and the Region's overall planning program. Before joining Reclamation, I worked for the US Army Corps of Engineers starting in 1984, working as a civil engineer in the Sacramento District. There I worked with hydrologic modeling, flood plain management, planning investigations, and reservoir operations within the Central Valley of California.