A Review of Delta Fish Population Losses from Pumping Operations in the Sacramento-San Joaquin River Delta

Prepared by Larry Walker Associates
January 2010

REPORT OVERVIEW

An Examination of Causes and Mitigation of Delta Fish Loss From Pumping Operations

The issues facing the Sacramento-San Joaquin Delta are serious and complex. Although the challenge of how to restore the Delta ecosystem and its fish populations while improving water supply reliability has taken center stage recently, it is not a new issue. For more than 30 years researchers have documented the significant direct impacts the south Delta water project operations have on Delta fish and their habitat. At the same time, the amount of water pumped from the Delta through the Central Valley Project (CVP) and the State Water Project (SWP) doubled from 1991 to 2005 as illustrated in the December 2009 report by the Public Policy Institute of California called "California Water Myths."

The recent collapse of Delta fish populations creates the need for immediate and renewed action to reduce fish losses in and around the water project facilities. Many questions remain and more research is necessary to fully examine the numerous issues facing the Delta. However, there is a significant amount of data – which this paper summarizes – that should not be overlooked.

Significant Fish Losses Documented at Delta Water Pump Operations For More Than 30 years

From 1976 to 2009, numerous research studies by credible Delta experts have determined that despite the creation of fish "protection" facilities, the vast majority of juvenile Chinook Salmon (63% to 99%) and delta smelt (up to 99%) that are "entrained" near major water project facilities in the South Delta do not survive.

The Clifton Court Forebay (CCF) is a regulating reservoir located between the Delta and the SWP intake. CCF helps water project operators control water level and water velocity at the screens. CCF also has become a convenient feeding ground for a large number of predators that include fish and birds. A recent 2009 study of delta smelt found that as many as 94% to 99% of the smelt introduced into the CCF were eaten by predators. These are referred to as "pre-screen" losses.

The SWP and the CVP have fish protection facilities that try to collect the fish before they reach the Delta pumps. Fish louvers are placed in front of the pumps to prevent fish from entering the pumps, but are not completely effective. A 1996 report by the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) cited studies performed by the departments in 1970-71 that determined the screens may allow as many as 30% of fish which enter the fish protection facilities to reach the pumps.

Fish are collected in the fish protection facilities so they can be "salvaged." From the collection area they are placed in holding tanks, then loaded into tank trucks, driven to specific locations in the Delta, and discharged from the trucks through pipes that extend out into Delta waters.

In a 2009 Biological Opinion, National Marine Fisheries Service (NMFS) reports there is typically debris in the holding tanks

ED_000733_DD_NSF_00045417-00002

along with the fish, which can disorient, injure and kill fish due to turbulent forces in the pipeline when the fish are released.

NMFS anticipates that 10% to 30% of salvaged fish are lost to predators at the Delta release sites and that an additional number die after release due to stress or injury associated with the handling process.

A 1996 report by DWR and DFG concluded that for every salmon salvaged at the fish protection facilities, more than three are lost to predators or are lost through the fish screens. The report stated that these loss rates "demonstrate a serious problem."

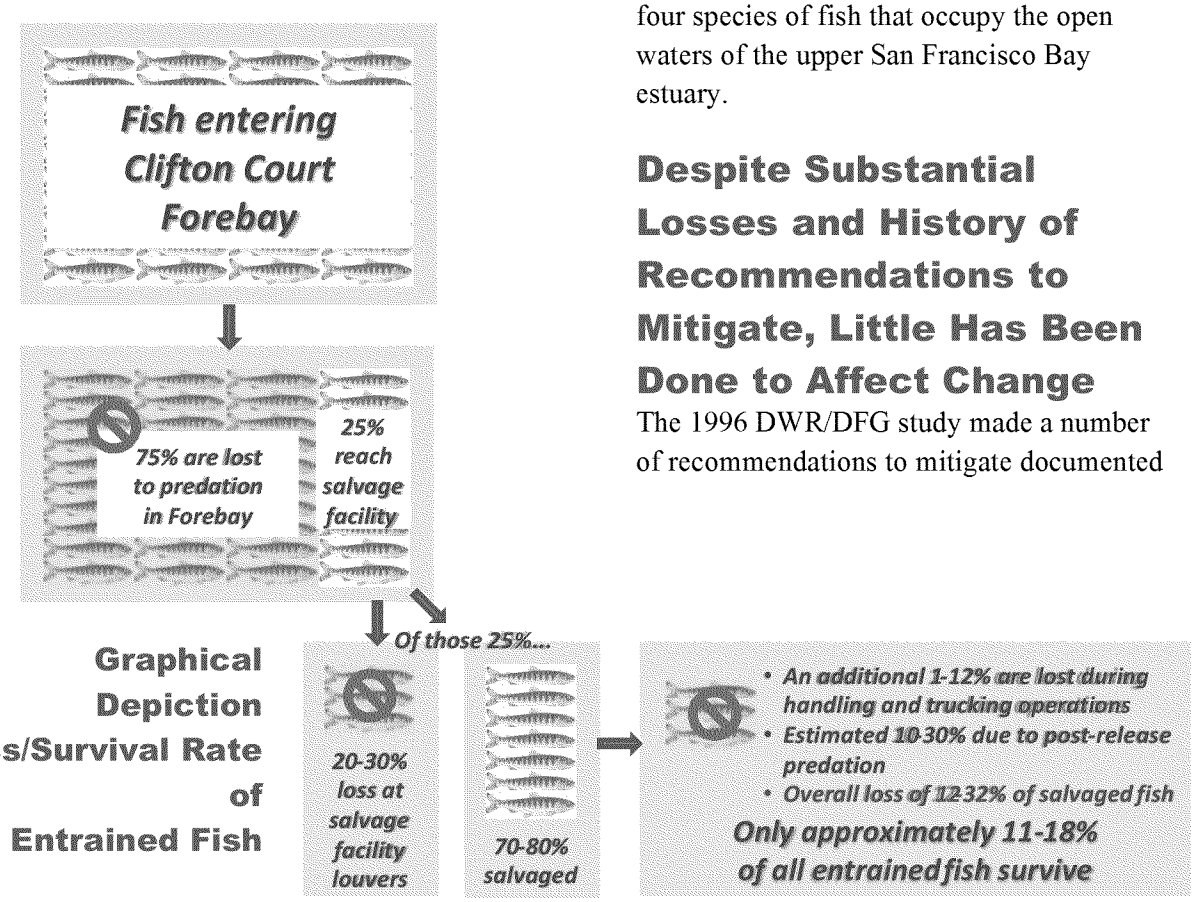
The same 1996 report stated that over a 15-year period (1979 to 1993), 110 million fish were reported to have been salvaged at Skinner Fish Facility, the fish protection facility at the SWP. These salvage statistics greatly understate the total number of fish entrained, since they do not include the number of fish lost to predators or lost through the fish screens. In fact, recent estimates indicate that 5-10 times more fish are lost than are salvaged, largely due to the high predation losses in and around water project facilities.

In 2008, Wim Kimmerer, a prominent ecologist and Delta researcher, estimated that approximately 30 times more delta smelt are entrained than are salvaged.

In 2008, United State Fish and Wildlife Service (USFWS) also reported that high entrainment rates during winter months are suspected as a contributing cause of the early 1980s delta smelt decline and the pelagic organism decline or "POD." The POD refers to the record low numbers of four species of fish that occupy the open waters of the upper San Francisco Bay estuary.

Despite Substantial Losses and History of Recommendations to Mitigate, Little Has Been Done to Affect Change

The 1996 DWR/DFG study made a number of recommendations to mitigate documented



Graphical Depiction of Loss/Survival Rate of Entrained Fish

ED_000733_DD_NSF_00045417-00003

fish losses such as replacing existing fish screens, reducing the number of salmon entering the CCF and encountering the screens, and moving the intake for the California aqueduct. Little or no action was taken to implement these suggestions.

In 2000 the CALFED Record of Decision highlighted the need to improve the fish screens at the South Delta pumps. Although these improvements were to be in operation by2006, they remain on hold.

Now underway is the Bay Delta Conservation Plan (BDCP), an effort intended to allow the water exporters to obtain another incidental take permit for fish losses associated with their operations. While the BDCP is proposed to serve co-equal goals of water supply and ecosystem restoration, operational improvement recommendations to date include a less than comprehensive predator control program and plans to study non-structural barriers to prevent fish from entering the CCF and other areas of the Delta. No measures to improve the south Delta fish screens or salvage facilities have emerged.

The fish protection facilities at the South Delta pumps, including the fish screens and salvage facilities, remain largely unchanged since they were first engineered over 40 years ago.

Full Impact of Pumping Operations Still Must Be Determined

In 2008, Wim Kimmerer published a paper that demonstrated that fish mortality associated with project operations can be causing adverse impacts on the populations of these species.

Prior to that work, most efforts have sought to assess the effects of project operations or export volumes through correlation analyses. Such analyses have limitations and are greatly affected by the study period selected and other assumptions.

There is a lack of data to fully quantify the impact that the ongoing fish mortality in and around the south Delta pumps is having on total fish populations.

Also absent is a strong analysis of "indirect" fish losses associated with hydrodynamic and habitat changes brought by south Delta pumping operations.

A Call to Action

For 30 years scientists and regulatory agencies have documented the significant impacts the water export operations have on Delta fish – and yet little action has been taken to correct the situation. When the POD signaled the Delta ecosystem is in real trouble a few years ago, the response was to shift the blame from the known impacts of the water exports to potential other "stressors."

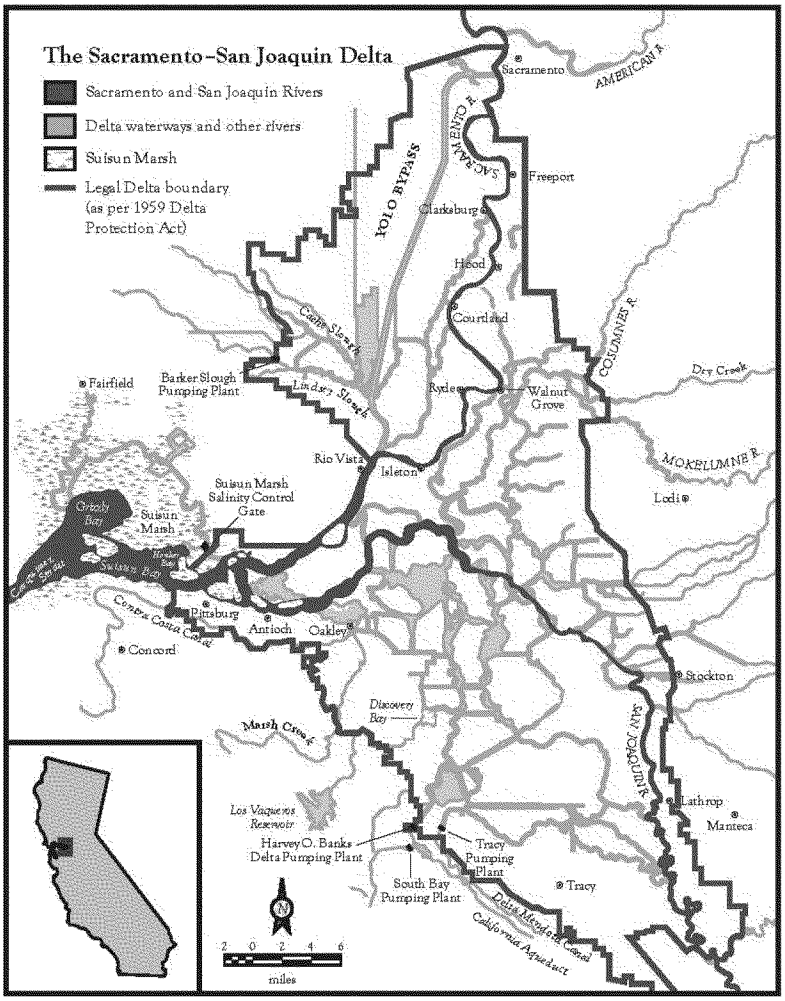
Certainly, more research must be done to fully understand all of the issues that may be affecting the health of the Delta and what action should be taken to address them, but the comprehensive and integrative research needed to yield sound data on these issues will take years. In the meantime, immediate action should be taken to mitigate the known and well documented impacts of the water exports on the Delta ecosystem and endangered fish species. Too much is at stake to allow further delay in addressing the ongoing fish mortality associated with the water project operations, especially when the evidence paints such a clear picture. ■

ED_000733_DD_NSF_00045417-00004

INTRODUCTION

Overview of the Delta

The Sacramento-San Joaquin River Delta is an inland river delta and estuary in northern California at the western edge of the Central Valley near the confluence of the Sacramento and San Joaquin rivers. It lies east of where the rivers enter Suisun Bay (an upper arm of San Francisco Bay).



Map Source: PPIC Report - *Envisioning the Sacramento-San Joaquin Delta.*

Water flows from the Sacramento and San Joaquin Valleys to the Delta where it enters a maze of sloughs and waterways leading to the San Francisco Bay. The flow of water in the Delta is directed by an extensive system of levees. The flow patterns through the Delta are largely determined by:

- Tidal influences that move salt water in and out of the Delta daily;
- Flows from major rivers that vary considerably throughout the year;
- Operation of flow control structures on certain waterways in the Delta; and
- Export of water from the Delta for urban and agricultural use.

Delta as Water Distribution System

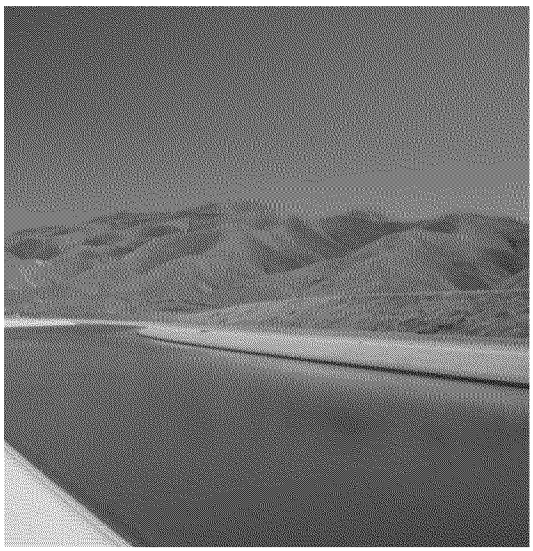
The Delta serves as a major water distribution system for many parts of the State, and also many agricultural and municipal water diverters surrounding and within the Delta itself. The two largest water export systems are the Central Valley Project (CVP) and the State Water Project (SWP). Both systems take water from the southern part of the Delta and send it to other parts of the state, primarily the south.

The CVP is operated by the U.S. Bureau of Reclamation (USBR). It includes reservoirs upstream of the Delta, in-Delta facilities, and conveyance facilities that head towards the southern part of the state (for example, the Delta Mendota Canal). Within the south Delta, the CVP includes the Tracy Fish Collection Facility that helps to prevent fish

ED_000733_DD_NSF_00045417-00005

from being pumped out of the Delta by the Jones Pumping Plant (formerly known as the Tracy Pumping Plant).

The SWP is operated by the California Department of Water Resources (DWR). It includes reservoirs upstream of the Delta, in-Delta facilities, and conveyance facilities that head towards the southern part of the state (i.e. the California Aqueduct). Within the south Delta, the SWP includes the intake

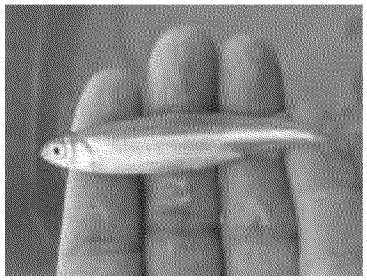


Aquaduct of the State Water Project

point known as Clifton Court Forebay, the Skinner Fish Protective Facility (a system designed to screen out fish from water pumped by the SWP so they can be transported back to the Delta), and the Banks Pumping Plant.

Fish Population Problems in the Delta

The Delta is home to approximately 22 species of fish including the **delta smelt**, a key indicator species for the health of the Delta's ecosystem. In 2004 the delta smelt was found to be on the edge of extinction. Other fish experiencing serious population declines include longfin smelt, salmon, steelhead and green sturgeon.



Delta smelt

Numerous hypotheses related to water quality conditions and other stressors have been put forth as the cause or causes of the recent precipitous decline in threatened Delta fish populations. Few of these hypotheses focus on areas where a definitive link exists to fish mortality or impacts on fish populations. However, fish losses due to State Water Project and Central Valley Water Project pumping operations in the south Delta are well-documented, and have potential population level effects.

This document provides an overview of key reports that have documented fish losses due to pumping operations, and a chronology of efforts to identify and implement mitigation measures to prevent fish loss. The information indicates that while substantial fish losses have been documented since the late 1970s, comprehensive mitigation actions directed to reduce these losses have not occurred.

This document provides an overview of key reports that have documented fish losses due to pumping operations and a chronology of efforts to identify and implement mitigation measures

ED_000733_DD_NSF_00045417-00006

Key Definitions

Entrainment: When fish are pulled into the vicinity and "trapped" in water project facilities. Entrainment occurs extensively in the Clifton Court Forebay when fish enter the forebay and cannot swim out.

Pre-Screen Loss: Losses of fish due to export operations that occur before they can be collected and salvaged at the fish protection facilities. Pre-screen losses can be particularly extensive in the Clifton Court Forebay due to predation from other fish and birds.

Salvage: Collection of fish upstream of pumping facilities with the intent of returning them safely to the Delta. The CVP's Tracy Fish Collection Facility and the SWP's Skinner Fish Protective Facility both use a series of louvers to direct fish away from the flow to the pumps and into holding tanks. From the holding tanks they are transported and released back into the Delta.

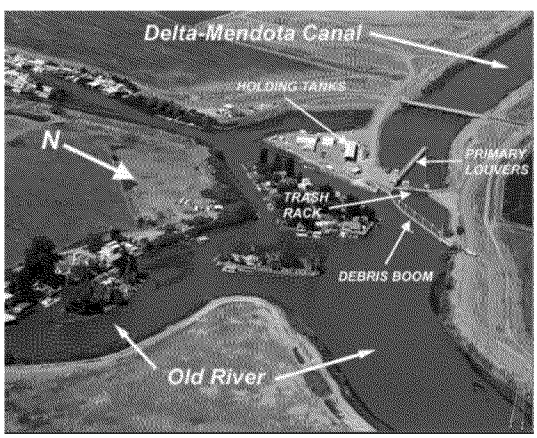
Additional losses: Some fish are not successfully diverted by the fish collection facilities and are pumped into the canals that head towards the south part of the State and are removed from the Delta population. Additional losses occur as a result of trauma during the salvage process. Fish are also killed by predators which congregate at locations where salvaged fish are released.

Total Fish Loss: Total of all fish losses associated with all components of water project operations. Includes pre-screen loss, loss during and after salvage, and loss at the pumps.

Fish Salvage Operations

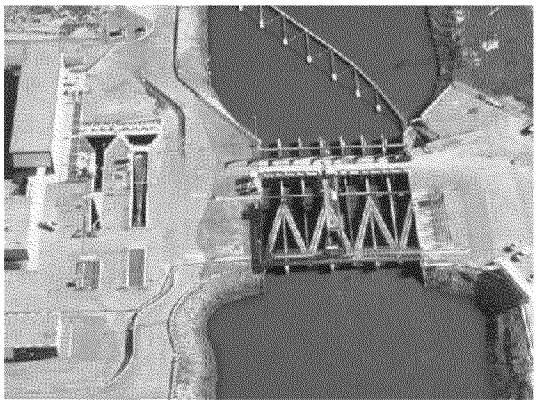
To reduce fish loss at the pumps, the state and federal water export facilities operate facilities which are designed to salvage fish from the water and return them to the Delta. Fish facilities include the SWP **Skinner Fish Protection Facility** and CVP **Tracy Fish Collection Facility**. The fish facilities utilize two sets of louvers to prevent fish from entering further into water project operations and ultimately the powerful pumps. The louvers concentrate fish so that they can be removed prior to the water diversions. However, these fish salvage operations are inefficient, as high numbers of fish are lost due to predation in the waterways leading to the fish facilities, and the louvers are inefficient (Gingras, 1997 and Bowen et al., 2004).

Fish caught at these facilities are placed in holding tanks, loaded into tank trucks, and pumped out of the trucks through pipes at two release sites each for the SWP and CVP. These are called "Collection, Handling, Trucking and Release Operations."



The CVP's Tracy Fish Collection Facility

ED_000733_DD_NSF_00045417-00007



The SWP's Skinner Fish Protection Facility

Clifton Court Forebay (CCF) is a man-made regulating reservoir located in the Delta immediately upstream of the SWP intake. Inflow of water and entrained fish to CCF is controlled by three gates, which are opened at higher tide elevations to fill the reservoir. The forebay allows water project operators to control water depth and velocity at the fish facility and pumps. The forebay contains high numbers of predators (fish and birds), which contribute to "pre-screen" mortality.

Aerial view of Clifton Court Forebay

Reports examining fish losses related to CVP and SWP pumping operations

Fish losses related to water project pumping operations have been documented in studies as far back as the 1970s. The following sections describe some of these key reports and studies that summarize fish losses.

1996 – DWR and DFG: Effectiveness of Fish Salvage Operations

A 1996 review by the Department of Water Resources and Department of Fish and Game (DFG) evaluated the effectiveness of fish salvage operations at the intake to the California Aqueduct between 1979 and 1993 (Brown et al., 1996). The authors evaluated fish salvage operations at the Skinner Fish Protection Facility, focusing on the fate of Chinook salmon throughout the salvage operations. **Based on an evaluation of previous studies examining pre-screen losses in Clifton Court Forebay, the review concluded that predation was responsible for a 75% pre-screen loss for Chinook salmon.** The 75% estimate was an average of the 1978, 1984, and 1985 pre-screen loss estimates, and was adopted in 1986 as part of a DFG and DWR mitigation agreement to offset direct losses of fish at the export facility.

The authors noted that additional fish are lost at the Skinner Fish Facility, as the louvers are not completely effective at blocking fish from entering the pumps. They cited a study by DFG and DWR from 1970-1971, which found that efficiency of the primary louvers ranged from 70-85%, and

Based on an evaluation of previous studies examining pre-screen losses in Clifton Court Forebay, a 1996 DWR and DFG study concluded that predation was responsible for a 75% pre-screen loss for Chinook salmon.

ED_000733_DD_NSF_00045417-00008

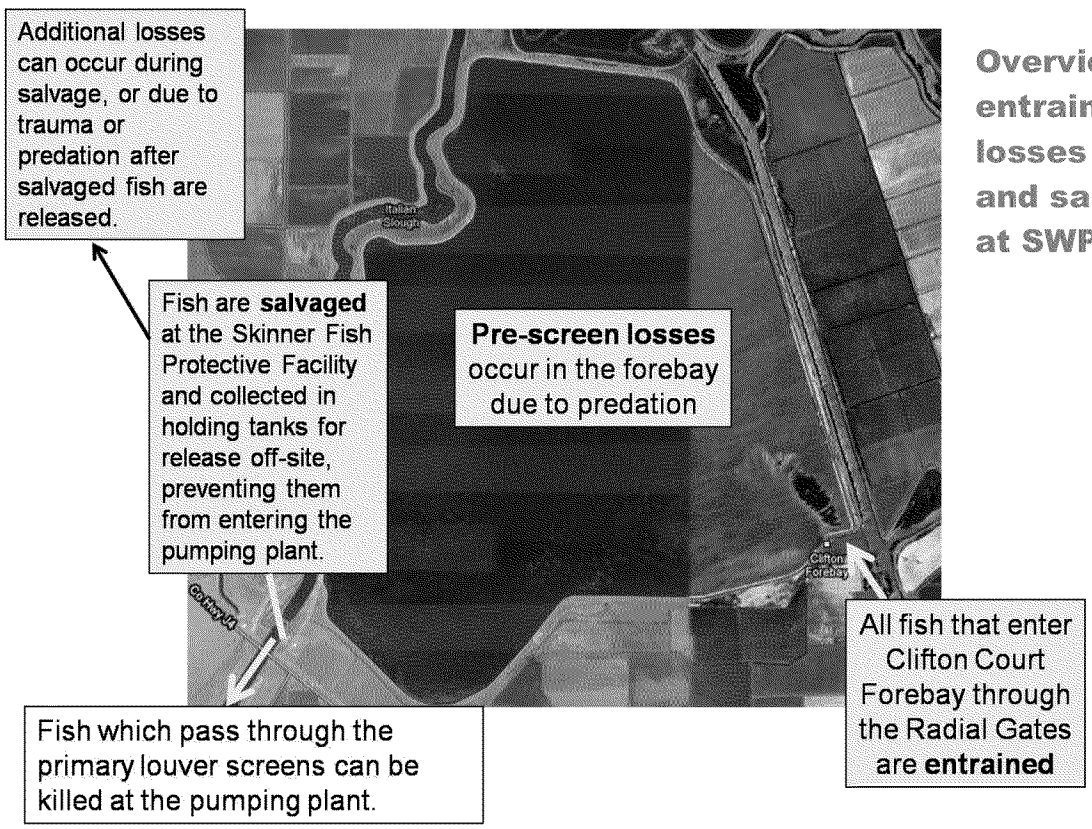
that efficiency of the secondary louvers ranged from 70-95%, and were more efficient for larger fish. The authors also noted that predation within the louvers could additionally cause an unknown portion of losses at the facilities.

The report concluded that **for every salmon salvaged, more than three were lost to predators in the forebay or through the fish screens, and that these statistics "demonstrate a serious problem."** Due to the magnitude of the problem, a number of efforts were suggested to mitigate fish losses. Efforts suggested were: replacing existing screens, reducing the number of salmon entering the forebay and encountering the screens, and moving the intake for the California aqueduct.

2008 – USFWS: Biological Opinion

In the 2008 biological opinion for delta smelt, United States Fish and Wildlife Service (USFWS) noted that fish entrainment at the Banks and Jones pumping plants is among the best-studied sources of fish mortality in the San Francisco estuary, due to the large volumes of water that are drawn from the estuary. All fish species inhabiting the Delta have been shown to be entrained in the export facilities.

Entrainment is of particular concern during dry years, when distributions of vulnerable fish populations shift upstream, closer to the export facilities. **The biological opinion pointed out the magnitude of entrainment at the export facilities, citing statistics that approximately 110 million fish were salvaged at the Skinner Fish Facility over a 15-year period.** The authors state that salvage statistics greatly underestimate the number of fish entrained, as they do not include losses through the louvers, nor do



Overview of entrainment, losses and salvage at SWP

they account for high rates of predation in Clifton Court Forebay. To emphasize the severity of the problem, **USFWS states that high entrainment during winter months was suspected as a contributing cause to the early 1980s delta smelt decline**, as well as the Pelagic Organism Decline (the detection of record low numbers of four fish species that occupy the open waters of the San Francisco Bay Estuary).

2009 -- NMFS: Biological Opinion

The 2009 Biological Opinion for Salmonids reported high pre-screen losses in Clifton Court Forebay. Two studies that estimated losses due to predation in the forebay found:

- Pre-screen loss ranging from 63-99% for juvenile Chinook salmon and 70-94% for juvenile striped bass (Gingras,1997).
- Pre-screen loss of steelhead ranging from 78-82% (DWR, 2008).

These studies indicate that mortality is very high in the forebay for Endangered Species Act-listed salmonids, with 75-80% lost due to predation. The biological opinion stated that, based on the increased frequency of greater pumping rates anticipated for the SWP, NMFS anticipates that substantial numbers of additional Chinook salmon and steelhead will be lost due to predation in the forebay. If pumping increases, additional salmonids will be drawn into the forebay, particularly during the months when those species are most present in the system and therefore vulnerable to predation. NMFS drew the conclusion that: "The proposed near term and future operations of the SWP, through the operations of the Clifton Court Forebay, will exert additional adverse effects upon the listed salmonid populations. The loss of these additional individual fish will further reduce the populations of listed salmonids."

The Plight of "Salvaged" Fish

Fish are impacted during the salvage operation due to trauma inflicted during the handling, trucking, and release operations when fish are transported from the collection facility to the release location in the Delta.

Typically, there is debris present in holding tanks along with the fish, which can injure and kill fish during transport. The biological opinion describes additional trauma to fish due to turbulent forces that occur when fish are pumped through the pipe which releases them into the river, and can injure and disorient fish; potential stranding of fish in the tanker truck if debris clogs the exit-way when water is emptied; vulnerability to predation when disoriented fish are released since predators are attracted to those release locations; delayed mortality from injuries; and shock from water quality conditions changing too quickly during the release procedure.

The biological opinion estimated that an additional 2% of fish die within 48 hours of release due to non-predation related stress. Release predation rates have not been quantified, but most likely add an additional 10 to 30% mortality.

- NMFS 2009 Biological Opinion

ED_000733_DD_NSF_00045417-00010

2009 – DWR: Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay

To follow up on a 2004 NMFS biological opinion, DWR conducted a series of studies to assess and quantify pre-screen losses of steelhead in Clifton Court Forebay, which was summarized in a 2009 report (DWR, 2009). The researchers completed smaller-scale studies in 2005 and 2006, and conducted a full-scale study in 2007. They tagged steelhead, released them at the entrance gates, and determined their fate by following the location of the tags. Pre-screen losses within Clifton Court Forebay ranged from 78-82%. Researchers focused on predation both by striped bass and by bird species, finding evidence that both predator types are foraging near the entrance gates.

The report recommended creating and implementing a management plan to reduce pre-screen losses within Clifton Court Forebay. It suggests revisiting predator reduction strategies which were studied during the 1990's, as well as conducting feasibility studies to determine if changes to the configuration of the forebay could reduce entrainment.

This report mentions that high losses in Clifton Court Forebay have been known about since the early 1980's. It refers to statistics on pre-screen losses from DFG studies conducted between 1976 and 1993, which show the range of pre-screen losses of juvenile Chinook salmon to be 63-99%.

2009 – USFWS: Ongoing Research on Delta Smelt Pre-Screen Loss and Salvage Efficiency

Ongoing research by Castillo with the USFWS has focused on estimating pre-screen loss and salvage efficiency for delta smelt (Castillo, 2009). Research conducted from February through June 2009 used marked delta smelt to evaluate salvage facility efficiency at Skinner Fish Protection Facility and pre-screen loss in Clifton Court Forebay. Results were presented in a poster at the 2009 State of the San Francisco Estuary Conference, where the study was noted as the "first experimental evaluation of the relation between delta smelt salvage at the Skinner Fish Protection Facility and underlying entrainment losses at the SWP in the south Delta."

Study results suggested that entrainment losses of delta smelt could be much higher compared to other species previously studied at the SWP, and that pre-screen losses were very high for delta smelt. The percent recovery of delta smelt released at the entry point of Clifton Court Forebay and then recaptured at Skinner Fish Facility was low: 2.98% in February, 0.42% in March, and 0.03% in June. **The vast majority of delta smelt mortality could be attributed to pre-screen losses, which were 94.2% in February, 99.0% in March, and 99.9% in June.**

Summary of Data Related to Pre-Screen Losses

The following table summarizes pre-screen loss data dating back to 1976. A report by Gingras (1997) summarized pre-screen loss data from mark-capture experiments in Clifton Court Forebay by DFG. More recent data were presented by Castillo (2009) in the presentation described in the previous section. Pre-screen loss percentages range from 63% to 99% for juvenile Chinook salmon, and from 94% to 99.9% for delta smelt.

ED_000733_DD_NSF_00045417-00011

Summary of Data related to Pre-Screen Losses			
Year	**Species**	**Pre-screen loss %**	**Study/Reference**
1976	Juvenile Chinook salmon	97	Gingras, 1997
1978	Juvenile Chinook salmon	88	Gingras, 1997
1984	Juvenile Chinook salmon	63	Gingras, 1997
1985	Juvenile Chinook salmon	75	Gingras, 1997
1986	Striped bass	70	Gingras, 1997
1992	Juvenile Chinook salmon	99	Gingras, 1997
1993	Juvenile Chinook salmon	99	Gingras, 1997
2007	Juvenile steelhead	78-82	Clark et al., 2009
2009 - February	delta smelt	94.2	Castillo, 2009
2009 – March	delta smelt	99.0	Castillo, 2009
2009 – June	delta smelt	99.9	Castillo, 2009

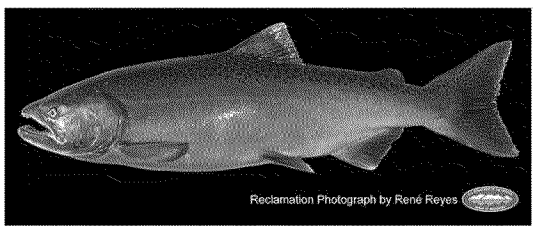
Linkage of fish loss findings to population level impacts

The absence of prior work to address the linkage between the ongoing fish mortality in and around the south Delta pumps and population level effects is striking.

An article prepared by Kimmerer (2008) for San Francisco Estuary & Watershed Science provides valuable analysis of the effect of the direct loss of salmon and delta smelt associated with fish screens and pumping operations on the populations of those species. Losses of fish to mortality associated with export pumping have been blamed in part for declines of numerous species including striped bass (Stevens et al. 1985), Chinook salmon (Kjelson and Brandes 1989), and delta smelt (Bennett 2005).

Prior reviews relied on correlation analysis to attempt to link the pumping operations to fish population declines. Yet despite strong correlation, no quantitative estimates have been made to determine the impact of fish losses at the water export facilities on the entire population of fish species. Moreover, there have been no published reports to measure the export losses against subsequent population size. As Kimmerer, a prominent ecologist and Delta researcher points out, this assessment "requires an analysis of mechanisms rather than one based on correlative relationships alone." Using a mechanistic rather than correlative approach, Kimmerer found the following:

- Based on management targets for the Delta, salmon losses are higher than expected. Levels of mortality at the export facilities may place constraints on the recovery rate of the listed winter- and spring-run stocks of salmon.



Chinook salmon, *Onchorhynchus tshawytscha*. Reclamation photo by Rene Reyes.

ED_000733_DD_NSF_00045417-00012

- For adult delta smelt, Kimmerer estimated that approximately 30 times more delta smelt are entrained than are salvaged, with an overall pre-salvage loss rate of 97%. The estimates for cumulative loss of delta smelt over one season ranged from 3% to 50% for years 2002-2006. When looking at data back to 1995, mean proportional losses ranged from 0 to 23%.
- The proportional loss rates for larval and juvenile delta smelt peaked in early April from 1997 to 2005. The proportional losses were related to export flow, with the lowest proportional losses (approximately 25%) occurring during the dry years 2001-2003, and with a proportional loss of 62% occurring when export flow was at a maximum.
- Manipulating export flow (and, to some extent, inflow) is the only means to influence the abundance of delta smelt that is both feasible and supported by the current body of evidence.
- Losses of fish due to altered hydrodynamic conditions or migration cues in the Delta are called "indirect" losses. Although export pumping has substantial impacts on flow patterns in the Delta, the extent to which such alterations affect survival of fish is much less clear. Indirect losses may be important (NMFS, 2004), but they remain hypothetical and unquantified.

Kimmerer speculated as to the population level consequences of these proportional losses, comparing them to losses from other sources of mortality. When compared to fishing mortality, Kimmerer concluded that "the calculated loss rate at the export facilities would be a significant component of direct anthropogenic mortality" for Chinook salmon.

The above findings are consistent with those used in the 2008 and 2009 biological opinions on delta smelt and Chinook salmon prepared by federal fisheries experts at US Fish and Wildlife Service and the NOAA National Marine Fisheries Service, respectively, which were summarized previously. The USFWS biological opinion noted, "Increased pumping at the Banks and Jones export facilities corresponds to the decline of the delta smelt population during the period both prior to and following its listing under the Act" (USFWS, 2008 p. 276), and the NMFS biological opinion states that "[T]he long-term operations of the CVP and SWP are likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, Southern DPS (distinct population segment) of North American green sturgeon, and Southern Resident killer whales" (NMFS, 2009 p. 575).

Remedial actions/projects that have been considered/taken by project operators

Actions aimed to prevent losses of fish at project facilities include the following types of projects, which are described in the following sections:

- Gates and physical barriers;
- Screens and ladders at Delta diversion points;

ED_000733_DD_NSF_00045417-00013

- Non-physical barriers;
- Pre-screen loss mitigation efforts in Clifton Court Forebay; and
- Efforts to reduce mortality during salvage operations.

Gates and Barriers

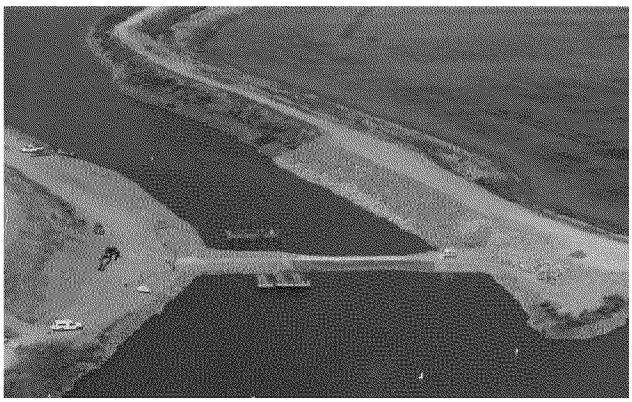
Head of Old River Barrier and the Vernalis Adaptive Management Program

The South Delta Temporary Barriers Project, initiated as a test project in 1991 and extended for five years in 1996 and again for seven years in 2001, occurred partially in response to a 1982 lawsuit filed by the South Delta Water Agency. The project consists of four rock barriers across south Delta channels which are installed and removed every year, except when prevented by high San Joaquin River flows.

The Barriers Project includes the Head of Old River Barrier (HORB), at the confluence of Old River and the San Joaquin River, which is in place most years since 1963 for 6 weeks in the Fall (September 15-November 30), and was in place for 6 weeks in the Spring (April 15-May 30) in 1992, 1994, 1996, 1997, 2000, 2001, 2002, 2003, and 2004, and 2007. Its purposes related to fish management are:

1. To prevent out-migrating salmon smolts in the San Joaquin River from entering Old River and getting drawn into south Delta export facilities; and
2. To increase attraction flows for upstream migrants by maintaining more of the San Joaquin River outflow within its natural channel.

The remaining three barriers are designed to increase water depths and improve quality



Head of Old River Barrier

for in-Delta agriculture and are installed between April 15-September 30 of each season. The Old River near Tracy barrier (ORT) has been installed since 1991 and the Middle River barrier (MR) has been installed since 1987. A rock barrier in Grant Line Canal (GLC) was first installed in spring 1996, and has since been installed in 1997, 1999, and 2000 through the present. The four rock barriers were not installed in 1998 due to high San Joaquin River flows.

The Vernalis Adaptive Management Plan (VAMP) was officially initiated in 2000 as part of State Water Resources Control Board (SWRCB) Water Right Decision 1641 (D1641), and is a 12-year experimental management program partially designed to determine what impact the HORB has on salmon smolt out-migration success. The plan provides a pulse flow in the San Joaquin River for a 31-day period at Vernalis during April and May and other flows identified by the Central Valley Project Improvement Act water acquisition plan, such as fall attraction flows.

The SWRCB Strategic Workplan for activities in the Delta calls for the review and potential amendment of southern Delta salinity and San Joaquin River flow objectives. The SWRCB requested in 2008 that the San Joaquin River Group Authority

ED_000733_DD_NSF_00045417-00014

(SJRGA) conduct a peer review of the VAMP to determine whether changes may be needed to the study to obtain necessary data points and to ensure the protection of San Joaquin River and Delta species. In 2009, the SWRCB conducted several workshops concerning potential amendments to San Joaquin River Flow objectives.

In 2008, a court order designed to protect delta smelt prohibited the installation of the spring HORB pending fishery agency actions or further order of the court.

South Delta Improvement Program and NMFS Prohibition

The South Delta Branch of the Bay-Delta Office of DWR[1] implements projects and actions in the south Delta as part of the CALFED California Bay Delta Authority Conveyance Program. The South Delta Improvement Program (SDIP)[2] was one of the key plans developed by the South Delta branch to implement several elements of the Preferred Alternative outlined in the CALFED Record of Decision (ROD). Stage 1 of the SDIP proposed four actions: (1) replacement of four seasonal rock gates currently installed in the Temporary Barriers Project (a fish barrier at Head of Old River, and three agricultural water control barriers at Old River at Tracy, Middle River, and Grant Line Canal) with permanent operable gates, (2) limited dredging in Middle and Old Rivers and West Canal, (3) extension of 24 existing local agricultural diversions in the south Delta to deeper water, and (4) an increase in the maximum SWP diversion to 8,500 cfs. Although one goal of the gate operations would be to reduce the movement of San Joaquin River fall/late fall–run juvenile Chinook salmon into the south Delta at the Head of Old River, a principal goal is to maintain water levels and water quality for agricultural diversions downstream of the head of Old River. All four proposed gates would be owned, operated, and maintained by DWR.

The SDIP was one of the elements of the SWP/CVP Operations Criteria and Plan (OCAP) analyzed by NMFS in its 2009 biological opinion. NMFS concluded that (1) the design, placement, and operation of permanent gates would create new habitat for predators and increase the proportion of winter-run Chinook salmon that encounter gates from 3% to 100%, (2) fish would have to negotiate an increased number of gates to move through the south Delta compared to the current Temporary Barriers Project, and (3) particle entrainment levels were too high, and the zone of entrainment too large, despite the planned operations of new gates. As a result, NMFS prohibited implementation of the SDIP as Action IV.6 in the Reasonable and Prudent Alternatives (RPAs) of the 2009 biological opinion.

2-Gates Fish Protection Demonstration Project

The RPAs in the USFWS (2008) and NMFS (2009) biological opinions for the SWP and CVP include actions to limit reverse flows in Old and Middle Rivers to reduce entrainment of fish at the export facilities. The 2-Gates Fish Protection Demonstration Project was designed by consultants of Metropolitan Water District of Southern California (MWD) and has been proposed as a 5-year adaptive management experiment to justify higher minimum export volumes than outlined in the USFWS and NMFS

---

[1] http://baydeltaoffice.water.ca.gov/sdb/.

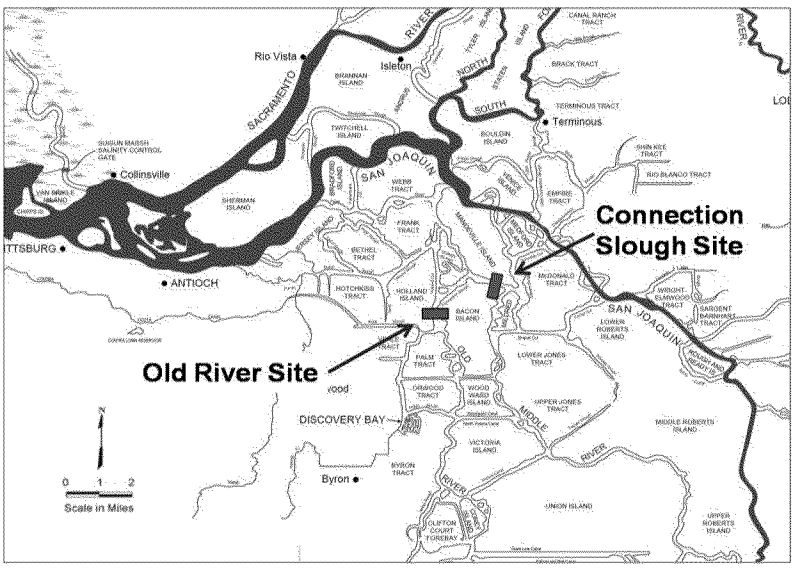
[2] http://baydeltaoffice.water.ca.gov/sdb/sdip/index_sdip.cfm.

ED_000733_DD_NSF_00045417-00015

biological opinions. A team comprised of staff from MWD[3], State Water Contractors, CVP contractors, and Contra Costa Water District formed in 2008 to expedite implementation of the project and initiate the environmental documents[4]; the USBR is serving as the project proponent for purposes of environmental review.[5]

The 2-Gates Project…has been proposed as a 5-year adaptive management experiment to justify higher minimum export volumes than outlined in the USFWS and NMFS biological opinions.

The project would use operable gates to modify flows in the central Delta. The justification for the 2-Gates project relies on an observation that high turbidity (in excess of 12-15 NTU) is correlated with and may be a functional cue for the annual spawning migration by delta smelt from Suisun Bay to the Delta, although this theory has only been specifically addressed to date in one peer-reviewed scientific paper (Grimaldo et al. 2009). During high river flow periods, turbidity enters the western Delta from the Sacramento River and the central Delta via Georgiana Slough, and the south Delta through Old River and Middle Rivers. Inflow from the San Joaquin River also contributes a pulse of turbidity, although the timing typically lags behind that from the Sacramento River. When these two water bodies meet, they form a continuous high turbidity zone which presumably encourages smelt to move south toward the pumps. In the 2-Gates Project, temporary gates would be placed across Old River and Connection Slough in the Central Delta, and operated December-March to



keep turbid water away from the export pumps. The purpose of the project is to demonstrate that operable gates, in conjunction with some restriction on negative OMR flows, could provide equal or greater protection for delta smelt than restrictions on reversing flow in Old and Middle rivers.

The CALFED Science Program convened an Independent Review Panel in August 2009 to review the 2-Gates Project Summary Document (MWD 2009, Anderson et al. 2009). The draft environmental assessment for the project was released for review in October 2009 (USBR 2009a, b). One of the California

---

[3] See minutes of June 9, 2009 MWD Board of Directors meeting and related letter to MWD Board of Directors from Water Planning and Stewardship Committee dated June 9, 2009.

[4] See December 2008 "Bay-Delta Management" report to the MWD Board of Directors.

[5] http://www.usbr.gov/mpnepa/nepa_projdetails.dfm?Project_ID=4472

ED_000733_DD_NSF_00045417-00016

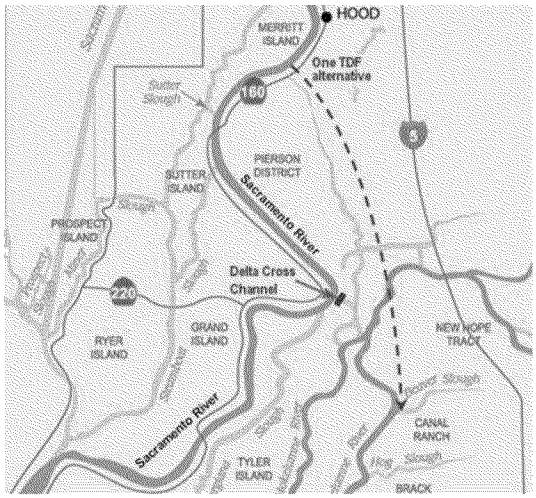
Senate bills in the comprehensive water package passed in November 2009 (SBX7-1, Delta Governance/Delta Plan) appropriates funding from Proposition 84 to fund the 2-Gates Fish Protection Demonstration Program.

Some of the objections raised regarding the 2-Gates project are:

(1) That submission of environmental documents consisting of a Finding of No Significant Impact and Mitigated Negative Declaration (as opposed to a full EIS/EIR) is inappropriate for a project whose purpose is to keep an endangered species out of a part of its critical habitat;
(2) Evaluations of potential impacts to other species (salmon, steelhead, sturgeon, longfin, splittail, threadfin shad, striped bass, etc.) have been cursory, or nonexistent;
(3) Required authorizations (i.e., Clean Water Act section 404 & 401 permits, streambed authorization agreement, consistency determinations with federal biological opinions, etc.) are on a fast track; and
(4) RPA IV in the 2009 NMFS biological opinion denied use of similar operable OMR barriers when it prohibited implementation of the South Delta Barriers Improvement Program (Action IV.6).

Re-Operation of Delta Cross Channel Gates

The Delta Cross Channel (DCC) was constructed in 1951 to assist in transferring water from the Sacramento River across the Delta. When the gates are open, Sacramento River water is diverted into the north and south forks of the Mokelumne River, and toward the south Delta pumps. Adult Chinook salmon use the Sacramento River, DCC, and Georgiana Slough as out-migration pathways. A major effect of water operations in the Delta is diversion of out-migrating juvenile salmon from the north Delta tributaries into the interior Delta when the DCC gates are open. Instead of migrating directly to the outer estuary and then to sea, juvenile salmon are caught in the interior Delta and subjected to predators, and altered food webs, and other stressors that may cause direct mortality or impair growth. Investigations in the early 1980's indicated that juvenile winter-run Chinook salmon may be entrained into the interior Delta in proportion to Sacramento River flow diverted through the DCC (Shaffter, 1980). In order to protect out-migrating winter-run Chinook salmon, the DCC gates are operated in accordance with Water Rights Decision 1641 (SWRCB 2000), requiring closure of the gates between February 1-May 20, and intermittent closures of proscribed total duration outside of that period when requested by the USFWS, NMFS, or CDFG for fisheries protection.



Delta Cross Channel (DCC) location

ED_000733_DD_NSF_00045417-00017

The Preferred Program Alternative described in the CALFED (2000) Record of Decision (ROD) included re-operation of the DCC as one of two north-Delta conveyance facilities improvements (the other was a proposed Through Delta Facility [TDF]). In 2001, the CALFED Science Program began a study of the effects of DCC gate operations and tides on flow and fish entrainment. An evaluation by scientists with DWR and DFG found a significant linear relationship between the proportion of Sacramento River flow diverted into the interior Delta and the proportion of the winter-run Chinook salmon population lost at the Project facilities between October and May of each year from 1995-2006 (Low et al., 2006). The study authors concluded that the strength of the observed relationship provided sufficient justification for changes in the decision criteria for DCC gate closures.

From November 2008-February 2009, DWR conducted a study of out-migrating Chinook salmon smolts on the Sacramento River.[6] The salmon investigation was designed to:

(1) Generate a regional database of out-migration movement, flows, and salinity, leading to a statistical analysis of route selection behaviors and reach specific survival rates; and
(2) Acquire a 3-dimensional array of salmon and hydrodynamic data at the Sacramento River junctions of Georgiana Slough and the DCC.

Among other things, the study involved releases of acoustically-tagged fish with different DCC gate operations scenarios. A CALFED Independent Science Review Panel expressed many concerns with the experimental design (Monismith 2008). Among the panel's comments was that the structure of the review was "somewhat extraordinary (i.e., reviewing a proposal that the funding agency had apparently already selected for funding via a sole-source selection process)." No report is yet available for the study.

New federal rules imposed in 2009 by the NMFS biological opinion for CVP and SWP operations now require the gates to be closed starting in October for at least three days whenever young salmon are present in the Sacramento River, and during more of the period November-February than was previously required under Water Right Decision 1641.

Screens and Ladders at Delta Diversion Points

Fish Screens

The Preferred Program Alternative outlined by CALFED agencies in the CALFED (2000) ROD recommended that new fish screens be designed and constructed at the Clifton Court Forebay and Tracy Pumping Plant facilities to allow the export facilities to pump at full capacity more regularly. The proposed schedule was:

- Complete funding plan by early 2003.
- Complete facilities design by the middle of 2004.
- Seek funding and authority to complete initial fish screens, and begin operations and performance testing by the middle of 2006.
- In addition, fish screens would be a necessary element of the Through-Delta facility proposed in the CALFED ROD.

[6] http://baydeltaoffice.water.ca.gov/ndelta/salmon/index.cfm.

ED_000733_DD_NSF_00045417-00018

Lack of Progress on Fish Screens

By the end of the very first of the post-ROD years (2000-2001), the CALFED Conveyance Program elements for installing fish screens at the Clifton Court Forebay and Tracy facility had already been put on "hold" for "reevaluation" of "scope and schedule" (see Schedule on page 11 in CBDP, 2003). By 2004, the CALFED activity related to fish screens was still on hold, and a new hydrodynamic study appeared to have taken its place as a CALFED action item (CBDP 2005, p. 10).

In the "Accomplishments" section of the 2006 annual plan (CBDP 2006), the scope of the hydrodynamic study referred to above was revealed to include food web components, but not to include research applicable to the design or construction of fish screens (CBDP 2006, p. 6).

After 2005, research priorities related to direct mortality of entrained fish appeared to have mostly shifted toward Capture, Handling, Trucking, and Release aspects of the existing salvage operations (CBDP 2007, p.6). And finally, by 2008, the original project area designated for work on fish screens was renamed from "Clifton Court Fish Screens" to South Delta Fish Facility Improvements (CBDP 2008).

In summary, CALFED apparently abandoned its explicit commitments for installing fish screens at the south Delta diversion points at the very beginning of the post-ROD CALFED program, and as of 2009, had not resurrected fish screens as a CALFED action item or serious subject of research (CBDP 2009).

Fish Ladders for a Proposed Through-Delta Facility

A potential Through-Delta Facility[7] was one of the two north-Delta conveyance facilities improvements included in the Preferred Program Alternative in the 2000 CALFED ROD. The TDF is a proposed screened conveyance which would pump up to 4,000 cfs from the Sacramento River into the Mokulmne River (SVS 2007). This project is distinct from the isolated alternative conveyance currently proposed by the Bay-Delta Conservation Plan (BDCP) because the diverted water would not be delivered directly to the south Delta pumps, but would be discharged into the central Delta. The objective of the proposed diversion is to reduce salinity at the south Delta export locations. Several potential alignments have been studied by DWR consultants.

Were the TDF to be built, anadromous fish migrating upstream from San Francisco Bay could get miscued by Sacramento River water passing into the southern Delta through the TDF and attempt to move upstream toward the Sacramento River via the San Joaquin and Mokelumne Rivers. Upstream migrants which do not find their way back to the Sacramento River via Three Mile Slough, Georgiana Slough or the Delta Cross Channel could be attracted by the TDF discharge. For these migrants, the TDF would serve as a physical barrier. The TDF would need upstream passage facilities for sturgeon and other anadromous fishes in order to ensure their ability to spawn upriver.

The southern distinct population segment (DPS) of the green sturgeon (*Acipenser medirostris*) was listed as threatened under

[7] http://baydeltaoffice.water.ca.gov/ndelta/TDF/.

ED_000733_DD_NSF_00045417-00019

the ESA in 2006 and is one of the anadromous species in the Delta that is addressed by the 2009 NMFS biological opinion on the SWP/CVP operations. Owing to their large body size and tendency to remain near the bottom, sturgeon require completely different kinds of fish ladders than salmonids. The DWR Fishery Improvements Section conducted a feasibility/design study for a sturgeon ladder using white sturgeon between 2003-2005 (*Through-Delta Facility White Sturgeon Passage Ladder Study*, Wilde 2007).

Non-Physical Barriers

In May 2009, DWR tested an experimental, non-physical fish barrier for juvenile Chinook salmon and steelhead[8] near the head of the Old River. The barrier combines acoustics and a strobe-lit sheet of bubbles to create an underwater wall of light and sound at frequencies that repel salmon smolts. The bubble-curtain was being tested as a replacement for the HORB to help keep juvenile salmon from straying into Old River as they out-migrate from the San Joaquin River through the Sacramento-San Joaquin Delta. The installation of the spring HORB did not take place in 2009 because of a court order related to the USFWS 2008 biological opinion for delta smelt. VAMP participants decided to test the strobe-lit, sound-generating bubble curtain as an alternative to the rock barrier, which can have adverse hydrodynamic impacts on delta smelt.

Seven releases of hatchery juvenile Chinook salmon implanted with acoustic tags were planned during the pilot study to evaluate their response to the bubble barrier. As of mid-May 2009[9], preliminary data from the first three releases suggested that the bubble curtain had increased the number of smolts staying in the San Joaquin River during their out-migration to San Francisco Bay and the ocean. However a large percentage of the smolts that were deterred from entering Old River were eaten by striped bass that were patrolling in the vicinity of the bubble curtain (CALFED Science News, December 2009[10]).

Mitigation of Pre-Screen Losses in Clifton Court Forebay

Alteration of Herbicide Applications

At certain periods of time, build up of pondweed at the Skinner Fish Facility can result in pumping restrictions. To control this, DWR has applied Copper-based herbicides such as Komeen® in Clifton Court Forebay since 1995, typically during the spring or early summer when listed salmonids have been present in the forebay. These herbicide applications present toxicity issues to salmonids and green sturgeon due to their high sensitivity to copper at both sub-lethal and lethal concentrations. Exposure of green sturgeon to herbicides in Clifton Court Forebay was one of four categories of effects of the Delta Division of SWP/CVP OCAP evaluated by the NMFS (2009) biological opinion. DWR, in response to NMFS' concern over the use of Komeen® during periods when listed salmonids may be present in the Clifton Court Forebay, has altered its operational

---

[8] Press release, photos, and video are available at http://www.water.ca.gov/news/archive/.

[9] May 18, 2009, DWR press release, available at: http://www.water.ca.gov/news/archive/index.cfm?yr=2009

[10] Available at http://www.science.calwater.ca.gov/publications/sci_news.html

ED_000733_DD_NSF_00045417-00020

procedure for application of copper-based herbicides from previous operations (NMFS 2009). DWR now proposes to apply copper sulfate or Komeen® only between July 1-August 31 of each year as needed. Other mitigation steps proposed by DWR include the following actions:

- Monitor the salvage of listed fish at the Skinner Facility prior to the application of the herbicides in Clifton Court Forebay;
- Close the radial intake gates at the entrance to Clifton Court Forebay 24 hours prior to the application of herbicides to allow fish to move out of proposed treatment areas and towards the salvage facility;
- Keep the radial gates closed for 24 hours after treatment to allow for at least 24 hours of contact time between the herbicide and the treated vegetation in the forebay. Reopen the gates after a minimum of 48 hours.

Implementation of the shortened period of Komeen® application is scheduled to begin during the summer of 2010.

Predator Removal Studies

Predator removal investigations were conducted in the 1990's to reduce predation by striped bass in Clifton Court Forebay. As part of the Interagency Ecological Program studies, the DFG estimated that in March 1993, the total striped bass population in the forebay was around 200,000, even after almost 29,000 striped bass were removed in a pilot predator removal program (Brown et al., 1996). The high loss estimates of fish due to striped bass predation in the forebay caused interest in a program to reduce losses by catching striped bass using nets and hauling them for release in San Pablo Bay or other locations far from the forebay, which was planned for 1994. However, opposition from angler organizations caused the program to be postponed, and in the meantime, results of an acoustic tagging program indicated that striped bass move freely through the radial gates to the Delta, indicating that the effectiveness of planned removal programs may be limited. In the mid-1990's, DWR and DFG were planning studies to further confirm that striped bass move freely between the forebay and the Delta (Brown et al., 1996).

Salvage Mortality

A number of investigations have been conducted into the mechanisms and factors affecting fish survival during the salvage process at both the SWP and CVP fish salvage facilities The USBR began a Tracy Fish Facility Improvement Program (TFFIP)[11] in 1989. Since then, the TFFIP has implemented a predator removal program, holding tank surveys, secondary louver netting programs, fish egg and larvae entrainment estimates, updated louver efficiency estimates, improved fish handling and identifications, "fish friendly" pumping system, and a "fish friendly" mitten crab removal system (traveling screen). Over three dozen TFFIP reports are posted on-line at: *http://www.usbr.gov/pmts/tech_services/tracy_research/tracyreports/index.html*.

Recent Collection, Handling, Transport and Release research for the SWP's Skinner Facility salvage operation has included an "Element 2" study to assess post-release predation mortality at SWP's Horseshoe Bend release site, and an "Element 3" study to measure injury and mortality associated

---

11 http://www.usbr.gov/pmts/tech_services/tracy_research/index.html.

ED_000733_DD_NSF_00045417-00021

with the release of fish from the tank trucks. Element 2 monitoring was scheduled August 2007-April 2008; techniques included Dual Frequency Identification Sonar (DIDSON) camera monitoring, hydroacoustics, acoustic telemetry, avian predation monitoring, and electrofishing. In the Element 3 study in 2007, delta smelt and juvenile Chinook salmon were released through a mock-up of the SWP release site into a receiving tank representing the receiving water body so that injury and mortality could be measured over a 48-hour mock post-release period. Reports have not been released yet for either study, so it is difficult to know whether the NMFS estimate above 12-32% would apply to delta smelt, as well as salmon smolts.

Proposed BDCP conservation measures that address fish loss

The proposed BDCP includes conservation measures in draft Chapter 3 to address predation of covered fish species and non-physical barriers to re-direct fish away from channels where survival is low. **The BDCP does not propose improvement, enhancement or replacement of the fish screens or salvage facilities in the south Delta, despite the fact that losses are ongoing and will continue into the future with the continued operation of these facilities.**

Predator Controls

BDCP conservation measure OCSM24 aims to "reduce the effects of predators on covered fish species by conducting localized predator control of high predator density locations." Predation has been identified as a stressor to covered fish species, and the BDCP recognizes that particular habitat conditions are conducive to predators. The conservation measure aims to identify the locations of predator hot spots, which are theorized to include areas that favor predators such as deep holes, shaded areas around docks and marinas, abrupt depth changes, and release sites for salvaged fish from CVP/SWP facilities. The conservation measure proposes that methods such as modification of channel geometry and targeted removal of predators could be used to control predator populations. Interestingly, Clifton Court Forebay is not specifically mentioned, despite being known for decades to be a hot spot for predation of covered fish species. In addition, the fact that permanent operable gates, such as were prohibited in the 2009 NMFS biological opinion, are known predator hot spots, is not mentioned in draft Chapter 3 of the BDCP. This is noteworthy because the operable gates proposed for testing in the 2-Gates Demonstration Project form the basis for BDCP Conservation Measure WOCMN8.

Non-Physical Barriers

BDCP conservation measure OCSM25 proposes to "improve survival of outmigrating juvenile salmonids by using non-physical barriers to re-direct them away from channels in which survival is lower." The proposed barriers would consist of sound, light and bubbles, such as were used in the 2009 DWR "bubble curtain" at HORB previously described. The list of potential locations for barrier installation includes Clifton Court Forebay. However, as explained previously, it is now known that non-physical barriers – such as bubble curtains – can serve as predator hot spots.

ED_000733_DD_NSF_00045417-00022

Moving Forward…

There is a large body of evidence that indicates that high percentages of covered fish species are lost due to SWP and CVP pumping operations in the south Delta. As captured in the above discussion, information indicates that the direct loss of various species of fish in and around the south Delta pumping facilities is significant, historic, and ongoing. Studies showing high mortality date back to the 1970s. Mitigation efforts to reduce losses have been suggested repeatedly over the past two decades but have either not been implemented or have been shown to not be successful.

Population level effects from mortality due to pumping operations are potentially significant. In contrast, evidence of direct loss of fish attributable to adverse water quality conditions; agricultural, stormwater and wastewater discharges, is generally lacking.

Studies showing high mortality date back to the 1970s, and mitigation efforts to reduce losses have been suggested repeatedly over the past two decades. Population level effects from mortality due to pumping operations are potentially significant.

As seen in the mitigation section of this paper, recent mitigation actions to protect fish from pumping operations primarily focus on physical devices such as gates. Less attention has been focused on improving fish screens, despite that being noted as a priority mitigation area in reports dating back to the mid 1990s. Little has been done to prevent fish from entering Clifton Court Forebay or to reduce the effects of predation.

Data and Research Gaps

In terms of direct loss of fish, clearly more effort is needed to develop feasible measures to reduce the ongoing loss of listed species that are entrained as a result of SWP and CVP operations.

In terms of indirect losses, the science supporting various hypotheses that have been offered (food web disruption, sublethal toxicity, proliferation of nuisance aquatic species) is less clear, and continued research is needed to explore the validity of those hypotheses. It is interesting to note the level of interest generated in the past several years around specific indirect stressors (ammonia, pyrethroids, endocrine disruptors, nutrients) that are not associated with Delta export operations. In contrast, there has not been a similar interest to examine the indirect effects associated with the loss of nutrients, phytoplankton and zooplankton from the Delta and the modification of hydrodynamic and habitat regimes in the Delta due to export operations.

More research is needed to investigate the extent to which fish populations are impacted as a result of altered hydrodynamic conditions. Indirect losses of fish due to pumping operations may be large, but have not yet been quantified. Mark-recapture investigations were intended to study indirect losses, but have not provided insight into their magnitude (Kimmerer, 2008).

ED_000733_DD_NSF_00045417-00023

In Summary: A Call to Action

For 30 years scientists and regulatory agencies have documented the significant impacts the water export operations have on Delta fish – and yet little action has been taken to correct the situation. When the POD signaled the Delta ecosystem is in real trouble a few years ago, the response was to shift the blame from the known impacts of the water exports to potential other "stressors."

Certainly, more research must be done to fully understand all of the issues that may be affecting the health of the Delta and what action should be taken to address them, but the comprehensive and integrative research needed to yield sound data on these issues will take years. In the meantime, immediate action should be taken to mitigate the known and well documented impacts of the water exports on the Delta ecosystem and endangered fish species. Too much is at stake to allow further delay in addressing the ongoing fish mortality associated with the water project operations, especially when the evidence paints such a clear picture. ■

ED_000733_DD_NSF_00045417-00024

References

Anderson, J., A. Blumberg, P. Goodwin, S. Monismith, C. Simenstad. 2009. Science review of the two gates project, Report prepared for CalFED Science Program, Sept. 29, 2009. 32 pp. Avail. at: http://science.calwater.ca.gov/events/reviews/review_2gates.html.

Bennett, WA. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science. 3(2). Available at: http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1

Bowen M.D., Baskerville-Bridges BB, Frizel KW, Hess L, Carp CA, Siegfried SM, Wynn SL. 2004. Empirical and experimental analyses of secondary louver efficiency at the Tracy Fish Collection Facility, March 1996 to November 1997. Tracy Fish Facility Studies: Volume 11. U.S. Bureau of Reclamation, Mid Pacific Region and Denver Technical Service Center.

Brown R, S. Greene, P. Coulston and S. Barrow. 1996. An evaluation of the effectiveness of fish salvage operations at the intake to the California aqueduct, 1979-1993. Pages 497-518 in J. T. Hollibaugh, ed. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco..

California Bay Delta Program (CBDP). 2003. California Bay Delta Program, Conveyance Program, Multi-Year Program Plan (Years 4-7). CalFed Bay-Delta Program, August 2003. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

California Bay Delta Program (CBDP). 2005. California Bay Delta Program, Conveyance Program, Multi-Year Program Plan (Years 6-9). CalFed Bay-Delta Program, October 2005. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

California Bay Delta Program (CBDP). 2006. Draft. Conveyance Program, Program Plan Year 7. CalFed Bay-Delta Program, August 3, 2006. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

California Bay Delta Program (CBDP). 2007. Draft Final. Conveyance Program, Program Plan Year 8. CalFed Bay-Delta Program, October 30, 2007. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

California Bay Delta Program (CBDP). 2008. Final Draft. Conveyance Program, Program Plan Year 9. CalFed Bay-Delta Program, September 10, 2008. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

California Bay Delta Program (CBDP). 2009. Final Draft. Conveyance Program, Program Plan Year 10. CalFed Bay-Delta Program, July 1, 2009. Avail. at: http://www.calwater.ca.gov/calfed/plans/index.html.

CALFED Programmatic Record of Decision (2000), CALFED Bay-Delta Program, avail at: http://calwater.ca.gov/calfed/library/Archive_ROD.html.

ED_000733_DD_NSF_00045417-00025

Clark K., M. Bowen, R. Mayfield, K. Zehfuss, J. Taplin, C. Hanson. 2009. Quantification of pre-screen loss of juvenile steelhead in Clifton Court Forebay. Department of Water Resources, The California Natural Resources Agency.

Gingras M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate prescreening loss to juvenile fishes: 1976-1993. Technical Report 55. Interagency Ecological Program.

Kimmerer W. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin. San Francisco Estuary & Watershed Science, June 2008.

Kjelson M, Brandes P. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. In Levings C., Holtby L., Henderson M. (eds) Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks., Canadian Special Publication of Fisheries and Aquatic Sciences 105. p. 100-115.

Low A, White J, Chappell E. 2006. Relationship of Delta Cross Channel Gate operations to loss of juvenile winter-run Chinook salmon at the CVP/SWP Delta facilities. California Department of Fish and Game and Department of Water Resources.

Metropolitan Water District of Southern California (MWD). 2009. 2-Gates Fish Protection Demonstration Project. Summary Document. Prepared for the CALFED Science Program Independent Review Panel, July 16, 2009. 43. pp. Avail at: http://science.calwater.ca.gov/events/reviews/review_2gates.html.

Meyer J, Mulholland P, Paerl H, Ward A. 2009. A Framework for Research Addressing the Role of Ammonia/Ammonium in the Sacramento-San Joaquin Delta and the San Francisco Bay Estuary Ecosystem. Submitted to the CALFED Science Program, April 13, 2009. Avail at: http://science.calwater.ca.gov/pdf/workshops/workshop_ammonia_research_framework_final_041609.pdf

Monismith S, Simenstad S, Denton R, Newman K, Bennett W, Rondorf D, and Rose K. 2008. Review of North Delta salmon out-migration study, January 23, 23008. Avail. at: http://baydeltaoffice.water.ca.gov/ndelta/salmon/documents/CALFED_ReviewPanelList.pdf.

National Marine Fisheries Service (NMFS). 2009. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. ESA Section 7 Consultation. National Marine Fisheries Service, Southwest Region, Long Beach, CA. June 4, 2009. 844 pp. Avail at: http://swr.nmfs.noaa.gov/sac/myweb8/webpages/biol_opinions.htm.

ED_000733_DD_NSF_00045417-00026

Shaffter R. 1980. Fish occurances, size and distribution in the Sacramento River near Hood, California during 1973 and 1974. California Fish and Game Anadromous Fish Branch Admin Report 80-3. 76 pp.

State Water Resources Control Board (SWRCB). 2000. Revised Water Right Decision 1641. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/decision_1641/index.shtml.

State Water Resources Control Board (SWRCB). 2008. Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/

Stevens DE, Kohlhorst, DW, Miller LW, Kelley DW. 1985. The decline of striped bass in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 114(1):12-30.

Strategic Value Solutions, Inc. (SVS). 2007. Final Value Planning Study Report for Through Delta Facility, Sacramento, California. Prepared for the Delta Conveyance Branch, Bay-Delta Office, California Department of Water Resources, June 2007. Avail at: http://baydeltaoffice.water.ca.gov/ndelta/TDF/. 167 pp.

U.S. Bureau of Reclamation (USBR). 2009a. Draft finding of no significant impact, 2-Gates Fish Protection Demonstration Project. FONSI-09-154. United States Department of the Interior, Bureau of Reclamation, Mid Pacific Region. Avail at: http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=4472.

U.S. Bureau of Reclamation (USBR). 2009b. 2-Gates Fish Protection Demonstration Project, Central Valley Project, California. Draft Environmental Assessment. United States Department of the Interior, Bureau of Reclamation, Mid Pacific Region. Avail at: http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=4472.

U.S. Fish and Wildlife Service (USFWS). 2008. Biological opinion on the coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP). Final. December 15, 2008.

Wilde J. 2007. Modeling of Value Engineering study alternatives for the Through Delta Facility. Technical memorandum prepared for the Delta Conveyance Branch, Bay-Delta Office, California Department of Water Resources, Sept. 25, 2007, avail. at: http://baydeltaoffice.water.ca.gov/ndelta/TDF/.