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

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FISH AND WILDLIFE SERVICE

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September 14, 2012

Technical Staff Comments to the State Water Resources Control Board re: the Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan, Public Workshop 2, Bay Delta Fishery Resources (Longfin Smelt)

The US Fish and Wildlife Service (Service) recently evaluated the longfin smelt for listing under the Endangered Species Act. The following excerpts were taken from the twelve-month finding determination published in the Federal Register on April 2, 2012. In this finding, the Service concluded that the San Francisco Bay Delta population of longfin smelt is warranted for protection under the Endangered Species Act, but precluded from immediate listing by other listing actions .

Species Information

Species Description and Taxonomy

Longfin smelt measure 9–11 centimeters (cm) (3.5–4.3 inches (in)) standard length, although third-year females may grow up to 15 cm (5.9 in). The longfin smelt belongs to the true smelt family Osmeridae and is one of three species in the *Spirinchus* genus; the night smelt (*Spirinchus starksi*) also occurs in California, and the shishamo (*Spirinchus lanceolatus*) occurs in northern Japan (McAllister 1963, pp. 10, 15). Because of its distinctive physical characteristics, the Bay-Delta population of longfin smelt was once described as a species separate from more northern populations (Moyle 2002, p. 235). Delta smelt and longfin smelt hybrids have been observed in the Bay-Delta estuary, although these offspring are not thought to be fertile because delta smelt and longfin smelt are not closely related taxonomically or genetically (California Department of Fish and Game (CDFG) 2001, p. 473).

Biology

Longfin smelt are considered pelagic (living in open waters away from the shore) and anadromous (moving from salt water to freshwater to spawn) (Moyle 2002, p. 236), although anadromy in longfin smelt is poorly understood, and certain populations are not anadromous, and complete their entire life cycle in freshwater lakes and streams. Within the Bay-Delta, the term pelagic refers to organisms that occur in open water away from the bottom of the water column and away from the shore. Juvenile and adult longfin smelt have been found throughout the year in salinities ranging from pure freshwater to pure seawater, although once past the juvenile stage, they are typically collected in waters with salinities ranging from 14 to 28 parts per thousand (ppt) (Baxter 1999, pp. 189–192). Longfin smelt are thought to be restricted by high water temperatures, generally greater than 22 degrees Celsius (°C) (71 degrees Fahrenheit (°F)) (Baxter *et. al.* 2010, p. 68), and will move down the estuary (seaward) and into deeper water during the summer months, when water temperatures in the Bay-Delta are higher. Within the Bay-Delta, adult longfin smelt occupy water at temperatures from 16 to 20 °C (61 to 68 °F), with spawning occurring in water with temperatures from 5.6 to 14.5 °C (41 to 58 °F) (Wang 1986, pp. 6–9).

Longfin smelt usually live for 2 years, spawn, and then die, although some individuals may spawn as 1- or 3-year-old fish before dying (Moyle 2002, p. 36). In the Bay-Delta, longfin smelt are believed to spawn primarily in freshwater in the lower reaches of the Sacramento River and San Joaquin River. Longfin smelt congregate in deep waters in the vicinity of the low salinity zone (LSZ) near X2 (see definition below) during the spawning period, and it is thought that they make short runs upstream, possibly at night, to spawn from these locations (CDFG 2009, p. 12; Rosenfield 2010, p. 8). The LSZ is the area where salinities range from 0.5 to 6 practical salinity units (psu) within the Bay-Delta (Kimmerer 1998, p. 1). Salinity in psu is determined by electrical conductivity of a solution, whereas salinity in parts per thousand (ppt) is determined as the weight of salts in a solution. For use in this document, the two measurements are essentially equivalent. X2 is defined as the distance in kilometers up the axis of the estuary (to the east) from the Golden Gate Bridge to the location where the daily average near-bottom salinity is 2 psu (Jassby *et al*. 1995, p. 274; Dege and Brown 2004, p. 51)).

Longfin smelt in the Bay-Delta may spawn as early as November and as late as June, although spawning typically occurs from January to April (CDFG 2009, p. 10; Moyle 2002, p. 36). Longfin smelt have been observed in their winter and spring spawning period as far upstream as Isleton in the Sacramento River, Santa Clara shoal in the San Joaquin system, Hog Slough off the South-Fork Mokelumne River, and in Old River south of Indian Slough (CDFG 2009a, p. 7; Radtke 1966, pp. 115–119).

Exact spawning locations in the Delta are unknown and may vary from year to year in location, depending on environmental conditions. However, it seems likely that spawning locations consist of the overlap of appropriate conditions of flow, temperature, and salinity with appropriate substrate (Rosenfield 2010, p. 8). Longfin smelt are known to spawn over sandy substrates in Lake Washington and likely prefer similar substrates for spawning in the Delta (Baxter *et. al.* 2010, p. 62; Sibley and Brocksmith 1995, pp. 32–74). Baxter found that female longfin smelt produced between 1,900 and 18,000 eggs, with fecundity greater in fish with greater lengths (CDFG 2009, p. 11). At 7°C (44.6°F), embryos hatch in 40 days (Dryfoos 1965, p. 42); however, incubation time decreases with increased water temperature. At 8–9.5°C (46.4–49.1 °F), embryos hatch at 29 days (Sibley and Brocksmith 1995, pp. 32–74).

Larval longfin smelt less than 12 millimeters (mm) (0.5 in) in length are buoyant because they have not yet developed an air bladder; as a result, they occupy the upper one-third of the water column. After hatching, they quickly make their way to the LSZ via river currents (CDFG 2009, p. 8; Baxter 2011a, pers comm.). Longfin smelt develop an air bladder at approximately 12–15 mm (0.5–0.6 in.) in length and are able to migrate vertically in the water column. At this time, they shift habitat and begin living in the bottom two-thirds of the water column (CDFG

2009, p. 8; Baxter 2008, p. 1).

Longfin smelt larvae can tolerate salinities of 2–6 psu within days of hatching, and can tolerate salinities up to 8 psu within weeks of hatching (Baxter 2011a, pers. comm.). However, very few larvae (individuals less than 20 mm in length) are found in salinities greater than 8 psu, and it takes almost 3 months for longfin smelt to reach juvenile stage. A fraction of juvenile longfin smelt individuals are believed to tolerate full marine salinities (greater than 8 psu) (Baxter 2011a, pers. comm.).

Longfin smelt are dispersed broadly in the Bay-Delta by high flows and currents, which facilitate transport of larvae and juveniles long distances. Longfin smelt larvae are dispersed farther downstream during high freshwater flows (Dege and Brown 2004, p. 59). They spend approximately 21 months of their 24-month life cycle in brackish or marine waters (Baxter 1999, pp. 2–14; Dege and Brown 2004, pp. 58–60).

In the Bay-Delta, most longfin smelt spend their first year in Suisun Bay and Marsh, although surveys conducted by the City of San Francisco collected some first-year longfin in coastal waters (Baxter 2011c, pers. comm.; City of San Francisco 1995, no pagination). The remainder of their life is spent in the San Francisco Bay or the Gulf of Farallones (Moyle 2008, p. 366; City of San Francisco 1995, no pagination). Rosenfield and Baxter (2007, pp. 1587, 1590) inferred based on monthly survey results that the majority of longfin smelt from the Bay-Delta were migrating out of the estuary after the first winter of their life cycle and returning during late fall to winter of their second year. They noted that migration out of the estuary into nearby coastal waters is consistent with captures of longfin smelt in the coastal waters of the Gulf of Farallones. It is possible that some longfin smelt may stay in the ocean and not re-enter freshwater to spawn until the end of their third year of life (Baxter 2011d, pers. comm.). Moyle (2010, p. 8) states that longfin smelt that migrate out of and back into the Bay-Delta estuary may primarily be feeding on the rich planktonic food supply in the Gulf of Farallones. Rosenfield and Baxter (2007, p. 1290) hypothesize that the movement of longfin smelt into the ocean or deeper water habitat in summer months is at least partly a behavioral response to warm water temperatures found during summer and early fall in the shallows of south San Francisco Bay and San Pablo Bay (Rosenfield and Baxter 2007, p. 1590).

In the Bay-Delta, calanoid copepods such as *Pseudodiatomus forbesi* and *Eurytemora sp.*, as well as the cyclopoid copepod *Acanthocyclops vernali* (no common names), are the primary prey of longfin smelt during the first few months of their lives (approximately January through May) (Slater 2009b, slide 45). Copepods are a type of zooplankton (organisms drifting in the water column of oceans, seas, and bodies of fresh water). The longfin smelt's diet shifts to include mysids such as opossum shrimp (*Neomysis mercedis*) and other small crustaceans (*Acanthomysis* sp.) as soon as they are large enough (20–30 mm (0.78–1.18 in)) to consume these larger prey items, sometime during the summer months of the first year of their lives (CDFG 2009, p. 12). Upstream of San Pablo Bay, mysids and amphipods form 80–95 percent or more of the juvenile longfin smelt diet by weight from July through September (Slater 2009, unpublished data). Longfin smelt occurrence is likely associated with the occurrence of their prey, and both of these invertebrate groups occur near the bottom of the water column during the day under clear water marine conditions.

Habitat

The Bay-Delta is the largest estuary on the West Coast of the United States (Sommer *et al*. 2007, p. 271). The modern Bay-Delta bears only a superficial resemblance to the historical Bay-Delta. The Bay-Delta supports an estuary covering approximately 1,235 square kilometers (km^2) (477 square miles (mi^2)) (Rosenfield and Baxter 2007, p. 1577), which receives almost half of California's runoff (Lehman 2004, p. 313). The historical island marshes surrounded by low natural levees are now intensively farmed and protected by large, manmade structures (Moyle 2002, p. 32). The watershed, which drains approximately 40 percent of the land area of California, has been heavily altered by dams and diversions, and nonnative species now dominate, both in terms of numbers of species and numbers of individuals (Kimmerer 2004, pp. 7–9). The Bay Institute has estimated that intertidal wetlands in the Delta have been diked and leveed so extensively that approximately 95 percent of the 141,640 hectares (ha) (350,000 acres (ac)) of tidal wetlands that existed in 1850 are gone (The Bay Institute 1998, p. 17).

The physical and biological characteristics of the estuary define longfin smelt habitat. The Bay-Delta is unique in that it contains significant amounts of tidal freshwater (34 km^2 (13 mi^2)) and mixing zone (194 km^2 (75 mi^2)) habitat (Monaco *et al*. 1992, pp. 254–255, 258). San Francisco Bay is relatively shallow and consists of a northern bay that receives freshwater inflow from the Sacramento-San Joaquin system and a southern bay that receives little freshwater input (Largier 1996, p. 69). Dominant fish species are highly salt-tolerant and include the commercially important Pacific sardine (*Sardinops sagax*) and rockfish (*Sebastes* spp.). Major habitat types include riverine and tidal wetlands, mud flat, and salt marsh, with substantial areas of diked wetland managed for hunting. The sandy substrates that longfin smelt are presumed to use for spawning are abundant in the Delta.

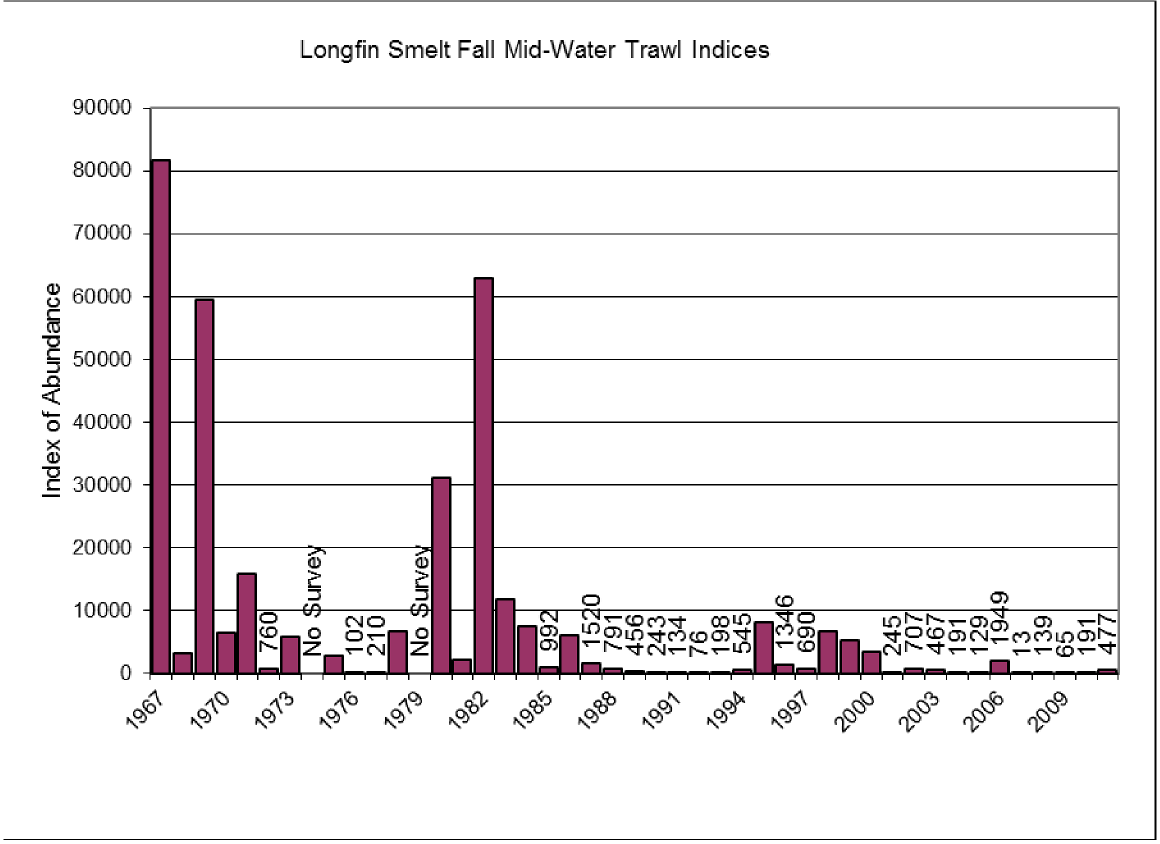
Abundance

Longfin smelt numbers in the Bay-Delta have declined significantly since the 1980s (Moyle 2002, p. 237; Rosenfield and Baxter 2007, p. 1590; Baxter *et. al.* 2010, pp. 61–64). Rosenfield and Baxter (2007, pp. 1577–1592) examined abundance trends in longfin smelt using three long-term data sets (1980–2004) and detected a significant decline in the Bay-Delta longfin smelt population. They confirmed the positive correlation between longfin smelt abundance and freshwater flow that had been previously documented by others (Stevens and Miller 1983, p. 432; Baxter *et al*. 1999, p. 185; Kimmerer 2002b, p. 47), noting that abundances of both adults and juveniles were significantly lower during the 1987–1994 drought than during either the pre- or post-drought periods (Rosenfield and Baxter 2007, pp. 1583–1584).

Despite the correlation between drought and low population in the 1980s and 90s, the declines in the first decade of this century cannot be fully explained by hydrology. Abundance of longfin smelt has remained very low since 2000, even though freshwater flows increased during several of these years (Baxter *et al*. 2010, p. 62). Abundance indices derived from the Fall Midwater Trawl (FMWT), Bay Study Midwater Trawl (BSMT), and Bay Study Otter Trawl (BSOT) all show marked declines in Bay-Delta longfin smelt populations from 2002 to 2009 (Messineo *et al.* 2010, p. 57). Longfin smelt abundance over the last decade is the lowest recorded in the 40-year history of CDFG's FMWT monitoring surveys. Scientists became concerned over the simultaneous population declines since the early 2000s of longfin smelt and three other Bay-Delta pelagic fish species—delta smelt (*Hypomesus transpacificus*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*) (Sommer *et al*. 2007, p. 273). The declines of longfin smelt and these other pelagic fish species in the Bay-Delta since the early 2000s has come to be known as the Pelagic Organism Decline, and considerable research efforts have been initiated since 2005, to better understand causal mechanisms underlying the declines (Sommer *et al*. 2007, pp. 270–277; MacNally *et al*. 2010, pp. 1417–1430; Thomson *et al*. 2010, pp. 1431–1448). The population did increase in the 2011 FMWT index to 477 (Contreras 2011, p. 2), presumably in a response to an exceptionally wet year.

The FMWT index of longfin smelt abundance in the Bay-Delta shows great annual variation in abundance but a severe decline over the past 40 years (Figure 2). The establishment of the overbite clam (*Corbula amurensis*) in the Bay-Delta in 1987 is believed to have contributed to the population decline of longfin smelt, as well as to the declining abundance of other pelagic fish species in the Bay-Delta (Sommer *et al*. 2007, p. 274). Figure 2 shows low values of the abundance index for longfin smelt during drought years (1976–1977 and 1986–1992) and low values overall since the time that the overbite clam became established in the estuary.

FIGURE 2. Longfin smelt abundance (total across year-classes) as indexed by the Fall Mid-Water Trawl of the Bay-Delta, 1967–2011.



* The survey was not conducted in 1974 or 1979.
** Index values for years of very low abundance were added.

Using data from 1975–2004 from the FMWT survey, Rosenfield and Baxter 2007 (p. 1589) found that longfin smelt exhibit a significant stock-recruitment relationship—abundance of juvenile (age-0) fish is directly related to the abundance of adult (age-1) fish from the previous year. They found that the abundance of juvenile fish declined by 90 percent during the time period analyzed. Rosenfield and Baxter (2007, p. 1589) also found a decline in age-1 individuals that was significant even after accounting for the decline in the age-0 population. If unfavorable environmental conditions persist for one or more years, recruitment into the population could be suppressed, affecting the species' ability to recover to their previous abundance. The current low abundance of adult longfin smelt within the Bay-Delta could reduce the ability of the species to persist in the presence of various threats.

Threats

When evaluating a species for federal ESA listing, we are required to access the species for threats. The following threats have been identified as significant because we believe that they are at least in part responsible for driving the population trend of the species.

Reduced Freshwater Flow

Many environmental attributes respond to variance in freshwater flow into the estuary, including patterns of flooding and drought, nutrient loading, sediment loading (turbidity), concentration of organic matter and planktonic biota, physical changes in the movement and compression of the salt field, and changes in the hydrodynamic environment (Kimmerer 2002a, p. 40). The San Francisco Estuary exhibits one of the strongest and most consistent responses of biota to flow among large estuaries (Kimmerer 2004, p. 14).

Reduced freshwater flows into estuaries may affect fish and other estuarine biota in multiple ways. Effects may include: (1) Decreased nutrient loading, resulting in decreased primary productivity; (2) decreased stratification of the salinity field, resulting in decreased primary productivity; (3) decreased organic matter loading and deposition into the estuary; (4) reduced migration cues; (5) decreased sediment loading and turbidity, which may affect both feeding efficiency and predation rates; (6) reduced dilution of contaminants; (7) impaired transport to rearing areas (e.g., low-salinity zones); and (8) reduction in physical area of, or access to, suitable spawning or rearing habitat Kimmerer (2002b, p. 1280).

Freshwater flow is strongly related to the natural hydrologic cycles of drought and flood. In the Bay-Delta estuary, increased Delta outflow during the winter and spring is the largest factor positively affecting longfin smelt abundance (Stevens and Miller 1983, pp. 431–432; Jassby *et al*. 1995; Sommer *et al*. 2007, p. 274; Thomson *et al*. 2010, pp. 1439–1440). During high outflow periods, 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 the boundary of spawning habitat and strong downstream transport of larvae (CFDG 1992; Hieb and Baxter 1993; CDFG 2009a). Conversely, during low outflow periods, 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. Despite numerous studies of longfin smelt abundance and flow in the Bay-Delta, the underlying causal mechanisms are still not fully understood (Baxter *et al*. 2010, p. 69; Rosenfield 2010, p. 9).

It is important to note that in the case of the Bay-Delta, freshwater flow is expressed as both Delta inflow (from the rivers into the Delta) and as Delta outflow (from the Delta into the lower estuary), which are closely correlated, but not equivalent. Freshwater flow into the Delta affects the location of the low salinity zone and X2 within the estuary. Because longfin smelt spawn in freshwater, they must migrate farther upstream to spawn as flow reductions alter the position of X2 and the low-salinity zone moves upstream (CDFG 2009, p. 17). Longer migration distances into the Bay-Delta make longfin smelt more susceptible to entrainment in the State and Federal water pumps (see Factor E: Entrainment Losses). In periods with greater freshwater flow into the Delta, X2 is pushed farther downstream (seaward); in periods with low flows, X2 is positioned farther landward (upstream) in the estuary and into the Delta. Not only is longfin smelt abundance in the Bay-Delta strongly correlated with Delta inflow and X2, but the spatial distribution of longfin smelt larvae is also strongly associated with X2 (Dege and Brown 2004, pp. 58–60; Baxter *et al*. 2010, p. 61). As longfin hatch into larvae, they move from the areas where they are spawned and orient themselves just downstream of X2 (Dege and Brown 2004, pp. 58-60). Larval (winter-spring) habitat varies with outflow and with the location of X2 (CDFG 2009, p. 12), and has been reduced since the 1990s due to a general upstream shift in the location of X2 (Hilts 2012, unpublished data). The amount of rearing habitat (salinity between 0.1 and 18 ppt) is also presumed to vary with the location of X2 (Baxter *et al.* 2010, p. 64). However, as previously stated, the location of X2 is of particular importance to the distribution of newly-hatched larvae and spawning adults. The influence of water project operations from November through April, when spawning adults and newly-hatched larvae are oriented to X2, is greater in drier years than in wetter years (Knowles 2002, p. 7).

Climate change may exacerbate the effects of reduced freshwater flow. Global sea level rose at an average rate of 1.8 mm (0.07 in) per year from 1961 to 2003, and at an average rate of 3.1 mm (0.12 in) per year from 1993 to 2003 (IPCC 2007a, p. 49). The IPCC (2007b, p. 13) report estimates that sea levels could rise by 0.18 to 0.58 m (0.6 to 1.9 ft) by 2100; however, Rahmstorf (2007, p. 369) indicated that global sea level rise could increase by over 1.2 m (4 ft) in that time period (CEC 2009, p. 49). Even if emissions could be halted today, the oceans would continue to rise and expand for centuries due to their capacity to store heat (CEC 2009, pp. 49–50). In the Bay-Delta, higher tides combined with more severe drought and flooding events are likely to increase the likelihood of levee failure, possibly resulting in major alterations of the environmental conditions (Moyle 2008, pp. 362–363). It is reasonable to conclude that more severe drought and flooding events will also occur in other estuaries where the longfin smelt occurs. Sea level rise is likely to increase the frequency and range of saltwater intrusion. Salinity within the northern San Francisco Bay is projected to rise 4.5 psu by the end of the century (Cloern *et al*. 2011, p. 7). Elevated salinity levels could push the position of X2 farther up the estuary and could result in increased distances that longfin smelt must migrate to reach spawning habitats. Elevated sea levels could result in greater sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (CDFG 2009, p. 30).

Introduced Species

The Bay-Delta is considered one of the most highly invaded estuaries in the world (Sommer *et al*. 2007, p. 272). Longfin smelt abundance in the Bay-Delta has remained low since the mid-1980s. This long-term decline has been at least partially attributed to effects of the introduced overbite clam (Kimmerer 2002a, p. 47; Sommer *et al*. 2007, p. 274; Rosenfield and Baxter 2007, p. 1589; Baxter *et al*. 2010, pp. 61–62). The overbite clam has impacted zooplankton abundance and species composition by grazing on the phytoplankton that comprise part of the zooplankton's food base (Orsi and Mecum 1996, pp. 384–386) and by grazing on larval stages of certain zooplankton like *Eurytemora affinis* (no common name) (Kimmerer 2002, p. 51; Sommer *et al*. 2007, pp. 274–276). These data suggest that changes in the estuary's food web following introduction of the overbite clam have had substantial and long-term impacts on longfin smelt population dynamics in the Bay-Delta.

In Suisun Bay, a key longfin smelt rearing area, phytoplankton biomass is influenced by the overbite or Amur River clam. A sharp decline in phytoplankton biomass occurred following the invasion of the estuary by this species, even though nutrients were not found to be limiting (Alpine and Cloern 1992, pp. 950-951). Abundance of zooplankton decreased across several taxa, and peaks that formerly occurred in time and space were absent, reduced or relocated after 1987 (Kimmerer and Orsi 1996, p. 412). The general decline in phytoplankton and zooplankton is likely affecting longfin smelt by decreasing food supply for their prey species, such as *N. mercedis* (Kimmerer and Orsi 1996, pp. 418 –419). Models indicate that the longfin smelt abundance index has been on a steady linear decline since about the time of the invasion of the non-native overbite (or Amur) clam in 1987 (Rosenfield and Swanson 2010, p. 14) even after adjusting for Delta freshwater flows (Nobriga 2010, slide 5).

Ammonium

Ammonia is un-ionized and has the chemical formula NH_3. Ammonium is ionized and has the formula NH_4^+. The major factors determining the proportion of ammonia or ammonium in water are water pH and temperature. This is important, as NH_3 ammonia is the form that can be directly toxic to aquatic organisms, and NH_4+ ammonium is the form documented to interfere with uptake of nitrates by phytoplankton (Dugdale *et al.* 2007, p. 17; Jassby 2008, p. 3).

Effects of elevated ammonia levels on fish range from irritation of skin, gills, and eyes to reduced swimming ability and mortality (Wicks *et al*. 2002, p. 67). Delta smelt have been shown to be directly sensitive to ammonia at the larval and juvenile stages (Werner *et al*. 2008, pp. 85–88). Longfin smelt could similarly be affected by ammonia as they utilize similar habitat and prey resources and have a physiology similar to delta smelt. Ammonia also can be toxic to several species of copepods important to larval and juvenile fishes (Werner *et al*. 2010, pp. 78–79; Teh *et al*. 2011, pp. 25–27).

In addition to direct effects on fish, ammonia in the form of ammonium has been shown to alter the food web by adversely impacting phytoplankton and zooplankton dynamics in the estuary ecosystem. Historical data show that decreases in Suisun Bay phytoplankton biomass coincide with increased ammonia discharge by the SRWTP (Parker *et al*. 2004, p. 7; Dugdale *et al*. 2011, p. 1). Phytoplankton preferentially take up ammonium over nitrate when it is present in the water. Ammonium is insufficient to provide for growth in phytoplankton, and uptake of ammonium to the exclusion of nitrate results in decreases in phytoplankton biomass (Dugdale *et al*. 2007, p. 23). Therefore, ammonium impairs primary productivity by reducing nitrate uptake in phytoplankton. Ammonium's negative effect on the food web has been documented in the longfin smelt rearing areas of San Francisco Bay and Suisun Bay (Dugdale *et al.* 2007, pp. 26–28). Decreased primary productivity results in less food available to longfin smelt and other fish in these bays.

Threats are acting synergistically

The primary threat to the DPS is from reduced freshwater flows. Upstream dams and water storage exacerbated by water diversions, especially from the SWP and CVP water export facilities, result in reduced freshwater flows within the estuary, and these reductions in freshwater flows result in reduced habitat suitability for longfin smelt. Freshwater flows, especially winter-spring flows, are significantly correlated with longfin smelt abundance—longfin smelt abundance is lower when winter-spring flows are lower. While freshwater flows have been shown to be significantly correlated with longfin smelt abundance, causal mechanisms underlying this correlation are still not fully understood and are the subject of ongoing research on the Pelagic Organism Decline.

In addition to the threat caused by reduced freshwater flow into the Bay-Delta, and alteration of natural flow regimes resulting from water storage and diversion, there appear to be other factors contributing to the Pelagic Organism Decline (Baxter 2010 *et al*., p. 69). Models indicate a steady linear decline in abundance of longfin smelt since about the time of the invasion of the nonnative overbite clam in 1987 (Rosenfield and Swanson 2010, pp. 13–14). However, not all aspects of the longfin smelt decline can be attributed to the overbite clam invasion, as a decline in abundance of pre-spawning adults in Suisun Marsh occurred before the invasion of the clam, and a partial rebound in longfin smelt abundance occurred in the early 2000s (Rosenfield and Baxter 2007, p. 1589).

The threats identified are likely acting together to contribute to the decline of the population (Baxter *et al*. 2010, p. 69). Reduced freshwater flows result in effects to longfin smelt habitat suitability, at the same time that the food web has been altered by introduced species and ammonium concentrations. It is possible that climate change could exacerbate these threats. The combined effects of reduced freshwater flows, the invasive overbite clam (reduced levels of phytoplankton and zooplankton that are important to the Bay-Delta food web), and high ammonium concentrations act to reduce habitat suitability for longfin smelt.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

September 14, 2012

Technical Staff Comments to the State Water Resources Control Board re: the Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan, Public Workshop 2, Bay Delta Fishery Resources (Salmonids)

The U.S. Fish and Wildlife Service (Service) submits the following written comments in response to the questions posed by the State Water Resources Control Board (Board) for discussion at the salmonid workshop that support the Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan. The following responses contain additional scientific and technical information that was not included in or available for the 2009 Staff Report (SWRCB, 2009) or the 2010 Delta Flow Criteria Report (SWRCB, 2010). These comments also supplement the Department of the Interior's April 25, 2012 comments to the Board. Overall, we make the following key points to supplement our April 25 key points:

KEY POINTS:

1. The Board should consider updated information on the status of the stocks (escapement, adult production and juvenile production indices) to inform potential changes to the Bay-Delta Plan.
2. The Board should consider recent genetic information on the timing of various runs of Chinook salmon in sampling near Sacramento, Chipps Island and at the salvage facilities to assure adequate protection of all runs of Chinook salmon in the Delta.
3. The Board should consider information from the 2010 VAMP study, indicating juvenile Chinook salmon survival through the Delta was only 5% at Vernalis flows of approximately 5,000 cfs in 2010. Juvenile salmon

survival in 2010 was lower than survival through the Delta in many past years measured with tagged fish released for the VAMP.

4. The Board should consider evaluating a physical barrier at the head of Old River to get higher juvenile salmon survival through the Delta at Vernalis flows of up to 7,000 cfs.
5. Survival through the Delta is a key component to determining adult recruits from juvenile salmon abundance coming into the Delta.
6. Continued monitoring of Chinook salmon survival is critical to assure flow criteria and other management actions result in increased Delta survival rates for Chinook salmon and for informing models and implementing adaptive management.
7. Results from 2011 and 2012 south Delta salmon and steelhead studies should be used to help determine appropriate Old and Middle River flow criteria to assure juvenile salmonids from the San Joaquin Basin are able to migrate successfully through the Delta.
8. There is evidence to suggest that if spring flows originating from the San Joaquin River are increased, predation will decrease and survival of juvenile salmon migrating through south Delta will improve.
9. Furthermore, increased predation-related mortality in the south Delta is related to changes in south Delta habitat related to the high export/inflow ratios between July and September.
10. The Board should consider new information in relation to modifying the timing and duration of Delta Cross Channel gate closures when revising the 2006 Water Quality Control Plan.
11. The Board should address scientific uncertainty and changing circumstances within an adaptive management plan. We reference a new DOI Applications Guide on adaptive management to help the Board design and implement a successful adaptive management program.
12. Specific biological indicators should be incorporated into the goals and objectives of the Plan to guide the monitoring and special studies program and to inform adaptive management.

What additional scientific information should the State Water Board consider to inform potential changes to the Bay-Delta Plan relating to Bay-Delta fishery resource, and specifically pelagic fishes and salmonids, that was not addressed in the 2009 staff Report and the 2010 Delta Flow Criteria Report?

The recent status of Central Valley Chinook salmon stocks should be considered to inform potential changes to the Bay-Delta Plan (Plan) and update information used in the 2009 Staff Report (SWRCB, 2009) and the 2010 Delta Flow Criteria Report (SWRCB, 2010). For example, fall-run escapement of Chinook salmon in the Central Valley has improved somewhat in 2010 and 2011 from the extreme low levels in 2008 and 2009, but numbers are still at relatively low levels compared to escapement since 1952 (Figure 1).

Escapement of fall-run Chinook salmon and the production of all four races of Chinook salmon in the Central Valley (DFG written comments, this proceeding) indicate recent conditions in the Delta and in other areas (i.e. ocean) have not facilitated positive population growth, such that the Plan’s narrative salmon protection objective is being met. The Board’s narrative salmon protection objective is to provide water quality conditions together with other measures in the watershed sufficient to achieve a doubling of natural production of Chinook salmon from the average production between 1967 and 1991, consistent with provisions of State and federal law.

In addition, the Board should consider recent assessments of the relative contribution of naturally produced Chinook salmon compared to hatchery contributions. Kormos et al., (2012) document the proportions of hatchery and natural origin Chinook salmon throughout the Central Valley based on the analysis of coded wire tags collected from escapement surveys and at hatcheries. This report finds roughly half of the returning adult salmon in the Stanislaus and Tuolumne rivers, and over three quarters of the Merced River returns are of hatchery origin (Figure 9, in Kormos et. al., 2012). Given that the aforementioned doubling goal applies to naturally produced salmon, the Board should evaluate the potential benefits of increased flows as numbers of natural origin salmon are lower than previously assumed based on escapement surveys.

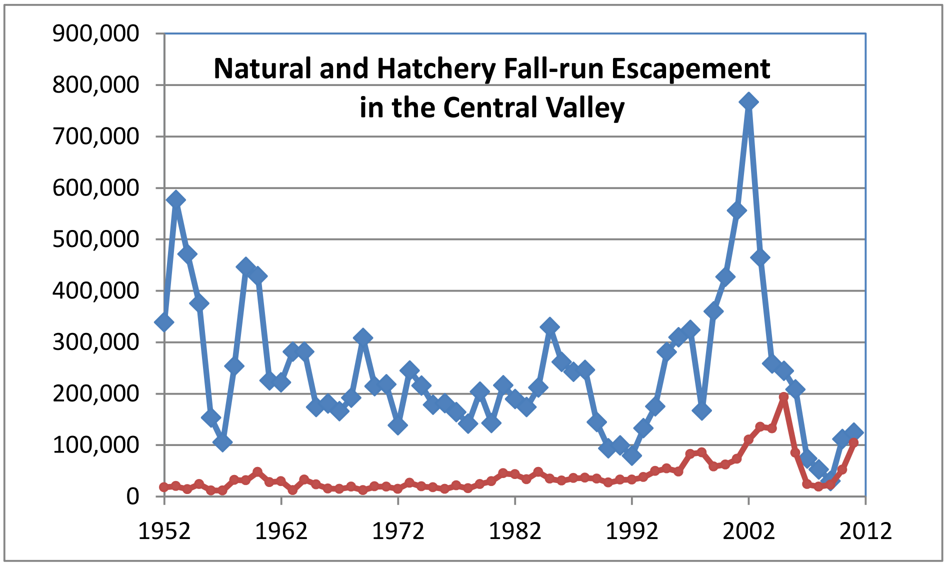


Figure 1: Fall run escapement in natural areas (diamonds) and in hatcheries (circles) in the Central Valley between 1952 and 2011. Escapement includes fish of both hatchery and natural origin (CDFG Grandtab, April 24, 2012).

The Board should also consider updated information on the relationship of flow and the abundance of juvenile salmon leaving the Delta in the spring. The relationship of unmarked juvenile salmon indices at Chipps Island between 1978 and 2011, and mean daily Rio Vista flows between April and June, continues to support the hypothesis that increased flow results in increased juvenile production leaving the Delta (Figure 2) (USFWS, 1987; Brandes and McLain, 2001; Brandes et al., 2006). Other factors, such as the prior year's escapement, could also affect these indices, but preliminary analysis indicates the relationship remains, even after accounting for varying prior-year escapement (fall run from the Sacramento Basin) except for those years with the lowest escapement values (USFWS, unpublished data). There is some evidence that, on average, abundance at Chipps Island was lower between 1995 and 2006 per unit flow at Rio Vista than during the period from 1978 to 1994 (Figure 3). In addition, since indices at Chipps Island only include unmarked juvenile salmon caught in sampling, indices between 2007 and 2011 contain proportionally fewer hatchery fish relative to years prior to 2007, since 25% of the fall-run hatchery production was marked starting in 2007 (Kormos et. al., 2012). Although indices are lower since 2007, they still appear to increase with flow, with the highest abundances at approximately 40,000 cfs at Rio Vista (Figure 3). Other updated information on juvenile salmon abundance and distribution and how it relates to flows is available from our Stockton Fish and Wildlife Office.

It should be noted that juvenile salmon indices at Chipps Island based on catches in April through June, likely include some spring-run, late-fall-run and a few winter-run, in addition to fall-run salmon. Most winter-run (as determined using genetics) enter the Delta between October and April and migrate from the Delta between December and April (USFWS, unpublished data; and Hedgecock, 2002). Most spring-run enter the Delta between February and June and leave the Delta between March and June (USFWS, unpublished data).   A report by California Department of Water Resources on the genetic composition of juvenile Chinook salmon in Central Valley Project and State Water Project salvage should be available soon (B. Harvey, personal communication) and could be used to better evaluate when winter -run and spring-run as well as the other races of Chinook salmon are most vulnerable to the direct and indirect impacts of water diversions.

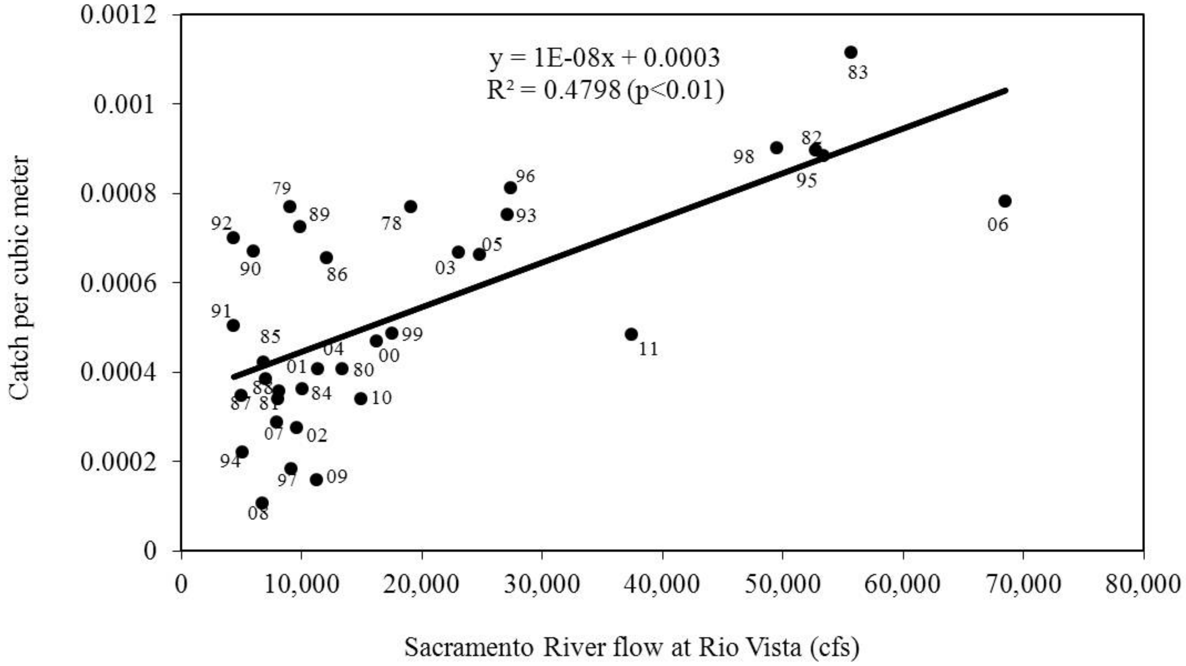


Figure 2: Mean monthly catch per cubic meter of unmarked juvenile Chinook salmon at Chipps Island between April and June of 1978 to 2011 versus mean daily Sacramento River flow at Rio Vista between April and June in cfs (USFWS, 1987, Brandes and McLain, 2001, Brandes, et al., 2006 and USFWS, unpublished data).

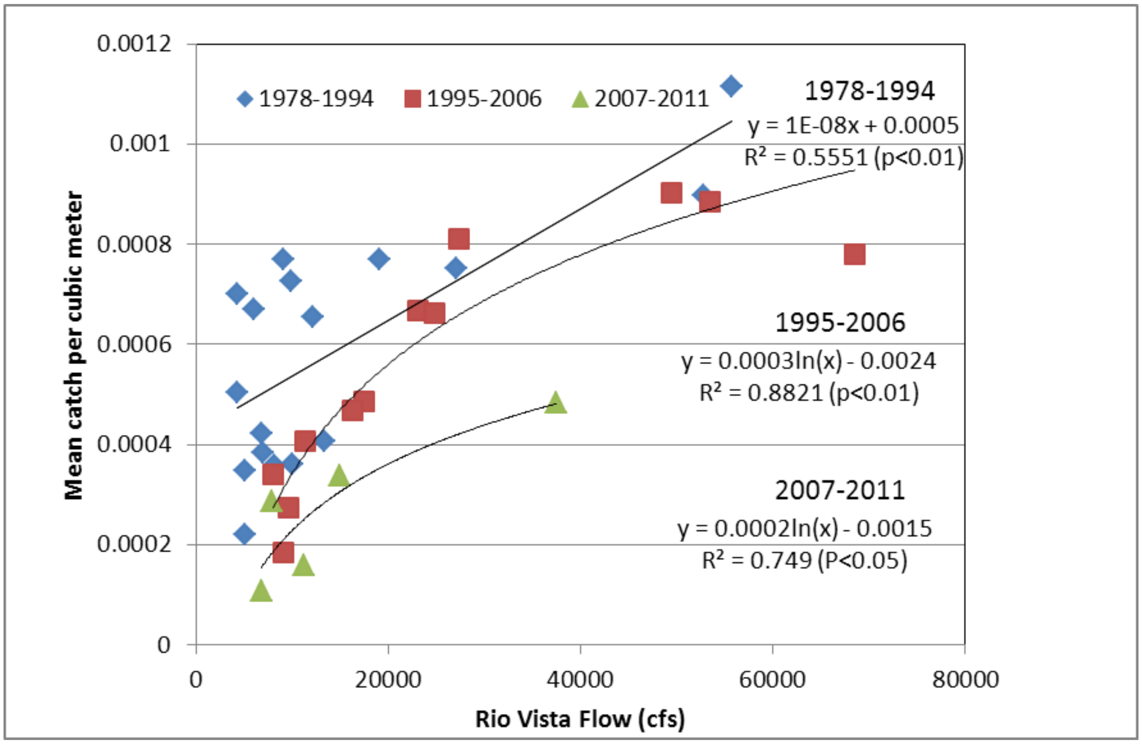


Figure 3: Mean monthly catch per cubic meter of unmarked juvenile Chinook salmon at Chipps Island between April and June in three historical periods, and mean daily Sacramento River flow at Rio Vista in cfs between April and June (USFWS, 1987, Brandes and McLain, 2001, Brandes, et al., 2006 and USFWS, unpublished data)

We suggest the Board and Board Staff consider including information from the 2010 Vernalis Adaptive Management Program (VAMP) annual report (SJRG, 2011) for modifying the 2006 Plan, which provides new information not available for the 2009 Staff Report (SWRCB, 2009) and the 2010 Delta Flow Criteria Report (SWRCB, 2010). Vernalis flows in May of 2010 were around 5,000 cfs, but smolt survival through the Delta in 2010 for tagged fish released in the San Joaquin River was estimated at only 0.05 (5%) – lower than most estimates since 1994 (Figure 4). While comparisons of juvenile salmon survival in common reaches of the Delta in the spring between 2009 and 2010 indicate survival was substantially greater in 2010 than in 2009 (SJRG, 2011), neither year had survival high enough through the Delta to sustain the population, given average estimates of survival in other phases of the life-cycle (DOI, 2011).

In our comments to the Board on the *Review of and Potential Modifications to the San Joaquin River Flow and Southern Delta Salinity Objectives* we concluded that an average juvenile Chinook salmon through-Delta survival of 0.50 survival (50%) is needed (given average survival in other phases of the life-cycle and an initial estimate of the population size) to achieve the Central Valley Project Improvement Act's Anadromous Fish doubling goal in 9 generations (27 years), whereas a survival rate of 0.05 (5%) results in a greatly increased risk of extirpation (DOI, 2011, page 18). Figure 5 illustrates how juvenile Chinook salmon survival in the Delta is important to resulting adult recruits as abundance of smolts at Mossdale changes.

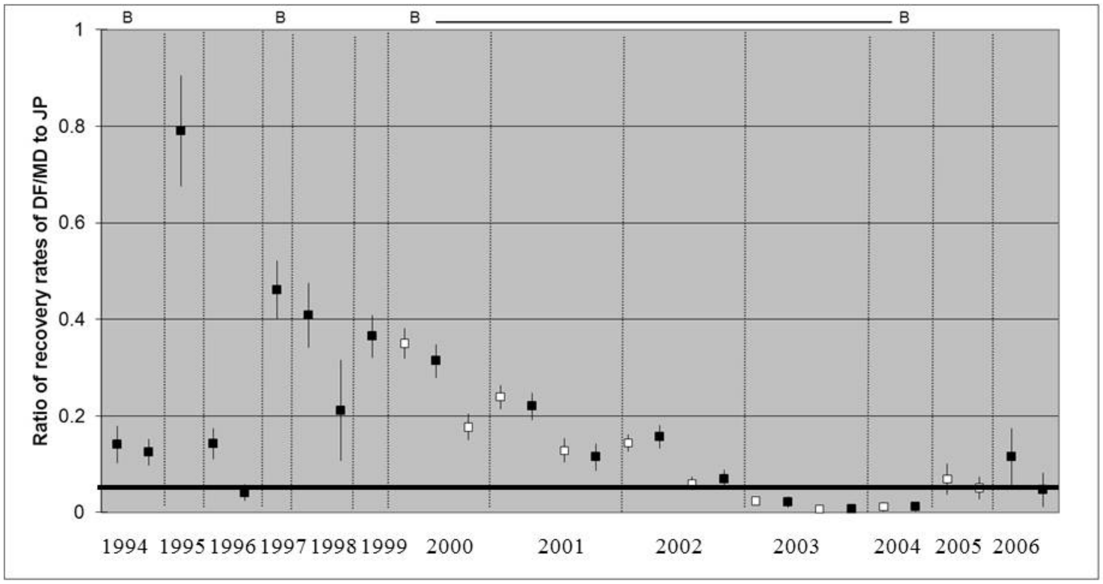


Figure 4: Estimates of smolt survival (+/- 2 Standard Errors) from Mossdale to Jersey Point during the VAMP between 1994 to 2006 using coded wire tagged fish. Years with the physical Head of Old River Barrier installed are denoted with B and are in 1994, 1997 and 2000-2004. The black line is the estimate of survival between Mossdale and Chipps Island in 2010 using acoustic tag technology and removing predator-type detections. (Brandes et al., 2008 and SJRG, 2011).

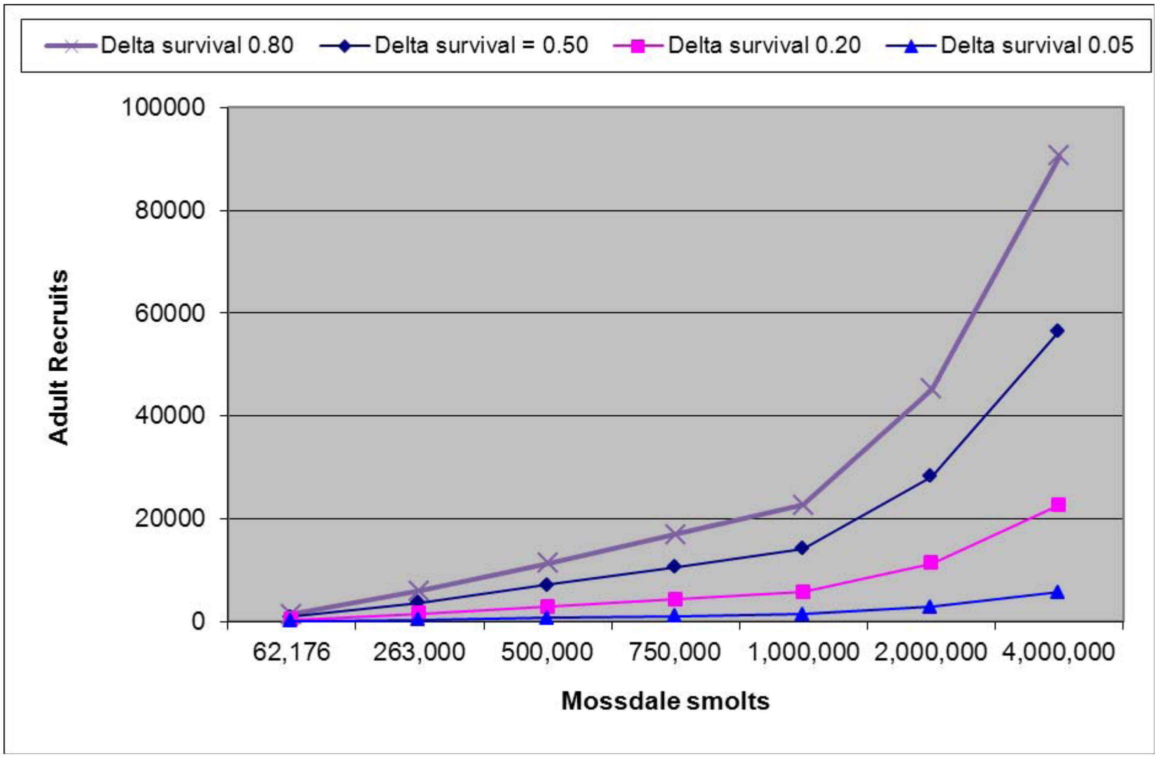


Figure 5: The relationship between simulated juvenile Chinook salmon Delta survival, tributary production (estimated as smolts at Mossdale) and adult recruits for Chinook salmon in the San Joaquin Basin. (DOI, 2011)

As the VAMP peer review panel identified, juvenile salmon survival through the Delta has been decreasing over time at very low, low, moderate and high flow levels (Hankin et al., 2010). Five percent survival through the Delta in 2010 suggests flows of over 5,000 cfs at Vernalis approximately 85% of time may not be sufficient to provide positive salmon population growth or to achieve the narrative salmon protection objective identified in the 2006 Bay-Delta plan. The data obtained in 2010 suggests the proposed minimum threshold of 5,000 cfs at Vernalis may be too low to meet the goals of the Plan.

Much of the information on salmon survival associated with the VAMP was collected with a physical Head of Old River Barrier (HORB) installed (2000-2004). The results from these years of data, in addition to past data gathered without a barrier, suggest the physical barrier resulted in higher survival at any given flow than would have occurred without a barrier (SJRG, 2007). Survival through the Delta in 2010, with the non-physical barrier installed, did not result in survival as high as in the past when the physical barrier was installed at similar flow levels at Vernalis (Figure 6). However, this comparison could be compounded by the decrease in survival over time. The past analyses suggests salmon survival at any flow (up to 7,000 cfs), could be further improved with a physical HORB compared to survival with a non-physical barrier or without a physical HORB. Results from studies in 2012, although not yet available, may provide additional information on the benefits of the physical HORB (with eight culverts), but river flows were lower in 2012 than in 2010 so results will not be directly comparable. Present information suggests a physical HORB would increase the survival of juvenile salmon at Vernalis flows of up to 7,000 cfs. However, exports may need to be decreased accordingly to avoid increasing negative Old and Middle river flows and ensure the protection of delta smelt. Another alternative is the Board could model and evaluate San Joaquin River inflow criteria from 60% to 75% of unimpaired flow, and assess whether the flows at Vernalis would be greater than 5,000 cfs more frequently.

Given the trend of decreasing survival and the uncertainty of the specific flow levels needed to meet the Board's narrative objective and immediate goal of halting the decline of native fish populations, continued monitoring of Chinook salmon survival is critical to assure the flow criteria and other management actions result in increased Delta survival rates for Chinook salmon originating from the San Joaquin Basin. Furthermore a robust, continuous, well-funded, long-term monitoring program measuring juvenile salmon survival in the Delta will inform models and future adaptive management of flow criteria for juvenile salmon.

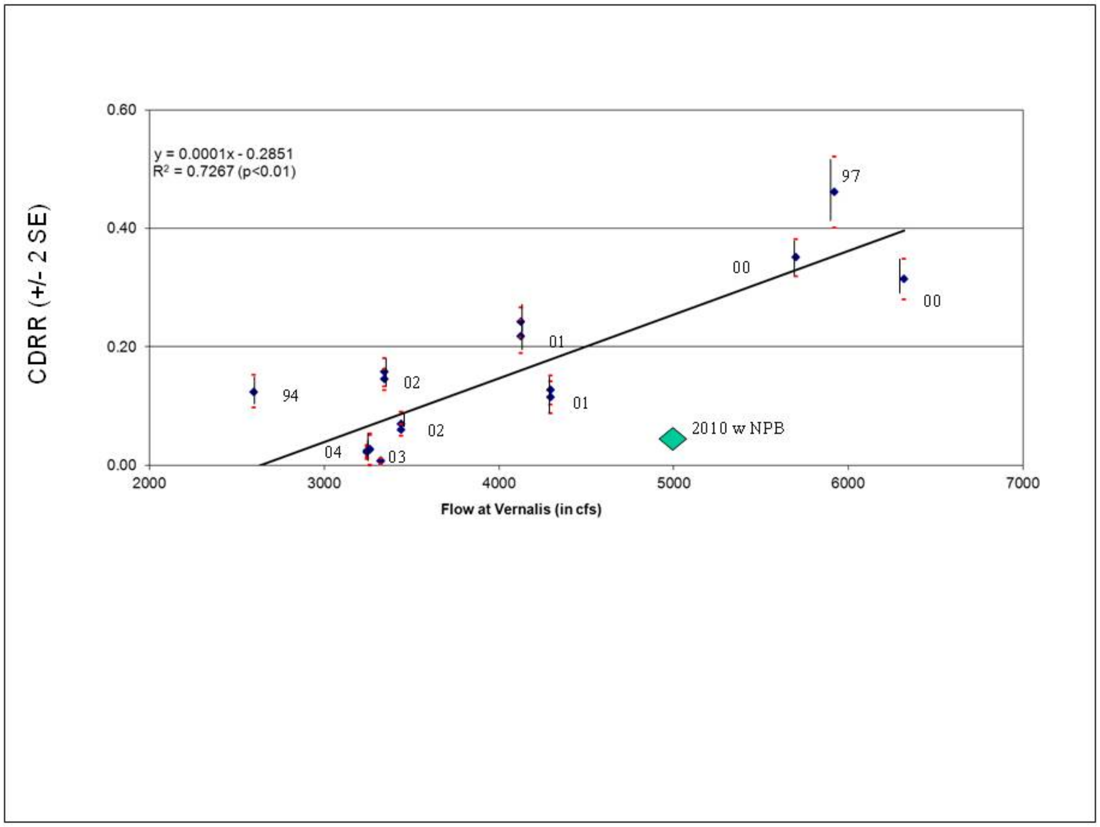


Figure 6: Combined Differential Recovery Rates (point estimates of survival) plus and minus 2 standard errors using Chipps Island, Antioch and ocean recoveries, for groups released at Mossdale or Durham Ferry and Jersey Point in 1994, 1997, 2000-2004 and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with the HORB in place (SJRG, 2007). Survival through the Delta in 2010 is also shown and includes survival measured with the non-physical barrier at the head of Old River (SJRG, 2011).

Once the VAMP agreement expired in 2011, funding was lost for estimating juvenile Chinook salmon survival through the Delta for salmon originating from the San Joaquin Basin. In 2012, stop-gap funding was found for the spring studies from a variety of sources, but no such funding exists for 2013. While the 2009 Staff Report (SWRCB, 2009, page 31) identifies VAMP monitoring as ongoing, it is no longer planned for the future, unless additional funding is secured.

Monitoring of juvenile salmon survival through the Delta for salmon originating from the San Joaquin Basin has been occurring in most years since 1994. It provides a historical perspective of the range of estimated smolt survival through the Delta and is the basis for present modeling, including Bay Delta Conservation

Plan (BDCP) related evaluations of San Joaquin Basin juvenile salmon survival in Delta. Additional monitoring of juvenile Chinook salmon survival is needed to further resolve the relationship between flow and exports, juvenile salmon survival through the south Delta with and without a HORB or non-physical barrier, and for determining the role of other covariates affecting survival. The Service believes continued monitoring of juvenile Chinook salmon survival in the Delta is critical to assessing present and future flow and export/inflow criteria. Although the NMFS biological opinion mandates a 6-year acoustic study for steelhead, it will not have the longer-term historic record of Chinook salmon survival for perspective. Both salmon and steelhead acoustic studies conducted in the south Delta in 2011 and 2012 will provide additional information that the Board and Board Staff should review, but these reports are not yet available. The results from these studies should also be used to help determine appropriate Old and Middle River flow criteria to assure juvenile salmonids from the San Joaquin Basin are able to migrate successfully through the Delta to Chipps Island.

One mechanism for the high mortality in the Delta, especially in the south Delta, is predation. In our February 8, 2011 comments to the Board (DOI, 2011, pages 35 and 36) we discuss the interaction between predation and flow and indicate that if spring flows originating from the San Joaquin River are increased, predation will decrease and survival of juvenile salmon in the south Delta will improve.

Furthermore, increased predation-related mortality in the south Delta is related to changes in south Delta habitat related to the high export/inflow ratios between July and September. The Service suggests the Board fully evaluate a range of flow regimes including reducing the export/inflow ratio during the summer and fall months. Moyle and Bennett (2008, page 14), discuss below how a change in timing of freshwater in the Delta has shifted the ecosystem from one benefiting native species to one dominated by non-native species, including non-native predators of juvenile salmonids.

> *"This shift presumably occurred as a result of the long-term (slow) process of steadily increasing pumping rates over time which requires the maintenance of freshwater conditions in the Delta during summer (Figure D.3), as well as the relatively rapid invasion by Brazilian waterweed and other factors that favored slough-resident (e.g., centrarchid species) and freshwater alien planktivore (e.g., inland silverside) fish assemblages. Species in these assemblages may suppress populations of desirable species through competition and predation (Bennett and Moyle 1996), and/or their expansion may reflect an overall shrinkage in brackish pelagic habitat required by native smelt and juvenile striped bass (Feyrer et al. 2007; Nobriga et al. 2008).*

> *This scenario is similar to those reported for temperate freshwater lakes where interactions between multiple processes operating at different temporal scales work together to shift a "desirable" clear-water regime with abundant aquatic vegetation and centrarchid fishes to an "undesirable" turbid-water regime with less vegetation and abundant planktivorous fishes (Carpenter 2003, Scheffer and Carpenter 2003, Folke et al. 2004, Rogers and Allen 2008). Once the shift to turbid water has occurred, it is very hard for the lakes to switch back to a clear-water state. (The obvious difference here is that the desirable regime for the Delta is the opposite of the one for temperate lakes.) The lake examples imply considerable ability for ecosystem states to persist even when the cause of the shift to a different state is removed. Likewise, even with a shift of the current water management strategy, it will be very difficult for the Delta ecosystem to shift back to the desirable regime (i.e., one with abundant pelagic native fishes) due to the habitat-stabilizing properties of the Brazilian waterweed and life history strategies (e.g. longer life spans) of the centrarchid fishes.*
>
> *Overall, the present state of the system will most likely continue as long as the Delta maintains its present configuration and water management practices. " (Moyle and Bennett, 2008).*

If the south Delta were returned to more riverine/estuarine habitat, as it was historically, instead of its more lake-like environment today, it would likely reduce the production of warm water predators and submerged aquatic vegetation and improve the survival of juvenile salmonids migrating through the south Delta in the spring.

Non-native invasive species like Brazilian waterweed and Asian clams have radically altered delta food webs, and thrive in the homogeneous flow and salinity environment. The Board should explore the efficacy of providing a more heterogeneous salinity environment that exceeds the salt tolerances of these non-native species, while still ensuring appropriate conditions for native species.

Additionally, the Central Valley Project Improvement Act's Anadromous Fish Restoration Program is implementing a study to determine the geographic distribution of the mortality of juvenile salmonids in the lower Stanislaus River (USFWS, unpublished data). Initial results indicate that survival of juvenile salmonids migrating through the lower Stanislaus River (between Oakdale and Caswell) is 0.07 (S.E. 0.03). A report documenting the study results will be forthcoming. Other similar studies evaluating juvenile Chinook salmon and predator movement in response to flow are currently being implemented in the Tuolumne River (TID and MID, 2011). Results from these and other such studies should be used to help determine what Vernalis flows should be and how inflows from each San Joaquin Basin tributary may influence juvenile salmon survival.

In their written comments to this proceeding, the California Department of Fish and Game provides support for modifying water quality objectives in the 2006 Plan to incorporate additional Delta Cross Channel gate closures. We also provided comments on new information supporting additional Delta Cross Channel closures in our April, 25, 2012 comments (DOI, 2012). In addition, Reclamation drafted an environmental assessment describing the benefits of closing the Delta Cross Channel gates for up to 10 days in October to decrease straying of adult Chinook salmon returning to the Mokelumne River (USBR, 2012*)*. We suggest the Board review and consider this new information in relation to modification of Delta Cross Channel gate closures when revising the 2006 Water Quality Control Plan.

Lastly, several articles have been published in the last year that may help the Board and Board staff as they consider potential changes to the Bay-Delta Plan. They are:

1. "*Migration route selection of juvenile Chinook salmon at the Delta Cross Channel, and the role of water velocity and individual movement patterns*" by Anna E. Steel, Philip T. Sandstrom, Patricia L. Brandes, A.Peter Klimley, in Environmental Biology of Fishes, DOI 10.1007/s10641-012-9992-6. Published online 05 April 2012.

2. "*Sensitivity of survival to migration routes used by juvenile Chinook salmon to negotiate the Sacramento-San Joaquin River Delta*" by Russell W. Perry, Patricia L. Brandes, Jon R. Burau, A.Peter Klimley, Bruce MacFarlane, Cyril Michel and John R. Skalski. Environmental Biology of Fishes, DOI 10.1007/s10641-012-9984-6 Published online 10 February 2012.

3. "*Adjusting survival estimates for premature transmitter failure: a case study from the Sacramento-San Joaquin Delta*" by Christopher M. Holbrook, Russell, W. Perry, Patricia L. Brandes and Noah S. Adams, Environmental Biology of Fishes, DOI 10.1007/s10641-012-0016-3. Published online 25 April 2012.

4. "*Interannual variation of reach specific migratory success for Sacramento River hatchery yearling late-fall run Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss)*" by Gabriel P. Singer, Alex R. Hearn, Eric D. Chapman, Matthew L. Peterson, Peter E. LaCivita, William N. Brostoff, Allison Bremner and A.P. Klimley.

Environmental Biology of Fishes. DOI 10.1007/s10641-012-0037-y. Published online on 22 May 2012.

5. "*Diel movements of out-migrating Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss) smolts in the Sacramento/San Joaquin watershed*" by Eric D. Chapman, Alex R. Hearn, Cyril J. Michel, Arnold J. Ammann, Steven T. Lindley, Michael J. Thomas, Philip T. Sandstrom, Gabriel P. Singer, Matthew L. Peterson, R. Bruce MacFarlane, A. Peter Klimley, Environmental Biology of Fishes. DOI 10.1007/s10641-012-0001-x. Published online 29 March 2012.

6. *"The effects of environmental factors on the migratory movement patterns of Sacramento River yearling late-fall run Chinook salmon (Oncorhynchus tshawytscha)"* by Cyril J. Michel, Arnold J. Ammann, Eric D. Chapman, Phillip T. Sandstrom, Heidi E. Fish, Michael J. Thomas, Gabriel P. Singer, Steven T. Lindley, Al Peter Klimley, R. Bruce MacFarlane. Environmental Biology of Fishes DOI 10.1007/s10641-012-9990-8. Published online 15 April 2012.

7. *"Effects of predator and flow manipulation of Chinook salmon (Oncorhynchus tshawytscha) survival in an imperiled estuary"*, by Bradley Cavallo, Joseph Merz and Jose Setka. Environmental Biology of Fishes. DOI 10.1007/s10641-012-9993-5.

8. *"Impending extinction of salmon, steelhead and trout (Salmonidae) in California"* by Jacob Katz, Peter B. Moyle, Rebecca M Quinones, Joshua Israel, and Sabra Purdy. Environmental Biology of Fishes, DOI 10.1007/s10641-012-9974-8. Published online 31 January 2012.

How should the State Water Board address scientific uncertainty and changing circumstances, including climate change, invasive species and other issues?

The Service believes the Board should address scientific uncertainty and changing circumstances, including climate change, invasive species and other issues (BDCP), within an adaptive management plan. The Department of Interior's (DOI) December 6, 2010 comments on the Board's draft technical report stated

"There is uncertainty in our understanding of how flow and salinity will affect future biological beneficial uses, consequently decisions must be made with uncertainty. Because of these uncertainties, any San Joaquin River flow objectives should be implemented, then evaluated and refined over time (adaptive management) to ensure the lessons learned are used to further refine the management of flows and salinity for meeting biological goals." (DOI, 2010a). Although there is uncertainty, there is evidence that increased flows will benefit native fishes, including salmonids by increasing survival through the Delta. The Board should identify biological goals and objectives and then use an adaptive management program to further define and refine how to achieve those goals and objectives.. All available indicators demonstrate the continued decline of the Central Valley salmonid populations. Consequently, the Board should consider a more protective approach, while development of an adequate adaptive management program proceeds.

Specifically, what kind of adaptive management and collaboration (short, medium and long-term), monitoring and special studies programs should the State Water Board consider related to Bay-Delta fisheries as part of this update to the Bay-Delta Plan?

We suggest the Board review the most recent DOI publication on adaptive management where several examples of successful adaptive management are documented. The DOI publication: Adaptive Management: The U.S. Department of the Interior Applications Guide (Williams et al., 2012), is in addition to the previously recommended and referenced DOI publication: Adaptive Management: The U.S. Department of the Interior Technical Guide (Williams et al., 2007)(DOI, 2010a; DOI, 2010b; DOI, 2011; DOI, 2012). These two documents will help the Board and Board Staff identify key components of a successful adaptive management program. Both documents can be obtained at: http://www.doi.gov/ppa/Adaptive-Management.cfm. These documents are especially applicable to criteria where the scientific underpinnings need further study.

Specific biological indicators should be incorporated into the goals and objectives to guide the monitoring and special studies program and to inform adaptive management. Biological objectives have been identified in the flow criteria report (SWRCB, 2010, page 43) as:

1. Provide sufficient flow to increase abundance of desirable species that depend on the Delta.
2. Create shallow brackish water habitat in Suisun Bay (and further downstream)
3. Provide floodplain inundation to enhance spawning and rearing opportunities for salmon and other native species.
4. Manage net OMR, and reverse flows to protect sensitive life stages of desirable species.
5. Provide sufficient flow in the Sacramento and San Joaquin Rivers and East side streams, to transport smolts through the Delta during the spring to contribute to Board's salmon protection water quality objective.
6. Maintain water temperatures and dissolved oxygen in rivers that flow into the Delta and its tributaries that will support adult Chinook salmon migration, egg incubation, smolting and early-year and late-year juvenile rearing.

However, to fully evaluate the flow criteria, and adaptively manage them, specific biological and physical indicators need to be identified. For example, how much increase in the abundance of desirable species is sufficient and how will it be determined if sensitive life stages of desirable species have been protected by net Old and Middle River flows? Identifying the level of protection the Board is targeting will help scientists determine if it is being achieved and will help resource managers adaptively manage the flow criteria to ultimately achieve those levels of protection. Monitoring (and funding for monitoring) should be identified to track the success or failure of the flow criteria using biological indicators and to provide a basis for future adaptive management of the flow criteria. We do not see where these biological and physical indicators have been identified in the Board's documents. While we see that there is discussion on biological indicators in the 2009 Staff Report (SWRCB, 2009, pages 46-48), we believe identifying specific biological indicators will help develop flow criteria and support the implementation of adaptive management.

The Service has suggested targeting an average of 0.50 (50%) survival through the Delta for salmon originating from the San Joaquin basin, to provide the needed survival through the Delta for meeting the CVPIA doubling goal within 30 years, given average survival in other aspects of the life-history (DOI, 2011, page 18). Similar goals and estimates of smolt survival should be developed for the Sacramento River and the San Francisco Bay. Also, catch per cubic meter at Chipps Island and near Sacramento, and abundance estimates at Mossdale provide historic measurement of juvenile production that can be used as monitoring metrics and can be compared to future indices. However, the Board should not assume present monitoring will continue given that current monitoring programs are not fully funded.

The Service supports the Board's management objectives to;

1. Combine flow needs comprehensively,
2. Establish mechanisms to evaluate Delta environmental conditions, periodically review underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted,
3. Review new research and monitoring to modify biological objectives and flow criteria,
4. Not recommend overly complex flow criteria as not to infer a greater understanding of specific numeric flow criteria than available science supports.

But we suggest the Board further specify how these management objectives will be achieved.

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