Effects Analysis

State Water Project Effects on Longfin Smelt

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Introduction

In response to the Department of Water Resources (DWR) request for a Permit for incidental take of longfin smelt for existing and future operations of the State Water Project (SWP) facilities (Project), we conducted an analysis based on existing data, literature, and particle tracking modeling results. We also present conceptual models for longfin smelt adult migration and spawning, and larva and juvenile dispersal to facilitate understanding of our analytical approach and results. In the sections below, we provide background information, methodologies and approaches used, and discussions and definitions of the terminology and information available.

As part of our analysis, we have consider that Project operations will be consistent with existing water supply contracts, flood control needs, and certain operational criteria and other actions set forth in the U.S. Fish and Wildlife Service (FWS) Delta Smelt Biological Opinion of the Operating Criteria and Plan for the Coordinated Operations of the Central Valley Project and State Water Project (OCAP) that the FWS issued on December 16, 2008 (2008 OCAP Biological Opinion) for the Project. In addition, we consider that the Project will comply with all applicable state, federal, and local laws in existence or adopted thereafter of issuance of the Permit as well as SWRCB Water Rights Decision 1485, which have been carried forward to SWRCB Water Rights Decision 1641.

Project Description

SWP facilities in the Delta include Clifton Court Forebay (CCF), John E. Skinner Fish Facility (Skinner Facility), Harvey O. Banks Pumping Plant (collectively referred to as the Banks Pumping Plant Complex), and the North Bay Aqueduct (NBA) at Barker Slough. Facilities run jointly with the Central Valley Project (CVP) are the Suisun Marsh Salinity Control Gates (SMSCG), Roaring River Distribution System (RRDS), Morrow Island Distribution System (MIDS), Goodyear Slough Outfall, and the South Delta Temporary Barriers Project (TBP). Within this project, there are four rock barriers across south Delta channels (at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River near the confluence of Old River and San Joaquin River) which can be installed and removed during spring and fall. This will continue until permanent gates are constructed. Other facilities of the SWP include Oroville Dam which is operated for flood control and water supply and described in general terms below in SWP operations.

The CCF is a 31,000 acre foot reservoir located in the southwestern edge of the Delta, about ten miles northwest of Tracy. The CCF provides storage for off-peak pumping, moderates the effect of the pumps on the fluctuation of flow and stage in adjacent Delta channels, and collects sediment before it enters the California Aqueduct. Diversions from Old River into CCF are regulated by five radial gates whose real-time operations are constrained by a scouring limit (i.e. 12,000 cubic feet per second (cfs)) at the gates and by water level concerns in the south Delta for local agricultural diverters. When a large head differential exists between the outside and the inside of the gates, theoretical inflow can be as high as 15,000 cfs for a very short time. However, existing operating procedures identify a maximum design flow rate of 12,000 cfs, to minimize water velocities in surrounding south Delta channels, to control erosion, and to prevent damage to the facility.

The South Delta Temporary Barriers Project consists of installation of four temporary rock barriers across south Delta channels. The barriers on Middle River, Old River near Tracy, and Grant Line Canal are flow control facilities designed to improve water levels for agricultural diversions. The head of Old River barrier is designed to reduce the number of out-migrating salmon smolts entering Old River. During the fall this barrier is designed to improve flow and dissolved oxygen conditions in the San Joaquin River for the immigration of adult fall-run Chinook salmon.

The SWP is operated to provide flood control and water for agricultural, municipal, industrial, recreational, and environmental purposes. Water from Oroville facilities and surplus Sacramento-San Joaquin flows are captured in the Delta and conveyed to SWP contractors. Water is conserved in Oroville Reservoir and released to serve three Feather River area contractors, two contractors by the NBA, and is delivered to the remaining 24 contractors in the SWP service areas south of the Delta from the Harvey O. Banks Pumping Plant in the south Delta.

Facilities of the SWP are permitted by the California State Water Resources Control Board (SWRCB) to divert surplus water in the Delta and re-divert water that is stored in upstream reservoirs. The Bureau of Reclamation and DWR coordinate the operations of the SWP and CVP to meet water quality, quantity, and operational criteria in the Delta set by the SWRCB. DWR proposes to divert and manipulate flows consistent with applicable law and contractual obligations.

Longfin smelt Life History

Below are conceptual models for longfin smelt adult migration and spawning, and larva and juvenile dispersal to facilitate understanding of our analytical approach and results. We also discuss and define terminology and information available

Conceptual Model of Longfin Smelt Migration and Spawning

During late fall, as water temperatures drop below 18ºC, maturing adults migrate from the lower estuary to the low salinity zone and congregate prior to spawning. As adults ripen, most often from December through February, they make generally short-distance, brief spawning runs into freshwater where spawning takes place over a sand substrate, then return to the low salinity zone. Spawning activity appears to decrease with distance upstream from the low salinity zone, so the location of X2 approximately predicts the geographic location of this upper estuary congregation and influences how far spawning migrations penetrate the Delta.

Mature longfin smelt may migrate directly to the south Delta and be entrained, or high OMR flows may miscue spent adults into swimming toward the pumps rather than to Suisun Bay.

Longfin smelt smaller than our current approximate size for maturity (≥ 80 mm FL) are also found within the Delta upstream of X2 during winter. This represents either occupation of habitat that expanded as Delta temperatures cooled in fall or fish maturing below our approximate size of maturity that are actually part of the spawning run.

Conceptual Model of Longfin Smelt Larva and Juvenile Dispersal

Larval longfin smelt hatch locations are, to some degree, determined by X2 location immediately prior to adult spawning. Larvae hatch farther into the Delta in low outflow as compared to high outflow years, because X2 and X0.5, which approximates the spawning habitat boundary, are located farther into the Delta in low outflow years. Net current direction within hatching channels determines whether larvae are transported downstream toward Suisun Bay or upstream toward the pumps. Once entrained within CCF, longfin smelt larvae may be rapidly transported into aqueducts heading south if export rates are high. Alternatively, wind-driven surface currents and the larvae's proclivity for the surface may cause them to remain within the CCF for a protracted period of time if export rates are low. This latter circumstance can lead to larvae growing to juvenile size (≥20 mm) within the CCF and lead to disjunction between dates of entrainment and salvage. Juvenile longfin smelt will attempt to migrate to avoid water temperatures > 20ºC, leading to increased salvage of already entrained fish. Longfin smelt cannot survive summer temperatures in the CCF.

Entrainment

The entrainment of longfin smelt into CCF represents a direct effect of SWP operations that is not assessed directly. Instead, total entrainment is calculated based upon expansions of estimates of the number of longfin smelt salvaged at the Skinner Facility (e.g., Kimmerer 2008). Brown et al. (1996) provides a description of fish salvage operations. Thus, entrainment estimates are indices because fish salvage is estimated from sub-samples and fish entrainment into the Forebay has not been quantified from direct observations (Table 1). Also, entrained fish may succumb to predation or, in late spring and summer, to lethal temperatures prior to entering the salvage facilities or they may not be effectively "screened" from diverted water (e.g., Brown et al. 1996). Fish <20mm in length are considered larval and not counted (Kimmerer 2008). Moreover, many of the entrained longfin smelt salvaged likely die due to handling, transport, and predation as part of the fish salvage operations (Morinaka 2008).

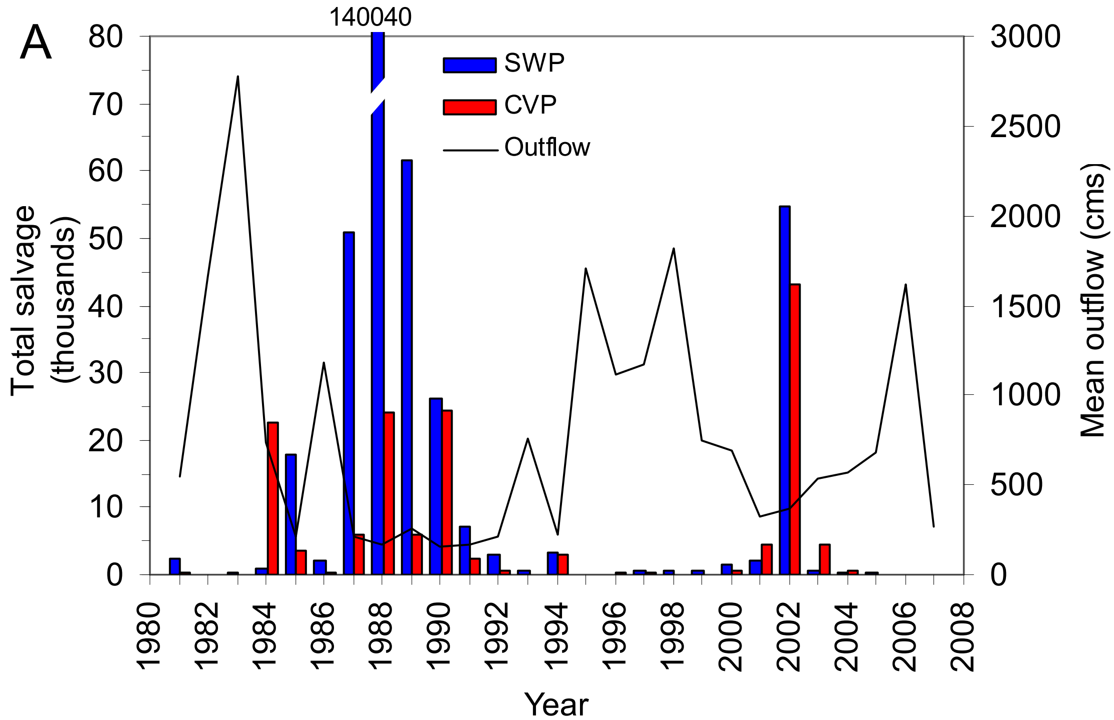
The population-level effects of longfin smelt entrainment have not been previously quantified. Longfin smelt salvage is highest during low outflow years (Sommer et al.

Table 1. Factors affecting longfin smelt entrainment and salvage.

	Adults >80 mm	Larvae < 20 mm	Juveniles 20-80 mm
Predation prior to encountering fish salvage facilities	Unquantified, assume similar to other fishes	Unquantified.	Unquantified, assume similar to other fishes
Mortality due to high temperatures in spring	Unquantified, probably small	Unquantified, probably small due to growth to juvenile.	Unquantified,
Louver efficiency (based on delta smelt results)	Limited data indicate an efficiency of about 27 percent for the CVP facility; about 37 percent for the SWP facility	~ 0 percent	Likely ≤ 30 percent at any size; << 30 percent at less than 30 mm
Collection screens efficiency	~ 100 percent	~ 0 percent	< 100 percent until at least 30 mm
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates
Fish survival after fish collection, handling, transport and release back into the Delta based on delta smelt studies)	78 percent for SWP and no information available for CVP	Unquantified	58 percent for SWP and no information available for CVP

1997, Figure 1A), so mortality associated with entrainment is highest when the population already faces adverse environmental conditions throughout the upper estuary.

Salvage during successive years of low outflow declined along with abundance (Figure 1A, B), so effects of salvage likely vary even across low outflow years. The longfin smelt has undergone a protracted abundance decline influenced by changes in hydrology, delta hydrodynamics and the upper estuary pelagic food web; changes in contaminant loads and predator numbers may also be involved (Sommer et al. 2007, Baxter et. al. 2008). Current thinking identifies increased delta outflow during the winter and spring as the largest factor positively affecting longfin smelt abundance (Baxter et al. 2008). During high outflow years, larvae presumably benefit from increased transport and dispersal downstream, increased food production, reduced predation through increased turbidity, and reduced loss to entrainment due to a westward shift in



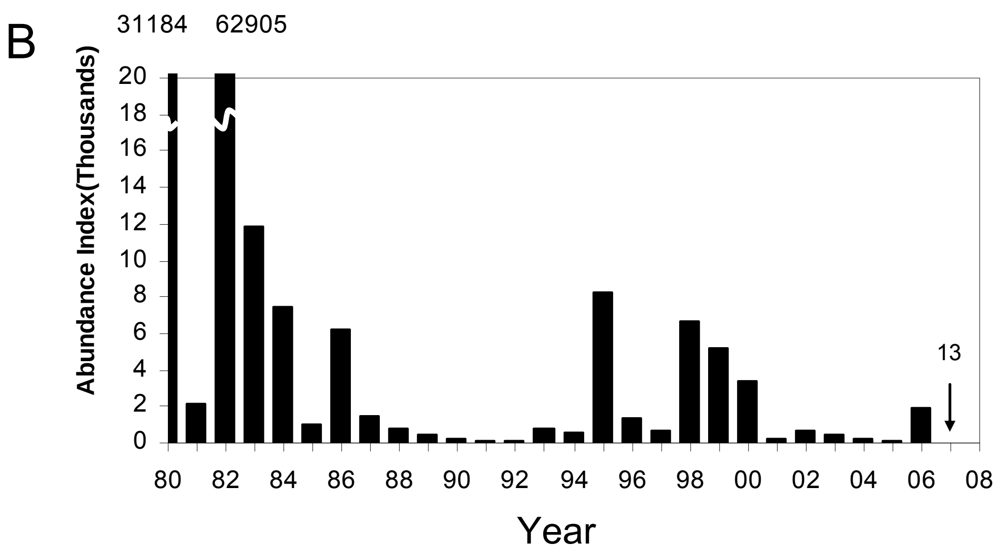


Figure 1. (A) Sum of annual salvage (Jan-Dec) of longfin smelt (all ages) at the State (SWP) and Federal (CVP) Facilities and mean Jan-Dec outflow (cms), 1981 – 2007. Note that annual salvage data for 2007 is limited to 01/01/2007 -07/31/2007. (B) Fall Midwater Trawl annual longfin smelt abundance indices (all ages combined) for 1980-2007. Longfin smelt salvage declined over successive dry years as abundance declined: compare trends in A and B for 1987-1992.

the boundary of spawning habitat and strong downstream transport of larvae (CDFG 1992, Hieb and Baxter 1993, CDFG 2009a). Conversely, during low outflow years, negative effects of reduced transport and dispersal, reduced turbidity and potentially increased loss of larvae to predation and increased loss at the export facilities result in lower young of the year recruitment. Analyses to separate effects of these multiple factors have not been done.

Installation and operation of south Delta barriers might have affected longfin smelt entrainment historically, but is unlikely to in the future given the Delta Smelt Biological Opinion (USFWS 2008). The Head of Old River Barrier (HORB) -- which influences where San Joaquin River flows enter into the south Delta, through the Old River or more northward channels -- was typically installed in April or May (http://www.iep.ca.gov/dsm2pwt/Bay-Delta_barriers_activ.txt) causing export flows to be satisfied from the north, potentially entraining longfin smelt. Currently, the spring HORB cannot be installed until the Service determines that delta smelt entrainment is no longer a concern (USFWS 2008), which could push back installation until July. The presence of delta smelt juveniles and the BO will eliminate negative effects of the HORB for longfin smelt. By June all longfin smelt adults have left the Delta, all eggs have hatched and the last of the current year's fish are emigrating from the Delta. For these reasons, installation and operation of the south Delta barriers are not expected to affect longfin smelt and were not specifically analyzed.

Methods

Our assessment approach was two-fold. We investigated a suite of hydrological variables for their influence on combined salvage of SWP and CVP to determine which had significant effects. Second, we summarized SWP salvage and estimated losses, then where possible, attempted to place loss in the context of longfin smelt population size. Two annual periods were important for our analyses. The first from the late 1960s through present covered the period during which the SWP was operational and was used wherever data were complete for the period to examine trends over time or plot relationships. The second time period, from 1993 to present, was used in instances when improved identification and measurement frequency of salvage data were needed. Seasonally, two periods were used most often to assess overall effects: December through March was used for winter effects on adult and juvenile salvage and April through June for spring effects on juvenile salvage. Hydrologic variables were similarly summarized for the December through March and April through June periods.

Adult Migration, Juvenile Distribution (~December though March)

We investigated entrainment of longfin smelt juveniles and adults by plotting annual salvage separately for juveniles and adults and for SWP and CVP. We also estimated total loss due to entrainment for juvenile and adult longfin smelt for both projects. We used available fish length data to classify the life stage of salvaged longfin smelt (20-79 mm for juvenile and ≥80 for adults). If length information was not available, we classified life stage based on seasonal patterns of salvage. We found salvage of different longfin smelt life stages highly seasonal so most of our analyses focused upon these identified seasonal periods: December through March for adults and March through June for juveniles; when length data were not available fish were classified based on this seasonal distinction also.

The distribution of adult and juvenile longfin smelt during winter and early spring is hypothesized to influence entrainment. Based on our conceptual model, we plotted relative catch from the Fall Midwater Trawl December through March surveys (when available) and overlaid the approximate average monthly locations of X2 and X0.5, the latter representing the freshwater boundary. X2 was derived from DayFlow and X0.5 was calculated from the X2 value as: X0.5 = -(X2 position) *(Ln((31-(target salinity))/(515.67* (target salinity)))/-7)-1.5), where 0.5 ppt is the target salinity (see Appendix A).

We used combined SWP and CVP salvage to examine the hydrological and environmental factors influencing salvage and SWP salvage alone to assess effects on longfin smelt. Similar to Grimaldo et al. (accepted), we used OMR flows rather than daily export because the former reflect the net daily draw of water toward the pumps and negate the need to account for periods when Clifton Court gates were open or closed. Old and Middle River flows from 1993 to 2007 were measured daily using acoustical velocity meters (installed by the United States Geological Survey, USGS) located near Bacon Island (Arthur et al. 1996). OMR flows from 1967 through 1992 were calculated from flows measured in other south Delta channels by Lenny Grimaldo. Total inflow, combined SWP and CVP exports and X2 location data were derived from DayFlow (http://www.iep.ca.gov/dayflow/index.html).

Entrainment and loss estimates were calculated with an equation routinely used to calculate juvenile Chinook salmon entrainment loss from reported salvage estimates. Estimator constants for pre-screen loss, screening efficiency, and handle and trucking losses were obtained from experiments using delta smelt and other fish species as proxies for longfin smelt (see Appendix B).

Larva Entrainment SWP (~January through April)

Current Banks (SWP) and Jones (CVP) fish salvage protocols excuse the identification of fishes <20mm long, so no salvage information exists to assess larvae entrainment (longfin smelt are classified as larvae until 20 mm long). Instead we used particle tracking modeling (PTM) to assess potential entrainment at and effects of State Water Project facilities. PTM model runs were accomplished by the California Department of Water Resources (CDWR) using Delta Simulation Model 11 (DSM2). Model daily results were transferred to CDFG for processing, summarization and analyses.

Limited computing and processing time sharply constrained the number of model runs possible, so we selected three years for hydrology, seven injection locations within the Delta and seven injection dates to capture as much variation as possible to assess the various risks to entrainment and factors influencing those risks. Each PTM year, date, location combination was run separately with surface oriented and neutrally buoyant particles to contrast the entrainment risk of each “behavior”. Surface oriented PTM runs best emulate the behavior of longfin smelt larvae.

The observed pattern of increased longfin smelt salvage during low outflow years, and concern for entrainment of larvae lead to the use of 1992, 2002 and 2008 hydrology (all low outflow years) as the basis for the PTM runs: 1992 low outflow with modest flow increase in mid-February, modest to high exports; 2002, one short early flow spike followed by low outflow and extremely high juvenile spring summer salvage; 2008 low outflow with three small flow spikes Jan, Feb and Mar and exports constrained by Wanger restrictions. Typically, PTM runs used neutrally buoyant particles (e.g., Kimmerer 2008), but longfin smelt larvae are initially oriented toward the surface (CDFG 1992, Bennett et al. 2002), so our PTM runs were conducted with both surface oriented and neutrally buoyant particle “behaviors” for both comparison and to evaluate whether surface orientation enhanced entrainment.

We chose 7 injection locations (Figure 2) to depict: 1) a range of potential for entrainment spread across putative spawning regions in the Sacramento and San Joaquin river channels, 2) to assess impacts of State Water Project facilities (e.g., NBA, Montezuma Sl, the south Delta export pumps), and 3) to correspond to limited larvae sampling data. No south Delta locations were selected because particles injected within south Delta channels were destined to be entrained in the export pumps, unless export rates were exceedingly low (Kimmerer and Nobriga 2008).

To cover the principal hatch period of longfin smelt, January through March (Baxter 1999), we selected injection dates of January 1 and15, February 1 and 15, March 1 and 15, and April 1. For each year, date, location, and behavior, 5000 particles were injected continuously over 24 hrs and their fates assessed daily for 90 days. This 90 day time period should cover the larval period of longfin smelt, which is about the same length (Hobbs pers comm. 2008).

For each injection permutation, particle flux (cumulative percent passage) was quantified daily at the SWP, the CVP, in agricultural diversions (AG diversions), at the North Bay Aqueduct, in Montezuma Slough and those passing Chipps Island to assess relative losses to exports. In addition, flux was measured daily at Three Mile Slough, each of the injection stations, Morrow Island and Roaring River in Suisun Marsh, and at channel entrances to the south Delta at False River near Fisherman’s Cut, Old River and Middle River near Columbia Cut.

For each injection location, date and behavior, we estimated an average Delta residence time as the mean time in days needed for ≥50% of the particles to resolve their fate: that is pass Chipps Island or into Montezuma Slough or become entrained in one of the aforementioned export facilities. Similar calculations were made for the Sacramento River channel and the San Joaquin River channel by combining the respective stations.

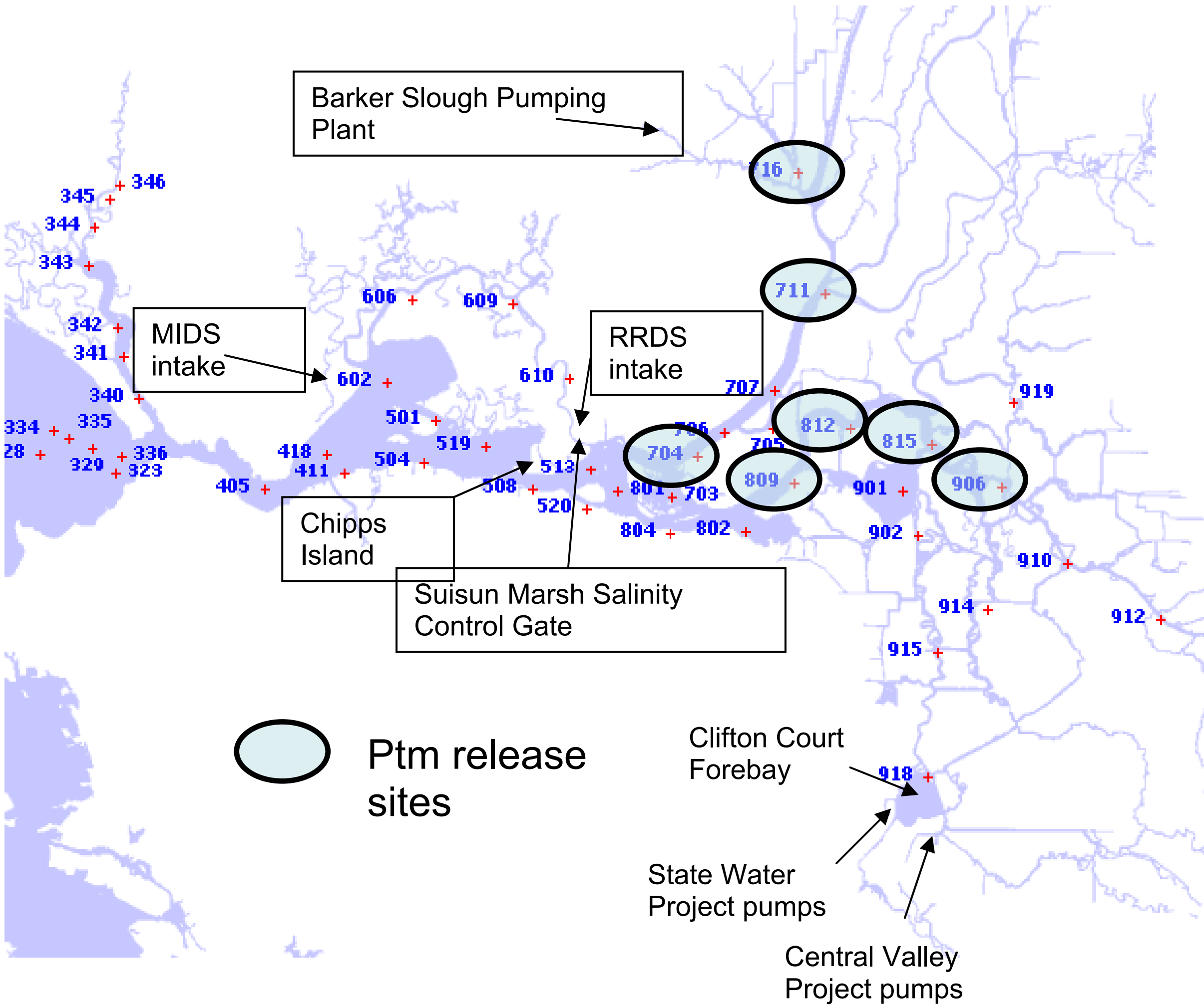


Figure 2. State Water Project facility locations and particle injection locations for 1992, 2002 and 2008 particle tracking model (PTM) runs for surface oriented and neutrally buoyant particles.

Finally, we estimated water export facility impact on larvae by scaling PTM results based on temporal and geographic estimates of relative larva hatch times and locations, the relative volumes of the Sacramento and San Joaquin river channels where most spawning was believed to take place, and another scaling factor to compensate for the higher number of injection sites, thus particles, in the San Joaquin River (4) as compared to the Sacramento River (3). The combined, scaled, 90th-day-particle-fate data for all injection locations and dates were used to calculate annual percent entrainment at the SWP, CVP, NBA, Ag Diversions separately for surface oriented and neutrally buoyant particles. Details are provided in following paragraphs.

Our estimates of temporal presence and spatial distribution of longfin smelt larvae in the Delta were constrained because of historically limited seasonal sampling and lack of

Osmerid identification in early sampling. Historically, egg and larvae sampling within the Delta did not often start prior to April with the onset of striped bass spawning and identification of Osmerids did not commence until the 1990s when delta smelt became a species of concern. The San Francisco Bay Study (Bay Study) provided the only year-round sampling data for longfin smelt larvae to assess monthly hatch timing. This study distinguished recently hatched, yolk-sac larvae from older, post-yolk-sac larvae for all samples. However, the survey only sampled as far upstream as Sherman Lake in the Sacramento River and Antioch on the San Joaquin River, so spring presence may have been slightly underestimated because larvae remained in the Delta upstream of sampling locations. Osmerid identification was attempted by the Bay Study from the start of the survey in 1980 and identifications confirmed in the early 1990s. Seasonal hatching (monthly) was estimated by yolk-sac larva monthly average catch per 1000 m^3 filtered by the plankton net. Bay Study surveys were usually completed during the first two weeks of each month. To develop seasonal scaling factors for weighting the twice monthly injections of particles, we used monthly densities for first-of-the-month injections and interpolated between monthly densities to estimate mid-month densities. First of the month and mid-month densities were directly used to scale PTM 90-day results: 1 Jan = 120, 15 Jan = 220, 1 Feb = 320, 15 Feb = 232, 1 Mar = 144, 15 Mar = 93, 1 Apr = 42.

Geographic estimates of larva hatch locations were based on in-Delta larva sampling conducted by CDFG for 1991-1994 and 2005. Three of four years during 1991 through 1994 were low outflow years in which larvae were not expected to be rapidly dispersed downstream. In 2005, outflow was relatively high, so larvae were probably rapidly dispersed. We also assumed that the total catch at a given station represented total "hatch at that station", and the relative contributions of stations representing the injection locations were derived from summing all the catches from 1991-1994 and normalizing by dividing all station total catches by the total catch at station 906, the station with the lowest catch; the station quotients were used as geographic hatch density scalars for all the PTM 90 day results. The first series of geographic hatch density scalars based on 1991-1994 larva densities were: 906 = 1, 815 = 4, 812 = 8, 809 = 28; 716 = 12, 711 = 21, 706 = 48. In a separate analysis, 2005 densities were also used as scalars: 906 = 1, 815 = 2, 812 = 3, 809 = 5; 716 = 7, 711 = 4, 706 = 37.

The scaled densities represented their locations, but not necessarily the channels in which they were located. We used historical channel volume estimates for the Sacramento and San Joaquin rivers derived by Ken Devore (CDFG GIS) to scale for channel volume. Although these estimates did not include the upper stations in each channel, they both extended below the lower stations and were believed approximately representative of the two channel volumes, and their absolute values were not important, only their relative value. The Sacramento River channel volume was divided by the San Joaquin River volume resulting in a quotient of 1.8, which was used to scale Sacramento River injection location data. Also, the number of injection locations within each river channel influenced the number of particles possible to entrain. To compensate for only 3 injection locations in the Sacramento River channel, all Sacramento River particle injection location results were scaled up by 1.33.

We assessed SWP effects on an annual basis and determined the annual fates of injected particles separately for surface oriented and neutrally buoyant particles by the following process. For each injection date and injection location we took the 90th day, final results (in percent) for flux to final fate locations (Chipps Island, Montezuma Slough, North Bay Aqueduct, Agricultural diversions, SWP and CVP, where particle fates were resolved) and multiplied by 1) 5000 (the original number of particles), 2) the seasonal scaling factor, and 3) the geographic scaling factor which contained the product of station and channel scaling. These products were then summed for each final fate location and for all final fate locations. Lastly, we calculated annual particle fates by dividing the summed results from each final fate location by the grand sum for all final fate locations and multiplying by 100, producing a result in percentage lost at each final fate location. This same process was run twice using a different geographic scaling factor each time. The first scaling factor based on 1991-1994 larva sampling results represents our “best estimate” for relative hatch distribution in low outflow years. The second scaling factor, based on 2005 larva sampling data, represents the entrainment effects resulting when hatching densities were not highly favoring the Sacramento River.

Results

Adult Migration, Juvenile Distribution (~December though March)

Winter conditions have become less favorable over time for longfin smelt. Winter Delta inflow has declined slightly since the 1970s, while combined winter exports (Dec-Mar) have climbed rapidly (Figure 3A, B). Inflow and exports influenced the location of X2. Average X2 position during winter moved into the Delta (>75) during the 1987-1992 drought and again in 2001 and 2007 (Figure 3C). Such an upstream shift may have caused more longfin smelt to spawn within or near the influence of the pumps. In addition, OMR flows have become more negative (Figure 4). More negative OMR flows could lead to additional entrainment of longfin smelt adults, older juveniles and subsequent larvae.

The winter distribution of longfin smelt (juveniles and adults combined) in the upper estuary appeared to be associated with the geographic position of the low salinity zone as indicated by the location of X2 (Appendix A) and X2 was periodically located within the Delta (X2>75) during winter (Figure 3C). As freshwater outflow increased from December 1994 though March 1995, the location of X2 and the apparent congregation location of longfin smelt moved lower in the estuary (Figure 5). The opposite occurred in water year 1997 as X2 moved back upstream after outflow declined beginning in February (Figure 6). Presumably, as X2 moves closer to the Delta, adult and juvenile longfin smelt become more vulnerable to entrainment (see next section).

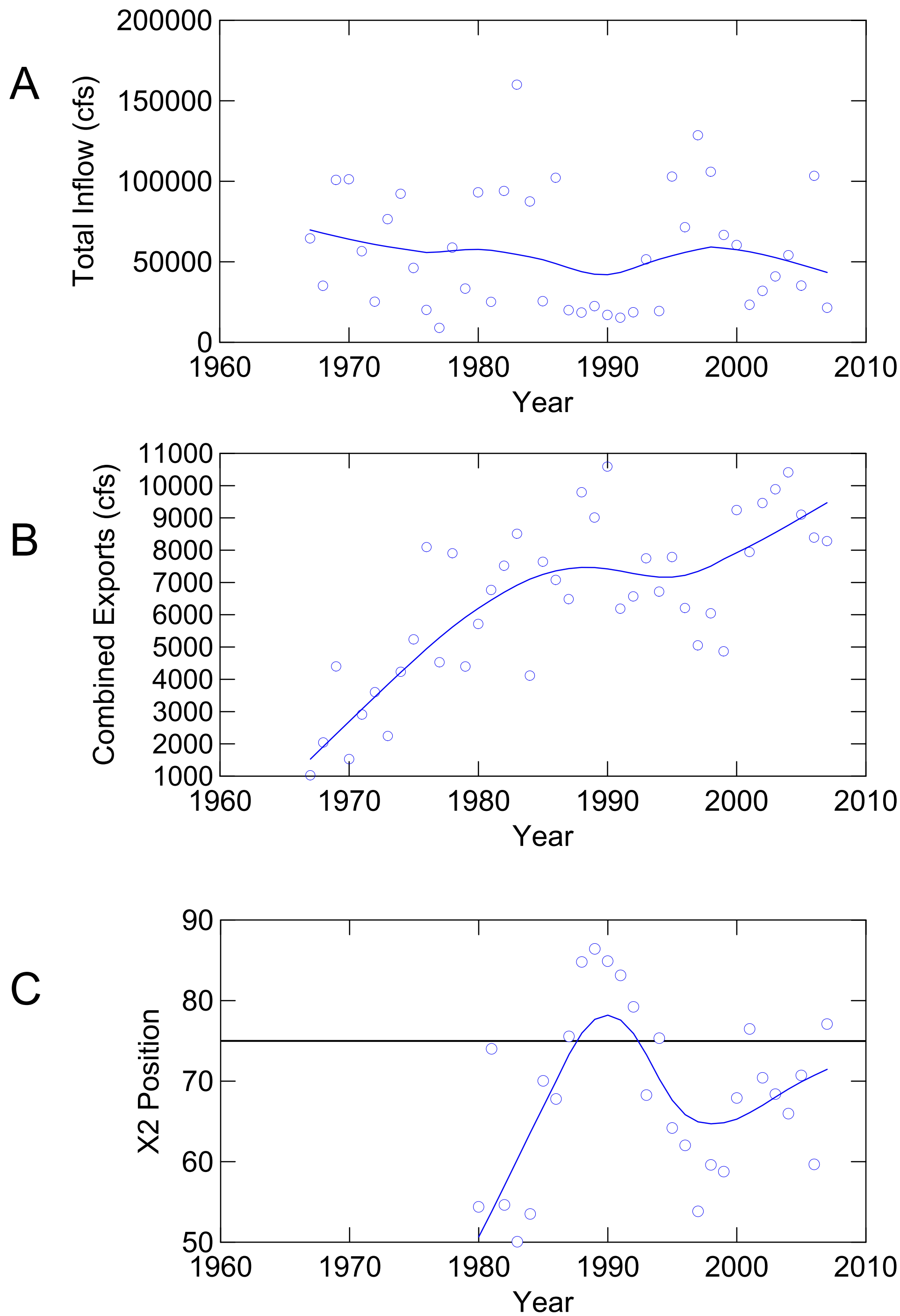


Figure 3. Trends in average winter (Dec-Mar) total delta inflow (A), combined SWP/CVP exports (B), and X2 position (C), 1967-2007, except for (C), which is 1980-2007. A LOWESS line was plotted through points to show general trend. The horizontal line at 75 km in (C) represents the location of Chipps Island.

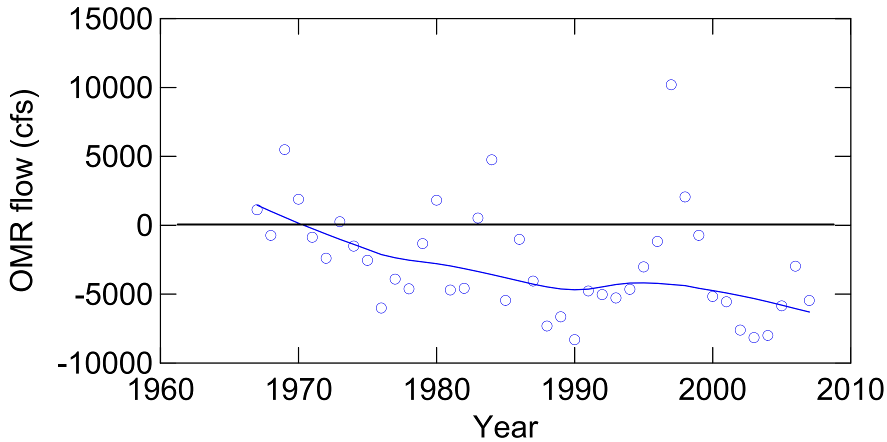


Figure 4. Trend in average winter (Dec-Mar) Old and Middle River (combined) flows, 1967-2007, based on estimated (1967-1992) and measured (1993-2007) flows. See text for data sources. A LOWESS line was plotted through points to show general trend.

Adult and Juvenile Entrainment SWP and Combined SWP, CVP (~December though March)

Adult (≥80 mm) and juvenile (age-1fish <80mm) longfin smelt have been salvaged in the SWP Skinner Fish Protective Facility as early in the water year as December (rarely November) and as late as March for adults and May for the previous year's juveniles, now designated age 1 (Figure 7). In years with salvage, both age groups were salvaged coincidentally in a series of 1-6 day pulses spread throughout the December through March spawning season. Peak salvage generally occurred in January for adults and varied from December through March for age-1 juveniles.

Winter salvage varied inversely with Delta outflow and has generally declined over time for both salvage facilities (Figure 8A). During the early portion of the 1987-1992 drought, SWP winter salvage exceeded 500 longfin smelt annually from 1987 through 1991 except for 1990, then declined with declining longfin smelt abundance (c.f., Figures 1B and 8A). Since that time SWP winter salvage only exceeded 200 longfin smelt in 2003 and 2004.

We hypothesized that the location of X2 affected winter salvage. That is as X2 moves upstream into the western Delta, the locations of congregation and spawning move eastward also. As this eastern movement continues, progressively more longfin smelt move to within the export pump zone of influence as they enter the Delta and lower rivers to spawn.

Winter combined SWP and CVP salvage was a significant positive function of X2 position and previous Fall Midwater Trawl abundance (r^2 = 0.395, 24 df, $p < 0.05$; Figure

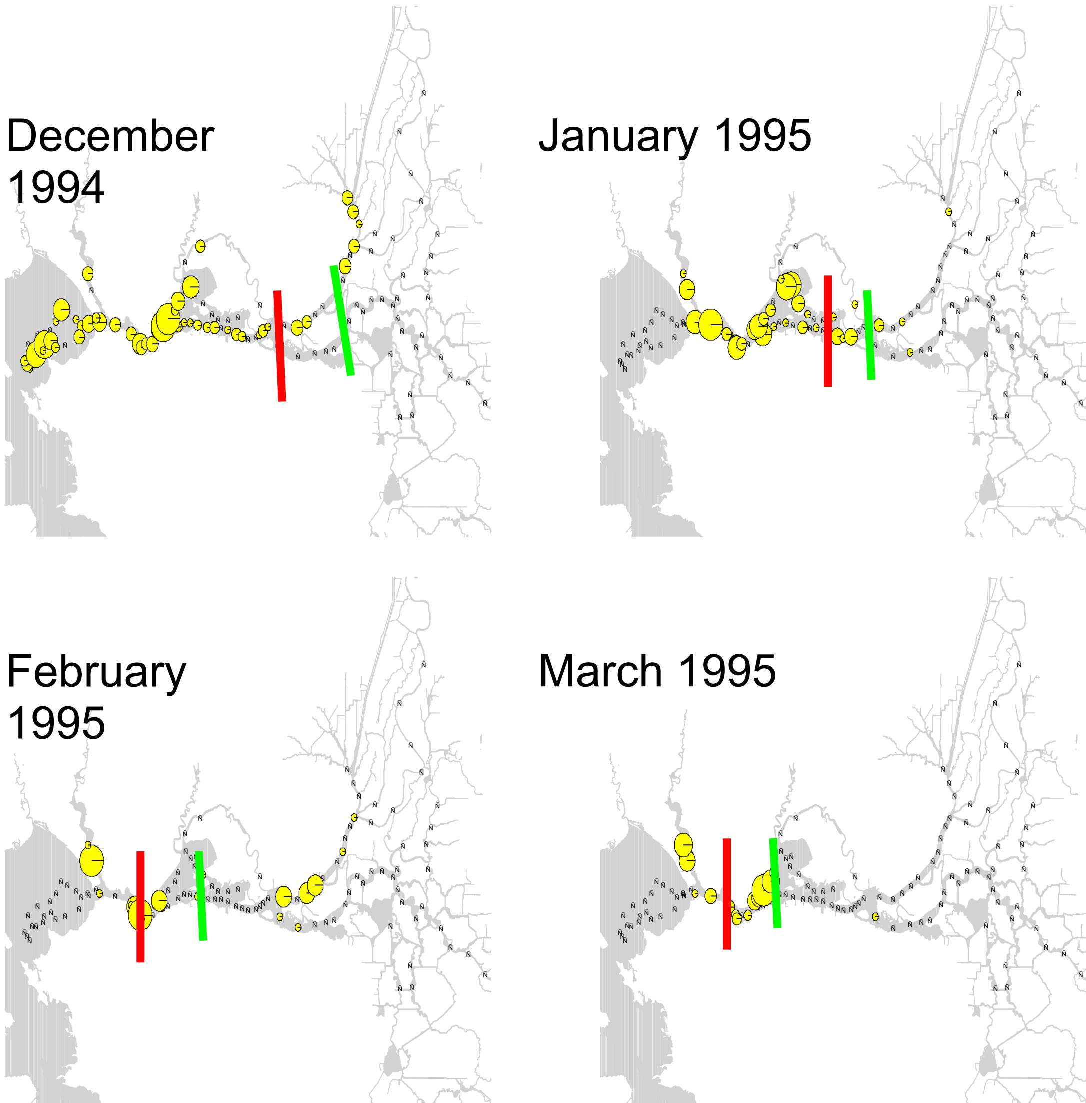


Figure 5. Winter longfin smelt catch in Fall Midwater Trawl sampling, December 1994 through March 1995. Relative catch per trawl is plotted in relation to average monthly position of X2 (red line) and X0.5 (green line, representing the freshwater boundary). Longfin smelt shifted downstream with X2. See also Appendix A.

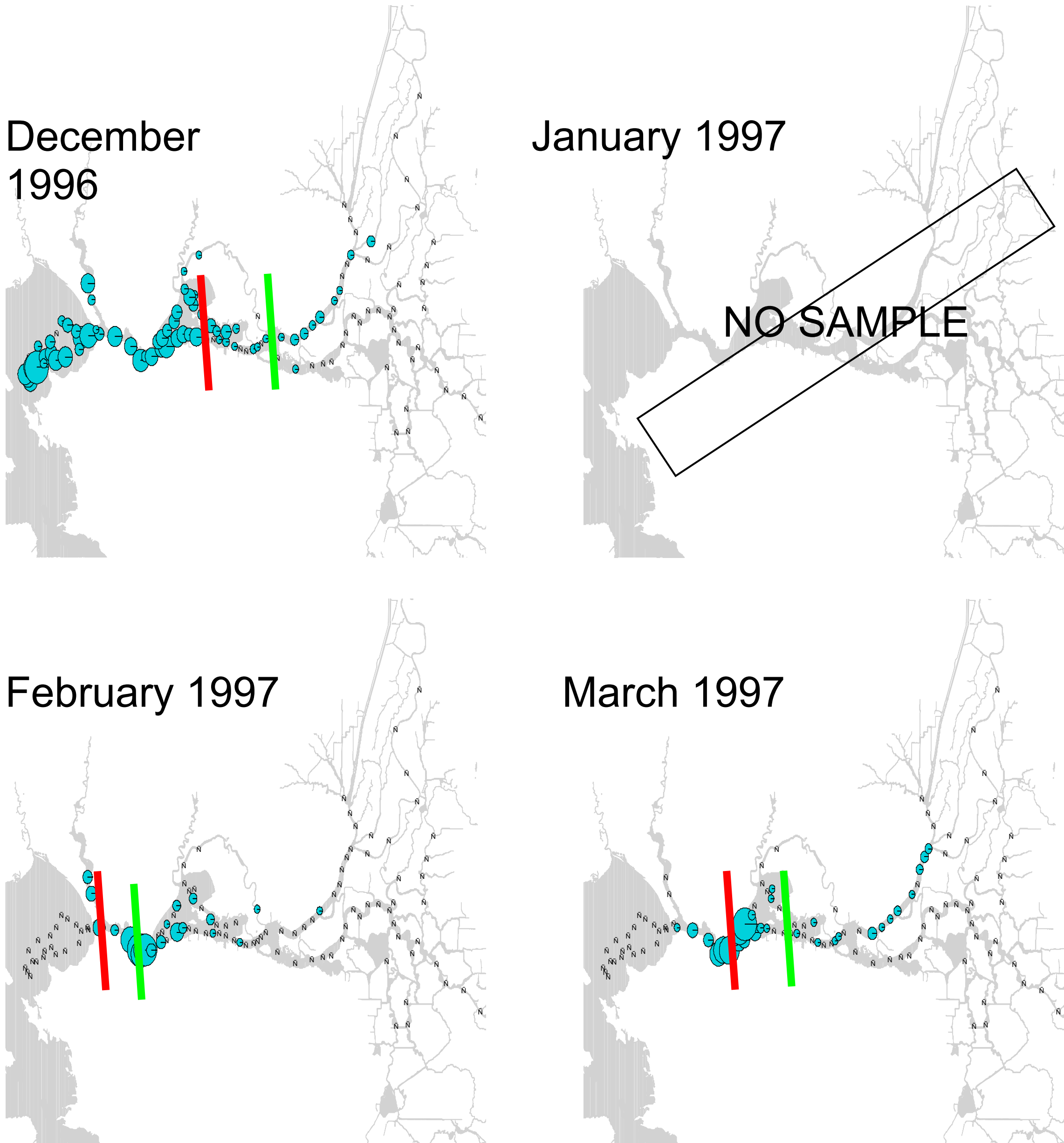


Figure 6. Winter longfin smelt catch in Fall Midwater Trawl sampling, December 1996 through March 1997. Relative catch per trawl is plotted in relation to average monthly position of X2 (red line) and X0.5 (green line, representing the freshwater boundary). Longfin smelt shifted downstream with X2. See also Appendix A.

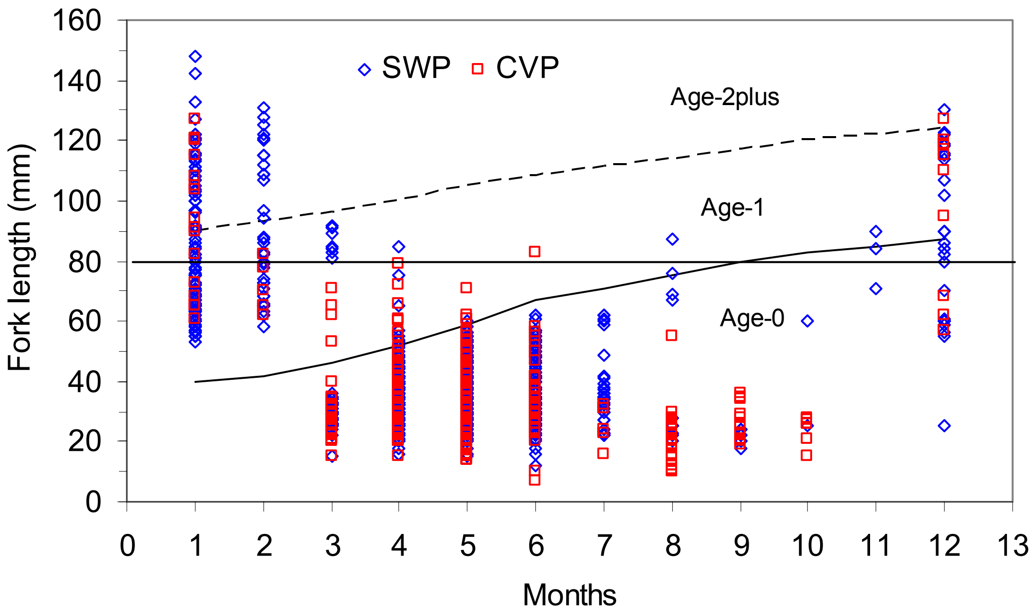


Figure 7. Length frequency of longfin smelt salvaged and measured at the State Water Project (blue diamonds) and Central Valley Project (red squares) by month for 1981-2007. Up-sloping lines represent the lengths of age class separation after Baxter 1999. The horizontal line represents the approximate size of maturity, such that lengths above represent mature fish and those below, immature fish. Fish < 20mm long are generally not identified or recorded at either salvage facility; this includes all longfin smelt larvae.

9). That is, as winter X2 position moved upstream toward and into the Delta, the ratio of total savage divided by the previous Fall Midwater Trawl index (to account for abundance) increased. The winter salvage in water years 1984 and 1985 was zero (exceptional for low outflow years), creating the two low points on Figure 9 and weakening the relationship.

Examining factors affecting longfin smelt winter salvage, Grimaldo et al. (accepted) used General Linear Modeling techniques to examine a suite of physical and biological factors: combined OMR flows, X2 position, water temperature, turbidity, zooplankton abundance and Fall Midwater Trawl, Summer Townet and 20mm Survey abundance indices. They found the best models explaining inter-annual winter salvage trends included combined Old and Middle River flows. Plotting winter combined salvage on average OMR flows (December through March) results in a broad scatter of points depicting rapidly increasing salvage at OMR values approaching and more negative than negative 5000 cfs (Figure 10A). Longfin smelt abundance also influenced salvage, such that salvage during years with positive or weakly negative OMR flows was generally driven by high numbers of longfin smelt present (Figure 10B).

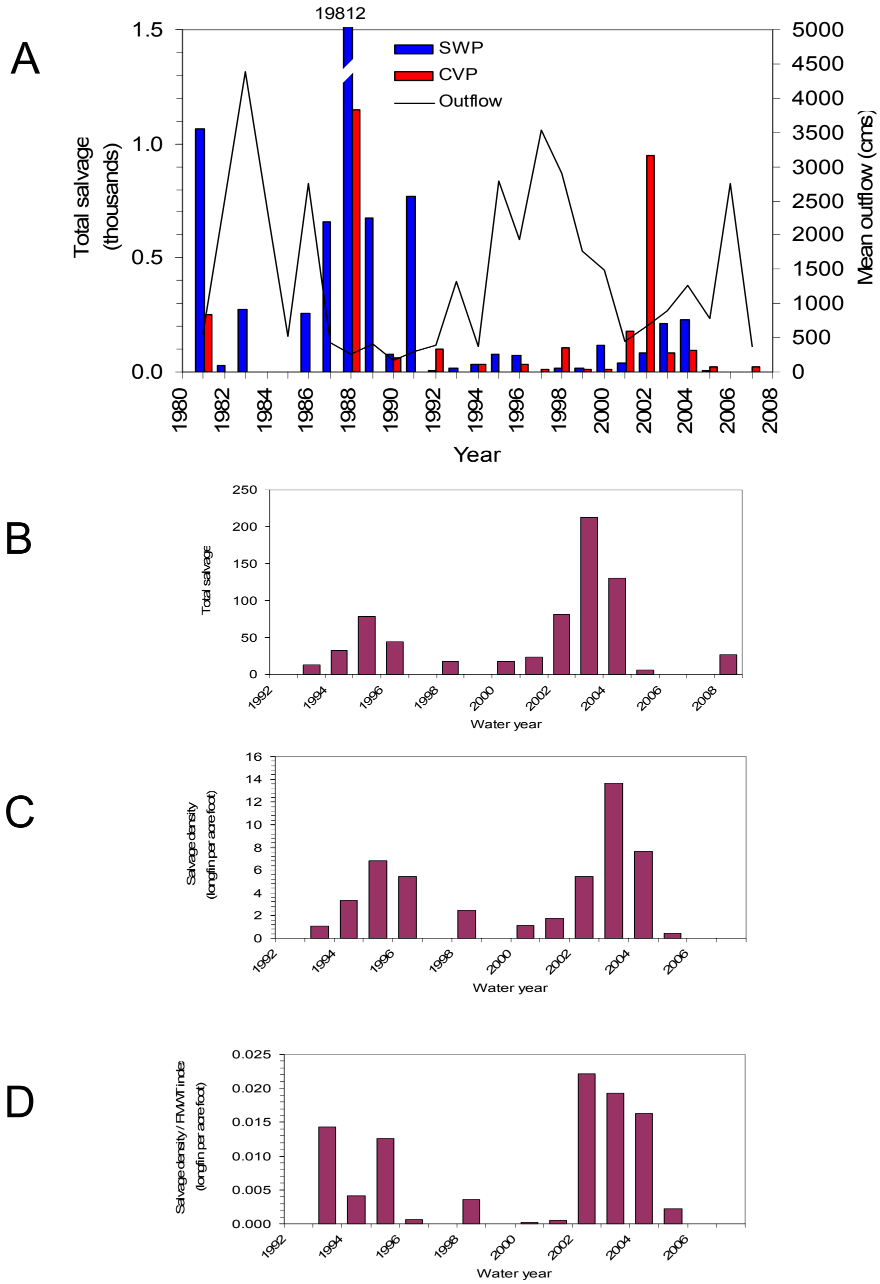


Figure 8. (A) Total winter (Dec-Mar) salvage of longfin smelt (**all ages**) at the State Water Project and Central Valley Project for 1981 through 2007 and mean Delta outflow in cubic meters per second for the same period. (B) SWP **adult** salvage, (C) adult salvage per acre ft exported and (D) adult salvage per acre ft divided by previous FMWT abundance index.

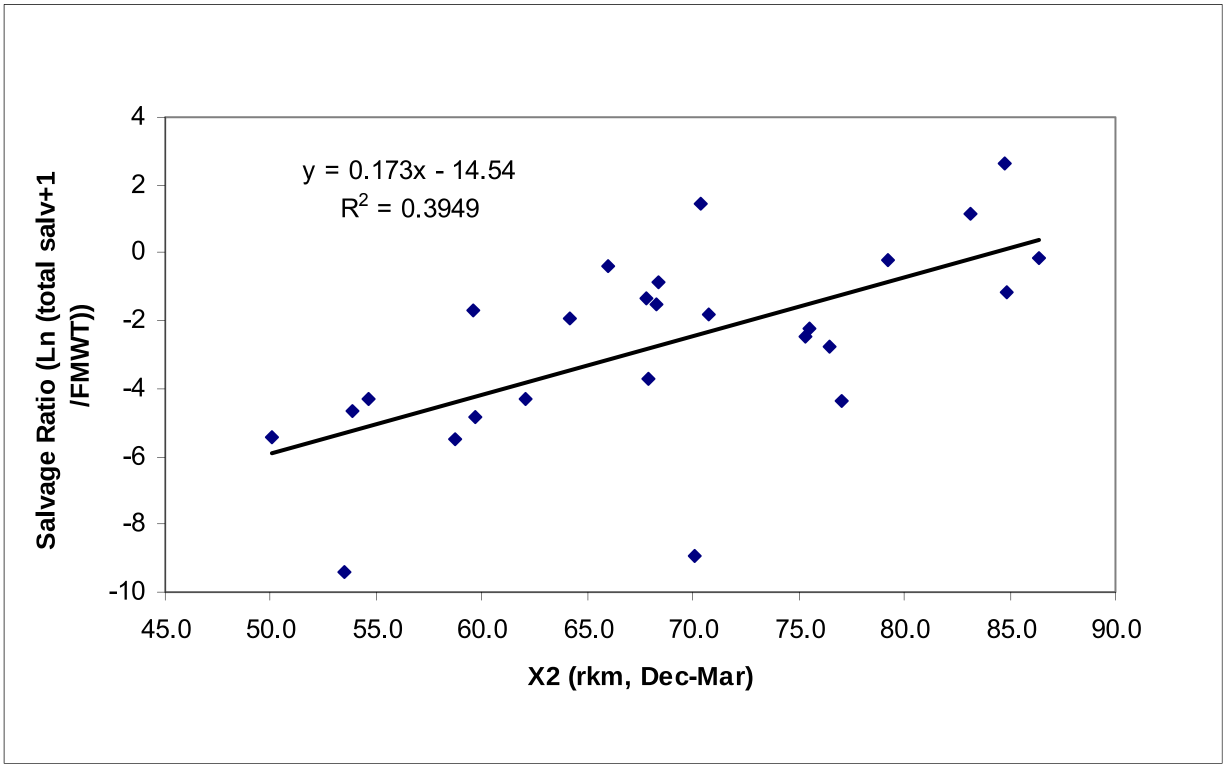
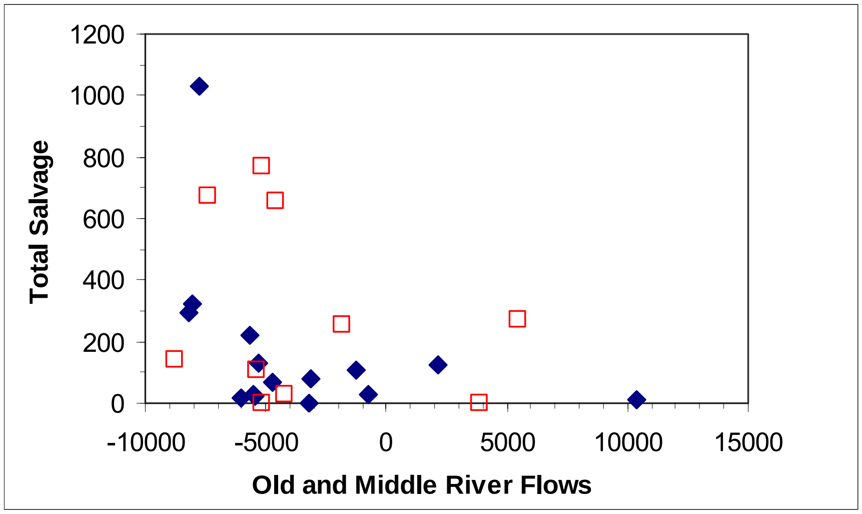


Figure 9. Total salvage of longfin smelt (December through March SWP+CVP) divided by the previous Fall Midwater Trawl longfin smelt index (all ages combined) as a function of X2 position during the same December through March period, 1982-2007. Relationship is significant, $r^2 = 0.395$, 24 df, $p < 0.05$.

Loss at the Export Pumps. Salvage is an index of longfin smelt entrainment and related to the loss at the export facilities. Entrainment in this case is defined as the number of fish drawn into each facility along with water being pumped (i.e., into Clifton Court Forebay for the SWP and past the trash racks for the CVP). Fish entrained suffer mortality from predation within each facility and are lost to the system if they pass through the louvers designed to behaviorally direct fishes from the soon to be exported water and into fish salvage facilities. Fishes successfully salvaged -- directed into the salvage facilities by the louvers AND survive the process of collection, handing, transport and release -- are subtracted from those estimated to be entrained to calculate loss. Fujimura (2009, Appendix B) calculated estimates of longfin smelt juvenile and adult losses using salvage as a starting point.

Annual losses of adults occurred almost exclusively from December through March and varied substantially from year to year during the 1993-2008 period examined (Table 2). No longfin smelt adults were lost in the SWP in just over 30 percent of the years – mainly those with relatively high winter outflow. Adult loss peaked at an estimated 3,429 in 2003 (Table 2), when winter OMR was most negative (Figure 4).

A



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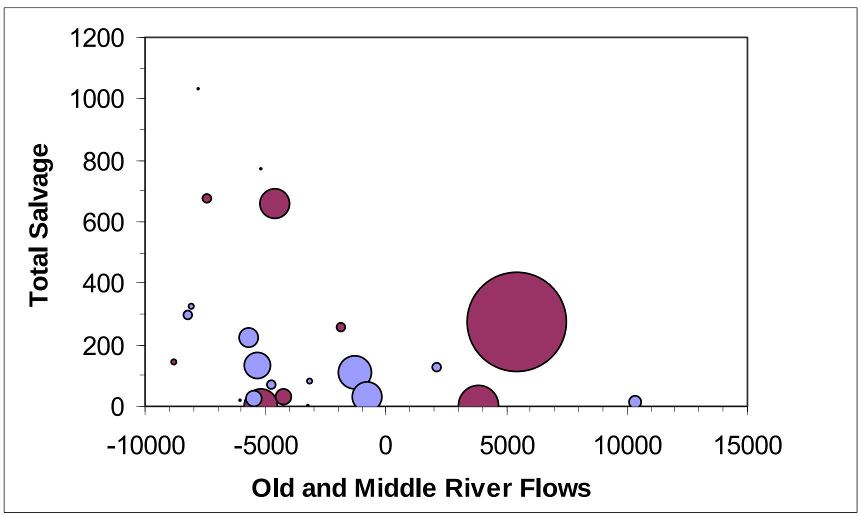

Figure 10. (A) Total salvage of longfin smelt (December through March SWP+CVP) as a function of average Old and Middle River flows during the same period for water years 1982-1992 (squares) and 1993-2007 (diamonds). OMR estimates for 1982-1992 were based on calculations conducted by Lenny Grimaldo; those from 1993-2007 were based on measured flows from USGS. A single point of salvage at 20,962 and OMR at -7744 is not depicted. (B) same data as (A) with bubble size scaled by the previous Fall Midwater Trawl abundance index (red for 1982-1992, blue for 1993-2007).

Table 2. Annual entrainment and loss by water year of longfin smelt juveniles (20 - < 80mm) and adult (≥80 mm) calculated by scaling number salvaged by estimates of prescreen and within facility mortality for other similar species (see Fujimura 2009). Survival of salvaged fish through the salvage, handling, trucking and return phases was also estimated and used to calculate loss from entrainment as (entrainment-survival =loss).

By Water Year

State Water Project

	ENTRAINMENT		*LOSS*		*TOTAL SALVAGE*		*SURVIVAL*	
YEAR	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS
1993	10,608	17	10,353	16	510	1	255	1
1994	69,964	541	68,282	515	3,364	32	1,682	26
1995	707	1,318	690	1,256	34	78	17	62
1996	1,934	744	1,888	708	93	44	47	35
1997	15,309	0	14,941	0	736	0	368	0
1998	13,187	0	12,870	0	634	0	317	0
1999	13,998	0	13,662	0	673	0	337	0
2000	28,829	304	28,136	290	1,386	18	693	14
2001	45,802	406	44,701	386	2,202	24	1,101	19
2002	1,133,870	1,369	1,106,614	1,304	54,513	81	27,257	65
2003	10,504	3,600	10,252	3,429	505	213	253	170
2004	4,211	2,206	4,110	2,102	202	131	101	104
2005	3,682	101	3,593	97	177	6	89	5
2006	0	0	0	0	0	0	0	0
2007	1,248	0	1,218	0	60	0	30	0
2008	22,578	448	22,036	427	1,086	27	543	21
Total	***1,376,432***	***11,054***	***1,343,345***	***10,530***	***66,175***	***654***	***33,087***	***523***

Central Valley Project

	ENTRAINMENT		*LOSS*		*TOTAL SALVAGE*		*SURVIVAL*	
YEAR	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS
1993	517	0	441	0	132	0	77	0
1994	11,819	0	10,070	0	3,015	0	1,749	0
1995	0	0	0	0	0	0	0	0
1996	517	105	441	86	132	24	77	19
1997	1,505	52	1,283	43	384	12	223	9
1998	329	105	281	86	84	24	49	19
1999	469	52	399	43	120	12	69	9
2000	1,929	52	1,643	43	492	12	285	9
2001	17,076	262	14,549	215	4,356	60	2,526	47
2002	168,403	419	143,486	344	42,960	96	24,917	75
2003	18,024	0	15,357	0	4,598	0	2,667	0
2004	2,540	0	2,164	0	648	0	376	0
2005	47	105	40	86	12	24	7	19
2006	0	0	0	0	0	0	0	0
2007	141	0	120	0	36	0	21	0
2008	1,290	174	1,099	143	329	40	191	31
Total	***224,606***	***1,325***	***191,374***	***1,088***	***57,298***	***304***	***33,233***	***237***

Winter salvage limit for adult longfin smelt. We continue to have concern that unusual winter salvage circumstances could have a negative effect on longfin smelt. Specifically, when combined SWP and CVP cumulative winter salvage surpasses 5 times the immediate previous Fall Midwater Trawl longfin smelt abundance index, a review of juvenile and adult distribution should take place and should include an assessment of whether to change OMR flows for the protection of longfin smelt.

Larva Entrainment SWP (~January through April)

The fates of particles were most influenced by injection site location proximity to export pumps or Chipps Island and Montezuma Slough, export levels as they influenced OMR flows and river flows (Sacramento River at Rio Vista or Qwest). Mean percentage of particles entrained in combined SWP and CVP exports was consistently higher for surface oriented particles than for neutrally buoyant particles: Sacramento River (surface oriented = 5.5% and neutral = 3.5%) and San Joaquin River stations (surface oriented = 45.6% and neutral = 43.4%). Significantly more surface oriented than neutrally buoyant particles from Sacramento River locations were entrained by SWP and CVP exports (Pooled Variance t = -2.340; 124 df; $p = 0.021$). The relationship for San Joaquin River injected particles was more complex and varied across stations (Figure 11). For stations immediately north and east of Old River (815 and 906), particle behavior did not appear to affect risk of entrainment, entrainment was high (median ≥ 50%), variable and approximately equal for both surface oriented and neutrally buoyant particles (Figure 11).

Mean residence time -- the average number of days to reach 50% of particle fate following injection -- was lower for surface oriented particles than for neutrally buoyant particles in the Sacramento River (buoyant = 18.1 and neutral = 20.1) and San Joaquin River (buoyant = 19.3 and neutral = 22.0). There was no significant difference in average residence time between surface oriented and neutral particles in the Sacramento River (Pooled variance t = 0.726, 124 df, $p = 0.469$), but there was for particles in San Joaquin River (Pooled variance t = 1.975, 166 df, $p = 0.050$).

Since particle behavior affected entrainment risk and residence time, most of our remaining PTM analyses focus on surface oriented particle analyses.

Particle Fate Analyses

Particle fate was strongly influenced by hydrologic variables, which varied considerably across the study years (Figure 12). In 1992, total exports tracked Rio Vista flow early in the year until Sacramento River flow increased in mid-February; a much smaller increase occurred in the San Joaquin River and corresponded to a strong positive Qwest pulse during the late February period (Figure 12). These flows led to a substantial drop in SWP entrainment for particles injected in mid-January through mid-February, which was otherwise relatively high for the San Joaquin River stations (Figure 13). In 2002, a high outflow event occurred in early January (Figure 12) and resulted in a brief substantial decline in SWP particle entrainment for those injected in

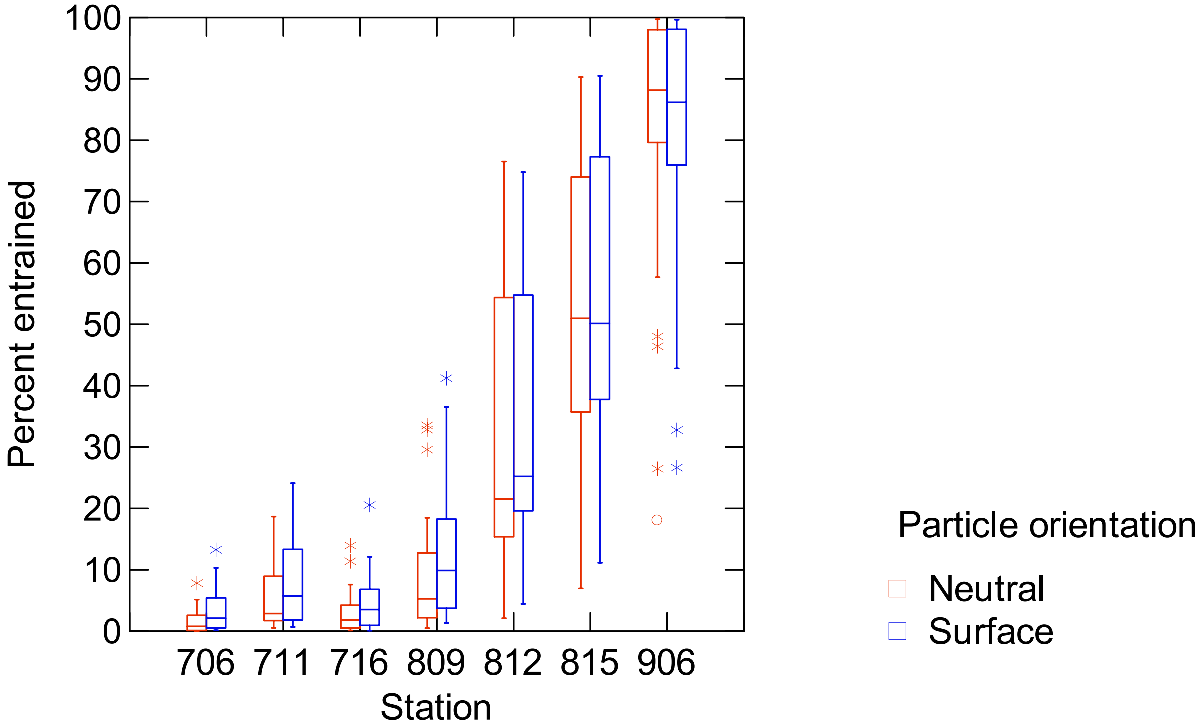

Figure 11. Box plot of percent entrainment at SWP and CVP by injection location (station) with all injection dates and years combined. The box plots show median values with lower and upper quartiles and whiskers showing the smallest and largest observations.

early January. SWP particle entrainment slowly declined again starting in mid-February or March when exports declined and Qwest and OMR flows became more positive (Figure 14). SWP particle entrainment from the San Joaquin River stations was relatively high for mid-January and early February 2002 injection dates as was entrainment Sacramento River stations. Later in spring 2002, exports declined with river flows, so entrainment dropped slowly across injection dates (Figure 14). In 2008, Sacramento River flows increased modestly in January, February and early March, yet exports only briefly in mid-January and late-February became a sizable fraction of the inflow (Figure 12). In particular, Qwest was often positive or near zero in 2008; positive Qwest occurred only sporadically after early January 2002 and before VAMP in mid-April (Figure 12). Positive Qwest and less negative OMR in 2008 led to a much reduced level of SWP particle entrainment (Figure 15). From late March through early June 2008, outflows and OMR flows were reduced to very low levels, which resulted in increasing fractions of injected particles remaining within the Delta after 90 days (i.e., fate unresolved), particularly for upper San Joaquin River stations 815 and 906 (Figure 15). Such a circumstance could have lead to increased salvage late in June as OMR became more negative (Figure 12). Further, the size range of historically salvaged juvenile (age-0) fish (20-60 mm; Figure 7) suggests a protracted

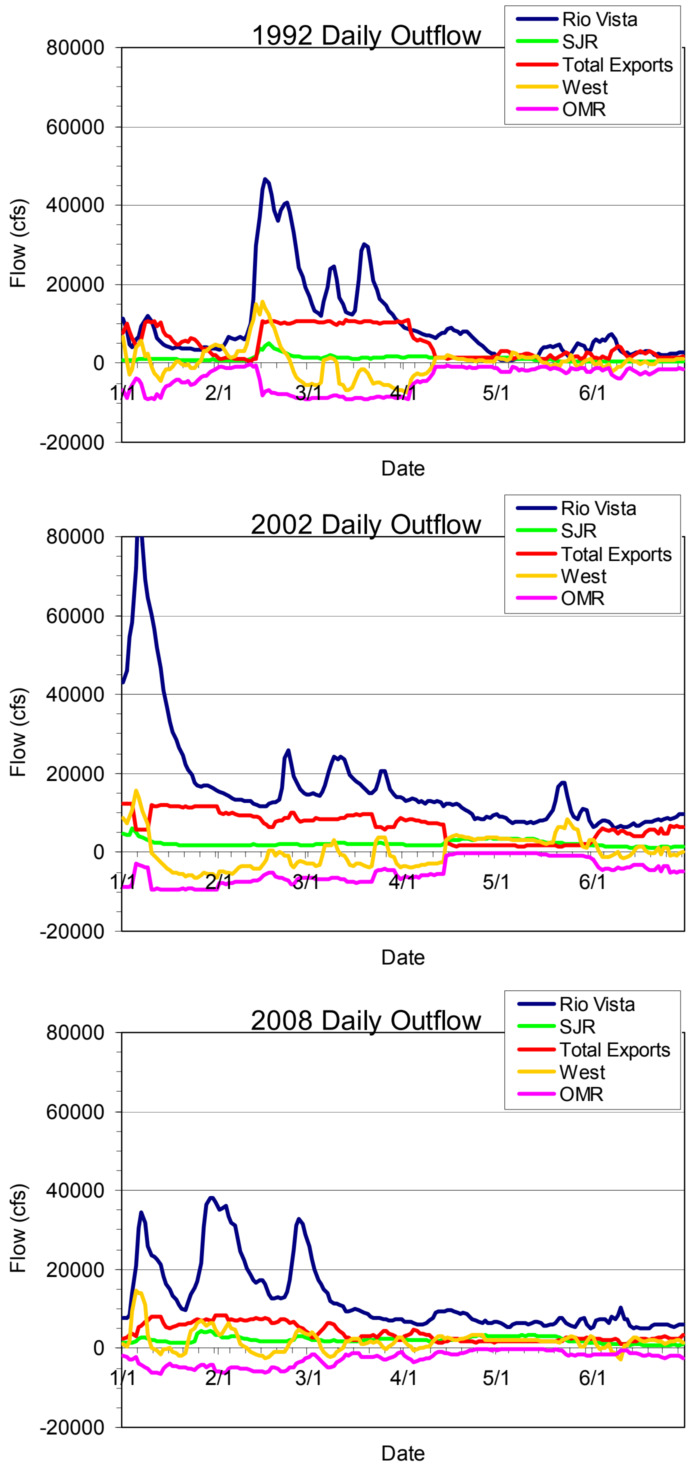

Figure 12. Average daily flow in cubic-feet-per-second (cfs) for the Sacramento River past Rio Vista, the San Joaquin River at Vernalis, total exports at SWP and CVP, flow in the San Joaquin River past Jersey Point (QWEST) and measured (2002) or modeled flow (1992, 2008) in Old and Middle rivers (OMR) for the first 6 months of 1992, 2002 and 2008.

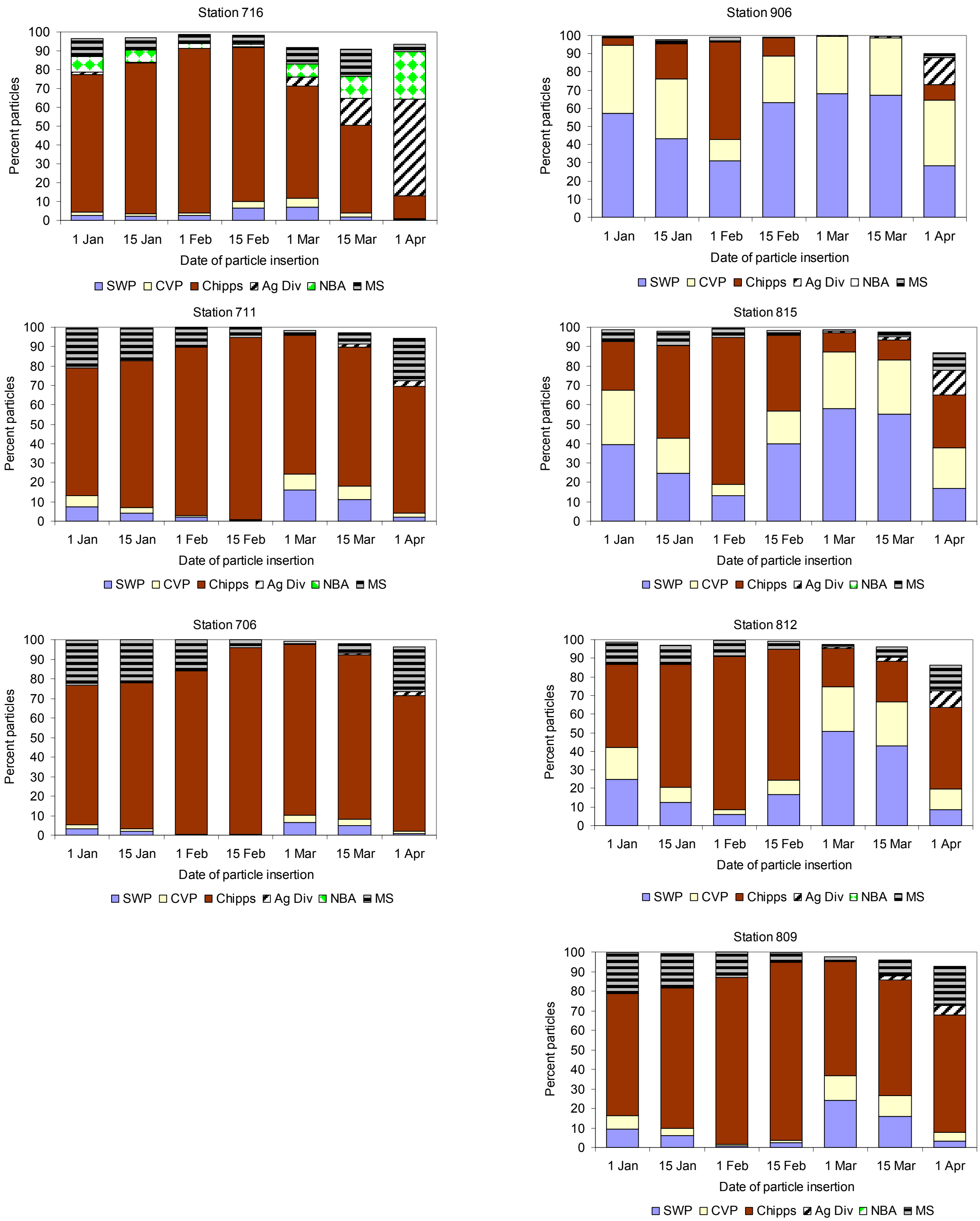

Figure 13. Percentages of surface-oriented particles entrained at the SWP, CVP, Agricultural diversions, North Bay Aqueduct or past Chipps Island after 90 days by station in 1992. Sacramento River stations oriented from upstream to downstream in the left column and San Joaquin stations similarly in the right column.

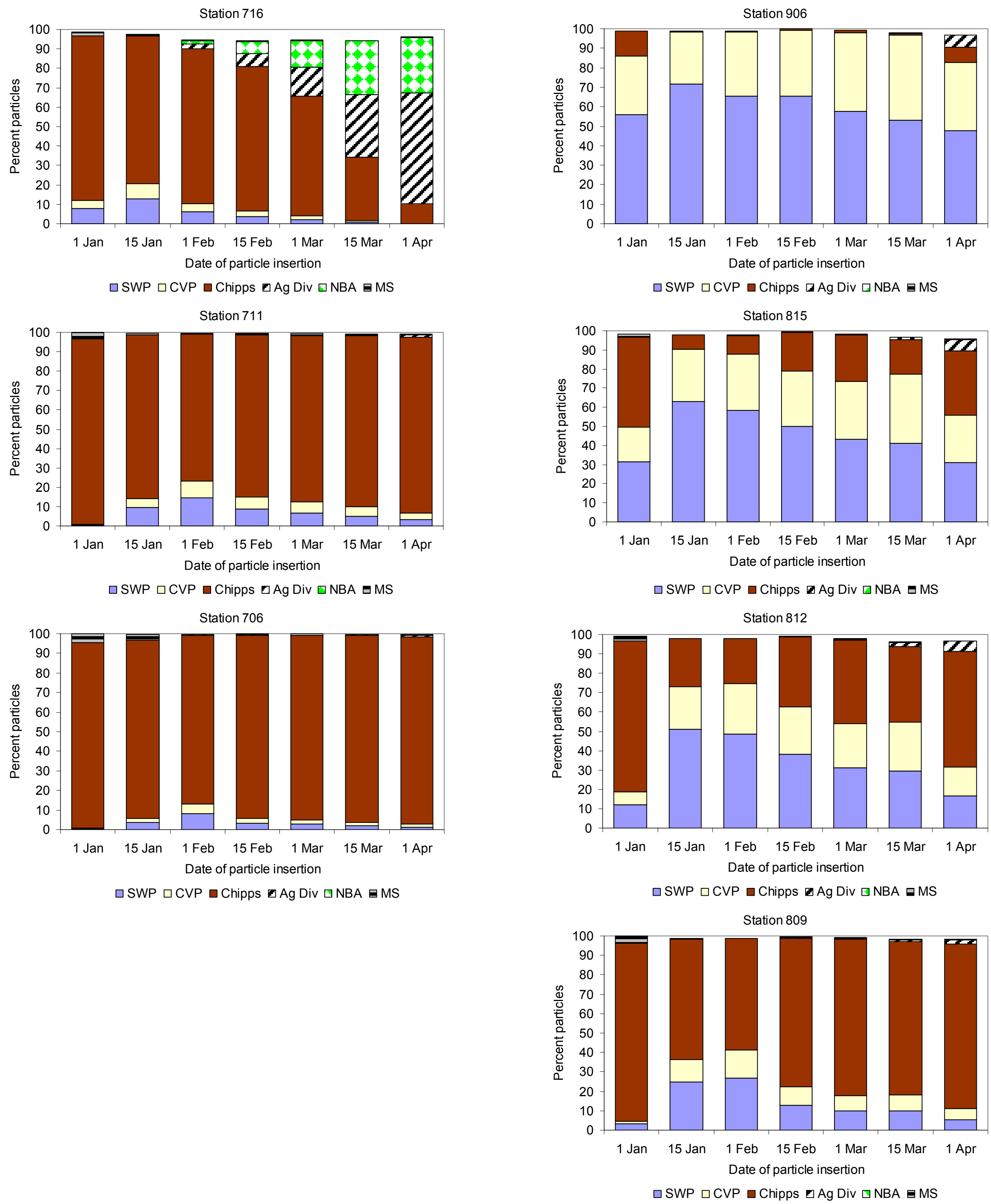

Figure 14. Percentages of surface-oriented particles entrained at the SWP, CVP, Agricultural diversions, North Bay Aqueduct or past Chipps Island after 90 days by station in 2002. Sacramento River stations oriented from upstream to downstream in the left column and San Joaquin stations similarly in the right column.

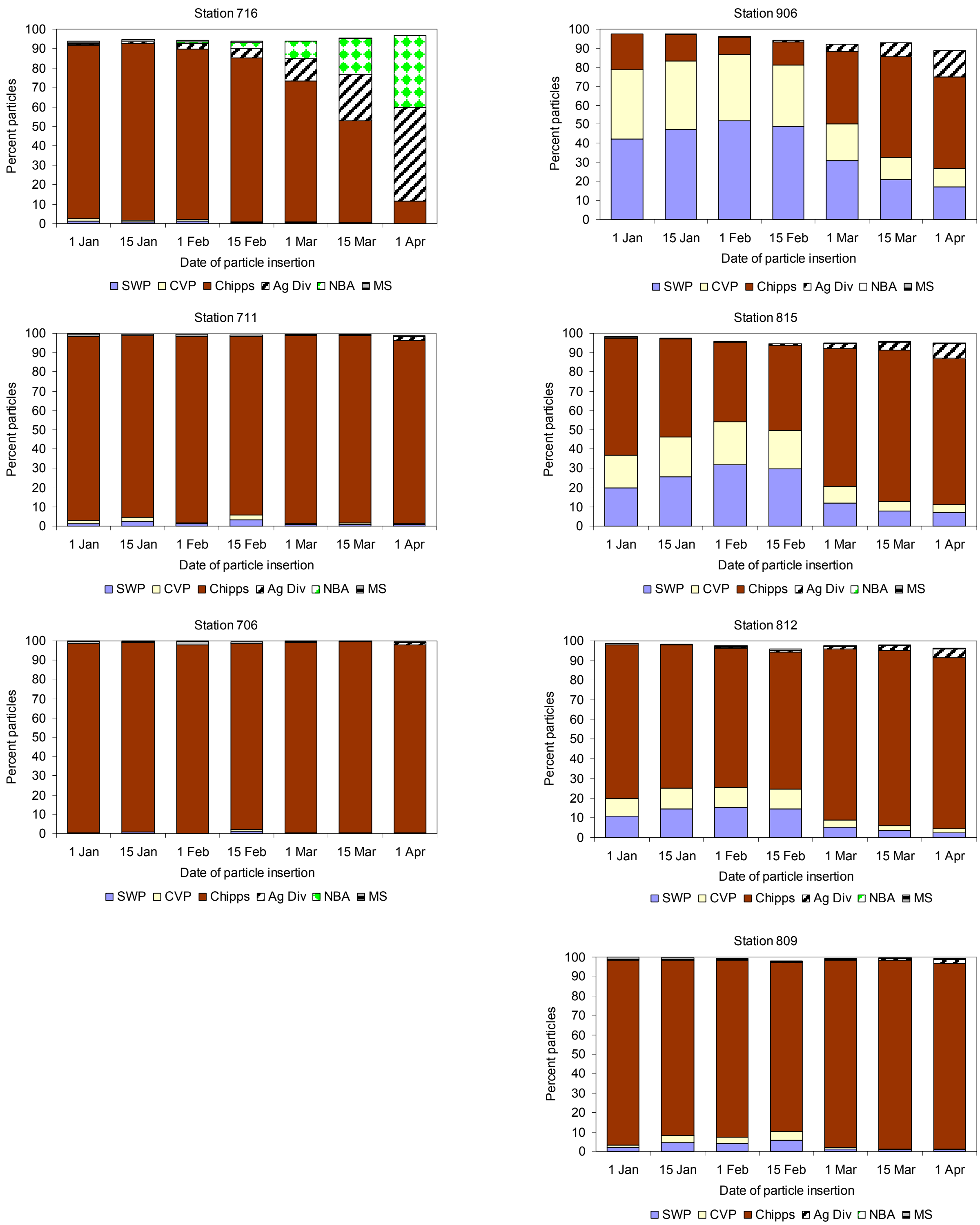

Figure 15. Percentages of surface-oriented particles entrained at the SWP, CVP, Agricultural diversions, North Bay Aqueduct or past Chipps Island after 90 days by station in 2008. Sacramento River stations oriented from upstream to downstream in the left column and San Joaquin stations similarly in the right column.

Delta residence time for some individuals or long travel times from some upstream spawning locations.

The effects of OMR and Qwest flows on particle entrainment appear to be antagonistic to one another. Increasingly negative OMR starting from -1000 cfs rapidly increases percent particle entrainment, whereas increasing Qwest tends to dampen the percent entrainment response (Figure 16). Limiting OMR flows to -2000 to -4000 while maintaining a positive Qwest substantially reduced entrainment for every injection period (Figure 16). In particular, during periods of positive Qwest, particles injected at stations 906 and 815 would flux into the south Delta via Old River (mostly) or Middle River, then flux out again via False River.

Mean residence time in the Delta generally decreased with more negative OMR flows (Figure 17). Conversely, when negative OMR flows ranged between -1000 and -2000 cfs mean residence time could substantially exceed 30 days, and in a few cases exceeded 50 days. Mean residence time was also lower for injection locations (706 and 809) in close proximity to Delta boundary locations of Chipps Island and Montezuma Slough than those farther upstream. In general most particles resolved their fates well within the 90 day larva development period; however, when OMR ranged between about -1000 to -3000 and Qwest was positive, mean residence times substantially exceeded 30 days for upstream injection locations.

Annual Entrainment and Effects

Total annual entrainment of surface-oriented particles was calculated to emulate loss of longfin smelt larvae over the January through June time period modeled for each year. Similar calculations for neutrally buoyant particles were provided for comparison. In each case we initially based calculations on larva hatching density estimates from a series of mostly dry years (1991-1994), during which larva densities were much higher at Sacramento River stations than at San Joaquin River stations. Based on higher Sacramento River hatch densities, annual total particle entrainment at the SWP was highest for surface-oriented relative to neutrally buoyant particles in every year and reached a peak under 2002 hydrology at just over 9% (Table 3). In 2008, with Wanger export restrictions in place and the resulting favorable hydrology described previously, percent entrainment at the SWP declined to about 2.2% for surface oriented particles (Table 3). For comparison, we repeated calculations with densities in the Sacramento and San Joaquin rivers about equal, as occurred in 2005 larvae sampling. The annual proportion of particles entrained in the SWP during 2008 increased by about 1% to 3.1% of the total particles (Table 4). Similar SWP entrainment increases of about 1% occurred in 1992 and 2002 when Sacramento River and San Joaquin River hatching densities approached equality, and a greater proportion of the particles “hatched” closer to the export pumps. Combined CVP and SWP entrainment was even more substantial, suggesting peak entrainment in the range of 15-17% (2002 in Tables 3 and 4).

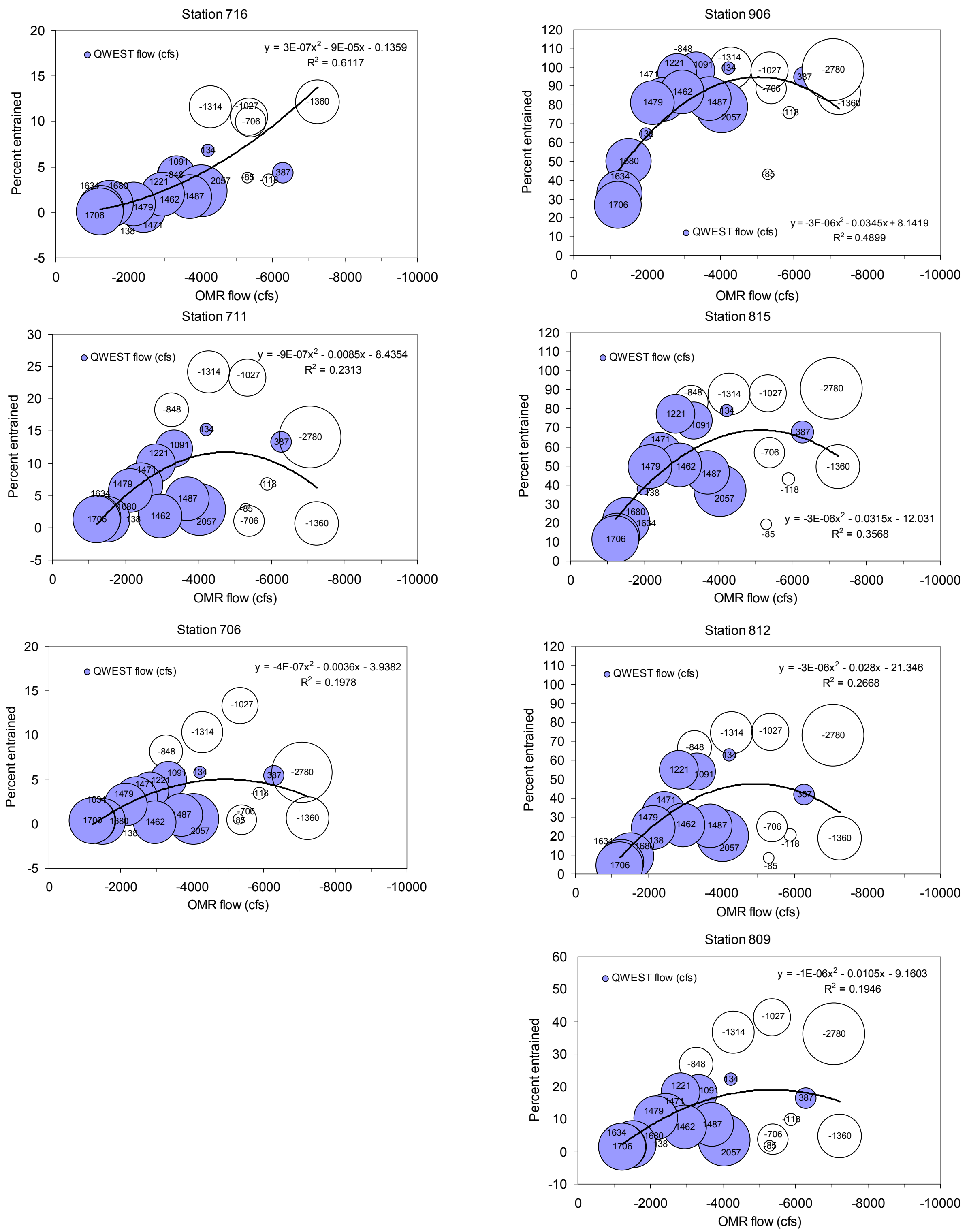

Figure 16. Relationships between Old and Middle River flows and percent of surface-oriented particles entrained at the SWP and CVP exports combined for 1992, 2002 and 2008 by station. The bubble sizes are scaled to and labeled with average Qwest flows for the same 90 day periods as OMR flows.

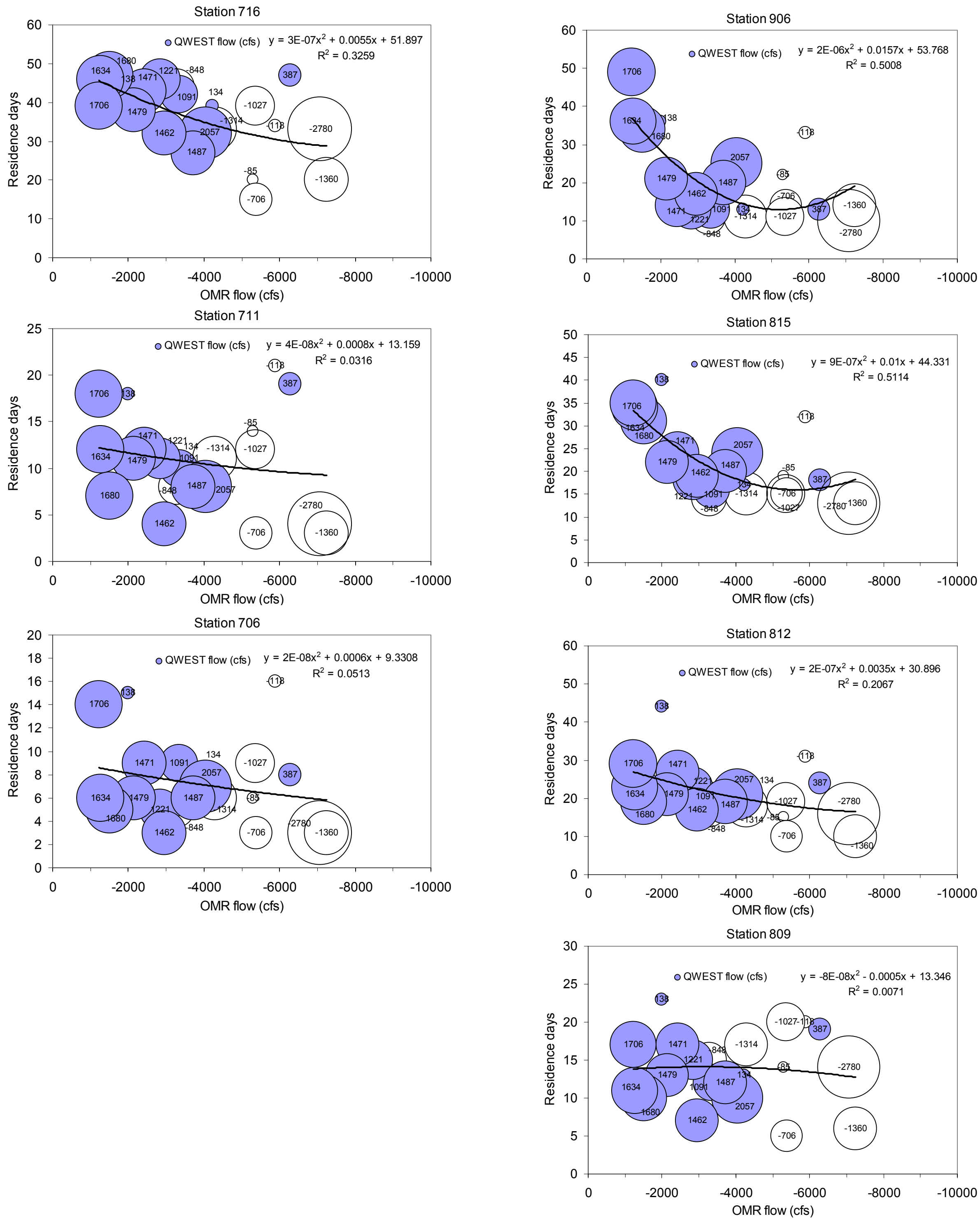

Figure 17. Relationships between Old and Middle River flows and average number of days to the fate of 50% of the particles entrained at the SWP+CVP exports, NBA, and Ag diversions, past Chipps, or into Montezuma Slough by station. The bubble sizes are scaled to and labeled with the average Qwest flows (cfs) for the same 90 day periods as the OMR flows.

Table 3. Annual particle fate (% of total resolved) by location from 90-day scaled PTM results using relative larva densities from 1991-1994 where Sacramento River station larva densities were much higher than those of San Joaquin River stations. Table does not include the fates of a small number of particles unresolved after the 90-day runs.

Year	Behavior	CVP%	Montezuma%	Chipps%	AgDiv%	NBA%	SWP%	CVP+SWP%
1992	neutral	2.06	10.96	82.02	0.74	0.74	3.49	5.55
1992	surface	2.91	11.33	79.43	0.71	0.71	4.91	7.82
2002	neutral	4.44	1.27	85.19	1.21	0.77	7.11	11.56
2002	surface	5.72	0.94	82.15	1.19	0.82	9.18	14.90
2008	neutral	1.10	1.10	94.52	1.11	0.60	1.56	2.66
2008	surface	1.54	0.96	93.69	1.04	0.59	2.17	3.71

Table 4. Annual particle fate (% of total resolved) by location from 90-day scaled PTM results using relative densities similar to 2005 where Sacramento River station larva densities were only slightly higher than those of San Joaquin River stations. Table does not include the fates of a small number of particles unresolved after the 90-day runs.

Year	Behavior	CVP%	Montezuma %	Chipps%	AgDiv%	NBA%	SWP%	CVP+SWP%
1992	neutral	2.59	10.98	80.39	0.73	0.73	4.58	7.16
1992	surface	3.36	11.33	78.07	0.70	0.71	5.83	9.20
2002	neutral	5.12	1.33	83.11	1.21	0.77	8.47	13.59
2002	surface	6.30	0.97	80.34	1.19	0.82	10.39	16.69
2008	neutral	1.73	1.09	92.88	1.16	0.60	2.54	4.27
2008	surface	2.18	0.96	92.09	1.07	0.59	3.10	5.29

To the extent that our data approximated actual hatching densities and PTM modeling with surface-oriented particles roughly emulated the movements of longfin smelt larvae within the Delta, our results suggest that larva entrainment at the SWP might be substantial (2-10% of total; Tables 3 and 4) under the relatively low outflow conditions modeled. Such high entrainment percentages would only be expected during periods of low downstream transport flows during which Qwest was generally negative. Conversely, when river flow surpassed about 40,000 cfs, SWP particle entrainment dropped substantially (c.f. Figures 12-15) and was generally low when river flow surpassed 55,000 cfs (c.f. Figures 12 and 14 for January 1 injections) even with exceptional high exports and negative OMR (Figure 12). If such a high river flow circumstances occurred throughout the principal hatching period of January through March, SWP expected larvae entrainment would be less than one percent of total, given the assumed relative San Joaquin River spawning densities. Also, we interpret these results as additive to subsequent salvage of juveniles described in the next section. Unfortunately, we have yet to devise absolute abundance estimates for juveniles to derive a complete estimate of entrainment.

The current OCAP and delta smelt BO could trigger export restrictions in December, January or February, based on a turbidity increase or adult delta smelt salvage, but neither trigger is guaranteed. Further, substantial OMR restrictions would not come into effect until a spent delta smelt adult or a larvae was detected or Delta water temperatures surpassed 12ºC; occurrence of these conditions was unlikely until late

February or more likely mid-March. Thus, some protections for longfin smelt larvae are needed, particularly in January and February, independent of those for delta smelt, even if these longfin smelt protections are uncommonly enacted.

Juvenile Entrainment (~March through June)

Circumstances leading to juvenile entrainment probably began during the spawning and larval stages; that is, spawning took place farther in the Delta and once hatched larvae were drawn into the south Delta during winter and spring, growing along the way -- or possibly within Clifton Court Forebay -- to the 20mm minimum size for identification and were salvaged in spring or early summer. A couple lines of evidence support this latter contention. First, the timing and pattern of age-0 salvage follows the same pattern as that of hatching, but shifted 3 months (90 days) later in the year (i.e., the time necessary to grow to 20mm) (Figure 18). Second, fish at the 20mm minimum size threshold continued to be salvaged in good numbers in June, about 3 months after the last of the strong hatching months, March (Figure 7). The sporadic salvage of 20-40mm longfin smelt in summer months (Figure 7) may have resulted from rare upstream spawning in the Sacramento or San Joaquin Rivers (see CDFG 2009) and later emigration or from portions of the Delta that have under some conditions extremely long residence times, that larvae and juveniles can travel large distances before being entrained or both. Our 90 day PTM runs described in the previous section were designed to capture the entire larval period and encompass a time span sufficient for particle fate to be resolved; however, fates were not always resolved at 90 days, particularly for spring injection dates (Figures 13-15). These findings lead to the conclusion that juvenile salvage and loss (Table 2) is additive to estimated larval loss as described by the PTM runs (Tables 3 and 4).

Juvenile salvage at the SWP was considerable in a few years when outflow was low (e.g., 1988 and 2002) and very low when outflow was high (e.g., 1982-1983, 1995-1996; Figure 19). Fujimura (2009, Appendix B) estimated that loss at the SWP was a multiple of salvage (ca. 16x higher; Table 2). Yet, even in high salvage years like 2002, juvenile (age-0) loss was only likely to add another few percent to the loss calculated for larvae based on the PTM runs. In 2008, juvenile loss may have been more substantial given the very low number of spawners believed present.

Spring hydrodynamics have been highly variable across all measures (Figures 20 and 21). Inflows declined over the period of record and since the late 1990s. Spring exports increased through the late 1980s, declined sharply starting about 1990 during the drought, and though highly variable, the trend remained essentially flat after about 1995 (Figure 20A-C). Spring OMR flows fluctuated over time, but remained generally negative and generally declining (Figure 21). Spring X2 position trended similar to exports, but with a lag (Figure 20B and C). Spring X2 position moved rapidly upstream with low inflows and increasing exports in the mid- to late-1980s, and continued to remain high even after exports dropped as the drought persisted through the early 1990s. With the return of higher outflows in the mid-1990s, X2 trended strongly

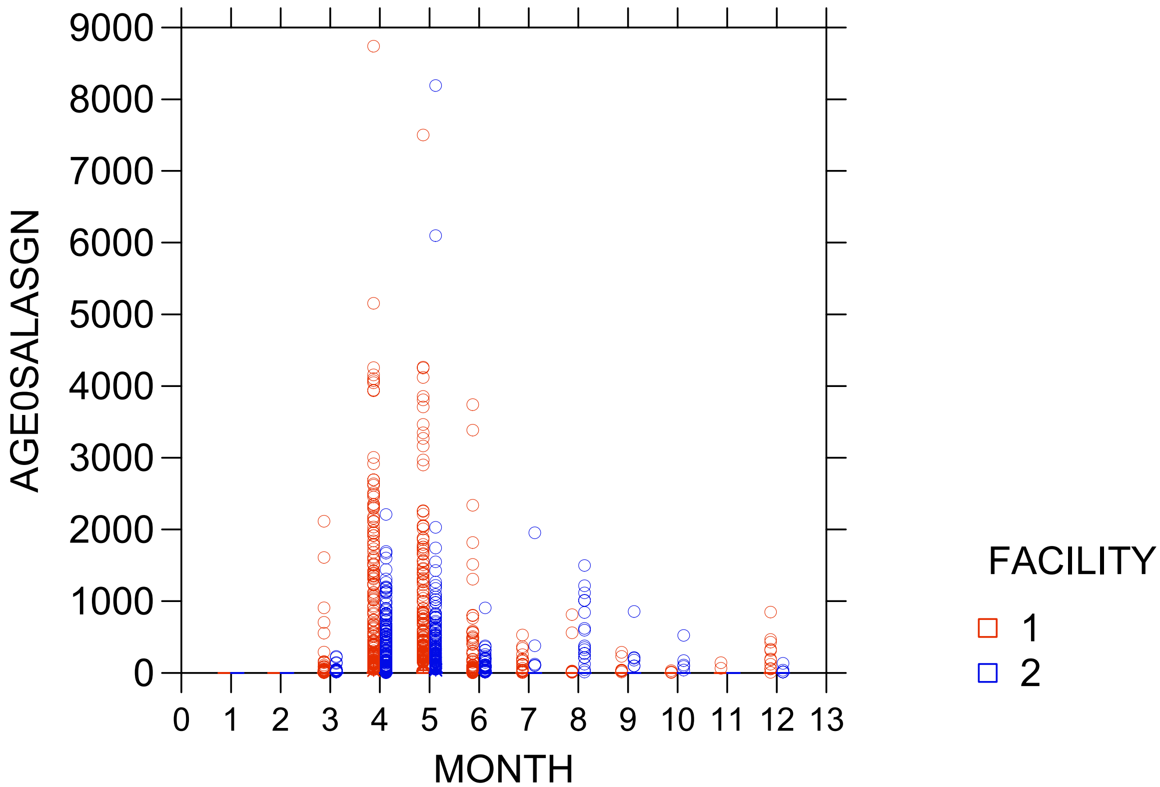

Figure 18. Scatter of juvenile longfin smelt salvage by month 1982 through 2007 for the SWP (red) and CVP (blue).

downward and has only increased slightly through the early 2000s. After an upswing with higher inflows during the mid-1990s, OMR flows declined and were strongly negative from the 2000 to 2004 and less negative in more recent years (Figure 21); the recent years of increased longfin smelt juvenile salvage corresponded with these strongly negative OMR flows (c.f., Figures 19 and 21).

Similar to Grimaldo et al. (accepted), we found a significant negative relationship between spring OMR flows and juvenile longfin smelt salvage ($r^2 = 0.466$, $p < 0.05$, 13 df; Figure 22A). Similar to patterns of particle entrainment in the SWP and CVP, juvenile salvage increased rapidly as OMR flows became more negative than about -2000 cfs (Figure 22A and B).

Conversely, as winter-spring or just spring outflows increased, X2 shifted downstream and salvage of juvenile longfin smelt decreased significantly ($r^2 = 0.656$, $p < 0.002$, 24 df; Figure 23A). This relationship improved when the outflow period was more contemporaneous with salvage in spring (Figure 23B). In these relationships, two mechanisms influenced salvage: 1) when X2 is located downstream of the Delta, substantial spawning may have occurred downstream of the Delta, reducing the proportion of juveniles (and larvae) susceptible to entrainment; and 2) when X2 was

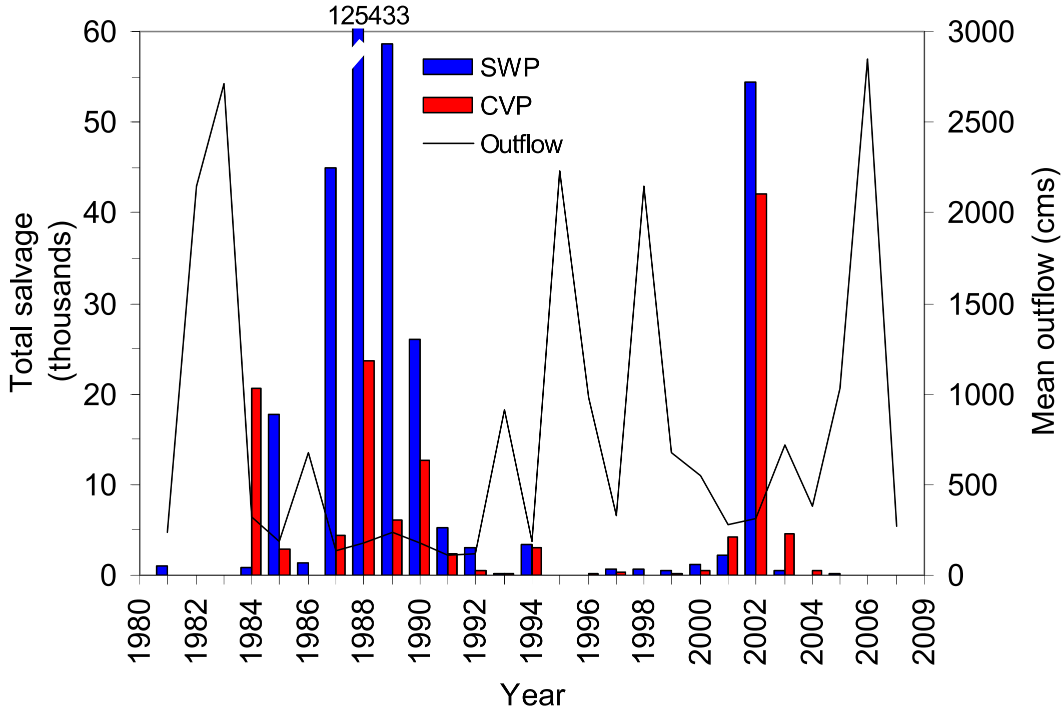

Figure 19. Total spring (Apr-Jun) salvage of longfin smelt at the State Water Project and Central Valley Project for 1981 through 2007 and mean Delta outflow in cubic meters per second for the same period.

located downstream of the Delta, the associated higher outflow would both increase the region of net downstream currents and would transport juveniles (and larvae) more rapidly downstream, reducing their vulnerability to entrainment. Thus, as spring outflow increased the entrainment risk to longfin smelt juveniles dropped rapidly in a manner similar to that detected through particle tracking.

The availability for and presence in salvage of juvenile longfin smelt from 20-60 mm FL (Figure 7) indicates a protracted period of vulnerability during low outflow years. This was suggested by incomplete fate resolution within 90 days for late March and April injected particles (cf. Figures 13-15). Also during spring, OMR flows became less negative during the Vernalis Adaptive Management Program (VAMP; about 15 April through 15 May; http://www.delta.dfg.ca.gov/jfmp/vamp.asp), generally increasing residence time (Figure 17) and allowing for more growth prior to salvage. Moreover, because OMR flows often become more negative in late May and June after VAMP restrictions abate, larvae and juveniles remaining in the Delta face increased risk of entrainment.

The pelagic orientation of larval and juvenile longfin smelt and their similar responses to outflows and OMR flows indicate that similar actions would benefit and should be taken for each. These could include: 1) short, periodic pulse flows through the central Delta January through June to transport larvae and juveniles away from the region of vulnerability; and 2) less negative OMR flows to reduce entrainment into the south

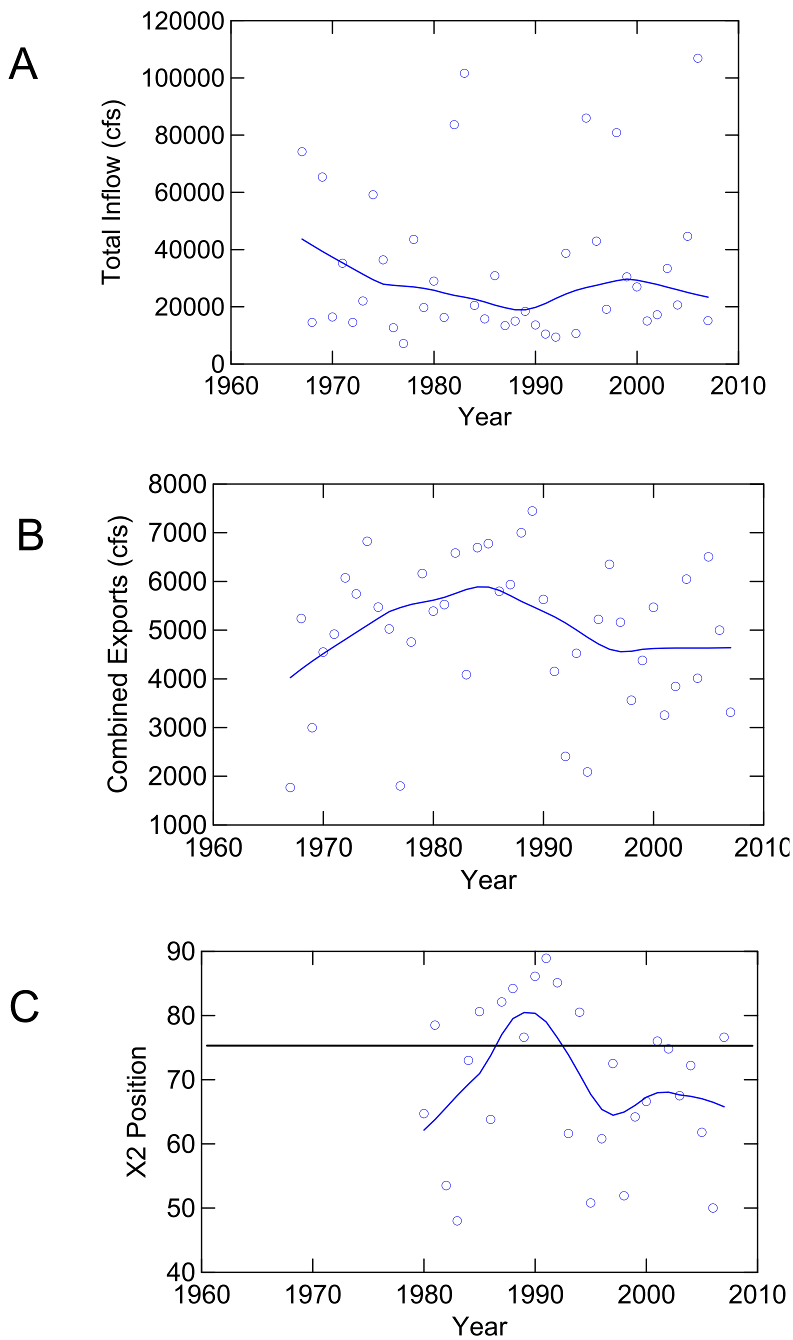

Figure 20. Trends in average spring (Apr-Jun) total delta inflow (A), combined SWP /CVP exports (B), and X2 position (C), 1967-2007, except for (C), which was 1980-2007. A LOWESS line was plotted through points to show general trend. The horizontal line in (C) at 75 km represents the location of Chipps Island.

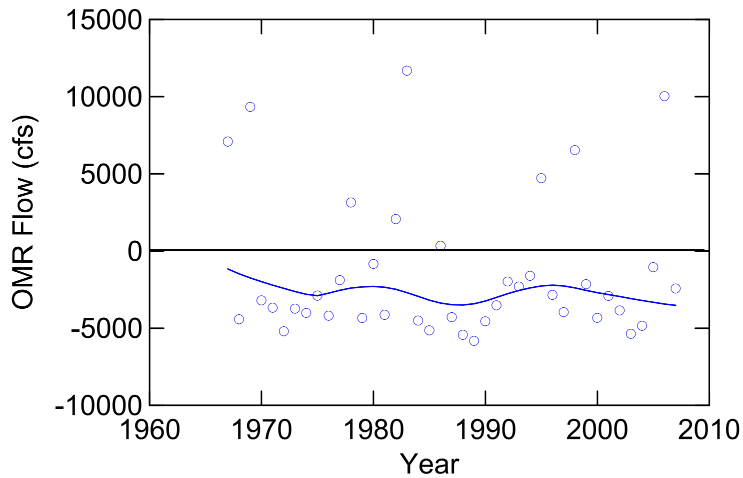

Figure 21. Trend in average spring (Apr-Jun) Old and Middle River (combined) flows 1967-2007, based on estimated (1967-1992) and measured (1993-2007) flows. See text for data sources. A LOWESS line was plotted through points to show general trend.

Delta. OMR restrictions in the delta smelt Biological Opinion and reduced exports and pulse flow associated with VAMP to assist salmon migration also benefit longfin smelt.

A

B

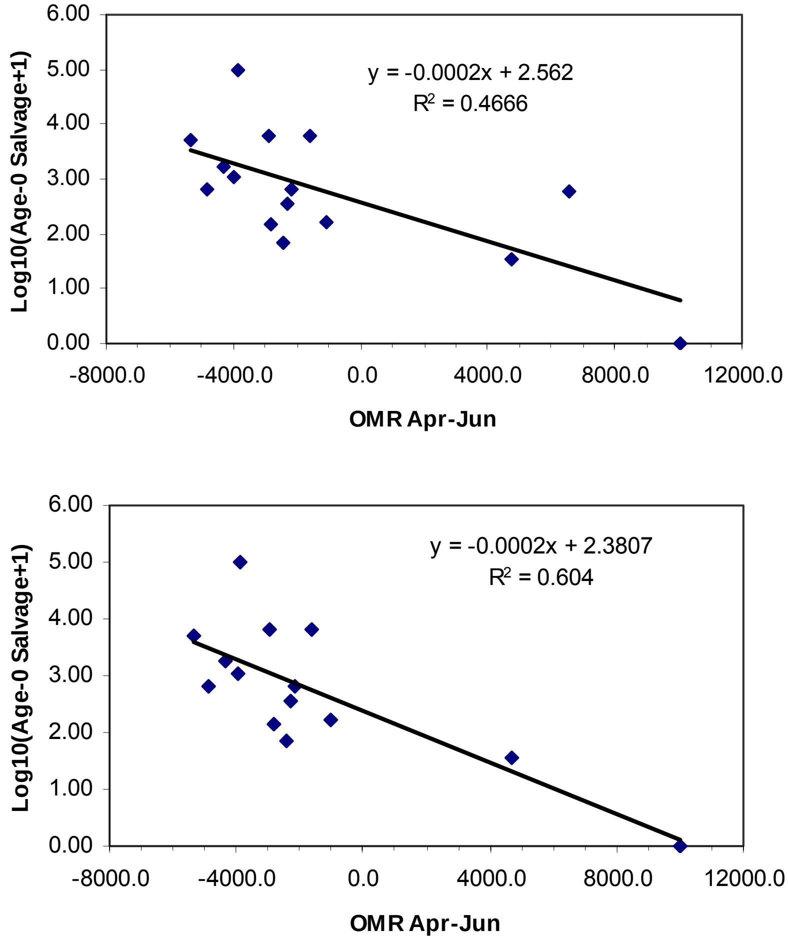

Figure 22. Relationship between spring (Apr-Jun) average Old and Middle River (combined) flows and sum of Apr-Jun combined SWP and CVP juvenile (age-0) longfin smelt salvage, 1993-2007 (A) and 1993-2007 without 1998 (B). In 1998, a protracted SWP export shut down allowed longfin smelt larvae to grow to salvageable size within Clifton Court before pumping resumed and fish salvage re-commenced; these fish would have passed through the system as larvae without recognition otherwise.

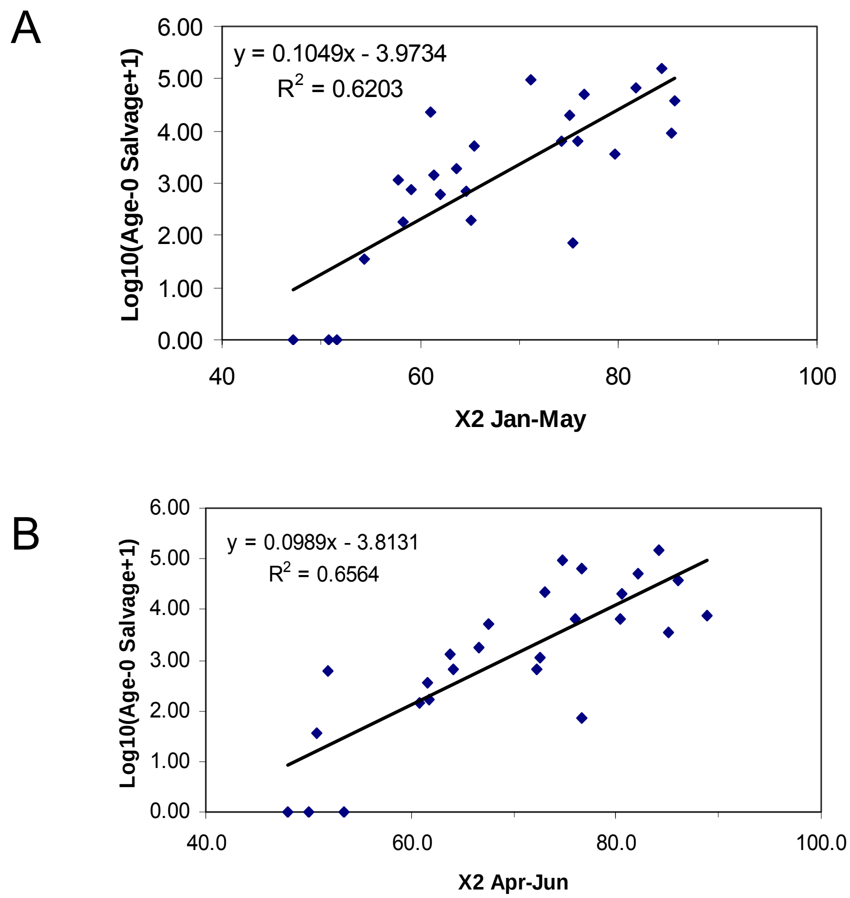

Figure 23. Relationship between winter-spring (Jan-May) average X2 location and sum of Mar-Jul combined SWP and CVP juvenile (age-0) longfin smelt salvage (A) and spring (Apr-Jun) average X2 location and Apr-Jun SWP and CVP juvenile (age-0) salvage (B). Salvage was incremented by one and log10 transformed.

Suisun Marsh Salinity Control Gates

Facility description: The SMSCG are located near the eastern confluence of Montezuma Slough and the Sacramento River near Collinsville (Figure 2). Operation of the SMSCG began in October 1988 as Phase II of the Plan of Protection for the Suisun Marsh. The objective of SMSCG operation is to decrease the salinity of the water in Montezuma Slough for multiple beneficial uses. The facility spans the 465-foot width of Montezuma Slough and consists of a boat lock, three radial gates, and removable flashboards. This array allows tidal control of the water entering Suisun Marsh, while allowing passage of watercraft. The gates reduce salinity by restricting the flow of brackish water from Grizzly Bay into Montezuma Slough during incoming tides and importing low salinity Sacramento River water during ebb tides, which results in a net movement of Sacramento River water into Suisun Marsh. The resulting net flow into Montezuma Slough is approximately 2500-2800 cfs. This net flow reduces salinity at Beldons

Landing by about 100%, and lesser amounts further west along Montezuma Slough. The net flow into the slough no longer contributes to the river flow entering Suisun Bay proper. Thus, the salinity field in Suisun Bay moves upstream when the gates are operated. However, because most of the water diverted in Suisun Marsh is circulated through its major distribution systems, net outflow past Carquinez Strait is not affected.

During the past several years, the SMSCG have not been used as frequently as they were in the past. The gates were operated approximately 40-270 days between October and May during 1988-2005 (Figure 24). Salmon passage studies between 1998 and 2003 increased the number of operating days by up to 14 to meet study requirements. Based on study findings and an agreement with NMFS, the boat lock is now always open to allow for continuous salmon passage. With increased understanding of the effectiveness of the gates at lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation since 2006. For instance, gate operation was not required at all in fall 2007 and was limited to 17 days in the winter of 2008. This operational frequency (10 – 20 days per year) is expected to continue, except perhaps during the most critical low outflow conditions. However, this conclusion cannot extend indefinitely due to rising sea level, which will eventually require more days of operation if salinity standards do not change.

The USACOE permit for operating the SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards. This overlaps the spawning migration and early life stage rearing of longfin smelt.

Adult longfin smelt: Adult longfin smelt typically migrate from brackish or marine habitats into low-salinity staging and spawning habitats during December-March. The SMSCG have the potential to cause short-term delays in salmonid spawning migrations (Tillman et al 1996: Edwards et al 1996). Thus, they may do the same to migrating longfin smelt. However, given that the boat locks are now always open based on NMFS' requirements for salmonid passage, longfin smelt passage delays may already be mitigated. If the SMSCG increased adult longfin smelt residence time in Montezuma Slough, entrainment at RRDS could increase. Presumably however, the fish screen on Roaring River Distribution System prevents the entrainment of adult longfin smelt. The MIDS is unscreened, but not directly connected to Montezuma Slough, so it seems unlikely that operation of the SMSCG would influence MIDS entrainment risk.

Larval and juvenile longfin smelt (young-of-year fish from January – June): Larval and juvenile longfin smelt rear in the low-salinity waters of the upper estuary year-around, but most larvae are present January-April and many remaining juvenile fish begin dispersing downstream as water temperatures warm during summer (Rosenfield and Baxter 2007). Thus, there also is considerable temporal overlap between SMSCG operations and the presence of early life stage longfin smelt. The ptm results show

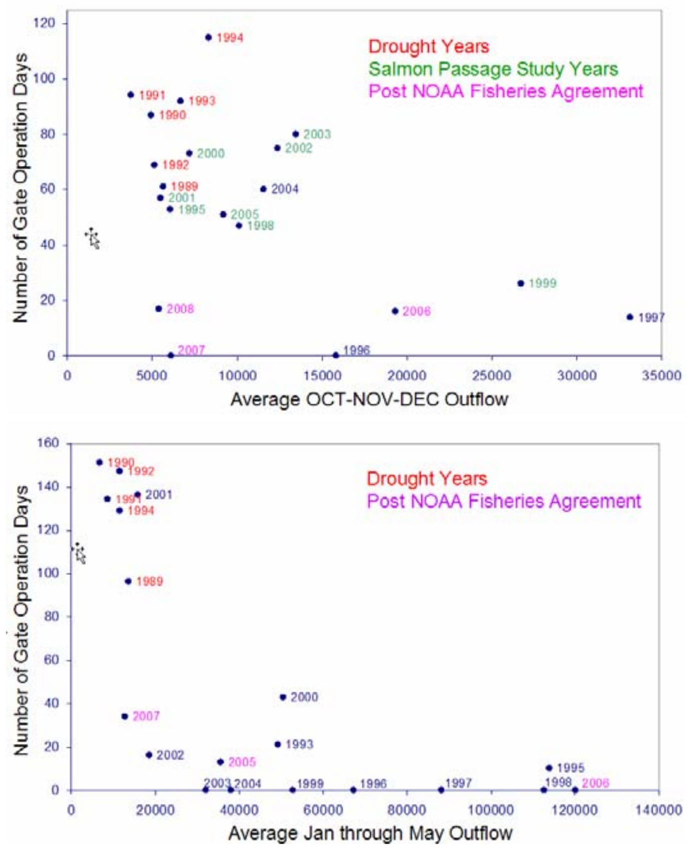

Figure 24. Scatterplots of fall and winter-spring Delta outflow versus the number of days the Suisun Marsh Salinity Control Gates were operated. Data points are labeled by year. Source: DWR permit application/2008 OCAP Biological Assessment for delta smelt.

clearly that the transport of larval longfin smelt is affected by SMSCG operation. In all three years modeled, the percentage of particles passing Chipps Island was correlated with the percentage of particles that entered Montezuma Slough (Figure 25). However, in 1992, a year when the SMSCG was operated about 150 days between January and May, over 20% of particles were predicted to enter Montezuma Slough in some instances. In 2002 and 2008, when the SMSCG were operated fewer than 20 days, ≤ 5% of particles were ever predicted to enter the marsh. The weighted ptm fluxes also show these differences. The indices were an order of magnitude higher in 1992 (Table 5).

Roaring River and Morrow Island Distribution Systems

The RRDS and MIDS were constructed in 1979 and 1980 as components of the Initial Facilities in the Plan of Protection for the Suisun Marsh. Details of these facilities are in Table 6. Immediately after the construction of RRDS and MIDS, fish densities in the UCD Suisun Marsh Otter Trawl Monitoring Program declined and they have remained comparatively low since, though longfin smelt was not a particularly dominant species,

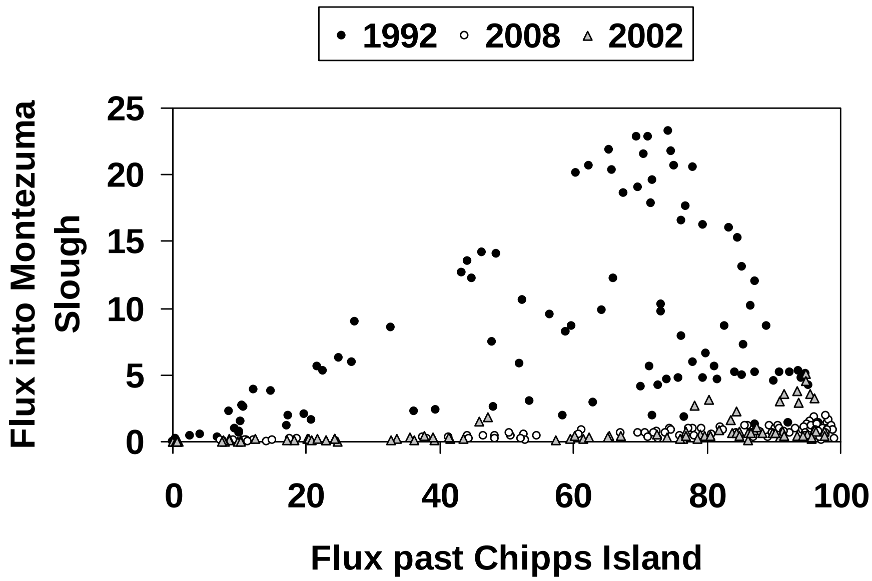

Figure 25. Scatterplot of particle flux past Chipps Island versus particle flux into Montezuma Slough for particles released Jan 1 – Apr 1, 1992 and 2008. Source: DWR particle tracking modeling in support of this permit.

Table 5. Weighted percentages for flux of particles into Montezuma Slough, 1992, 2002, and 2008.

Year	Particle behavior	Weighted flux
1992	Neutrally buoyant	10.9%
1992	Surface oriented	11.3%
2002	Neutrally buoyant	1.27%
2002	Surface oriented	0.94%
2008	Neutrally buoyant	1.1%
2008	Surface oriented	0.96%

averaging only 6% of the catch from 1979-1999 (Matern et al. 2002). The relative abundance of nonnative species has also increased through time in the UCD surveys, but this trend is due to steeper declines of native fish rather than increased nonnative fish densities. The RRDS was screened because it was recognized that it was a significant source of fish entrainment (Pickard and Kano 1982). The MIDS is not screened, mainly because it has not been demonstrated that doing so would protect special-status fishes (Culberson et al. 2004; Enos et al. 2007) such as delta smelt and salmonids.

Table 6. Comparison of the Roaring River and Morrow Island Distribution Systems in Suisun Marsh.

	Roaring River	Morrow Island
Primary purpose	Reduce salinity of water delivered to privately and publically managed wetlands used primarily for waterfowl hunting	Increase water circulation through Suisun Slough and drain high salinity water from Suisun Slough and adjancent managed wetlands used primarily for waterfowl hunting
Construction	1979-1980	1979-1980
Intake specifications	Eight 60-inch culverts	Three 48-inch culverts
Fish screens	Yes – 3/32 inch mesh operated to average approach velocity of 0.2 ft/s since 1993	No

Adult longfin smelt: During the fall, longfin smelt migrate into low-salinity waters to 'stage' before spawning. During staging and spawning some longfin smelt occupy Suisun Marsh. They should be protected from entrainment at RRDS by the fish screens, but some are entrained at MIDS (Enos et al. 2007; Figure 26). Enos et al. (2007) sampled entrained fishes at MIDS during 2004-2006. More adult longfin smelt were entrained in fall of 2004 than fall of 2005 (Figure 26). There was a correspondence of timing between maximum sampling effort by Enos et al., entrainment of longfin smelt, and relative abundance in the estuary as indexed by DFG (Table 7). In fall 2004, the highest entrainment occurred coincident with the highest amount of diverted water sampled in December. This also coincided with the highest monthly DFG catch in the FMWT, which suggests the high entrainment was due to both higher sampling effort and movement of longfin smelt into adult staging habitats. In fall 2005, the highest DFG catches occurred in September when MIDS sampling effort was low. In October 2005, sampling effort increased substantially and a few longfin smelt were observed to be entrained even though FMWT catches had dropped considerably.

Fish catch data from MIDS suggest there is an operational threshold that can minimize fish entrainment at this diversion. Few adult longfin smelt were entrained when the maximum velocity of water diverted through MIDS on a tidal cycle was less than 3 ft/s (Figure 27). However, as explained above, adult longfin smelt were not frequently observed in samples of entrained fish. Therefore, we also looked at age-0 splittail entrainment versus maximum velocity. We used age-0 splittail for two reasons. First, they were entrained more frequently and second, they were smaller than the longfin smelt, but are fairly strong swimmers, so we think this represents a comparison of two

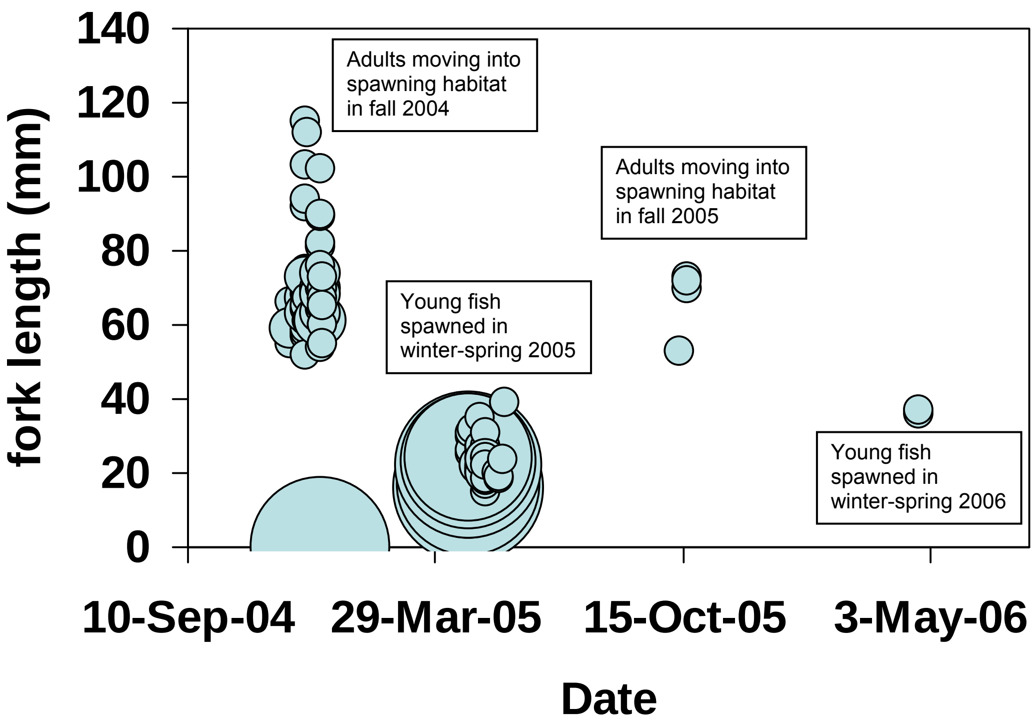

Figure 26. Bubble plot of collection date versus longfin smelt fork lengths from a study of fish entrainment at Morrow Island Distribution System. Each data point is sized by the number of fish at the length shown. The large dots at length = 0 mm correspond to fish that were counted, but not measured. Source: DWR unpublished data.

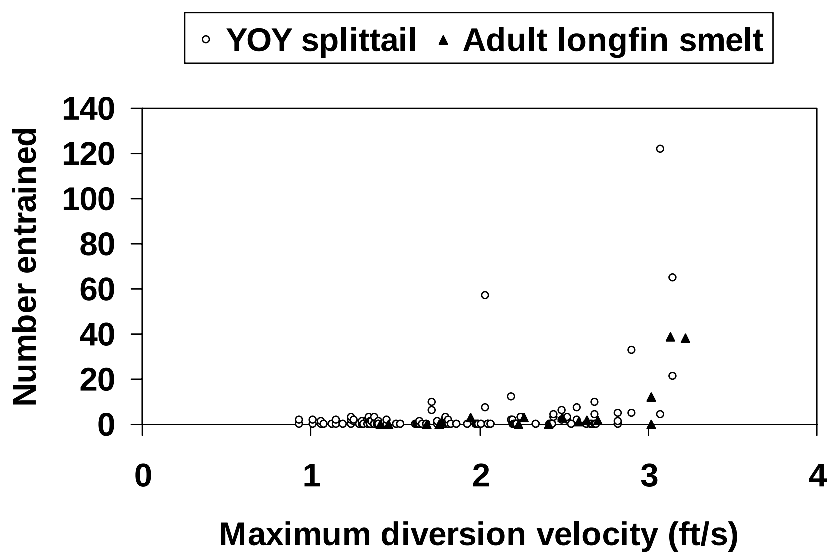

Figure 27. Scatterplot of average water velocity at the Morrow Island Distribution System intake versus numbers of age-1 and older longfin smelt and age-0 splittail entrained into the diversion.

Table 7. Comparison of adult longfin smelt entrainment at MIDS during fall 2004 and 2005 with the monthly DFG Fall Midwater Trawl relative abundance indices.

	MIDS volume sampled (ft^3)	Observed longfin smelt entrainment	FMWT index
September 2004	710,169	0	44
October 2004	0	0	9
November 2004	1,478,569	0	9
December 2004	6,729,396	104	129
September 2005	82,867	0	1563
October 2005	5,331,814	4	169
November 2005	762,157	0	184
December 2005	1,010,333	0	33

fishes with similar swimming ability. Excepting one data point near 2 ft/s, the splittail entrainment also increased when maximum velocity approached 3 ft/s.

Larval and juvenile longfin smelt: Culberson et al. (2004) used the DSM2 particle tracking model (ptm) to demonstrate that proximity to the MIDS diversion was the primary factor influencing entrainment risk. Particles released outside of the sloughs affected by MIDS were seldom if ever entrained. Similarly, none of the particles released in the Delta for simulations done by DWR for this permit were entrained into MIDS or RRDS. Thus, the weighted ptm indices for MIDS and RRDS were always zero.

The entrainment of adult longfin smelt into MIDS suggests that suitable spawning habitat exists nearby since MIDS is not predicted to entrain particles released distant from it (Culberson et al. 2004). This hypothesis is also supported by the subsequent catches of young-of-year longfin smelt at MIDS. Fewer larvae and juveniles were observed being entrained in spring 2006 following low adult entrainment the previous fall than in spring 2005, which followed the higher fall 2004 adult entrainment (Figure 26).

North Bay Aqueduct

Facility description: North Bay Aqueduct can convey up to about 175 cfs diverted from the Barker Slough Pumping Plant. North Bay Aqueduct diversions are conveyed to Napa and Solano Counties. As its name suggests, Barker Slough Pumping Plant is located in Barker Slough, which is located in the northwest part of the Cache Slough system (Figure 2). The NBA intake is located approximately 10 miles from the main stem Sacramento River. The diversion is operated year-round and is located in or near longfin smelt spawning habitat (see below). Per DFG screening criteria, each of the ten NBA pump bays is individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish approximately 25 mm or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2

ft/s. The larger units were designed for a 0.5 ft/s approach velocity, but actual approach velocity is about 0.44 ft/s.

Adult longfin smelt: Longfin smelt use the Cache Slough region as spawning habitat more during low outflow winter/springs when the low-salinity zone encompasses parts of the Delta, but DFG has not found evidence that longfin smelt spawn extensively in the Cache Slough region like delta smelt do. As mentioned above, the Barker Slough Pumping Plant diversions are screened and approach velocities are fairly low, so entrainment and impingement of adult longfin smelt staging or spawning in Barker Slough should be minimal. Further, the flooding of Little Holland Tract and Liberty Island seems to have decreased the NBA/Yolo Bypass flow ratio, greatly reducing the risk of false attraction flows toward the Barker Slough Pumping Plant during the longfin smelt spawning season (Figure 28).

Larval and juvenile longfin smelt: Water diversions into NBA have typically been less than 100 cfs with maximum diversion rates occurring during the summer months (Figure 29) when longfin smelt are not present or present only at very low densities. Annual diversions into NBA have generally increased since the facility came online in 1988 (Figure 29). However, diversions have not increased during January-March when most larval longfin smelt are nearby (Figure 30). The winter diversions have usually averaged about 40 cfs and have seldom exceeded 80 cfs on a daily basis.

However, the projected winter diversions into NBA presented in the OCAP Biological Assessment are much higher (Figure 31). In future scenarios in which full SWP water demand is assumed, the Barker Slough Pumping Plant is expected to frequently operate to full capacity (175 cfs) during January-March except in very wet years. This would mean water diversion rates up to 4-5 times higher than current conditions.

Station 716, located in Cache Slough (Figure 2), was the only station in the ptm analyses DFG requested for this permit from which particles were entrained at Barker Slough. The ptm results indicated that the loss of surface-oriented particles to NBA ranged from 1.5% to 37% depending on release date; particle loss was nonlinearly related to the average pumping rate the particles were exposed to (Figure 32). The weighted ptm percent fluxes into NBA were very consistent among years, and suggested this diversion currently has only a very minor effect on longfin smelt larvae; less than 1% of longfin smelt larvae are expected to be entrained into NBA in dry years under current operations even if the fish screens provide no protection to larvae (Table 8). In wet years, entrainment has probably been lower still because even fewer longfin smelt spawn in the Cache Slough region in wet years. Based on Figure 32, NBA diversions ≤ 40 cfs during low outflow winter-springs are unlikely to entrain larvae spawned in the greater Cache Slough region.

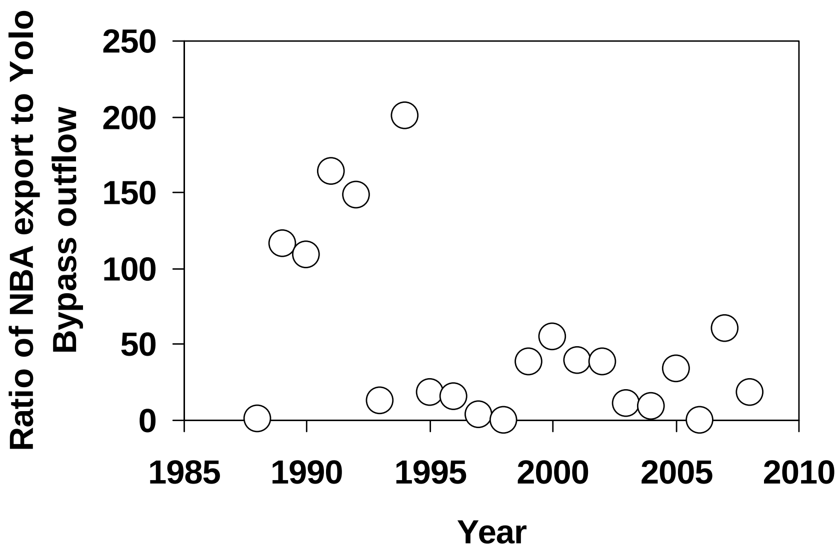

Figure 28. Average January-March ratio of water diversion into the North Bay Aqueduct relative to outflow from Yolo Bypass. Source: DAYFLOW.

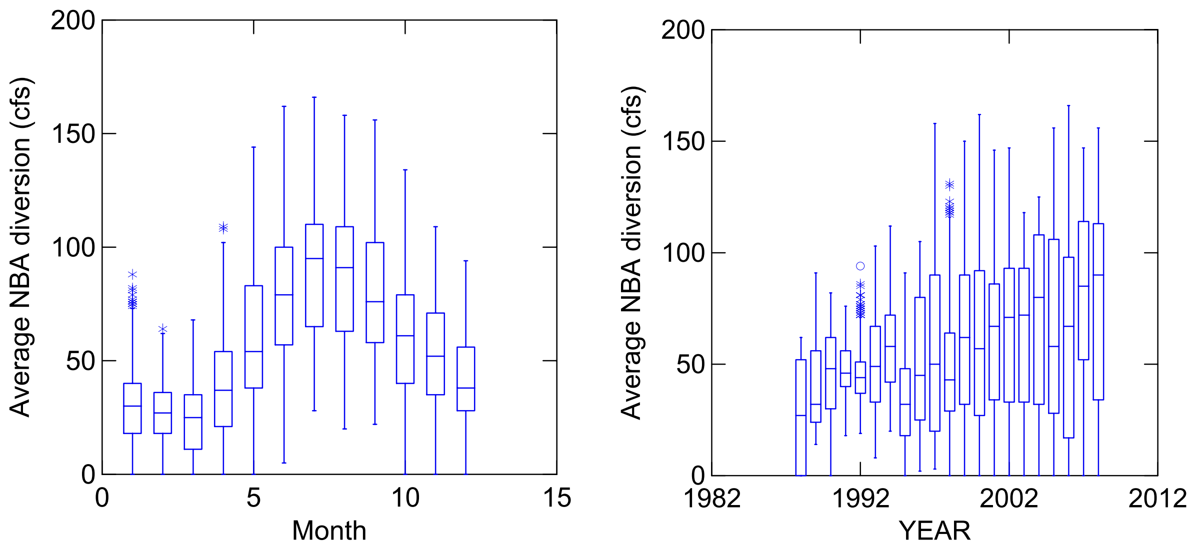

Figure 29. Boxplots summarizing water diversions at Barker Slough Pumping Plant into the North Bay Aqueduct. Left panel = monthly diversion summaries. Right panel = annual diversion summaries. The boxplots show monthly median values (1988-2008) and quartile ranges and the whiskers and asterisks show more extreme values. Source: DAYFLOW.

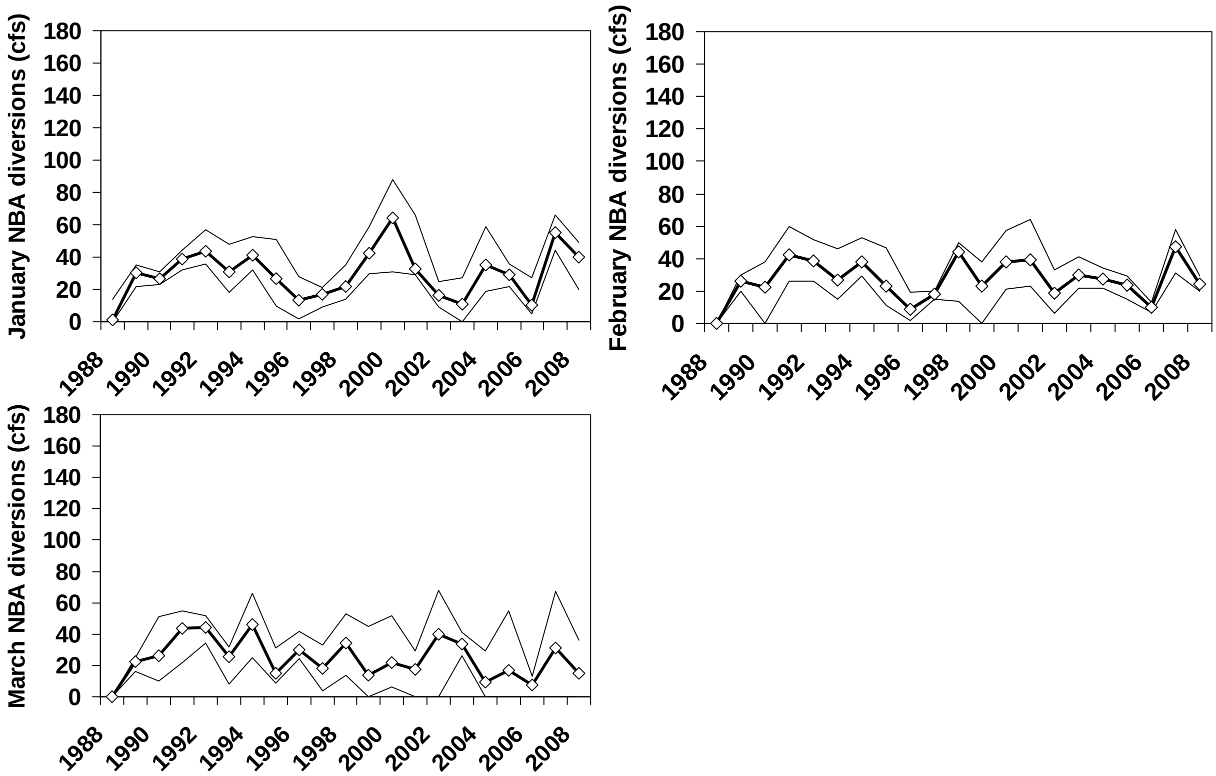

Figure 30. Time series of minimum, average, and maximum water diversions at Barker Slough Pumping Plant into the North Bay Aqueduct during January, February, and March, 1988-2008. Source: DAYFLOW.

The proposed increases in Barker Slough diversion rate are beyond what DFG can evaluate based on the commissioned ptm runs because historical divesions during the modeled periods have not been so high. However, we can conclude that about 100% of particles would be entrained from Cache Slough in low outflow years under the proposed operations. This would include the peak larval hatching months of January-March, which are not currently exposed to high diversion rates. The evidence for 100% entrainment loss comes from April-June ptm simulations in which about 100% of particles wound up entrained in NBA and local ag diversions (Figure 33) even though average Barker Slough diversion rates during these simulations never exceeded 100 cfs (Figure 32). Positive barrier fish screens similar to those in Barker Slough have been shown to exclude larval fishes smaller than their design criteria (Nobriga et al. 2004). However, it has not been demonstrated that they can do so when placed at the back of a dead-end slough like the Barker Slough screens. Thus, the proposed future operations of NBA might severely degrade longfin smelt spawning success in low outflow years.

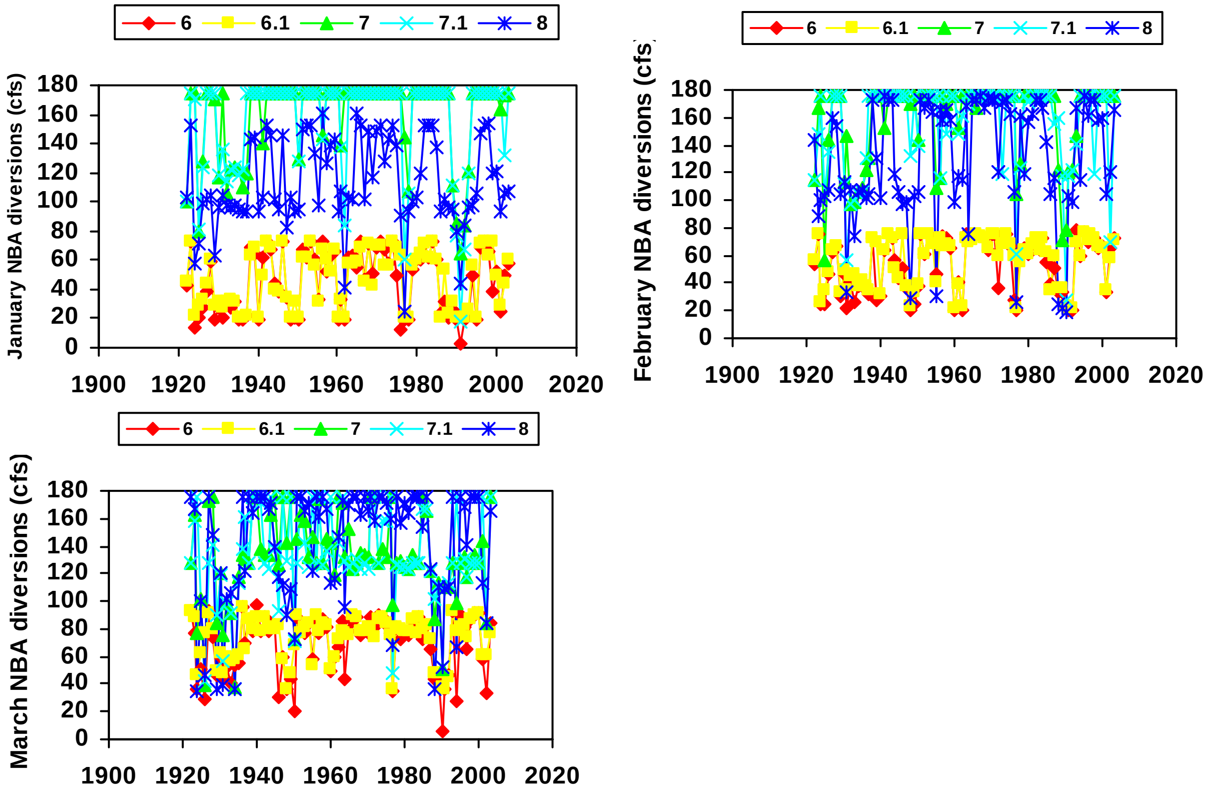

Figure 31. Pseudo-time series plots of predicted (future demand) water diversions at Barker Slough Pumping Plant into the North Bay Aqueduct during January, February, and March. Source: CalSim modeling presented in Appendix E of the OCAP biological assessment prepared by USBR and DWR.

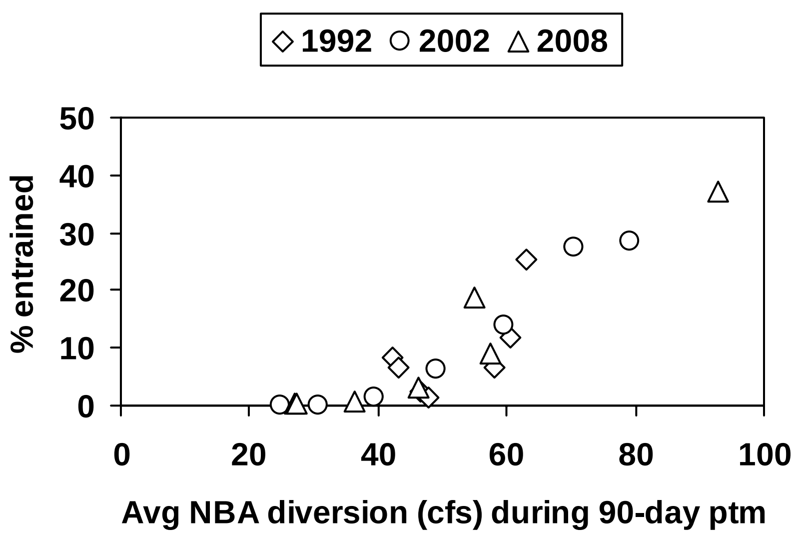

Figure 32. Scatterplot of average water diversion rate (cfs) into North Bay Aqueduct versus percentage of particles released at station 716 in particle tracking simulations. The averaging periods for the NBA diversions are the same as the particle tracking simulations so they range from Jan 1 – Mar 30 and Apr 1 – Jun 29, 1992. Source: DAYFLOW and DWR permit application.

Table 8. Weighted percentages for flux of particles into the North Bay Aqueduct, 1992, 2002, and 2008.

Year	Particle behavior	Weighted flux
1992	Neutrally buoyant	0.73%
1992	Surface oriented	0.70%
2002	Neutrally buoyant	0.76%
2002	Surface oriented	0.81%
2008	Neutrally buoyant	0.59%
2008	Surface oriented	0.58%

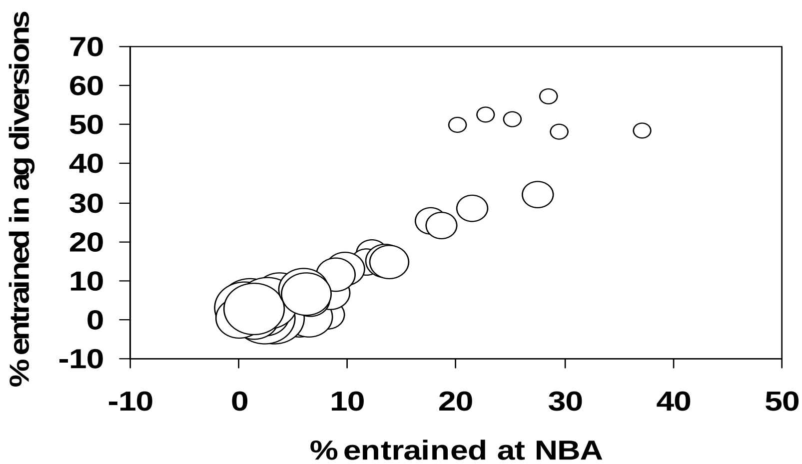

Figure 33. Bubble plot showing the relationship between percentages of particles released at station 716 that were predicted to be entrained into NBA and into Delta irrigation diversions, presumably in the Cache Slough region. The data points are sized by the proportion of larval hatching expected to be represented by each simulation. Source: DWR particle tracking modeling in support of this permit. The hatch date distribution for longfin smelt is based on DFG Bay Study egg and larval sampling.

Indirect effects of the SWP on longfin smelt

The springtime X2 standard: Water Rights Decision D-1641 codified an estuarine habitat standard based on X2, the distance in km from the Golden Gate Bridge to the location in the estuary where the average near-bottom salinity is 2 psu (Jassby et al. 1995). The X2 standard was implemented to improve estuarine habitat conditions by restoring springtime Delta outflows. This water quality standard was adopted due to statistical correlations between variation in X2 and responses of the estuarine ecosystem such as abundance and survival of numerous organisms including longfin smelt (CDFG 1992, Jassby et al. 1995; Kimmerer 2002). The X2 standard is in effect each year from February-June. Thus, the Delta outflows required to meet the X2 standard overlap considerably with the spawning and early life stage rearing of longfin smelt. The X2 standard enhances outflow during low-flow winter-springs and can extend very high outflow periods during wetter winter-springs by requiring X2 to remain at Roe Island in Suisun Bay. This extra increment of outflow displaces spawning and rearing longfin smelt seaward, reducing entrainment in water diversions, increasing transport to the low-salinity zone and enhancing rearing habitat suitability. Since the overbite clam invasion (discussed below) longfin smelt abundance is only demonstrably higher on average in years when average X2 was at or downstream of Roe Island (Figure34).

During the approximate history of the SWP (1967-2007), there is a nearly linear relationship between estimates of the unimpaired runoff[1] in Central Valley rivers and the average X2 during February-June (Figure 35). The residuals from a linear regression of Figure 35 have a distinct time trend (Figure 36) that shows what the X2 standard accomplished. Residuals greater than zero depict years when X2 was upstream of where it was expected to be based on unimpaired runoff; negative residuals depict years when X2 was downstream of where it was expected to be based on unimpaired runoff. Both the frequency and magnitude of positive residuals increased from the latter 1960s to the early 1990s because more unimpaired runoff was being diverted from the Delta. The initial adoption of an X2 standard in 1995 reversed this trend; positive residuals have been rare since, occurring only in the very wet springs of 1995, 1998, and 2000. Note that wet year residuals tend to be positive because Central Valley reservoirs are operated to attenuate flood flows by capturing portions of major runoff events. The net effect of the X2 standard is that more runoff flows out of the Delta under present SWP springtime operations than typically did during the 1970s and 1980s.

Habitat and food supply for longfin smelt: The primary indirect mechanism by which the SWP could affect longfin smelt is through effects on abiotic habitat quality and food supply that might occur when the SWP has control over X2. When Banks pumping is entraining longfin smelt, it follows that it is also entraining longfin smelt habitat (water of suitable quality) and co-occurring food. These direct effects are analyzed as appropriate in other sections of this effects analysis. This section describes what is known about longfin smelt habitat and food at times of year when longfin smelt are not being entrained (summer and fall) and provides a rationale for why DFG does not think the SWP strongly affects habitat or food when longfin smelt are not also being entrained. We contrast this conclusion with those recently drawn for delta smelt during the OCAP consultation (USFWS 2008).

The statistical relationship between X2 and longfin smelt abundance suggests winter-spring river flow generates some kind of habitat opportunity, but not all of the mechanisms are known (Jassby et al. 1995; Kimmerer 2002). The drop in longfin smelt abundance after the estuary was invaded by overbite clam suggests a big part of the mechanism was prey availability for young fish, but food production is not the only factor involved because the X2 response has persisted (Kimmerer 2002, Kimmerer et al. 2009).

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[1] Unimpaired runoff is the amount of water that would theoretically enter the Delta if there were no dams or water diversions to capture the water.

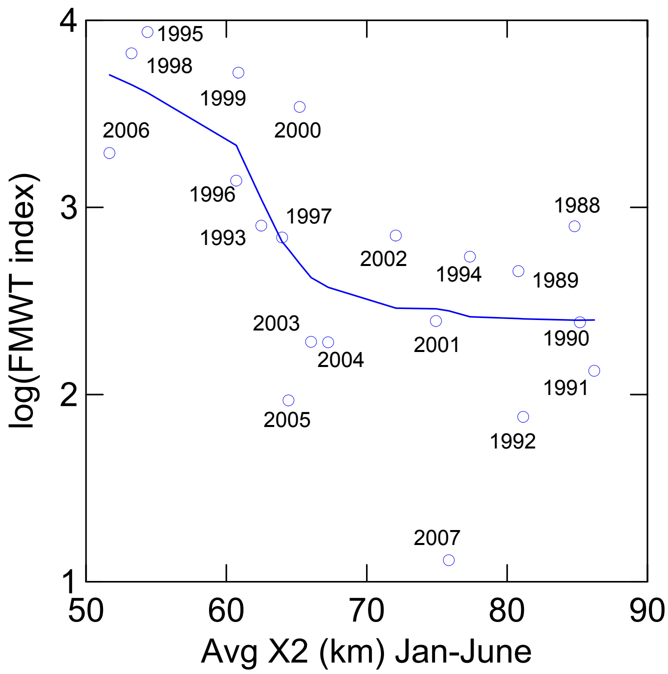

Figure 34. Scatterplot of average January-June X2 versus the log10-transformed FMWT abundance indices for longfin smelt for 1988-2007 (the period of food web change precipitated by the overbite clam invasion following Kimmerer 2002). The smoother is a LOWESS regression line.

Fishes generally eat larger prey as they grow. Longfin smelt are no exception – their diet shifts from small zooplankton (copepods) to larger mysid shrimp as the season progresses because the fish are getting larger (Figure 37). The USFWS (2008) concluded that Banks and Jones likely influenced prey availability for delta smelt during the summer because Banks and Jones pumping affected the flux of the copepod *Pseudodiaptomus forbesi* out of the central and south Delta. This argument does not hold for longfin smelt because longfin smelt do not eat very much *Pseudodiaptomus* (Figure 37). *Pseudodiaptomus* blooms begin in late spring and continue into summer. By that time of year, longfin smelt are targeting larger prey – mainly mysids.

Both of longfin smelt's primary prey items – the copepod *Eurytemora affinis* and mysid shrimp - have populations that bloom in the vicinity of X2 and both were greatly depleted by the overbite clam (Kimmerer et al. 1994; Kimmerer and Orsi 1996; Kimmerer 2002). Apparent suppression of phytoplankton blooms by free ammonium ion in the Sacramento River and Suisun Bay may also affect the abundance of the phytoplankton that feeds longfin smelt's prey (Wilkerson et al. 2006; Dugdale et al. 2007). The estuary's food web consumes most of the available supply of phytoplankton (Jassby et al. 2002). For instance, Jassby et al. (2002) estimated that water diversions at Banks and Jones removed about 8 tons of phytoplankton per day, about 14% of the potentially available primary production, while the food web and settling into the substrate removed about 38 tons per day. Note that most primary production in the Delta occurs during summer when most longfin smelt are feeding in brackish and

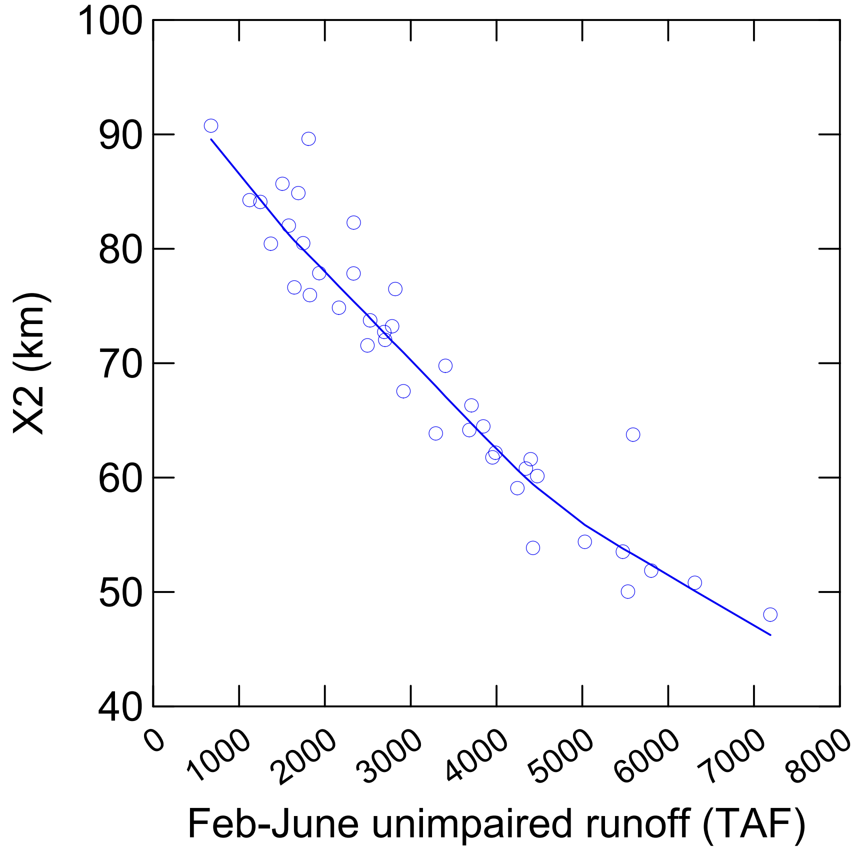

Figure 35. Scatterplot of estimated unimpaired Central Valley runoff (8 river index) versus X2 (February-June averages for both axes). The smoother is a LOWESS regression line.

marine habitats.

If entrainment of phytoplankton that feeds zooplankton or entrainment of the zooplankton that feed longfin smelt were strongly affected by SWP diversions, then food availability should correlate with X2. The abundance of *Eurytemora* did not vary with X2 prior to the overbite clam invasion (Kimmerer 2002). This means that flow variation among years, which is partly under the control of SWP did not cause differences in availability of this prey item for longfin smelt, but longfin smelt abundance did vary with X2. Thus, *Eurytemora* availability was not the underlying reason for the longfin smelt response to X2. Note that since the overbite clam invasion, X2 does predict *Eurytemora* abundance during spring, but not during summer when its abundance is always near zero due to grazing by overbite clam (Kimmerer et al. 1994).

Historically, average March-November X2 predicted mysid shrimp abundance over the same averaging period; mysid abundance was higher in wet years (Jassby et al. 1995). This relationship changed after the clam invasion. Mysid abundance was suppressed in all water year types, but highest in low outflow years (Kimmerer 2002). If mysid

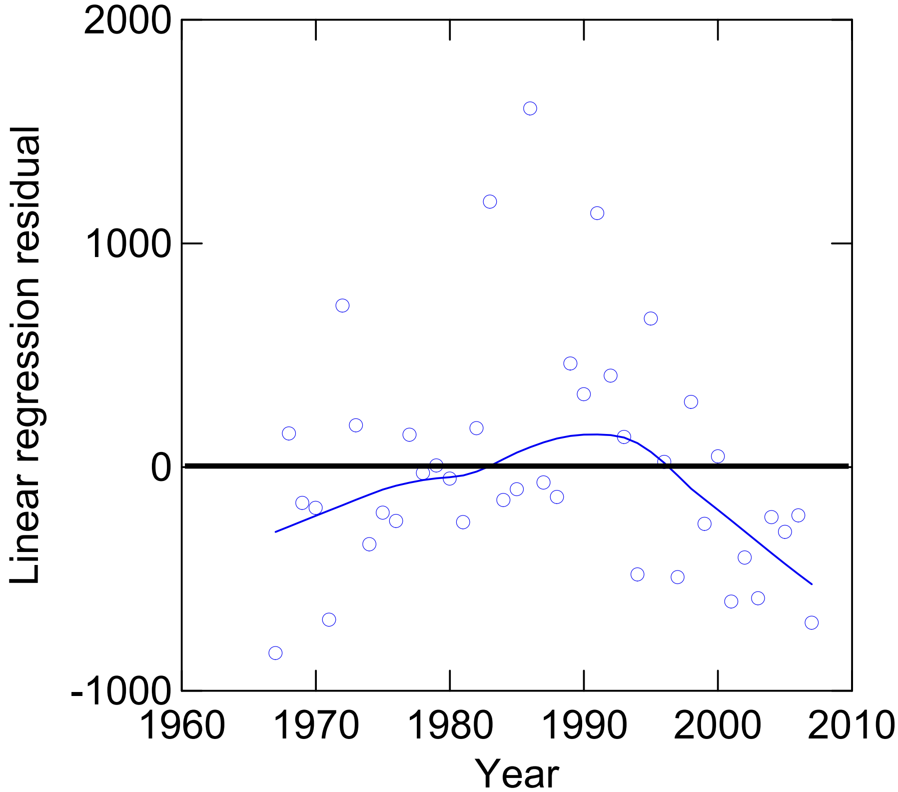

Figure 36. Time trend in the linear regression residuals between the variables shown in Figure 35. The smoother is a LOWESS regression line. The zero line depicts each year's predicted value of X2.

entrainment were the mechanism driving the historical relationship, post-clam abundance would not be highest in low outflow years because more mysids are probably entrained when low outflows cause X2 to get closer to Banks and Jones. As stated above, most of the variation in X2 is caused by climatic variation in precipitation (Figure 35) and the mysid decline was strongly driven by overbite clams (Orsi and Mecum 1996; Kimmerer 2002). Thus, DFG cannot find any conceptual evidence that the SWP affects food availability for longfin smelt strongly enough to influence the species' population dynamics. The effects of the overbite clam swamp any signals that might be due to entrainment of zooplankton.

Another possible mechanism for the SWP to influence longfin smelt is via effects on abiotic habitat suitability. Longfin smelt is a pelagic fish, so abiotic habitat in open-water is water with suitable levels of salinity, temperature and other characteristics is much more important than structural aspects. Since its implementation, the X2 standard has enhanced Delta outflow during the February-June period (Figure 36), which should have improved abiotic habitat suitability in the open-water environment during these months.

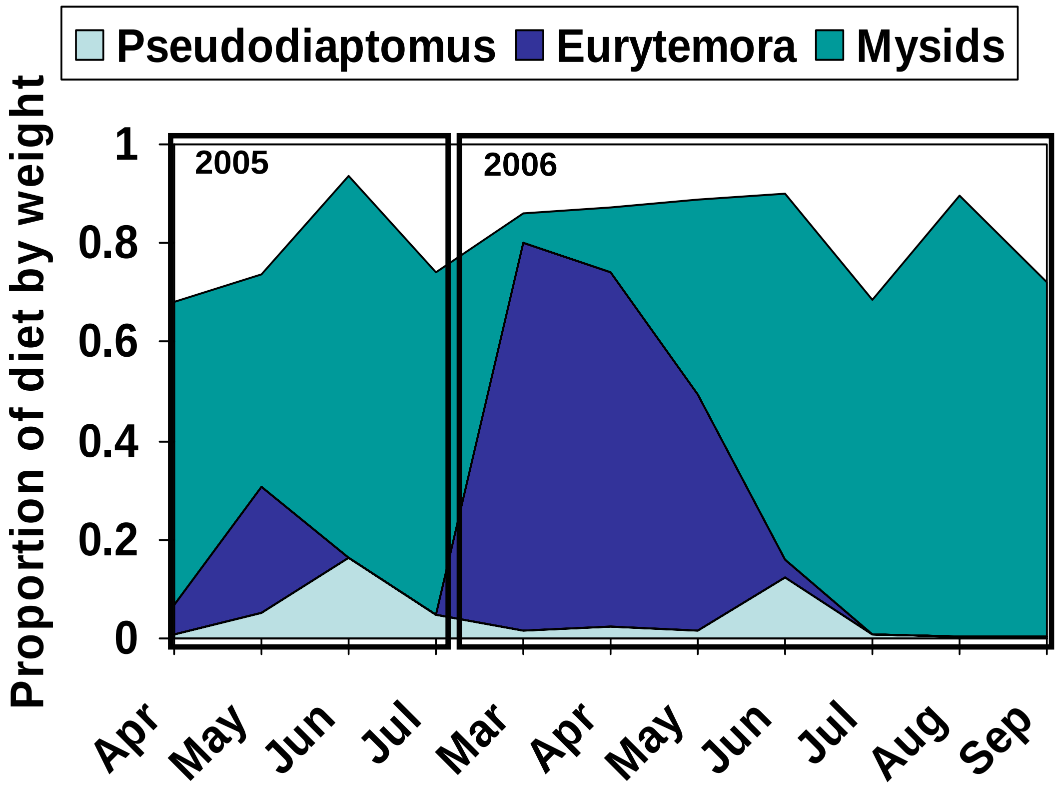

Figure 37. Proportions of age-0 longfin smelt stomach contents accounted for by the copepods Eurytemora and Pseudodiaptomus, and by mysid shrimp, April-July 2005 and March-September 2006. Source: Steve Slater, DFG unpublished data.

However, there is a long-term increase in fall X2 that has resulted from increasing exports relative to inflows (USFWS 2008). This has reduced abiotic habitat suitability for delta smelt and age-0 striped bass (Feyrer et al. 2007). The influence of this trend on longfin smelt has not been determined, but longfin smelt have higher salinity tolerance than either delta smelt or age-0 striped bass and thus, they often occur in marine habitats during summer and fall (Rosenfield and Baxter 2007). The portion of the longfin smelt population rearing in Suisun Bay during summer and fall has declined through time; Rosenfield and Baxter 2007). However this may just reflect the greatly reduced mysid abundance caused by the overbite clam – a similar hypothesis was posed for northern anchovy (Kimmerer 2006). Because longfin smelt can and do rear in marine habitats during summer and fall, DFG does not think lower fall outflow has significantly lowered abiotic habitat suitability for longfin smelt like it has for delta smelt and age-0 striped bass. This conclusion is supported by the recent flow versus habitat volume analysis for longfin smelt by Kimmerer et al. (2009).

Acknowledgements

Tara Smith, Kijin Nam and Min Yu provided particle tracking model runs and assistance in interpreting data.

Lenny Grimaldo and James Hobbs shared pre-published data analyses.

Dave Contreras, Virginia Afentoulis and Omid Ebrahimi organized and summarized particle tracking model output.

Brad Burkholder and Kathy Hieb provided valuable comments that improved the organization and clarity of the text.

Personal Communications

Hobbs, James. In person and email August and September 2008. Assistant Project Scientist, Center for Inductively Coupled Plasma Mass Spectrometry, UC Davis, 1 Sheilds Ave. Davis, CA 95618.

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Appendix A

Longfin smelt winter distributions (Dec-Mar) from CDFG midwater trawl sampling in relation to the locations of X2 and X0.5

Source: Randall Baxter DFG, 209 942-6081
December 2008

Longfin Distribution by Month and Year for several outflow years (LFSMWT WinterDist.ppt revised from Longfin smelt distribution select year.ppt)

Midwater trawl longfin smelt catches by month for select years when trawling was conducted December through March. Years with all three months of Spring MWT available are: 1968, 1969, 1971, 1972, 1991-1997, 2000 and 2001. Spring Kodiak Trawl was initiated in 2002 and Spring MWT terminated.

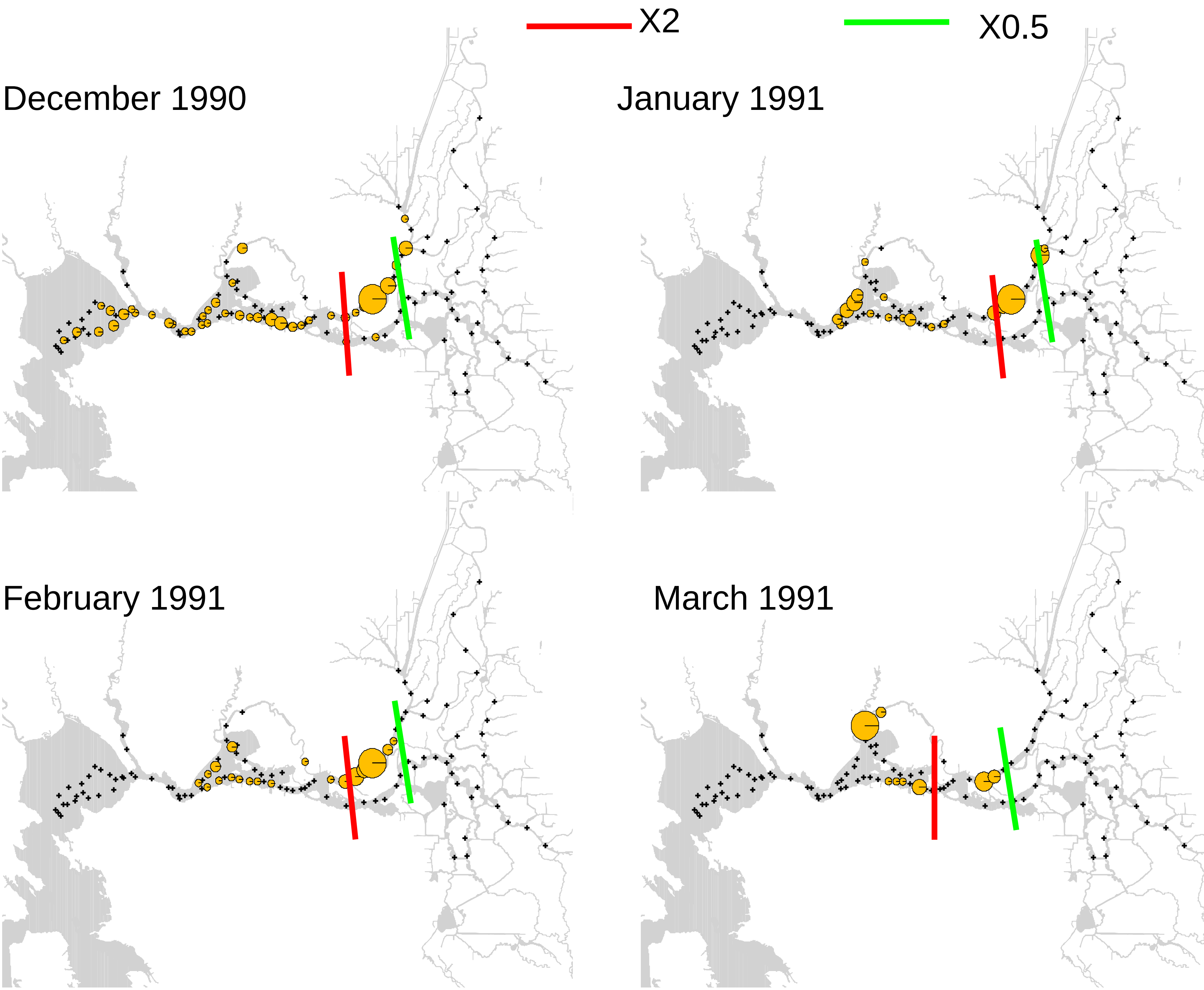
Graphics provided by Kelly Souza May 21, 2008 from ArcView 3.2 plots. Revised June 6, 2008. Graphics depict variable scale of catch per station and month. Only years from 1991 through 2001 were plotted, because X2 locations were only calculated back to 1980 (Chris Enright calculation from Lenny Grimaldo January 2008).

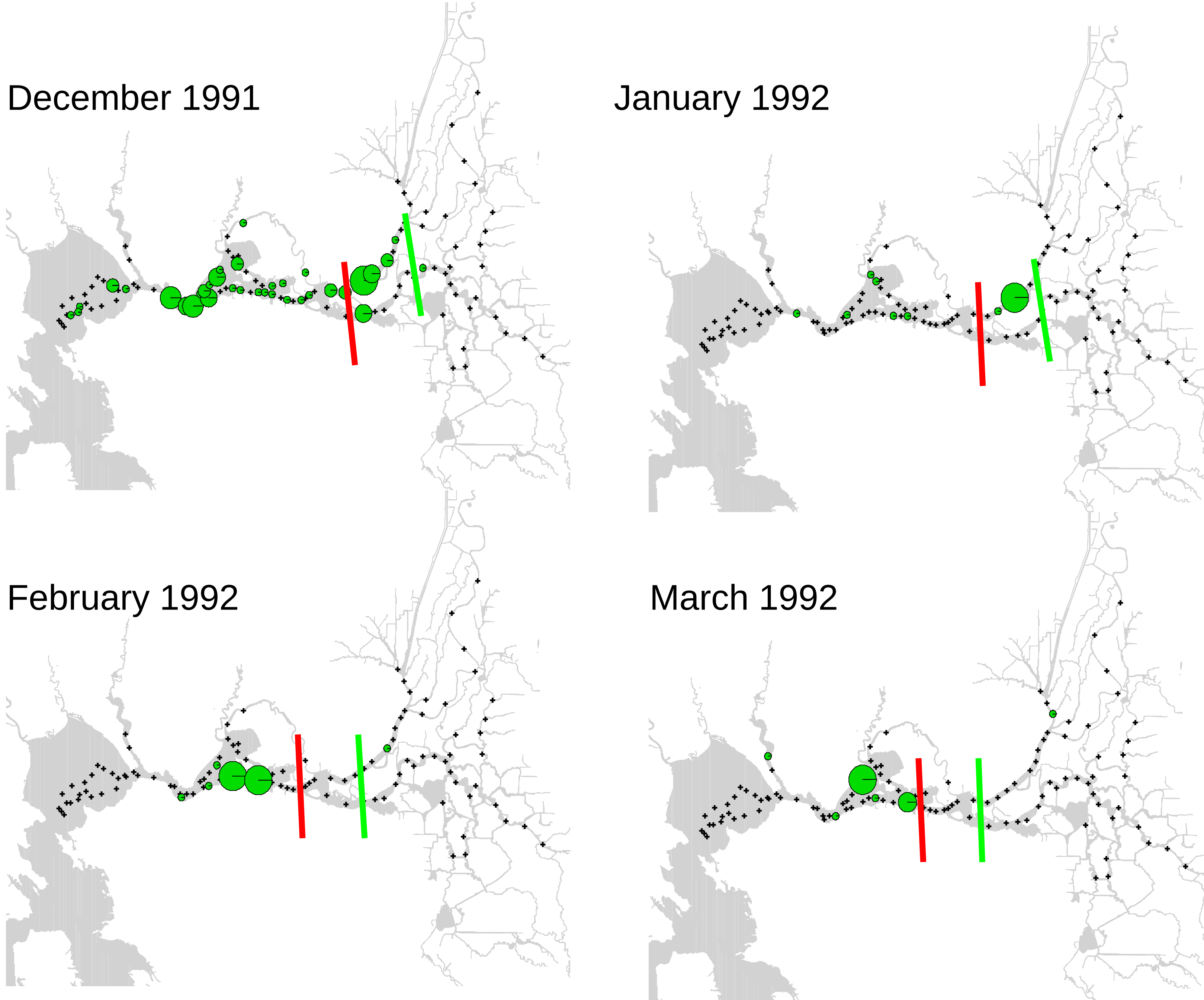
X2 position determined by averaging daily values for each month from DAYFLOW data and monthly X0.5 was estimated using monthly X2 value and the relation:

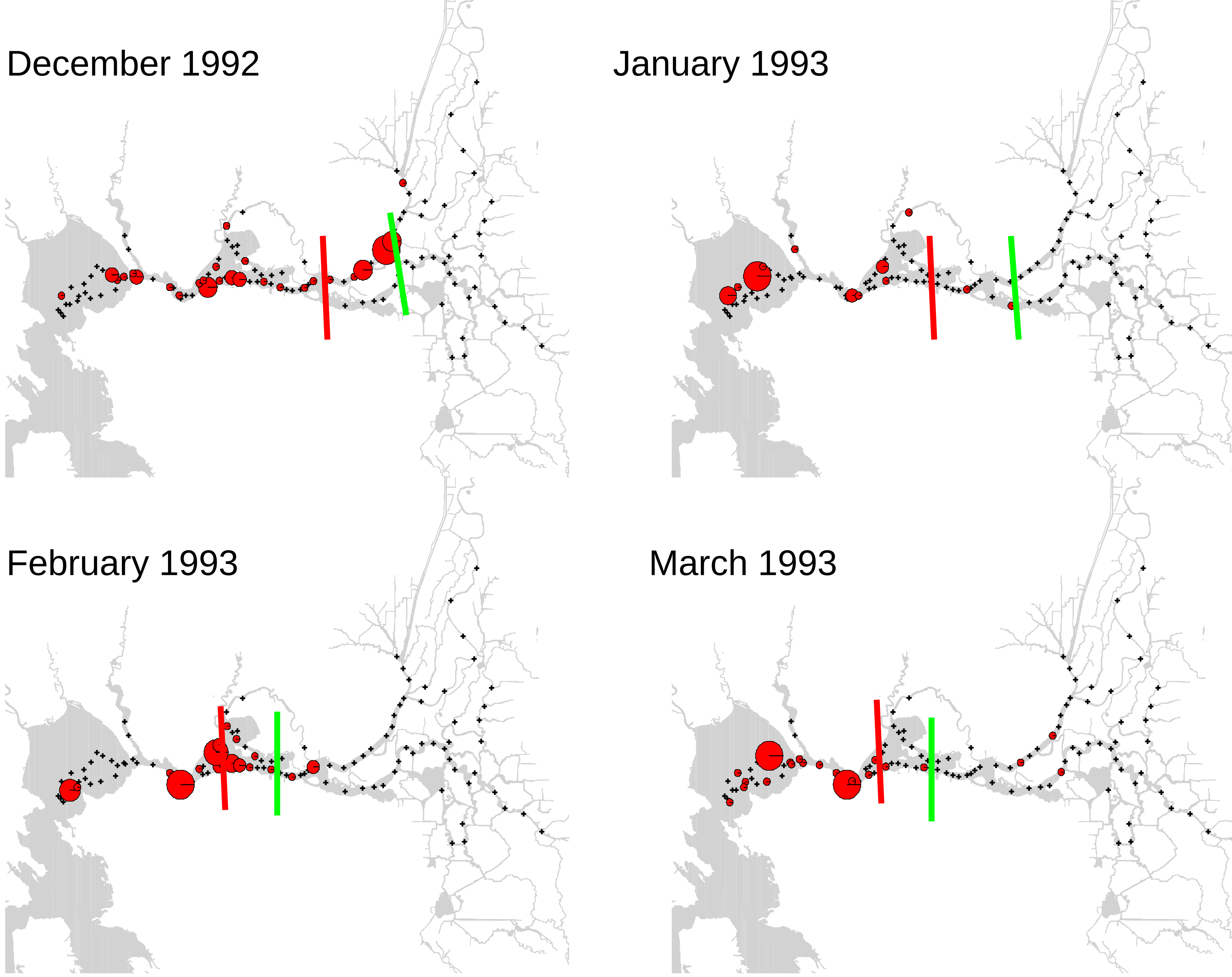
$$X0.5 = -(\text{X2 position}) *(\text{Ln}((31-(\text{target salinity}))/(515.67* (\text{target salinity})))/-7)-1.5)$$

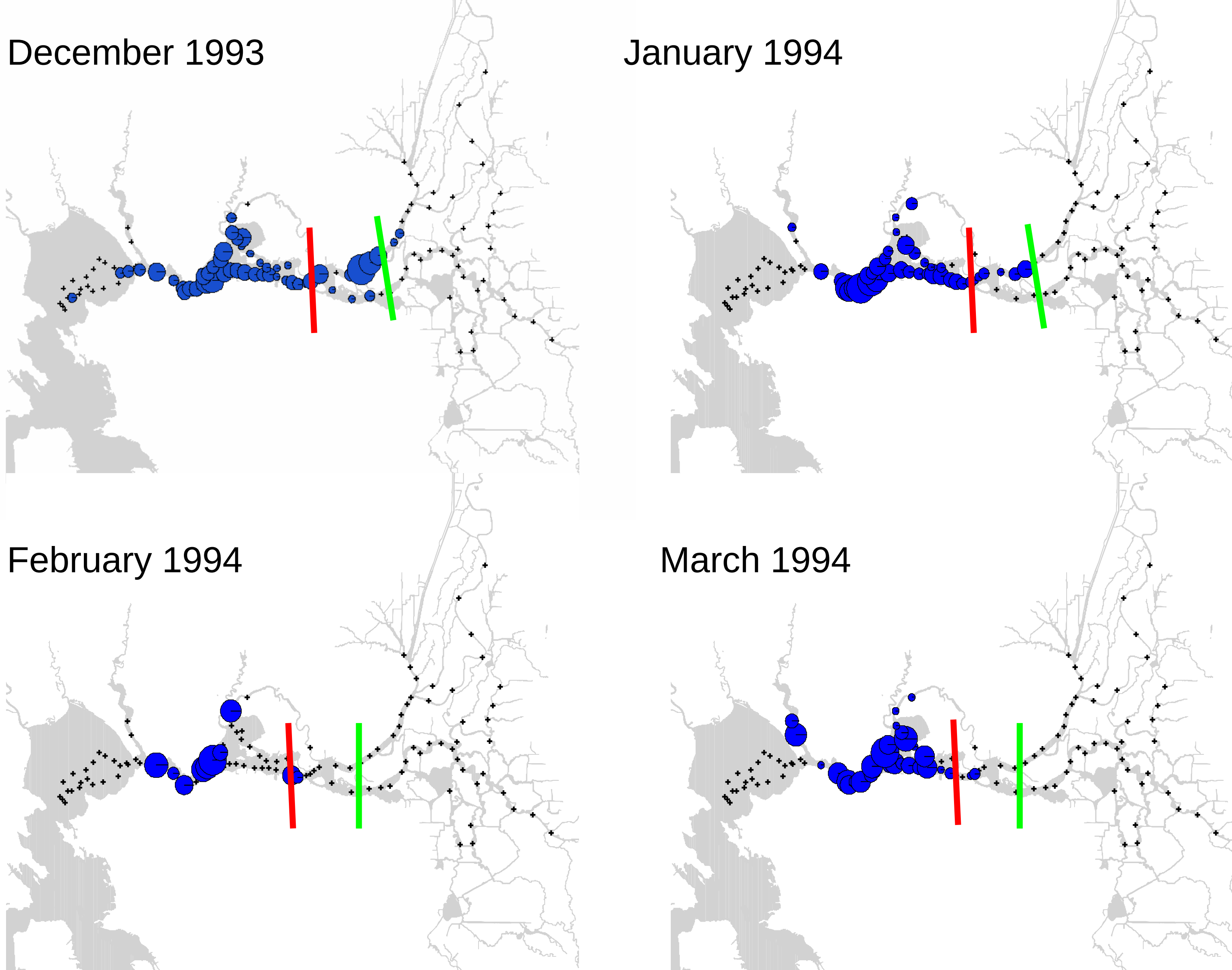
Where 0.5 is the target salinity.

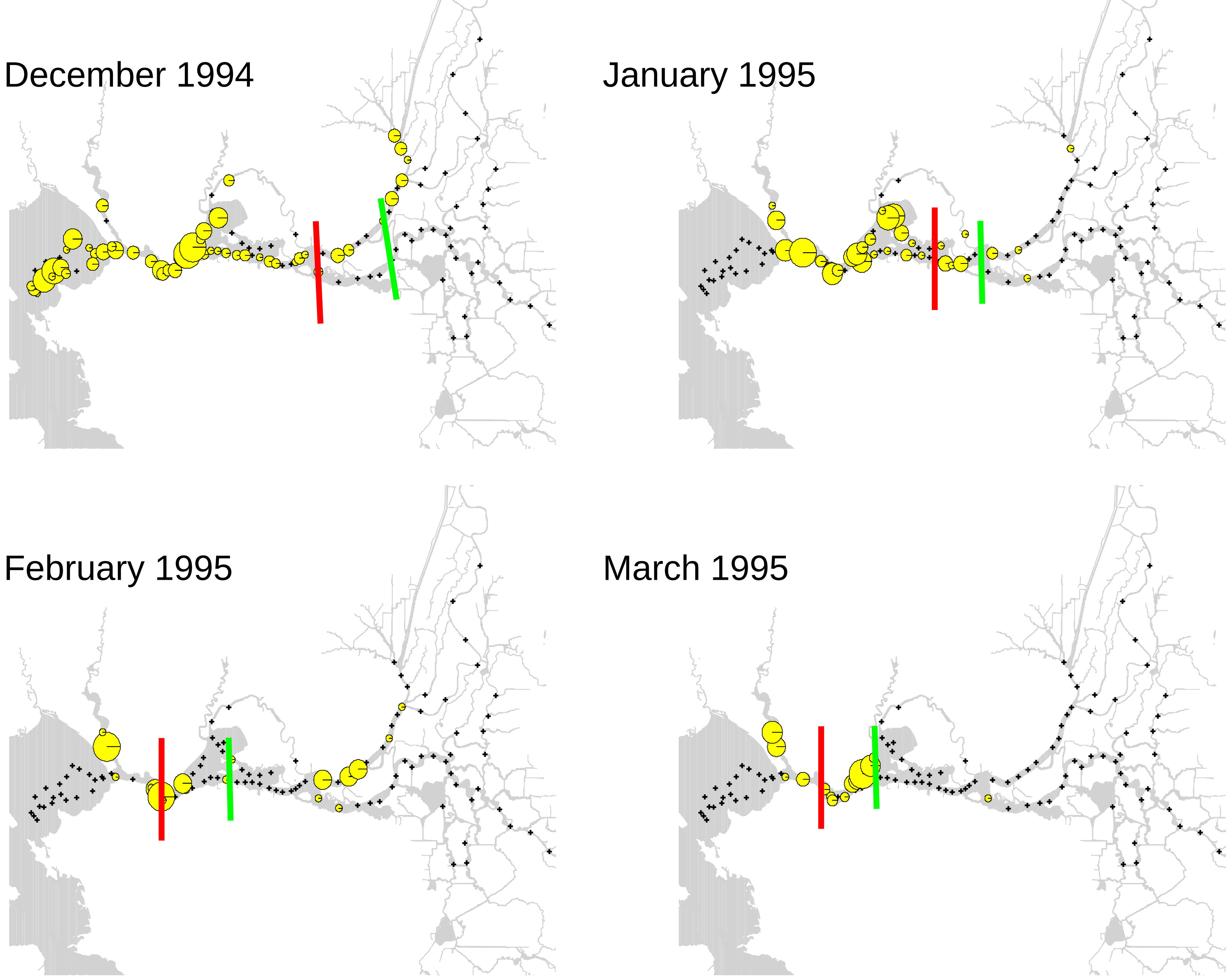
Monthly average X2 (red line) and X0.5 (green line) were plotted by eye referencing the X2 map in Jassby et al. 1995.

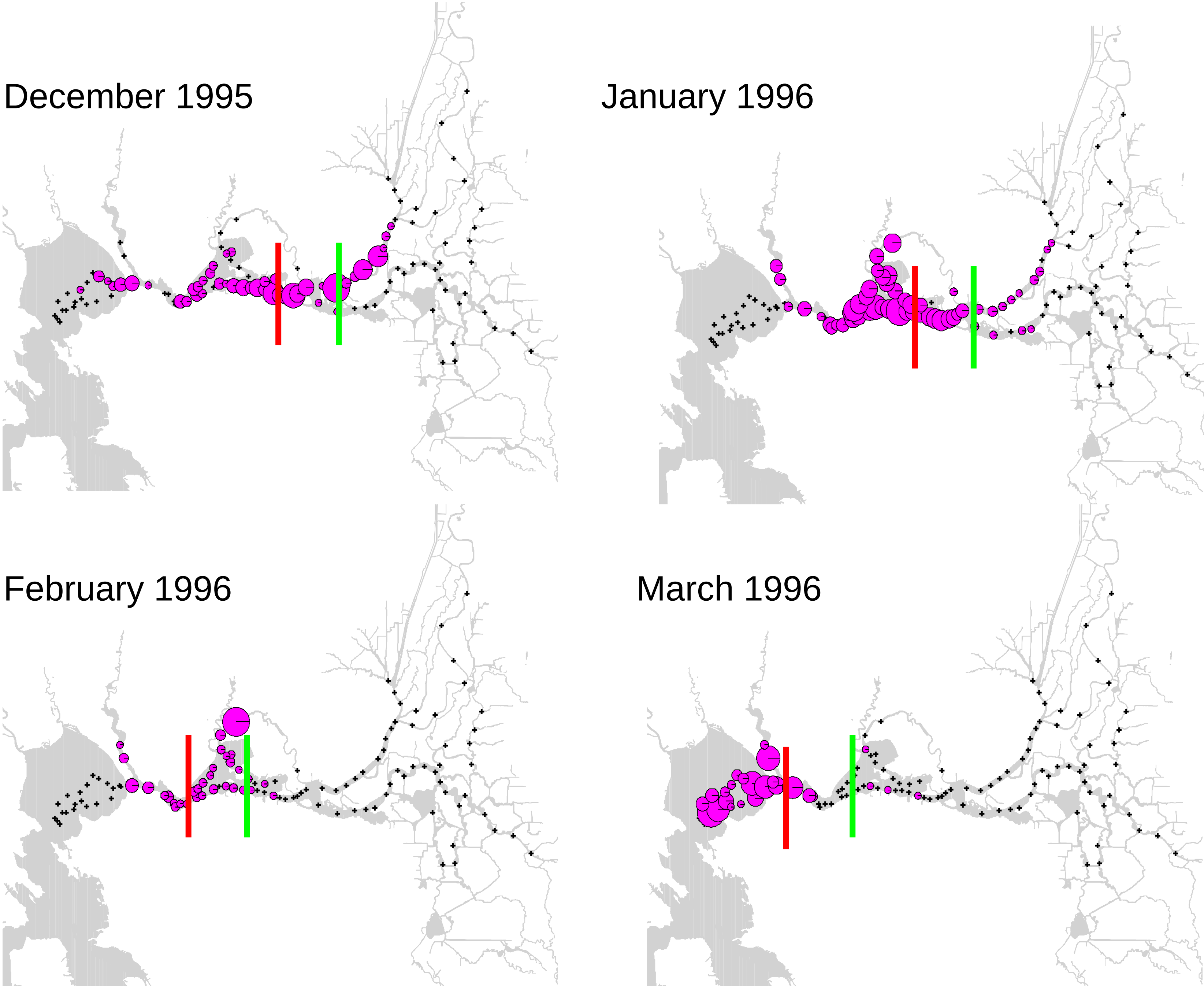

X2
X0.5
December 1990
January 1991
February 1991
March 1991

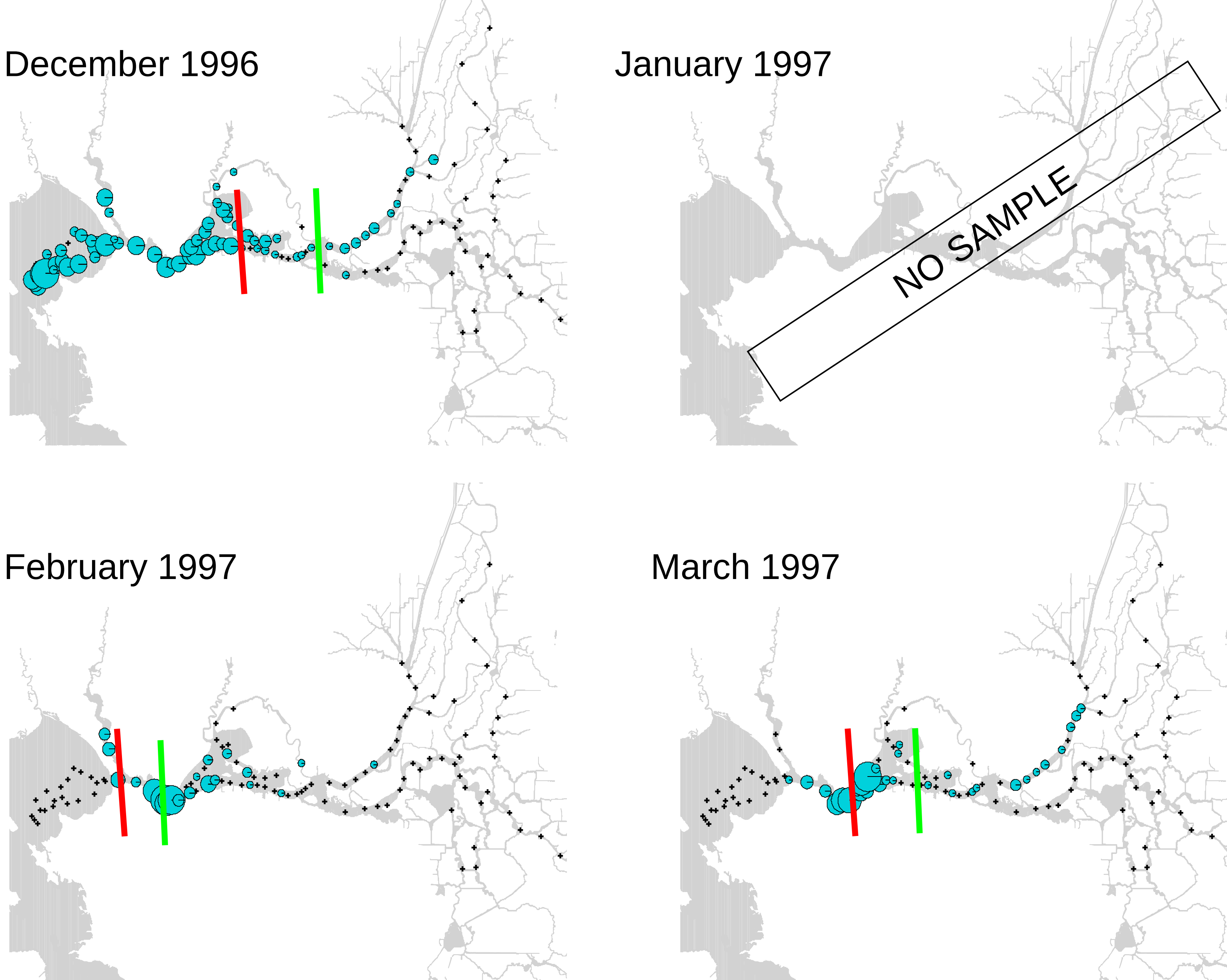

December 1991
January 1992
February 1992
March 1992


December 1992
January 1993
February 1993
March 1993

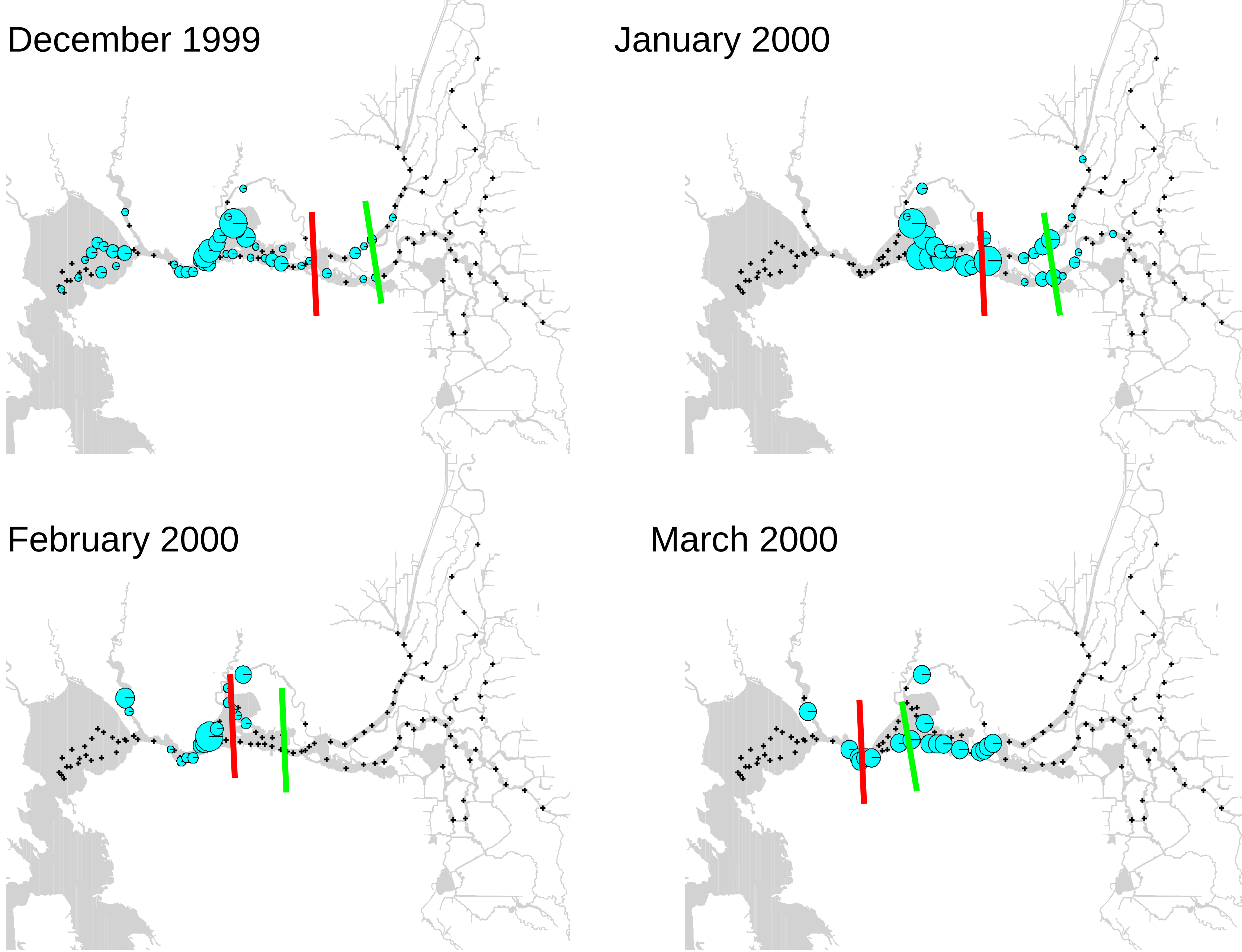

December 1993
January 1994
February 1994
March 1994

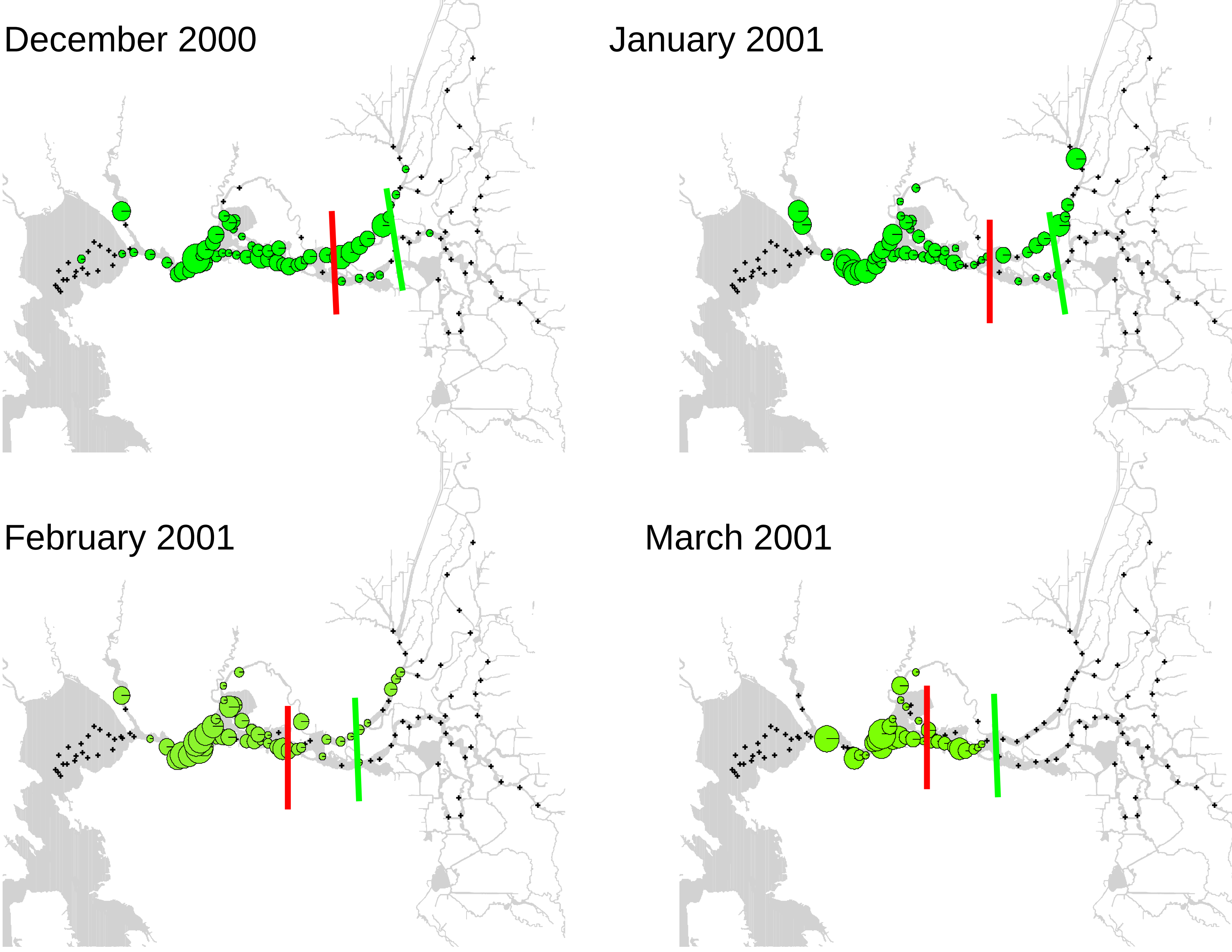

December 1994
January 1995
February 1995
March 1995


December 1995
January 1996
February 1996
March 1996



December 1996
January 1997
NO SAMPLE
February 1997
March 1997


December 1999
January 2000
February 2000
March 2000


December 2000
January 2001
February 2001
March 2001

Appendix B

R. Fujimura. 2009. Longfin smelt juvenile and adult loss estimates by water year, 1993-2008.

State of California
Department of Fish and Game

M e m o r a n d u m

Date: January 8, 2009

To: Marty Gingras
Supervising Biologist
California Department of Fish and Game

From: Robert Fujimura
Senior Biologist
California Department of Fish and Game

Subject: Longfin Smelt Entrainment and Loss Estimates for the State Water Project's and Central Valley Project's South Delta Export Facilities

The enclosed Table A provides annual (by water year) estimates of entrainment, loss, and survival of longfin smelt for the State Water Project's (SWP) and Central Valley Project's (CVP) South Delta export facilities from 1993 through 2008. These estimates were calculated using a simple equation routinely used to calculate juvenile Chinook salmon entrainment loss from reported salvage estimates. Estimator constants for pre-screen loss, screening efficiency, and handle and trucking losses were obtained from experiments using delta smelt and other fish species as proxies for longfin smelt. I have included metadata tables and documentation for further information on the estimation method.

The findings indicate that entrainment of longfin smelt at the SWP is approximately 17 to 21 times the reported salvage and 4 times the reported salvage at the CVP. The cumulative entrainment at the SWP from 1993 through 2008 was 1,376,432 juvenile and 11,054 adult longfin smelt. The cumulative 1993-2008 entrainment was 224,606 juvenile and 1,325 adult longfin smelt at the CVP.

Most of these entrained longfin smelt were lost prior to collection within the fish salvage facilities. Ninety-eight percent of juveniles and 95% of adults were lost at the SWP, and 85% of juveniles and 82% of adults were lost at the CVP. Higher pre-screen loss in Clifton Court Forebay is the primary cause of the higher entrainment losses at the SWP compared to those at the CVP. Relatively few of the entrained longfin smelt are salvaged and returned to the Delta alive.

I would like to acknowledge that these estimates were enhancements of earlier work done by Geir Aasen. Geir also provided the salvage queries for this analysis. I would also thank Jerry Morinaka for his technical advice and for verifying the accuracy of the computations.

Marty Gingras

Attachments

Table A: Annual Salvage and Entrainment Estimates for Longfin Smelt by Life Stage

By Water Year

State Water Project

	ENTRAINMENT		LOSS		TOTAL SALVAGE		SURVIVAL	
YEAR	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS
1993	10,608	17	10,353	16	510	1	255	1
1994	69,964	541	68,282	515	3,364	32	1,682	26
1995	707	1,318	690	1,256	34	78	17	62
1996	1,934	744	1,888	708	93	44	47	35
1997	15,309	0	14,941	0	736	0	368	0
1998	13,187	0	12,870	0	634	0	317	0
1999	13,998	0	13,662	0	673	0	337	0
2000	28,829	304	28,136	290	1,386	18	693	14
2001	45,802	406	44,701	386	2,202	24	1,101	19
2002	1,133,870	1,369	1,106,614	1,304	54,513	81	27,257	65
2003	10,504	3,600	10,252	3,429	505	213	253	170
2004	4,211	2,206	4,110	2,102	202	131	101	104
2005	3,682	101	3,593	97	177	6	89	5
2006	0	0	0	0	0	0	0	0
2007	1,248	0	1,218	0	60	0	30	0
2008	22,578	448	22,036	427	1,086	27	543	21
Total	***1,376,432***	***11,054***	***1,343,345***	***10,530***	***66,175***	***654***	***33,087***	***523***
Percent of Entrainment:			*97.6%*	*95.3%*	*4.8%*	*5.9%*	*2.4%*	*4.7%*

Central Valley Project

	ENTRAINMENT		LOSS		TOTAL SALVAGE		SURVIVAL	
YEAR	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS
1993	517	0	441	0	132	0	77	0
1994	11,819	0	10,070	0	3,015	0	1,749	0
1995	0	0	0	0	0	0	0	0
1996	517	105	441	86	132	24	77	19
1997	1,505	52	1,283	43	384	12	223	9
1998	329	105	281	86	84	24	49	19
1999	469	52	399	43	120	12	69	9
2000	1,929	52	1,643	43	492	12	285	9
2001	17,076	262	14,549	215	4,356	60	2,526	47
2002	168,403	419	143,486	344	42,960	96	24,917	75
2003	18,024	0	15,357	0	4,598	0	2,667	0
2004	2,540	0	2,164	0	648	0	376	0
2005	47	105	40	86	12	24	7	19
2006	0	0	0	0	0	0	0	0
2007	141	0	120	0	36	0	21	0
2008	1,290	174	1,099	143	329	40	191	31
Total	***224,606***	***1,325***	***191,374***	***1,088***	***57,298***	***304***	***33,233***	***237***
Percent of Entrainment:			*85.2%*	*82.1%*	*25.5%*	*22.9%*	*14.8%*	*17.9%*

***Summary*:**

Entrainment at the SWP is approximately 17 to 21 times reported salvage and 4 times the reported salvage for the CVP.
Pre-screen loss in Clifton Court Forebay is the primary cause of higher entrainment losses at the SWP compared to those at the CVP.
Few entrained longfin smelt survive because most are lost before collection within the fish salvage facilities.
Mark-recapture experiments to determine PSL and SE for longfin smelt are needed to validate our entrainment estimates.

Attachment 1: Skinner Estimates

Table 1 Summary of Pre-Screen Loss Studies at Clifton Court Forebay

Prepared by Robert Fujimura

Species	Date	Fork Length	Mean Water Temp	RG Flow	Pre-Screen Loss	TB Survival	Citation	Comments
Chinook salmon	October-76	114	69	252	97		Gingras 1997	
Chinook salmon	October-78	87	60	4,476	88	85	Gingras 1997	
Chinook salmon	April-84	79	61	6,000	63	90	Gingras 1997	
Chinook salmon	April-85	44	62	6,825	75	52	Gingras 1997	
Chinook salmon	May-92	77	75	306	99	29	Gingras 1997	
Chinook salmon	December-92	121	47	3,390	78	75	Gingras 1997	
Chinook salmon	April-93	66	63	3,390	95	25	Gingras 1997	
Chinook salmon	November-93	117	53	6,780	99	39	Gingras 1997	
Mean		88.13	61	3,927	86.8	56.4		
Std dev		27.33	9	2,628	13.4	26.9		
N		8	8	8	8	7		
CV		31%	14%	67%	15%	48%		
Striped bass	July-84	52		4,000	94	37	Gingras 1997	
Striped bass	August-86	55		7,622	70	29	Gingras 1997	
Mean		53.50		5,811	82.0	33.0		
Std dev		2.12		2,561	17.0	5.7		
N		2		2	2	2		
CV		4%		44%	21%	17%		

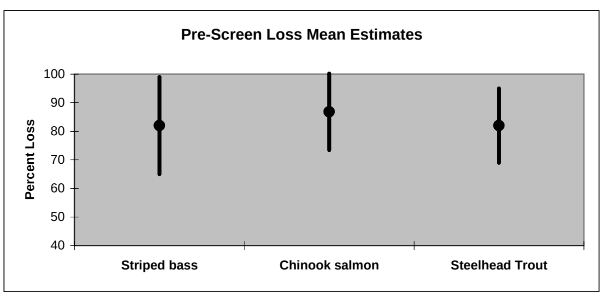
Species	Date	Fork Length*	Mean Water Temp**	BPP Flow	Pre-Screen Loss	TR Recovery	Citation	Comments
Delta smelt	Apr-07	65	60	6,400		34	Morinaka 2008a	Age 1; PIT pilot study; based on detection information
Delta smelt	Apr-07	83	60	6,400		40	Morinaka 2008a	Age 2; PIT pilot study; based on detection information
Mean		74.00	60.0	6,400		37.0		
Std dev		12.73		0		4.2		
N		2		2		2		
CV		17%		0%		11%		

*unpublished data, Jerry Morinaka 2008, personal communication

**from Clark 2008

Species	Date	Fork Length	Mean Water Temp	BPP Flow	Pre-Screen Loss	TR Recovery	Citation	Comments
Steelhead trout	Jan-07				84		Clark 2008	Monthly mean
Steelhead trout	Feb-07				83		Clark 2008	Monthly mean
Steelhead trout	Mar-07				86		Clark 2008	Monthly mean
Steelhead trout	Apr-07				76		Clark 2008	Monthly mean
Mean					82.3			
Std dev					4.3			
N					4			
CV					5%			
Steelhead trout	Overall	217			82*	82**	Clark 2008	Entire study; PSL and TR estimates includes emigration correction
					* SD = 13	** SD = 24		
					*N = 58	**N=47		

	Striped bass	Chinook salmon	Steelhead Trout	
SD+1	99	100	95	
SD-1	65	73	69	Grand Mean =
Mean	82	87	82	84
SD	17	13	13	



Species	Date	Fork Length	W Temp Release**	BPP Flow***	Percent Recovery	TR Recovery	Citation	Comments
Delta smelt	Jun-08		68	2,260		30	Castillo 2008	Juvenile DS M-R releases
Delta smelt	Jun-08		68	375-2,260	8*		Castillo 2008	*Fish release on west side of CCF
Delta smelt	Jun-08		70	3,390-5,650	2*		Castillo 2008	*Fish release on north central portion of CCF

** Jerry Morinaka 2008, personal communication

*** Gonzalo Castillo 2008, personal communication

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Poster Presentation at the 2008 Interagency Ecological Program. Asilomar, CA.

Attachment 2: Tracy Estimates

TFCF Pre-Screen Loss = 15%

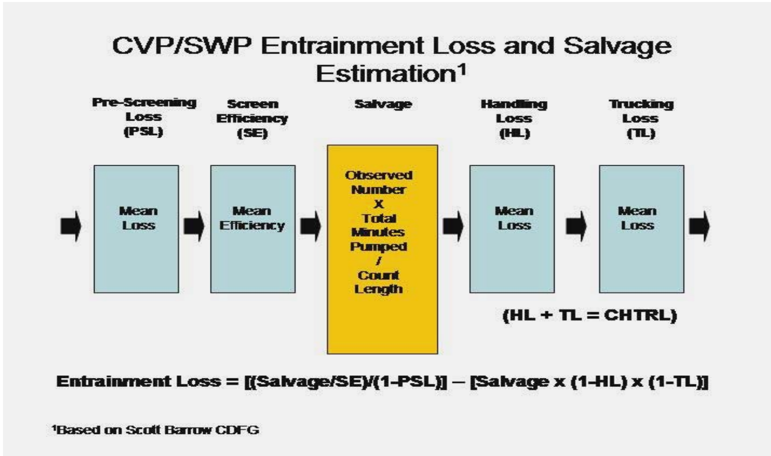
Species	Date	Fork Length	SD	BPP Flow	TR SD	TR Recovery	Citation	Comments
Delta smelt	Nov-03	67.3	(10.3)		(7.0)	14.2	Bowen 2008	PACV = 3.23 (0.17) fps
Delta smelt	Nov-07	62.7	(6.1)		(7.9)	38.9	Bowen 2008	PACV = 2.48 (0.20) fps
Mean		65.0				26.6		
Std dev		3.3				17.5		
N		2				2		
CV		5%				66%		

Personal Communications

Mark Bowen. US Bureau of Reclamination. Email communication. December 11, 2008.

Attachment 3:
Longfin Smelt Loss Estimate Assumptions/Definitions
Prepared by Robert Fujimura
December 18, 2008

1. Entrainment losses are functions of:
   - Salvage estimates
   - Size or life stage
   - PSL rates
   - Primary channel velocity
   - CHTR losses
2. Entrainment is defined as the fish entering the intake channel of the CVP or the radial gates of Clifton Court Forebay (SWP).
3. Pre-screen loss is defined as the fish lost within the intake channel and/or Clifton Court Forebay.
4. Pre-screen loss for the TFCF is set as 15% (Exhibit 1 1987)
5. Emigration out of the intake facilities is considered negligible for LFS.
6. The pre-screen loss rate for LFS in CCF is similar to other fish species.
7. The screening efficiency for LFS is similar to the screening efficiency for DS. Although there is no data on LFS performance, this assumption is probably not true since adult LFS may be more capable swimmers than DS and juveniles LFS are salvaged when the FF operate at higher channel velocities. Using DS SEs c
8. Screening efficiency includes within facility losses such as entraining through screens and louvers, emigration away from the fish louvers, and fish predation. Screening efficiency is emprically defined as the percent recovery of marked fish released from the facility's trash racks.
9. No estimates are available for post-release predation at this time for this species (or for any other species).
10. Holding tank losses are considered negligible for this analysis.
11. The CHTR loss rates of LFS are similar to those for DS. Using DS CHTR loss rates may overestimate juvenile LFS CHTR losses since juvenile DS CHTR losses were influenced by higher temperatures.
12. No empirical information is available to adjust SE values to varying primary channel velocities.
13. For life stage classification purposes in the absence of length data, LFS salvaged in December, January, and February were considered adults or Age 1. LFS salvaged in the other months were considered juveniles.



CCF PSL = 0.84
SWP SE (Adults) = 0.37
SWP SE (Juveniles) = 0.30
SWP CHTRL (Adults) = (1-0.78*) = 0.22
SWP CHTRL (Juveniles) = (1-0.58*) = 0.42

TFCF PSL = 0.15
CVP SE (Adults) = 0.27
CVP SE (Juveniles) = SWP SE (Juveniles) = 0.30
CVP CHTRL (Adults) = SWP CHTRL (Adults) = 0.22
CVP CHTRL (Juveniles) = SWP CHTRL (Juveniles) = 0.42

*Based on mean survival of delta smelt after 48 hours; Morinaka 2008b

Entrainment Estimate = (Salvage/SE)/(1-PSL)
Entrainment Loss = [(Salvage/SE)/(1-PSL)] - [Salvage x (1-CHTRL)]

SWP Entrainment Estimate (Adults) = (Salvage/0.37)/(1-0.84) = Salvage x 16.9
SWP Entrainment Loss (Adults) = (Salvage x 16.9) - [Salvage x (1-0.22)] = (Salvage x 16.9) - (Salvage x 0.78) = Salvage x 16.1

SWP Entrainment Estimate (Juveniles) = (Salvage/0.30)/(1-0.84) = Salvage x 20.8
SWP Entrainment Loss (Juveniles) = (Salvage x 20.8) - [Salvage x (1-0.42)] = (Salvage x 20.8) - (Salvage x 0.58) = Salvage x 20.2

CVP Entrainment Estimate (Adults) = (Salvage/0.27)/(1-0.15) = Salvage x 4.36
CVP Entrainment Loss (Adults) = (Salvage x 4.36) - [Salvage x (1-0.22)] = (Salvage x 4.36) - (Salvage x 0.78) = Salvage x 3.58

CVP Entrainment Estimate (Juveniles) = (Salvage/0.30)/(1-0.15) = Salvage x 3.92
CVP Entrainment Loss (Juveniles) = (Salvage x 3.92) - [Salvage x (1-0.42)] = (Salvage x 3.92) - (Salvage x 0.58) = Salvage x 3.34

Attachment 4: Entrainment Calculations

Calculation Checks

	PSL	SE	CHTRL	EF	ELF
SWP Entrainment Estimates(Adults)	0.84	0.37	0.22	16.9	16.1
SWP Entrainment Estimates (Juveniles)	0.84	0.30	0.42	20.8	20.3
CVP Entrainment Estimates (Adults)	0.15	0.27	0.22	4.36	3.58
CVP Entrainment Estimates (Juveniles)	0.15	0.30	0.42	3.92	3.34

Cited Reference

Morinaka, J. Acute Mortality and Injury of Delta Smelt Associated with Collection, Handling, Transport, and Release at the State Water Project Fish Salvage Facility September 2008. Draft Report. California Department of Fish and Game. Stockton, CA

Abbrivations

PSL	Pre-screen loss
SE	Screening efficiency (= whole facility salvage efficiency)
CHTR	Collection, handling, transport, and release
CHTRL	Collection, handling, transport, and release loss
EF	Entrainment factor
ELF	Entrainment loss factor
CCF	Clifton Court Forebay
TFCF	Tracy Fish Collection Facility
SWP	State Water Project
CVP	Central Valley Project
BPP	Banks Pumping Plant
TR	Trash rack
SD	Standard deviation
PACV	Primary approach channel velocity
LFS	Longfin smelt
DS	Delta smelt
FL	Fork length in mm
RG	Radial gates

Attachment 5: Salvage Entrainment Worksheet

Longfin Smelt Salvage/Entrainment Estimates 1993-2008 - Age Classification

Year	Month	Facility	Organism Code	Total Salvage	% Ratio Juvenile	% Ratio Adults	Juvenile Salvage (20-79 mm FL)	Adult salvage (≥80mm)	Est Juv Salvage	Est Adult Salvage
1992	12	1	25	1						1
1993	1	1	25	12	100		12			12
1993	4	1	25	8					8	
1993	5	1	25	206	100		206		206	
1993	6	1	25	12					12	
1993	7	1	25	240					240	
1993	8	1	25	32					32	
1993	12	1	25	6						6
1994	1	1	25	8						8
1994	2	1	25	18						18
1994	4	1	25	340	100		340		340	
1994	5	1	25	2,903	100		2,903		2,903	
1994	6	1	25	121	100		121		121	
1994	12	1	25	10		100		10		10
1995	1	1	25	56		100		56		56
1995	2	1	25	12		100		12		12
1995	4	1	25	4	100		4		4	
1995	5	1	25	12	100		12		12	
1995	6	1	25	18					18	
1996	1	1	25	56	50	50	28	28	28	28
1996	2	1	25	16		100		16		16
1996	4	1	25	1	100		1		1	
1996	5	1	25	24	100		24		24	
1996	7	1	25	32					32	
1996	8	1	25	8					8	
1997	4	1	25	4					4	
1997	5	1	25	704	100		704		704	
1997	6	1	25	16					16	
1997	7	1	25	12					12	
1997	12	1	25	6	100		6			6
1998	1	1	25	12	100		12			12
1998	4	1	25	616	100		616		616	
1999	3	1	25	14	100		14		14	
1999	4	1	25	338	100		338		338	
1999	5	1	25	171	100		171		171	
1999	6	1	25	48	100		48		48	
1999	7	1	25	54	100		54		54	
1999	8	1	25	48	100		48		48	
2000	1	1	25	39	100		39		39	
2000	2	1	25	18						18
2000	3	1	25	60	100		60		60	
2000	4	1	25	960	100		960		960	
2000	5	1	25	264	100		264		264	
2000	6	1	25	33	100		33		33	
2000	7	1	25	24	100		24		24	
2000	8	1	25	6					6	
2000	10	1	25	33	100		33		33	
2000	11	1	25	18					18	
2001	2	1	25	24		100		24		24
2001	3	1	25	15					15	
2001	4	1	25	219	100		219		219	
2001	5	1	25	1,917	100		1,917		1,917	
2002	1	1	25	81		100		81		81
2002	4	1	25	11,022	100		11,022		11,022	
2002	5	1	25	41,949	100		41,949		41,949	
2002	6	1	25	1,536	100		1,536		1,536	
2002	7	1	25	6	100		6		6	
2002	12	1	25	12						12
2003	1	1	25	191		100		191		191
2003	2	1	25	10						10
2003	4	1	25	81	100		81		81	
2003	5	1	25	370	100		370		370	
2003	6	1	25	54	100		54		54	
2004	1	1	25	204	36	64	73	130.56	73	131
2004	2	1	25	24	100		24		24	
2004	5	1	25	48	100		48		48	
2004	6	1	25	33					33	
2004	9	1	25	24					24	
2005	1	1	25	6		100		6		6

2005	5	1	25	33	100		33		33	
2005	6	1	25	120	100		120		120	
2005	7	1	25	24					24	
2007	5	1	25	48	100		48		48	
2007	6	1	25	9	100		9		9	
2007	8	1	25	3					3	
2008	1	1	25	22	25	75	6	16.5	6	17
2008	2	1	25	10		100		10		10
2008	3	1	25	8	100		8		8	
2008	4	1	25	146	100		146		146	
2008	5	1	25	924	100		924		924	
2008	6	1	25	2	100		2		2	
1993	5	2	25	132	100		132		132	
1994	3	2	25	36	100		36		36	
1994	4	2	25	615	100		615		615	
1994	5	2	25	2,268	100		2,268		2,268	
1994	6	2	25	96	100		96		96	
1996	1	2	25	24						24
1996	2	2	25	12	100		12		12	
1996	4	2	25	12					12	
1996	5	2	25	72					72	
1996	6	2	25	36					36	
1997	2	2	25	12						12
1997	4	2	25	96	100		96		96	
1997	5	2	25	288	100		288		288	
1997	12	2	25	48	100		48		48	
1998	1	2	25	48	75	25	36	12	36	12
1998	2	2	25	12						12
1999	2	2	25	12						12
1999	4	2	25	43					43	
1999	5	2	25	65					65	
1999	8	2	25	12	100		12		12	
2000	1	2	25	12		100		12		12
2000	4	2	25	396	100		396		396	
2000	5	2	25	96	100		96		96	
2000	12	2	25	24		100		24		24
2001	1	2	25	36		100		36		36
2001	2	2	25	24	100		24		24	
2001	3	2	25	96	100		96		96	
2001	4	2	25	2,268	100		2,268		2,268	
2001	5	2	25	1,968	100		1,968		1,968	
2001	12	2	25	12						12
2002	1	2	25	84		100		84		84
2002	3	2	25	852	100		852		852	
2002	4	2	25	26,268	100		26,268		26,268	
2002	5	2	25	15,708	100		15,708		15,708	
2002	6	2	25	132	100		132		132	
2002	12	2	25	36	100		36		36	
2003	1	2	25	48	100		48		48	
2003	4	2	25	1,608	100		1,608		1,608	
2003	5	2	25	2,894	100		2,894		2,894	
2003	6	2	25	12	100		12		12	
2004	1	2	25	24	100		24		24	
2004	3	2	25	72	100		72		72	
2004	4	2	25	204	100		204		204	
2004	5	2	25	348	100		348		348	
2005	1	2	25	24		100		24		24
2005	4	2	25	12					12	
2007	1	2	25	12					12	
2007	2	2	25	12					12	
2007	5	2	25	12	100		12		12	
2007	12	2	25	12	75	25	9	3	9	3
2008	1	2	25	4						4
2008	2	2	25	20		100		20		20
2008	3	2	25	15	75	25	11	3.75	11	4
2008	4	2	25	184	100		184		184	
2008	5	2	25	134	100		134		134	

Attachment 6: Salvage Query Metadata

Metadata for Salvage Queries and Life Stage Classification

Prepared by G. Aasen unless noted otherwise

Object: Compute juvenile and adult monthly salvage of longfin smelt between December 1992 to 2008

Step1:

Generate 1993-2008 monthly length salvage files from Access by creating 2 files for juveniles (20-79 mm FL) and adults (over 80 mm FL)

C:\Data\SALVAGEACCESS\XP2000\ salvagequery_xp.mdb\1993-2008 LFS <=79 mm monthly length GAA 12112008.mdb and 1993-2008 LFS >=80 mm monthly length GAA 12112008.mdb

Column Headings:
Samplemethod: "1" for SWP and "2" for CVP

Organismcode: species code

SumOfLengthFrequency: sum of number of fish measured

Year: year

Month: month of year

Step 2:
Combine the juvenile and adult Access files into a Excel file:
C:\Data\salvage request\data request bob fujimura LFS length\1992-2008 LFS juvenile and adult length ratios and salvage GAA12122008.mdb

Column Headings:
Year: year

month: month of year

Facility: 1 for SWP and 2 for CVP

Organismcode: species code

Total Salvage: combined juvenile and adult salvage

% ratio juvenile: % ratio of juvenile salvage

% ratio adults: % ratio of adult salvage

Juvenile Salvage (20-79 mm FL): juvenile salvage between 20 mm and 79 mm

Adult salvage (≥80mm): adult salvage over 80 mm

Step 3:
Add 1993-2008 salvage from:

C:\Data\SALVAGEACCESS\XP2000\ salvagequery_xp.mdb\1993-2008 LFS monthly salvage GAA 12122008.mdb

Column Headings:
SampleMethod: 1 for SWP and 2 for CVP

Organismcode: species code

SumOfSalvage: monthly salvage

Year: year

Month: month of year

Step 4:
Add 1992 December salvage from original data sheets since the Access data base only contains data after 1993

Step 5:
Determine % ratio of adult and juvenile salvage by dividing adult or juvenile number of lengths by total number of lengths from juvenile and adult files in step 1

Step 6:
Calculate juvenile and adult salvage based upon the monthly juvenile and adult %ratios by the formula: salvage X % ratio

Note: not all months had length measurements. Consequently, it was not possible to calculate adult and juvenile salvage for all months reflected by blank boxes

Step 7: Copy the longfin smelt juvenile and adult monthly salvage into a microsoft word file (Table 1):

C:\Data\salvage request\data request bob fujimura LFS length\1992-2008 LFS juvenile and adult salvage V2 GAA12122008.mdb

Step 8: Classify salvage months without length measurement into life stages by season and merge previously classified entries (rwf)

Step 9: Create monthly and annual life stage table (Table 2) (rwf)

Step 10: Create annual salvage and entrainment table by life stage (Table A) (rwf)

Attachment 7: Interim Table 1

Table 1 Longfin smelt juvenile (20-79 mm FL) and adult (≥80 mm FL) salvage from December 1992 to 2008

Prepared by G. Aasen

Year	Month	Facility SWP=1 CVP=2	Salvage	% Ratio juvenile (20-79 mm FL)	Juvenile salvage (20-79 mm FL)	% Ratio adults (≥80mm)	Adult salvage (≥80mm)
1992	12	1	1				
1993	1	1	12	100	12		
1993	4	1	8				
1993	5	1	206	100	206		
1993	6	1	12				
1993	7	1	240				
1993	8	1	32				
1993	12	1	6				
1994	1	1	8				
1994	2	1	18				
1994	4	1	339.67	100	339.67		
1994	5	1	2903	100	2903		
1994	6	1	121	100	121		
1994	12	1	10			100	10
1995	1	1	56			100	56
1995	2	1	12			100	12
1995	4	1	4	100	4		
1995	5	1	12	100	12		
1995	6	1	18				
1996	1	1	56	50	28	50	28
1996	2	1	16			100	16
1996	4	1	1	100	1		
1996	5	1	24	100	24		
1996	7	1	32				
1996	8	1	8				
1997	4	1	4				
1997	5	1	704	100	704		
1997	6	1	16				
1997	7	1	12				
1997	12	1	6	100	6		
1998	1	1	12	100	12		
1998	4	1	616	100	616		
1999	3	1	14	100	14		
1999	4	1	338	100	338		
1999	5	1	171	100	171		
1999	6	1	48	100	48		
1999	7	1	54	100	54		
1999	8	1	48	100	48		
2000	1	1	39	100	39		
2000	2	1	18				
2000	3	1	60	100	60		
2000	4	1	960	100	960		
2000	5	1	264	100	264		
2000	6	1	33	100	33		
2000	7	1	24	100	24		
2000	8	1	6				
2000	10	1	33	100	33		
2000	11	1	18				
2001	2	1	24			100	24
2001	3	1	15				
2001	4	1	219	100	219		
2001	5	1	1917	100	1917		
2002	1	1	81			100	81
2002	4	1	11022	100	11022		
2002	5	1	41949	100	41949		
2002	6	1	1536	100	1536		
2002	7	1	6	100	6		
2002	12	1	12				
2003	1	1	191			100	191
2003	2	1	10				
2003	4	1	81	100	81		
2003	5	1	370	100	370		
2003	6	1	54	100	54		
2004	1	1	204	36	73.44	64	130.56
2004	2	1	24	100	24		
2004	5	1	48	100	48		
2004	6	1	33				
2004	9	1	24				
2005	1	1	6			100	6
2005	5	1	33	100	33		
2005	6	1	120	100	120		
2005	7	1	24				
2007	5	1	48	100	48		

2007	6	1	9	100	9		
2007	8	1	3				
2008	1	1	22	25	5.5	75	16.5
2008	2	1	10			100	10
2008	3	1	8	100	8		
2008	4	1	146	100	146		
2008	5	1	924	100	924		
2008	6	1	2	100	2		
1993	5	2	132	100	132		
1994	3	2	36	100	36		
1994	4	2	615	100	615		
1994	5	2	2268	100	2268		
1994	6	2	96	100	96		
1996	1	2	24				
1996	2	2	12	100	12		
1996	4	2	12				
1996	5	2	72				
1996	6	2	36				
1997	2	2	12				
1997	4	2	96	100	96		
1997	5	2	288	100	288		
1997	12	2	48	100	48		
1998	1	2	48	75	36	25	12
1998	2	2	12				
1999	2	2	12				
1999	4	2	43.07				
1999	5	2	64.5				
1999	8	2	12	100	12		
2000	1	2	12			100	12
2000	4	2	396	100	396		
2000	5	2	96	100	96		
2000	12	2	24			100	24
2001	1	2	36			100	36
2001	2	2	24	100	24		
2001	3	2	96	100	96		
2001	4	2	2268	100	2268		
2001	5	2	1968	100	1968		
2001	12	2	12				
2002	1	2	84			100	84
2002	3	2	852	100	852		
2002	4	2	26268	100	26268		
2002	5	2	15708	100	15708		
2002	6	2	132	100	132		
2002	12	2	36	100	36		
2003	1	2	48	100	48		
2003	4	2	1608	100	1608		
2003	5	2	2894	100	2894		
2003	6	2	12	100	12		
2004	1	2	24	100	24		
2004	3	2	72	100	72		
2004	4	2	204	100	204		
2004	5	2	348	100	348		
2005	1	2	24			100	24
2005	4	2	12				
2007	1	2	12				
2007	2	2	12				
2007	5	2	12	100	12		
2007	12	2	12			100	12
2008	1	2	4				
2008	2	2	20			100	20
2008	3	2	15	75	11.25	25	3.75
2008	4	2	184	100	184		
2008	5	2	134	100	134		

Attachment 8: Interim Table 2

Longfin Smelt Salvage by Life Stage (as defined by size and season)

Longfin Smelt Salvage Estimates 1993-2008 - Age Classification

Year	Month	Facility	Total Salvage	Est Juv Salvage	Est Adult Salvage	Yr Juv Total	Yr Adult Total
1992	12	1	1		1		
1993	1	1	12	12			
1993	4	1	8	8			
1993	5	1	206	206			
1993	6	1	12	12			
1993	7	1	240	240			
1993	8	1	32	32		510	1
1993	12	1	6		6		
1994	1	1	8		8		
1994	2	1	18		18		
1994	4	1	340	340			
1994	5	1	2,903	2,903			
1994	6	1	121	121		3,364	32
1994	12	1	10		10		
1995	1	1	56		56		
1995	2	1	12		12		
1995	4	1	4	4			
1995	5	1	12	12			
1995	6	1	18	18		34	78
1996	1	1	56	28	28		
1996	2	1	16		16		
1996	4	1	1	1			
1996	5	1	24	24			
1996	7	1	32	32			
1996	8	1	8	8		93	44
1997	4	1	4	4			
1997	5	1	704	704			
1997	6	1	16	16			
1997	7	1	12	12		736	0
1997	12	1	6	6			
1998	1	1	12	12			
1998	4	1	616	616		634	0
1999	3	1	14	14			
1999	4	1	338	338			
1999	5	1	171	171			
1999	6	1	48	48			
1999	7	1	54	54			
1999	8	1	48	48		673	0
2000	1	1	39	39			
2000	2	1	18		18		
2000	3	1	60	60			
2000	4	1	960	960			
2000	5	1	264	264			
2000	6	1	33	33			
2000	7	1	24	24			

2000	8	1	6	6		1,386	18
2000	10	1	33	33			
2000	11	1	18	18			
2001	2	1	24		24		
2001	3	1	15	15			
2001	4	1	219	219			
2001	5	1	1,917	1,917		2,202	24
2002	1	1	81		81		
2002	4	1	11,022	11,022			
2002	5	1	41,949	41,949			
2002	6	1	1,536	1,536			
2002	7	1	6	6		54,513	81
2002	12	1	12		12		
2003	1	1	191		191		
2003	2	1	10		10		
2003	4	1	81	81			
2003	5	1	370	370			
2003	6	1	54	54		505	213
2004	1	1	204	73	131		
2004	2	1	24	24			
2004	5	1	48	48			
2004	6	1	33	33			
2004	9	1	24	24		202	131
2005	1	1	6		6		
2005	5	1	33	33			
2005	6	1	120	120			
2005	7	1	24	24		177	6
2007	5	1	48	48			
2007	6	1	9	9			
2007	8	1	3	3		60	0
2008	1	1	22	6	17		
2008	2	1	10		10		
2008	3	1	8	8			
2008	4	1	146	146			
2008	5	1	924	924			
2008	6	1	2	2		1,086	27
1993	5	2	132	132		132	0
1994	3	2	36	36			
1994	4	2	615	615			
1994	5	2	2,268	2,268			
1994	6	2	96	96		3,015	0
1996	1	2	24		24		
1996	2	2	12	12			
1996	4	2	12	12			
1996	5	2	72	72			
1996	6	2	36	36		132	24
1997	2	2	12		12		
1997	4	2	96	96			
1997	5	2	288	288		384	12
1997	12	2	48	48			
1998	1	2	48	36	12		

1998	2	2	12		12	84	24	
1999	2	2	12		12			
1999	4	2	43	43				
1999	5	2	65	65				
1999	8	2	12	12		120	12	
2000	1	2	12		12			
2000	4	2	396	396				
2000	5	2	96	96		492	12	
2000	12	2	24		24			
2001	1	2	36		36			
2001	2	2	24	24				
2001	3	2	96	96				
2001	4	2	2,268	2,268				
2001	5	2	1,968	1,968		4,356	60	
2001	12	2	12		12			
2002	1	2	84		84			
2002	3	2	852	852				
2002	4	2	26,268	26,268				
2002	5	2	15,708	15,708				
2002	6	2	132	132		42,960	96	
2002	12	2	36	36				
2003	1	2	48	48				
2003	4	2	1,608	1,608				
2003	5	2	2,894	2,894				
2003	6	2	12	12		4,598	0	
2004	1	2	24	24				
2004	3	2	72	72				
2004	4	2	204	204				
2004	5	2	348	348		648	0	
2005	1	2	24		24			
2005	4	2	12	12		12	24	
2007	1	2	12	12				
2007	2	2	12	12				
2007	5	2	12	12		36	0	
2007	12	2	12		12			
2008	1	2	4		4			
2008	2	2	20		20			
2008	3	2	15	11	4			
2008	4	2	184	184				
2008	5	2	134	134		329	40	
			124,430	*123,472*	*958*	*123,472*	*958*	*124,430*
					124,430			

Attachment 9:

Number of Fish Reported in SWP Entrainment Experiments

Prepared by RW Fujimura December 29, 2009 for Randy Baxter

See Table 1 from Gingras 1997 for fish numbers reported in juvenile Chinook salmon experiments.

Table 2. Number of fish used in recent SWP entrainment loss experiments

Species	Date	TR % Recovery	Citation	Number of Fish	Comments
Delta smelt	Apr-07	34	Morinaka 2008a	36	PIT tagged fish
Delta smelt	Apr-07	40	Morinaka 2008a	42	PIT tagged fish

Species	Date	Pre-Screen Loss %	Citation	Number of Fish
Steelhead trou	Jan-Apr-07	82	Clark 2008	130 acoustical; 922 PIT tagged

Species	Date	Percent Recovery	TR % Recovery	Citation	Number of Fish	Comments
Delta smelt	Jun-08		30	Castillo 2008	200	Juvenile DS M-R releases
Delta smelt	Jun-08	8*		Castillo 2008	500	*Fish release on west side of CCF
Delta smelt	Jun-08	2*		Castillo 2008	2,647	*Fish release on north central portion of CCF

Species	Date	Life Stage	CHTR % Survival	Citation	Number of Fish
Delta smelt	2006	Adults	78	Morinaka 2008b	275
Delta smelt	2006	Juveniles	58	Morinaka 2008b	254

I was not provided with the number of fish in the 2 Tracy Fish Collection Facility (CVP) releases but I recall that they were in the low hundreds.