Public Workshop (10/1-2/12)
Bay-Delta Workshop 2
Deadline: 9/14/12 by 12 noon

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Documents Being Submitted on
September 14, 2012 to State Water Resources Control Board
By
Sacramento Valley Water Users (SVWU), Glenn-Colusa Irrigation District (GCID), and
Northern California Water Association (NCWA)

Re: Bay-Delta Workshop 2 – Bay-Delta Fishery Resources (Anadromous Salmonids)

In Response to
Public Workshops and Request for Information:
Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan

Electronic File Name	**Title/Description of File**
SVWU Vogel Submittal	Written Submittal of David A. Vogel, Natural Resource Scientists, Inc. on behalf of Glenn-Colusa Irrigation District, Sacramento Valley Water Users, and Northern California Water Association (includes Exhibits 1 and 2) ***Insights Into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration for Consideration in the Bay Delta-Water Quality Control Plan Update***

STATE WATER RESOURCES CONTROL BOARD
PUBLIC WORKSHOPS AND REQUEST FOR INFORMATION:
COMPREHENSIVE (PHASE 2) REVIEW AND UPDATE TO THE BAY-DELTA PLAN

Workshop 2: Bay-Delta Fishery Resources (Anadromous Salmonids)

Insights Into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration for Consideration in the Bay Delta-Water Quality Control Plan Update

Written Submittal of David A. Vogel, Natural Resource Scientists, Inc.
on behalf of Glenn-Colusa Irrigation District, Sacramento Valley Water Users,[1]
and Northern California Water Association

INTRODUCTION

I am a fisheries scientist with Natural Resource Scientists, Inc., and have been employed in this discipline for 37 years while conducting anadromous salmonid studies in the Central Valley for the past 31 years. I previously worked for the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) for 15 years, and I have worked as a private consultant for the past 22 years. During this time I have served as a Principal Scientific Investigator in dozens of fish research projects in the western United States on behalf of state and federal agencies, Indian tribes, county governments, municipalities, water districts, consulting firms, and numerous other organizations. I have authored approximately 100 technical reports on fishery science. Most of my work has focused on anadromous fish throughout the Sacramento River basin, the Delta, and the San Joaquin River basin. Attached is a copy of my resume (Exhibit 2).

The State Water Resources Control Board (Board) Notice requested information relevant to the October 1-3, 2012 Workshop on salmonids. In this regard, I prepared a comprehensive report entitled "*Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration"* in 2011 for the Northern California Water Association (NCWA) and the Sacramento Valley Water Users (SVWU). That report provides extensive information to inform the Board on topics highly relevant to the October Workshop on Bay-Delta Fishery Resources. It was previously provided to the Board in an April 25, 2012 submittal to the Board as Exhibit 3 to the "Sacramento Valley Water Users' Comment Letter – Bay-Delta Plan Supplemental Notice of Preparation – Comprehensive Review" (SVWU's April 2012 Comments)[2] and will hereafter be referred to as "Exhibit 3 – Salmon Report."[3] Much of the following summarizes information from that document, which focused on the threatened or endangered native Sacramento River basin anadromous fish. It includes findings from many of my studies on Central Valley salmonids conducted over the past 31 years and research performed

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[1] The parties comprising the Sacramento Valley Water Users are listed on Exhibit 1, attached hereto.

[2] See http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/comments_042512/andrew_hitchings.pdf.

[3] Note: The report also discussed green sturgeon but that topic will not be addressed here because it was not identified in the Board Workshop Notice.

by others relevant to the Board's Workshop. Additionally, I am also providing new information responsive to the questions posed by the Board in the Workshop Notice.

EXECUTIVE SUMMARY

This submittal presents key information, conclusions, and recommendations that build from the previously submitted Exhibit 3 – Salmon Report, as follows.

First, there has been significant progress over the last few decades on relevant Sacramento River Basin salmonid restoration actions, including the following:

- Adult fish passage at many important upstream migration barriers has been extensively improved in recent decades and some major barriers have been completely removed, providing fish access to upstream areas essential for increased fish production.

- Thermal conditions in the rivers downstream of large dams have dramatically improved, yielding critically important protection of fish during highly temperature-sensitive periods in the life cycle.

- Remedial actions at the abandoned Iron Mountain Mine near the upper Sacramento River have largely eliminated a previous major source of fish mortality.

- A massive program over the past two decades to screen unscreened or inadequately screened water diversions costing approximately $574 million has resulted, or will soon result, in protection of fish at most diversions, which collectively divert a maximum of nearly 13,000 cfs.

- Watershed restoration programs to protect and enhance conditions on numerous tributaries have proliferated in recent times, and are believed to have benefited fish habitats and overall watershed health.

- Improved flow regimes in the rivers downstream of the Sacramento River basin's major dams have been implemented in recent decades, providing fish protection during all the freshwater life phases.

Second, until significant progress is made on correcting the habitat problems and largely site-specific sources of native juvenile anadromous fish mortality in the Delta, it is likely that many of the benefits of upstream actions are, and will continue to be, negated. Overall, predation is likely the highest source of mortality to anadromous fish in the Delta. While some opportunities remain in the Sacramento Valley – such as larger additions of gravel in important spawning reaches, juvenile fish rearing habitat improvements, and increased fish protection on smaller tributaries – the available evidence indicates that conditions have become worse, not better, in the Delta during the most-recent decades. Despite the enormous, unprecedented actions to improve fish production in the upper watersheds, there has been a remarkable lack of focus or progress to fix the serious predation and habitat problems in the Delta, through which all Sacramento Valley anadromous fish must migrate. Re-focused study efforts in the Delta are sorely needed with the objective of locating and fixing fish mortality sites. Overall, until major predation problems in the Delta are corrected, difficulties for anadromous fish restoration will remain.

Third, implementation of high unimpaired flow criteria as part of the Bay-Delta Plan Update would have a high potential of largely undoing the decades of progress in restoring conditions for salmonids in the Sacramento Valley. By far, the most-overwhelming adverse effects to salmonids in the Sacramento River basin resulting from attempts to implement high unimpaired Delta inflow and outflow criteria are major reductions in water storage in the large reservoirs (Shasta, Oroville, Folsom). Without this critical water supply and cold-water pool available for fishery resources, the negative effects on anadromous salmonids could be devastating. Additionally, improperly timed high flows could provide unfavorable conditions for mainstem rearing fish. Careful examination of the impacts of large flow increases is warranted by thorough modeling studies to determine the effects on water supplies, thermal impacts to fish, and alteration of instream habitats.

Fourth, the Board should consider a number of opportunities for implementation of actions to benefit salmonids, including: (1) resolve adult salmon blockage by the Delta Cross Channel Gates, and at Fremont Weir and other flood-control weirs; (2) alleviate predation problems at key locations in the Delta; (3) fix problems with breached Delta levees; (4) re-create shallow-water Delta rearing habitats; (5) avoid creating predation problems at future Delta structures; (6) examine short-duration pulse flow actions in the spring, while avoiding impacts to other beneficial purposes (e.g., cold-water storage, water supply, etc.); and (7) improve management of the cold-water pool in Shasta Reservoir through potential structural alterations to the Shasta Dam Temperature Control Device, and fine-tune downstream temperature compliance points.

Fifth, there are significant scientific uncertainties regarding juvenile salmon emigration, both in the riverine environment, and through the Delta. In particular, there are significant uncertainties and limitations with some acoustic telemetry studies of salmon smolts and the timing of when those studies are conducted in the Delta.

Sixth, Section 9 of this submittal itemizes and summarizes numerous proposed actions and studies to address problems, opportunities, and scientific uncertainties concerning anadromous salmonids in the Sacramento River basin and Delta.

Finally, the Board's Notice lists two sets of questions for the Workshop on anadromous salmonids. This written submittal is organized to respond to those specific questions.

First Set of Questions Posed by the Board for the October Workshop on Anadromous Salmonids

1. What additional scientific information should the State Water Board consider to inform potential changes to the Bay-Delta Plan related to Bay-Delta fishery resources, and specifically pelagic fishes and salmonids, that was not addressed in the 2009 Staff Report and the 2010 Delta Flow Criteria Report? For large reports or documents, what pages or chapters should be considered? What is the level of scientific certainty or uncertainty

regarding the foregoing information? What changes to the Bay-Delta Plan should the State Water Board consider based on the above information to address existing circumstances and changing circumstances such as climate change and BDCP?

RESPONSE

1.0 INTRODUCTION

In order to appropriately answer these questions, it is important that the Board be adequately informed of the current status of programs to restore Sacramento River basin anadromous salmonids. Information concerning Sacramento River basin anadromous salmonids presented in the 2009 Staff Report and the 2010 Delta Flow Criteria Report is incomplete and largely out-of-date. Unless the Board explicitly acknowledges and incorporates new information and progress made in salmonid restoration in the Sacramento River basin, the Board's focus may be directed in the wrong areas. For example, those two reports implicitly suggest that flow and habitat problems in the basin have not been adequately addressed. Likewise, an uninformed reader of the two Board reports would likely conclude that if new flow-related measures, based on a hypothetical criterion of percent of unimpaired flow, are implemented, then Sacramento River basin salmonid populations will positively respond. This ignores the fact that there has already been unprecedented, major progress toward actions to restore anadromous salmonids through both flow-related measures (implemented differently than the postulated concept of percent of unimpaired flow) and non-flow measures linked with flow. The relative importance of these actions cannot be overemphasized and these actions are very relevant to the Board's consideration of present-day issues affecting the fishery resources. Additionally, the two Board reports do not address major scientific uncertainties and highly complex variables affecting salmonids (both in upstream areas and, in particular, the Delta) where the Board could more appropriately focus its attention. The following are some main examples.

2.0 PROGRESS ON RELEVANT SACRAMENTO RIVER BASIN SALMONID RESTORATION ACTIONS NOT ADDRESSED BY THE BOARD REPORTS

The 2009 and 2010 Board reports do not consider the habitat restoration actions that have already been developed to benefit salmonids throughout the Sacramento River basin. The following are examples.

2.1 Fish Migration Barriers

Adult fish passage at many important upstream migration barriers has been significantly improved in recent decades and some major barriers have been completely removed. These actions have greatly enhanced salmon access to upstream areas essential for increased fish production and have a considerable bearing on how flow-related issues are intertwined with these positive measures. The most notable among these barriers are described below.

2.1.1 Red Bluff Diversion Dam (RBDD)

The most-prominent impediment to salmon migration cited for decades was the construction and operation of the RBDD on the Sacramento River [river mile (RM) 243] beginning in 1966. At one time, it was considered one of the largest threats to anadromous fish in the Sacramento River; that has now changed. Numerous actions over the past several decades incrementally lessened the problem for salmon upstream migration and have ultimately lead to year-round gates-open status at RBDD. (Exhibit 3 – Salmon Report, pp. 32-34, 39 (Table 1).) Due to this action, fish now have free passage to the upstream-most reaches and some tributaries where flow and physical habitats will enhance natural fish production. This unimpeded access to the coldest-water reaches in the upper Sacramento River will undoubtedly benefit not only the endangered winter-run Chinook, but overall will result in remarkable beneficial effects for salmon compared to recent history. This dramatic change has a major positive influence on how Sacramento River flows can be managed and are pertinent to the Board's Order 90-5, the 2009 NMFS Biological Opinion, and this Board Workshop (discussed in more detail later in this submittal).

Table 1. Improvements in fish passage at Red Bluff Diversion Dam (RBDD) on the Sacramento River.

Fish Protection Measure	Effective Date	Fish Passage Improvement
Eliminating Adult Salmon Delay and Mortality at the Louver Bypass Terminal Box	1985	Elimination of significant adult salmon mortality at the dam bypass
Improved RBDD Fish Ladder Maintenance	1985	Improved fish attraction into the fish ladders
Installation of the Training Wall at the Right-Bank Fish Ladder	1985	Improved fish attraction into the right-bank fish ladder
RBDD gates out 6 months/year	1987	Unimpeded upstream fish passage 6 months/year
Relocation of the Fish Screen Bypass Outfall	1990	Reduced delay of salmon downstream of the dam
RBDD gates out 8 months/year	1993	Unimpeded upstream and downstream fish passage 8 months/year
RBDD gates out 12 months/year	2012	Unimpeded upstream and downstream fish passage 12 months/year

2.1.2 Anderson-Cottonwood Irrigation District (ACID)

Since construction of the ACID dam on the Sacramento River (RM 299) in Redding, California, substantial problems with upstream fish passage have been well documented. Those issues were largely eliminated with the installation of new fishways in 2001. (Exhibit 3 – Salmon Report, pp. 34-35, 39.) This action has resulted in a greater portion of the winter-run Chinook populations spawning in areas farther upstream, where significant gravel replenishment projects have been implemented in recent years to boost natural production.

2.1.3 Keswick Dam

At the upstream terminus for salmon migration at Keswick Dam (RM 302), a significant problem with lethal entrapment of adult salmon in the spillway stilling basin was well-known for decades, but has also now been fixed. (Exhibit 3 – Salmon Report, pp. 35, 39.) Correcting this mortality issue has resulted in a greater ability of adult salmon to survive and spawn downstream of the dam, thereby increasing natural fish production.

2.1.4 Barriers on Tributaries

Historically many, if not most, salmon-producing tributaries in the Sacramento River basin possessed significant barriers that impeded or blocked fish from reaching optimal spawning and rearing areas. In recent years, most of those problems have been either improved or eliminated, in some instances with total dam removal. (Exhibit 3 – Salmon Report, pp. 36-38, 39.) Key examples include barriers on Butte Creek, Battle Creek, and Clear Creek. These actions have substantially expanded the geographic range of favorable habitats for anadromous salmonids.

2.2 Water Quality

Thermal conditions for salmonids downstream of the major dams in the Sacramento Valley have been significantly improved over the years, and a major source of fish mortality caused by acid mine drainage (AMD) on the Sacramento River has essentially been eliminated. These two factors were previously considered to be major problems for salmonids. Except for some critically dry water years, the historical periodic summer water temperature trouble for salmon associated with Shasta Reservoir during lower-water elevations was largely eliminated following the installation of the $84 million Temperature Control Device (TCD) on the face of Shasta Dam, and the installation of a water temperature curtain in Whiskeytown Reservoir, which maintained cooler water introduced into the upper Sacramento River via the Trinity River trans-basin water diversion. Releases of hypolimnetic water deep in the reservoir provides for suitable water temperatures during critical salmon egg incubation periods, while concurrently providing for power generation. (Exhibit 3 – Salmon Report, pp. 33, 39, 41-42, 44-45, 47-49, 51-53, 58-59, 62-63.) Although the TCD went into operation in 1997, cold water releases were made through low-level outlets on Shasta Dam's spillway (which bypassed the hydroelectric turbines) from 1987 through 1996. Also, multi-million dollar actions through the Environmental Protection Agency's Superfund Program have largely eliminated the previous, well-known source of fish mortality on the upper Sacramento River associated with Iron Mountain Mine AMD. Additionally, improved thermal conditions for salmonids have been, or will soon be, implemented on the Yuba and Feather Rivers through the recent Yuba River Accord (see SWRCB Corrected Order WR 2008-0014) and the Oroville Dam Federal Energy Regulatory Commission (FERC) relicensing process (see SWRCB Order WQ 2010-0016), respectively. These restoration actions have had a significant positive effect on how flows and water temperatures are now managed to benefit salmonids.

2.3 Physical Spawning Habitats

Although physical spawning habitats downstream of some major dams in the Sacramento River basin have slowly and incrementally degraded over time since dam construction due to lack of gravel recruitment from upstream to downstream areas, major expenditures on spawning gravel replenishment projects have helped to restore those habitats. (Exhibit 3 – Salmon Report, pp. 45-46, 53.) This has increased the quantity and quality of areas immediately downstream of the dams where instream flow conditions are most favorable for natural fish production.

2.4 Fish Screens Installed at Riverine Water Diversions

Historically, the loss of young anadromous fish in unscreened riverine diversions has almost universally been cited as a significant contributing cause for declines in fish populations. That has now dramatically changed in the Sacramento River valley. Screening of agricultural diversions has been a common practice in recent years in order to conserve and restore populations of anadromous fishes. The maximum flow now screened is nearly 13,000 cfs **at a cost of over $500 million**. All of the largest and most of the mid-sized agricultural and urban diversions have been screened to meet fishery agencies' criteria, while many smaller diversions have also been screened. (Exhibit 3 – Salmon Report, pp. 64-83, 123 (Figure 1).) Loss of fish due to entrainment into Sacramento River diversions is no longer considered a major factor affecting the fish populations.

2.5 Watershed Restoration

Due to heightened awareness of the importance of anadromous fish, there has been a proliferation of watershed groups in most Sacramento River valley tributaries which have focused on improving overall watershed health. (Exhibit 3 – Salmon Report, pp. 53, 60-63.) Cumulatively, efforts by these numerous groups (Figure 2) have undoubtedly improved habitat conditions for salmonids in the Sacramento River basin.

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Figure 1. Recent fish screening projects (depicted by red dots). (Figure from Exhibit 3 – Salmon Report, p. 81.)

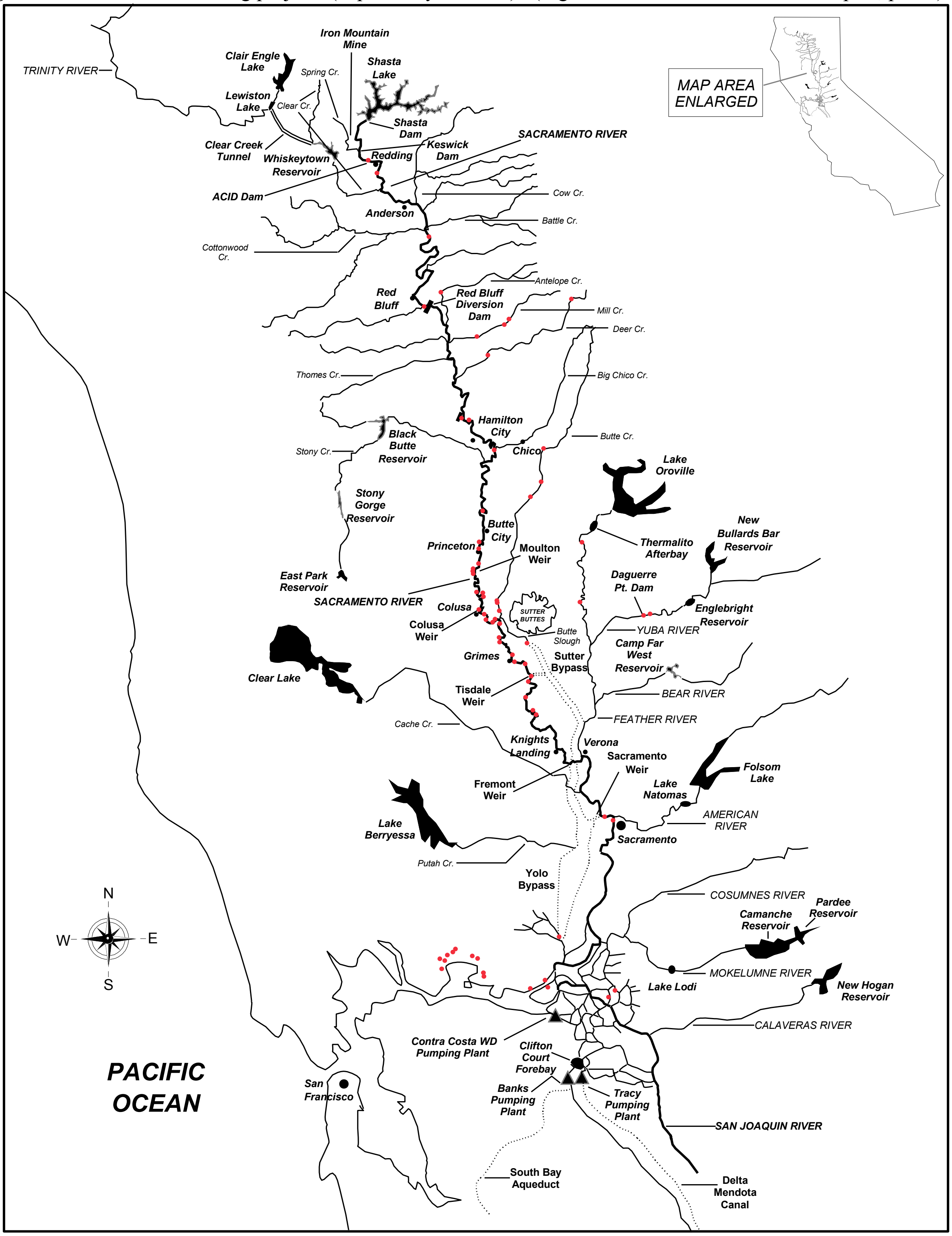
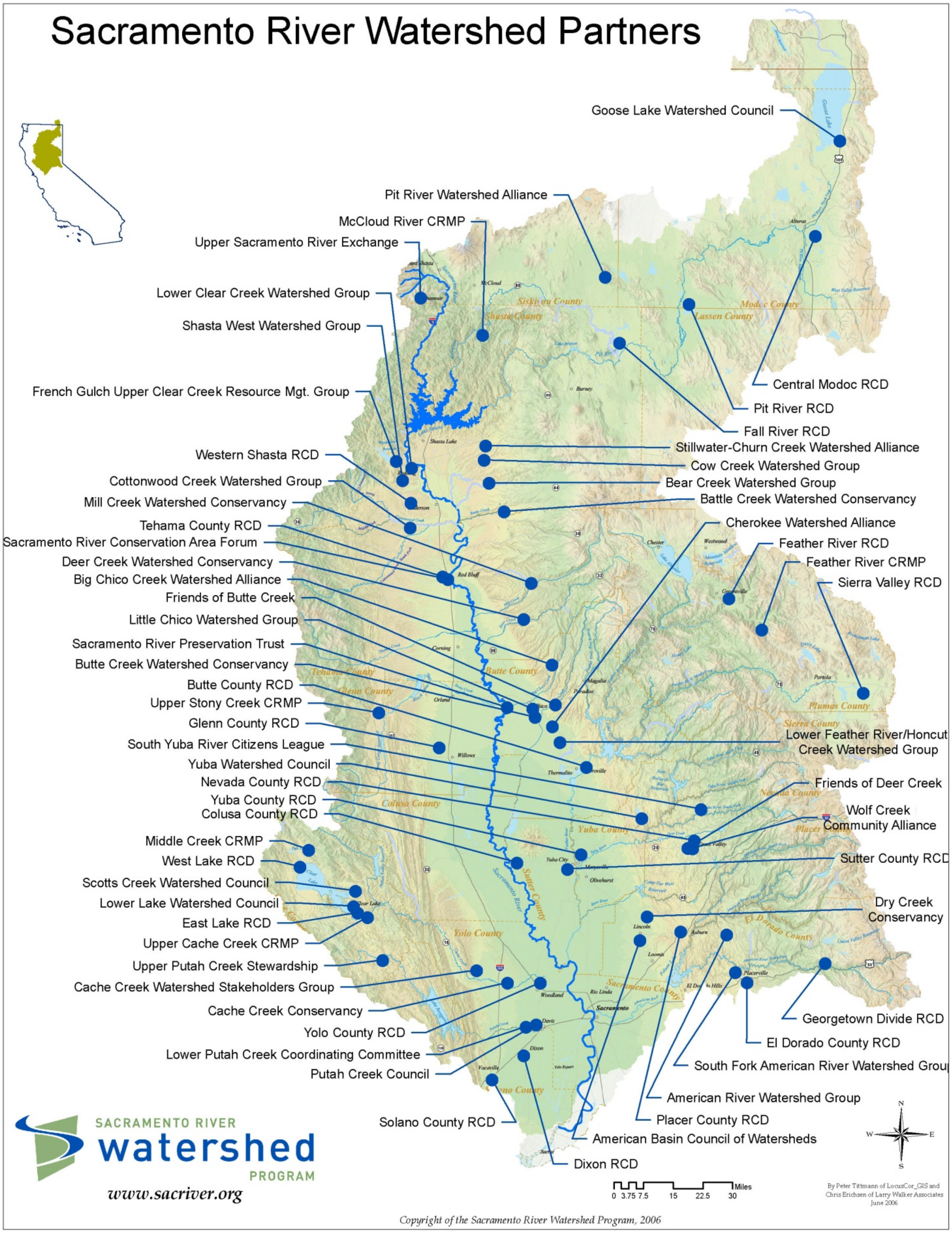


Figure 2. Map of Sacramento River basin watershed groups. (Source: www.sacriver.org. Figure from Exhibit 3 – Salmon Report, p. 61.)



2.6 Downstream Migrant Salmonid Losses at RBDD

Fishery resource investigations conducted at RBDD during the 1970s and 1980s identified severe downstream anadromous salmonid passage problems. Incrementally, over the years, those issues became less prominent and were eventually eliminated with raising of the dam gates year-round. (Exhibit 3 – Salmon Report, pp. 84-85, 123 (Table 2).) Considerable benefits to the anadromous fish populations resulted from these actions.

Table 2. Downstream fish passage improvements at Red Bluff Diversion Dam (RBDD). (Table from Exhibit 3 – Salmon Report, p. 85.)

Fish Protection Measure	Effective Date	Fish Passage Improvement
RBDD lights off at night	1983	Significant reduction in predation when RBDD gates in
Improved louver maintenance	mid-1980s	Major reduction of entrainment when RBDD gates in
Unclogging fish bypass pipe	1985	Major elimination of physical injury when RBDD gates in
Elimination of flow-straightening vanes inside fish bypasses	1985	Elimination of physical injury and mortality of large numbers of juvenile fish
Implementation of spring pulse flow	1985	Significant reduction in salmon mortality at RBDD
Fixing leaks on the Dual-Purpose Canal fish screens	1985, 1986	Elimination of fish entrainment into the Tehama-Colusa irrigation canal
Change in Acrolein treatment in the Dual-Purpose Canal	mid-1980s	Elimination or significant reduction in juvenile salmon mortality
TCC headworks deflector wall	late 1980s	Significant reduction in entrainment when RBDD gates in
RBDD gates out 6 months/year	1987	Major seasonal elimination of predation and significant reduction of predation when RBDD gates in
Abandonment of salmon spawning channels	1987	Elimination of seasonal entrainment and significant reduction when RBDD gates in
Installation of new fish screens	1990	Elimination of entrainment when RBDD gates in
Installation of new fish bypass	1990	Major reduction of predation when RBDD gates in
RBDD gates out 8 months/year	1993	Major seasonal elimination of entrainment and significant reduction of predation when RBDD gates in
RBDD gates out 12 months/year	2012	Remaining seasonal elimination of entrainment and reduction of predation when RBDD gates in

2.7 Actions Implemented for the Recovery of Winter-Run Chinook

Winter-run Chinook was the first run of salmon listed under the federal Endangered Species Act. Prior to this listing, an action plan to benefit the population was developed in 1986 by myself and the Department of Fish and Game (DFG) and subsequently implemented. (Vogel and Hayes 1986.) Most of those actions have since been completed and have benefited not only winter-run, but other runs of salmon and steelhead as well (Table 3). (Exhibit 3 – Salmon Report p. 33.)

Table 3. Restoration actions* developed in June 1986 by Dave Vogel (U.S. Fish and Wildlife Service) and John Hayes (Department of Fish and Game) to benefit winter-run Chinook salmon ("Winter-Run Chinook 10-Point Action Program").	
Restoration Action	**Status**
1) Raise the Red Bluff Diversion Dam gates from December 1 to April 1**	Completed
2) Develop winter-run Chinook salmon propagation program at Coleman National Fish Hatchery	Completed
3) Restore spawning habitat in Redding area	Partially completed
4) Develop measures to control pikeminnow at Red Bluff Diversion Dam	Completed
5) Restrict in-river fishery	Completed
6) Develop water temperature control for drought years	Completed
7) Correct Spring Creek pollution problem	Completed
8) Correct adult migration problems at Anderson-Cottonwood Irrigation District dam	Completed
9) Correct stilling basin problem at Keswick Dam	Completed
10) Continue and expand studies on winter-run Chinook	Partially completed
* Many of these restoration actions are discussed in Exhibit 3 – Salmon Report. ** Note: As of 2012, the RBDD gates are raised (removed) year-round.	

3.0 EXISTING INSTREAM FLOW REGIMES DOWNSTREAM OF THE MAJOR SACRAMENTO RIVER BASIN DAMS NOT ADDRESSED BY THE BOARD REPORTS

The 2009 and 2010 Board reports do not consider the existing flow standards that have already been developed to benefit salmonids throughout the Sacramento River basin. In this regard, NCWA wrote a report (NCWA Report) to compile and summarize those flow standards, and the report was most recently submitted to the Board as Exhibit 4 to the SVWU's April 2012 Comments. Information in that report, as it relates to anadromous salmonids, is highly instructive for the Board Workshop on fishery resources because existing flow standards already in place in the basin to protect the fish populations must be taken into account. The following are highlights of that report.

3.1 Sacramento River

There are a variety of state and federal regulatory measures in place to protect fishery resources in the Sacramento River downstream of Keswick Dam (the upstream terminus for salmon migration). These instream flow schedules were carefully crafted by the fishery resource agencies and water project operators to ensure fish protection downstream of the major dams. These include:

1) A 1960 Memorandum of Agreement between DFG and the U.S. Bureau of Reclamation (USBR) for flow objectives to protect fishery resources in normal and critically dry years, including minimum water level fluctuations. (NCWA Report, p. 2.)

2) A 1981 agreement with DFG and USBR negotiated to eliminate the deleterious effects of salmonid redd dewatering from the original minimum flow of 3,900 cfs during the fall down to 2,600 cfs in the winter. The new agreement established a base flow of 3,250 cfs during the fall and winter. (NCWA Report, p. 2; Exhibit 3 – Salmon Report, pp. 50-51.)

3) SWRCB Water Rights Orders 90-5 and 91-1 modified USBR's water rights to operate Shasta and Keswick Dams and the Spring Creek Powerplant to provide for cold water (56°F) as far downstream from Keswick Dam as practicable during periods when higher temperatures would be harmful to salmon. A Sacramento River Temperature Task Group is responsible for formulating and coordinating appropriate water temperature regimes in the Sacramento and Trinity Rivers each year with the Board having overall authority on the sufficiency of annual plans.

4) At times, the USFWS may use its discretionary use of Central Valley Project Improvement Act (CVPIA) 3406(b)(2) water to benefit Sacramento River fishery resources. (NCWA Report, p. 1.)

5) The 2009 NMFS Biological Opinion outlines a comprehensive strategy to manage Central Valley Project (CVP) operations in the upper Sacramento River basin for the needs of anadromous fishery resources (i.e., primarily winter-run Chinook salmon, but also spring-run and fall-run Chinook salmon). The Biological Opinion specifies Reasonable and Prudent Alternative measures for fish protection in the upper Sacramento River that include flows, water temperature control, and reservoir carryover storage levels, among other measures. That document lists a suite of performance measures to achieve specific water temperature objectives at certain compliance locations downstream of Keswick Dam over varying frequencies in multi-year periods. Those measures are summarized in the NCWA Report at pages 3-7.

3.2 Clear Creek

The 2009 NMFS Biological Opinion specifies a range of Reasonable and Prudent Alternative flow-related measures to benefit salmon production in Clear Creek, including spring attraction flows, channel maintenance flows, spawning gravel replenishment, water temperature objectives, and flows to adaptively manage physical habitat attributes for salmon. Those measures are summarized in the NCWA Report at pages 4-5.

3.3 Wilkins Slough Standard

As mandated by Congress, USBR must comply with a 5,000 cfs navigation flow standard at Wilkins Slough on the lower Sacramento River. For the design of Sacramento River water diversion fish screens, the screen criteria were based on the Wilkins Slough flow standard. A description of the Wilkins Slough standard and interrelationships with the 2009 NMFS Biological Opinion is provided in the NCWA Report at pages 6-7.

3.4 Yuba River

Using a collaborative process, the Yuba County Water Agency (YCWA), DFG, NMFS, USFWS, and environmental groups developed streamflow requirements for the lower Yuba River to address stressors for salmon and steelhead. As a result, in 2008, the Board adopted Corrected Order WR 2008-0014 that implemented the Yuba River Accord's new instream flow requirements and related measures to benefit anadromous salmonids in the lower Yuba River as changes to YCWA's water right permits, thereby resolving 20 years of streamflow disputes. That process was recognized as a landmark achievement for benefits to fish habitat protection and water supply reliability. Those actions are summarized in the NCWA Report at pages 11-12.

3.5 Feather River

In connection with the FERC relicensing of the Department of Water Resources' (DWR) Oroville Project on the Feather River, the Board adopted a water quality certification (SWRCB Order WQ 2010-0016) which contains a range of instream flow and water temperature control requirements downstream of Oroville Dam for both the Low Flow and High Flow Channels to protect fishery resources. Those actions are summarized in the NCWA Report at pages 12-14.

3.6 Lower American River

In 2000, a diverse group of individuals and organizations, working with USBR, DFG, NMFS, and USFWS developed the Flow Management Standard (FMS) which is intended to improve habitat conditions for Chinook salmon and steelhead in the lower American River downstream of Folsom and Nimbus Dams. The FMS includes: 1) minimum flow requirements, 2) water temperature objectives, 3) implementation criteria, 4) creation of an agency group to address river management and operational actions, and 5) a monitoring and evaluation component. These measures are summarized in the NCWA Report at pages 8-10. In its 2009 Biological Opinion for the CVP, NMFS included the FMS flow, operational criteria, agency group, and monitoring requirements as Reasonable and Prudent Alternative measures, and also required an iterative temperature management planning process consistent with water temperature objectives of the FMS.

Collectively, the foregoing instream flow and water temperature standards for the rivers downstream of the major dams in the Sacramento River basin provide a wide range of protection for the various runs of anadromous salmonids in the mainstem and major tributaries. It is reasonable to assume that those standards were developed to be protective for fish because the measures were formulated in concert with the fishery resource agencies based on site-specific conditions downstream of each dam.

4.0 SUMMARY ON UPSTREAM RESTORATION PROGRESS

To summarize, in most respects and relative to other parts of the state, habitat conditions for anadromous fish in the Sacramento River and its tributaries have improved significantly over the past two decades, as evidenced by the following:

- Adult fish passage at many important upstream migration barriers has been extensively improved in recent decades and some major barriers have been completely removed, providing fish access to upstream areas essential for increased fish production.

- Thermal conditions in the rivers downstream of large dams have dramatically improved, yielding critically important protection of fish during highly temperature-sensitive periods in the life cycle.

- Remedial actions at the abandoned Iron Mountain Mine near the upper Sacramento River have largely eliminated a previous major source of fish mortality.

- A massive program over the past two decades to screen unscreened or inadequately screened water diversions costing approximately $574 million has resulted, or will soon result, in protection of fish at most diversions, which collectively divert a maximum of nearly 13,000 cfs.

- Watershed restoration programs to protect and enhance conditions on numerous tributaries have proliferated in recent times and are believed to have benefited fish habitats and overall watershed health.

- Improved flow regimes in the rivers downstream of the Sacramento River basin's major dams have been implemented in recent decades, providing fish protection during all the freshwater life phases.

Although there has been unprecedented progress toward salmonid restoration in the Sacramento River valley by the implementation or near implementation of the most significant restoration measures to date, not all of the upper basin problems for fishery resources have been solved. There are some additional up-river actions which would benefit salmonids in the Sacramento River basin that I have identified and recommended in the Exhibit 3 – Salmon Report and other forums, but are not fully discussed here; these include:

- More aggressive spawning gravel replenishment programs downstream of dams.

- Better protection of salmonids and improved fishways in the smaller tributaries.

- Improved flows during critical upstream and downstream salmonid migration periods in some of the smaller tributaries with no storage reservoirs.

- Alterations to nighttime lighting on riverine structures to reduce predation.

- Prevention of adult salmon entering the Colusa Basin Drain.

- Juvenile salmon rearing habitat improvements in the mainstem river channels.

5.0 WHY HAVE THE SALMON POPULATIONS NOT RECOVERED?

5.1 Salmon Recovery Takes Time

One of the reasons salmonid populations have not appreciably rebounded is the fact that many up-river restoration actions have only recently been implemented. For example, the raising of the RBDD gates on a year-round basis started only this year. The massive multi-million dollar Battle Creek Restoration Program, which holds great promise for salmon restoration, has only begun with just the initial actions having been implemented with many more yet to come in the near future. Dam removal and improved fish passage on some important salmonid-producing tributaries are other recent actions. Oroville Dam FERC re-licensing provisions to improve fish protection only recently went into effect. Some of the larger, previously-unscreened water diversions on the mainstem Sacramento River were only recently screened to prevent fish entrainment. Gravel injection into the rivers downstream of dams may take years to measurably benefit salmon because the gravel can only be mobilized during very high-flow events (that do not naturally occur every year) and the gravels must be re-distributed into areas where salmon will use the substrate for spawning. Importantly, current water project operating requirements and other measures resulting from the 2009 NMFS Biological Opinion have only been in effect for a short time. Responses of the salmon populations resulting from these actions can take years to be realized due to the predominately three-year life cycle of most salmonids. Even if a particular action has resulted in a dramatic beneficial effect on a salmon's freshwater life phase, it will take a minimum of three years to observe those benefits at the adult salmon population level as measured by fish caught in the ocean fishery or returning to the river systems. Additionally, several recent years of poor ocean rearing conditions for salmon in 2005 and 2006 did not help matters due to possible overriding negative impacts on salmon runs compared to other freshwater factors limiting fish production. (Lindley et al. 2009.)

However, even with those foregoing caveats, many other upstream restoration actions were implemented many years ago, and one would have expected to see a measurable response in the fish populations. For example, the AMD from the Iron Mountain Mine was largely eliminated years ago, and that previously well-known source of salmon mortality is gone. Although the TCD on Shasta Dam went into operation in 1997, the release of cold-hypolimnetic water from the dam's spillway already had been implemented from 1987 through 1996. Although the RBDD gates are now raised year-round, the adverse impacts from the dam's operations were largely eliminated for most salmon runs because gates had already been seasonally raised when most fish passed the dam and, as previously discussed, numerous other beneficial measures had been implemented many years ago. The first releases of juvenile winter-run Chinook salmon from Livingston Stone National Fish Hatchery (located at the foot of Shasta Dam) into the Sacramento River occurred in 1998 (USFWS 2011) and appeared to result in a positive response, but the populations subsequently returned to low levels in the most-recent years (shown in Figure 4 later in this submittal). Many other examples exist. These circumstances suggest that some other problems significantly limiting the salmon populations have not yet been addressed and/or solved.

5.2 Problems for Juvenile Anadromous Fish in the Delta Have Not Been Eliminated

The CVPIA fish restoration program has made actions in the Delta region the highest priority within the Central Valley because it is exceedingly degraded. All Central Valley anadromous fish must pass through the Delta as juveniles and adults, and some of these fish rear there. (Cummins et al. 2008.) Impacts on young salmonids entering the Delta are extremely important because those fish have already survived density-dependent factors (e.g., redd superimposition, disease) and density-independent factors (e.g., temperature, dessication, siltation) in upstream areas. In other words, those fish reaching the Delta would be expected to have the highest survival rates as compared to all earlier life phases (e.g., a salmon smolt reaching the Delta has a higher probability of surviving to an adult fish than a salmon fry in one of the upstream-most river reaches). The earliest life phases suffer the greatest losses, whereas the later life phases can be expected to have higher survival rates and more likely reach the adult life phase, perpetuating the population. Ultimately, minimizing exposure of juvenile salmonids to potentially lethal factors in the Delta will provide a major complement to past and ongoing efforts to save salmonids in upstream areas. (Exhibit 3 – Salmon Report, p. 88.)

With most of the major problems for salmonids in the upper watershed resolved, the Exhibit 3 – Salmon Report provides compelling evidence that the most important remaining factors adversely impacting Sacramento River basin salmonids are in the Delta. Although there are additional restoration actions warranted in the upper watershed, the Delta has the highest priority opportunities to increase the survival of salmon. The following discussion provides examples.

5.2.1 Habitat Quantity and Quality (Lack of Sufficient Shallow-Water Rearing Habitats)

The loss of shallow-water rearing locales for salmon in the Delta has been severe. (Cummins et al. 2008.) Lindley et al. (2009) summarized this salmon habitat problem in the Delta as follows:

> *One of the most obvious alterations to fall Chinook habitat has been the loss of shallow-water rearing habitat in the Delta. . . . From this perspective, the biggest problem with the state and federal water projects is not that they kill fish at the pumping facilities, but that by engineering the whole system to deliver water from the north of the state to the south while preventing flooding, salmon habitat has been greatly simplified.*

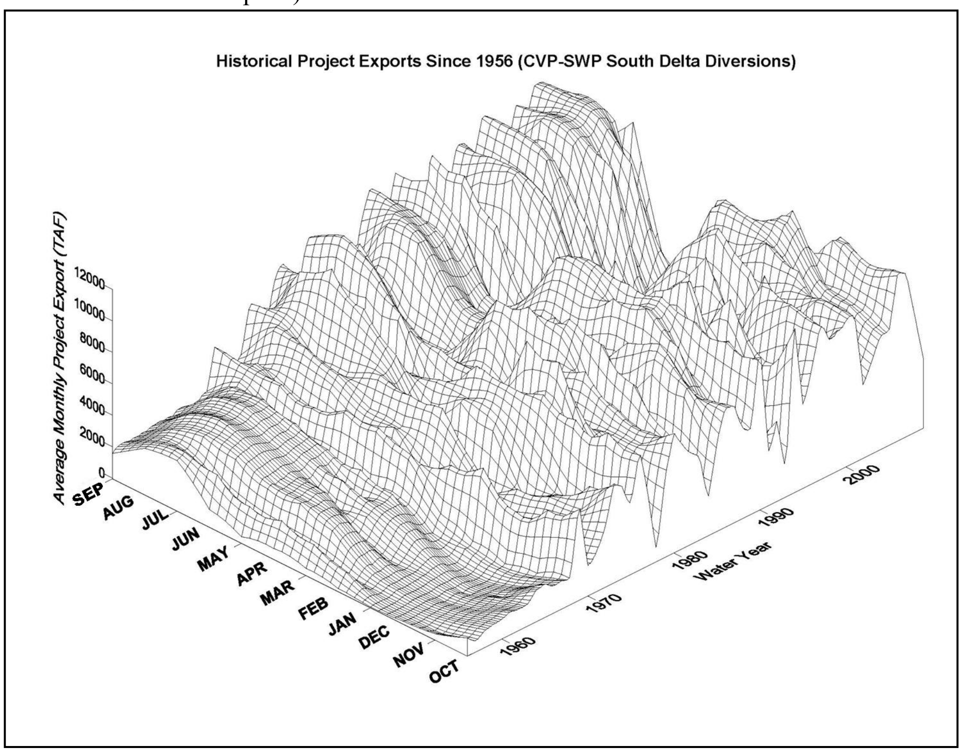
The available habitats where USFWS personnel can seine in the Delta to monitor the relative abundance and distribution of rearing fish are limited due to the low presence of naturally occurring shallow-water areas. In some instances, recreational swimming beaches and boat ramps have been used to sample fish because most areas are deep and rip-rapped. In studies where fish sampling to compare shallow beaches with rip-rapped zones was achieved, salmon fry densities were higher in shallow beach areas. (McLain and Castillo 2009.) An obvious restoration measure which should be pursued to a larger degree because of its high probability of success, is the re-creation of shallow, near-shore water habitats that juvenile salmon prefer in the Delta (as contrasted to flooded islands). These types of Delta restoration actions have not been forthcoming. Importantly, these sites must be designed to avoid creation of predatory fish habitats and be established in locations likely to be utilized within the principal fish migration corridors. Some actions implemented in the Delta under the auspices of benefiting native fish (e.g., flooding islands) have actually backfired, making conditions worse. (Exhibit 3 – Salmon Report, pp. 93, 120-123.)

5.2.2 Correlation with South Delta Exports

The increase in south Delta water exports corresponds with the period when significant declines of anadromous fish occurred. Reverse flows, entrainment of fish into the pumping facilities, and increased predation at water facilities have been believed to be problems for salmon for a long time. (Reynolds et al. 1993.) Prior to 1966 and during the earlier era of the CVP (pre-San Luis

Reservoir), CVP south Delta exports were concentrated in the spring, summer, and early fall, with only minor exports in the late fall and winter. More specifically, the seasonal Delta export pattern was a peak in summer and a low in winter (Figure 3). The timeframe of this pattern coincided with larger populations of anadromous salmonids. After the mid-1960s, when the SWP and San Luis Reservoir facilities began operation, the south Delta exports continued year-round with more reliance on winter-spring diversion; this era corresponds to the period when the populations of anadromous salmonids experienced a precipitous decline. More recently, total annual exports from the Delta increased, from a maximum of about 5 million acre-feet (MAF) in the late 1990s to about 6 MAF after 2000. (EPA 2011; Exhibit 3 – Salmon Report, p. 105.) The mechanisms explaining how south Delta exports directly and indirectly impact salmon are complex and have been discussed in numerous previous Board workshops and proceedings. It appears this problem has gotten worse, not better, for salmonids.

Figure 3. Historical south Delta exports (SWP and CVP combined) since 1956 (data from DWR DAYFLOW). (Figure from Exhibit 3 – Salmon Report.)



5.2.3 Predation

Predation of anadromous fish has emerged as one of the hypothesized primary sources of mortality in the Delta. Although over 200 exotic species have been introduced into the estuary and the rate of invasion is apparently increasing (Cohen 1997), the greatest probable impact to native anadromous fish would be expected from only several introduced predatory species (e.g., striped bass and largemouth bass). Beginning in 1992, DFG ceased stocking juvenile striped bass in the Delta due to concerns of impacts on winter-run Chinook salmon. (IEP 1992a.) Nevertheless, the population of sub-adult and adult striped bass capable of preying on native juvenile anadromous fish remains large. DFG introduced the Florida strain of largemouth bass into the Delta in the early 1980s and the sport fishery for this species has become increasingly popular during recent decades. (Lee 2000.) Amazingly, given all the focus and enormous expense on anadromous fish protection in upstream areas, predation mortality in the Delta has received little attention in the form of remedial actions. For many years most of the attention has focused on predation in the south Delta, keying in on the two large water export facilities, but insignificant or no corrective actions have been implemented. (Exhibit 3 – Salmon Report, p. 106.)

5.2.3.1 Clifton Court Forebay (CCF)

Numerous studies of predators in CCF have been conducted, but little action has transpired to control the predators or alleviate the site-specific problem (other than federal Biological Opinion measures controlling water exports). Recent studies using acoustic-tagged juvenile salmon and acoustic-tagged striped bass empirically demonstrated the severe predation problem in CCF. Specifically, a very small area immediately behind the CCF gates was shown to harbor striped bass for extended periods (Vogel 2010a, 2010b), and mortality was significant when salmon passed under the gates and were eaten by predators (Vogel 2010a). This isolated predator haven undoubtedly causes the highest mortality for anadromous fish reaching the south Delta and will remain significant without corrective measures. (Exhibit 3 – Salmon Report, pp. 107-108.)

5.2.3.2 Tracy Fish Facilities (TFF)

Predation mortality at the TFF has been a long-known serious problem for anadromous fish. These issues are well-described in a recent peer review of CVPIA restoration program activities, which was highly critical of the lack of significant efforts to correct the problem:

> *. . . the operation of the Tracy Pumping Plant and Fish Collection Facility is a serious mortality source for salmon and steelhead (and for Delta smelt). All aspects of the pump operations have significant adverse impacts on salmon and steelhead, from the way juveniles are drawn to the pumps and away from the natural migration routes out through the Delta, to predation and other mortality factors in the channels leading to the pumps, to high mortalities at the out-dated louvers screening the pumps, to even higher mortalities likely during the archaic "salvage" collection and transport operation at the pumps, to predation mortality at the point of re-release, and finally to the overall adverse effects on salmon survival and productivity from regulating and diverting that much of the natural Delta outflow. Data on direct and indirect juvenile mortality is uncertain but likely to be high, and may run as high as 50% for spring-run Chinook and steelhead, and possibly 75% for winter-run Chinook.* (Cummins et al. 2008.)

Recent studies using acoustic-tagged juvenile salmon found that fish mortality near the TFF may be much higher. For example, in 2007, mortality of tagged salmon in front of the facilities was estimated at 100% and no tagged salmon successfully reached the downstream fish salvage facilities. (D. Vogel, Natural Resource Scientists, Inc., unpub. Data.) Detailed analyses of recorded acoustic "signatures" from data loggers at the site determined that predators just upstream and downstream of the trash racks in front of the TFF had consumed the tagged salmon. The magnitude of striped bass accumulation in the area was demonstrated in 1991 when USBR personnel removed 1,925 striped bass during periodic, quarterly sampling from the TFF. (IEP 1992b.) Until the site-specific predation issues are resolved at this facility, mortality of juvenile salmonids reaching the south Delta will continue to be significant. (Exhibit 3 – Salmon Report, pp. 108-110.)

5.2.3.3 Fish Salvage Release Sites in the Western Delta

All fish entrained toward the state and federal south Delta water export facilities experience a "dead end" on the migration route. Because of the net southerly flow created by the water export processes, artificial intervention is necessary to screen the exported water, then capture and transport the fish to one of four active release sites in the western Delta (Miranda et al. 2010) out of the water export influences. However, only a small proportion of juvenile salmon and other fish species successfully negotiating the numerous hazards in the south Delta in the vicinity of these water export operations reach the fish salvage facilities at the state's Skinner Fish Facilities at the south-west portion of CCF and the TFF. This circumstance is primarily attributable to predation which occurs en route to the salvage facilities. (Vogel 2011a.) Among those rescued, the subsequent collection, handling, transport, and release of the fish back into the Delta is also believed to result in high mortality. Cummins et al. (2008) described the fish salvage collection and transport operations at the TFF as "archaic" and the associated mortality among salvaged fish, including predation at the fish release sites, as a serious problem. The methods for fish collection, handling, transport, and release at the state's Skinner Fish Facilities are similar to those at the federal facility. Despite the many years of well-known problems at these facilities, little, if any, actions have been implemented to minimize this source of high fish mortality in the Delta.

5.2.3.4 Predation "Hot Spots"

Studies in the Delta have demonstrated that juvenile salmon mortality can be very high at localized "hot spots." Predation on juvenile anadromous fish is unlikely to be uniform throughout the Delta, but rather concentrated in limited areas where unique site-specific conditions favor this behavior such as: scour holes, bridge piers, remaining false bridge works, docks and marinas, wastewater treatment outfalls, agricultural intakes and outlets, and breached levees. While the effects of these Delta "hot spots" have never been evaluated, the cumulative predation mortality could, and likely does, have a major adverse impact on juvenile anadromous fish. (Exhibit 3 – Salmon Report, pp. 113-123.)

5.2.4 Summary on Delta Problems for Anadromous Salmonids

Overall, predation is likely the highest source of mortality to anadromous fish in the Delta. Despite many years of well-known predation activity at a variety of Delta locations, very little progress (in many instances, no progress) has been made on ameliorating those problems. Ironically, some measures implemented in the Delta under the auspices of improving fish habitats have likely increased this circumstance (e.g., flooding islands). The best available evidence indicates that the predation predicament has gotten worse, not better, during recent decades.

Both the state and federal fish salvage facilities and associated operations have been studied for decades. Many of the evaluations have focused on fish louver screening efficiencies and other mechanical concerns, predation within the facilities, debris loading problems, and fish transportation/release issues, among others. However, arguably, not much has been accomplished in terms of actions to reduce overall fish mortality. Among the most relevant and serious dilemmas facing the fish salvage operations are: 1) predation on fish in the vicinity of the facilities and 2) predation on salvaged fish at the four release sites in the western Delta. Despite decades of studies, little progress has been made on alleviating these severe issues.

Despite the enormous, unprecedented actions to improve fish production in the upper watersheds, there has been a remarkable lack of focus or progress to increase shallow-water rearing habitats, and fix the serious predation mortality in the Delta, through which all fish must migrate. Until large steps forward are made on correcting these in-Delta problems, it is likely that many of the benefits of upstream actions will continue to be negated.

6.0 BIOLOGICAL PROBLEMS FOR SALMONIDS ASSOCIATED WITH A HIGH UNIMPAIRED FLOW CRITERIA

The 2010 Board report concludes that potential extremely high unimpaired Delta inflow and outflow criteria would be the most appropriate action for the Board to take in amending the Bay/Delta Water Quality Control Plan to protect anadromous salmonids. However, it is my opinion that implementation of such criteria would have a high potential of largely undoing the decades of progress in restoring conditions for salmonids in the Sacramento Valley. Recognizing those serious potential adverse impacts, the 2010 Board report is appropriately replete with statements affirming that modeling studies should be conducted to examine the feasibility of implementing high unimpaired flow criteria.

> *Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 6.)

> *Thorough temperature and water supply modeling analyses should be conducted to adaptively manage any application of these flow criteria to suit real world conditions and to best manage the competing demands for water needed for the protection of public trust resources, especially in the face of future climate change.* (2010 Board report, p. 94.)

> *Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both outflow and cold water temperature goals.* (2010 Board report, p. 108.)

> *Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 112.)

> *Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 118.)
>
> *Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 123.)
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> *Temperature and water supply modeling analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 123.)
>
> *Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.* (2010 Board report, p. 136.)

An April 25, 2012 report by MBK Engineers, submitted to the Board as Exhibit 2 to SVWU's April 2012 Comments, provides results of the water supply modeling effort that was necessary to determine the efficacy of the high unimpaired flow criteria proposed in the 2010 Board report. Although that 2010 Board report suggests proposed criteria of 75% of unimpaired flow for Delta inflow and outflow during January through June, the MBK report demonstrates that such criteria are not even in the realm of practical application for the Sacramento River basin. Instead, for reasons described in that document, analyses of 50% and 40% of unimpaired flows were conducted. Even at these lower percentages, the MBK report demonstrates that severe adverse impacts to Sacramento River basin water supplies and concomitant impacts on fishery resources would occur. Notably, even those analyses were conservative because the modeling results underestimated the impacts that would actually occur. (April 25, 2012 MBK Report, p. 12.)

One of the noteworthy findings in the MBK report states:

> *Although there were hydrologic fluctuations and varying regulatory requirements during the post-1944 period, the January through June averages of Delta inflows as percentages of unimpaired flows into the Delta from the Sacramento River have changed minimally during this almost 70-year period.* (April 25, 2012 MBK Report, p. 8 and Figure 5, p. 9.)

The biological significance of this circumstance is that during many post-dam construction years, the Sacramento River basin salmonid runs were large; however, the fishery resources have generally been steadily declining in recent years. Although correlation does not mean causation, if there had been a pattern of decreasing Delta inflows over time corresponding to fishery resource declines, it could suggest a potential cause-and-effect, but that has not been the case.

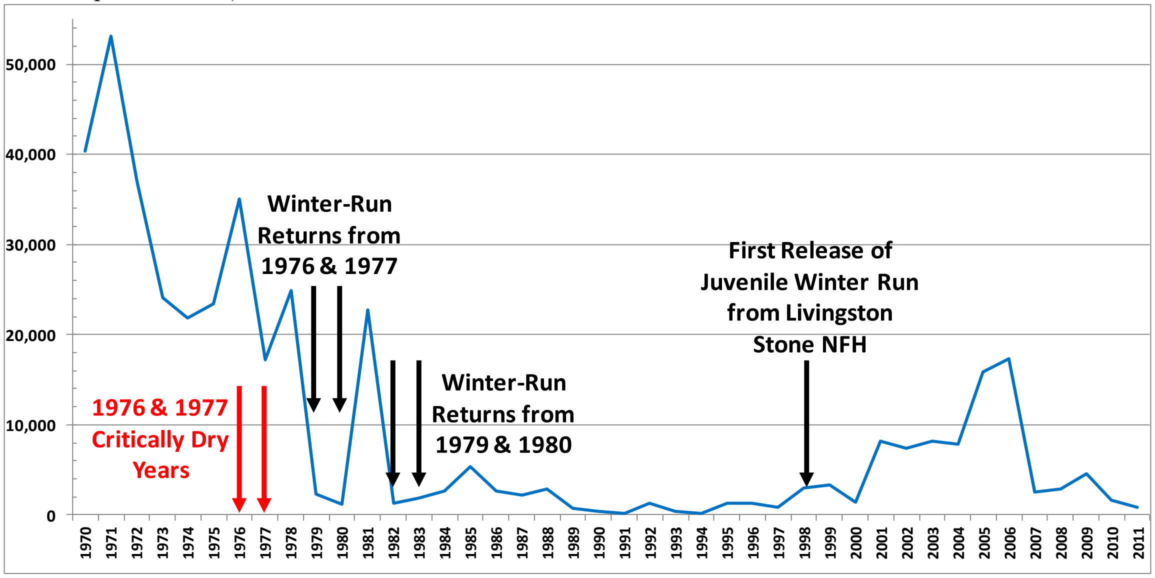
The MBK report also provides insight into the ancillary adverse environmental impacts that could result from attempts to implement 50% and 40% unimpaired flow criteria. Besides significant reductions in wetlands and wildlife habitats, increased groundwater pumping would likely occur causing impacts to groundwater recharge and resultant decreases in tributary stream flows to the Sacramento River. (April 25, 2012 MBK Report, p. 16.) Reductions in flows in salmonid-producing streams could negatively impact fish production, particularly in streams possessing spring-run Chinook, fall-run Chinook, or steelhead populations. The 2010 Board report does not address those impacts to the environment.

By far, the most-overwhelming adverse effects to salmonids in the Sacramento River basin resulting from attempts to implement high unimpaired Delta inflow and outflow criteria are major reductions in water storage in the large reservoirs (Shasta, Oroville, Folsom). Without this critical water supply available for fishery resources, the negative effects on anadromous salmonids could be devastating. Theoretical implementation of a 50% unimpaired flow requirement as described in the MBK report would deplete storage in Shasta and Folsom in 20% of all years and Oroville in 40% of all years; a 40% unimpaired flow requirement would deplete storage in Shasta and Folsom in 10% of all years and Oroville in 30% of all years. (April 25, 2012 MBK Report, pp. 17-18.) The resulting consequence on salmonids would be severe due to reduced flows and loss of cold water. This would be especially true in multi-year droughts, when the reservoirs' cold-water pools would be depleted in multiple consecutive years. Such depletions of cold-water storage would result in multiple consecutive year-classes of Chinook salmon experiencing highly adverse water temperatures during their spawning and rearing lifestages. Accordingly, during droughts spanning multiple years, some runs of salmonids could go extinct.

Based on the large hydrologic impacts described in the MBK report, it is not even necessary to conduct water temperature modeling to understand that the adverse impacts to salmonids resulting from high unimpaired flows as suggested by the 2010 Board report would be severe. History provides very strong evidence that severe impacts to the Central Valley's salmon would occur as a result of dramatically reduced cold-water storage. In the consecutive critically dry years of 1976 and 1977, Shasta Reservoir and its available cold-water storage were at low levels. As a result, the reservoir released water into reaches downstream of Keswick Dam at temperatures that were lethal to a large portion of winter-run Chinook salmon eggs in the river gravels. As would be expected due to that species' predominantly three-year life cycle, the numbers of winter-run that returned in 1979 and 1980, were dramatically lower than in previous years (Figure 4). This devastating impact on the populations were then propagated into the future such that the poor salmon returns in 1979 and 1980 resulted in similar poor returns three years later in 1982 and 1983, respectively (Figure 4). Based on the MBK report, it is not reasonable to assume that such population-level effects on Central Valley salmon would occur if the Board were to implement Delta flow requirements for the January-June period of even 50% or 40% of unimpaired flow.

Although the Shasta TCD was not in operation and the RBDD gates were down year-round during the late 1970s and early 1980s, those factors could not have overcome the adverse impacts of lost cold-water storage. Even with the TCD in operation, the impacts to salmonids would be far worse with implementation of a 50% or 40% unimpaired flow criteria (as described in the MBK report) in the present day. Effects to other runs of salmonids in reaches downstream of all the major dams (Shasta, Oroville, Folsom) during temperature-sensitive periods would also undoubtedly be severe.

Figure 4. Annual run sizes of adult winter-run Chinook in the Sacramento River, 1969-2011 (source: DFG's GrandTab, April 23, 2012).



7.0 ADDITIONAL OPPORTUNITIES FOR ACTIONS TO BENEFIT SALMONIDS

The Board should consider the following opportunities for implementation of actions to benefit salmonids, which were not addressed in the 2009 and 2010 Board reports.

7.1 Adult Salmon Blockage by the Delta Cross Channel (DCC) Gates

Once adult salmon enter the Mokelumne River system upstream of Georgiana Slough and the DCC gates are subsequently closed, those fish become "trapped" in that river system and can only re-enter the Sacramento River by migrating back downstream (uncharacteristic of upstream migrating anadromous fish) or when the DCC gates are reopened. (Exhibit 3 – Salmon Report, pp. 29, 38.) A structural solution to this problem is available and should be implemented.

7.2 Adult Salmon Blockage at Fremont Weir and Other Flood-Control Weirs

Adult salmon attracted into the Yolo Bypass during flood flows can become stranded or blocked at Fremont Weir when flows recede. (Exhibit 3 – Salmon Report, pp. 29, 38.) The same problem exists for the other three flood-control weirs on the Sacramento River. Structural solutions to these problems are available and should be implemented.

7.3 Alleviate Predation Problem Areas in the Delta

The previously discussed, key locations in the Delta where predatory fish are concentrated ("hot spots") should have remedial actions developed and implemented to reduce predation losses of anadromous fish.

7.4 Fix Problems with Breached Delta Levees

There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have not only changed the tidal prisms in the Delta, but have also changed the degree in which juvenile fish are advected back and forth with the tides. Additionally, many of the breaches were narrow, creating deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example. Recent acoustic tagging of striped bass in this vicinity confirmed a high presence of this fish. (Exhibit 3 – Salmon Report, pp. 120-123.) Potential solutions to avoid predation at breached levees should be developed and implemented. For example, "feathering" back these levees over a much wider area instead of keeping the narrow channels would reduce high water velocities, reduce scour hole formation, and lessen predation opportunities as tides flood and ebb.

7.5 Re-Create Shallow-Water Delta Rearing Habitats

Significant actions should be implemented to re-create shallow-water rearing habitats for anadromous fish in the primary migratory corridors of the Delta. However, those restoration sites should be designed to minimize predation.

7.6 Implement a Predatory Fish Removal Program at the South Delta Water Export Facilities

An aggressive predator removal program at the CCF and TFF should be designed and implemented. The removal should be either lethal or by relocation to waters not connected to the Delta.

7.7 Avoid Creating Predation Problems at Future Delta Structures

Plans for future structures, including habitat restoration projects, contemplated in the Delta should recognize and avoid the potential predation hazards for anadromous fish.

7.8 Appropriate Flow-Based Actions

Based largely on tagging studies of hatchery fish, a significant increase of freshwater flow in the Delta has been suggested as a principal factor benefiting survival of anadromous fish. (Brandes and McLain 2001.) Juvenile anadromous salmonid emigration through the Delta usually occurs during the fall, winter, and spring months, depending on the particular species and run. Naturally high flow years during wet hydrologic conditions are generally believed to provide favorable conditions for juvenile fish in the Delta.

However, the specific threshold of flow necessary to provide good survival for anadromous fish has yet to be determined. The causal effects of flow/survival relationships have been difficult to ascertain because of complex inter-relationships with numerous variables associated with flow. The following are just some examples, and many others exist. Flow can affect turbidity, which is known to stimulate juvenile salmon outmigration. Higher turbidity, increased channel velocities, and faster outmigration timing may positively affect juvenile fish survival by reducing predation and exposure to hazards. Increased flows of high magnitude can result in large numbers of young fish using flood bypasses where survival and growth may be better than mainstem reaches. Increased flows can affect the proportional distribution in various migration routes in the north Delta (e.g., mainstem, Sutter, Steamboat, and Georgiana Sloughs) where survival rates can be different. The magnitude of flow alters the extent of tidal excursion in some lower reaches, which can alter migration timing and routes. Increased flows may affect the relative abundance and distribution of predatory fish in key salmon migration corridors. Higher flows may also alter lateral fish distribution in river channels affecting migration routes. (Exhibit 3 – Salmon Report, pp. 89-91.)

However, little progress has been made on parsing out the various factors related to flow that may influence fish survival. Most fish tagging studies over the past several decades have appeared to simply conclude "more flow is better," without determining numerical thresholds or examination of site-specific causal mechanistic effects of flow on survival. This circumstance is partially attributable to study designs reliant on relatively few releases of coded-wire tagged salmon annually at only several locations under limited environmental conditions. Additionally, those studies required years to complete due to waiting for tag recoveries from adult fish that are captured in the fisheries or return to the rivers, cumulating in only a few data points for each year. Perhaps most importantly, there has been a lack of data collected on other factors (e.g., site-specific environmental conditions in the Delta, relative distribution and abundance of predatory fish) that could have affected survival after juvenile fish were released. Plainly stated, the traditional coded-wire tagged hatchery salmon studies have run their course. Future research should place more focus on this topic using different (and more modern) techniques and analytical tools. There is promise in this area of research with using miniaturized radio and acoustic transmitters to evaluate fish movements, but some of these studies have been highly prone to errors if not properly implemented and analyzed (discussed later in Scientific Uncertainties) (Vogel 2010a, Vogel 2011b) and, very importantly, have not been designed to determine specific sources of fish mortality. Much like the coded-wire tag efforts, some recent telemetry studies have only been oriented toward attempts to estimate overall survival in very long reaches of the Delta. That approach is unlikely to yield the site-specific data that is necessary to lead to remedial actions for increased fish survival. Regardless of the techniques, enough studies have been conducted over the decades to demonstrate overall fish survival through the Delta is poor. A new approach should be designed and implemented to determine: 1) exactly where mortality is occurring and 2) how to fix the specific problems where they are occurring. (Exhibit 3 – Salmon Report, pp. 89-91.)

The large-scale increases in reservoir releases that would be necessary to implement proposed new high unimpaired flow criteria (2010 Board report) are examples of a proposed approach to use flow, and flow alone, as a possible means of trying to alleviate non-flow related stressors in the Delta. As described above, there are many variables intertwined with flow that may be the most important to affect fish survival. Depending on the timing, magnitude, and duration of flow increases, reservoir releases to downstream areas according to schedules different than existing regimes could have beneficial effects on anadromous fish (if those releases do not impact cold-water storage and water supplies needed at other important periods for fish). For example, increased reservoir releases at appropriate times could have beneficial effects on outmigrant fish through enhanced floodplain rearing; alternatively, if not appropriately implemented, such releases could be devastating to large numbers of fish through stranding and high predation mortality in flood bypasses. Increased transport timing through suitably timed pulse flows could raise turbidity, stimulate outmigration, and reduce transport timing from upstream to downstream areas. Presently in the Sacramento River basin, such flows frequently occur naturally through accretions and flood control operations (discussed below). However, flows must be carefully timed and tailored to specific needs, instead of one all-encompassing high percentage of unimpaired flow throughout much of the year and in every watershed as contemplated by the 2010 Board report. As previously discussed, the problem is that the underlying reasons for how flow precisely affects survival of fish in the Delta are lacking, and the site-specific problems are not being addressed. (Exhibit 3 – Salmon Report, pp. 89-91.)

7.8.1. Pulse Flows

To enhance the outmigration success of juvenile salmon to the Delta, using an adaptive management approach such as short-duration pulse flows in the spring while avoiding impacts to other beneficial purposes (e.g., cold-water storage, water supply, etc.) may be an option for the Board to consider. However, creative reservoir re-operation scenarios may be required to ensure adverse impacts to fishery resources and water supplies do not occur. Additionally, it must be recognized that pulse flows, as an action by itself, cannot overcome all the problems in the Delta. Previously described remedial actions on in-Delta problems still must be pursued. The following discussion addresses this topic.

The majority of the salmon emigration in wet winter conditions occurs January through March. (Vogel and Marine 1991.) In wet and above-normal water years, sufficient accretions and reservoir releases for flood storage control result in high numbers of fry-sized fall-run salmon to emigrate from the upper river to the Delta either through volitional or non-volitional mechanisms. High water velocities and turbidity are likely the primary causal factors. A later emigration of juvenile salmon occurs in April and May as smolts if the fish have not already emigrated from the primary rearing grounds in the upper river (Vogel 2012), particularly in years when significant storm events are lacking.

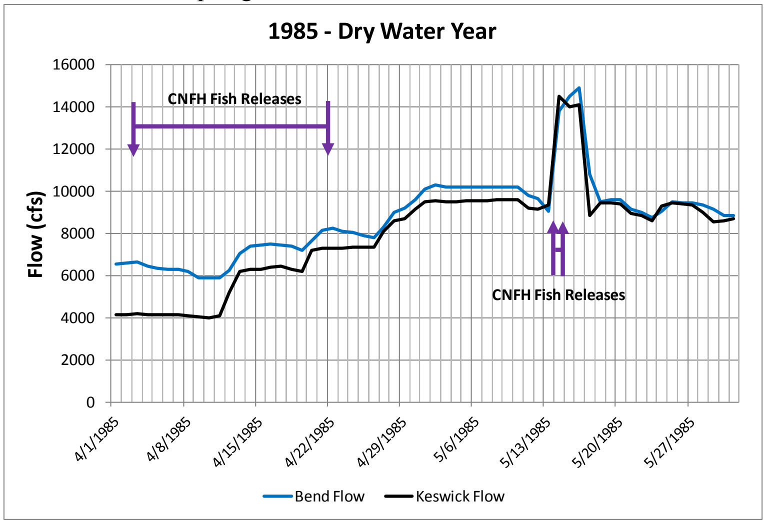
Some of the most-robust datasets on the outmigration of juvenile salmon from the upper Sacramento River were developed by the USFWS juvenile fish trapping program just downstream of RBDD. Using a series of rotary screw traps, both when the dam gates were in (down) and out (up), USFWS found that the highest captures of young fall-run Chinook occurred in January, February, and March, coinciding with high flow and turbidity events. Those results corroborated earlier USFWS salmon research by Kjelson et al. (1982) and Vogel (1982, 1989), in which they reported increased downstream movements of fry Chinook relating to increased river flows and turbidity, respectively. However, if flows or turbidity are low in the spring during water years classified as wet and above-normal, later-emerging salmon must emigrate as smolts when hazards to the fish are greater in the lower river and Delta (e.g., predation, entrainment, stressful water temperatures). In particular, in below-normal, dry, and critically dry water years, if sufficient reservoir releases from flood storage control operations or accretions from storm events have not occurred in the winter, a higher proportion of an entire salmon brood year may emigrate later, again, when hazards are greater.

The rationale for the timing of the pulse flows is to provide sufficient environmental cues (e.g., increased water velocities, increased turbidity) to stimulate the outmigration of the largest-sized juvenile salmon remaining in the upper river prior to the onset of stressful or lethal warm water temperatures in the lower river and Delta. Additionally, the pulse flows are intended to increase fish survival through reduced predation in the lower river and reduced entrainment into the interior Delta where survival is low. During wet years, although most of the salmon have already left the upper river as fry, a significant portion of the largest-sized salmon remain until the spring when the fish emigrate as smolts. These larger-sized salmon are particularly important to protect because those fish have a higher survival rate than fry-sized salmon and may provide a greater contribution to future salmon runs. The pulse flow timing would be later in wet and above-normal water years as compared to drier years because the larger fish are believed to remain rearing longer in the upper river due to cooler water temperatures. In dry water years, the majority of juvenile salmon may remain in the upper river until the spring months; providing environmental cues to stimulate the outmigration of these fish are particularly important to minimize potentially high mortality through the lower river and Delta earlier in the spring. The duration of pulse flows would decrease with drier year conditions to conserve water for other beneficial uses later in the season (e.g., cold-water storage, spawning flows, water supplies, etc.).

In May of 1985, I developed the concept of implementing the first use of significant pulse flows to stimulate the outmigration of fall-run Chinook salmon in the Central Valley. In that dry water year, USBR, at the request of the USFWS, increased Keswick Dam releases over a three-day period to assist in the outmigration of juvenile salmon. The increased pulse flow was elevated to the Keswick Dam power plant capacity of 14,000 cfs[4] from 9,000 cfs on May 13 (Figure 5). In a coordinated program with Coleman National Fish Hatchery (CNFH), 4.3 million fall-run Chinook, including some tagged salmon, were released into Battle Creek at 3 a.m. the following morning (May 14). Based on real-time monitoring, the bulk of the salmon passed Red Bluff around 10 p.m. on May 14. A significant increase in river turbidity was caused by the onset of the pulse flow and it appeared that a large number of naturally-produced salmon moved with it. Also, as part of the coordinated pulse flow effort, further downstream near Hamilton City, Glenn-Colusa Irrigation District (GCID) curtailed pumping operations to assist salmon passage at the old, ineffective DFG screens positioned in front of the GCID pump station. The USBR concurrently requested other water diverters on the Sacramento River to voluntarily and temporarily curtail pumping during the pulse flow period. Trawling at Chipps Island in the western Delta showed that most of the hatchery fish reached that area eight days following release from the hatchery with an average travel time of 1.4 miles/hour. The trawling data also indicated that most of the untagged salmon also reached Chipps Island at a similar time. (Myshak 1985.) Unfortunately, the DCC gates were open during the period when most of the fish likely reached the DCC and an unknown number of fish were entrained into the interior Delta where survival is poor.

[4] Note: the present-day Keswick Dam power plant capacity is approximately 15,000 cfs.

Figure 5. The timing of pulse flows (cfs) released from Keswick Dam, Bend flows (cfs), and CNFH releases of juvenile fall-run Chinook salmon in the spring of 1985.



The benefits to fish survival from pulse flows caused by or implemented in concert with large storage reservoir flood-control releases and/or significant precipitation events could be considerable. For example, in the spring of 2003, CNFH released the hatchery's entire production prior to and during a combination of Shasta Reservoir flood control releases and large storm events (Figure 6). Two and one-half years later, the resulting return of adult salmon to the hatchery was the highest number of salmon recorded since 1952 (142,673 salmon) and more than 700% higher than the average annual return (source: DFG's GrandTab) (Figure 7). Part of this increase was attributable to changes in hatchery operations allowing the hatchery to take in more fish which may otherwise spawn downstream of the hatchery in Battle Creek. However, even when combining the annual returns to both the hatchery and Battle Creek, the return of salmon two and one half years later was the second highest on record.

Figure 6. Releases of CNFH juvenile fall-run Chinook salmon into Battle Creek, average daily Keswick Dam releases (cfs), average daily flow (cfs) at Bend Bridge, water turbidity at Bend Bridge [nephelometric turbidity units (ntu's)] and precipitation events, April 1 – May 31, 2003.

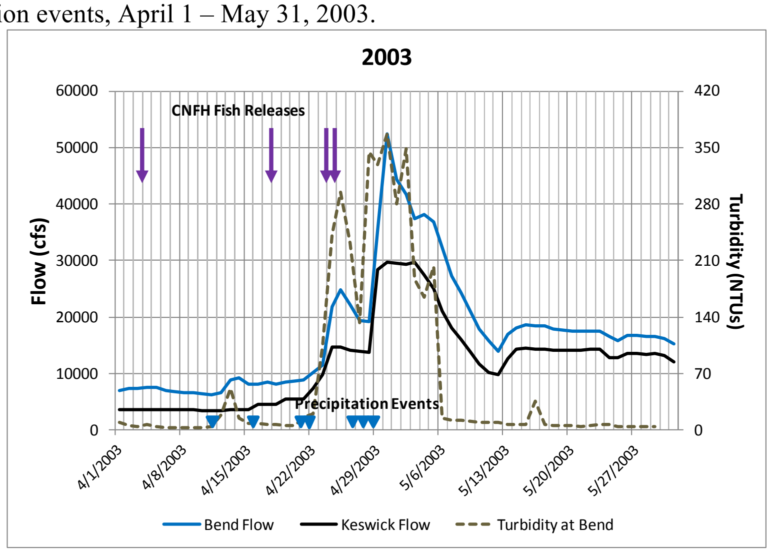
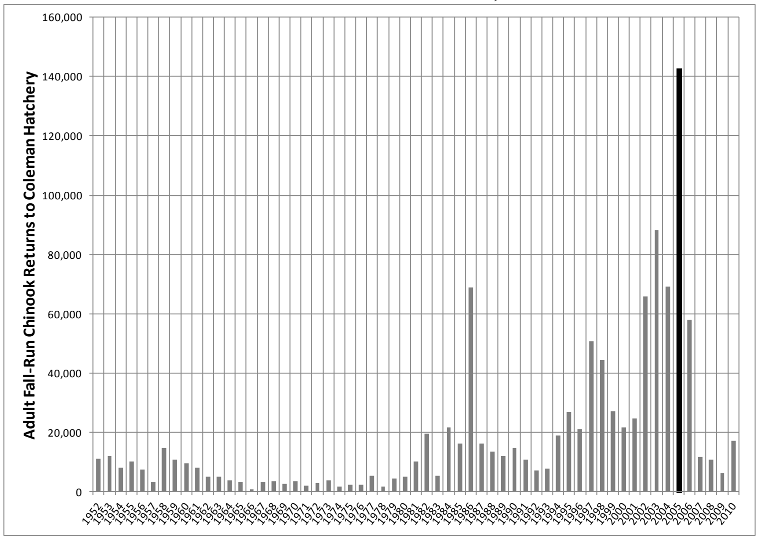


Figure 7. Annual returns of adult fall-run Chinook salmon to CNFH, 1952-2010.



An example of conditions where pulse flows likely could have been implemented without significant adverse impacts to water supplies and cold-water storage occurred in the spring of 2010. Although classified as a below-normal water year (source: cdec.water.ca.gov), Shasta Reservoir nearly filled to capacity. Releasing pulse flows up to Keswick Dam power plant capacity for six days would have provided a major boost in flows to enhance the outmigration survival of salmon (Figure 8), but likely would not have caused significant resultant impacts to water supply and cold-water storage (Figure 9).

Figure 8. Hypothetical pulse flows (cfs) from Keswick Dam and comparable Bend flows (cfs) for a six-day period (April 25 – April 30, 2010) in a below-normal water year to benefit the outmigration of juvenile Chinook salmon.

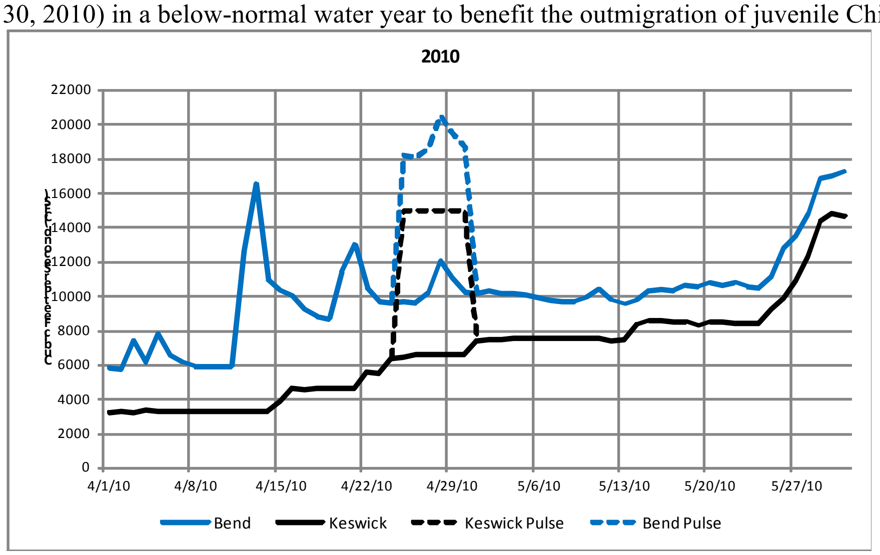
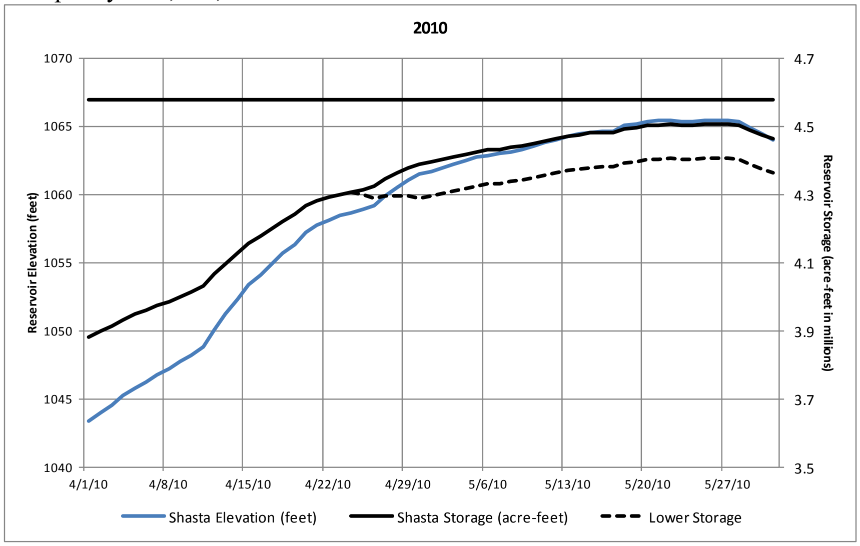


Figure 9. Effect on Shasta Reservoir storage resulting from hypothetical pulse flows for a six-day period (April 25 – April 30, 2010) in a below-normal water year to benefit the outmigration of juvenile Chinook salmon. Horizontal line is the maximum capacity of 4,552,000 acre-feet in Shasta Reservoir at 1067-ft elevation.



Prior to implementation of pulse flows such as described above, modeling studies of water supplies and temperatures would be necessary to determine the feasibility of such actions.

7.9 Water Temperatures and Shasta TCD Fixes

There may be opportunities for improved management of the cold-water pool in Shasta Reservoir through structural alterations to the Shasta Dam TCD and fine-tuning downstream temperature compliance points. The following discussion addresses those points.

The overwhelming driving factor on the utilization of cold-water storage in Shasta Dam and the use of the TCD is to protect winter-run Chinook egg incubation in the reaches downstream of Keswick Dam. In this regard, NMFS has outlined a comprehensive strategy in the agency's 2009 Biological Opinion to manage water project operations for the needs for fishery resources (i.e., primarily winter-run, but also spring-run, fall-run, Delta X2, and other beneficial uses). That document outlines a suite of performance measures to achieve specific water temperature objectives at certain compliance locations over varying frequencies in multi-year periods. On an overall basis, those performance measures appear sound, but may be subject to further refinements to be more effective.

It is unclear if a significant part of the strategy for managing the cold-water pool in Shasta Reservoir includes careful management of relatively warmer water releases (but still safe for salmon) in the late winter and early spring to entice a higher proportion of adult winter-run to migrate further upstream closer to Keswick Dam. This type of operation was one of the original intended purposes of the TCD: conserve the cold-water pool for later in the season and "draw" more adult winter-run into the upper river reaches during upstream migration in late winter and early spring to avoid fish ultimately spawning further downstream where water temperature control is more problematic. (Vogel 1990.) Releasing too much very cold water too early in the season may not provide the majority of winter-run salmon sufficient incentive to migrate farther upstream to more desirable spawning grounds. The operational strategy should be to use the TCD to avoid or minimize winter-run Chinook from potentially spawning in far-downstream reaches, thereby encouraging the fish to move into the upper-most reaches of the river below Keswick Dam. Doing so would provide substantial benefit for preserving the Shasta Reservoir cold-water pool.

In a 1999 Shasta TCD Modeling Study, Higgs and Vermeyen (1999) reported that the TCD had a significant amount of leakage:

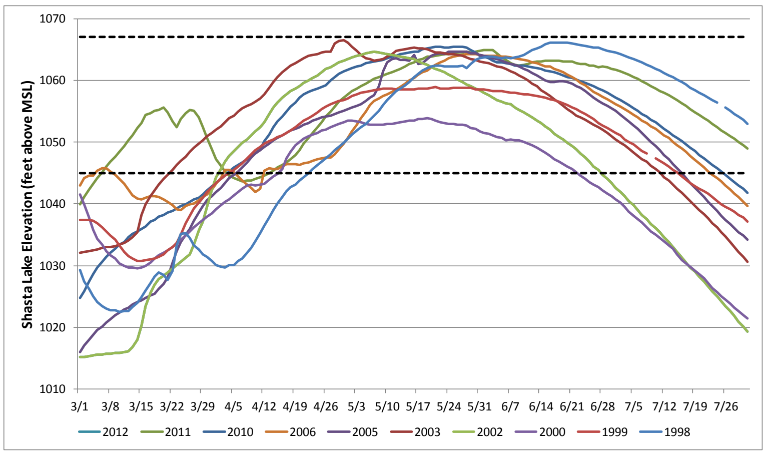
> *The TCD structure has significant leakage area, which impacts outflow temperatures and increases the complexity of the model.*
>
> *. . . it is recommended that if any additional leakage areas are blocked or the TCD is modified, the leakage areas should be recalibrated and a new optimized model be created.*

Since then, much of the leakage was plugged but some still occurs. (T. Vermeyen, USBR, Denver, pers. comm.) There are a variety of small gaps between steel plates on the TCD and between the TCD and dam face; however, the cost of plugging those gaps may be cost-prohibitive to do so when the reservoir is high. Elevated reservoir levels would require divers to work at great depths, which is extremely expensive. However, plugging small gaps on such devices with divers has been conducted elsewhere. Therefore, fixing the remaining leakage on the Shasta TCD would be more cost-effective in years of low reservoir elevations but a cost-benefit analysis would be necessary before doing so. (D. LaFond, USBR, Denver, pers. comm.) As a suggestion to make the operation more cost-effective, submersible remotely operated vehicles could be used in lieu of divers to plug the leaks. Because of the high importance in optimal management of the cold-water pool in Shasta Reservoir (and in recognition of the major expense of constructing the original structure), the remaining TCD leaks should be closely examined and, if warranted, identify the feasibility of this action. Even a 1^{o}F improvement in reservoir releases could be of significant benefit for optimizing water project operations for multiple purposes, including possibly preventing premature depletion of the cold-water pool.

During high reservoir levels, warm surface water in Lake Shasta can enter a large portion of the top of the TCD through trash racks in that location. These conditions can compromise the ability to optimize use of the TCD and make it more problematic to control release-water temperatures by requiring access to deeper, colder water to compensate for the thermal mixing. Placing metal cladding or other suitable materials over the upper portion of the structure could potentially prevent this problem. (L. Ball, Operations Manager, USBR, Shasta Dam, pers. comm.) Reservoir elevation at the bottom of this opening is 1045 feet above mean sea level (MSL) and the top deck of the TCD is at 1072 feet MSL. (D. LaFond, USBR, Denver, pers. comm.) Therefore, accounting for metal structural members and other metal plates, there appears to be approximately $^{\pm}$20 feet of vertical surface where warm water can flow into the top of the TCD during high lake events in the spring. An examination of Shasta Lake levels since the TCD was installed demonstrates that this situation is not rare; it was evident in 10 of the last 16 years (63%) (Figure 10). This issue could be particularly troublesome in managing temperatures for winter-run and preserving cold-water storage for fall-run in October. When examining

Figure 10, note that a large portion of winter-run eggs are in the gravels by June. (Vogel and Marine 1991.) Assuming it is desirable to do so for temperature control purposes, those openings could be sealed with metal cladding (D. LaFond and L. Ball, USBR, pers. comm.) or some lighter-weight material. Because of the potential high importance, it is recommended that the USBR seriously examine the need, feasibility, and cost of sealing off the upper portion of the TCD. This action could be relatively inexpensive and easily accomplished "in the dry" without divers. Any action to significantly conserve cold-water storage, even in high lake level years, would be of significant benefit to both winter-run and fall-run Chinook.

Figure 10. Daily Shasta Lake elevations (feet above mean sea level) from March through July in 10 of the 16 years since the temperature control device (TCD) was installed on the face of Shasta Dam. The elevations between the lower dotted line (indicating the bottom of the TCD trash rack opening at 1045 feet) and the upper dotted line (indicating full pool at 1067 feet) are the approximate conditions where warmer surface lake water can flow freely through the trash racks and down into the TCD.



7.9.1 Temperature Control Compliance Points

The NMFS Biological Opinion may be overly protective of winter-run Chinook to the point of ultimately causing harm to winter-run and fall-run Chinook by depleting too much cold-water storage. This circumstance may be caused by setting a water temperature compliance point too far downstream from Keswick Reservoir (e.g., Bend gauge), which requires substantial releases of cold water from low elevations in the hot summer months. The USBR Biological Assessment for the Operations Criteria and Plan for the Central Valley Project reported that the distribution of total winter-run spawning for the period from 1993 through 2005 averaged 96% in the 18-mile reach from Keswick Dam (RM 302) to Anderson, California (RM 284), and 99% in the 31-mile reach from Keswick Dam to Battle Creek (RM 271), the latter of which is 11 river miles upstream of Bend (RM 260). Notably, this average spawning distribution occurred when the RBDD gates were down (in) from May 15 – September 15. This previous RBDD operation likely adversely affected some winter-run by causing delayed migration resulting in spawning occurring farther downstream, unlike the unimpeded route that is present today since the dam gates are out year-round. Unquestionably, the vast majority of winter-run Chinook spawn in the upper-most reaches where water temperatures are coldest with very, very few fish spawning as far downstream as Bend. Now that the RBDD gates are completely removed from the water, there is no longer delay and partial blockage of migrating winter-run at the dam, which has resulted in an even greater proportion of winter-run spawning further upstream than occurred when the dam gates were in. Unnecessary use of cold water to obtain a temperature compliance point of 56°F at Bend (42 river miles downstream of Keswick Dam) or even Jellys Ferry (35 river miles downstream of Keswick Dam) could unnecessarily reduce the cold-water pool available later in the season, and perhaps in the following year. This continued practice could adversely impact some winter-run and fall-run by reducing the availability of cold water in some years.

Additionally, in a somewhat different problem as posed above, it is postulated here that overly-conservative in-season adjustments to the downstream temperature compliance points could reduce cold-water storage, potentially adversely impacting cold-water storage, and adversely affecting fall-run Chinook spawning in October. For example, if the early-season, downstream-most compliance point is specified at the Bend gauge, then a subsequent decision is made to move the compliance point further upstream (e.g., Balls Ferry or Airport Road), a significant amount of cold water could be lost, resulting in possible adverse impacts for fall-run spawning in October. This circumstance likely occurred in 2010, but was apparently attributable to the fact that aerial counts of winter-run redds were performed late in the season. (Revised 2009 NMFS Biological Opinion.)

8.0 SCIENTIFIC CERTAINTIES AND UNCERTAINTIES

8.1 Juvenile Salmon Emigration

8.1.1 Riverine Environment

The 2010 Board report identifies January through June as the primary period to provide 75% unimpaired flows to benefit juvenile salmon emigration with apparently equal weight given to each of those six months. However, a correlative assumption of the timing and magnitude of salmon emigration during those months would be incorrect and is not demonstrated by extensive empirical data. As previously discussed, salmon emigration is complex and highly variable depending on natural inter- and intra-annual hydrologic conditions and interconnected factors. To demonstrate this point, I examined historical data from the fishery agencies' (USFWS and DFG) juvenile salmon monitoring programs in the upper and lower Sacramento River, and have provided that information below.

As shown by USFWS fish trapping operations in the Sacramento River at Red Bluff, a bi-modal length-frequency distribution of young fall-run was evident with the great majority passing RBDD in the winter months as fry and smolt-sized salmon in the spring (Figure 11). (Gaines and Martin 2002.) However, for the six years of data reported in Gaines and Martin (2002), five were wet water years and one was critically dry. In 1994, a critically dry water year, the highest monthly numbers of salmon emigrated in April as smolts, whereas in 1995, a wet water year, the highest monthly numbers of salmon emigrated in February as fry (Figure 12).

Figure 11. Length-frequency distributions for fall-run Chinook captured by rotary screw traps below RBDD. Data summarized from July 1995 through June 2000. (Figure from Gaines and Martin 2002.)

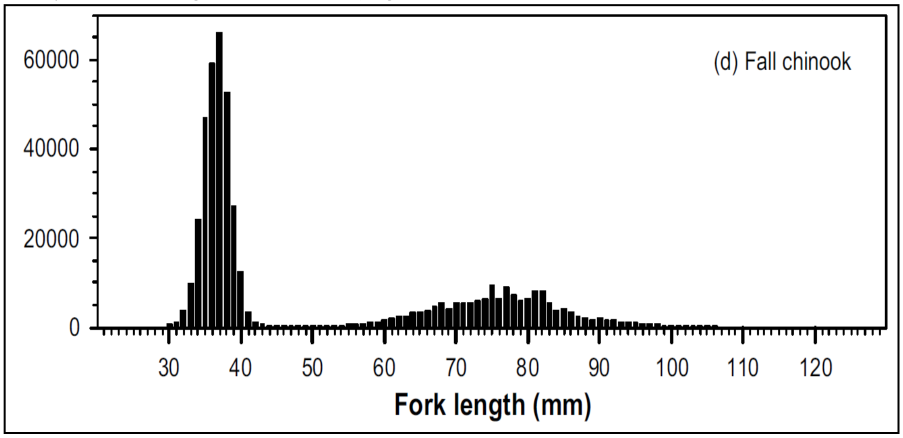
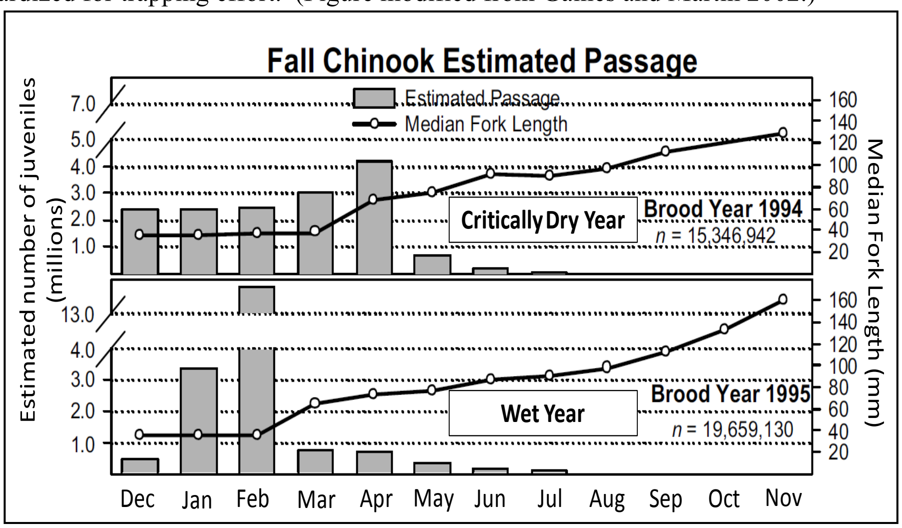


Figure 12. Juvenile passage estimates and median fork lengths of naturally produced fall Chinook salmon based on fish captured by rotary-screw traps below RBDD for the period December 1994 through November 1996. Estimates have been standardized for trapping effort. (Figure modified from Gaines and Martin 2002.)



Much farther downstream, salmon movements of fry and smolts into the Delta are demonstrated by the DFG fish sampling program in the Sacramento River near Knights Landing. The DFG fish trapping data demonstrate the relationship between initial river pulse flows and salmon emigration and the inter- and intra-annual variability in fish behavior. To illustrate these points, I have plotted the weekly numbers of juvenile salmon captured in DFG's sampling program with Sacramento River flows measured near Grimes, California, for the years 1999 through 2010 (Figures 13 through 24). (Note: the Y1 and Y2 axes values are not the same between graphs.) There are several noteworthy observations to point out from this comprehensive DFG fish sampling program useful to the Board for this workshop.

First, juvenile salmon emigration shows an obvious response to initial pulse flows in the upper river caused by tributary accretions from precipitation events or increased reservoir releases for flood control storage in Shasta Reservoir, or a combination of both. In wet and above-normal water years, elevated river flows create riverine conditions which cause juvenile salmon migration from the upper river to the lower river and to the Delta through complex mechanisms previously described. For example, in 1999, 2000, 2003, and 2006 (all wet water years), winter-time precipitation events increased river flows with a corresponding surge in salmon emigration (Figures 13, 14, 17, and 20, respectively). Even in dry or critically dry years, such as 2007, 2008, and 2009, winter-time precipitation events causing pulses in river flows result in salmon emigration (Figures 21 through 23, respectively).[5]

Figure 13. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 1999.

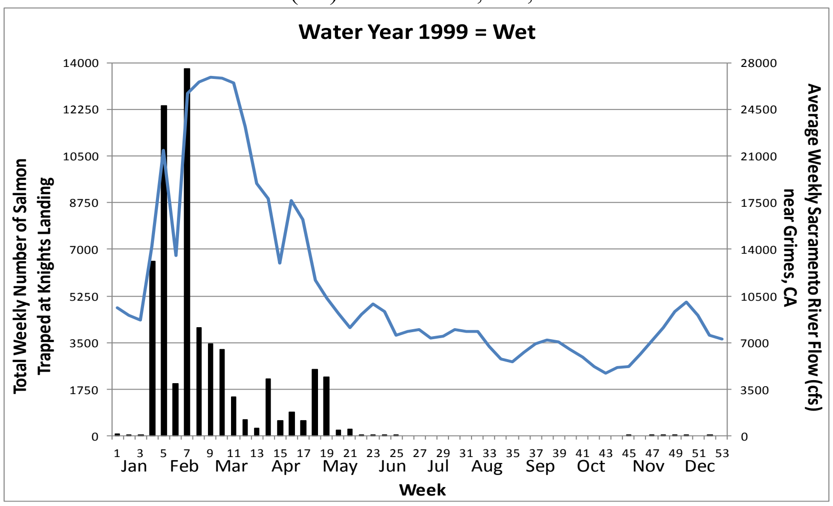
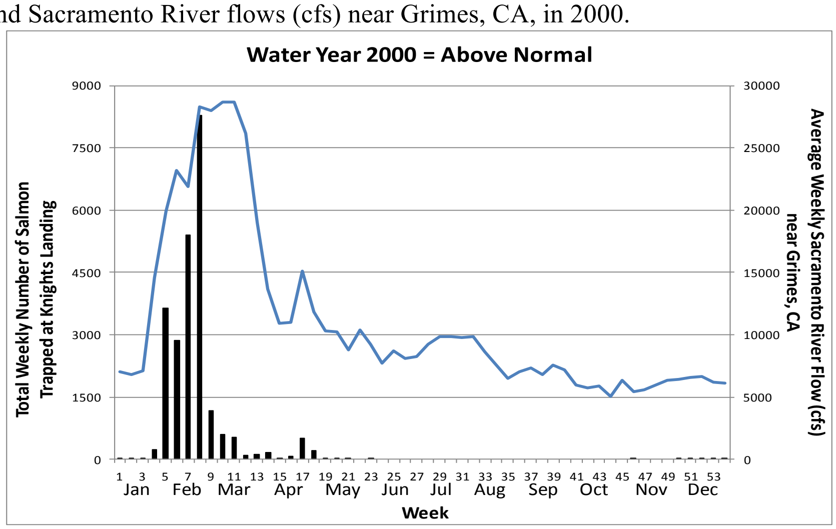


Figure 14. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2000.



[5] Note that short-term pulses in salmon emigration in the spring during 2001 and 2002 (dry years) (Figures 15 and 16, respectively) and 2010 (below-normal year) (Figure 24) were undoubtedly attributable to large-scale releases of hatchery fall-run Chinook from CNFH.

Figure 15. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2001.

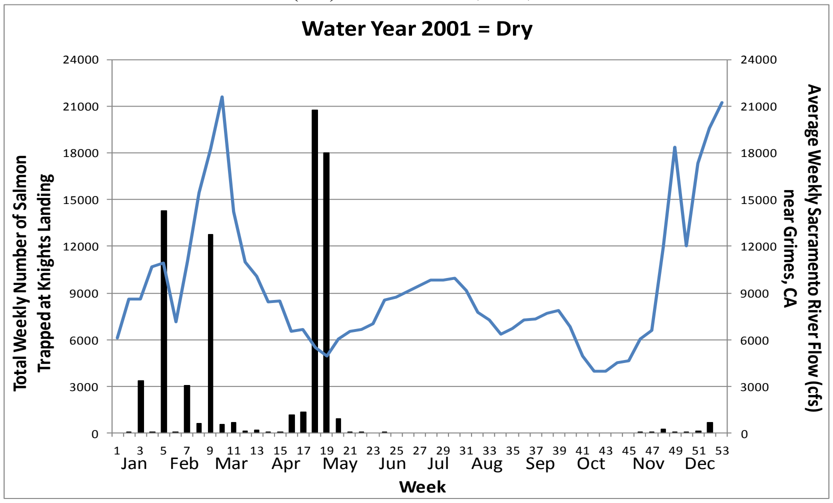


Figure 16. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2002.

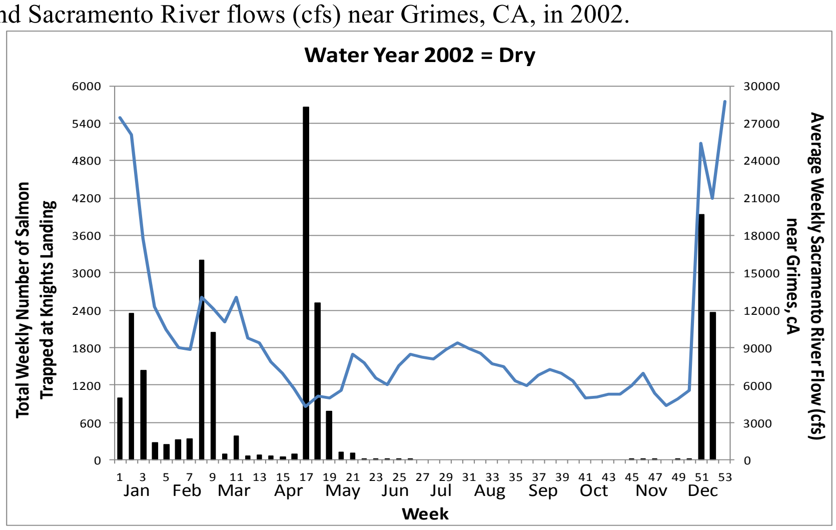


Figure 17. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2003.

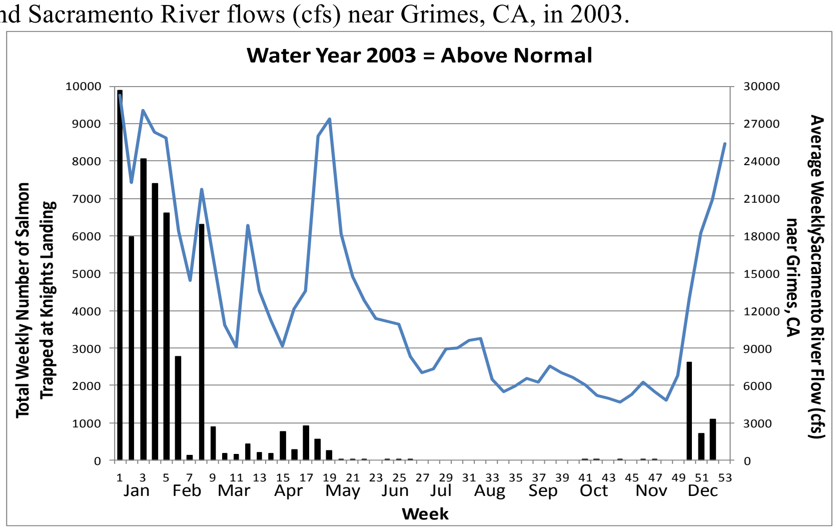


Figure 18. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2004.

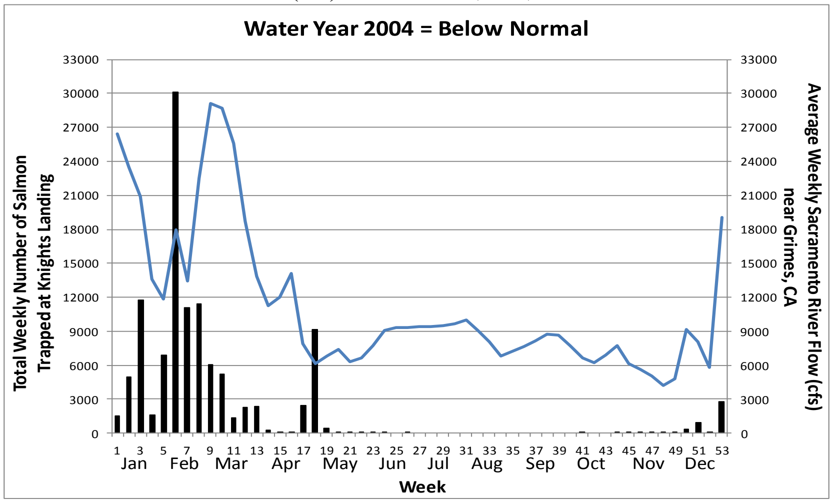


Figure 19. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2005.

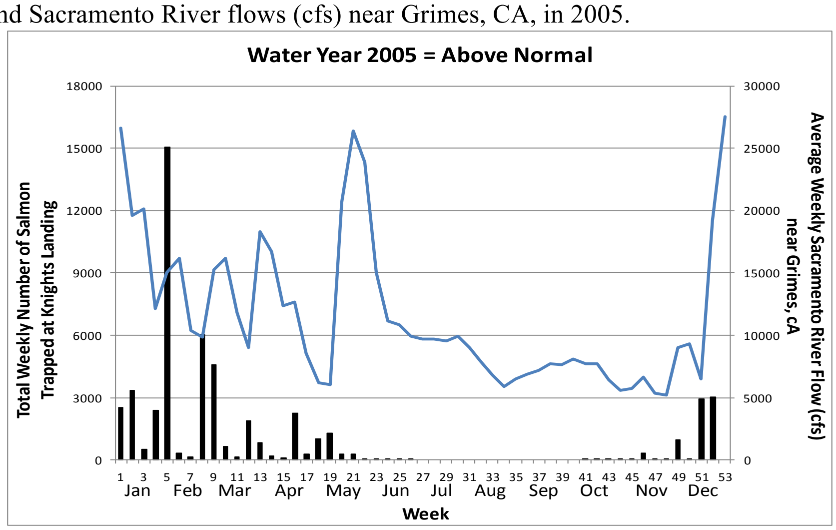


Figure 20. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2006.

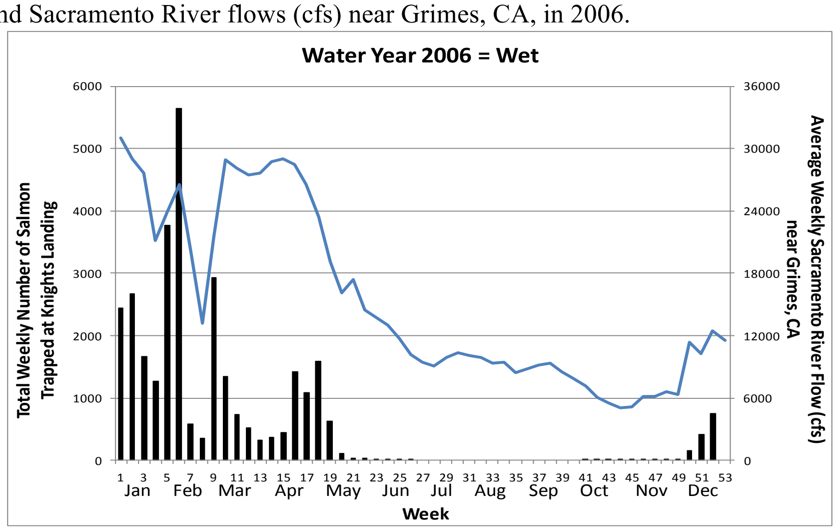


Figure 21. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2007.

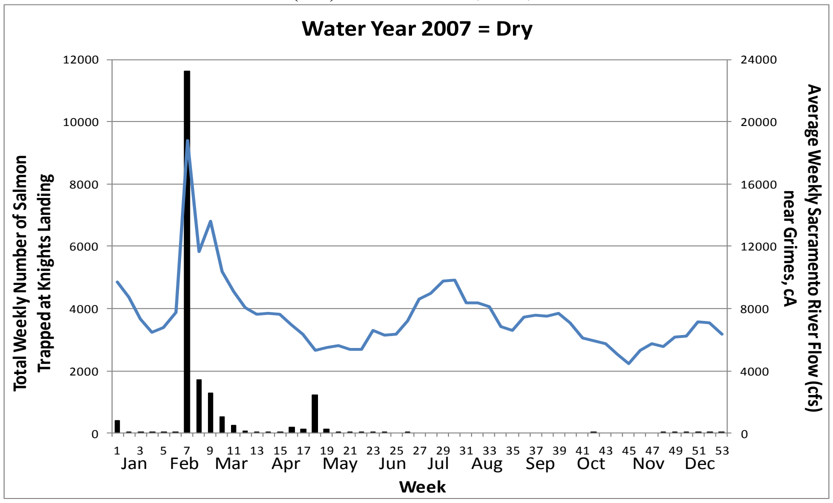


Figure 22. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2008.

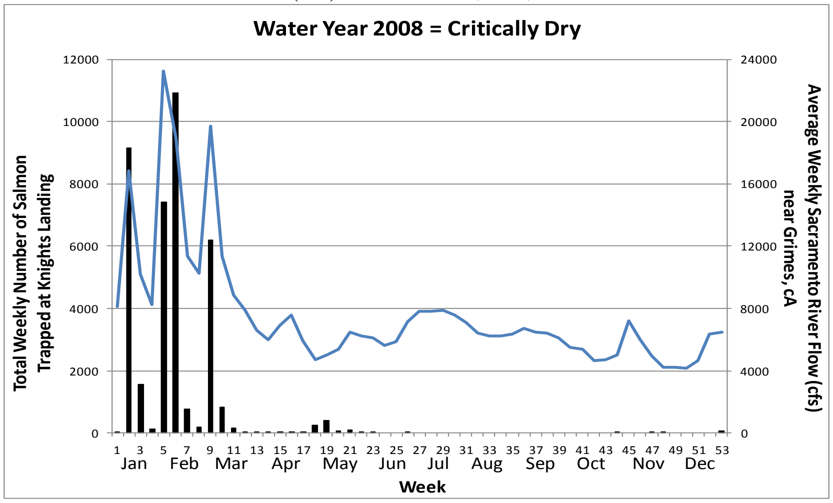


Figure 23. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2009.

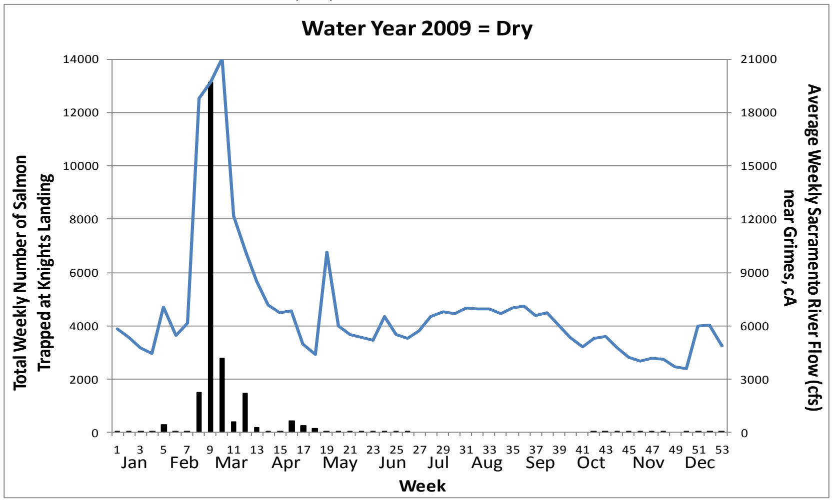
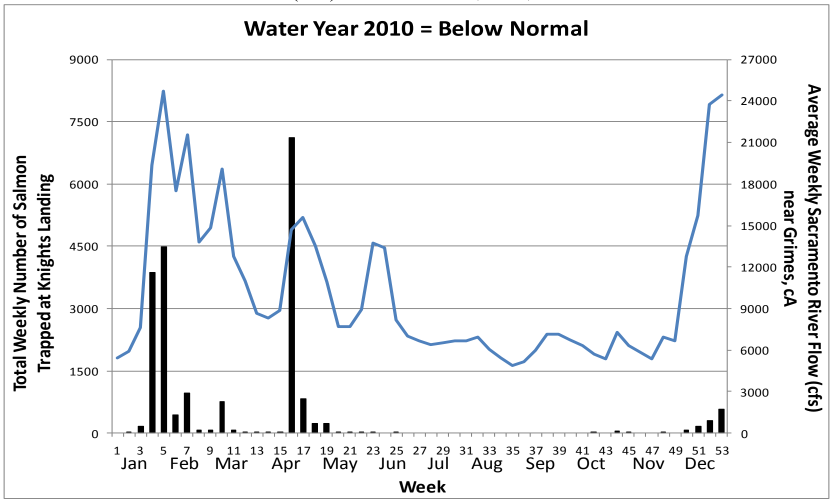


Figure 24. Weekly numbers of juvenile Chinook salmon (all runs) captured by DFG in the Sacramento River near Knights Landing and Sacramento River flows (cfs) near Grimes, CA, in 2010.



Second, in the late spring and summer months, a naturally-occurring, river temperature thermal block to salmon emigration from the upper river to the Delta occurs which is attributable to ambient air temperatures. The onset of this barrier is dependent on weather and hydrologic conditions; in cold, wet springs, some portion of the salmon emigrate later, whereas in warm, dry springs, emigration occurs earlier. If young salmon do not emigrate prior to the thermal block, those fish are believed to either perish or remain in the upper river until naturally-occurring conditions are favorable for outmigration the following fall or winter. Note from the foregoing data (Figures 13 through 24) that fall-run salmon movements in the lower river near Knights Landing and DFG's monthly summaries show that emigration of all runs of salmon (Figure 25) are largely non-existent during June. DFG ends trapping operations in May or June with no trapping in July, August, and September due to a lack of salmon; it resumes in October or November. It is unknown if comparable fish emigration data are available for the lower Feather and American Rivers. However, due to the seasonally warm water temperatures in the lower Sacramento River downstream of the Feather and American River confluences and just upstream of the Delta in June, salmon movements in that area are also likely essentially non-existent.

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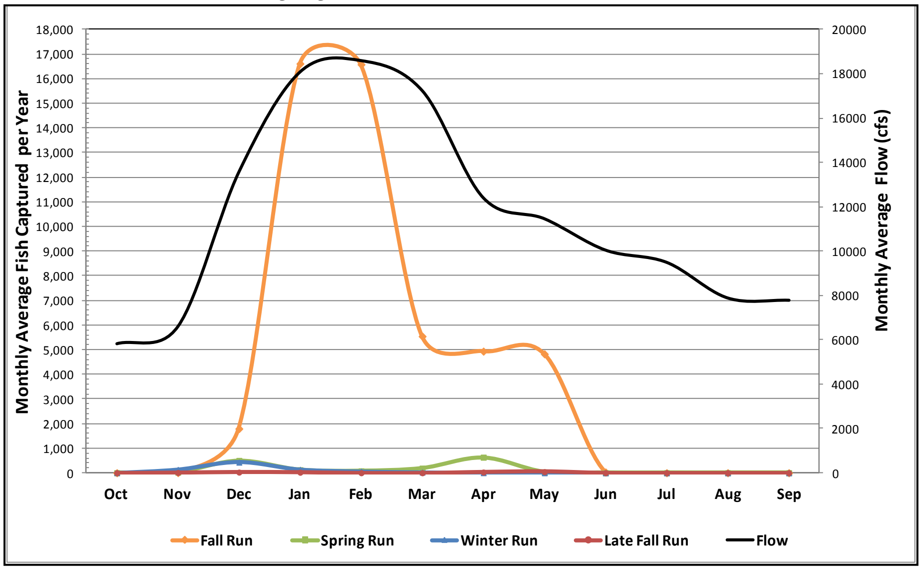
Figure 25. Timing, composition and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, 1997 – 2007. Data and graph from DFG (some labels were modified for clarity). Sacramento River flow data from USGS gauge near Grimes, CA.



To summarize, the Board should acknowledge this normal high variability in inter- and intra-annual salmon emigration and interrelationships with naturally occurring hydrologic conditions. Therefore, the Board should not assume that “one-size-fits-all” when contemplating flow standards to benefit juvenile salmon emigration. Also, it is readily apparent that elevated pulse flows in the Sacramento River already naturally occur which stimulates the outmigration of juvenile salmon from the upper river to the Delta. A uniform application of a very high percentage of unimpaired flow each month from January through June from the upper watershed (i.e., 40% or 50%, or higher), would not have any practical application for management actions to benefit salmon survival and, assuming the major water supply impacts identified by the MBK report, would cause much more harm for the salmon resource than good (i.e., adverse impacts on cold-water storage and salmon habitats). Other opportunities to improve conditions for salmon are possible and should be seriously examined.

8.1.2 Delta Environment

As evident from prior Board proceedings, one of the major scientific uncertainties relates to juvenile salmonids the Delta. Historically, detailed empirical data on juvenile salmonid behavior and survival in the Delta’s discrete reaches were largely unknown or severely lacking. In the 1990s, I extensively canvassed other biologists familiar with the Delta and found that there were widely-varying, speculative ideas on how juvenile salmonids behaved in the Delta’s complex tidal environment; opinions abounded but all-important supportive data were unavailable.

8.1.2.1 Salmonid Smolts in the Delta

From 1996 through 2010, I served as a Principal Scientific Investigator for 22 separate research projects on juvenile salmon (including four studies of predatory fish) in the Delta using radio- or acoustic-telemetry as a means to gain an improved understanding of fish movements and mortality. (Vogel 2010c.) As a result, comprehension of fish behavior has improved substantially. These now readily-available tools have subsequently created a proliferation of juvenile salmonid telemetry studies in the Delta. Results from some of those studies have been used in attempts to accurately estimate fish survival and develop computer models of salmon migration and survival, including application to life cycle models. There are, however, significant questions regarding the validity of this information. The following provides some background on the topic to inform the Board of important aspects of our present-day understanding of juvenile salmon in the Delta and the associated scientific uncertainties.

The deficiency of significant knowledge on fish behavior led to the first successful use of radio-telemetry on juvenile salmonids in the Central Valley when, in 1996 and 1997 on behalf of East Bay Municipal Utility District, I brought this new technology to the lower Mokelumne River portion of the Delta. New data were developed that determined fish did not behave as a school but, instead, rapidly dispersed, exhibiting a wide range in migratory behaviors. Salmonids were carried many miles back and forth each day with the ebb and flood tides. Fish movements into side channels and dead-end sloughs (where flow was minimal) were largely non-existent. Site-specific hydrodynamic conditions had a major effect in initial route selection when telemetered fish arrived at channel flow splits. Importantly, some of the juvenile salmonids were believed to have been preyed upon based on aberrant telemetry patterns. (Vogel 2010b.)

CALFED subsequently hired me to perform radio-telemetry experiments at the DCC and Georgiana Slough in 2000 and 2001. Those field investigations indicated that fish entrainment into the DCC depends on site-specific flow conditions at the time juvenile salmon encounter the flow split. During ebb tide conditions, fish released into the Sacramento River upstream of the DCC migrated past the structure when flow in the DCC was minimal. Conversely, during flood tide conditions, fish released into the Sacramento River upstream of the DCC were swept into that channel when flow into the channel was high. It was also established that, even when fish successfully passed the DCC during ebb tides and remained in the Sacramento River, the fish could be advected back upstream and into the DCC with subsequent flood tide conditions. Some of the most extensive, detailed behavior of smolt movements in real-time on a micro-scale in the highly complex (and controversial) region of the north Delta near the DCC were acquired during those radio-telemetry studies. CALFED, however, never funded completion of those studies and technical reports were never written.

I also performed smolt radio-telemetry studies on behalf of the USFWS and CALFED on a much-larger scale in the north Delta (Vogel 2001, 2004) and was funded to complete those research reports. Triangulating radio-tagged fish locations in real-time clearly demonstrated how juvenile salmon moved long distances with the twice-daily ebb and flood tides, and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands. In the larger Delta channels, telemetered fish favored migration in mid-channel areas, not the channel fringes. I learned that some radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands. Monitoring telemetered fish revealed that higher mortality occurred in Georgiana Slough as compared to the lower Sacramento River (Vogel 2004), similar to results of coded-wire tag studies (Brandes and McLain 2001).

Later, I greatly expanded the geographic scope of the investigations into the central and south Delta. Those studies, cumulating in comprehensive technical reports, provided considerable new information on smolt behavior in the much-more complex central and south Delta regions in terms of hydrodynamic and migration channels. (Vogel 2002, 2004.) Those studies were used to build upon empirical data on fish behavior and survival in the Delta and refine study techniques and experimental designs.

After extensive field testing of newly developed miniaturized acoustic[6] transmitters, we found that technology also had application to the Delta. (Vogel 2006a.) As a result, DWR contracted with my firm to conduct the first large-scale acoustic-telemetry study in the north Delta, further expanding our understanding of how fish move not only into the DCC and Georgiana Slough, but also into Sutter and Steamboat Sloughs. (Vogel 2008.) Additionally, the San Joaquin River Group Authority contracted with me to conduct similar work in the south and central Delta as part of the Vernalis Adaptive Management Program (VAMP). (Vogel 2006b, 2010a, 2011b.) These latter, most-recent efforts led to a major breakthrough in the interpretation of juvenile acoustic-telemetry studies in the Delta (discussed below).

8.1.2.1.1 Limitations of Smolt Acoustic-Telemetry Studies ("The Predation Problem")

Lately, studies conducted by releasing acoustic-tagged fish and recording their movements at strategically-placed data loggers in downstream Delta channels have attempted to accurately quantify fish survival and route selection. The experimental designs were relatively simple: if telemetered fish released upstream failed to reach and be recorded by downstream electronic data loggers, the fish were assumed to have died (for unknown reasons) in the area between the original fish release location and the data logger; a tagged fish recorded as passing the data logger was assumed to be alive. Additional data loggers positioned further downstream within the migratory pathways furthered that logic using simple presence/absence data. However, highly detailed, extensive data discovered in new research clearly demonstrated that the accuracy and precision of survival estimates from this latter approach are not believable due to a major limitation of the technology. Findings from recent acoustic-telemetry investigations indicate that existing smolt survival estimates, migration routes, models, and assumptions must incorporate this previously unavailable information to avoid misinterpretation of data and improve quantitative estimates of fish survival and movements. (Vogel 2010a, 2011b.) This current research has found that fish survival estimates in the Delta are biased high, perhaps considerably so, with the precision of those previous estimates much more imprecise than previously assumed. Importantly, this circumstance has greatly compromised some original prior studies' purposes, and significantly added to our scientific uncertainties of salmonids in the Delta.

Limitations of the acoustic-telemetry technology were inadvertently discovered during experiments I conducted by releasing acoustic-tagged juvenile salmon upstream of the Delta on the Sacramento River, then electronically recording passage of each fish at fixed-station electronic acoustic data loggers positioned farther downstream (much like the strategy for experiments in the Delta). Initial results of that research indicated a 100% survival of acoustic-tagged juvenile salmon. These original survival estimates were derived by simply using presence/absence data recorded by the data loggers. That is, assuming 100% detection

[6] A different technology than radio-telemetry.

probability of a tagged salmon passing a data logger, the salmon is assumed to be alive; if the fish is not recorded by the data logger, it is assumed to have died somewhere upstream. In this particular study, using the telemetry vendor's hardware and software provided much more data than simple presence/absence of tagged fish detection. It allowed close visual examination of the "echograms" or "acoustic signatures" of subtle movements of fish at a fine- or micro-scale within detection range of the data loggers. Later, highly-detailed, manual post-processing of the study data found that three acoustic-tagged salmon released upstream at different times and locations reached the downstream data loggers at the exact same second, a probability close to zero. Further closer examination of the echograms showed that those three tags moved in perfect unison for extended periods. It was therefore confirmed that the three acoustic-tagged salmon had been eaten by a predator and the data loggers had actually recorded the three dead fish inside the predator's stomach instead of as individual live salmon. After this inadvertent, but extremely-revealing discovery, additional data from those experiments were re-examined. The original salmon survival estimates using only presence/absence detection data changed from 100% survival to 100% mortality using manual examination of the echograms; all fish had been consumed by predatory fish which otherwise would have not been known.

On a much-larger scale in the Delta region, this major technological limitation for estimating juvenile salmon survival and fish route selection dramatically surfaced during the VAMP fish studies. Through detailed analyses of acoustic-tag echograms recorded by a large array of fixed-station data loggers[7] distributed throughout the Delta, we found that, in numerous instances, we were actually tracking the movements of dead salmon inside predatory fish, not live acoustic-tagged salmon. Literally hundreds of test fish were believed to have been preyed upon, which would have otherwise been misinterpreted as live acoustic-tagged salmon migrating through the Delta. (Vogel 2010a, 2011b.) Importantly, a separate, concurrent study using different techniques for evaluating the behavior of migrating acoustic-tagged juvenile salmon during the VAMP study at the head of Old River estimated that approximately 50% of the tagged salmon were actually dead salmon inside predatory fish. The magnitude of potential misinterpretation of study results would have been enormous if only the usual and customary tag presence/absence data had been used. Some experiments have attempted to overcome the "experimental noise" created by this predator problem by simply releasing more acoustic-tagged salmon hoping that sheer numbers will dampen the issue. Still, if half the tagged salmon are eaten, the problem remains. Even "sub-sampling" during data processing to compare presence/absence data versus visual echogram data would not resolve the dilemma due to high variability in predation throughout Delta regions.

8.1.2.1.2 Ramifications of "The Predation Problem"

The principal predator creating this major study limitation problem in the Delta is non-native striped bass. Some acoustic-telemetry study designs performed in the Delta expected that predatory fish would be relatively stationary[8] (as in Columbia River dam studies) and the predicament described here would not surface, but that assumption is now known to be invalid.

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[7] We chose to manually examine each and every echogram instead of reliance of simple presence/absence data because of the previously discussed discovery.

[8] The studies also assumed that predators would only move in an upstream direction (uncharacteristic of a salmon smolt) and resultant telemetry data could be corrected for anomalous tag behavior.

In separate, but related studies concurrently performed during the releasing of acoustic-tagged salmon, I found that acoustic-tagged adult striped bass moved readily throughout the data logger arrays in the Delta over long distances, commonly in a downstream direction to the western Delta much like assumed juvenile salmon behavior. (Vogel 2010b, 2011b.) In fact, many of the striped bass exhibited a strong tendency to migrate from the northern, interior, and south Delta regions to the west Delta and showed a strong affinity to the area around Chipps and Mallard Islands. Unfortunately, this site is where the western-most acoustic data loggers were positioned as an "end point" in the expectation of estimating overall salmon survival through the Delta. With striped bass showing the same migration tendency as anticipated from a salmon smolt and the species' high propensity to eat young salmon, the assumption of stationarity of predators was not only found invalid, it greatly compromised the ability to estimate salmon survival to the western Delta and salmon route selection through Delta channels.

The ramifications of these new results cannot be overstated. Delta fish survival estimates derived from some past telemetry studies are undoubtedly biased high, perhaps severely so, and accurate portrayal of fish selection routes in the Delta remains elusive. Therefore, the Board is highly cautioned regarding the use of any data and models resulting from prior acoustic-telemetry studies when formulating flow-related measures for salmon in the Delta. Importantly, relevant to this Board Workshop and other Delta-related forums (e.g., BDCP), if these invalid salmon survival and fish route selection estimates were used for management decisions in the Delta, inappropriate measures could be implemented and considerable time, resources, and fish could be lost. Until methods or technologies are developed to differentiate between live tagged salmon and tagged salmon eaten by predators, such survival studies will be prone to misinterpretation and error. As a result, I have recommended a moratorium on large-scale acoustic-telemetry studies of this nature in the Delta until this misconception can be resolved. (Vogel 2010a.) To the extent possible, all acoustic-telemetry data used to create models and assumptions on juvenile salmon in the Delta must be re-examined and corrected.

8.1.2.1.3 The Need to Conduct Smolt Studies to Reflect "Real-World" Conditions

Another significant problem occurred when some past telemetry studies were conducted using salmon that had not yet smolted. EPA (1994) describes a smolt as ". . . *a salmon in the process of acclimating to a change from a fresh water environment to a salt water environment. This occurs when young salmon migrate downstream through the Delta to the ocean.*" While accurate, this definition is simplistic because there are complex morphological, physiological, and behavioral changes associated with the transformation of a parr salmon to a smolt salmon. These biological mechanisms have a major influence on how young salmon may or may not interact with Delta conditions. The implication of what constitutes a smolt salmon has a substantial bearing on Delta water management issues. If pre-smolts are released for migration experiments instead of smolts, poor results would be expected mainly because the test fish are not biologically ready to leave freshwater. And, most importantly, if the test fish are subjected to conditions which do not resemble those that wild smolts may be exposed to during their natural migration to the ocean, the test results cannot be extrapolated to represent wild smolt behavior.

For example, during the early DCC studies noted above, I recommended a postponement until the winter months when we would have a high degree of confidence that the test fish we used were smolts, not parr. Some experiments, however, were conducted as early as late October. As a result, during the early season fish releases some fish actually swam upstream rather than downstream, as is expected for smolts instinctively wanting to migrate to saltwater. Additionally, some fish exhibited a residency behavior suggesting a rearing, not migratory tendency. To further prove this consequence, I had gill Na^+/K^+ ATPase[9] activity tests conducted on salmon used for the experiments. The basis for such tests is that numerous investigations have shown a correlation between young anadromous salmonid downstream migration and gill Na^+/K^+ ATPase activity. Measurement of gill ATPase activity has been demonstrated to be a useful and quantitative test to determine the optimum release date of salmonids from hatcheries. (Adams et al. 1975.) Zaugg (1989) indicated that stage of smolt development as measured by gill Na^+/K^+ ATPase activity can be related to migratory behavior and survival in underyearling Chinook salmon.

Not surprisingly, smoltification among the brood year of hatchery salmon used in the DCC studies did not occur until rains began in the month of December, well after most components of the DCC studies had ended [e.g., coded-wire hatchery fish releases, fish trawling, hydroacoustic (sonar), hydrodynamic measurements, etc.]. Fortunately, I continued the tracking the radio-tagged fish in the vicinity of Georgiana Slough later in the season after salmon had smolted, but unfortunately, as previously described, CALFED never funded completion of those experiments in a final report.

8.1.2.1.4 Summary of the Smolt Telemetry Problem

In summary, the Board is urged to use great caution in its deliberations when examining results from any acoustic-telemetry studies on small fish in the Delta because of great scientific uncertainty associated from such experiments. Simply assuming some of those studies are "the best available science" would not be correct in this circumstance because of the highly misleading information that can result from such a postulation. However, subject to the previously-described caveats, the use of telemetry to study outmigration of salmonid smolts in the Delta can be a powerful tool to better understand fish behavior, but only if the technology is applied properly, analyzed appropriately, and results are not misinterpreted or misrepresented. (Vogel 2010a.) Use of the technology to accurately quantify small fish survival and fish route selection in long reaches of the Delta and through the entire Delta is not viable at the present time until the major predation problem previously discussed is resolved. In this regard, I have recommended that telemetry vendors develop small transmitters that can detect when a telemetered fish has been preyed upon to resolve this critical problem. (Vogel 2010a.) Unlike acoustic telemetry, radio-telemetry has considerable merit to evaluate smolt migration in the Delta because its proper application can detect predation.

Lastly, I examined the environmental conditions when many telemetry studies were conducted in the Delta and found that most occurred during periods when natural salmon migration would not be expected. All future studies should only be performed under real-world conditions to provide meaningful data for reducing scientific uncertainty.

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[9] A gill enzyme used as a measure of smoltification.

8.1.2.2 Salmonid Fry in the Delta

The fish telemetry studies previously described have not provided necessary information on salmonid fry behavior and survival in the Delta mostly because radio or acoustic transmitters are too large for application to very small fish. Consequently, whatever conclusions some may derive from past and existing salmonid smolt telemetry studies in the Delta, these conclusions have little bearing on salmonid fry behavior. This is because of the markedly different behaviors between the two fish life stages. For these reasons, salmon fry movements, rearing, and survival in many discrete reaches of the Delta remain a major scientific uncertainty.

Some of the most important questions to elucidate the uncertainty associated with evaluating the survival of young salmon through the Delta lie in the different degrees of fry and smolt downstream migratory behavior and fry rearing in the Delta. Downstream migration of Central Valley Chinook salmon may be passive or active. Passive migration is associated with dispersal or displacement of fry or parr salmon (pre-smolts) from upstream rearing areas to lower river reaches. In contrast, active downstream migration is associated with the physiological, morphological, and behavioral changes attributable to smoltification. This signifies that the smolts are purposefully migrating toward the ocean and are physiologically able to adapt to saltwater, as compared to juvenile salmon fry which may not be ready to migrate to saltwater.

If certain water management actions are implemented in the Delta (under the auspices of providing protection to salmon smolts), the results may be ineffective because many, if not most, juvenile salmon migrating to and rearing in the Delta may not respond as anticipated because those fish are not physiologically prepared to migrate. Therefore, the Board should consider the complexities and scientific uncertainties of differential juvenile salmonid life history attributes in the Delta. More research on salmonid fry rearing in the Delta is needed prior to implementation of major structural changes in how Delta flows are managed.

Second Set of Questions Posed by the Board for the October Workshop on Anadromous Salmonids

2. How should the State Water Board address scientific uncertainty and changing circumstances, including climate change, invasive species and other issues? Specifically, what kind of adaptive management and collaboration (short, medium, and long-term), monitoring, and special studies programs should the State Water Board consider related to Bay-Delta fisheries as part of this update to the Bay-Delta Plan?

RESPONSE

9.0 Proposed Actions and Special Studies to Address Scientific Uncertainties

The following are some proposed actions and studies to address problems, opportunities, and scientific uncertainties concerning anadromous salmonids in the Sacramento River basin and Delta.

9.1 The Delta

- Remedial actions for the serious problem with the upstream fish passage barrier at Freemont Weir should be implemented as soon as possible to assist in restoring depressed fish populations. This same problem is evident at other flood-control weirs. In each instance, engineering solutions or operational measures to correct the problem are likely to be feasible. For example, short-duration pulses of relatively low-volume, but high-velocity flows can attract fish into bypasses. Elimination of these migration barriers through the installation of fish passage facilities or operational measures presents a significant restoration opportunity. (High Priority Action)

- Significant efforts should be implemented to re-create shallow-water rearing habitats for anadromous salmonids in the Delta within the primary migration corridors. However, those restoration sites should be designed to minimize predation. (High Priority Action)

- Plans for future structures, including habitat restoration projects, contemplated in the Delta should recognize and avoid the potential hazards for anadromous fish. (High Priority Action)

- Design and construct alternative fish release structures (fish acclimation chambers) and implement different release strategies in the western Delta for fish salvaged from the federal and state water export facilities. (High Priority Action)

- Provide a small structural opening (submerged operable orifice) in one Delta Cross Channel radial gate to attract Sacramento River salmon trapped behind the closed gates in the north/south forks of the Mokelumne, Delta Cross Channel, Deadhorse Cut, and Snodgrass Slough back into the Sacramento River. (High Priority Action, High Priority Study)

- An aggressive predator removal program at CCF and TFF should be designed and implemented. The removal should be either lethal or relocation to waters not connected to the Delta. The technology is available to determine the presence of predatory fish and survival of juvenile anadromous fish moving with the flow under in-Delta structures (e.g., telemetry, sonar camera). Depending on site-specific findings, measures to reduce predatory fish habitats or localized predatory fish control measures could be implemented. (High Priority Action, High Priority Study)

- New study approaches in the Delta should be designed and implemented to determine exactly where mortality is occurring in the Delta and how to ultimately fix the problems. For example, intensive studies in smaller discrete areas of the Delta (e.g., in Georgiana Slough, around large marinas, artificially-created scour holes, levee breaches) using tools such as radio-telemetry, DIDSON™ sonar camera imaging, side-scan sonar, electrofishing, and other techniques are likely to yield useful information within a short period of time. (High Priority Study, High Priority Action)

- Potential solutions to avoid predation at breached levees should be developed and implemented. For example, "feathering" back these levees over a much wider area instead of keeping the narrow channels would reduce high water velocities, reduce scour hole formation, and reduce predation opportunities as tides flood and ebb. (High Priority Study, High Priority Action)

- Studies should be conducted of the channel geometry at key locations in the Delta where predatory fish are concentrated and remedial actions, where warranted, should be developed and implemented to reduce predation losses of anadromous fish. (High Priority Study, High Priority Action)

9.2 Upstream Areas

- Some new fishways to provide access for spring-run Chinook to upper reaches of Big Chico Creek have yet to be constructed, and should be implemented as soon as feasible. (High Priority Action)

- All existing fishways on important anadromous fish tributaries should be continually maintained and periodically examined to ensure conditions are optimal for fish passage. (High Priority Action)

- Because Butte, Mill, and Deer Creeks likely possess the only true remaining wild spring-run in the entire Central Valley, both state and federal law enforcement presence in the watersheds should be maintained or increased as a deterrent for illegal harvest. Low-cost, digital infrared motion-detecting cameras could be installed at locations where adult fish are highly vulnerable to illegal harvest or human disturbance. (High Priority Action)

- The relatively few and small holding areas where over-summering adult spring-run Chinook are exposed and highly vulnerable to human recreational activities in the summer months should be better protected. Greater scrutiny of snorkeling surveys in spring-run Chinook holding areas or development of alternative survey techniques should occur through the ESA take regulations (ESA section 4(d)) or research provisions (ESA section 10) to minimize and perhaps eliminate that risk to the populations. Formal seasonal refuges at critical areas, akin to that historically provided for bald eagle nesting areas, should be provided to protect adult spring-run and minimize human disturbance. State and federal law enforcement presence in the watersheds should be increased as a deterrent for illegal harvest. (High Priority Action)

- Because spring-run Chinook prefer shade and cover during over-summering in small tributary pools, greater protection of riparian corridors in holding areas where that species actually over-summers should be provided. In some areas, such as in Butte Creek, adult spring-run are highly exposed and could benefit from structural measures to provide shade and cover. (High Priority Action)

- Because of the biological importance and high probability of success, spawning gravel introductions should continue, and be significantly expanded downstream of all major dams. (High Priority Action)

- Proposed plans to extract spring-run Chinook fertilized eggs from Mill or Deer Creeks should be held in abeyance until the populations recover from currently depressed levels. Butte Creek would be a more appropriate egg source for a donor stock to be used elsewhere. (High Priority Action)

- Reduce predatory fish habitat in the vicinity of large water intake structures. (High Priority Action)

- Prevent adult salmon from entering the Colusa Basin Drain outfall near Knights Landing caused by fish attraction to agricultural drainage from the west side of the Sacramento Valley. (Medium Priority Action)

- Instream studies should be conducted to determine the quantity and quality of favorable rearing habitats. Projects to replenish coarse substrates (i.e., gravels, boulders) and woody debris in the upper portion of the mainstem river in key locations should be implemented because of the high probability of improving and expanding mainstem rearing habitats. Pilot projects to create new rearing habitats should be conducted, and if found feasible, be expanded in reaches immediately downstream of dams. (High Priority Study, High Priority Action)

- Evaluate the potential to improve water temperature management in the upper Sacramento River through fine-tuning water temperature compliance points and structural changes to the Shasta Dam Temperature Control Device. Include other Sacramento River stakeholders in the Sacramento River Temperature Task Group. (High Priority Study, High Priority Action)

- Evaluate the potential to implement short-duration pulse flows from reservoirs to enhance the outmigration of juvenile salmon to the Delta in the spring. If feasible without adversely impacting cold-water storage, water supplies, and other beneficial uses, implement and evaluate the effectiveness of pulse flows. Include Sacramento River stakeholders in this process to insure operations are well coordinated. (High Priority Study, High Priority Action)

- Reduce night-time lighting in the vicinity of man-made structures in the rivers and Delta (e.g., fish screens, bridges, docks, marinas) by eliminating or altering lighting methods and equipment. (Medium Priority Study, Medium Priority Action)

- Detailed modeling studies should be conducted of the effects of any flow regimes contemplated by the SWRCB for the Bay-Delta Plan Update, in order to determine impacts to water supplies and the thermal regime as those factors affect anadromous fish spawning, incubation, rearing, and outmigration. (High Priority Study)

- Instream studies of potential predation problems immediately downstream of Daguerre Point Dam on the Yuba River and ACID dam on the Sacramento River should be conducted; if necessary, remedial actions should be developed and, if warranted, implemented. The issue may be particularly important at the ACID dam because of the high concentration of winter-run fry in the vicinity during the period the diversion is in operation. (High Priority Study)

- Attempts to create anadromous fish rearing habitats in the lower Sacramento River through placement of woody debris structures and other measures should be closely scrutinized to determine if those efforts are inadvertently creating favorable predatory fish habitats at the expense of anadromous fish. (Medium Priority Study)

- Detailed data on spawning habitat quantity and quality in many tributaries are limited, but because of their importance, those habitats should be examined to determine potential restoration measures; such studies are easy to conduct and relatively low in cost. Gravel replenishment projects in important spawning areas lacking sufficient natural gravel recruitment would undoubtedly benefit anadromous fish. (Medium Priority Study)

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EXHIBIT 1

Parties comprising the Sacramento Valley Water Users

Anderson-Cottonwood Irrigation District
Biggs-West Gridley Water District
Browns Valley Irrigation District
Butte Water District
Calaveras County Water District
Calaveras County Water District
City of Folsom
City of Roseville
El Dorado Water & Power Authority
Glenn-Colusa Irrigation District
Meridian Farms Mutual Water Company
Natomas Central Mutual Water Company
Northern California Water Association
Pelger Mutual Water Company
Reclamation District No. 1004
Reclamation District No. 108
Richvale Irrigation District
River Garden Farms
Sacramento County Water Agency
Sacramento Municipal Utility District
Sacramento Suburban Water District
San Juan Water District
South Feather Water and Power
South Sutter Water District
Sutter Extension Water District
Sutter Mutual Water Company
Western Canal Water District
Yolo County Flood Control & Water Conservation District
Yuba County Water Agency

EXHIBIT 2

David A. Vogel
Senior Fisheries Scientist
Natural Resource Scientists, Inc.

Education

M.S., 1979, Natural Resources (Fisheries), The University of Michigan
B.S., 1974, Biology, Bowling Green State University

Experience

Dave Vogel specializes in aquatic resource assessments and resolution of fishery resource issues associated with water development. His 37 years of work experience in this field includes large-scale assessments in river systems, lakes and reservoirs, and estuaries, mostly associated with restoration of western United States fishery resources. Many of these programs entailed major fish population studies and investigations into freshwater and estuarine habitat requirements and factors limiting fish populations. He has designed and conducted numerous projects to determine fish habitat criteria and population limiting factors leading to development and implementation of innovative measures to increase fish populations. Dave Vogel has served as a Principal Scientific Investigator in dozens of fish research projects in the western United States on behalf of state and federal agencies, Indian tribes, county governments, municipalities, water districts, consulting firms, and numerous other organizations and has authored approximately 100 technical reports on fishery science. Mr. Vogel has worked on Central Valley fishery resource issues for the past 31 years. During the 1980s he was the U.S. Fish and Wildlife Service's (USFWS) Project Leader directing research on Sacramento River basin salmon and steelhead populations and successfully developed measures to increase fish runs.

Mr. Vogel served as Task Manager on numerous projects for the U.S. Bureau of Reclamation (USBR), Mid-Pacific Region, to define interrelationships of fishery resources and water project operations. He developed a life history guide for salmon in California's Central Valley to improve interagency coordination and communication concerning fishery and water resource management. He also assessed techniques to estimate the annual run sizes of the endangered winter Chinook salmon to recommend improved methodologies to enhance population restoration. He was the Task Manager for the original Biological Assessment of the federal Central Valley Project. Recently, under contract for the USBR, Mr. Vogel completed a comprehensive in-river, habitat-mapping survey of all the unscreened water diversions in the Sacramento River between Verona and Red Bluff using a DIDSON™ sonar camera and an acoustic Doppler current profiler.

Mr. Vogel has 31 years of experience in designing, directing, and conducting investigations to improve upstream and downstream fish passage. He has strong expertise in designing and implementing complex projects to sample entrainment of juvenile fish in large unscreened water intakes. During previous employment with the USFWS during the 1980s, he designed and conducted evaluations on a variety of water diversions, fish screens, and fishways and provided oversight on the operation and maintenance of some of those facilities. He was the project leader of a major evaluation on fish entrainment into a 2,700 cfs diversion which lead to the design and installation of state-of-the-art fish screening and fish bypass facilities. Mr. Vogel was also a key individual in the development of the biological criteria and associated bioengineering design for those facilities. As a member of multi-agency groups which have developed the concepts and designs of new screening facilities, he is thoroughly familiar with modern-day fish screen technologies. Dave Vogel was the Principal Investigator in a study of fish entrainment at the largest unscreened agricultural diversion in Oregon and developed the conceptual design that ultimately led to a fish screen and bypass facility on the A-Canal in the Klamath Irrigation Project. Recently, Dave Vogel has been serving as the Principal Scientific Investigator on behalf of the state/federal Central Valley Improvement Act's Anadromous Fish Screen Program for multi-year evaluations of fish entrainment in unscreened diversions on the Sacramento River.

Dave Vogel has served as a Principal Scientific Investigator for 22 research projects in the Sacramento – San Joaquin Delta. Mr. Vogel has conducted fish telemetry studies in the north, central, and south Delta. From 1996 through 2010, he used telemetry to evaluate the migratory behavior and migratory pathways utilized by salmon smolts (including four studies of predatory fish). He served on the Delta Cross Channel Work Team as one of the scientists evaluating the movements of juvenile salmon at the Delta Cross Channel and Georgiana Slough using both radio- and acoustic-telemetry methods. Mr. Vogel was also a Principal Scientific Investigator for the Vernalis Adaptive Management Program from 2006 through 2010. He recently conducted four research projects on the behavior and movements of predatory fish in the Delta. Based on his extensive field experience, he has acquired a highly specialized knowledge of the Delta, including fish habitat characteristics, migratory pathways utilized by salmon and fish mortality by reach, fish behavior, site-specific sources of fish mortality, and Delta hydrodynamic conditions. He has used a Natural Resource Scientists, Inc. DIDSON™ sonar camera extensively throughout the Delta to study fish habitats and predator/prey interactions.

Mr. Vogel has worked on various work teams to evaluate numerous proposed projects in the Delta. He has served on the CALFED Integration Panel and other committees to evaluate and recommend ecosystem restoration projects. He also worked on the Bay/Delta Oversight Committee's technical team. He has been involved with several evaluations of proposed projects in the Delta using particle tracking model results and other analytical tools.

Dave Vogel worked as the biological study team leader on behalf of state and federal agencies for the new fish screen facilities at the Glenn-Colusa Irrigation District's Sacramento River 3,000 cfs pumping station. This multi-year evaluation program involved extensive testing of the new fish screens and bypass systems using fish mark-recapture techniques. Additionally, he evaluated the associated new Sacramento River gradient facility by capturing, tagging and monitoring the telemetered movements of adult green and white sturgeon at the site, as well as monitoring the relative distribution and abundance of predatory fish. For more than a decade, Mr. Vogel conducted pre- and post-project conditions at the fish screen site. He was instrumental in developing biological criteria for the new fish screens.

Dave Vogel is very knowledgeable of provisions of the Federal Endangered Species Act (ESA) having served on the original National Marine Fisheries Service's Winter-Run Chinook Salmon Recovery Team and the USFWS's Endangered Lost River Sucker and Shortnose Sucker Working Group. He developed the framework for the original winter-run Chinook salmon restoration program and has worked on projects associated with the endangered monk seal, threatened green sea turtle, bald eagle, and other species. He has given public presentations to a wide variety of groups concerning the ESA including Congressional testimony on three separate occasions. He frequently works on ESA Section 7 Consultations and Section 10 permitting associated with threatened and endangered fish.

Mr. Vogel previously worked for the U.S. Government in the USFWS's Fishery Research Division and the Fishery Resources Division. He received the "Fishery Management Biologist of the Year" award for six western states and numerous outstanding and superior achievement awards. He served as Chairman of the USFWS SCUBA Diving Control Board for six western states during an eight-year period. At the time he left the Federal government, he directed an extensive program to develop restoration measures for salmon and steelhead populations. Much of this work involved large-scale monitoring projects and the development of mitigation programs associated with water development facilities. Mr. Vogel designed and conducted evaluations of Federal and state fish hatcheries to improve their effectiveness. He was Chairman of the Sacramento River Steelhead Trout Technical Committee for six years. He also developed and directed numerous projects to improve the survival and contribution of hatchery salmon and represented the USFWS on the California Department of Fish and Game's Salmon Smolt Quality Committee during the 1980s. Mr. Vogel served as a peer reviewer for the Interim and Final reports of the National Academy of Sciences' National Research Council Klamath Committee (Interim Report: Scientific Evaluation of Biological Opinions on Endangered and Threatened Fish in the Klamath River Basin; Final Report: Endangered and Threatened Fish of the Klamath River Basin: Causes of Decline and Strategies for Recovery).

Sacramento River, San Joaquin River, and Delta Technical Reports Authored or Co-Authored by Dave Vogel

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