State of California
The Resources Agency

DEPARTMENT OF FISH AND GAME

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE LONGFIN SMELT (*Spirinchus thaleichthys*) IN CALIFORNIA

January 23, 2009

TABLE OF CONTENTS

Report to the Fish and Game Commission: A Status Review of the Longfin Smelt (*Spirinchus thaleichthys*) in California

EXECUTIVE SUMMARY

Background

Pursuant to the California Endangered Species Act (CESA) (Fish and Game Code §§ 2050 et seq.), this report reviews the best scientific evidence available regarding the longfin smelt (*Spirinchus thaleichthys*) and makes recommendations to the California Fish and Game Commission (Commission) regarding its management, recovery, and listing under CESA.

On August 14, 2007, the Commission received a petition from The Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council to use emergency rulemaking to list longfin smelt as an Endangered Species under CESA.

On August 21, 2007, the Commission referred the petition to the Department of Fish and Game (Department) for evaluation.

On September 12, 2007, the Department responded to the Commission's referral with a letter indicating that while the petitioned rationale for emergency rulemaking was insufficient, the petition was complete and a report on the Department's evaluation of the petition was being prepared.

On October 11, 2007, the Commission denied the request for an emergency action but continued under a standard rulemaking procedure.

On February 7, 2008, the Commission accepted the petition for consideration and noticed its action in the February 29, 2008 California Regulatory Notice Register. (Fish & G. Code § 2074.2.)

CESA requires that within twelve months of the publication of the notice of a petition's acceptance for consideration the Department shall provide a written report regarding the status of the species. (Fish & G. Code § 2074.6.)

Findings

The longfin smelt is a small fish native to California's San Francisco Estuary and some other estuaries along the Northeast Pacific coast. Longfin smelt occur in the ocean, bays, estuaries, and rivers. This species feeds exclusively on zooplankton, spawns in freshwater, and has a predominantly 2-year life cycle.

Very little information on longfin smelt abundance in California is available, except for the San Francisco Estuary population. However, the San Francisco Estuary population clearly contains the most individuals in California. Survey data indicates that the population of longfin smelt in the San Francisco Estuary has declined substantially since the 1980s and that other populations in California may have declined similarly. As demonstrated by the following pertinent milestones, the status of longfin smelt has been a concern for decades:

1. Longfin smelt range-wide was proposed for listing under the Federal Endangered Species Act in 1992.

2. The Department classified longfin smelt as a Species of Special Concern by 1995.

3. Moyle et al. (1995) rated longfin smelt as "endangered", citing these threats in priority order: Reduction in outflows, entrainment[1], climatic variation, toxic substances, predation, and introduced species.

4. The American Fisheries Society classified longfin smelt in California as "threatened". They cited habitat destruction and alteration of spawning and nursery areas, dams, logging, and agricultural water diversions (Musick 2000).

The Department finds that the longfin smelt throughout California should be listed as a Threatened species based on Section 670.1(i) of Title 14 of the California Code of Regulations and Section 2074.6 of the Fish and Game Code. The Department's finding is based in large part on the following aspects of the longfin smelt population in the San Francisco Estuary:

1. Longfin smelt abundance has declined substantially and in relation to beneficial freshwater outflow.

2. Low numbers of spawning longfin smelt may result in reproductive failure and increase the likelihood that a catastrophic event could severely affect the population.

3. Longfin smelt are entrained by and lost[2] at water diversions — including diversions for cooling of power plants and diversions operated by the State Water Project, Central Valley Project, municipal entities, and for agricultural and recreational purposes. Continuing entrainment and loss is[3] a threat to longfin smelt recovery.

4. Operations of the State Water Project and the Central Valley Project alter the character and position of the upper estuary salinity gradient. When these operations increase Suisun Bay salinity during the longfin smelt spawning migration, longfin smelt distribution shifts upstream where they are subject to entrainment and loss by diversions. Continuing increased Suisun Bay salinity coupled with increased entrainment and loss at diversions is a threat to longfin smelt recovery.

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[1] Entrainment is the involuntary movement of fish by flowing water. For example, a fish is entrained if it is sucked into a pipe that diverts river flow for irrigation.
[2] Throughout this report, loss is synonymous with death.
[3] A factor *is a threat* to longfin smelt if longfin smelt loss or collection has been documented. A factor *may be a threat* to longfin smelt if it is likely to cause loss or to suppress an increase in longfin smelt abundance.

5. Longfin smelt habitat — including prevalence of exotic species and food items — has changed and the change may be a threat to longfin smelt recovery.

6. A small fraction (14 of 822) of water samples in Suisun Bay, Suisun Marsh and the Sacramento-San Joaquin Delta were acutely toxic to standard aquatic test organisms in laboratory trials. Longfin smelt were present in the vicinity of those locations and may have been adversely affected by toxicity of the water. Continuing water pollution may be a threat to longfin smelt recovery.

7. Managed and other fishes prey on longfin smelt. Piscivorous striped bass, halibut, salmonids, and managed warm-water fishes (e.g., largemouth bass) co-occur — to varying degrees in space and time — with longfin smelt. Piscivorous striped bass number in the millions and are known to eat longfin smelt, salmonids, striped bass, and many other pelagic fishes. Largemouth bass are abundant, their numbers have increased since the 1980s, and they are known to eat many fishes. Little is known about the current populations of other warm-water fishes, but as a group they are considered abundant. Continuing predation on longfin smelt by managed fishes is a threat to longfin smelt recovery.

8. Little is known about the impacts to longfin smelt attributable to dredging and sand mining in the San Francisco Estuary, but operations conducted in freshwater could entrain adults, eggs, and larvae during winter spawning and incubation while operations in saltwater could entrain juveniles and adults in summer and fall. Loss of longfin smelt to dredging and sand mining operations may be a threat to longfin smelt recovery.

9. A commercial bait fishery for bay shrimp in the San Francisco Estuary takes longfin smelt as by-catch. Historical assessments of juvenile striped bass mortality in the fishery and longfin smelt catches by the fishery suggest that the fishery is a threat to longfin smelt recovery.

10. Longfin smelt are collected from the San Francisco Estuary during research and monitoring to assess threats to their conservation by adverse impacts attributable to development projects. Loss of longfin smelt to scientific collections is a threat to longfin smelt recovery.

Recommendations

<u>Petition Action</u>

1. The Commission should find that classification of longfin smelt as Threatened is warranted.

2. The Commission should publish notice of its intent to amend Title 14 CCR 670.5 to list longfin smelt as Threatened.

<u>Management/Recovery Measures</u>

The Department's objective is the protection of a sufficient number of longfin smelt to make its long-term survival and recovery in its native habitat and range a certainty.

Because there is not yet a quantitative basis for estimating the benefits of any given action(s), attempting to assure longfin smelt persistence and recovery during the foreseeable future will involve implementing management measures and evaluating their success empirically.

The Department believes the following actions — which are not listed in priority order and are not all under the Department's authority — would have population-level benefits for longfin smelt:

- Reduce pollution of estuaries by chemicals harmful to longfin smelt and their food web.

- Reduce entrainment and loss of longfin smelt at water diversions — including diversions for cooling of power plants and diversions operated by the State Water Project, Central Valley Project, municipal entities, and for agricultural and recreational purposes. For example, moving State Water Project and the Central Valley Project diversions from the south Sacramento-San Joaquin Delta to the north Sacramento-San Joaquin Delta would reduce loss of longfin smelt to entrainment and loss.

- Reduce entrainment and loss of adult, juvenile, and larval longfin smelt to dredging.

- Reduce predation on longfin smelt by managed non-native fishes.

- Improve and/or expand habitat for longfin smelt. For example, this could include increasing average December-May Sacramento-San Joaquin Delta outflow, restoring intertidal or shallow subtidal habitat, and/or improving habitat in the flood plain or in open water.

- Modify commercial fishery regulations to reduce loss associated with by-catch of longfin smelt.

- Adaptively manage the scientific collection of longfin smelt.

Report to the Fish and Game Commission: A Status Review of the Longfin Smelt (*Spirinchus thaleichthys*) in California

INTRODUCTION

PETITION HISTORY

On August 14, 2007, the Fish and Game Commission (Commission) received a petition from The Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council to use emergency rulemaking to list longfin smelt (*Spirinchus thaleichthys*) as an endangered species under the California Endangered Species Act (CESA).

On August 21, 2007, the Commission referred the petition to the Department of Fish and Game (Department) for evaluation.

On September 12, 2007, the Department responded to the Commission's referral with a letter indicating that the while the petitioned rationale for emergency rulemaking was insufficient, the petition was complete and a report on the Department's evaluation of the petition was being prepared.

On October 11, 2007, the Commission denied the request for an emergency action but continued under a standard rulemaking procedure.

On February 7, 2008, the Commission accepted the petition for consideration and noticed their action in the February 29, 2008 California Regulatory Notice Register. (Fish & G. Code § 2074.2.)

DEPARTMENT REVIEW

This report contains the results of the Department's review and the Department's recommendation to the Commission, based on the best scientific information available, as to whether the petitioned action is warranted. It also identifies habitat that may be essential to the continued existence of the species and suggests prudent management activities and other recovery actions.

The Department has contacted affected and interested parties, invited comment on the petition, and requested any additional scientific information that may be available, as required under Section 2074.4, Fish and Game Code (Appendices B and C).

LIFE HISTORY

DESCRIPTION

The longfin smelt found in California is a euryhaline (i.e., able to live in waters with a wide variation in salinity) and anadromous member of the family Osmeridae. It typically inhabits open-water channels and bays in salinities ranging from freshwater to seawater (Moyle 2002). Longfin smelt have a predominantly two-year life cycle reaching lengths of 90-124 mm fork length (FL), though some live a third year and reach maximum lengths of about 140-150 mm (Baxter 1999, Moyle 2002). Longfin smelt are translucent silver with an olive-to-grayish-brown back and pinkish iridescence laterally.

Other true smelts co-occur with longfin smelt: (1) The night smelt (*Spirinchus starksi*), the whitebait smelt (*Allosmerus elongates*) and the surf smelt (*Hypomesus pretiosus*) are uncommon marine transients; (2) the delta smelt (*Hypomesus transpacificus*) is a once-common upper-San Francisco Estuary native; and (3) the wakasagi (*Hypomesus nipponensis*) is an introduced species invading the upper San Francisco Estuary from freshwater (Baxter 1999; Moyle 2002).

Longfin smelt are distinguished from other Osmerids in California by characteristics including their: (1) long pectoral fins, which typically extend 84%[4] or more of the distance to the base of their pelvic fins, (2) long maxillary bones, which extend past mid-eye, almost to the posterior margin of the eye, (3) lack of striations (rarely 1-2 present) on the gill cover, (4) lack of a complete lateral line or of large canine teeth on vomer; and (5) lower jaw extends anterior of the upper jaw (McAllister 1963, Miller and Lea 1972, Moyle 2002).

For further taxonomic information, consult Miller and Lea (1972) and Moyle (2002). Wang (1986, 1991) provides distinguishing characteristics for larvae.

TAXONOMY

Historically, the longfin smelt was split into two species: The Sacramento smelt (*S. thaleichthys*) for those in the San Francisco Estuary and the longfin smelt (*S. dilatus*) for all other populations (Shultz and Chapman 1934). McAllister (1963) united the two species, contending that meristic characters distinguishing Sacramento smelt from longfin smelt represented the southern limit on a north-south cline rather than an independent set. Nonetheless, the common name Sacramento smelt continued in local usage through the 1970s.

Electrophoretic analysis (Stanley et al. 1995) confirmed McAllister's lumping of the Sacramento smelt and longfin smelt by showing only minor differences in allele frequencies between the San Francisco Estuary population and the Lake Washington (Washington State) population. Stanley et al. (1995) concluded that the differences in gene frequency were significant and probably resulted from restricted gene flow, and suggested (as did Moyle 2002) that the San Francisco Estuary population should be treated as a discrete entity.

The United States Fish and Wildlife Service (Federal Register: May 6, 2008; Volume 73, Number 88) stated that substantial scientific or commercial information indicate "…that the San Francisco Bay-Delta population of longfin smelt may be a DPS [distinct population segment] based on its separation from other populations of longfin smelt, the unique setting in which it

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[4] The Department made no effort to apply 'significant figure' rules for the myriad numbers included in this report. Applying such rules was infeasible because there are many numbers and many of those numbers are from the published works of others. Although some numbers suggest too-high precision, the Department's analysis recognizes and addresses associated uncertainty.

occurs, and potential genetic differences between the San Francisco Bay-Delta population and other longfin smelt populations…" and "…thus may be a listable entity under the [Federal Endangered Species] Act..."

RANGE

Scattered populations of longfin smelt occur along the Pacific coast of North America from Alaska (McAllister 1963) to the San Francisco Estuary (Moyle 2002) (Figure 1). Although individual fish have been caught as far south as Monterey Bay (Robert Lea, personal communication, 1994), there is no evidence of spawning south of the San Francisco Estuary.

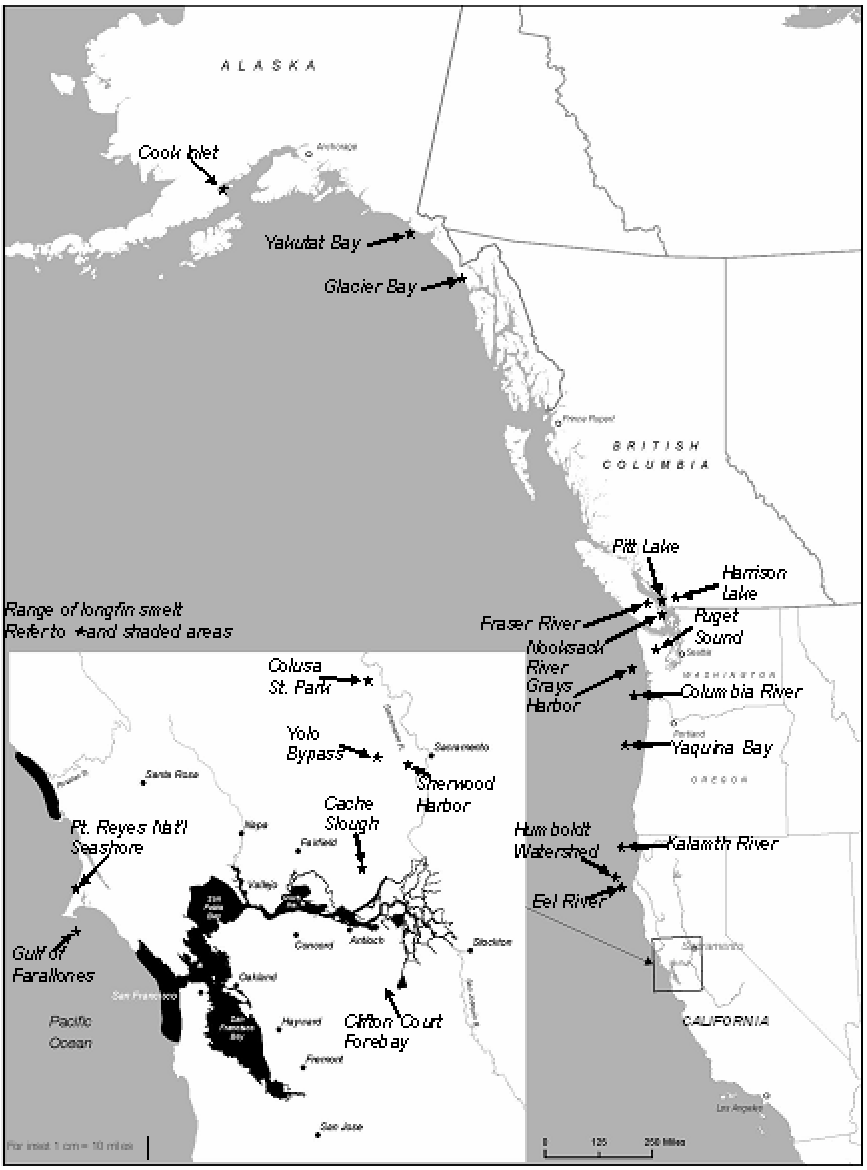

Figure 1. Geographic distribution of longfin smelt.

The San Francisco Estuary supports the southern-most longfin smelt population and the largest population in California (Moyle 2002). Longfin smelt inhabit the entire San Francisco Estuary

(Baxter 1999; Rosenfield and Baxter 2007), including portions of the Napa River (Stillwater Sciences 2006), Suisun and Napa marshes (Meng and Matern 2001; Matern et al. 2002; DFG unpublished data, Napa and Suisun Marsh Sampling 1975-1979), and the Sacramento-San Joaquin Delta (Radtke 1966; Dege and Brown 2004).

The following descriptions of longfin smelt catch or populations from Alaska southward present the extent of our discovery and analysis regarding occurrence of longfin smelt outside the San Francisco Estuary.

Alaska

Cook Inlet **—** Cook Inlet is west of Prince William Sound at approximately the same latitude. During the 1990s longfin smelt were commonly found in the northern and southern regions of the lower Cook Inlet (Moulton 1997; Abookire et al. 2000; Abookire and Piatt 2005).

Yakutat Bay and Glacier Bay — Longfin smelt were common within the boundaries of Wrangell-St Elias National Park (2000-2001) and present in Glacier Bay National Park, both located in central and southeast Alaska (Arimitsu et al. 2003).

British Columbia

Harrison Lake and Pitt Lake — Longfin smelt were collected from Harrison Lake in the 1950s and reported from Pitt Lake (Dryfoos 1965; Chigbu and Sibley 1994).

Fraser River — Using similar methods and with similar findings, Richardson et al. (2000) collected longfin smelt in 1993-1994 and Northcote (Northcote et al. 1978, cited in Richardson et al. 2000) collected longfin smelt in 1972-1973.

Washington

Puget Sound — Moulton and Penttila (2000) summarized historical records of longfin smelt collected in the San Juan County region of Puget Sound.

Nooksack River — Longfin smelt were present and easily captured in the early 1960s (Dryfoos 1965).

Grays Harbor — Longfin smelt appeared to be common in Grays Harbor (United States Army Corps of Engineers 2000 and reference therein).

Oregon

Columbia River — Longfin smelt were common as larvae, juveniles, and adults in the lower river (Haertel and Osterberg 1967; Misitano 1977; Bottom et al. 1984). Longfin smelt were uncommon in recent sampling with beach seines (Curtis Roegner, personal communication, January 2008).

Coastal Rivers — No longfin smelt were collected in beach seines from 2003-2005 by Oregon Department of Fish and Wildlife in the Coquille, Siuslaw, Alsea, Yaquina, Salmon, and Nestucca estuaries (Trevan Cornwell, personal communication, January 2008).

California

Klamath River Watershed — Longfin smelt were common in the lower Klamath River during 1979-1989 (Kisanuki et al. 1991). In November 1992, two adults (116 and 124 mm FL) were collected in the Klamath Estuary. In March 2001, one adult of about 150mm FL was collected and verified from a photograph.

Humboldt Bay Watershed — From the 1960s through the early 1980s, longfin smelt were common within and outside Humboldt Bay and probably spawned in tributary watersheds.

Larvae were collected from the main bay and sloughs (Eldridge and Bryan 1972; Chamberlin 1988; Barnhart et al. 1992; Chamberlin and Barnhart 1993).

Beginning in 1960 and continuing through fall 1969, HSU professors and students sometimes collected longfin smelt with otter trawls inside and outside Humboldt Bay. Outside Humboldt Bay, sampling occurred along the Samoa Peninsula from just north of the bay entrance and for several miles north along the coast.

Mike Prall (DFG, personal communication, August 2008) reported the following about catches of longfin smelt inside Humbolt Bay during the mid-1990s:

> From our collections four longfin smelt were captured in three separate trawls over sparse eelgrass at station one on 19 January 1995. They ranged in size from 55mm to 69mm SL. In addition, on 30 September 1995, six longfin smelt ranging in size from 95mm to 123mm SL, were captured trawling over the Army Corps of Engineers dredge disposal site near the mouth of Humboldt Bay (station six) at 14m depth. Two of these specimens were female (115mm and 123mm SL) with well developed ovaries.

Small numbers of adult and juvenile longfin smelt were captured in recent years inside Humboldt Bay proper and in tributary sloughs (Cole 2004; Pinnix et al. 2005; Mike Wallace personal communication, 2007).

Small-but-consistent catches of a few dozen longfin smelt occurred during annual collections around a dredge disposal site about two miles offshore of Humboldt Bay (Tim Mulligan, Humboldt State University, 2008, reported to J. Milliken, USFWS)

Eel River Watershed — The Eel River may have had a spawning run and recent evidence suggests that longfin smelt at least periodically inhabit the river.

On December 1, 1955, twenty-three (23) longfin smelt were collected from a fyke trap fished 4.5 miles from the river mouth (Jensen 1957; HSU Fish Collection # 81-023).

Moyle (2002) reported longfin smelt from the Van Duzen River. A collection of longfin smelt from the Van Duzen River by a United States Fish and Wildlife Service beach seine crew from November 30, 1956 is maintained by the Humboldt State University (Fish Collection # 89-198).

Pucket (1977) collected 16 longfin smelt from the lower Eel River during fall and winter of 1974 and made a non-specific note of having observed spawning.

One adult longfin smelt was collected from the Eel River Estuary in December 1994 and as many as 40 longfin smelt were collected from the lower Eel River in Spring 1995 (Steve Cannata, DFG personal communication, August 2008).

Russian River watershed — Small numbers of longfin smelt have been caught in otter trawls fished in the Russian River Estuary (Jana Milliken, personal communication, June 2008).

No longfin smelt were caught from 2003-2007 in the Russian River (i.e., upstream of the estuary; Jana Milliken, personal communication, June 2008).

Point Reyes National Seashore — One longfin smelt was captured in Abbotts Lagoon in 1999 (Saiki and Martin 2001).

Gulf of the Farallones — In the 1980s and 1990s, longfin smelt were occasionally identified from the catch of National Marine Fisheries Service rockfish-centric midwater trawl surveys and the City and County of San Francisco (CCSF) regularly identified longfin smelt from catch of otter trawl surveys conducted in the vicinity of San Francisco's sewage outfall.

The National Marine Fisheries Service identified longfin smelt in trawls from 1984, 1994, 1996, and 2001 (Osmerids were not identified to species in numerous tows), before the survey changed in 2003 and Osmerids were no longer identified to species (Keith Sakuma, personal communication, September 2003). Most longfin smelt catches occurred near-shore north of the Golden Gate from the Marin headlands to the mouth of Tomales Bay.

From October 1982-June 1984, CCSF periodically used otter trawls to collect fish near their sewage outfall several miles south of the Golden Gate and captured longfin smelt almost every sampling month. Beginning in fall 1984, CCSF stopped attempting to identify Osmerids. From March 1994-December 1996, Osmerids from CCSF sampling were sent to DFG Stockton for identification and enumeration. At least one longfin smelt was captured at each of the 11 sampling intervals where catch was identified except June 1984. Two longfin smelt age classes often inhabited the open coast at the same time. In 5 of 11 sampling intervals two longfin smelt age groups were documented based on length analyses. In the most-recent sampling year where longfin smelt were identified (1996) longfin smelt catch per trawl ranged from about 23 to 47 in spring and fall sampling.

DISTRIBUTION

In the San Francisco Estuary, the longfin smelt is euryhaline (Wang 1986; Moyle 2002) and during its life cycle uses the entire estuary from the freshwater Sacramento-San Joaquin Delta downstream to South San Francisco Bay and out into coastal marine waters (Baxter 1999; Moyle 2002; Rosenfield and Baxter 2007). From its spawning grounds in the upper estuary, longfin smelt move downstream through a combination of passive transport and migration (Baxter 1999; Dege and Brown 2004; Rosenfield and Baxter 2007). Geographic and age-specific detail on distribution of longfin smelt in the San Francisco Estuary follows:

General upstream distribution

- Longfin smelt have been collected in the Cache Slough complex (including the lower Deepwater Ship Channel and Miner Slough), the Yolo Bypass, the lower Sacramento River to almost the city of Sacramento, the Mokelumne River to Hog Slough, within the San Joaquin River to the vicinity of Turner Cut and Rough-and-Ready Island, and in the South Sacramento-San Joaquin Delta.
- Near their upstream limits, longfin smelt catches were more frequent and more numerous during winters and springs with low and moderate river flows.

Upstream distribution based on collections of juveniles and adults

- Juvenile and adult longfin smelt were not common within the Sacramento-San Joaquin Delta during summer and were not collected during fall (Radtke 1966).
- During winter and spring, Radtke (1966) found adult-sized longfin smelt in his most-upstream locations: 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.
- Schaffter (1980) trawled extensively in the Sacramento River between Clarksburg Bend and Walnut Grove during 1973-1974. He only collected longfin smelt during low flows in 1973 (nine adults in March-April and three juveniles in June-July).
- The United States Fish and Wildlife Service has collected longfin smelt from Isleton on the Sacramento River (Table 1). Collection of longfin smelt occurred to Colusa State Park (river mile 144) in 1986. Longfin smelt were collected at Elkhorn (river mile 71, above the American River confluence) and Sherwood Harbor.

Upstream distribution based on collection of larvae

The following information on the upstream distribution of longfin smelt were determined or inferred primarily from unpublished data on collections of larvae, juveniles, and adults.

- The upstream distribution of longfin smelt appeared to be influenced by freshwater flow such that fish were found farther upstream in low- and moderate-outflow years than during high-outflow years, probably in part due to rapid downstream dispersal in high-outflow years.
- The longfin smelt was among the first fishes to spawn in the calendar year and historical collections of larval fish (which initially targeted striped bass) started after what the Department later learned is the January-March period of high longfin smelt larva abundance.
- Wang (1991) reported that from 1989-1990 longfin smelt larvae were regularly collected upstream to Rio Vista on the Sacramento River and to Medford Island on the San Joaquin River during April-July.
- From 1992-1994, sampling for larval fish started mid-February and sampled more-extensively within the Sacramento-San Joaquin Delta. Longfin smelt larvae were

detected multiple times per year in Barker Slough, Lindsey Slough, Cache Slough and Steamboat Slough in the north Sacramento-San Joaquin Delta, and in the lower Sacramento River near Georgiana Slough. Longfin smelt were collected uncommonly farther upstream in the Sacramento River. In the San Joaquin River, larvae were detected in the vicinity of Medford Island almost annually and repeatedly within years. Larvae were detected annually and repeatedly in the vicinity of Prisoners Point.

- In 2008, the *20mm Survey* sampled for larvae in Cache Slough, Lindsey Slough, Sacramento Deepwater Ship Channel, and Miner Slough. Small numbers of longfin smelt larvae or juveniles were collected at every station and during every sampling period in spring (e.g., http://www.delta.dfg.ca.gov/data/20mm/CPUE_map3.asp).

General larval distribution

- Winter-spring outflows transport larvae — hatched primarily January through March — downstream to Suisun Bay, San Pablo Bay, and San Francisco Bay (Baxter 1999).
- Until they reach about 12-15mm, longfin smelt larvae are concentrated in the upper 1/3 of the water column (DFG 1992; Bennett et al. 2002). They later descend and tend to occupy the lower 2/3 of the water column (DFG 1992; Bennett et al. 2002).
- Vertical migrations over tidal cycles were observed for longfin smelt larvae >10mm long (Bennett et al. 2002) and not in others (DFG 1992; Bennett et al. 2002).
- Increased freshwater outflow resulted in increased downstream distribution of longfin smelt larvae (DFG 1992; Baxter 1999; Dege and Brown 2004).
- Collections of longfin smelt showed a strong positive relationship between outflow and downstream distribution, and extreme flows transported larvae into central and south San Francisco Bay (Baxter 1999).
- Dege and Brown (2004) found that longfin smelt <20mm long were distributed 20-30 km farther downstream in high-outflow years (average outflow greater than 1,500 m^3/s) than in low-outflow years (average outflow less than 360 m^3/s).
- During high-outflow periods, most larvae were probably transported out of the Sacramento-San Joaquin Delta (Baxter 1999).
- During a brief period of intensive Sacramento-San Joaquin Delta ichthyoplankton sampling February-July in 1991-1995, longfin smelt larvae were uncommon (31 larvae from 2% of samples; Feyrer 2004).
- Sampling from March-July by the *20mm Survey* regularly detected low numbers of longfin smelt larvae and small juveniles in the south Sacramento-San Joaquin Delta (e.g., http://www.delta.dfg.ca.gov/data/20mm/CPUE_map3.asp).

Juvenile spatial distribution

- The distributions of small juveniles and larvae were initially similar, but over time juveniles were found farther downstream (Baxter 1999; Dege and Brown 2004). The difference in distribution between the two life stages probably resulted from increased mobility with growth.
- In low-outflow years approximately half of the longfin smelt larvae and early juveniles may have remained for weeks within the Sacramento-San Joaquin Delta (Dege and Brown 2004), where model simulations indicate they are vulnerable to entrainment into State Water Project, Central Valley Project, and other diversions (Kimmerer and Nobriga 2008).

Table 1. Longfin smelt catches by the United States Fish and Wildlife Service during surveys in the Sacramento River and San Joaquin River, 1976-2007. Catches during December were combined with catches from January and February of the subsequent year and labeled by that year. The numerals within the station name designate the river-mile sampled. Collections were made using midwater trawls (M) and beach seines (S).

Sacramento River								
Gear	Station	Location	Year	Catch	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
M	SR043W	Clarksburg	1977	1		1		
S	SR017E	Isleton	1979	3		3		
S	SR071E	Elkhorn	1984	7	7			
S	SR144W	Colusa State Park	1986	4		4		
S	SR071E	Elkhorn	1987	1		1		
M	SR055M	Sherwood Harbor	1988	1		1		
M	SR035M	Courtland	1990	1		1		
M	SR055M	Sherwood Harbor	1993	10	10			
S	SR060E	Discovery Park	1993	1				1
S	SR071E	Elkhorn	1993	1				
S	SR090W	Knights Landing	1993	2			2	
S	SR043W	Clarksburg	1994	1	1			
M	SR055X	Sherwood Harbor	1994	2	2			
S	SR071E	Elkhorn	1994	4	4			
K	SR055M	Sherwood Harbor	1995	1	1			
S	SR024E	Koket	1996	6		6		
K	SR055M	Sherwood Harbor	1998	1	1			
S	SR049E	Garcia Bend	1998	1				1
S	SR017E	Isleton	2002	1		1		
S	SR024E	Koket	2002	1		1		
K	SR055M	Sherwood Harbor	2002	8	8			
S	SR060E	Discovery Park	2002	1		1		
K	SR055M	Sherwood Harbor	2004	1	1			
San Joaquin River								
S	SJ051E	Dos Reis	1996	1		1		

AGE AND GROWTH

Longfin smelt larvae hatched during the coldest water temperatures of the year (Baxter 1999). Recently-hatched yolk-sac larvae became abundant in January, typically peaked in February, and declined March-May (Figure 2).

Large larvae and small juveniles grew an estimated 0.19 mm/day (range 0.12 – 0.23 mm/day; Baxter unpublished apparent growth from *20mm Survey* data). Analysis of otoliths from younger larvae suggested a growth rate of 0.14 mm/day (i.e., about 90 days to reach 20 mm long; James Hobbs personal communication, 2008). This difference might be expected for the following two reasons: (1) apparent growth measurements were based on larger fish that probably grew at a faster rate and (2) apparent growth does not account for slower-growing fish that suffer higher mortality. The 0.14mm per day winter growth rate is supported by the first appearance of juveniles (≥20mm long) approximately 90 days after first hatching in December (Figure 2).

The longfin smelt has a predominantly 2-year life cycle. Based on length frequency analyses, longfin smelt reached 50-86 mm FL at the end of their first year, 87-123 mm FL by the end of their second year and putative age-3 fish ranged in size from 124-140 mm (Baxter 1999).

REPRODUCTION

Most longfin smelt are mature at the end of their second year and some are mature at the end of their first and third years (Dryfoos 1965; Moulton 1974; Moyle 2002; Paulinus Chigbu, personal communication, 2007; DFG unpublished).

To estimate size and age of maturity, the Department examined all longfin smelt ≥70mm FL and a few smaller individuals caught during trawling at Chipps Island in December 1993 and January 1994 (n=374). The smallest mature female was 64 mm long and the smallest mature male was 70 mm long, most fish were mature after surpassing 80 mm long, and all were mature by 90 mm long (DFG unpublished). Lower limits of 87 mm long in December and 90 mm long in January distinguished fish at the end of their second year from those at the end of their first year (Baxter 1999). Males matured at slightly larger sizes than females (DFG unpublished).

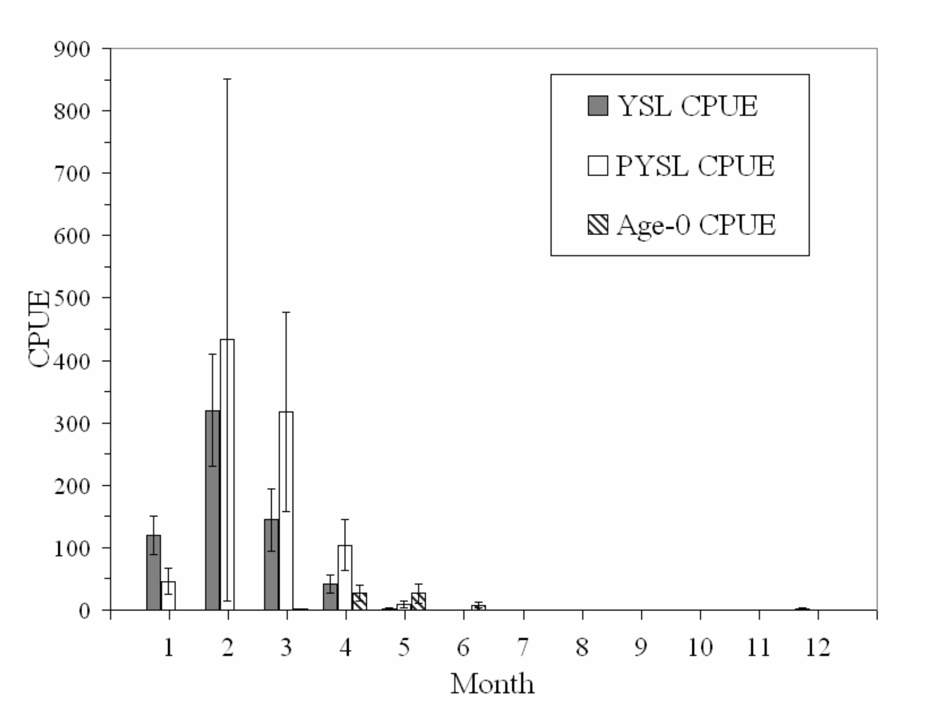

Figure 2. Monthly average catch per unit effort (per 1000 m3 filtered) and 95% confidence intervals for longfin smelt yolk-sac larvae (yolksac present; YSL CPUE), post-yolk-sac larvae (no yolk and <20mm long: PYSL CPUE) and juveniles (≥ 20mm long: Age-0 CPUE) from *Bay Study Survey* larvae collections, 1981-1988.

Longfin smelt fecundity increased exponentially with female length and ranged from about 1900 eggs in a 73 mm female to about 18000 eggs in a 120 mm female (Figure 3). This relationship is similar to that found by Chigbu and Sibley (1994).

In Lake Washington, mature adults congregated at creek mouths and staged short (≤1000 m) spawning migrations into tributaries at night (Moulton 1974; Martz et al. 1996; Sibley and Brocksmith 1995). Spawning in Lake Washington tributaries took place primarily over sand in low-velocity river habitats (<0.2 m/s; Martz et al. 1996; Sibley and Brocksmith 1995).

In laboratory experiments, more eggs were released onto sand (approximately 94%) than gravel (approximately 6%) (Moulton 1974; Martz et al. 1996; Sibley and Brocksmith 1995). High river flows during egg incubation were associated with poor recruitment, whereas increased river flows later in the season — during the hatching period — were associated with greater recruitment (Chigbu 2000).

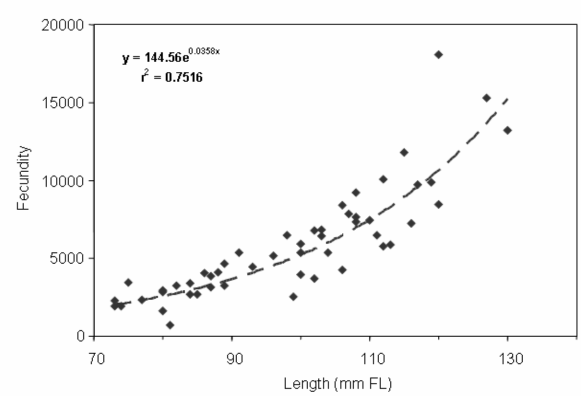

Figure 3. Longfin smelt fecundity-length (mm FL) relationship for females captured from March 1992 to January 1994 by *Bay Study Survey* midwater and otter trawls, *Fall Midwater Trawl Survey* and *Chipps Island Trawl Survey* in the San Francisco Estuary. As an approximation, fish less than about 90 mm were destined to spawn at the end of their first year; fish from 90mm to less that 124mm at the end of their second year; and larger fish at the end of their third year.

Spawning in California has not been detailed, but is inferred from the presence of newly-hatched larvae. Spawning takes place during late fall, winter, spring, and (rarely) early summer (Wang 1986; Baxter 1999; Moyle 2002). Assuming a 25-day incubation period (Paulinus Chigbu, personal communication, 2007) and based on the presence of yolk-sac larvae, longfin smelt probably spawned November-April. Spawning started when water temperature dropped below 16ºC and became consistent when water temperature dropped below 13ºC (DFG unpublished data).

Spawning probably takes place in freshwater (Wang 1986; Moyle 2002). Mature fish migrated upstream to Suisun Bay and the western Sacramento-San Joaquin Delta in preparation for spawning (Rosenfield and Baxter 2007). December-March catches showed that all ages of longfin smelt were congregated in low salinity near the 2% bottom salinity (grams of salt per kilogram of water) position known as X2 (Jassby et al. 1995) and showed that the congregations moved seasonally and annually with shifting X2. Fish upstream of X2 were probably adults on their spawning run.

Incubation time decreases with increasing water temperature. Modal hatching times in Lake Washington tributaries were 40 days at 7°C (range 37-47 days; Dryfoos 1965), 29 days at 8-9.5°C (Sibley and Brocksmith 1995), and 25 days at 9.6-10.6°C (Paulinus Chigbu, personal communication, 2007).

DIET AND FEEDING

Longfin smelt first begin feeding on copepods and cladocerans. With subsequent growth their diet expands to include mysids and amphipods among a variety of lesser food items (Dryfoos 1965; Chigbu and Sibley 1998a and 1998b; Hobbs et al. 2006; Slater 2008).

Chigbu and Sibley (1998b) observed that mysids dominated the diets of age-1+ longfin smelt; amphipods, copepods and daphnia contributed substantially; and fish made up a small portion. Older-juvenile and adult longfin smelt sometimes fed strongly on mysids and Lake Washington's mysid population dynamics have been controlled by longfin smelt predation (Chigbu and Sibley 1998a).

Longfin smelt fed throughout the day and into darkness (Dryfoos 1965; Hobbs et al. 2006). Successful nighttime feeding suggests turbidity would not hinder feeding, though whether increased turbidity enhances feeding — as it does with delta smelt (Baskerville-Bridges et al. 2004) — is not known. Longfin smelt larvae — and (thus) probably adults — have a well-developed olfactory organ that would facilitate location of food in turbid and dark environments (Foott and Stone 2008).

HABITAT REQUIREMENTS

Water quality must support longfin smelt growth, maturity and successful reproduction. Water quality in the Sacramento-San Joaquin Delta and Suisun Bay is most critical for the San Francisco Estuary population because those are longfin smelt incubation and early nursery areas. Longfin smelt larvae and small juveniles are rarely found in water warmer than 22ºC. Competent-swimming young juveniles disperse toward more-saline and deeper-water habitats. Mature longfin smelt require cool-to-cold (less than 16ºC) freshwater habitats for spawning.

Specific spawning locations are unknown in the San Francisco Estuary, but eggs were laid preferentially on sand substrate in low velocity habitats in Lake Washington tributaries.

Eggs, larvae, and small juveniles require adequate winter-spring river flows from spawning habitat and require suitable brackish-water rearing habitat.

ABUNDANCE TREND

Due to a paucity of information about the abundance trend of longfin smelt outside of the San Francisco Estuary, the following regards only the abundance trend within the Estuary.

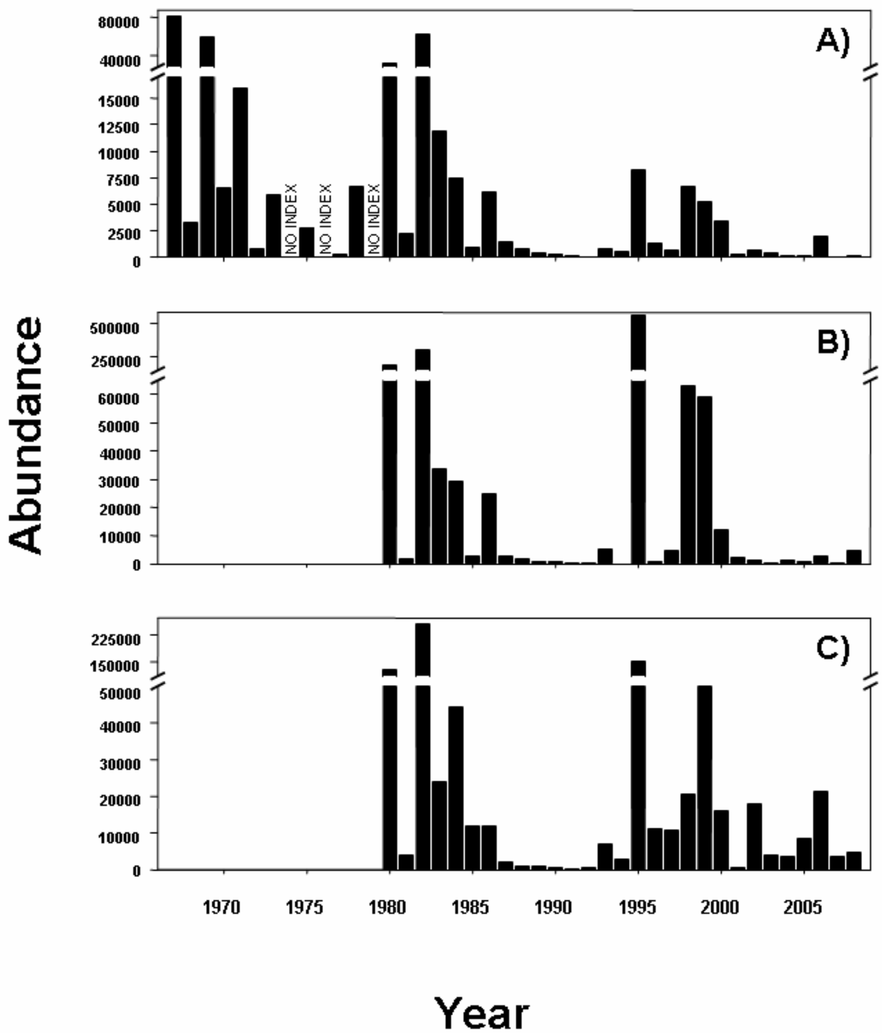

Figure 4. Annual relative abundance of longfin smelt: A) Fall Midwater Trawl Survey, all sizes, September-December, 1967-2008; B) Bay Study Survey otter trawl, age-0, May-October, 1980-2008; C) Bay Study Survey midwater trawl, age-0, May-October, 1980-2008.

The Department calculates three indices to monitor longfin smelt relative abundance trends in the San Francisco Estuary (Honey et al. 2004). All three of those indices have declined steeply since the late 1980s (Figure 4).

Longfin smelt abundance is primarily influenced by outflow during the egg and larva periods (Jassby et al. 1995; Baxter 1999; Kimmerer 2002b; Sommer et al. 2007). In addition, there is a weak stock-recruit relationship such that during periods with successive years of good outflows the combined effects of good survival and increasing stock size can increase recruit abundance by almost an order of magnitude per generation. Conversely, during successive years of low outflow, the first year-class in a series is bolstered/buffered by relatively high adult abundance (lots of eggs spawned from adults produced in a higher outflow year), but relatively poor larval then survival leads to declining recruitment and subsequently declining stock numbers.

The recent extremely-low indices of longfin smelt abundance (Figure 4), reduced age-1 to age-2 survival (Rosenfield and Baxter 2007), and reduced recruitment of young per unit of outflow (see below) suggest an increased risk of 'Allee effects' wherein small populations can suffer loss of genetic diversity, increased difficulty finding mates, and increased vulnerability to catastrophic mortality (Berec et al. 2006; Waldman et al. 1998). Because trends in the abundance indices probably parallel trends in risk attributable to Allee effects, the risks to longfin smelt due to this issue alone have rarely been greater.

POPULATION SIZE

Abundance is a very important population metric, because it speaks to the risks particular to small populations. The Department has not yet identified a valid means to estimate the range-wide absolute abundance of longfin smelt.

The United States Fish and Wildlife Service has made preliminary estimates of adult (>30 mm) longfin smelt abundance during fall months within the upper San Francisco Estuary (i.e., a subset of their geographic range) based upon *Fall Midwater Trawl Survey* data for the period 1975-2007. The estimates suggest that abundance peaked in the "tens of millions" in 1982 and declined to the "tens of thousands" by 2007 (Ken Newman, personal communication, December 2008).

The accuracy of the absolute estimates is disputable due to potential selection biases in the trawl, incomplete sampling of longfin smelt habitat and considerable month-to-month variation in catches. However, evidence for a decline of at least two orders of magnitude in the relative abundance of the fall upper estuary population between 1982 and the present is quite strong (Ken Newman, personal communication, January 2009).

FACTORS AFFECTING LONGFIN SMELT ABUNDANCE

Baxter et al. (2008) used a conceptual model to organize their discussion of the many factors related to the recent declines of four pelagic fishes of the upper estuary and the model provides a useful structure to describe the factors affecting longfin smelt abundance. The model recognizes that longfin smelt abundance is affected by multiple factors that can be categorized as: (1)

previous abundance; (2) habitat; (3) top-down; and (4) bottom-up. The following section is organized according to the conceptual model used in Baxter et al. (2008).

Much — but not all — of the information on factors affecting longfin smelt abundance was developed from the actual capture of longfin smelt during scientific sampling, which in some cases involves systematic sub-sampling of large samples. It is sometimes possible to estimate total loss of longfin smelt. Because total loss is more informative than the number of fish collected in sub-samples, the Department has made every feasible effort to describe total loss.

Total loss of longfin smelt at various intervals (e.g., daily, monthly, annually, or episodically) was estimated for bycatch from a commercial fishery, entrainment[5] at State Water Project and the Central Valley Project diversions in the south Sacramento-San Joaquin Delta, predation (on a proxy fish) by striped bass, and entrainment at two power plants in the Sacramento-San Joaquin Delta. With additional scientific or systematic sub-sampling, total loss could be estimated at other water diversions (including diversions for dredging), from additional predatory species, and at different intervals.

Statistical models can be used to estimate total loss from information that is not developed from the actual capture of longfin smelt during scientific or systematic sub-sampling. For example, loss of longfin smelt attributable to exposure to toxics would rarely result in the collection of sick or dead longfin smelt, but the population-level impact of toxic exposure can be modeled. Efforts to develop stage-based and individual-based models of population dynamics for longfin smelt are currently underway.

PREVIOUS ABUNDANCE

A 'stock-recruitment relationship' exists if an increased number of parents produce an increased number of offspring. A weak longfin smelt stock-recruit relationship is expected given the strong relationship between longfin smelt year-class strength and winter-spring outflow (Stevens and Miller 1983; California Department of Fish and Game 1992; Jassby et al. 1995; Kimmerer 2002b; Rosenfield and Baxter 2007; Sommer et al. 2007).

Longfin smelt exhibited a stock-recruitment relationship in which adult numbers accounted for about 24% of the variation in Log_{10} juvenile numbers (The Bay Institute et al. 2007). Similarly, Rosenfield and Baxter (2007) showed that age-2 longfin smelt abundance was a significant and positive function of age-1 longfin smelt abundance. This stage-to-stage relationship changed after the 1987-1992 drought, such that juveniles produced significantly fewer adults after the drought (Rosenfield and Baxter 2007).

HABITAT

Longfin smelt habitat is the suite of physical, chemical and biological attributes of the space they occupy (*sensu* Hayes et al. 1996). Longfin smelt habitat can be categorized as *spawning habitat* and *open-water habitat*.

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[5] Entrainment is the involuntary movement of fish by flowing water.

Spawning Habitat

Longfin smelt eggs are adhesive and larvae come only from eggs that were attached to suitable substrate (Wang 1986; Moyle 2002). Spawning by longfin smelt in California has not been detailed, but sand is likely its preferred substrate in California because sand was its preferred substrate for spawning in Lake Washington (Moulton 1974; Martz et al. 1996; Sibley and Brocksmith 1995). Field observations suggest that sand is widespread in the Sacramento-San Joaquin Delta, the lower Sacramento River, and the lower San Joaquin River. The supply of sand for longfin smelt spawning substrate may be reduced due to construction and/or operation of dams (Wright and Schoellhamer 2004), sand mining, and other activities that alter the flux of sediment.

During their almost month-long incubation period, eggs are attached to the bottom and thus in close proximity to any sediment-associated contaminants. Contaminants known from sediments in the Sacramento-San Joaquin Delta include mercury, selenium, legacy organochlorines (Anderson et al. 2007), and pyrethroid insecticides (Oros and Werner 2005). Pyrethroid insecticides are highly toxic to aquatic organisms and are increasingly used in both agricultural and urban applications (Oros and Werner 2005; Anderson et al. 2007).

Urban runoff and river flows carry sediment-bound pesticides into the San Francisco Estuary, and these pesticides are often concentrated in the "first flush" of suspended sediments (Bergamaschi et al. 2001) during winter. Among the sediments collected during the first flush of water-year 1996, Bergamaschi et al. (2001) detected an average of 10 pesticides in the 15 suspended-sediment samples they assayed, and found far fewer (3) dissolved pesticides.

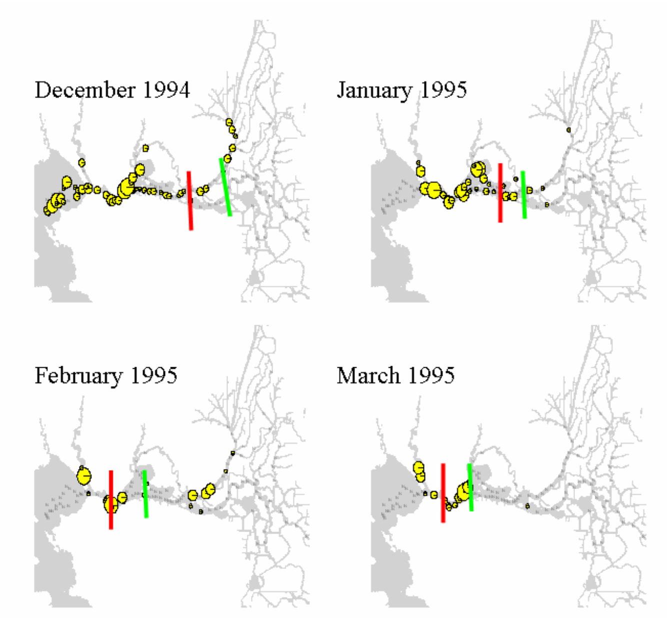

Figure 5. Longfin smelt relative catch (all ages) by sampling location and month from the *Fall Midwater Trawl Survey* and *Spring Midwater Trawl Survey*, December through March. Red lines depict the monthly average X2 position; green lines the position of X0.5 (freshwater). X0.5 = -(X2 position) *(Ln((31-(target salinity))/(515.67*(target salinity)))/-7)-1.5). All longfin smelt caught upstream of X0.5 were adults.

Changes in outflow immediately before and during longfin smelt spawning alter the geographical position of the boundary between fresh water and brackish water (Kimmerer and Monismith 1993) and alter the distribution of longfin smelt during spawning (Figure 5). Longfin smelt adults and larvae were found farthest upstream in years of low river flow. When longfin smelt distribution during spawning places them in the south Sacramento-San Joaquin Delta, they are at risk of loss to predation by an abundance of non-native piscivorous fishes (Brown and Michniuk 2007; DFG unpublished data) and loss to entrainment by the State Water Project, Central Valley Project, and other diversions.

Open Water Habitat

Open water with suitable salinity, turbidity, temperature, and levels of contaminants is a key

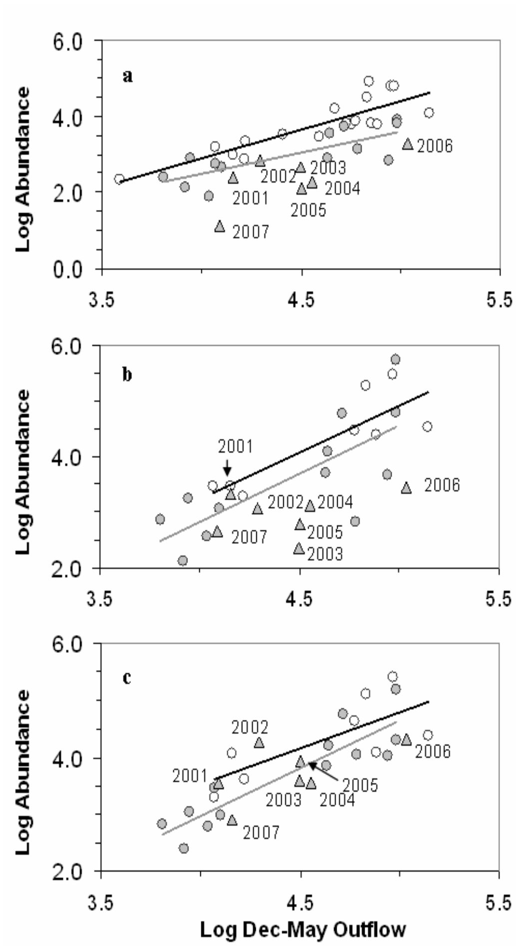

Figure 6. Longfin smelt annual abundance indices plotted on December through May average Sacramento-San Joaquin Delta outflow for a) *Fall Midwater Trawl* Survey (all ages); b) *Bay Study Survey* midwater trawl age-0; c) *Bay Study* Survey otter trawl age-0. Relationships depicted are pre-*Corbula amurensis* (1967-1987; open circles, black line) and post-*Corbula amurensis* (1988-2000; filled circles, grey line) and more recent years during the Pelagic Organism Decline (2001- 2007; grey triangles, no line).

habitat for longfin smelt, just as it is delta smelt, threadfin shad, and young striped bass. Abundance of all those species has declined over the long term and recently.

Freshwater outflow creates open-water rearing habitat (defined in part by salinity) and transports longfin smelt larvae to that habitat (DFG 1992; Dege and Brown 2004). Longfin smelt abundance has been positively related to Sacramento-San Joaquin Delta outflow during the winter-spring period (Stevens and Miller 1983; Jassby et al. 1995; Baxter 1999; Kimmerer 2002a and 2002b). The relationship first changed after the introduced clam *Corbula amurensis* took hold in 1987 (Kimmerer 2002b) and may have changed again when abundance failed to increase with increasing outflow 2003-2005 (Baxter et al. 2008). After 1987, longfin smelt produced fewer young per unit of outflow than they had previously (1988-2000; Figure 6). This relationship appears to have changed after 2002 because abundance continued to decline under previously-favorable outflow conditions (e.g., 2003-2005; Figure 6). The abundance change was most substantial to the upper-estuary rearing portion of the population and not detectable in the lower estuary (Figure 6).

Toxicity of open water habitat — attributable to pollution — has been demonstrated and may still be an issue (Werner et al. 2008). Baxter et al. (2008) reported findings about water toxicity as follows:

> Larval delta smelt bioassays were conducted simultaneously with a subset of the invertebrate bioassays. The water samples for these tests were collected from six sites during May-August of 2006 and 2007. Results from 2006 indicate that delta smelt is highly sensitive to high levels of ammonia, low turbidity, and low salinity. There is some preliminary indication that reduced survival under low salinity conditions may be due to disease organisms (Werner, unpublished data). No significant mortality of larval delta smelt was found in the 2006 bioassays…, but there were two instances of significant mortality in June and July of 2007 (Werner, unpublished). In both cases, the water samples were collected from sites along the Sacramento River and had relatively low turbidity and salinity and moderate levels of ammonia. It is also important to note that no significant *H. azteca* mortality was seen in these water samples. While the *H. azteca* tests are very useful for detecting biologically relevant levels of water column toxicity, interpretation of the *H. azteca* test results with respect to fish should proceed with great caution. The relevance of the bioassay results to field conditions remains to be determined.

Toxicity of open water habitat — attributable to biological organisms — has also been demonstrated. Baxter et al. (2008) summarized findings about water toxicity attributable to a cyanobacterium as follows:

> We have also monitored blooms of the toxic cyanobacterium Microcystis aeruginosa. Large blooms of *M. aeruginosa* were first noted in the Delta in 1999 (Lehman et al. 2005). Further studies (Lehman et al. in prep.) suggest that microcystins, the toxic chemicals associated with the algae, probably do not reach concentrations directly toxic to fishes, but during blooms, the microcystin concentrations may be high enough to impair invertebrates, which could influence prey availability for fishes. The *M. aeruginosa* blooms peak in the freshwaters of the central Delta during the summer at warm temperatures (20-25°C; Lehman et al. in prep). Longfin smelt and delta smelt are generally not present in this region of the Delta during summer (Nobriga et al. in press; Rosenfield and Baxter 2007) so *M. aeruginosa* toxicity is not likely a factor in their recent decline. However, large striped bass (Moyle 2002) and all life stages of threadfin

shad occur widely in the central and south Delta during summer, and thus may be at higher risk. Moreover, in the low flow conditions of 2007, blooms of this cyanobacterium spread far downstream to the west Delta and beyond during summer (Lehman, unpublished data), so toxicity may have been a much broader issue than previously.

Increasing levels of ammonia from the Sacramento and San Joaquin river systems is an emerging issue (Jassby 2008). Ammonia loading has increased substantially and there is evidence of delta smelt sensitivity to ammonia (Werner et al. 2008), but the Department can not conclude that longfin smelt are similarly sensitive (Inge Werner, personal communication, January 2009).

TOP DOWN

Longfin smelt are lost to diversion of surface water, predation, scientific collections, and bycatch in a commercial fishery.

Diversion of Surface Water

Surface waters are diverted at Mirant power plants, Contra Costa Water District facilities, agricultural diversions, wildlife diversions, the State Water Project, the Central Valley Project, dredging operations, and sand-mining operations. These diverted flows entrain longfin smelt and/or similar fishes and the preponderance of those fish are lost.

State Water Project and Central Valley Project in the South Sacramento-San Joaquin Delta — The State Water Project and the Central Valley Project export water from the south Sacramento-San Joaquin Delta, and the exported water contains fish. The number of fish entrained has never been estimated directly, but entrainment of some fishes has been estimated indirectly using data from research and monitoring that is uniquely comprehensive in scope, intensity, and duration.

Each Project includes a fish-salvage facility. These facilities are elaborate systems of louvers[6] and pipes that direct some water into holding tanks where some entrained fish — these fish are described as ”salvaged” — are collected, placed in a truck, driven to the western Sacramento-San Joaquin Delta, and released (Brown et al. 1996; DeMoyer 2007) in an effort to reduce the adverse impact of water export. These facilities operate 24 hours/day, 365 days/year.

Fish from a known fraction of exported flow are collected, identified, counted, and (a subset) measured in a process known as “species counts”. Species counts are arithmetically expanded by the fraction of water diverted for the collection and the product is used as an index of entrainment known as “salvage”. Historical salvage data are not a complete record of longfin smelt entrainment or loss at the diversions because, (1) many individuals are lost to various factors after entrainment but before encountering the louvers, (2) many larvae and other small poor-swimming individuals pass through the louvers into the aqueduct system, (3) salvaged fish are not identified or recorded until they are ≥ 20 mm in length, and (4) longfin smelt larvae are < 20 mm in length (Figure 7).

[6] Unlike screens, these louvers are ‘behavioral barriers’ that only protect entrained fish that can swim away from them. The louvers are thought to be relatively ineffective at protection of fish < 20 mm long.

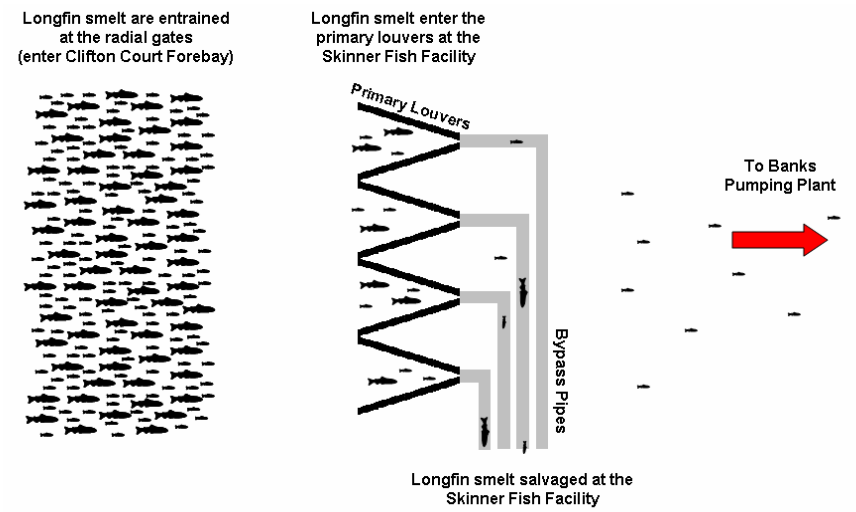

Figure 7. Schematic of loss of entrained fish at the SWP diversion in the south Sacramento-San Joaquin Delta. A small fraction of entrained fish survive movement across Clifton Court Forebay, a small fraction of those survivors are salvaged and returned to the Delta in tanker trucks, and the remainder are lost into the aqueduct system. Figure courtesy of J. Morinaka.

The fact that salvaged fish are a small subset of fish lost directly by the entrainment into the State Water Project and Central Valley Project diversions from the south Sacramento-San Joaquin Delta has been the subject of management concern and actions for many decades. The Delta Pumping Plant Fish Protection Agreement — signed in 1986 and commonly known as the 4-Pumps Agreement — between the Department of Water Resources and the Department of Fish and Game provided for mitigation for the direct loss of Chinook salmon, steelhead, and striped bass.

As part of the 4-Pumps Agreement, direct loss of Chinook salmon, steelhead, and striped bass has been routinely estimated using an algorithm that includes estimates of the number of fish salvaged and their size, pre-screen loss[7], ineffectiveness of fish-exclusion screens, and other (primarily operational) parameters. Pre-screen loss of entrained juvenile Chinook salmon and striped bass (Gingras 1997) and steelhead trout at the State Water Project facility has been estimated — via experimental methods — at 63-99% of the fish entrained and is the major component of total direct loss.

[7] Pre-screen loss in this context is mortality of fish — attributed primarily to predation by aggregations of striped bass — following their entrainment into Clifton Court Forebay but before encountering louvers at the fish-salvage facility.

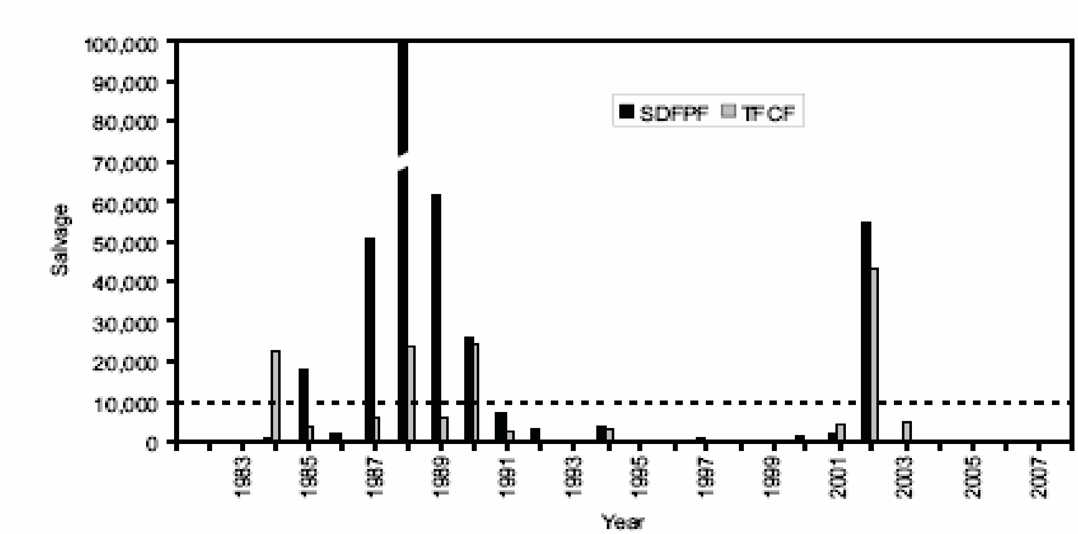

Figure 8. Salvage of longfin smelt at the State Water Project and Central Valley Project, 1983-2007 (Aasen 2008). Peak salvage during the period was 164,045 fish in 1988.

Loss of longfin smelt has not been estimated using experimental methods. Using longfin smelt salvage data and results from experiments on loss of delta smelt and other species (as proxies) at various stages of the salvage process, Fujimura (2009) estimated that cumulative 1993-2008 longfin smelt entrainment at the State Water Project was 1,376,432[8] juveniles and 11,054 adults, and estimated that 97.6% of those juveniles and 95.3% of those adults were lost. These results are not surprising given the level of pre-screen loss — a subset of all types of loss — estimated for entrained Chinook salmon, steelhead trout, striped bass at the State Water Project diversion.

Fujimura (2009) also estimated 1993-2008 loss to juvenile and adult longfin smelt at the Central Valley Project. He found that cumulative 1993-2008 entrainment was 224,606 juvenile and 1,325 adult longfin smelt, 85.2% of those juveniles and 82.1% of those adults were lost, and State Water Project loss rates were higher in large part because of pre-screen loss in Clifton Court Forebay.

Salvage of longfin smelt ≥ 20 mm long (Figure 8; Aasen 2008) — and presumably the much-larger entrainment loss of longfin smelt of all sizes — has varied substantially over time and included a 1983-2007 peak of 164,045 fish. Salvage of longfin smelt increased during dry years when the distribution of longfin smelt appeared to shift upstream where risk of entrainment by the State Water Project and Central Valley Project was higher (Sommer et al. 2007).

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[8] The Department made no effort to apply 'significant figure' rules for the myriad numbers included in this report. Applying such rules is infeasible because there are many numbers and many of those numbers are from the published works of others. Although some numbers suggest too-high precision, the Department's analysis recognizes and addresses associated uncertainty.

Previous efforts to reduce delta smelt loss to entrainment may have also reduced longfin smelt loss to entrainment, thereby incidentally providing benefit to longfin smelt. Additionally, the December 2008 Delta Smelt Biological Opinion for the State Water Project and Central Valley Project Operations Criteria and Plan contains measures that may further benefit longfin smelt.

State Water Project North Bay Aqueduct — The North Bay Aqueduct export facility is located in the northern Sacramento-San Joaquin Delta and draws water from Barker Slough. The facility serves the annual water entitlements of Solano County Water Agency and Napa County Flood Control and Water Conservation District. Initially designed for delivery of 175 cubic feet per second to meet obligations, the current maximum export rate is about 142 cubic feet per second and actual export rate is typically less.

Concern over the potential loss of planktonic eggs and fish instigated larval fish sampling in Barker Slough and Lindsay Slough to estimate and evaluate potential entrainment. Larval fish sampling was conducted 1994-2004. Oblique plankton tows were conducted every other day at four locations in Barker and Lindsey sloughs February-July.

Longfin smelt catches were periodically high, particularly in the early 2000s when outflows declined that otherwise would have transported longfin smelt larvae away from the pumps (Table 2). Once longfin smelt larvae were drawn into the slough beyond the range of tidal excursion, they would have continued to the pumps unless they grew large enough to swim away.

Table 2. North Bay Aqueduct Plankton sampling longfin smelt catch by year and station. No longfin smelt larvae were collected in 1996 or 1998. Stations 718, 720, 727 and 721 sample the path to the export facilities from distal to proximal.

Station Name	Number	1994	1995	1997	1999	2000	2001	2002	2003	2004
Lindsey Slough	718	252	4	184	28	5	1531	7486	373	318
Barker Slough Mouth	720	99		13			237	1798	82	25
Barker Slough	727			11			125	1326	57	7
Barker Slough Near pumping plant	721	72	1	12	2		129	1145	58	
Cache Slough by conf w/ Shag	722		6	118		1	212	7554	181	2
Sac. Deepwater Ship Channel	723		41	219		5	133	4479	225	16
Miner Slough Near Prospect	724		4	30		1	17	638	34	5
Sac. River Near Georgiana Slough	725	7								
Miner Slough Upstream	726		2	10			4	750	16	2

Additional information about the North Bay Aqueduct and sampling there are at the following locations:
http://wwwoco.water.ca.gov/cmplmon/reports/hydro.html
http://www.delta.dfg.ca.gov/data/NBA/background.asp

Mirant Power Plants — Monitoring at the *Potrero Power Plant (Potrero)*, the *Pittsburg Power Plant (PPP)*, and the *Contra Costa Power Plant (CCPP)* demonstrate that they have taken and may continue to take many longfin smelt through entrainment[9] and impingement[10] of larvae and adults, and through thermal and chemical discharges.

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[9] Entrainment is the involuntary movement of fish by the movement of flowing water.

The *Potrero* is located in San Francisco on the east bank of the peninsula. Only Unit 3 of the plant includes a cooling system that uses water from San Francisco Bay before returning the water to its source. This area of the San Francisco Bay is rearing and migratory habitat for longfin smelt. The Department found little information on entrainment and/or impingement from the *Potrero*, but learned that the twenty (20) longfin smelt collected during impingement surveys from May 1, 2006 to May 9, 2007 comprised 0.14% of 14,034 fish collected. The surveys were conducted for one 24-hour period each week that pumps were operating (Mirant Potrero 2007a).

The *PPP* and the *CCPP* are in the western Sacramento-San Joaquin Delta on the south bank of Suisun Bay in Pittsburg and on the San Joaquin River in Antioch. Their once-through cooling systems circulate a substantial volume of water from an important rearing and migratory region for longfin smelt. Since entrainment monitoring in 1978-1979 (Tables 3 and 4), operations of the two plants has changed from using 14 units year-round to using five units only when the California Independent System Operator or Pacific Gas and Electric Company calls for them (primarily during summer). Mirant also implemented conservation measures to restrict maximum permitted flows, including the installation of Variable Frequency Drives that can reduce diversion flow and velocity (Steven Bauman, Personal Communication, January 2009, citing Mirant Delta, LLC. 2006; Mirant Delta, LLC. 2007b; Mirant Delta, LLC. 2007c; Pacific Gas and Electric Company 1981a; Pacific Gas and Electric Company 1981b). To the extent that entrainment is directly proportional to flows, the decreased operation of the plants has correspondingly reduced entrainment.

Table 3. Estimated Annual Entrainment and Impingement at *PPP* (March 1978 – March 1979). From IEP 2006, Appendix 2.

Fish Species	Estimated Entrainment	Estimated Impingement
Delta Smelt	455,413 ± 184,516	14,082 ± 6,454
Longfin Smelt	190,229 ± 198,009	137,261 ± 55,576
Larval Osmeridae	64,784,071 ± 29,475,225	25 ± 29
Sacramento Splittail	155,289 ± 60,064	8,732 ± 4,596
Winter-run Chinook salmon	0	323 ± 132
Spring-run Chinook salmon	0	469 ± 192
Fall/late fall-run Chinook salmon	23,598 ± 35,468	776 ± 318
Steelhead	0	0
Green Sturgeon	0	0

[10] Impingement is the entrapment — assumed to be lethal — of fish on the outer part of an intake structure or against a fish-exclusion screen. Impingement depends the intake structure surface area and the velocity of water entering the structure, and tends to be a greater issue on intake structures with fish-exclusion screens.

Table 4. Estimated Annual Entrainment and Impingement at *CCPP* (March 1978 – March 1979). From IEP 2006, Appendix 2.

Fish Species	Estimated Entrainment	Estimated Impingement
Delta Smelt	21,887 ± 23,881	8,253 ± 1,595
Longfin Smelt	0	19,475 ± 11,758
Larval Osmeridae	20,543,854 ± 5,601,594	0
Sacramento Splittail	189,659 ± 118,820	12,455 ± 3,422
Winter-run Chinook salmon	0	53 ± 22
Spring-run Chinook salmon	0	275 ± 114
Fall/late fall-run Chinook salmon	10,318 ± 18,820	755 ± 313
Steelhead	0	38 ±39.2
Green Sturgeon	0	0

Recent entrainment and impingement monitoring at *PPP* and *CCPP* started in fall 2007 but occurred regularly from March through October 2008 (Tenera Environmental 2006). Longfin smelt were reported in three monthly reports summarized in Table 5. No longfin were collected in November-December 2007 sampling or in January 2008.

Table 5. Longfin Smelt Entrainment and Impingement Monitoring at *CCPP* and *PPP*.

Date	Length (TL mm)	Sample Minutes	Sample Type	Power Plant
3/18/08	6.4	35	Entrainment	CCPP
3/18/08	7.0	35	Entrainment	CCPP
4/02/08	6.2	3	Entrainment	CCPP
4/15/08	19.3	33	Entrainment	CCPP
3/18/08	6.8	38	Entrainment	PPP
3/18/08	7.0	38	Entrainment	PPP
4/30/08	21.0	34	Entrainment	PPP
4/30/08	22.3	34	Entrainment	PPP
6/19/08	32.0	*see note	Impingement	PPP
6/19/08	38.0	*see note	Impingement	PPP

Note: Four pumps at 100% power for four hours then reduced to 75% power for last 15 minutes.

Water temperatures resulting from thermal discharges from *Potrero*, *CCPP*, and *PPP* could produce local regions outside the tolerance of young longfin smelt. The following major observations were from *PG&E Contra Costa and Pittsburg Power Plants Thermal Effects Assessment, 1991-1992* which is a report submitted to the Central Valley Regional Water Quality Board:

- During April-June *CCPP* Units 6 and 7 discharge averaged 74-81ºF (un-inhabitable by longfin smelt).
- During March-June 1992 — when longfin smelt larvae and young juveniles were not yet fully mobile — *CCPP* Units 6 and 7 discharged water 4.5-16ºF warmer than intake temperatures.
- During April-June 1992, *PPP* units 5 and 6 discharged 75-81ºF water that averaged 6.5-13.2ºF warmer than ambient.

Contra Costa Water District — Contra Costa Water District export facilities divert water from the Sacramento-San Joaquin Delta at the *Rock Slough Pumping Plant*, the *Old River Pumping Plant* and the *Mallard Slough Pumping Plant.* Longfin smelt have been collected at two of the three facilities (see below) during the entrainment studies the Department reviewed for this report.

The *Rock Slough Pumping Plant* diverts from Rock Slough, which is a dead-end slough south of Holland Tract in the southwestern Sacramento-San Joaquin Delta. The plant diverts at a maximum of 350 cubic feet per second and does not use fish-exclusion screens. During 1994-1996 entrainment sampling, four longfin smelt juveniles were collected. No longfin smelt were observed during 1999-2002 entrainment sampling at the Contra Costa Canal headworks where water is first diverted from Rock Slough. Three adult delta smelt and one juvenile delta smelt were collected at the pumping plant from 1994 to 1996. One delta smelt larvae was collected during the 1999-2002 entrainment sampling at the headworks (Morinaka 1997, 2000b, 2001b, 2002b, 2003b). Collection of delta smelt suggests longfin smelt are at risk of entrainment.

The *Old River Pumping Plant* diverts directly off Old River in the south Sacramento-San Joaquin Delta. The plant diverts at a maximum of 250 cubic feet per second. Flow is drawn through flat-plate panels of 3/32-inch stainless steel wedge-wire with a maximum approach velocity of 0.33 feet per second. Approach velocity is 0.20 feet per second at 150 cubic feet per second. No longfin smelt were observed during 1998-2002 entrainment sampling (Morinaka 1999, 2000a, 2001a, 2002a, 2003a).

The *Mallard Slough Pumping Plant* diverts a maximum of 37 cubic feet per second. Flow is drawn through flat-plate panels of 3/32-inch stainless steel wedge-wire with a maximum approach velocity of 0.20 feet per second. Fish monitoring in 1995-1997 within the 0.5-mile intake channel of the pumping plant — where they were vulnerable to entrainment at the pumps — collected 79 longfin smelt larvae (Mecum 1995, 1996, 1997, 2001). During the 1998-2000 entrainment monitoring, fish were sampled after passing through the *Mallard Slough Pumping Plant* and 71 longfin larvae were collected (Mecum 1998, 1999, 2000, 2001). During the last year of DFG monitoring (2003), entrainment sampling behind the screen collected three longfin smelt larvae (Mecum 2003).

Agricultural diversions — Agricultural diversions occur throughout the Sacramento-San Joaquin Delta, Suisun Bay, and Suisun Marsh. Herren and Kawasaki (2001) reported just over 2,200 water diversions within the legally-defined Sacramento-San Joaquin Delta and another 414 diversions in Suisun Marsh. However, those estimates were likely too high because the authors did not accurately distinguish intake siphons and pumps from discharge pipes (Chappell, personal communication, 2008).

Diversions that occur when and where longfin smelt are present may entrain longfin smelt. A few studies have investigated entrainment of fishes at in-Delta agricultural diversions. Longfin smelt were never collected from diversion sampling, but were occasionally collected in nearby trawling (Spaar 1994; Cook and Buffaloe 1998; Nobriga et al. 2002).

Suisun Marsh Diversion — Longfin smelt are common in western Suisun Marsh, particularly during the winter and spring (Matern et al. 2002). Duck-club diversions draw water October-May (or July) to provide water-fowl habitat using gated culverts (Pickard et al. 1982; Enos et al. 2007). This period corresponds to that of the adult longfin smelt spawning migration and larval/juvenile dispersal and early rearing. Two studies were located that investigated fish entrainment within Suisun Marsh. In both studies, longfin smelt catch occurred when the diverted fraction of the channel volume was high.

In the early 1980s, Pickard et al. (1982) studied fish entrainment in large (60 inch diameter), screened (n=2) and unscreened (n=6) culverts diverting water from Montezuma Slough. They sampled November 1980-May 1981 and September 1981-March 1982. Over 1000 juvenile and adult longfin smelt were collected from unscreened culverts during the 1980-1981 season. During the next year 29 longfin smelt were caught. Diversions as large as those studied by Pickard et al. (1982) are no longer present in Suisun Marsh.

In a two-year diversion-entrainment study, 124 longfin juveniles and adults were found in 2.3 million m^3 water diverted from Goodyear Slough in the western Suisun Marsh (Enos et al. 2007). When larvae were included, the total increased to 284 longfin smelt (all life stages) over the same period. Entrainment was periodic with most entrainment of adults in December 2004, larvae in April 2005, and juveniles in May 2005. Entrainment was likely influenced by the large proportion (1/3 of the volume) of Goodyear Slough diverted when the intakes were open and operating on a flood tide. Longfin smelt larvae were abundant in Suisun Marsh starting in February (when annual sampling commenced) through April (Meng and Matern 2001). Though present in small numbers throughout the year, older juveniles and adults were primarily present from October-February (Rosenfield and Baxter 2007).

Water diversions from main sloughs within Suisun Marsh and from Suisun Bay are subject to restrictions when Chinook salmon or delta smelt might be present (U.S. Army Corps of Engineers 2008). These restrictions include: (1) restricting water diversion pipes to 25% of capacity from November 1 through the end of duck season (date varies by year from December through March), (2) complete prohibition of diversion February 21-March 31, (3) use only 35% capacity from April 1-May 31, and (4) if two of three *20mm Survey* station's 'catch per 10000 cubic meters' surpasses 20 from April 1-May 31, then diversions are restricted to 20% capacity.

Dredging and sand mining — Dredging and sand mining occurs at locations throughout the lower estuary, and effects to water-surface-oriented larvae, mobile juveniles, and adults are expected to be small and localized. However, dredge spoil disposal may create an unavoidably-large plume that exposes fish to re-suspended contaminants, gill-clogging sediments, and possibly low-oxygen water (LFR Levine-Fricke 2004). A review of direct and indirect dredging effects on fishes and benthos can be found in LFR Levine-Fricke (2004).

Two suction-dredge fish-entrainment studies for the local area were available and reviewed. Both indicated that few individual fish were entrained during dredging and that those species were predominantly bottom-dwellers (i.e., not longfin smelt).

Taplin and Hanson (2006) developed pertinent information on suction dredge entrainment of juvenile fishes while investigating potential entrainment of juvenile Chinook salmon and steelhead in the San Francisco Estuary. Between April 26 and June 8, 2006, they examined fish entrainment in sand mining gear by suspending a suction-dredge intake greater than three feet above the bottom and running about 100 one-hour samples using equipment from three different companies while collecting fishes using 3/8-inch-mesh nets on the discharges. Thirty-six (36) fish of 8 species were caught. No longfin smelt were collected, but the 2006 year-class ranged between 15-35 mm long and would not have been retained well in 3/8-inch mesh.

SWCA Environmental Consultants assessed suction dredging in two regions of the San Joaquin River ship channel and three regions in the lower Sacramento River ship channel. They discharged a fraction of suction dredge slurry into experimental settling ponds and monitored the ponds once drained and pond overflows for fishes. All of the monitored dredging used a hydraulic cutter-head suction dredge with an 18-inch (inside diameter) discharge pipe. In both years dredging and entrainment sampling was conducted September-December when longfin smelt were in the vicinity. During September-December 2006, eight lamprey, two catfish, and one goby were found after sampling 3,350,000 gallons of slurry. During September-December 2007, twelve fish (catfish and gobies) were found after sampling of 1,310,000 gallons of slurry. During coincidental otter trawl fish-community monitoring, 895 juvenile and adult longfin smelt were collected nearby.

Dredging and sand mining during winter and spring pose a threat to longfin smelt eggs. Egg entrainment is potentially the most serious effect, because other life stages are not associated with the bottom (i.e., larvae) or can move away from the intake (juveniles and adults).

Predation

Longfin smelt are relatively small fish even as adults and are thus food for many animals (e.g., birds, jelly fish, and other fish). Due to a paucity of information about predation on longfin smelt and similar species in the Sacramento-San Joaquin Estuary by animals other than fish, the following regards only predation by fish.

In general, piscivorous fish feed predominantly on the most-available prey (Nobriga and Feyrer 2007 and reference therein). Given its recent low abundance and limitations typical of field-based food-habit studies, longfin smelt should rarely be identified in the diet of piscivorous fishes. The abundance and diets of two non-native piscivorous fishes in the San Francisco Estuary have been studied and give insight into predation on longfin smelt.

Recent adult[11] striped bass abundance peaked in 2000 at approximately 1.5 million fish (DFG unpublished data), and largemouth bass abundance in the Sacramento-San Joaquin Delta has increased during the last two decades (Brown and Michniuk 2007). Studies on the diets of striped bass (Stevens 1966; Thomas 1967; DFG unpublished data) and largemouth bass (DFG unpublished data; Nobriga and Feyrer 2007) in Suisun Marsh and the Sacramento-San Joaquin Delta have rarely identified longfin smelt in the contents of their stomachs.

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[11] Adult striped bass are generally ≥ age-3 and ≥18 inches total length.

The great abundance of piscivorous striped bass and largemouth bass — as well as the many other piscivorous fishes that co-occur with longfin smelt — suggests that even a small predation rate by fishes results in the loss of many longfin smelt. For example, DFG (1999) wrote that, "...Based on the 1994 abundance of delta smelt (4,803,000), annual consumption of delta smelt by the present (mean 1992-94) striped bass population in the Estuary is estimated to be 5.3% of the population…" The "(mean 1992-94) striped bass population" used by DFG (1999) was 6,760,385 and included estimated abundance of piscivorous age-1, age-2 and age- ≥3 striped bass (DFG, unpublished analysis). Thus, the striped bass population characterized by DFG (1999) would have consumed 254,559 delta smelt annually, even though delta smelt "frequency of occurrence" in striped bass stomachs had never been observed to be greater than 0.0033 (DFG 1999).

In late-winter and spring when longfin smelt larvae are present, large numbers of Chinook salmon juveniles migrate through the Sacramento-San Joaquin Delta. Because juveniles of both species are known to eat larval fishes (Merz 2001 and 2002), they may eat larval longfin smelt.

Scientific Collections

Longfin smelt collected from the San Francisco Estuary during most research and monitoring are used to assess threats to their conservation by adverse impacts attributable to development projects. This is especially true for monitoring under the auspices of the Interagency Ecological Program.

The Interagency Ecological Program's *20mm Survey*, *Summer Townet Survey*, *Fall Midwater Trawl Survey*, *Spring Kodiak Trawl Survey*, and *Bay Study Survey* are mandated by one or more of the following:

(1) *Natural Resources Defense Council v. Kempthorne* (E.D. Cal., Dec. 14, 2007, No. 1:05-cv-1207 OWW GSA) 2007 WL 4462391

(2) The 2008-2009 longfin smelt Fish and Game Code section 2084 regulation, tit. 14 California Code of Regulations section 749.3

(3) The Delta Smelt Biological Opinion for the State Water Project and Central Valley Project Operations Criteria and Plan

(4) Decision 1641 and Decision 1485 by the State Water Resources Control Board.

From 1987-2008, the annual collection of longfin smelt juveniles and adults from 10 Interagency Ecological Program studies has ranged from 461 to 85,742 (Appendix A). During the same 11-year period, the number of larval longfin smelt collected by four Interagency Ecological Program studies has ranged from 343 to 72,824. Collections are the complete extent of impact attributable to research and monitoring.

Bycatch in a Commercial Fishery

Commercial fisheries are conducted in brackish-water regions of the lower San Francisco Estuary and have at times caught longfin smelt. Commercial bait fishers target an aggregate of bay shrimps using otter trawls and from on-board observations, also caught longfin smelt (field notes of Paul Reilly, DFG Biologist).

Current trawls measure about 20 ft-by-3 ft and most use 1" cod end mesh. The bay shrimp fishery concentrates effort in a few brackish-water locations, specifically: (1) Carquinez Strait to an upstream regulatory boundary in western Suisun Bay (to limit impact on age-0 striped bass), (2) the lower Petaluma River and channel extending into San Pablo Bay, (3) the Coyote Creek Estuary, and (4) the Redwood Creek Estuary (Reilly 1991).

Commercial shrimp fishers are required to return most trawl-caught fishes, except for staghorn sculpin, yellowfin goby, longjaw mudsucker, and plainfin midshipman, which can be retained and sold for bait, immediately to the water (Cal. Admin. Code tit. 14, § 119.). Reilly (1991) found age-0 striped bass suffered 22% mortality from 86 tows observed in San Pablo Bay from September 1989-September 1990. Tow durations tended to be 30-145 minutes and collected fishes came aboard stressed.

From the 86 tows observed in San Pablo Bay during 1989-1990, 558 longfin smelt were counted in the bycatch (Reilly, unpublished). Eighty-six (86) percent of longfin smelt catch occurred November-January when adult fish were present and of sufficient size to be retained by the trawl's 7/8-inch mesh.

Hieb (2009) estimated that bycatch from bay shrimp trawlers working in San Pablo Bay during 1989-1990 included 15,539 longfin smelt. In 2004, 8 trawlers fished in San Pablo Bay and trawled approximately 1,000 hours (i.e., ~33% of the 1989-1990 effort). Given higher longfin smelt abundance in 2004 compared to 1989-1990 and the lower trawling effort, Hieb (2009) estimated a similar total longfin smelt bycatch in 2004.

BOTTOM-UP

The quality and availability of food for pelagic fish like longfin smelt has changed over the long term and recently, and longfin smelt and some other pelagic fishes in the San Francisco Estuary appear to have been adversely affected as a consequence (Baxter et al. 2008).

The potential impact to longfin smelt attributable to food limitation is severe and rarely results in collection of sick or dead fish. However, the population-level impact of food limitation on longfin smelt can be modeled and some such work has been completed.

Feeding by the non-native overbite clam (*Corbula amurensis*) reduced primary productivity (Kimmerer 2002b; Alpine and Cloern 1992) and a consequential reduction in fish biomass is likely.

A reduction in longfin smelt abundance per unit outflow after 1987 was attributed to the reduction in upper estuary productivity after arrival and establishment of the overbite clam, *Corbula amurensis*, in 1987 (Kimmerer 2002b). Primary productivity in Suisun Bay and the Sacramento-San Joaquin Delta declined to very low levels by the mid-1990s (Jassby et al. 2002), and through a trophic linkage (see Kimmerer and Orsi 1996, Orsi and Mecum 1996), was believed principally responsible for the long-term declines of pelagic fishes, including longfin smelt (Kimmerer 2002b).

CLIMATE CHANGE

Existing threats to longfin smelt may be exacerbated by climate change, causing a further decrease in its abundance as well as the quality and quantity of its habitat.

Sea level rise will likely increase the rate and extent of salt water intrusion resulting in increased sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems. These flooding events may result in changes to water availability and quality, in turn altering longfin smelt habitat and prey distributions. The loss of tidal marsh habitat, lower oxygen levels in wetlands due to increased sedimentation, and competition with invasive species may result in reduced productivity and have a direct impact on the species.

Climate change is likely to result in increased temperatures at high elevations resulting in earlier snow melt and more frequent and intense flood events. These types of events will likely affect longfin smelt habitat by increasing freshwater inflows during the winter and early spring rather than the late spring in which the species is adapted (Anderson 2006; Easton and Ejeta 2006). An increase in the frequency and intensity of flood events may also amplify movement of pollutants and contaminants.

Changes to the freshwater inflows will also impact the timing of flows and water temperatures which could result in a change in the timing of migration of adult longfin smelt. If the climate-change models that predict warmer temperatures in California (Dettinger 2005) are accurate, the longfin smelt spawning period may become briefer than the current November-April range. A briefer spawning period increases the probability of year-class failure.

NATURE AND DEGREE OF THREAT

The Department understands the nature of threats to longfin smelt, but to aid management efforts the Department seeks additional understanding of the degree of threats. Toward that end, the Department is working with agency and outside experts to define causes, design appropriate studies, and develop potential solutions to the decline of longfin smelt in the San Francisco Estuary. Since 2005, that effort has been implemented largely through the Interagency Ecological Program's Pelagic Organism Decline work (Interagency Ecological Program 2005; Interagency Ecological Program 2006; Interagency Ecological Program 2008).

CURRENT MANAGEMENT

Prior to its candidacy period there were no management measures in place specifically for longfin smelt. Longfin smelt are being managed during its candidacy period through a protective regulation that governs State Water Project and Central Valley Project operations in the south Sacramento-San Joaquin Delta, research and monitoring, local water diversions and the State water Project North Bay Aqueduct, dredging, and sand mining. The regulation was in some cases adaptive and used near-real-time information on the abundance and distribution of longfin smelt from surveys conducted by the Department and salvage of longfin smelt at the Skinner Delta Fish Protective Facility and Tracy Fish Protective Facility.

CONCLUSIONS

The longfin smelt is a small fish native to California's San Francisco Estuary and some other estuaries along the Northeastern Pacific coast. This species feeds exclusively on zooplankton, spawns in freshwater, and has a (predominantly) two-year life cycle. Survey data indicates that the population of longfin smelt in the San Francisco Estuary has declined substantially since the 1980s.

The Department's evaluation of factors affecting longfin smelt abundance did not specify the exact cause(s) of this decline. However, it appears that the longfin smelt is vulnerable due to the cumulative and possibly synergistic effects of its low abundance, distance between local populations, direct loss of individuals by myriad projects and activities, reduction in its reproductive potential, and reduced carrying capacity of its habitat.

A threatened species is one "…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts…" (Fish & G. Code § 2067).

The Department believes that the longfin smelt population is likely to become an endangered species in the foreseeable future. Based on the best scientific information available (Fish and G. Code § 2074.6), the Department finds the petitioned action to list longfin smelt as Threatened under CESA is warranted.

RECOMMENDATIONS

PETITION ACTION

1. The Commission should find that classification of longfin smelt as Threatened is warranted.

2. The Commission should publish notice of its intent to amend Title 14 CCR 670.5 to list longfin smelt as Threatened.

MANAGEMENT/RECOVERY MEASURES

The Department's objective is the protection of a sufficient number of longfin smelt to make their long-term survival and recovery in their native habitat and range a certainty.

Because there is not yet a quantitative basis for estimating the benefits of any given action(s), attempting to assure longfin smelt persistence and recovery during the foreseeable future will involve implementing management measures and evaluating their success empirically.

The Department believes the following actions — which are not listed in priority order and are not all under the Department's authority — would have population-level benefits for longfin smelt:

- Reduce pollution of estuaries by chemicals harmful to longfin smelt and their food web.

- Reduce entrainment and lost of longfin smelt at water diversions — including diversions for cooling of power plants and diversions operated by the State Water Project, Central Valley Project, municipal entities, and for agricultural and recreational purposes. For example, moving State Water Project and the Central Valley Project diversions from the south Sacramento-San Joaquin Delta to the north Sacramento-San Joaquin Delta would reduce loss of longfin smelt to entrainment and loss.

- Reduce entrainment and loss of adult, juvenile, and larval longfin smelt to dredging.

- Reduce predation on longfin smelt by managed non-native fishes.

- Improve and/or expand habitat for longfin smelt. For example, this could include increasing average December-May Sacramento-San Joaquin Delta outflow, restoring intertidal or shallow subtidal habitat, and/or improving habitat in the flood plain or in open water.

- Modify commercial fishery regulations to reduce loss associated with by-catch of longfin smelt.

- Adaptively manage the scientific collection of longfin smelt.

PROTECTION AFFORDED BY LISTING

If longfin smelt are listed as threatened or endangered under CESA, take of longfin smelt would be unlawful absent take authorization from the Department. (Fish & G. Code §§ 2080 et seq. and 2835.) Take can be authorized by the Department pursuant to the following FGC sections: 2081.1, 2081, 2086, and 2835.

Pursuant to FGC section 2081(b), the most common form of take authorization, the Department can authorize take through an Incidental Take Permit if certain conditions are met. These conditions include:

- The impacts of the take are minimized and fully mitigated
- The measures are capable of successful implementation
- The applicant ensures adequate funding to implement and monitor the effectiveness of the measures
- The measures are roughly proportional in extent to the impact
- Where various measures are available, the measures shall maintain the applicant's objectives to the greatest extent possible
- Issuance of the permit will not jeopardize the continued existence of a species.

As a listed species, longfin smelt would also receive protection under the California Environmental Quality Act. Among other things, state lead agencies must consult with the Department on the impact of a proposed project on listed species. (Pub. Resources Code 21104.2. See also Cal. Code Regs, tit. 14, § 15065.)

ECONOMIC CONSIDERATION

The Department is not required to prepare an analysis of economic impacts (Fish & G. Code, section 2074.6).

PUBLIC RESPONSE

Comments were invited in response to the current petition in a Press Release dated June 20, 2008. Comments received are included in Appendix C.

PERSONAL COMMUNICATIONS

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APPENDIX A: INTERAGENCY ECOLOGICAL MONITORING PROJECT CATCH OF LONGFIN SMELT

Table 1. Total annual catch of longfin smelt juveniles and adults by mandated and other Interagency Ecological Program projects, 1987-2008. Dashes indicate no sampling occurred.

Project	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Project Total
20 MM Survey[1,2]	-	-	-	-	-	-	-	-	3,693	5,848	9,694	15,605	39,664	70,195	19,784	23,166	7,916	4,586	2,376	8,109	860	8,728	220,224
Summer Townet Survey[2]	166	40	68	3	10	10	35	17	562	166	24	188	571	1,106	57	442	90	127	43	180	4	813	4,722
Fall Midwater Trawl Survey[2]	963	487	340	178	99	53	604	307	4,478	703	397	4,768	3,110	2,467	169	533	346	138	67	800	10	95	21,112
Spring Kodiak Trawl Survey[2]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	87	99	113	37	10	78	1774	2,198
Bay Study Survey[2]	1,889	1,295	429	161	158	95	561	442	12,698	1,919	1,408	4,895	6,869	3,057	1,154	1,032	738	888	638	1,213	478	280	42,297
Broodstock Collections	-	-	-	-	-	-	-	-	-	-	-	-	-	103	19	27	46	45	21	0	-	0	261
Delta Juvenile Salmon	258	4,935	1,618	803	173	693	1,275	11,629	3,194	15,949	9,186	3,544	11,337	8,430	10,563	5,284	5,073	2,506	1,589	489	526	440	99,494
Yolo Bypass	-	-	-	-	-	-	-	-	-	-	-	0	0	0	2	122	2	4	0	0	1	0	131
UCD Suisun Marsh	110	198	133	242	21	3	5	26	106	279	1277	38	1133	394	291	658	490	135	32	46	44	15	5,676
POD Directed Fish Collections	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,462	352	-	1,814
Annual total, longfin ≥ 20 mm	3,386	6,955	2,588	1,387	461	854	2,480	12,421	24,731	24,864	21,986	29,038	62,684	85,752	32,039	31,351	14,800	8,542	4,803	12,309	2,353	12,145	397,929

/1 Number of longfin smelt calculated by applying the ratio of measured longfin smelt < 20 mm and ≥ 20mm to the total number of longfin smelt collected.

/2 These studies are mandated.

APPENDIX B: EXPERT COMMENTS REQUESTED

The Department distributed drafts of the status report to experts at intervals during the report's development. The Department circulated a complete draft — differing from the final draft only slightly, primarily to address issues of clarity and tone — to the following experts on January 17 and January 19, 2009 and solicited their comments.

Anke Mueller-Solger; California Bay Delta Authority
Bernie May; University of California at Davis
Bradley Cavallo; American Fisheries Society, California Nevada Chapter
Bruce Herbold; United States Environmental Protection Agency
David Ostrach; University of California at Davis
Fred Feyrer; United States Bureau of Reclamation
Gonzalo Castillo; United States Fish and Wildlife Service
Jon Rosenfield; The Bay Institute
Kevin Urquhart, California Department of Fish and Game, former Senior Biologist Supervisor.
Larry Brown; United States Bureau of Reclamation
Mike Chotkowski; United States Bureau of Reclamation
Patrick Coulston; California Department of Fish and Game, retired Supervising Biologist.
Peter Moyle; University of California at Davis
Rick Sitts; Metropolitan Water District
Ted Sommer; California Department of Water Resources
Victoria Poage; United States Fish and Wildlife Service
William Bennett; University of California at Davis
Wim Kimmerer; San Francisco State University

No comments have been received as of this writing, but the Department anticipates that comments will be available for the Commission's consideration in February 2009.

APPENDIX C: PRESS RELEASE AND RESPONSES

DFG News Release

DFG Seeks Public Input on Longfin Smelt Listing Petition June 20, 2008

Contact:
Marty Gingras, DFG Bay Delta Region Supervising Biologist, (209) 948-3702
Steve Martarano, DFG Office of Communications, (916) 322-8639

The California Department of Fish and Game (DFG) seeks public input regarding a petition to list longfin smelt under the California Endangered Species Act (CESA).

The California Fish and Game Commission is currently considering the petition to list the fish as threatened or endangered under CESA. The petition was filed Aug. 14, 2007 by the Bay Institute, the Center for Biological Diversity and the Natural Resources Defense Council. By operation of law, longfin smelt became a "candidate species" under the CESA when the Commission found that the petition contained sufficient information to warrant further consideration.

Pursuant to the provisions of Section 2074.6 of the Fish and Game Code, DFG must complete a status review of the species and provide a written report to the commission that recommends - based upon the best scientific information available - whether listing the longfin smelt as threatened or endangered under CESA is warranted. DFG plans to submit its report to the commission in January 2009 and seeks information from the public to help formulate its recommendation.

The longfin smelt is a small native fish that migrates from salty water to spawn in fresh water. In California the fish are found mostly in the Sacramento-San Joaquin River Delta and San Francisco-area bays. Their abundance has declined substantially since systematic monitoring began in 1959 and has been at record-low levels since 2000.

Comments from interested and affected parties, including members of the public and local agencies, are requested by Aug. 1, 2008. Please send data and comments related to the petitioned action and/or the status of longfin smelt to:

DFG Supervising Biologist Marty Gingras
Department of Fish and Game
Re: Longfin Smelt Petition
4001 North Wilson Way
Stockton, CA 95205

Or via e-mail to mgingras@dfg.ca.gov with "Re: Longfin Smelt Petition" in the subject line.
Send faxes to (209) 946-6355, Attention: Marty Gingras, Re: Longfin Smelt Petition

APPENDIX C: PRESS RELEASE AND RESPONSES

DFG News Release

DFG Seeks Public Input on Longfin Smelt Listing Petition June 20, 2008

Contact:
Marty Gingras, DFG Bay Delta Region Supervising Biologist, (209) 948-3702
Steve Martarano, DFG Office of Communications, (916) 322-8639

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MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

December 19, 2008

Mr. Marty Gingras
Supervising Biologist
California Department of Fish and Game
4001 North Wilson Way
Stockton, CA 95205-2486

Re: Public Input on Longfin Smelt Status Review

Dear Mr. Gingras:

I wanted to be sure that you had longfin smelt materials for your ongoing longfin smelt CESA status review for the California Fish and Game Commission (Commission) that the water contractors had submitted for the 2084 proceedings. Please find these materials enclosed. They include a cover letter from Dan Nelson and Terry Erlewine to the Commission dated November 13, 2008, and four attachments, which merit consideration in this status review. The enclosed information addresses entrainment, entrainment as a small portion of abundance, vulnerability to entrainment, and other stressors such as ammonia.

I understand you are preparing a report for the Commission with recommendations on whether or not to list the longfin smelt. Please send me a copy or let me know of its availability as soon as it is released.

Sincerely,

Richard M. Sitts

Richard M. Sitts, PhD

cc: R. Neudeck (w/o attach.)
A. Azhderian (w/o attach.)
T. Erlewine (w/o attach.)
D. O'Hanlon (w/ attach.)

San Luis & Delta-Mendota Water Authority

PO Box 2157
Los Baños, CA 93635
Phone: 209/826-9696
Fax: 209/826-9698

State Water Contractors

1121 L St., Suite 1050
Sacramento, CA 95814
Phone: (916) 447-7357
Fax: (916) 447-2734

November 13, 2008

Sent Via E-mail, Fax and Regular Mail

Mr. Richard B. Rodgers, President
Ms. Cindy Gustafson, Vice President
Mr. Jim Kellogg, Member
Mr. Michael Sutton, Member
Mr. Daniel W. Richards, Member
California Fish and Game Commission
1416 Ninth Street
Sacramento, CA 96814

Re: AGENDA ITEM 5 – COMMENTS ON PROPOSED LONGFIN SMELT INCIDENTAL TAKE REGULATION

Dear Commissioners:

The San Luis & Delta-Mendota Water Authority ("Authority") and the State Water Contractors ("SWC") (collectively, "Water Agencies"),[1] provide the following comments on the proposed emergency take regulation concerning the incidental take of longfin smelt (*Spirinchus thaleichthys*) (the "Proposed Regulation"). The California Fish and Game Commission is scheduled to consider the Proposed Regulation at its meeting on November 14. The Water Agencies offer these comments individually, on behalf of each of their 58 member agencies, and on behalf of the millions of California residents, businesses, and farms that their member agencies serve with vital water supplies. The Water Agencies are gravely concerned that the Proposed Regulation will inflict severe harm upon California, with little benefit to the longfin smelt.

The Proposed Regulation is not supported by available data, provides no measurable protection to longfin smelt, and violates the most basic principles of regulatory law. The Proposed Regulation calls for potentially enormous reductions in the delivery of water supplies pumped through the Sacramento-San Joaquin Delta to the Water Agencies' member agencies that serve the needs of two-thirds of California's population. It is being proposed in the midst of one of the worst droughts in our history, when the State's water supply systems are already hampered by court-ordered restrictions, and just after the Department of Water Resources (DWR) has announced drastically reduced allocations of water for the coming year. And the

[1] See Attachment 1 for a description of the Authority and SWC, including a listing of each member agency.

Proposed Regulation has been presented to the Commission even though there is no evidence that these costly restrictions would provide any appreciable benefit to the longfin smelt.

Moreover, the Proposed Regulation ignores important factors driving the decline of longfin smelt in the Delta.[2] It continues an almost singular focus on operations of the Central Valley Project ("CVP") and State Water Project ("SWP"), which cannot be shown to have any measureable effect on the overall longfin smelt population within the Delta. The Department of Fish and Game ("DFG") monitoring data demonstrate that longfin smelt rarely inhabit areas influenced by operation of CVP and SWP in-Delta facilities (i.e., the pumps). It is reasonable that if longfin smelt are not in the vicinity of the pumps, they cannot be affected by their operation, which is substantiated by data showing consistently low entrainment (Figure 7 in Attachment 2). Nevertheless, the Proposed Regulation, if adopted, would further constrain the CVP and SWP, jeopardizing, on average, and in addition to existing regulatory impacts, another 750,000 acre-feet of water per year that is essential for meeting the needs of the public we serve. All of this comes at a time when the Governor has declared a drought and convened a special session of the Legislature to improve the State's water supply.

The analysis of potential water supply impact in 2009 prepared by DWR is based upon a comparison of operations under the Interim Remedy imposed by Judge Wanger of the United States District court for the Eastern District of California to protect the Delta smelt in 2008 and the restrictions described by DFG in the Proposed Regulation. The months in which these two criteria differ are December, January, and February. If triggered, the Proposed Regulation would limit Old and Middle River (OMR) flow to -5,000 cubic-feet per second (cfs) as early as December 1. During the months of January and February, the analysis assumes OMR criterion is set at -750 cfs, which is the most stringent criteria presented in the Proposed Regulation. These criteria constrain operations beyond those that were established for 2008 and, therefore, result in additional water supply impacts of 1,100,000 acre-feet for average year conditions.

Along with the Proposed Regulation, the Commission has received a Supplement To Statement Of Emergency Action prepared by DFG that, in summary, concludes the likelihood of such a high degree of impact is remote. Unfortunately, Water Agencies do not have the luxury of guessing what their water supplies will be when preparing allocation forecasts. Water Agencies plan for at least a 90% level of certainty when preparing to meet the needs of the public. In other words, what is planned to occur has occurred historically 9 times out of 10. This degree of certainty is necessary to ensure a level of reliability adequate to assure essential water to California's families, farms, and environment. Unfortunately, the Proposed Regulations would substantially reduce water supply certainty. In fact, DFG acknowledges that severe impacts are possible, and that is the scenario that Water Agencies must assume for their planning. The resulting lack of water supply certainty resulting from the Proposed Regulation, by itself, will result in water being lost because, for example, farmers will be unable to plant irrigated crops for which no water supply is certain. In Section 4 of the Proposed Regulation, DFG goes to some length to explain the holding of the court in *Natural Resource Defense Council vs. Kempthorne*, E.D. Cal. Case No. 05-1207, in a way that seems to suggest that the findings of that case support the Proposed Regulation for longfin smelt. That suggestion is not supported by the facts. For example, the Proposed Regulation states that, "The Commission

[2] As the Commission is aware, the longfin smelt – in stark contrast to the delta smelt – has a broad distribution that extends north from Monterey through Oregon, Washington, and British Columbia and far into Alaska. Furthermore, status reviews of the species indicate it is abundant.

recognizes that there are statistical correlations between negative OMR flows and take of longfin smelt life stages, as there are for delta smelt" but offer no such analysis for review.

Additionally, as we will demonstrate, there is no correlation between the take of longfin smelt by the CVP and SWP pumps and subsequent longfin smelt abundance. DFG provides no evidence that the OMR limits temporarily required under *Kempthorne* actually provided any protection or benefit to the delta smelt population, much less the longfin smelt population. Unfortunately, this approach reflects a long history of establishing regulatory standards for fish and wildlife without adequate scientific basis, and perpetuating such standards once they are established despite the absence of supporting information and in the face of more recent contrary information.

As history shows, when the United States Fish and Wildlife Service, National Marine Fisheries Service, or DFG seek to modify the Bay-Delta estuary, they have done so almost exclusively through regulation of the CVP and SWP. Since California's last major drought 15 years ago, regulations have annually shifted to fish and wildlife purposes priority of use for nearly 3,000,000 acre-feet of CVP and SWP water.[3] During this same period, over $1.5 billion[4] has been spent at the behest of wildlife agencies in an attempt to improve ecological conditions. And yet, despite this considerable investment of resources, the ecological health of the Bay-Delta estuary and population levels of certain fish dependent upon it have continued to decline. As we enter into the next drought with significantly diminished flexibility in the system and in the midst of mounting socio-economic impact, we suggest that this is not the time to continue down the same deleterious path.

During the period the longfin smelt is a candidate for listing under the California Endangered Species Act ("CESA"), the Water Agencies recognize the need for the Commission to provide authorization for the take of longfin smelt incidental to otherwise lawful activities. Clearly, the State's broad interests weigh in favor of continuing lawful operation of the CVP and SWP to provide water to California's environment, farms, families, and businesses. However, the Commission is now considering a Proposed Regulation that is not supported by substantial evidence and is contrary to law. If it is adopted, the Proposed Regulation will be arbitrary and capricious, constitute an abuse of the Commission's discretion, and exceed the Commission's legal authority.

The Proposed Regulation, while providing authority for incidental take during the candidacy period, does so at a disproportionate risk to public water users. Worse, it fails to offer any measures to address, understand, and control the important threats to the longfin smelt populations in the Delta. The Water Agencies recommend that the Commission adopt a more limited regulation that authorizes continued operation of the CVP and SWP for the longfin smelt candidacy period, provided that DWR and the United States Bureau of Reclamation ("Reclamation") continue to monitor and report the take of longfin smelt, and that DWR and Reclamation continue to meet their other regulatory requirements intended to protect fish and

[3] 500,000 af Shasta cold water pool; 400,000 af Trinity River restoration; 800,000 af Sacramento River and Delta fish restoration; 400,000 af wildlife refuge supply; 750,000 af CVP and SWP OMR constraints; 100,000 af Water Quality Control Plan
[4] Approximately $715,000,000 per 2007 CALFED Annual Report plus approximately $760,000,000 per CVPIA annual accounting through 2006 federal fiscal year.

wildlife. Such an approach would be at least as restrictive as the regulatory approach being applied to all other resources of longfin smelt mortality in the Delta.

I. Summary Of Comments

The Proposed Regulation is not supported by the best scientific data available. Most importantly, no data are presented to support a conclusion that the Proposed Regulation will increase longfin smelt population levels. It threatens to significantly reduce CVP and SWP water supplies during a drought when water supply is particularly critical to California. It is a prime example of poor science being used to justify bad public policy.

The Proposed Regulation also violates law and oversteps the Commission's legal authority by: (a) proposing to regulate in excess of the powers accorded to it under CESA; (b) proposing to apply the regulation to entities that fall outside the jurisdiction of the Commission; and (c) by disparately treating the CVP and SWP as compared to other factors.

II. Detailed Comments

The Water Agencies prepared a review of the Proposed Regulation that summarizes available DFG data related to longfin smelt. Additionally, the Water Agencies previously submitted comments on earlier versions of the draft regulations which remain applicable to the current proposal. Attachment 3, "Stakeholder Input on Drafting a Longfin Smelt Section 2084 Regulation" was submitted to DFG on June 6, 2008, in response to an earlier request for information. Attachment 4, "Updates to Attachment 3" provides corrections and additions to Attachment 3. The detailed comments summarized below either excerpt from or rely on the information contained in Attachments 2, 3 and 4.

A. The Proposed Regulation Is Unsupported By The Best Available Science

1. Longfin Smelt Are Rarely In The "Zone Of Influence"

The proposed "Longfin Smelt Risk Assessment Matrix (LSRAM)" identifies an increased level of concern when significant numbers of longfin smelt are distributed south and east (effectively upstream) of Jersey Point on the San Joaquin River. This area of the Delta east or south of Jersey Point is effectively a "Zone of Influence." However, analysis of DFG's sampling data show that nearly all fish surveys show that longfin smelt reside in locations outside of this "Zone of Infleunce," where entrainment by the CVP and SWP is highly unlikely. Data from the Fall Midwater Trawl (FMWT) (Table 3 of Attachment 2) and Spring Kodiak Survey (Table 5 of Attachment 2) show that adult longfin smelt typically are located outside of the "Zone of Influence," far from the CVP and SWP facilities during the months of December, January and February. Additionally, data from the 20 mm survey (Summarized in Table 6 of Attachment 2), show that populations of longfin smelt larvae and juveniles are outside of the "Zone of Influence" during the period March through June.

The low likelihood of longfin smelt presence in a "Zone of Influence" subject to entrainment is confirmed by direct analysis of entrainment monitoring data gatherd by Reclamation and DWR. Review of such data indicates that a negligible fraction of longfin smelt that reside in the Delta are entrained during the period December through February. The highest year of longfin smelt entrainment in December was 1997, when an estimated 0.6% of the population was entrained (Table 2 of Attachment 2). Entrainment of longfin smelt in other years was a smaller percentage, and was often zero. Entrainment of larvae and juveniles from March through June has also been low historically, with the highest percentage of entrainment occurring in 2002, when an estimated 0.0017% of the population was entrained (Figure 7 of Attachment 2). This data regarding entrainment of longfin smelt demonstrates their absence from the Zone of Influence, that is the area from which entrainment by CVP and SWP in-Delta facilities might be expected.

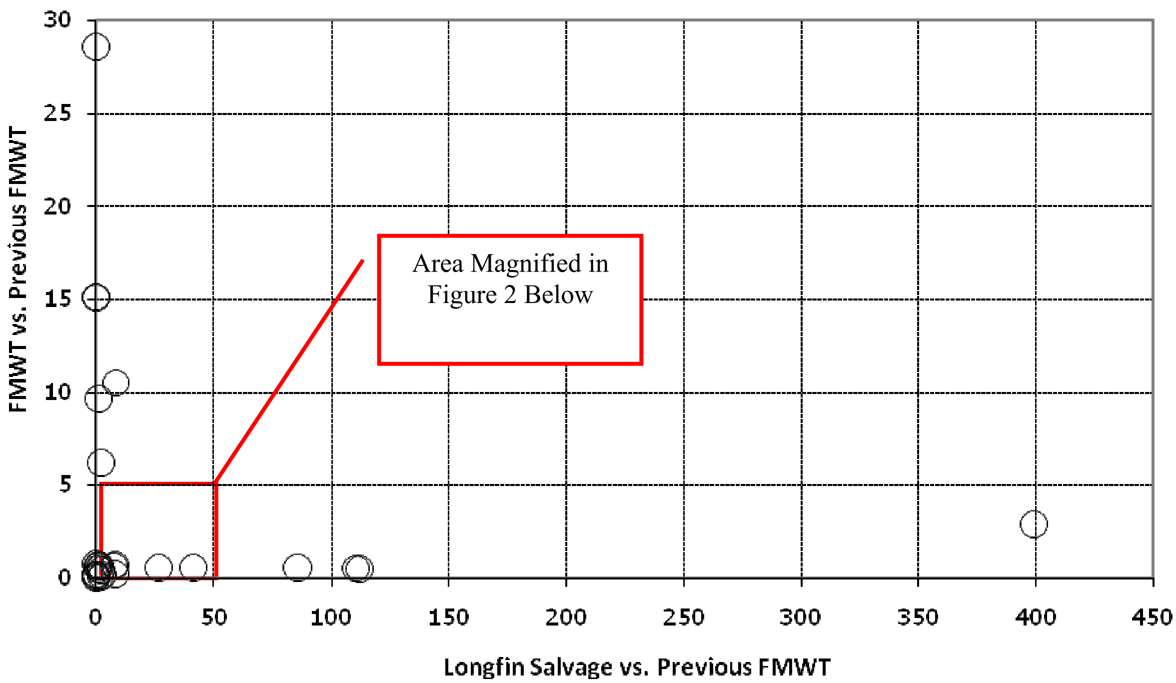
2. The CVP And SWP Entrain Few Longfin Smelt

The absence of longfin smelt in the south Delta surveys is, as one would expect, reflected in the exceedingly low salvage rates actually recorded at the SWP and CVP pumping facilities. According to DFG data, median annual salvage of longfin smelt from 1993 through 2007 is 805 fish, or 67 longfin smelt per month. Salvage for the last three years recorded (2005-2007) totaled 219, 0 and 96, respectively (Table 1 in Attachment 3, obtained from ftp://ftp.delta.dfg.ca.gov/salvage/). To place these levels of entrainment into context, the December mean abundance of longfin smelt in the Delta during 2005-2007 is estimated to have been 159,244, 83,311, and 21,376, respectively (Table 2 in Attachment 2). The data thus provide very clear evidence that SWP and CVP pumping operations are not a significant cause of the level of longfin smelt fall abundance and, therefore, should not be singled out for undue treatment in the Proposed Regulation.

To further illustrate this lack of relationship, analysis of salvage data displayed in **Figure 1** shows the relative change in longfin smelt abundance for each year between 1979 and 2008 versus the relative longfin smelt salvage for the corresponding year. In this figure, the relative change in longfin smelt abundance is plotted as a fraction comparing each year to the prior year. If there was no change in abundance from year to year, the value plotted is one. If there was an increase in abundance, the value plotted is greater than one. If there was a decrease, then the value plotted is less than one. This ratio of abundance from year to year is compared to the amount of entrainment, which is adjusted by the FMWT level the prior year to reflect relative entrainment impacts on population.

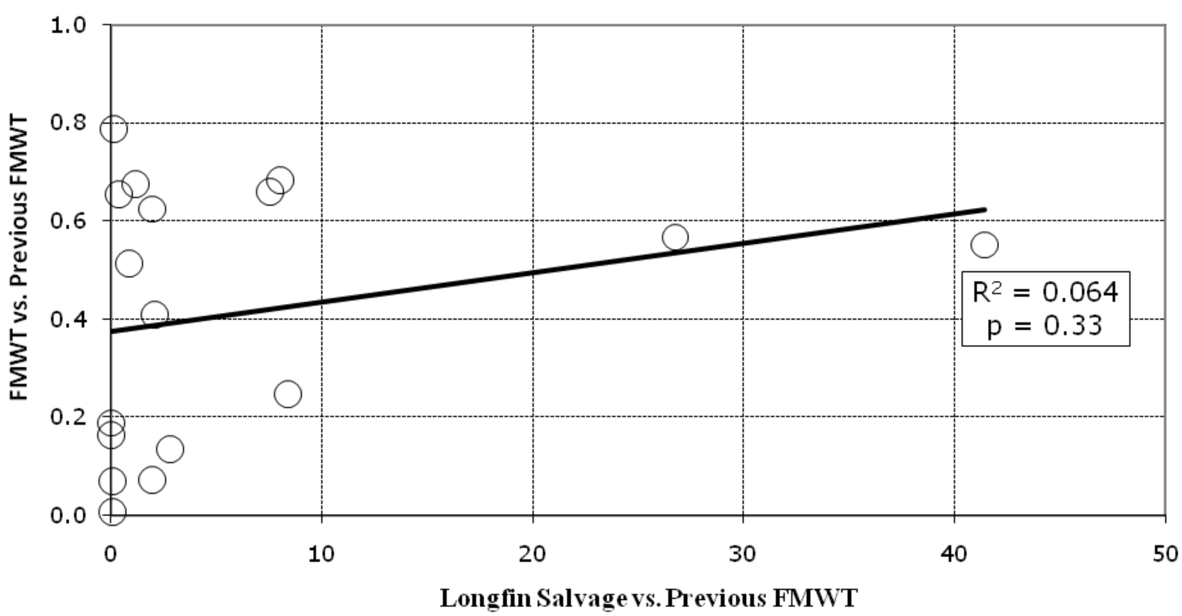
If entrainment was a significant factor affecting population, one would expect to find that high relative entrainment (on the horizontal axis) would cause a low population level impact (on the vertical axis.) Figure 1 shows that there is no such relationship. The year with the highest level of salvage relative to FMWT, with 400, had a slight increase in subsequent year FMWT. Put another way, longfin smelt population, as measured by the FMWT, actually increased in the year following the higher relative entrainment. Conversely, several years with zero entrainment were followed by years with decreased longfin smelt FMWT indices. This effect shows up most clearly in a closer examination of the data near the origin, as displayed in **Figure 2**. This figure shows many years when abundance declined were preceded by years in which there was virtually no salvage or none at all. The most recent example of this effect was in 2006, when there were no longfin smelt taken and the longfin smelt FMWT fell from 1949 to 13.

Figure 1. Ratio of the Longfin FMWT Abundance Index to the Prior Fall's FMWT Index, and the Ratio of Intervening Longfin Salvage to Prior Fall's FMWT Index



Graph and Analysis by Dr. William J. Miller

Figure 2. Zoom-In on Origin of Figure 1



Graph and Analysis by Dr. William J. Miller

It is noteworthy that the demonstrated lack of relationship between longfin smelt salvage and abundance represents data almost entirely collected when severe restrictions were not in place ostensibly to protect delta smelt. In other words, the stringent operational constraints that exist today for delta smelt are clearly not necessary to protect longfin smelt.

3. The Proposed Regulation Fails To Adequately Protect Longfin

In a letter to Reclamation dated March 5, 2008, DFG acknowledged that numerous activities harm the longfin smelt in the Delta and committed to evaluation of the adverse effects of those activities and development of protective measures to minimize of mitigation such effects.

> The Department is committed to working with Reclamation and others … in updating the assessment of the status of the longfin populations in the Delta and preparing a more comprehensive evaluation of the factors limiting the abundance of that species. There are a number of factors that affect the status of longfin, as well as Delta smelt. Examples include invasive species, toxics, predation, ocean conditions, and a changing food web.
>
> The Department is committed to working with the DWR, Reclamation, the U.S. Fish and Wildlife Service, BDCP participants and other interested groups over the next six months to craft a 2084 regulation to govern the management of longfin conservation during the remainder of the candidacy period … after the current regulation expires. I look forward to the input of the many Delta interests in the development of that replacement regulation, including the identification of other elements of the Delta ecosystem that can be adjusted to address species concerns.
> Letter from J. McCamman to J. Davis (March 5, 2008).

Despite these assurances that DFG is committed to identifying and addressing the causes of longfin smelt decline in the Delta, the Proposed Regulation does not include any measures to address factors DFG itself previously referenced including invasive species, toxics, predation, ocean conditions, and a changing food web.

Moreover, DFG has evidently decided to turn a blind eye to in-Delta diversions less than 250 cfs – which number in the thousands – in the Proposed Regulation. DFG previously recognized that these diversions are a source of longfin smelt mortality and extended take authorization to them without requiring any monitoring, minimization, or mitigation. But, in the Proposed Regulation, DFG has now proposed to withdraw take authorization though it is certain that those diversions will continue to operate and take longfin smelt. In the Petition to List the Longfin Smelt, petitioners indicate that water diversions are taking the species and its habitat. (Petition to the State of California Fish and Game Commission and Supporting Information for Listing the Longfin Smelt (*Spirinchus thaleichthys*) as an Endangered Species under the California Endangered Species Act at pp. 33, 41 (Aug. 8, 2007) (hereinafter "Petition").) This claim is supported by existing literature.. In its evaluation of the Petition, the Department of Fish and Game characterizes the impacts as "adverse" and likely "substantial." (Department of Fish and Game, Evaluation of Petition at p.4 (Nov. 16, 2007).) Furthermore, in its 1996 Recovery Plan for the longfin smelt and other fish species native to the Delta, the Fish and Wildlife Service identified losses to water diversions as one reason for the decline of the longfin smelt. (U.S. Fish and Wildlife Service, Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes at p. 53 (1996).) The Commission should decline to adopt DFG's policy decision to maintain a myopic focus on the pumps while ignoring other causes of take and the major drivers of longfin smelt abundance in the Delta.

4. The Proposed Regulation Fails To Consider Impacts And Benefits

a. Existing Operational Constraints

As described above, historical levels of CVP and SWP entrainment of longfin smelt have been extremely low and do not have a statistically significant correlation with longfin smelt populations. Significantly, this historical period of low entrainment was also a period when CVP and SWP in-Delta facilities operated under far less stringent operational criteria than are currently in effect. Over the past 15 years, the CVP and SWP have been subjected to a myriad of terms and conditions intended to protect both water quality and fish. In addition, each year the Projects provide millions of dollars pursuant to federal law and state agreements to support actions intended to benefit fish and wildlife. The result of these existing regulatory and voluntary actions has been the annual shift of priority for nearly 3 million acre-feet of water, on average, to fish and wildlife, and the expenditures of over $1.5 billion over the last years. Obviously, these efforts have not been successful, as evidenced by continued declines in longfin smelt and other fish species. To propose an entirely new layer of regulations and water supply impacts without any data indicating a likelihood of success of such regulations, is not reasonable for fisheries or water users.[5]

b. Projected Impacts of Proposed Regulation

The Water Agencies estimate that the Proposed Regulation could cost the SWP and CVP as much as 1,100,000 acre-feet of water annually. This amount is in addition to the considerable volumes of water already prioritized for environmental purposes. These new water losses will only exacerbate the economic impacts associated with job losses and the significant financial demands of securing alternative sources of water, if available, due to existing regulatory actions. The Commission and DFG have not quantitatively analyzed and have not considered the adverse environmental and economic impacts associated with this lost water, the resulting loss of agricultural and industrial production, and the need to secure replacement supplies as the Government Code requires.

Government Code section 11346.1(b)(2) states "[a]ny finding of an emergency shall include a written statement that contains the information required by paragraphs (2) to (6), inclusive, of subdivision (a) of Section 11346.5 …" Government Code section 11346.5(a), requires, among other things, that the Commission provide an informative digest including "[a] policy statement overview explaining the broad objectives of the regulation and, if appropriate, specific objectives." (Gov. Code § 11346.5(a)(3)(C).) Furthermore, the Commission must provide "[a]n estimate … of the cost or saving to any state agency, the cost to any local agency …, other nondiscretionary cost or saving imposed on local agencies …" (Gov. Code

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[5] The nature of the Proposed Regulation is exacerbated by the fact that the Director of Fish and Game would "have the final approval for any actions", at least as contemplated under section 749.3(a)(4)(C) and (D). (*See* Proposed Regulations, § 749.3 (a)(4)(B).)

§ 11346.5(a)(6).) The statute further states, "'cost or savings' means additional costs or savings, both direct and indirect, that a public agency necessarily incurs in reasonable compliance with the regulations." (*Id.*) Thus, the Commission must estimate the cost to local water districts throughout the state of obtaining alternative water supplies to replace those lost through implementation of the Proposed Regulation.

c. Lack Of Benefit To Longfin Smelt Abundance

While the analyses of longfin smelt populations survey and entrainment demonstrate the lack of effect CVP and SWP operations have on the abundance of longfin smelt, the Proposed Regulation would implement new and costly regulation on CVP and SWP operations. The potential costs of the Proposed Regulation could exceed $220,000,000 per year,[6] would disproportionately impact our customers and would not provide a demonstrable biological benefit for the longfin smelt population. Adoption of the Proposed Regulation by the Commission would amount to an abuse of discretion.

B. The Proposed Regulation Oversteps The Commission's Legal Authority

1. The Commission Has No Authority To Regulate DWR And Reclamation Under CESA

The Proposed Regulation exceeds the Commission's authority by imposing limitations on Reclamation and DWR, the operators of the CVP and SWP, respectively. The take prohibition in Section 2080 of the Fish and Game Code simply does not and cannot apply to DWR and Reclamation. CESA's take prohibition is clear, and nowhere does it evince intent by the Legislature to regulate state or federal agencies, especially when they are involved in such important functions as providing much of California's water supply. Specifically, Fish and Game Code section 2080 only applies to natural persons and certain private entities. It states:

> No *person* shall import into this state, export out of this state, or take, possess, purchase, or sell within this state, any species, or any part or product thereof, that the commission determines to be an endangered species or a threatened species, or attempt any of those acts, except as otherwise provided in this chapter … .(Fish & Game Code, § 2080 (emphasis added).)

"Person" is defined by Fish and Game Code section 67 as, "any natural person, or any partnership, corporation, limited liability corporation, trust or other type of association." (Fish & Game Code, § 67.) From the plain language of the statute, "person" does not include federal or state agencies.

Further, Fish and Game Code section 67 was amended in 1988 and 1994 to include "trust" and "limited liability corporation," respectively. Both amendments presented opportunity for the California Legislature to expressly include federal or state agencies within the definition, but the Legislature declined to do so. When the Legislature intends to include state or federal agencies within the statutory term person, it does so expressly. (*See, e.g.*, Fish and Game Code section 711.2 defining persons who must pay fees to DFG as including "the state, and any of the agencies of those entities.") Our research shows that the Legislature intended to regulate state

[6] Potential average annual impact of 1,100,000 acre-feet at a replacement value of $200 per acre-foot.

agencies under CESA through operation of former Fish and Game Code sections 2090-2097, originally included in CESA as the "State Agency Consultation" provisions. However, the Legislature allowed these provisions to expire, and did not adopt any replacement scheme, thus expressly indicating an intent not to regulate state agencies like DWR under CESA. Given this analysis, it is unclear how or why the Commission and DFG believe that the Legislature ever intended Section 2080 to apply to DWR and Reclamation. The Legislative intent appears to be exactly the opposite, or at the very least unclear and ambiguous.

Recently, the California Supreme Court addressed a very similar issue involving the scope of the term "person" as used in another statute, California's False Claims Act. The Court held that school districts were not "persons" who were subject to suit under the False Claims Act. The Court reaffirmed the "sovereign powers" principle, a longstanding rule of statutory construction that statutory terms of general applicability like "person" must not be construed to operate against the sovereign when involved in governmental functions unless a clear Legislative intent to that effect is established. (*Wells v. One2One Learning Foundation* (2006) 39 Cal. 4th 1164, 1192.) This rule also finds independent justification in principles of state sovereign immunity and the rule demanding that laws in derogation of sovereignty be strictly construed in favor of the state and its agencies.

The same rationale used in *Wells* must be applied to CESA and the application of Fish and Game Code section 2080. In the absence of clear Legislative intent to apply Section 2080 to DWR and Reclamation, the Commission cannot interpret the general term "person" so as to infringe or impede the sovereign water supply functions of DWR and Reclamation in operating the SWP and CVP, respectively. Neither the Commission, nor DFG, has satisfied the burden of showing the necessary evidence of clear Legislative intent to bring DWR and Reclamation within the scope of Section 2080. In the absence of such intent the Commission must favor the sovereignty of the SWP and CVP instead of subjecting California's main water supply infrastructure, and over 20 million residents, to an onerous regulation that jeopardizes the public's water supply on the basis of erroneous and overzealous administrative interpretations.

2. Under The Supremacy Clause, CESA Cannot Be Used To Regulate Reclamation Under Sovereign Powers Principle

As explained above, as a matter of statutory construction, the take prohibition in CESA section 2080 does not apply to either state or federal agencies. There is an additional reason why that provision cannot apply to the federal Bureau of Reclamation, or its operation of the CVP. The Supremacy Clause of the United States Constitution (U.S. Const., art. IV, cl. 2), the federal enclave doctrine, and principles of federal preemption protect federal facilities and agencies from state regulation. (*EPA v. State Water Resources Control Board* (1976) 426 U.S. 200.) Any consent to subject federal facilities to regulation under state law must come from Congress, and must be explicit. (*Hancock v. Train* (1976) 426 U.S. 167, 179.) No federal statute waives federal sovereign immunity from state regulation under CESA. Hence, because the CVP is a federal facility operated by Reclamation, CESA cannot be enforced against the Bureau of Reclamation or CVP operations. The Proposed Regulation is therefore fundamentally flawed.

3. The Proposed Regulation Ignores CESA's Proportionality Mandate

Under CESA, the Commission has the authority to permit take of a species pursuant to section 2084 of the California Fish and Game Code. The authorization, however, must be for take that is incidental to an otherwise lawful activity. Furthermore, CESA evidences a conscious legislative intent to ensure that the impact of any take be minimized and fully mitigated through measures that are "roughly proportional in extent to the impact of the authorized taking," and that " maintain the applicant's objectives to the greatest extent possible." (*See,* Cal. Fish and Game Code, §§ 2052.1, 2081.) The Proposed Regulation includes measures that are not tailored to addressing take as defined in the Fish and Game Code, but rather attempt to expand that definition. The Proposed Regulation also fails to incorporate the careful balancing between project objectives and impacts to the species embodied in CESA's rough proportionality mandate.

The Proposed Regulation violates CESA's rough proportionality mandate because it imposes operational constraints and attendant water supply and economic impacts that are far in excess of the trivial effects caused by take at the CVP and SWP in-Delta facilities. Clearly, the CVP and SWP in-Delta facilities take longfin smelt. But available data show the percent of the total longfin Smelt population taken by the CVP and SWP facilities is small and does not affect the overall population level or viability of the longfin smelt. The burdensome Proposed Regulation cannot be rationally explained in the context of the minimal impact of the CVP and SWP in-Delta facilities on the population of longfin smelt in the Delta. Thus, the Proposed Regulation fails to adhere to the Legislative directive that measures to avoid or minimize take should be roughly proportional to the impacts of that take and fails to maintain the water supply objectives of the SWP and CVP to the greatest extent possible.

4. The Proposed Regulation Goes Beyond Regulating Take

Although ostensibly directed at take, the Proposed Regulation does much more than address take; its measures are largely focused on impacts to habitat (in the form of flow pattern changes) from CVP and SWP operations, irrespective of whether take is actually occurring. It does not specify particular levels of incidental take as measured by individual fish. Instead, its prescriptions are tied to flows in Old and Middle Rivers.

This expands the statutory concept of "take" beyond that authorized by state law. Specifically, CESA defines "take" to mean "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill." (Fish & Game Code, § 86.) As defined, a prohibited taking under CESA involves mortality or direct effects on individuals of the species. (*Environmental Council of Sacramento v. City of Sacramento* (2006) 142 Cal.App.4th 1018, 1040; *Dept. of Fish & Game v. Anderson-Cottonwood Irrigation Dist.* (1992) 8 Cal.App.4th 1554, 1562 (holding "take" means kill).) In this way, CESA's definition of take is narrower than the federal Endangered Species Act's definition, which includes harming and harassing listed species through activities that modify habitat. (*See* 16 U.S.C. § 1532(19).) Fish and Game Code section 2084, the CESA provision authorizing the Commission to allow take of candidate species, does not expand CESA's definition of take. Thus, the take concept the Commission must employ in promulgating the Proposed Regulation must focus on take rather than perceived habitat modifications caused by the CVP and SWP.

However, the Proposed Regulation ignores this limitation. Because the rulemaking authority of an agency is circumscribed by the substantive provisions of the law governing the agency, agency regulations which enlarge or amend a statute are void. (*Henning v. Division of Occupational Safety & Health* (1990) 219 Cal.App.3d 747, 757-758.) The Proposed Regulation, therefore, should be directed at take rather than Delta flow patterns. In its current form, the Proposed Regulation is unlawful.

5. Violation Of The Right To Equal Protection

The Proposed Regulation addresses three general categories of actions: (1) research and monitoring, (2) dredging and extraction of sand and gravel resources, and (3) water diversions. Restrictions on take of longfin smelt for purposes of research and monitoring are without foundation and counterproductive. Comparison of the number of longfin smelt that would be taken as part of a comprehensive program of research and monitoring to identify the true causes of the abundance decline is trivial relative to estimates of total numbers of longfin smelt in the Delta. We suspect that such restrictions are, in part, an attempt to justify and assuage similarly unsupported restrictions of take by the CVP and SWP.

DFG has stated that the take of even one longfin smelt requires legal take authority and we concur. However, the Proposed Regulation does not carry this statement forward in an equitable or consistent manner. For example, it does little to regulate direct take by the thousands of diverters in the Delta. It also ignores all other factors that might harm longfin smelt, including toxics and boating. DFG will argue this is because they lack evidence of take by these other sources. We observe that this lack of evidence is, in fact, really a lack of effort to investigate the important causes of the longfin smelt decline. Sadly, the Proposed Regulation continues to disproportionately focus on the CVP and SWP, to the exclusion of other factors and against the great weight of scientific evidence, which violates Constitutional protections.

The Fourteenth Amendment to the United States Constitution requires the laws of a state to treat an individual in the same manner as others in similar conditions and circumstances. The protections of the Fourteenth Amendment extend to the governmental treatment of entities. (*RK Ventures, Inc. v. City of Seattle* (2002) 307 F.3d 1045, 1057, fn. 7.) Here, the Proposed Regulation would impose wholly unwarranted regulatory and enforcement treatment on the CVP and SWP. There is no rational basis for that disparate treatment. As such, the Proposed Regulation illegally discriminates against the Water Agencies and the millions of individual water users that depend on SWP and CVP supplies for their health, welfare, and economic livelihood.

III. <u>Potential Alternative Approaches</u>

Without waiving any arguments made and objections raised above, the Water Agencies propose changes to the emergency regulation that would properly balance the science against the Commission's goals, and increase the effectiveness of the Proposed Regulation towards its intended purpose. Specifically, the Water Agencies propose that the Fish and Game Commission modify the proposed regulation as follows:

- Omit the sections of the Proposed Regulation related to the CVP and SWP, as the data indicates take of longfin smelt has had no measurable impact on their population.
- Authorize continued operation of the CVP and SWP for the longfin smelt candidacy period; provided that DWR and Reclamation continue to monitor and report the take of longfin smelt, as allowed for the other activities covered by the Proposed Regulation; and provided further that DWR and Reclamation continue to meet their other regulatory requirements intended to protect fish and wildlife.

To address the other factors that have been identified to adversely affect longfin smelt, the Water Agencies recommend that the Fish and Game Commission direct DFG to take the following actions:

- Inventory all sources of industrial and wastewater discharges that affect the region occupied by longfin smelt
- Require monitoring of all activities producing toxicity that might be resulting in their take
- Implement analysis program of monitoring data to identify chemical constituents and specific levels of toxicity affecting the natural mortality of longfin smelt.
- Promulgate regulations to mitigate for these impacts.
- Prohibit all boating and watercraft activities in areas where monitoring data indicate the presence of longfin smelt, as DFG states that larval longfin smelt reside at the surface of the water column and therefore are exposed to unlawful take by these unregulated activities.

Sincerely,

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

Dan Nelson
Executive Director

STATE WATER CONTRACTORS

Terry Erlewine
General Manager

cc: Office of Administrative Law
300 Capitol Mall; Room 1250
Sacramento, CA 95814

Mr. Marty Gingras, Biologist, CA Department of Fish & Game
Mr. Donald Koch, Director, CA Department of Fish & Game
Mr. Lester Snow, Director, CA Department of Water Resources
Mr. Mike Chrisman, Secretary, CA Resources Agency
Mr. Ren Lohoenfener, Regional Director, US Fish & Wildlife Service
Mr. Rodney McInnis, Regional Administrator, US NOAA Fisheries Service
Mr. Donald Glaser, Regional Director, US Bureau of Reclamation

ATTACHMENT 1

The San Luis & Delta-Mendota Water Authority

The San Luis & Delta-Mendota Water Authority represents 31 member agencies, each of whom contract with the United States Bureau of Reclamation for water supplied from the federal Central Valley Project, to serve the public interest. To that end, on average, the Water Authority delivers approximately 2,000,000 acre-feet of water to about 1,200,000 acres of highly productive and diversified agricultural land, 200,000 acre-feet for urban usage in California cities ranging from just over 7,000 persons to just under 1,750,000, and 300,000 acre-feet for environmental purposes serving about 100,000 acres of publicly and privately managed wetlands located in the vital Pacific Flyway.

The member agencies of the Authority are: Banta-Carbona Irrigation District; Broadview Water District; Byron Bethany Irrigation District (CVPSA); Central California Irrigation District; City of Tracy; Columbia Canal Company; Del Puerto Water District; Eagle Field Water District; Firebaugh Canal Water District; Fresno Slough Water District; Grassland Water District; Henry Miller Reclamation District #2131; James Irrigation District; Laguna Water District; Mercey Springs Water District; Oro Loma Water District; Pacheco Water District; Pajaro Valley Water Management Agency; Panoche Water District; Patterson Irrigation District; Pleasant Valley Water District; Reclamation District 1606; San Benito County Water District; San Luis Water District; Santa Clara Valley Water District; Tranquillity Irrigation District; Turner Island Water District; West Side Irrigation District; West Stanislaus Irrigation District; Westlands Water District; and Widren Water District.

State Water Contractors

The State Water Contractors is a non-profit association of 27 public agencies from Northern, Central and Southern California. Each of the SWC's member agencies contract with the California Department of Water Resources for water supplied from the State Water Project. In total, the SWC's member agencies deliver water to more than 25 million residents throughout the state and more than 750,000 acres of agricultural lands.

The member agencies of the SWC are: Alameda County Flood Control and Water Conservation District Zone 7; Alameda County Water District; Antelope Valley-East Kern Water Agency; Casitas Municipal Water District; Castaic Lake Water Agency; Central Coast Water Authority; City of Yuba City; Coachella Valley Water District; County of Kings; Crestline-Lake Arrowhead Water Agency; Desert Water Agency; Dudley Ridge Water District; Empire-West Side Irrigation District; Kern County Water Agency; Littlerock Creek Irrigation District; Metropolitan Water District of Southern California; Mojave Water Agency; Napa County Flood Control and Water Conservation District; Oak Flat Water District; Palmdale Water District; San Bernardino Valley Municipal Water District; San Gabriel Valley Municipal Water District; San Gorgonio Pass Water Agency; San Luis Obispo County Flood Control and Water Conservation District; Santa Clara Valley Water District; Solano County Water Agency; and Tulare Lake Basin Water Storage District.

ATTACHMENT 2

RESPONSES TO CALIFORNIA DEPARTMENT OF FISH AND GAME 2084 DRAFT REGULATIONS FOR LONGFIN SMELT

SUMMARY

Although recent abundance levels for longfin are low and likely to be low again this fall and winter, controlling Old and Middle rivers (OMR) offers little benefit, if any, to the longfin population. Almost all of the adult and spawner longfin smelt in the surveyed waters are seaward of OMR and Jersey Point on the San Joaquin River, well away from the pumps. Further, almost all (92-100%) larval and juvenile longfin smelt during late-March-June are seaward of OMR, and except on the rare occasion, seaward of Jersey Point.

INTRODUCTION

The intent here is to add to the content in the attachment to our June 6, 2008 submittal.

California Department of Fish and Game (CDFG) intends to use the most protective of these 2084 Old and Middle Rivers (OMR) limits, Kempthorne OMR flows, or the forthcoming BO; however, the 2084 actions will be at the discretion of CDFG's Director. Criteria with 2084 and Kempthorne triggers and actions differ (**Table 1**). 2084 brings all of December into play and OMR restrictions to -750 as early as January 1 instead of a more likely February for delta smelt. Further, 2084 triggers are based on presence in a survey rather than flow or life cycle events.

Table 1. Actions and triggers from Kempthorne and the proposed 2084 regulation.

Month	Kempthorne (Wanger)	2084
December	Starting as early as December 25, 10-day pulse of OMR > -2,000 cfs if turbidity increases as specified	Starting as early as December 1, OMR > -5,000 cfs starting when adults detected as specified, or combined salvage exceeds 24 adult longfin smelt.
January and February	After pulse or by January 15, OMR > -5,000 cfs	Starting as early as January 1, OMR > -5,000 cfs to -750 cfs starting when larvae or juveniles are detected as specified
March - April	Starting after spawning, OMR > -5,000 cfs to -750 cfs	OMR > -5,000 cfs to -750 cfs
May	OMR > -5,000 cfs to -750 cfs	
June	OMR>-5,000 cfs to -750 cfs until June 20	

DATA

Except as specified otherwise below, these analyses utilize several of DFG's survey program databases. Salvage data was collected from the DFG's public salvage ftp website in 2008. Daily SWP and CVP salvage values for longfin were filtered for 1993 and after. Salvage is summed for each winter month and for the spring entrainment period. Bay Study catch data was received from DFG personnel in 2006. Longfin data was isolated and filtered for near-field stations 863, 864 and 865, which were identified in CDFG's 2084 proposed longfin smelt protection measures. Longfin catches for each station were summed for the month of December. Fall Mid-Water Trawl (FMWT) catch data were collected from CDFG's ftp site, with permission, in 2008. The December FMWT survey, Survey 6, was filtered for longfin data at the list of FMWT stations proposed as trigger station in CDFG's 2084 protection measures.

Spring abundance and entrainment were calculated with longfin smelt catches of the 20mm Survey. Using CDFG's 20mm catch and tow information and, longfin catch densities were calculated. Population abundances were estimated by multiplying densities to delta water volume estimates developed by Miller (unpublished) (**Figure 1**). Before converted to density, the longfin catch values were adjusted by a delta smelt 20mm gear efficiency developed by Kimmerer (2008). It was assumed that the gear efficiency could also be applied to longfin smelt as the two species are of similar body proportion and size. Entrainment was estimated by multiplying density by negative flows in the Old and Middle Rivers (i.e. flows in the southeast delta channels traveling toward the pumps). Flow data was received from the USGS in 2007.

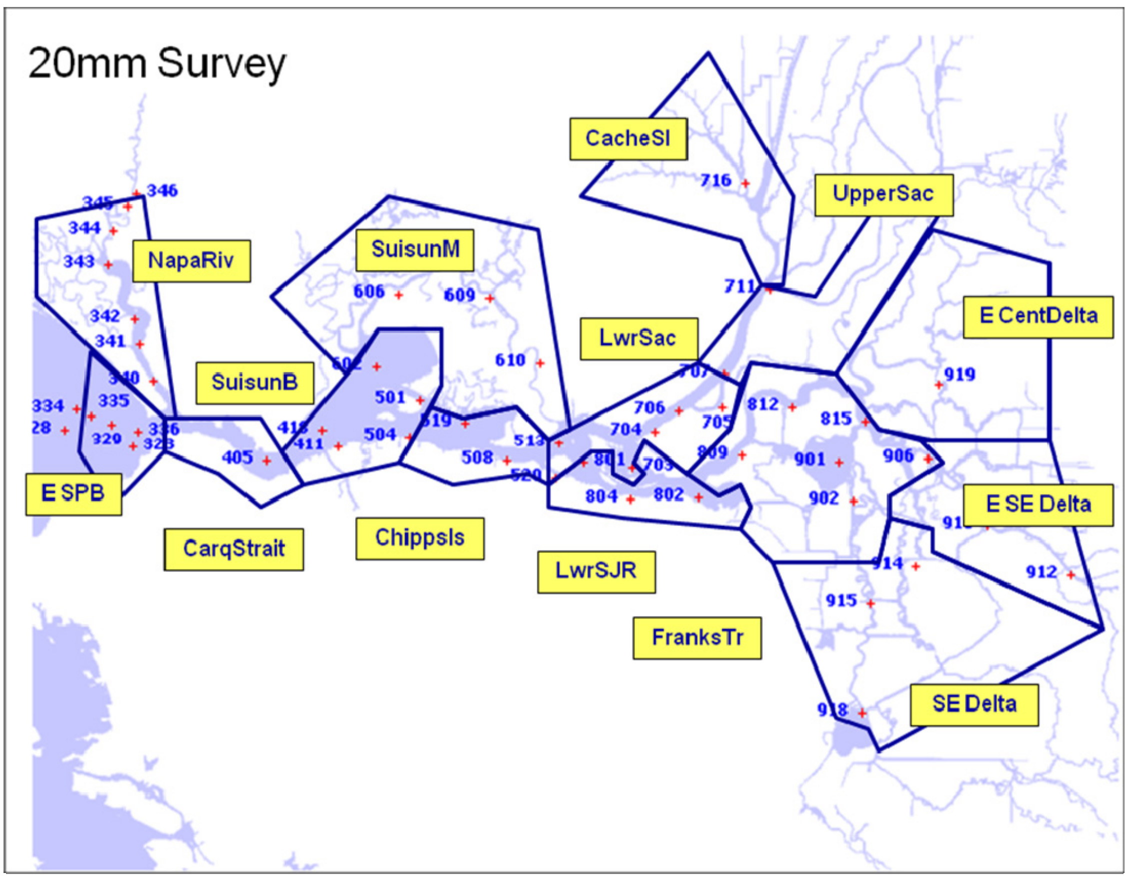


Figure 1. Regional Map for Abundance Percentage Estimates.

VARIANCES FOR FALL AND WINTER OVERALL ABUNDANCE ESTIMATES

Spring Kodiak Trawl (SKT) surveys were generally conducted once a month in the winter and spring (January – May) in the years 2002 – 2007 During a survey, a single trawl was conducted at each sampling station, and the number of fish caught in each trawl was tallied by species. Gear efficiency was assumed to be 100%; that is, catch probability was assumed to be 1 for all fish, irrespective of size.

For each region and each SKT survey, density was calculated using the ratio method, where mean density equals the sum of the catches at all stations within a region divided by the sum of the corresponding trawl volumes. In contrast, the standard method for calculating mean density would entail first estimating tow (or station) density as catch divided by tow volume and then averaging these estimates (across all stations in a region). Abundance was obtained by multiplying mean density by estimated water volume in that region. Total abundance for a survey was the sum of the regional abundances.

A bootstrapping procedure was conducted to estimate variance in longfin smelt abundance from the SKT survey data. First, to account for unknown variability in individual trawls, a parametric bootstrap was conducted. It was assumed that the catch was a random variate from a negative binomial distribution (a "natural" distribution to consider for count data) with mean equal to the observed catch. The corresponding variance for the simulation distribution was calculated using the estimated dispersion parameter from a negative binomial regression model that had been fitted to the entire dataset. Second, stations within regions were sampled with replacement to obtain bootstrap estimates of region densities. Thus, each bootstrap iteration consisted of: (1) simulation of catch at each station using a Negative Binomial distribution; (2) randomly sampling stations, with replacement, in each region; and, (3) calculation of fish density via the ratio method in each region for each survey and year. Repeating this process 5,000 times generated bootstrap distributions of density. Note that region volume was assumed to be constant through time, so that variability in abundance was determined solely by variability in density. Thus, abundances were calculated after conducting the bootstrap procedure. Bootstrap distributions of abundance were summarized by calculating the mean, median, standard deviation, and 95% confidence limits using the percentile method. Summary statistics were calculated for the distribution of total abundance (across all regions) by survey and year.

Bootstrapping for the FMWT differed from those of the Spring Kodiak Trawl due to an important difference in survey methods. Gear efficiency was not assumed to be 100% for the FMWT. Instead, a gear efficiency correction based on fish length was employed. This feature necessitated changes in the bootstrapping.

ACTION 1 - DECEMBER

Salvage – A Small Fraction of the Population

We did not provide a breakdown of the December salvage data in our June submittal. Over 1993-2006, December SWP plus CVP salvage totaled 164 longfin. SWP salvage totaled 34 longfin; 17 juveniles and 17 age-0 adults, and no larvae, subadults or age-2 longfin. Over the same period, CVP salvage totaled 120 longfin, 30 each for juveniles, subadults, adults and age-2 longfin. The average combined December salvage is 11 fish/year.

Bootstrapped estimates of longfin abundance including 95% confidence limits in survey 6 (December) over 1993 to 2007, range from 6k to 8.4M (**Table 2** and Figure 2). In every year with December salvage, from 6 to 54 longfin, December mean abundance ranged from 252k to 6.3M. (Note that the abundances are probably underestimated because much of the population is seaward of the FMWT survey.) Since 2003, there has been no recorded longfin December salvage. Even in 1997, 54 longfin salvaged amounted to approximately 0.02% of the longfin population.

Table 2. FMWT bootstrapped mean longfin smelt abundances for the December (survey 6) and 95% confidence limits (CLs), and December salvages. (Insufficient samples for a 1998 estimate.)

Year	Survey	Mean	Lower 95% CL	Upper 95% CL	SWP slvg	CVP slvg
1993	6	2,121,299	1,539,453	2,923,767	6	0
1994	6	762,931	492,457	1,185,366	10	0
1995	6	1,897,507	1,280,158	2,626,755	0	0
1996	6	2,505,703	1,707,191	3,556,312	0	0
1997	6	356,804	169,092	623,598	6	48
1999	6	893,531	548,077	1,371,856	0	0
2000	6	6,261,994	4,538,034	8,417,526	0	24
2001	6	252,942	142,355	422,206	0	12
2002	6	1,627,699	1,038,290	2,369,905	12	36
2003	6	1,145,721	801,008	1,605,858	0	0
2004	6	475,231	271,314	756,977	0	0
2005	6	159,244	90,862	257,436	0	0
2006	6	83,311	26,826	159,348	0	0
2007	6	21,376	6,255	43,048	0	0

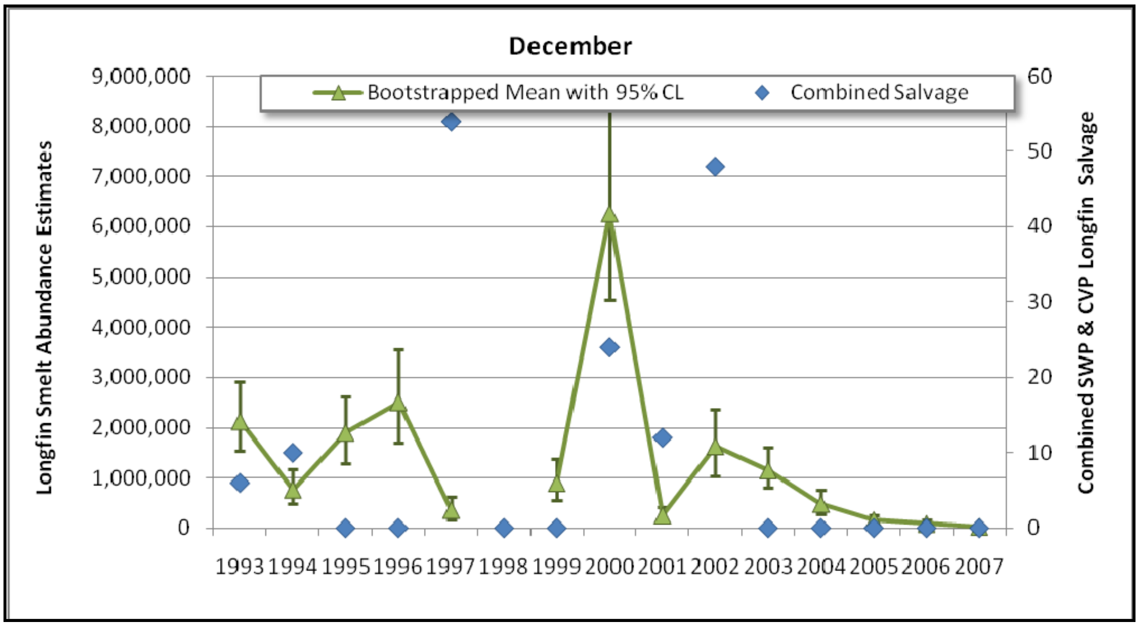


Figure 2. December longfin smelt abundance estimates with 95% confidence limits, and salvage.

Results in Table 2 also indicate that December longfin smelt abundance has been lowest during the last few years, especially in 2007. However, December salvage has been 0 during these years, and therefore did not contribute to these levels.

December longfin salvage can be converted to entrainment using Kimmerer's ratio of entrainment to salvage for adult delta smelt of 30. For 1997, this would amount to 0.6% of the population, and other years would again be less. Protecting 0-0.02% or 0-0.6% of the population from entrainment during December with an arbitrary standard of -5,000 cfs OMR seems likely to yield little protection, if any, even when longfin may be in the area.

Not in Near Shore Samples in Winter

To further evaluate the presence of longfin in the Delta near shore, as opposed to FMWT mid-channel locations, we searched the Resident Fish Survey database provided in 2005 by CDFG. This near-shore electrofishing survey data covers 1995, 1997, 1999 and 2001-04, and includes December surveys. However, longfin smelt were not among the 45 species in the dataset. It appears that few if any longfin smelt were near shore in the Delta, at least during the daytime.

Most Longfin Appear Seaward of the south Delta.

New information since June includes allocation of December longfin smelt among several Bay/Delta regions (Figure 1). We estimated regional percentages based on abundance of longfin in each habitat region as the product of the average CPUE and volume of water in each region. We estimated the percentage of longfin in each region as the quotient of each area's abundance and the total abundance for all areas. We made no corrections for gear efficiency except for CPUEs from the 20 mm survey. For that survey, we used gear efficiency factors developed for delta smelt by Kimmerer (2008). The percentage of total abundance estimated for each region for each surveys show few if any in the Delta upstream of Jersey Point during 1993-2007 (**Table 3**). In each December survey from 1995 through 2006, 100% of the longfin were seaward of the southeastern and eastern portions of the Delta. Further, in 10 of 12 Decembers, 100% were seaward of Jersey Point and the Franks Tract area as well. These were larger longfin that can control their positions in the water column, and not planktonic drifters with the currents. Thus, as reflected in the salvage and overall abundance estimates, few longfin have been in the south or southeast Delta. The vast majority of the December population routinely is not vulnerable to the pumps.

Table 3. FMWT longfin smelt percent distributions for November and December.

Year	Month	Napa River	San Pablo Bay	Carquinez St.	Suisun Bay	Chipps Is.	Lower Sac. R.	Cache Sl.	Upper Sac R.	Lower SJR	nr. Franks Tract	SE Delta	E-SE Delta	E-Central Delta
1995	11	0.1%	4.5%	9.8%	21.5%	42.4%	18.0%	0.0%	0.3%	3.3%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	9.6%	9.2%	18.6%	23.1%	38.2%	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%
1996	11	12.6%	0.0%	31.8%	48.9%	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	4.8%	43.5%	24.8%	22.2%	1.7%	2.3%	0.3%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%
1997	11	1.2%	3.6%	23.1%	10.1%	2.6%	57.2%	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%
	12	2.2%	65.0%	4.1%	14.5%	3.4%	10.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1998	11	1.0%	7.3%	6.2%	35.1%	32.2%	18.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	5.3%	18.5%	75.4%	0.5%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1999	11	1.3%	11.3%	8.5%	25.7%	18.0%	35.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	0.0%	0.0%	87.5%	2.6%	5.5%	0.0%	0.0%	4.4%	0.0%	0.0%	0.0%	0.0%
2000	11	3.4%	0.1%	11.4%	21.7%	14.3%	45.8%	0.0%	0.0%	3.2%	0.0%	0.0%	0.0%	0.0%
	12	6.6%	0.8%	19.2%	31.8%	16.3%	23.4%	0.1%	0.0%	1.8%	0.2%	0.0%	0.0%	0.0%
2001	11	0.0%	5.4%	0.0%	50.6%	19.3%	24.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	4.8%	5.7%	21.1%	31.8%	3.8%	22.7%	3.4%	1.5%	2.1%	3.0%	0.0%	0.0%	0.0%
2002	11	0.0%	8.3%	1.5%	31.6%	18.4%	38.5%	0.6%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%
	12	6.3%	1.6%	1.1%	37.7%	11.3%	38.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%
2003	11	2.8%	1.7%	17.7%	45.0%	8.9%	21.5%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%

Year	Month	Napa River	San Pablo Bay	Carquinez St.	Suisun Bay	Chipps Is.	Lower Sac. R.	Cache Sl.	Upper Sac R.	Lower SJR	nr. Franks Tract	SE Delta	E-SE Delta	E-Central Delta
	12	0.0%	7.4%	19.4%	39.3%	17.8%	14.5%	0.3%	0.0%	1.3%	0.0%	0.0%	0.0%	0.0%
2004	11	0.0%	0.0%	0.0%	24.2%	46.2%	29.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	20.8%	15.4%	54.1%	1.8%	6.3%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%
2005	11	0.0%	34.8%	0.0%	29.3%	0.0%	35.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	36.3%	4.5%	39.7%	7.6%	10.6%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
2006	11	0.0%	22.0%	0.0%	5.8%	5.6%	66.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	12	0.0%	34.8%	52.5%	4.6%	4.4%	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

>0% and ≤5%

>5% and ≤10%

>10%

December Salvage and Old and Middle Rivers Flow

December salvage trends downward as Old and Middle Rivers (OMR) flow increases (**Figure 3**). However, as above the salvage levels are low.

Few and Infrequent Longfin Likely in the Three Bay Study Samples

The Bay Study data for the 8-longfin trigger stations show only 5 longfin caught during December over all years from 1995 -2003, and only in the Bay Study midwater trawl (**Table 4**). Further, 3 was the maximum, in 2000, and 1 was caught in 1995 and 2004. The 7 other years of sampling caught 0 adult longfin.

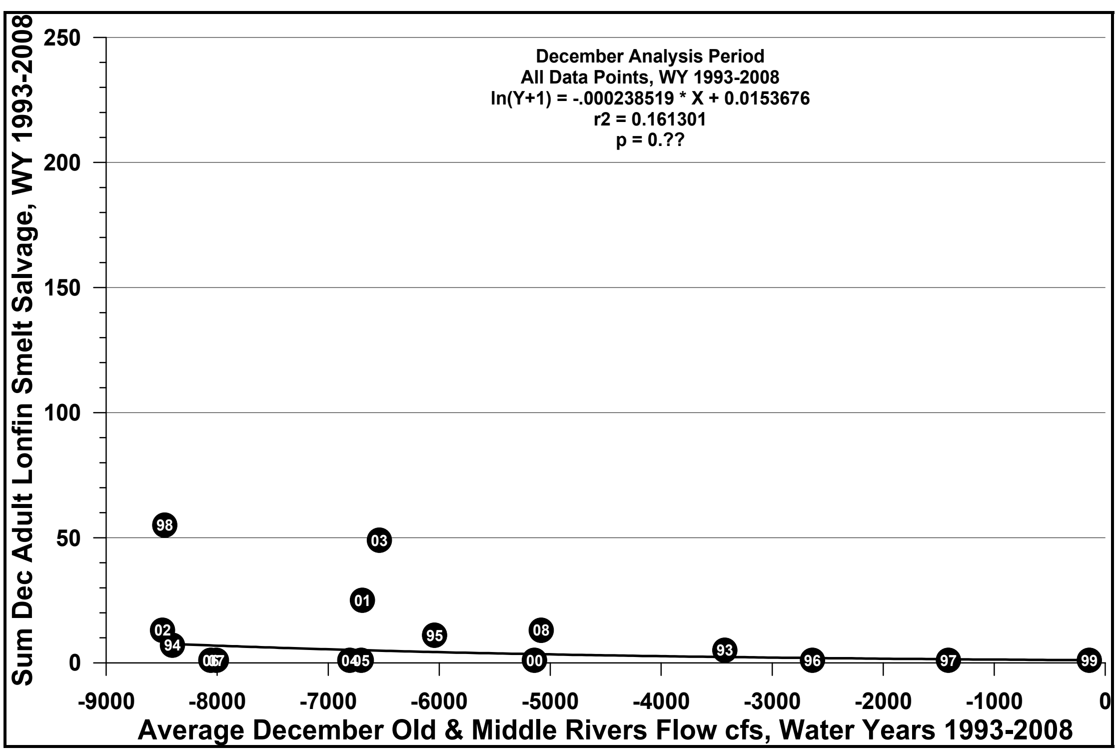


Figure 3. Average December salvage and Old and Middle Rivers flows (Source: S. Greene 2008).

Table 4. Bay Study Total Longfin Catch in December Survey.

	Net1 = Midwater Trawl			Net2 = Otter Trawl		
	fish/tow			fish/tow		
Units	Stn 863	Stn 864	Stn 865	Stn 863	Stn 864	Stn 865
1995	0	1	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	--	--	--	--	--	--
2000	2	1	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	0	0
2003	0	0	0	0	0	0
2004	0	0	1	0	0	0
2005	0	0	0	0	0	0

The FMWT has a longer period of record than the Bay Study, but the indications are similar. Only in 6 Decembers did FMWT total catch among the 2084 stations equal or exceed 8 longfin smelt (**Figure 4**). These were three times in the late 1960s and three in the 1980s, over 20 years ago.

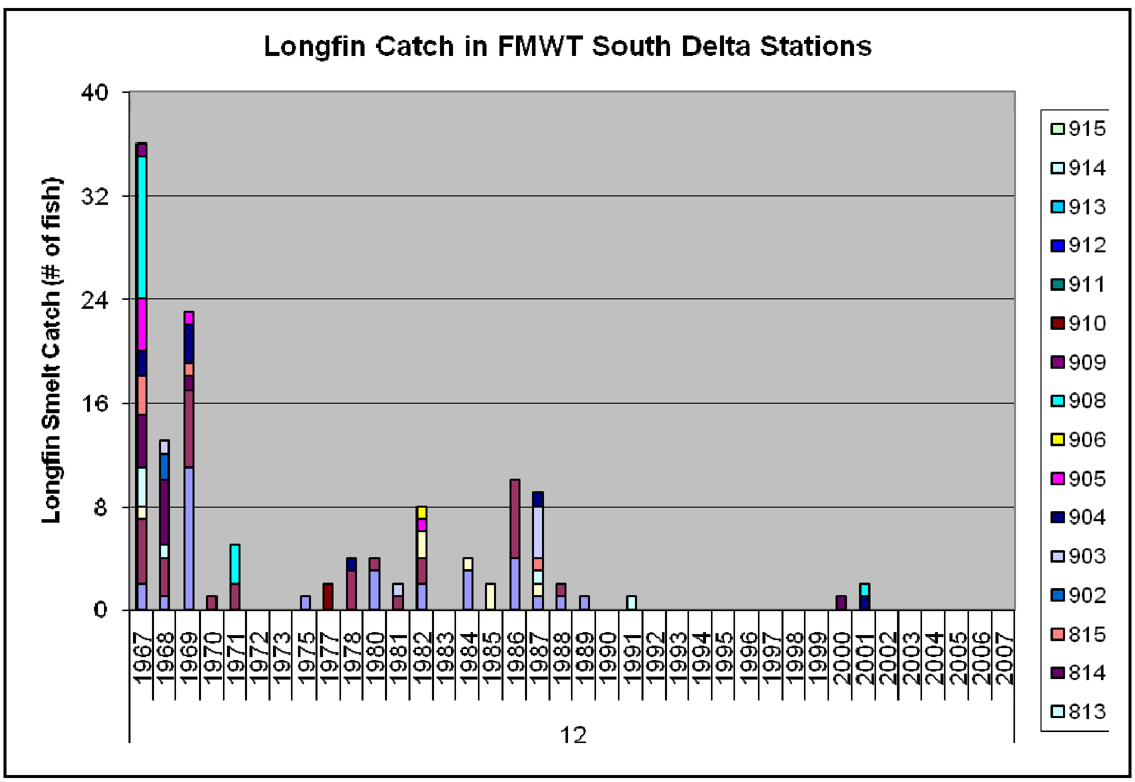


Figure 4. Longfin catch in the FMWT at stations specified in the draft 2084 regulation.

Overall indications for Action 1

The above evidence indicates that for December very few of the adult longfin smelt are vulnerable to entrainment and that adult salvage does not drive catch, and controls on OMR flows in December will do little if anything to protect longfin smelt:

- Only a very small fraction of the longfin smelt adult population, if any, appears to inhabit the south Delta, and infrequently.
- Past salvage probably has been <0.02% of the longfin smelt population.

ACTION 2 – JANUARY ONWARD

Most Spawners are Away from the Pumps

Longfin smelt have been abundant during the winter, though fewer lately, compared to salvage (**Figure 5** and **Figure 6**). During January and February, abundance could have been in the millions or hundreds of thousands in most years, while salvage was 0 – 250 fish. In February, out of perhaps 1-2M longfin smelt, 0-50 may have lost to salvage.

Based on the SKT distributions during winter and spring, longfin smelt spawners have not near the pumps (**Table 5**). Except for a few in 2002, a dry year, they were always seaward of the lower San Joaquin River, or occasionally longfin adults were in the Sacramento River or Cache Slough areas, again well away from the pumps.

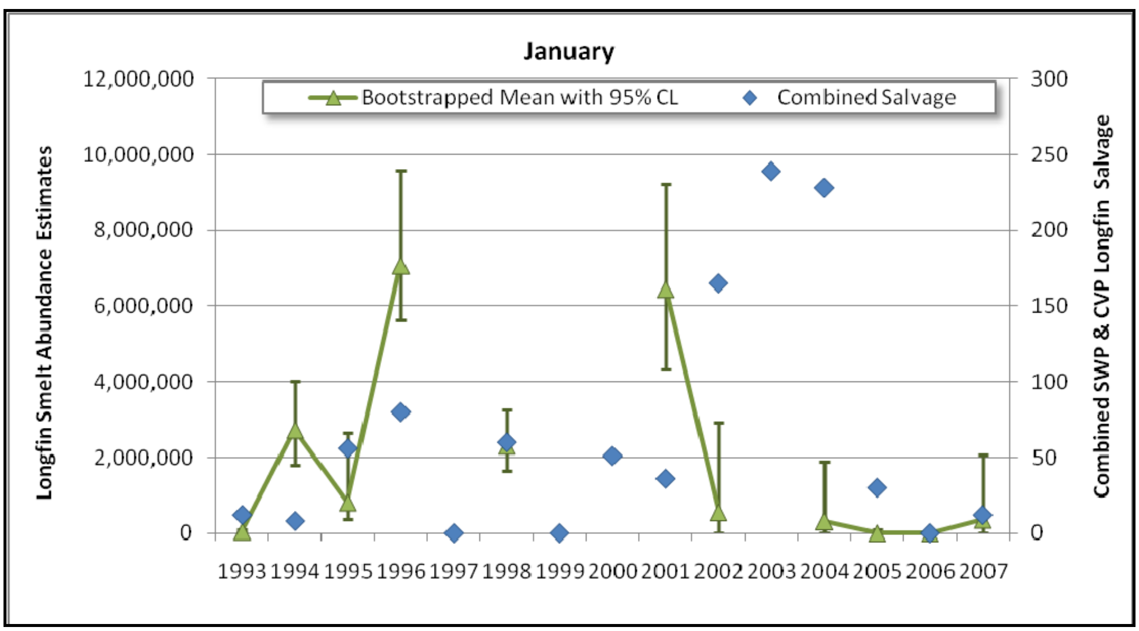


Figure 5. January longfin smelt abundance estimates with 95% confidence limits, and salvage.

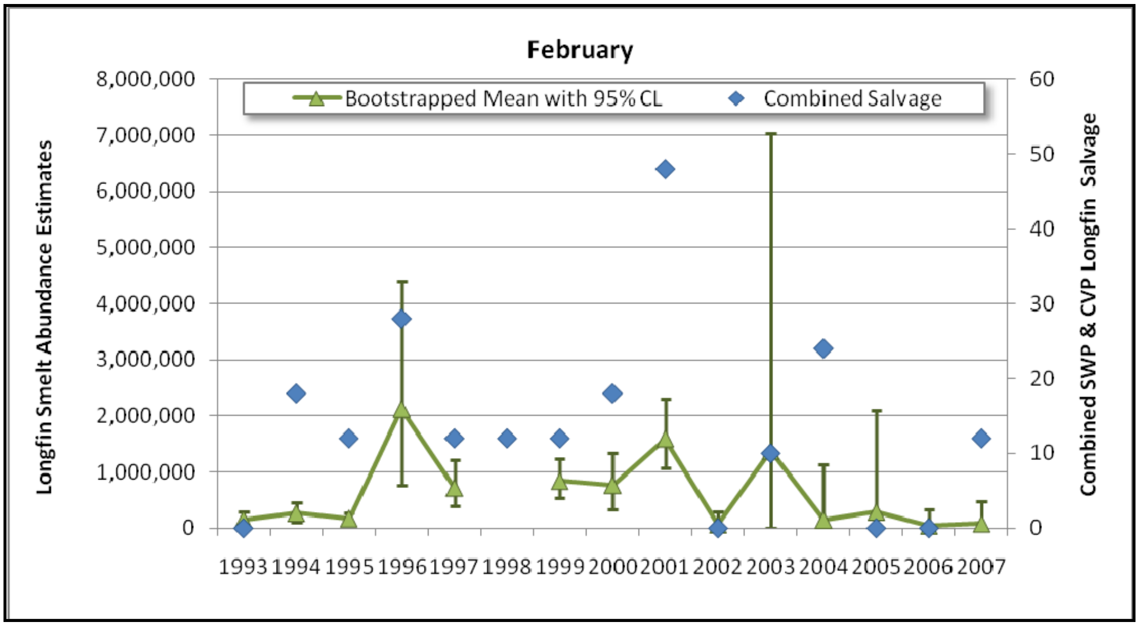


Figure 6. February longfin smelt abundance estimates with 95% confidence limits, and salvage.

Table 5. Distribution of longfin smelt in Spring Kodiak Trawl.

Year	Month	Napa River	Carqui-nez Strait	Suisun Marsh	Suisun Bay	Chipps Island	Lower Sac. River	Upper Sac. River	Cache Slough	Sacramento Ship Channel	Lower SJR	nr Franks Tract	South-east Delta	E-SE Delta	East-Central Delta
	1	0%	0%	3%	71%	12%	9%	0%	3%		1%	0%	0%	0%	0%
2002	2	0%	0%	41%	17%	31%	0%	0%	0%		11%	0%	0%	0%	0%
	3	0%	0%	7%	16%	9%	29%	12%	28%		0%	0%	0%	0%	0%
2003	2	25%	48%	4%	22%	1%	0%	0%	0%		0%	0%	0%	0%	0%
	3	0%	37%	5%	58%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	4	0%	0%	24%	76%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2004	1	5%	56%	12%	23%	2%	2%	0%	0%		0%	0%	0%	0%	0%
	2	0%	0%	79%	0%	21%	0%	0%	0%		0%	0%	0%	0%	
	3	88%	0%	3%	0%	10%	0%	0%	0%		0%	0%	0%	0%	0%
	4	0%	88%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	5	0%	0%	0%	100 %	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2005	1	0%	0%	100%	0%	0%	0%	0%	0%		0%	0%	0%	0%	0%
	2	0%	86%	9%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	3	0%	97%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2006	1	0%	0%	24%	0%	0%	66%	0%	11%	0%	0%	0%	0%	0%	0%
	2	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	3														
	4	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2007	1	49%	10%	22%	19%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	2		0%	65%	28%	0%	7%	0%	0%	0%	0%	0%	0%	0%	0%
	3	0%	0%	27%	73%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	4	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	5	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%				0%
2008	1	0%	0%	0%	0%	0%	100	0%	0%	0%	0%	0%	0%	0%	0%

Year	Month	Napa River	Carqui-nez Strait	Suisun Marsh	Suisun Bay	Chipps Island	Lower Sac. River	Upper Sac. River	Cache Slough	Sacramento Ship Channel	Lower SJR	nr Franks Tract	South-east Delta	E-SE Delta	East-Central Delta
							%								
	2		0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%
	3	0%	0%	99%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	4	0%	13%	85%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	5	0%	78%	19%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%

>0% and ≤5%

>5% and ≤10%

>10%

Winter Larvae at the Pumps in 2008

The earliest known entrainment of longfin larvae we discovered is February 24, 2008, at the SWP, per the Smelt Working Group advisory of March 10, 2008 (http://www.fws.gov/sacramento/es/documents/ds_working_group/SWG_recommendation_10-March-08.pdf page 3). Two larvae were collected March 6 and 8, 2008, at the CVP and SWP.

Spring Larvae and Juveniles are Away from the Pumps.

Most larval and juvenile longfin smelt in mid-March or April surveyed areas, usually appeared to be seaward of Franks Tract (**Table 6**). Only in four cases were they in the southeast Delta, the region with the pumps. Although this is not January or February, the larval/juvenile pattern is consistent with winter spawner abundances from the SKT above (Table 5) in that in the surveyed waters most are away from the southeast Delta.

Table 6. Distribution of larval and juvenile longfin smelt.

survey mid-date	San Pablo Bay	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chipps Is.	Lower Sac R	Cache Sl.	Lower SJR	nr Franks Tract	SE Delta	E-SE Delta	E-Central Delta
26-Apr-95	73%	17%	3%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%
10-May-95	11%	88%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
24-May-95	72%	11%	15%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%
7-Jun-95	45%	1%	36%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%
21-Jun-95	10%	0%	83%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%
6-Jul-95	0%	1%	78%	0%	21%	0%	0%	0%	0%	0%	0%	0%	0%
20-Jul-95	28%	7%	32%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%
4-Aug-95	0%	0%	50%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%
13-Apr-96	60%	6%	6%	0%	28%	1%	0%	0%	0%	0%	0%	0%	0%
27-Apr-96	1%	22%	1%	0%	74%	0%	0%	0%	0%	0%	2%	0%	0%
11-May-96	10%	2%	15%	2%	64%	7%	0%	0%	0%	0%	0%	0%	0%
25-May-96	11%	2%	56%	0%	32%	0%	0%	0%	0%	0%	0%	0%	0%
11-Jun-96	0%	2%	27%	0%	70%	1%	0%	0%	0%	0%	0%	0%	0%
26-Jun-96	6%	0%	49%	0%	20%	15%	2%	0%	7%	0%	0%	0%	0%
10-Jul-96	0%	0%	9%	0%	78%	10%	3%	0%	0%	0%	0%	0%	0%

Table 6. Distribution of larval and juvenile longfin smelt.

survey mid-date	San Pablo Bay	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chipps Is.	Lower Sac R	Cache Sl.	Lower SJR	nr Franks Tract	SE Delta	E-SE Delta	E-Central Delta
24-Jul-96	0%	0%	31%	1%	43%	15%	10%	0%	0%	0%	0%	0%	0%
2-Apr-97	0%	5%	0%	0%	95%	0%	0%	0%	0%	0%	0%	0%	0%
16-Apr-97	4%	7%	10%	5%	8%	13%	32%	0%	16%	5%	0%	0%	0%
30-Apr-97	0%	0%	7%	2%	15%	10%	47%	0%	18%	1%	0%	0%	0%
14-May-97	0%	0%	4%	1%	36%	9%	44%	0%	6%	0%	0%	0%	0%
29-May-97	0%	0%	0%	1%	94%	4%	0%	0%	2%	0%	0%	0%	0%
11-Jun-97	11%	0%	0%	0%	36%	50%	3%	0%	0%	0%	0%	0%	0%
26-Jun-97	30%	3%	0%	0%	46%	12%	5%	0%	4%	0%	0%	0%	0%
10-Jul-97	0%	4%	0%	0%	84%	12%	0%	0%	0%	0%	0%	0%	0%
24-Jul-97	11%	0%	43%	0%	33%	5%	6%	0%	2%	0%	0%	0%	0%
8-Apr-98	46%	53%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
23-Apr-98	0%	0%	0%	0%	93%	7%	0%	0%	0%	0%	0%	0%	0%
6-May-98	31%	2%	0%	0%	67%	0%	0%	0%	0%	0%	0%	0%	0%
20-May-98	53%	4%	32%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%
3-Jun-98	63%	7%	25%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%
17-Jun-98	0%	19%	59%	0%	22%	0%	0%	0%	0%	0%	0%	0%	0%
30-Jun-98	0%	4%	41%	0%	55%	0%	0%	0%	0%	0%	0%	0%	0%
15-Jul-98	48%	1%	46%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%
30-Jul-98	54%	0%	24%	0%	22%	0%	0%	0%	0%	0%	0%	0%	0%
14-Apr-99	2%	37%	8%	0%	49%	2%	1%	0%	1%	0%	0%	0%	0%
28-Apr-99	0%	0%	6%	1%	91%	0%	1%	0%	1%	0%	0%	0%	0%
12-May-99	47%	25%	4%	0%	16%	5%	1%	0%	2%	0%	0%	0%	0%
25-May-99	0%	0%	0%	5%	57%	33%	3%	0%	2%	0%	0%	0%	0%
9-Jun-99	78%	0%	8%	0%	12%	1%	0%	0%	0%	0%	0%	0%	0%
23-Jun-99	27%	0%	37%	0%	36%	0%	0%	0%	0%	0%	0%	0%	0%
8-Jul-99	12%	0%	56%	0%	31%	0%	0%	0%	0%	0%	0%	0%	0%
21-Jul-99	0%	0%	7%	0%	82%	8%	2%	0%	0%	0%	0%	0%	0%
22-Mar-00	6%	5%	62%	0%	27%	0%	0%	0%	0%	0%	0%	0%	0%
5-Apr-00	2%	30%	13%	0%	41%	6%	0%	0%	6%	0%	0%	0%	0%
19-Apr-00	3%	19%	2%	1%	63%	11%	0%	0%	0%	0%	0%	0%	0%
3-May-00	12%	3%	2%	3%	62%	13%	4%	0%	2%	0%	0%	0%	0%
17-May-00	1%	0%	59%	1%	36%	3%	1%	0%	0%	0%	0%	0%	0%
31-May-00	25%	3%	33%	1%	39%	0%	0%	0%	0%	0%	0%	0%	0%
14-Jun-00	21%	0%	36%	0%	38%	1%	0%	0%	0%	0%	0%	3%	0%
28-Jun-00	0%	0%	44%	0%	36%	18%	2%	0%	0%	0%	0%	0%	0%
12-Jul-00	9%	0%	16%	3%	39%	19%	12%	0%	3%	0%	0%	0%	0%
21-Mar-01	0%	17%	5%	1%	32%	25%	1%	0%	18%	0%	0%	0%	0%
4-Apr-01	3%	40%	21%	2%	20%	6%	2%	0%	5%	1%	0%	0%	0%
18-Apr-01	0%	32%	11%	2%	19%	13%	6%	0%	13%	3%	0%	1%	0%
3-May-01	0%	30%	15%	10%	14%	4%	13%	1%	11%	3%	0%	0%	0%
16-May-01	0%	0%	7%	5%	10%	4%	58%	0%	14%	0%	1%	0%	0%
1-Jun-01	0%	0%	6%	2%	17%	38%	10%	0%	26%	1%	0%	0%	0%
13-Jun-01	10%	0%	0%	2%	82%	0%	3%	0%	0%	2%	0%	0%	0%
27-Jun-01	0%	0%	37%	5%	35%	5%	13%	0%	5%	0%	0%	0%	0%
9-Jul-01	no delta smelt smelt collected												

Table 6. Distribution of larval and juvenile longfin smelt.

survey mid-date	San Pablo Bay	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chipps Is.	Lower Sac R	Cache Sl.	Lower SJR	nr Franks Tract	SE Delta	E-SE Delta	E-Central Delta
20-Mar-02	0%	10%	46%	10%	16%	10%	1%	2%	4%	1%	0%	0%	0%
4-Apr-02	0%	1%	1%	11%	29%	22%	10%	0%	22%	4%	0%	0%	0%
17-Apr-02	0%	5%	1%	6%	7%	9%	8%	2%	*30%*	31%	1%	0%	0%
1-May-02	0%	1%	18%	3%	10%	3%	13%	0%	*37%*	14%	0%	0%	0%
15-May-02	0%	0%	13%	4%	18%	8%	14%	1%	35%	5%	0%	0%	0%
30-May-02	0%	0%	22%	2%	42%	14%	13%	1%	5%	1%	0%	0%	0%
12-Jun-02	0%	0%	0%	2%	35%	16%	44%	0%	4%	0%	0%	0%	0%
26-Jun-02	0%	0%	8%	0%	66%	16%	8%	0%	2%	0%	0%	0%	0%
26-Mar-03	0%	21%	8%	3%	31%	22%	7%	0%	7%	0%	0%	0%	0%
9-Apr-03	0%	20%	8%	3%	6%	14%	10%	0%	33%	3%	1%	2%	1%
23-Apr-03	0%	5%	2%	5%	28%	26%	7%	0%	24%	1%	0%	1%	0%
7-May-03	1%	1%	7%	3%	86%	0%	0%	0%	3%	0%	0%	0%	0%
21-May-03	0%	0%	6%	1%	81%	9%	3%	0%	0%	0%	0%	0%	0%
4-Jun-03	0%	1%	0%	0%	95%	4%	0%	0%	0%	0%	0%	0%	0%
18-Jun-03	0%	0%	0%	0%	76%	24%	0%	0%	0%	0%	0%	0%	0%
1-Jul-03	0%	0%	58%	0%	38%	0%	5%	0%	0%	0%	0%	0%	0%
31-Mar-04	0%	0%	6%	7%	39%	29%	0%	0%	19%	0%	0%	0%	0%
14-Apr-04	1%	13%	16%	3%	41%	16%	2%	0%	7%	1%	0%	0%	0%
28-Apr-04	0%	5%	17%	20%	17%	24%	6%	0%	11%	0%	0%	0%	0%
12-May-04	1%	0%	2%	3%	12%	39%	8%	0%	35%	1%	0%	0%	0%
26-May-04	0%	0%	4%	3%	27%	32%	24%	0%	10%	0%	0%	0%	0%
10-Jun-04	0%	0%	0%	2%	42%	15%	35%	0%	4%	1%	0%	0%	0%
23-Jun-04	0%	0%	36%	0%	37%	16%	7%	0%	3%	0%	0%	0%	0%
8-Jul-04	0%	0%	0%	0%	12%	40%	48%	0%	0%	0%	0%	0%	0%
16-Mar-05	0%	17%	46%	1%	21%	6%	2%	0%	4%	3%	0%	0%	0%
30-Mar-05	1%	58%	19%	7%	14%	0%	0%	0%	1%	0%	0%	0%	0%
13-Apr-05	0%	7%	13%	0%	72%	2%	1%	0%	4%	0%	0%	0%	0%
27-Apr-05	2%	1%	69%	0%	16%	9%	3%	0%	0%	0%	0%	0%	0%
11-May-05	1%	1%	34%	0%	62%	0%	0%	0%	0%	0%	0%	0%	0%
25-May-05	19%	3%	64%	1%	11%	0%	2%	0%	0%	0%	0%	0%	0%
8-Jun-05	14%	6%	47%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%
22-Jun-05	0%	5%	66%	0%	21%	0%	0%	0%	0%	0%	0%	8%	0%
8-Jul-05	0%	0%	71%	0%	18%	11%	0%	0%	0%	0%	0%	0%	0%
22-Mar-06	30%	56%	5%	1%	9%	0%	0%	0%	0%	0%	0%	0%	0%
5-Apr-06	99%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
19-Apr-06	97%	2%	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
3-May-06	95%	2%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%
17-May-06	71%	25%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%
1-Jun-06	3%	9%	37%	0%	51%	0%	0%	0%	0%	0%	0%	0%	0%
14-Jun-06	0%	87%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	0%
28-Jun-06	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13-Jul-06	83%	0%	5%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%
15-Mar-07	0%	0%	0%	32%	23%	15%	4%	0%	26%	0%	0%	0%	0%
28-Mar-07	3%	6%	19%	12%	4%	41%	2%	0%	13%	0%	0%	0%	0%
11-Apr-07	12%	1%	2%	33%	6%	10%	10%	0%	27%	0%	0%	0%	0%

Table 6. Distribution of larval and juvenile longfin smelt.

survey mid-date	San Pablo Bay	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chipps Is.	Lower Sac R	Cache Sl.	Lower SJR	nr Franks Tract	SE Delta	E-SE Delta	E-Central Delta
25-Apr-07	0%	0%	20%	22%	17%	7%	21%	0%	11%	2%	0%	0%	0%
9-May-07	0%	0%	29%	5%	26%	21%	9%	0%	9%	0%	0%	0%	0%
23-May-07	0%	0%	10%	5%	38%	37%	5%	0%	6%	0%	0%	0%	0%
6-Jun-07	5%	0%	80%	0%	8%	2%	1%	0%	3%	0%	0%	0%	0%
20-Jun-07	0%	0%	91%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%
4-Jul-07	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%

(light shading)	>0% & ≤5%
(medium shading)	>5% &≤10%
(dark shading)	>10%

Larval/Juvenile Entrainment, Abundance and Flows

Entrainment losses are small in comparison to abundance estimates (**Figure 7**). Loss estimates for larvae and juveniles range from nearly 0 to ~2.5M out of larvae/juvenile populations of hundreds of millions, or a few billion. Obviously, entrainment would have little control over the abundance of longfin in March-June.

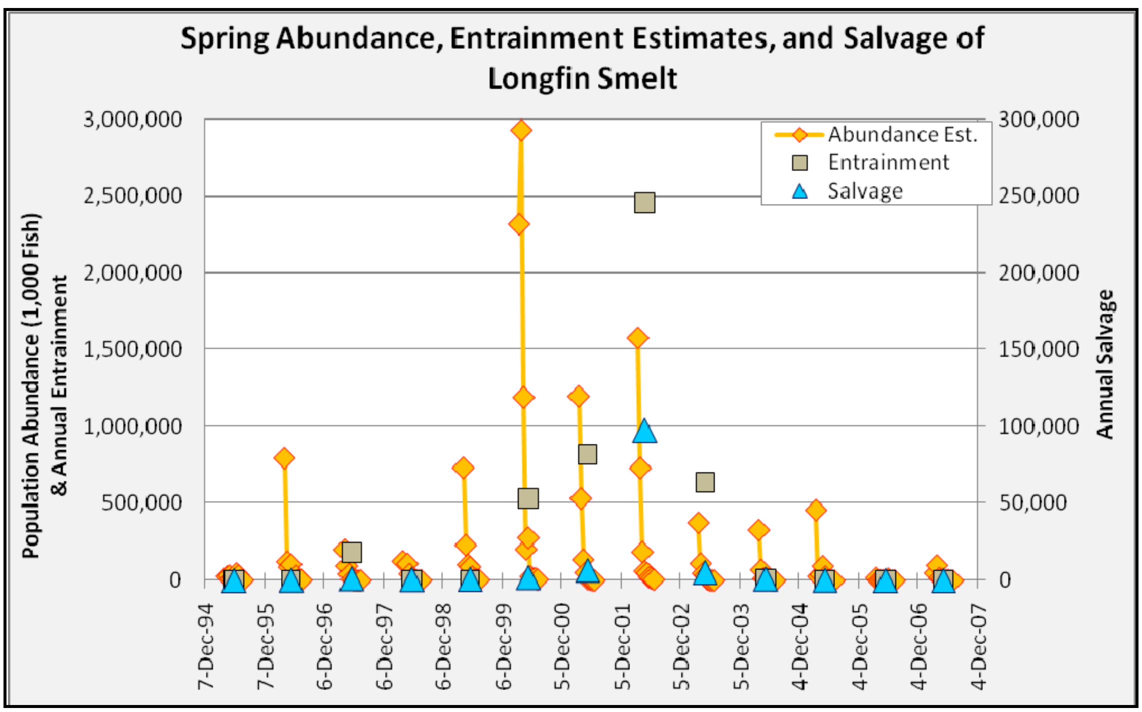


Figure 7. Longfin smelt spring abundance and losses.

CONCLUSIONS

Regarding Action 1 in December, there is little reason for expecting the longfin smelt population to respond to OMR controls. There has been little or no longfin salvage over the years. Further, in the surveyed waters almost all of the adult spawner, larval and juvenile longfin smelt appear seaward of OMR and Jersey Point on the San Joaquin River, well away from the pumps.

Regarding Action 2 in January and beyond, no recent data for January-mid-February on larval or juvenile longfin entrainment has been discovered. However, in 2008, there were three larvae salvaged during late February and March, almost nothing. Evidence for OMR flows protecting longfin from entrainment at the pumps in January-mid-February is not discernable.

Again in March-June, entrainment is a small part of the longfin smelt population as almost all (92-100%) larval and juvenile longfin smelt in surveyed waters appear to be seaward of OMR, and except on the rare occasion, seaward of Jersey Point. Again, controlling OMR flow offers little, if any, benefit to the longfin population.

REFERENCES

Greene, S. 2008. Longfin salvage and flow charts. email from T. Erlewine to R. Sitts et al. FW: new Longfin charts. October 30, 2008.

Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science [Internet]. 6(2). http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art2/

Attachment 3

Stakeholder Input on Drafting a Longfin Smelt Section 2084 Regulation

INTRODUCTION

The California Department of Fish and Game (Department) is "seeking stakeholder input" to the process of drafting a" Section 2084 regulation to protect longfin smelt during August 2008 through February 2009." A "final draft" regulation will go to the Fish & Game Commission in time for its August 7 meeting. Section 2084 states:

> **2084**. The commission may authorize, subject to terms and conditions it prescribes, the taking of any candidate species, or the taking of any fish by hook and line for sport that is listed as an endangered, threatened, or candidate species.
> (http://www.leginfo.ca.gov/cgi-in/waisgate?WAISdocID=61392411368+0+0+0&WAISaction=retrieve)

The following are comments on the science related to longfin smelt and the effects of the State Water Project (SWP) and Central Valley Project (CVP) (collectively, the "Projects") export facilities in the southeast Delta. These effects are addressed on two scales:

- First, in terms of entrainment risk and salvage at the pumps, and
- Second in the broader context of what factors are most associated with the long term changes in longfin smelt abundance, as measured by the Fall Midwater Trawl index.

Salvage and entrainment risks are discussed first and relate to two periods; subadults and spawners salvaged in the late fall and winter, and larvae and juvenile longfin smelt salvaged January through June. The data indicates almost all longfin smelt are far from the pumps, whether spawners, larvae or juveniles, year after year. In terms of abundance, the fraction near the pumps is so small as to appear to have little capacity to affect overall abundance. Other factors including temperature, ammonia and very high X2 levels are strongly associated with the long term trend and recent decline in longfin smelt.

SWP AND CVP SALVAGE AND ENTRAINMENT RISK

Salvage of Subadults and Spawners

The proportion of the population of longfin smelt salvaged at the SWP and CVP is small. Actual salvage data collected for the SWP and CVP from 1993 through 2007 are presented on Figure 1 and provided in Table 1. As shown, over the last 15 years, average salvage by the Projects has been a combined annual average of 8,202 fish. Excluding 2002 data, which is an atypical high salvage year, the average salvage rate equates to 1,805 longfin. The median annual salvages of all life stages for the Projects during 1993 through 2007, with and without 2002, were 805 and 746 longfin smelt, respectively.

Figure. 1 Longfin smelt annual salvage at SWP and CVP facilities.

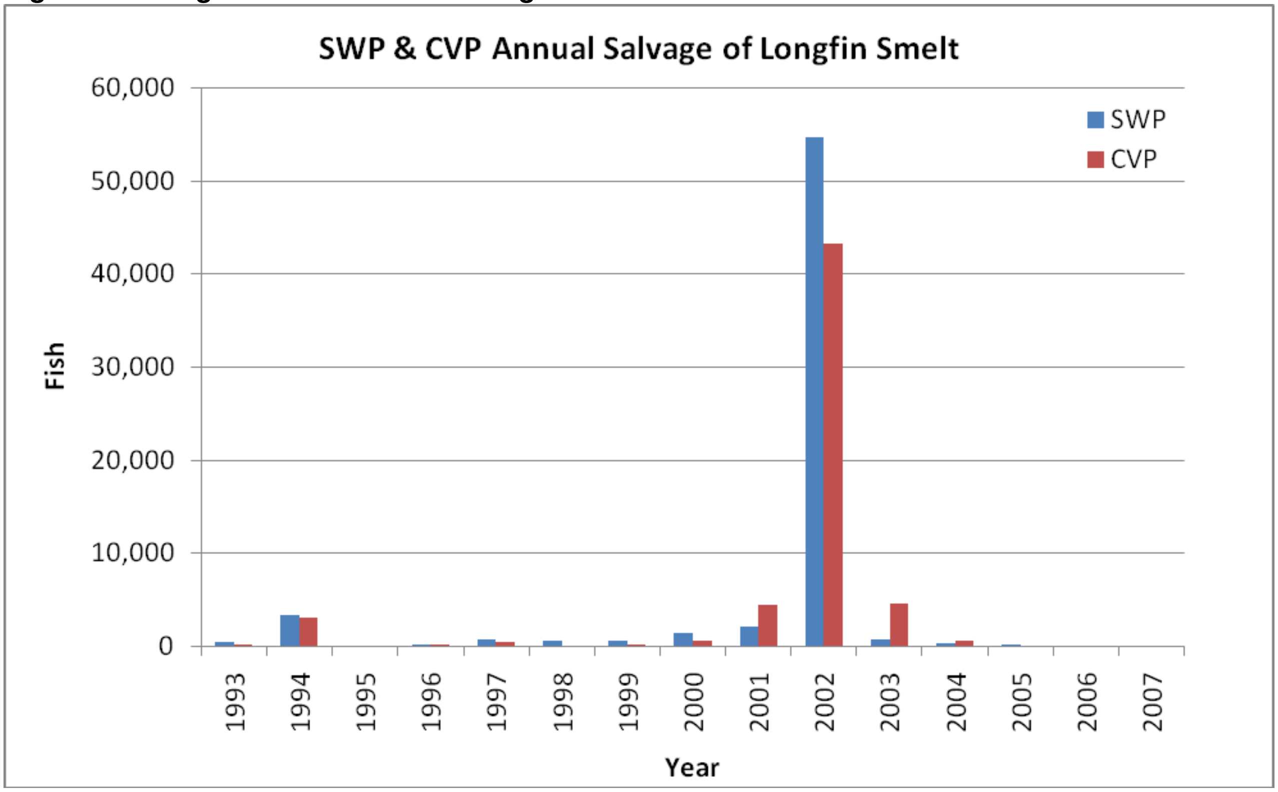
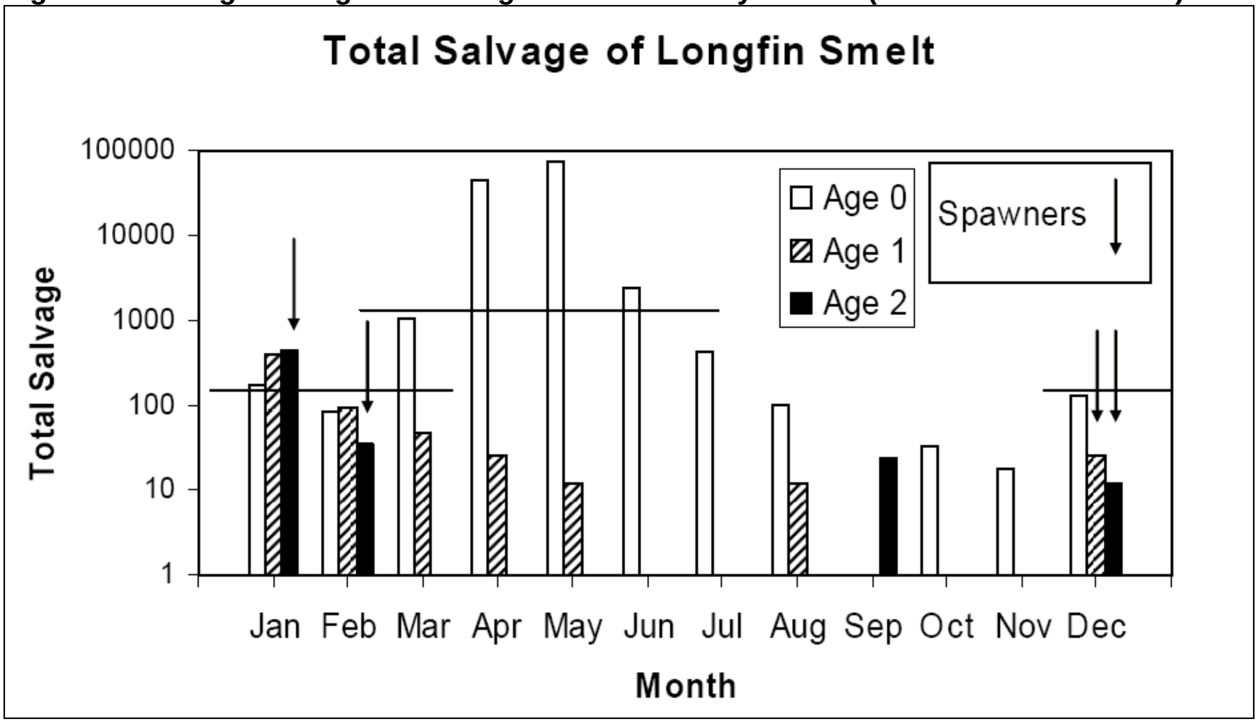


Table 1. Longfin smelt annual salvage for the SWP and CVP.

Year	SWP	CVP
1993	516	132
1994	3,400	3,015
1995	102	0
1996	137	156
1997	742	444
1998	628	60
1999	673	132
2000	1,455	528
2001	2,175	4,404
2002	54,582	43,188
2003	706	4,562
2004	333	648
2005	183	36
2006	0	0
2007	60	36

Salvage of longfin smelt by the SWP and CVP operations is further illustrated by information presented by the Department (Baxter 2008a) (Figure 2). Figure 2 shows 15-year cumulative monthly salvage estimates. The 15-year cumulative monthly salvages of Age-1 and Age-2 longfin smelt total 1,133 longfin smelt (Baxter 2008b). This equates to an average of 76 fish year and 6 fish/month, and a median of 1 fish/month over 1993 to 2007. Cumulative salvage was greatest in January at 833 Age 1&2 longfin smelt, which averages out at 56 fish/year for the month of January. If subadults (Age-0) are included, the annual average January salvage is 67 longfin. Annual Age 1&2 salvage rates for the remaining months average 2 longfin smelt/year.

Figure 2. Salvage during 1993 though 2007 totaled by month. (Source: Baxter 2008a)

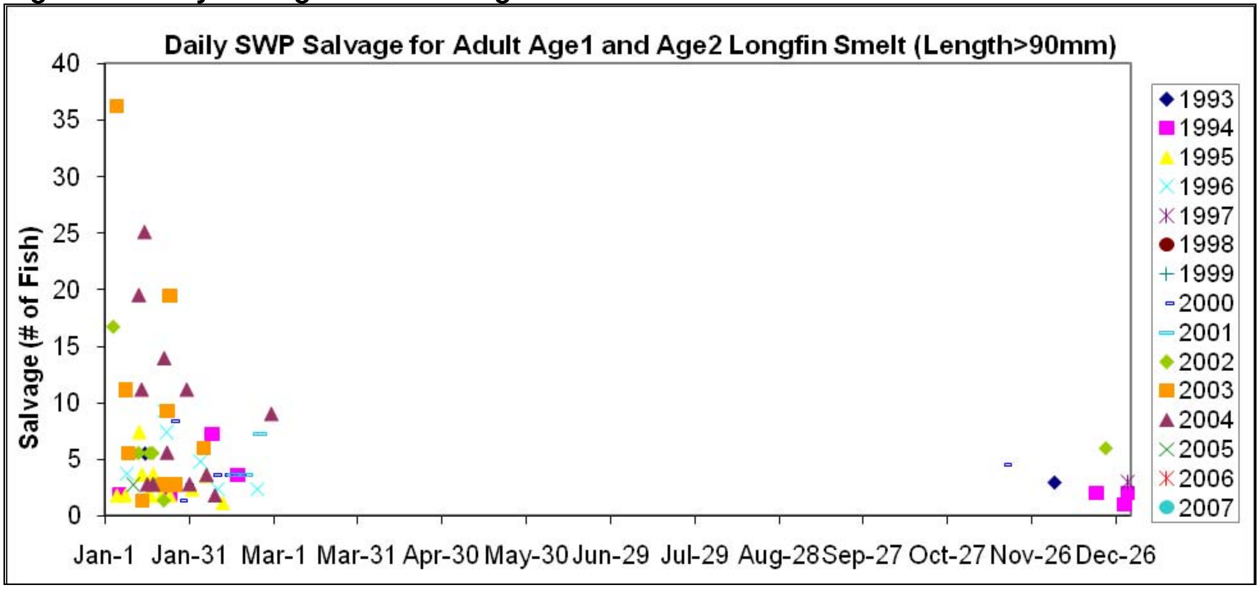


Daily winter salvage data for 1993-2007, show January with the highest daily rates (Figure 3). Also, there is considerable variation in salvage within months of a given year and over the years within months (Figure 3). Adult daily salvage is absent during March-October and rare in November and December.

Geographic Distribution

It appears that only a very small fraction of the subadult and adult longfin population is in the southeast Delta and thus most subject to potential effects of the Projects. The Department conducts a number of surveys at various times of the year that provide information on the location and numbers of subadult and adult longfin smelt. Surveys that monitor subadult and adult fish include the Fall Midwater Trawl (FMWT), Winter Midwater Trawl (WMWT), and Spring Kodiak Trawl (SKT) surveys. (The spring 20mm survey samples for larval and juvenile longfin). Each of these surveys samples throughout much of the Delta and Suisun Bay year after year. We obtained the Departments datasets for each of these surveys for this analysis (Appendix A). For analysis purposes, we grouped the sampling stations to represent five-major geographic regions; the Napa-River-Carquinez Strait (NapaCarq), Suisun Bay and Marsh (Suisun), North Delta, South Delta, and Southeast Delta (Figure 4). Note that six of the many FMWT and WMWT stations are in the southeast Delta, while only stations 914 and 915 are sampled by the SKT (Figure 5). Based on the Department's survey data, from 1993 to 2007, there is no evidence of longfin smelt being caught in the FMWT, WMWT or SKT samplings at southeast Delta stations.

Figure 3. Daily salvage of adult longfin smelt for the SWP and CVP.



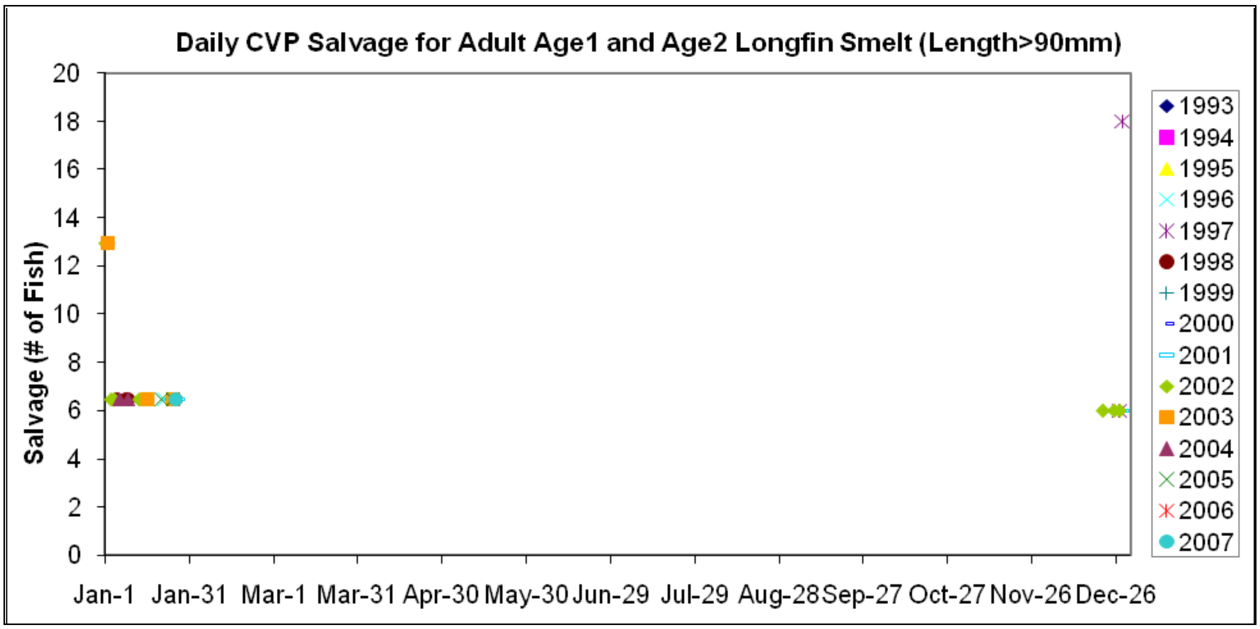


Figure 4. Five regions for allocating sampling stations of the FMWT, SKT, and 20mm survey (using the 20mm as a base map here).

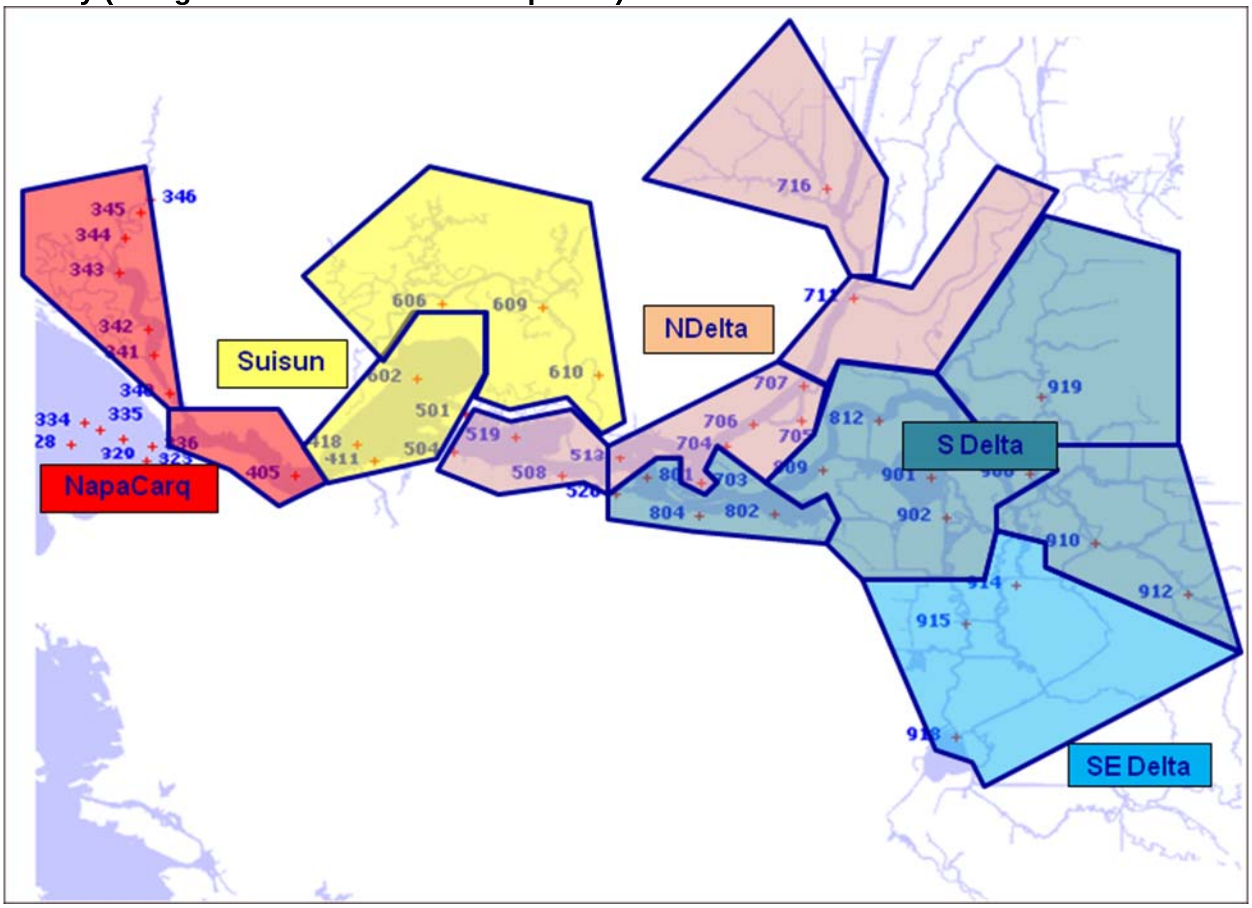
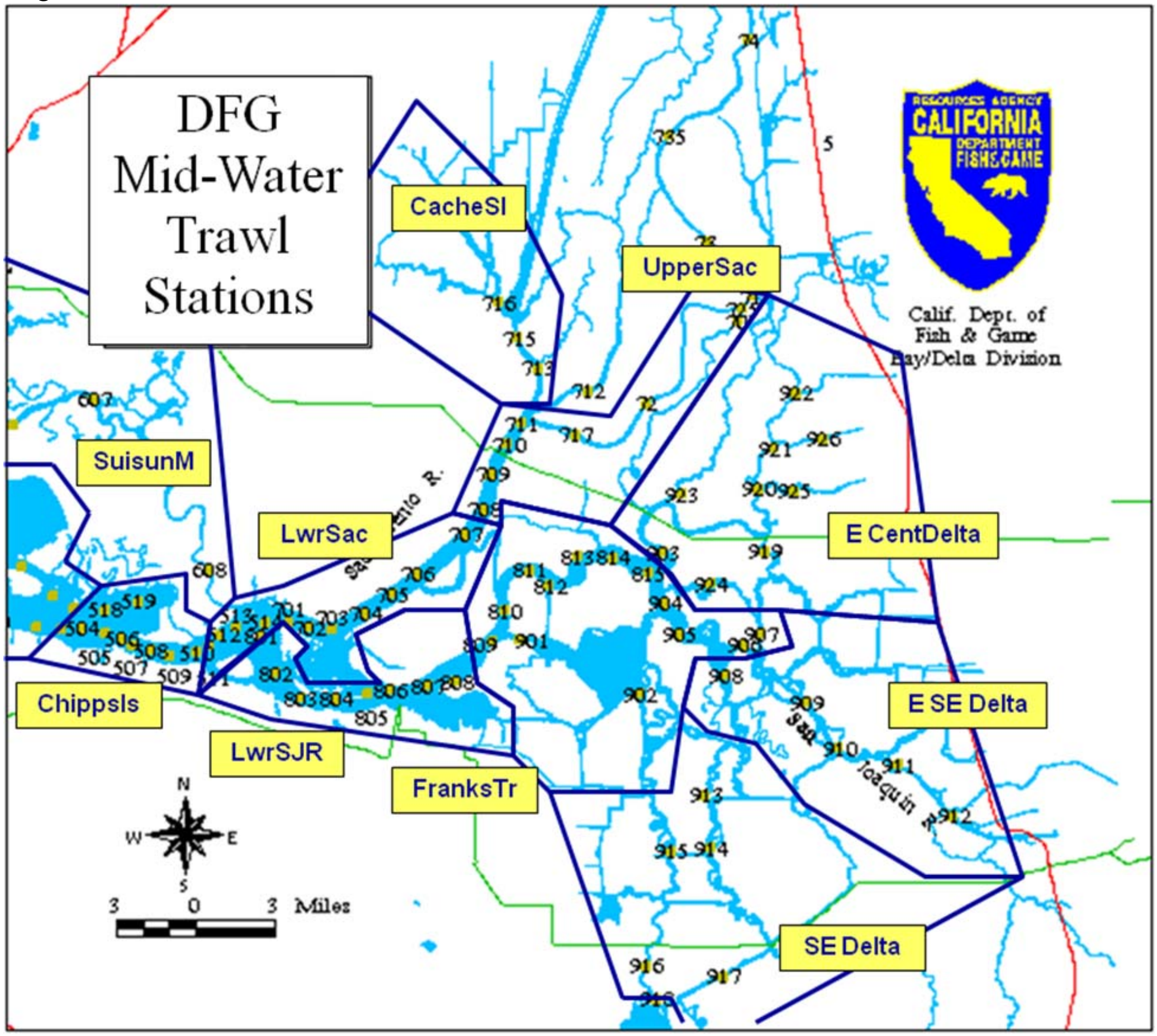


Figure 5. Fall and Winter Midwater Trawl survey stations and the Southeast (SE) Delta Region.



We used the trawl data to estimate regional abundance indices. Briefly, we used the catch and volume of the tow data to estimate average densities within each region. Then, these average densities were multiplied by the region volume to yield regional abundance values. Summing regional abundances provided an estimate of overall abundance index. By dividing the Southeast Region abundance index by the overall abundance value, we obtained an indication of the risk of entrainment. Details on the data and the calculations are provided in Appendix A. Unfortunately, the surveys do not sample upstream of the pumps or Stockton, so we cannot tell if longfin were there. Note however, that there is no claim here that any of the abundance indices are accurate estimates or that any of the differences among indices are statistically significant. Note also, that comparisons of abundance indices among regions or over a survey program, can be more reliable when considered on a relative basis, that is, relative to each other. This removes the issue of accuracy in absolute abundance estimates.

Overall longfin smelt abundance indices vary within and between years as well as between sampling programs (Figure 6). The WMWT indices averaged 940,398 fish, had a median of 456,858, ranged from 0 to 7.1 million longfin. The SKT indices averaged 161,039 fish, had a median of 57,485, and ranged from 0 to 1.3 million. Most of these winter longfin were far from the pumps. While zero longfin smelt are estimated for the southeast Delta region, up to 4 million was estimated for the Napa-Carquinez region for January 2001 (Figure 7). Few were in ever in the South Delta region. For the winter of 2002, up to 0.4M was estimated, and for the Suisun region. Again, the South Delta region had few while the Southeast Delta region had no longfin.

Population Effects from SWP and CVP

Focusing on just January, the highest spawner salvage month (Figure 2), subadult and spawner salvage over 1993-2007 averaged 67 longfin smelt, as mentioned above. January abundance indices for longfin could be made for all but four years over 1993-2007 (Table 2). The average for the 11 years with data is 1.6 million, for which an average January salvage of 67 longfin amounts to 0.004%. Switching from a 15-year perspective to just the January 2002 (and late December 2001), salvage totaled 177 longfin, which amounts to 0.03% of the concurrent SKT abundance index of the 626,459 longfin (Figure 8). These percentages indicate controlling salvage will do little to influence winter abundance of longfin smelt.

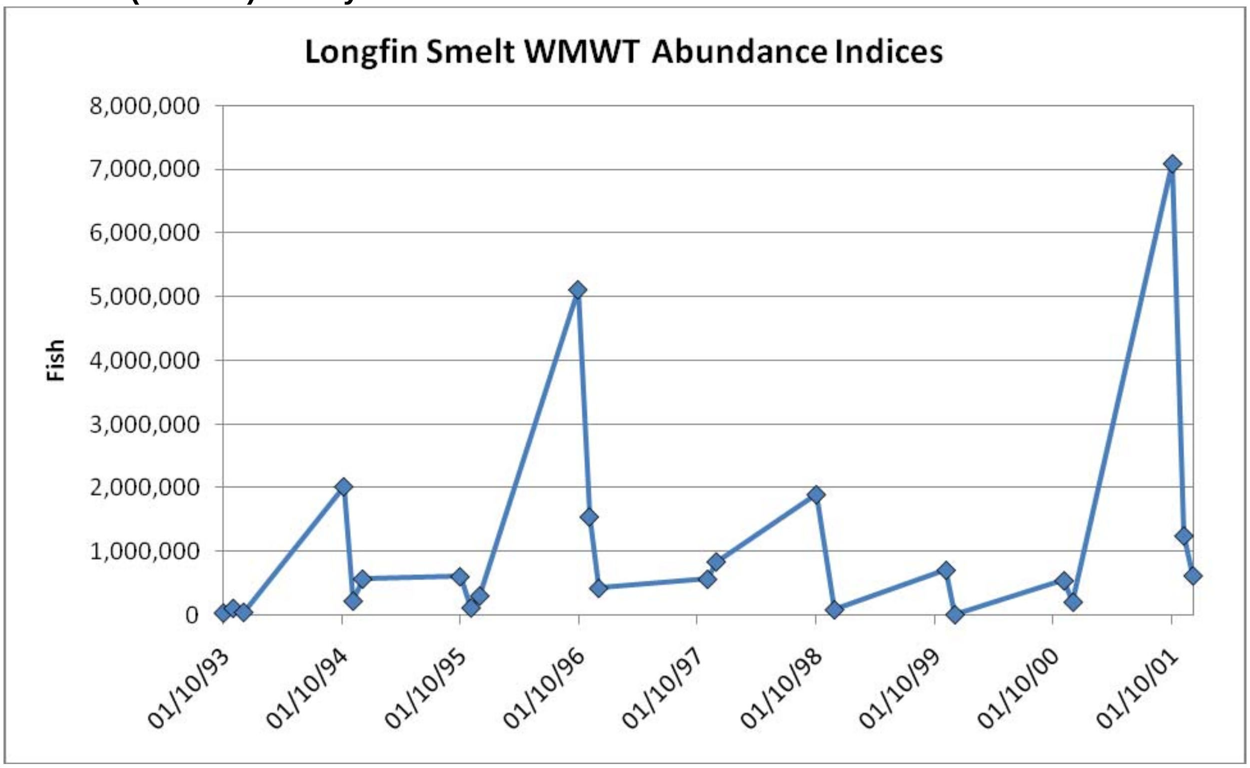
Conclusion on Subadults and Spawners

In conclusion, it seems difficult to manipulate winter salvage with the expectation of making a difference in the winter population. Few subadult and adult longfin smelt are salvaged, most longfin are far from the pumps, and salvage numbers seem small relative to abundance indices.

Table 2. January abundance indices for longfin smelt.

January	Longfin smelt indices of abundance from WMWT or SKT
1993	35,525
1994	2,019,298
1995	605,417
1996	5,115,441
1997	No survey
1998	1,895,058
1999	No survey
2000	No survey
2001	7,095,904
2002	626,459
2003	No survey
2004	314,409
2005	11,724
2006	10,752
2007	369,043

Figure 6. Longfin smelt abundance indices based on data from the WMWT (1993-2001) and SKT (2002-07) surveys.



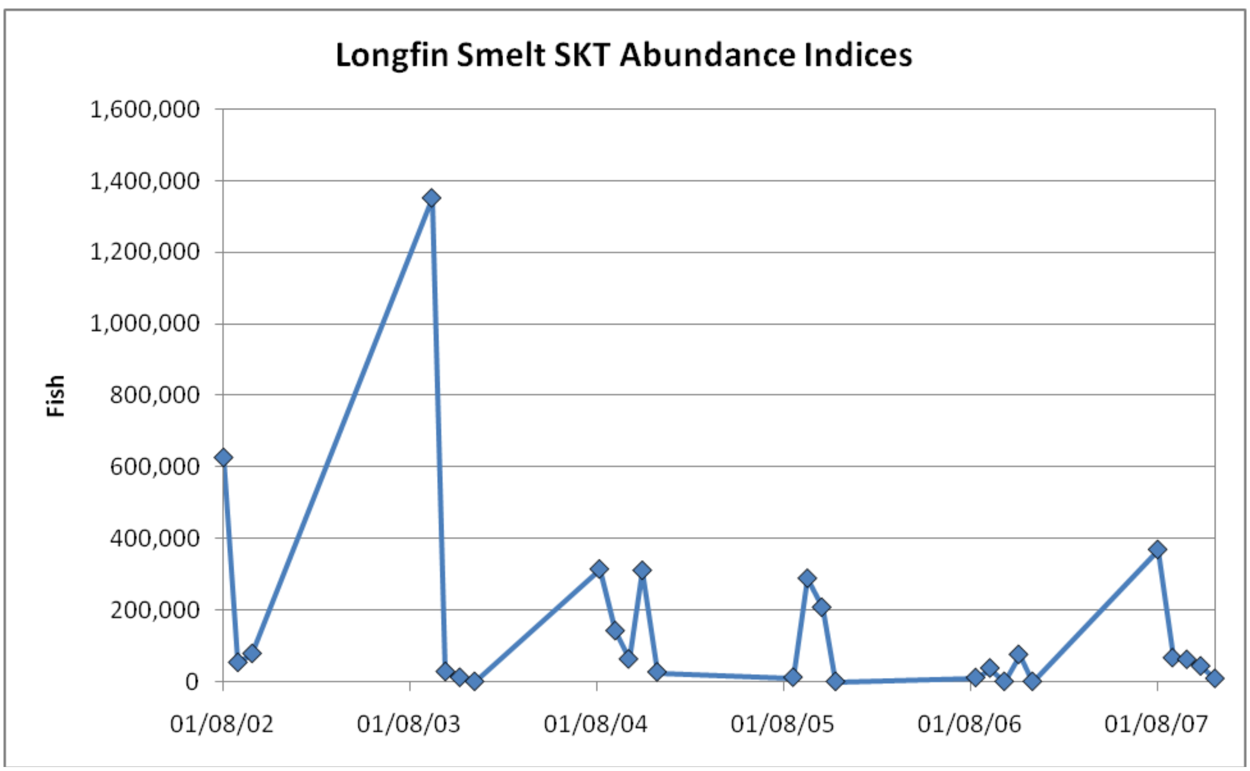
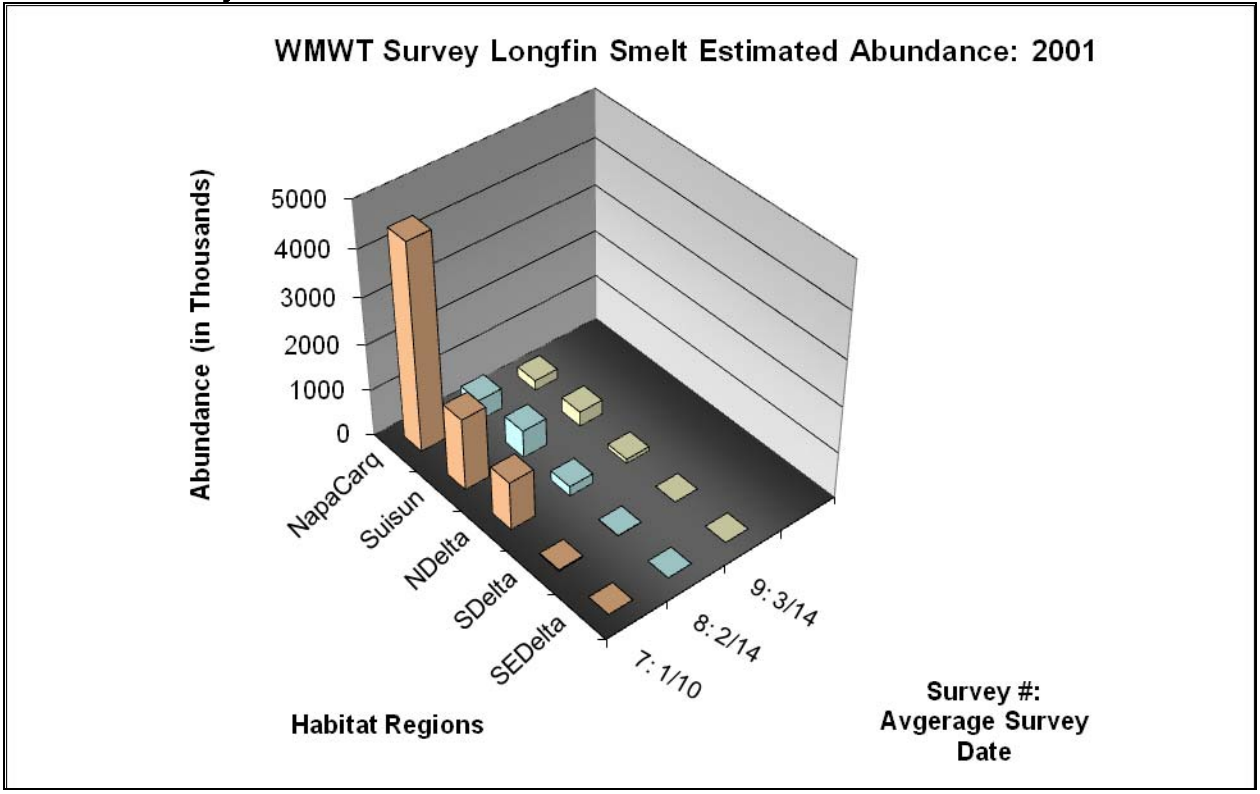


Figure 7. Regional abundance indices for longfin smelt during the 2001 WMWT and the 2002 SKT surveys.



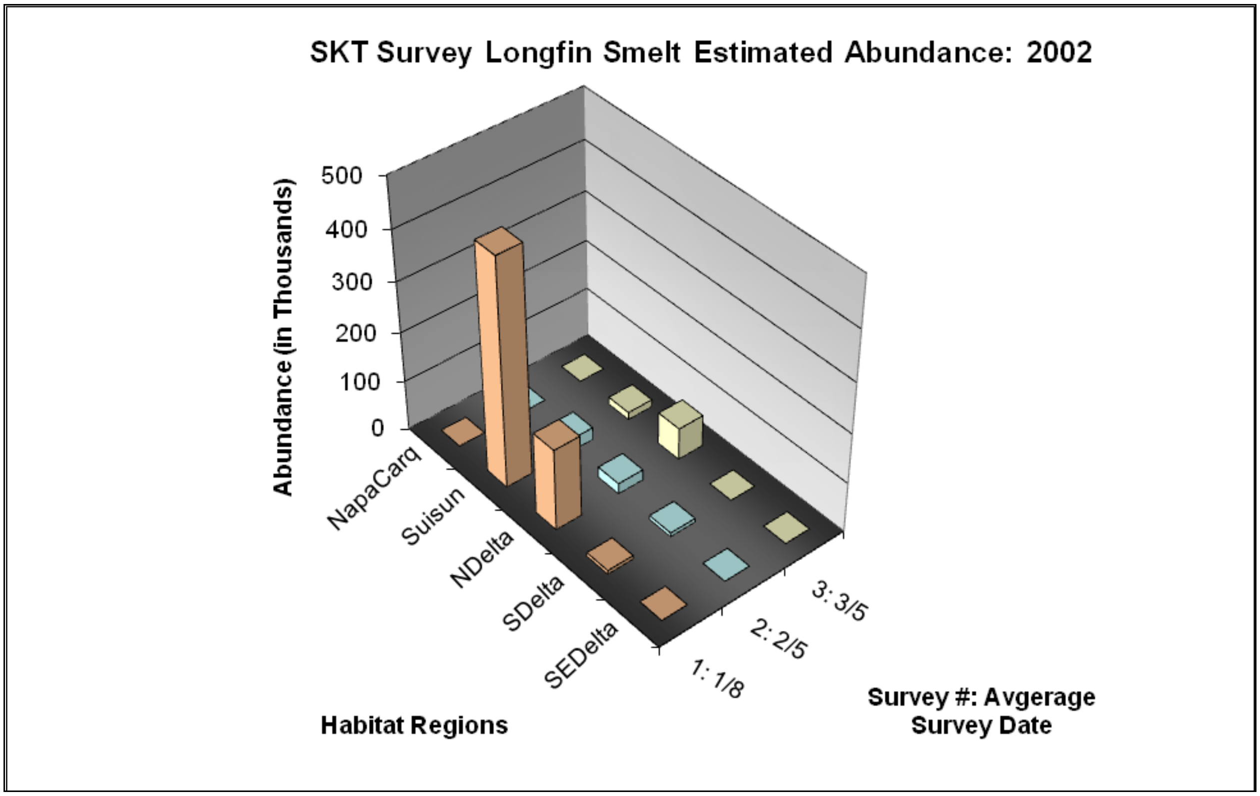
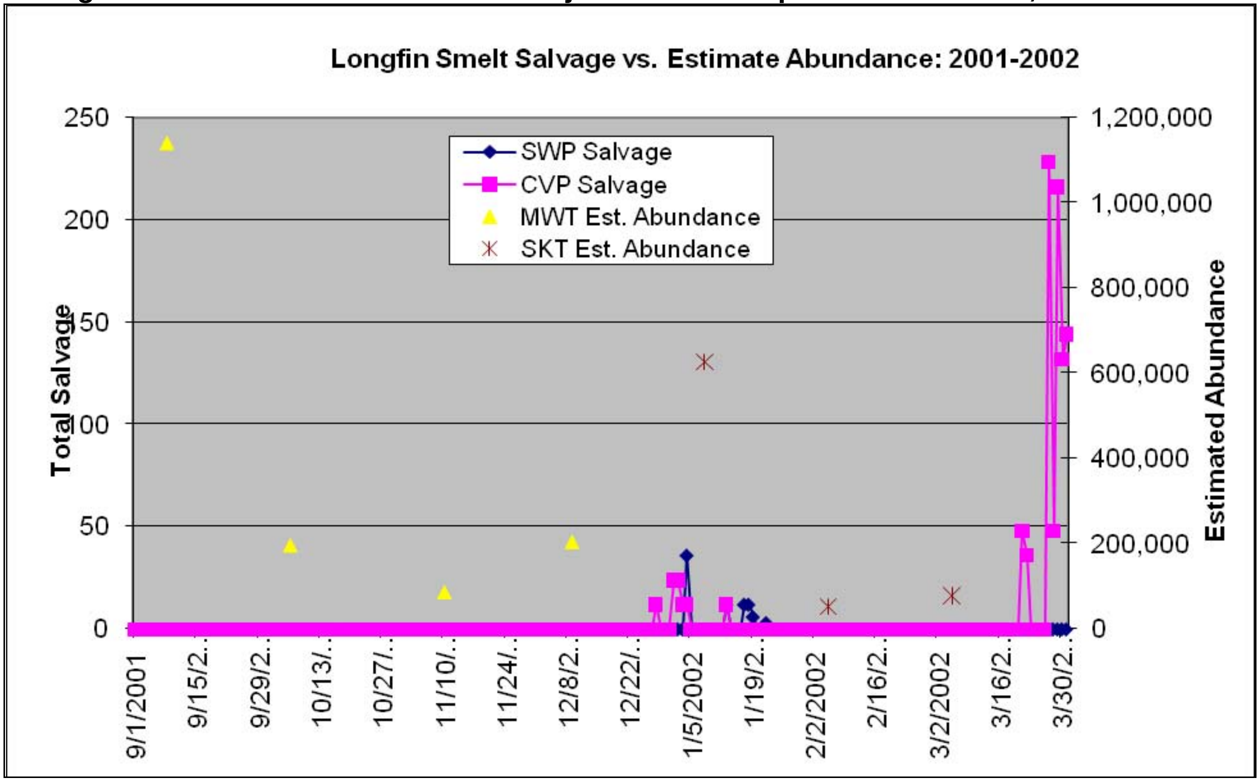


Figure 8. Longfin smelt daily salvage and WMWT or SKT abundance indices for the average survey dates during fall and winter of 2001 and 2002. Salvage in December and January was subadults and adults, except for maybe 3 juveniles in December, while CVP salvage in March was >=95% larvae and juveniles and up to 5% subadults, and no adults.

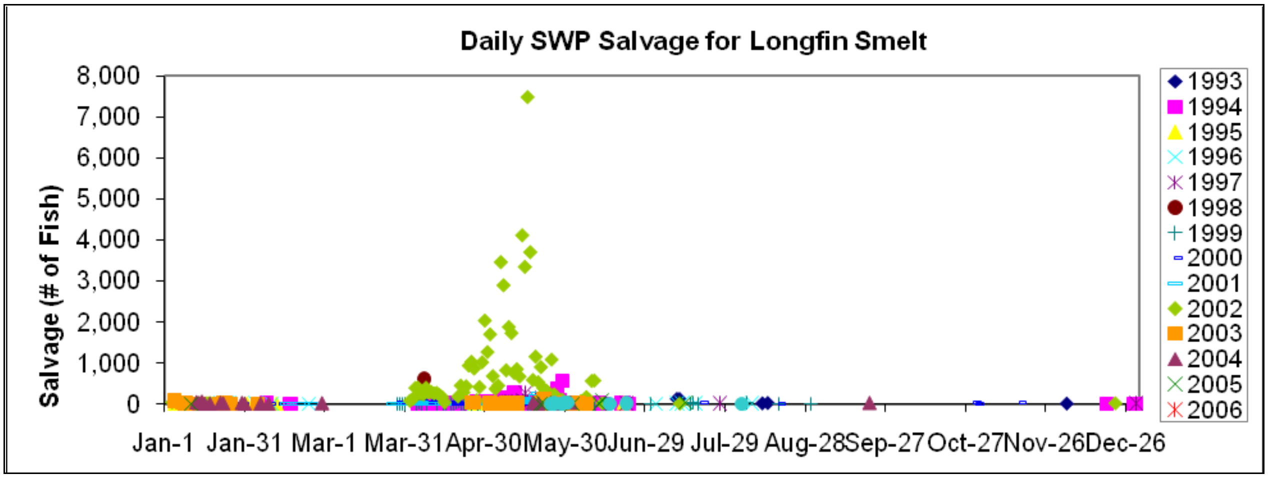


Larvae and Juveniles and Entrainment.

Salvage

Although larvae are abundant in the Bay/Delta during January-April (Baxter 2008a), salvage operations do not detect longfin smelt until March, when fish reach 20mm or more in length (Figures 9 and 10). Larvae (<20mm) are likely to be entrained although the numbers are unknown.

Figure 9. SWP and CVP longfin smelt daily salvage. Most of these fish are juveniles, and larvae are too small to be detected.



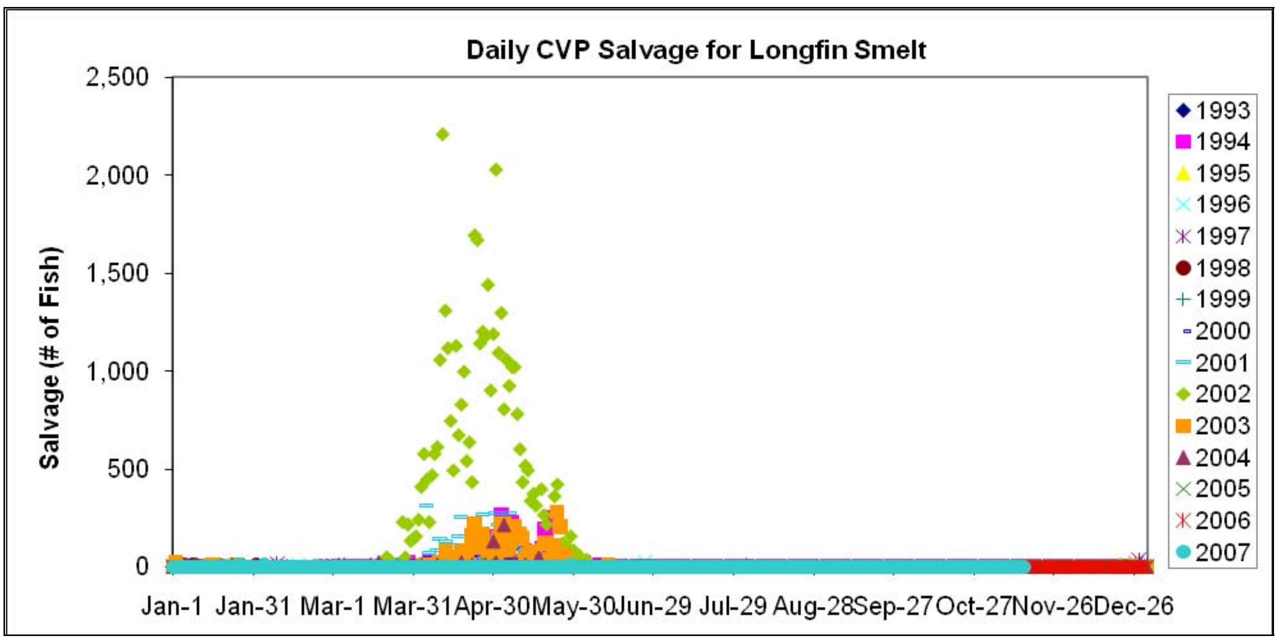
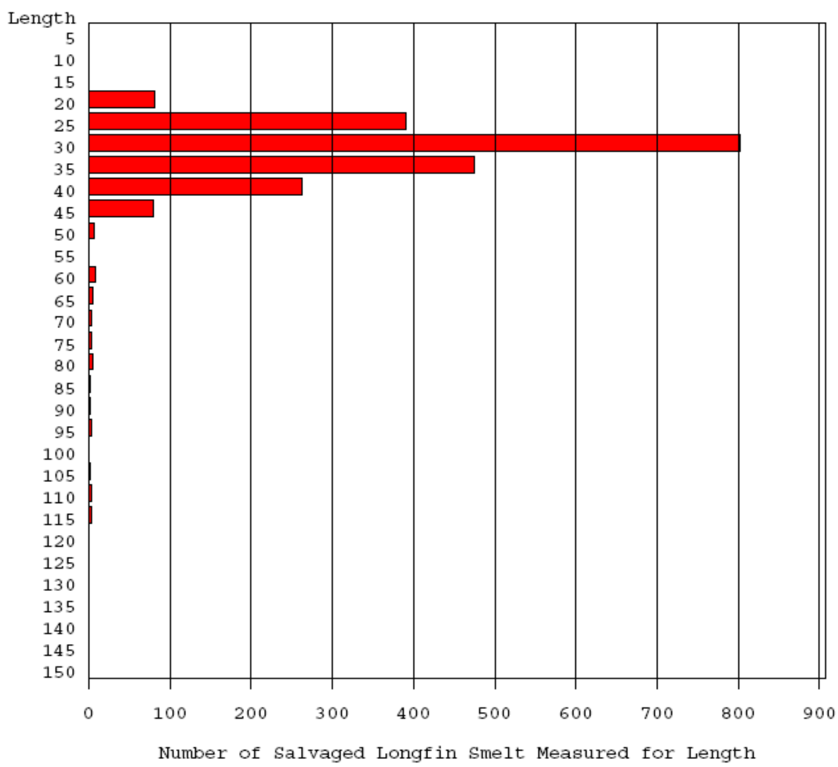


Figure 10. Longfin smelt lengths from SWP salvage.

SWP Length Frequency of LongfinSmelt for 1993 to 2007 Salvage



Length	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
5	0	0	0.00	0.00
10	0	0	0.00	0.00
15	0	0	0.00	0.00
20	82	82	3.83	3.83
25	391	473	18.25	22.07
30	803	1276	37.47	59.54
35	474	1750	22.12	81.66
40	263	2013	12.27	93.93
45	79	2092	3.69	97.62
50	6	2098	0.28	97.90
55	1	2099	0.05	97.95
60	8	2107	0.37	98.32
65	5	2112	0.23	98.55
70	4	2116	0.19	98.74
75	3	2119	0.14	98.88
80	5	2124	0.23	99.11
85	2	2126	0.09	99.21
90	2	2128	0.09	99.30
95	3	2131	0.14	99.44
100	1	2132	0.05	99.49
105	2	2134	0.09	99.58
110	3	2137	0.14	99.72
115	4	2141	0.19	99.91
120	1	2142	0.05	99.95
125	0	2142	0.00	99.95
130	0	2142	0.00	99.95
135	0	2142	0.00	99.95
140	0	2142	0.00	99.95
145	0	2142	0.00	99.95
150	1	2143	0.05	100.00

LongfinSWPLengFreq93to07.pdf SAS Program:LongfinSalvLengthData 79thru07.sas 29APR2008

Entrainment Risk

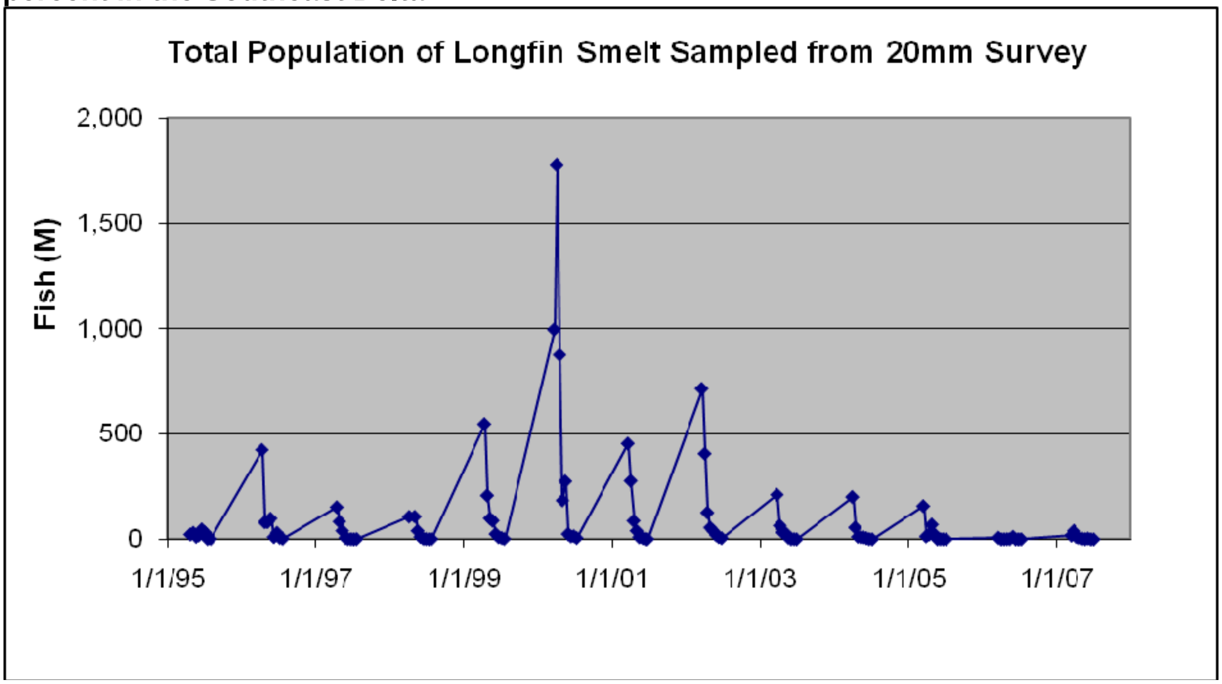
Larval-plus-juvenile longfin smelt abundance indices for the Southeast region relative to over all regions can be useful in gauging entrainment risk and potential population effects. Although the 20mm surveys data are conducted March-June, two to three months after longfin start hatching, it is the only source of data available for evaluating the distribution and abundance of these life stages. Using the methodology described above in Appendix A for the WMWT- and SKT-based adult abundance indices, the 20mm survey catch data was expanded to provide total as well as regional larvae and juvenile abundance estimates.

A small portion of the larval and juvenile longfin smelt population has resided in the southeast region of the Delta. Overall larval and juvenile longfin smelt abundance indices range from the hundreds of thousands to over 1.5 billion, with most years in the 10s of millions range. (Figure 11). The fraction of the overall longfin smelt abundance indices accounted for by longfin in the southeast Delta range from 0 to 2%, with most values at 0% (Figure 11). Instead of being in the Southeast Delta, most longfin appear to have been seaward. In 2002, the highest salvage year, and the two preceding years, for example, most longfin smelt were in the North Delta, Suisun, and Napa-Carquinez areas (Figure 12).

Conclusion

Based on available data, only a small fraction of the longfin smelt population resides in the South or Southeast Delta near the pumps. The fraction likely to be salvaged this coming winter appears to be a small part of the overall population. Project operation criteria for protection of delta smelt would provide protection for longfin smelt as well. Consequently, further manipulation of operations this winter for longfin smelt protection seems unlikely to provide much benefit to the population.

Figure 11. Longfin smelt larval and juvenile abundance indices over all regions and the percent in the Southeast Delta.



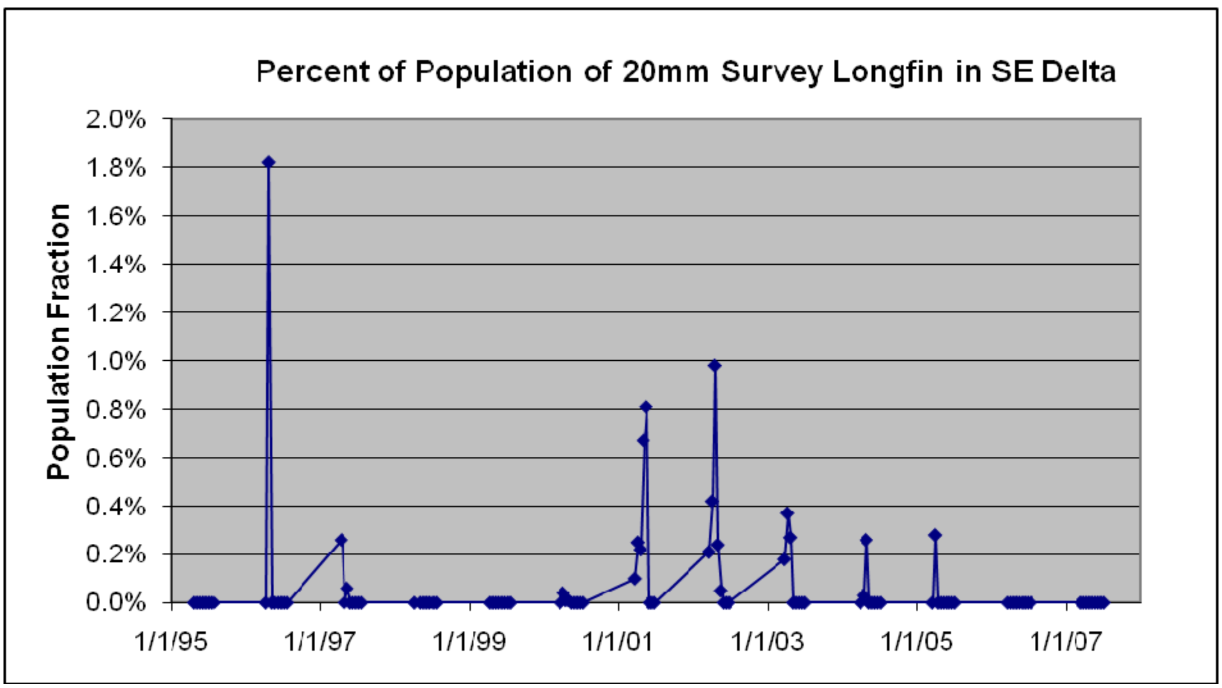
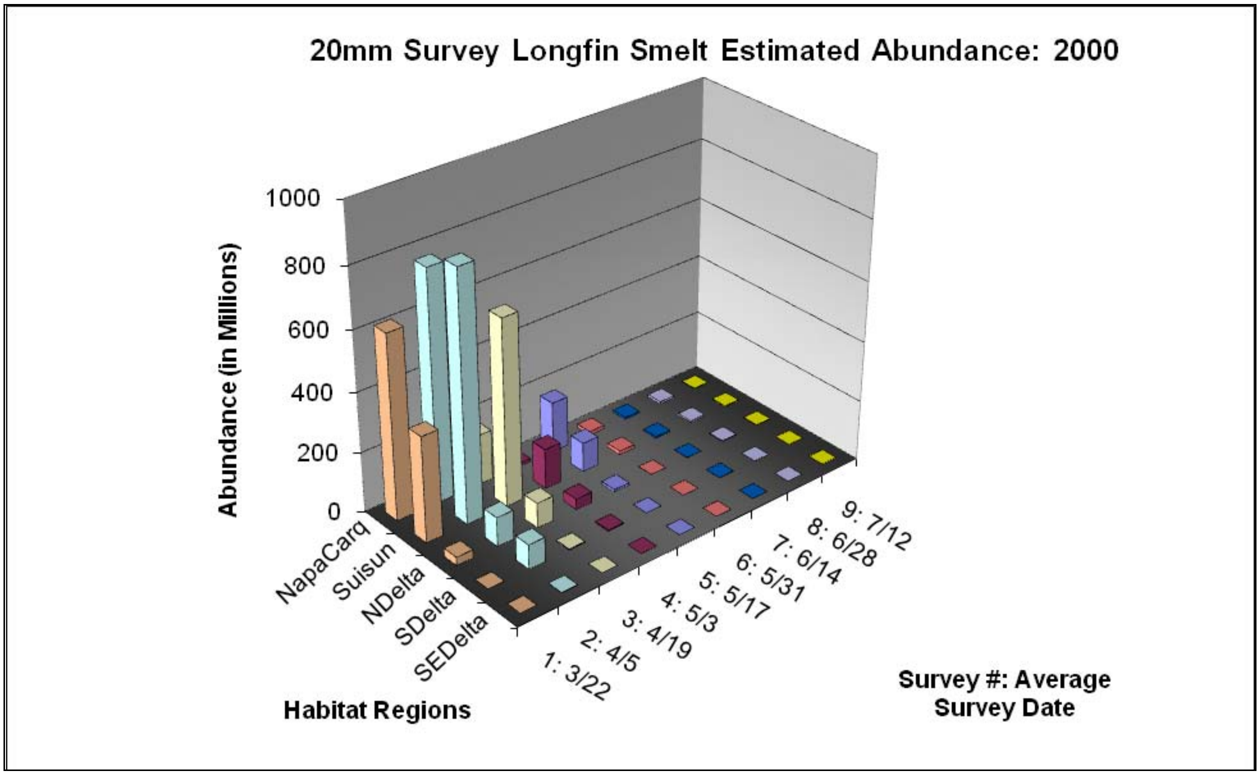


Figure 12. Larval and juvenile longfin smelt abundance indices across regions for 2000, 2001 and 2002.



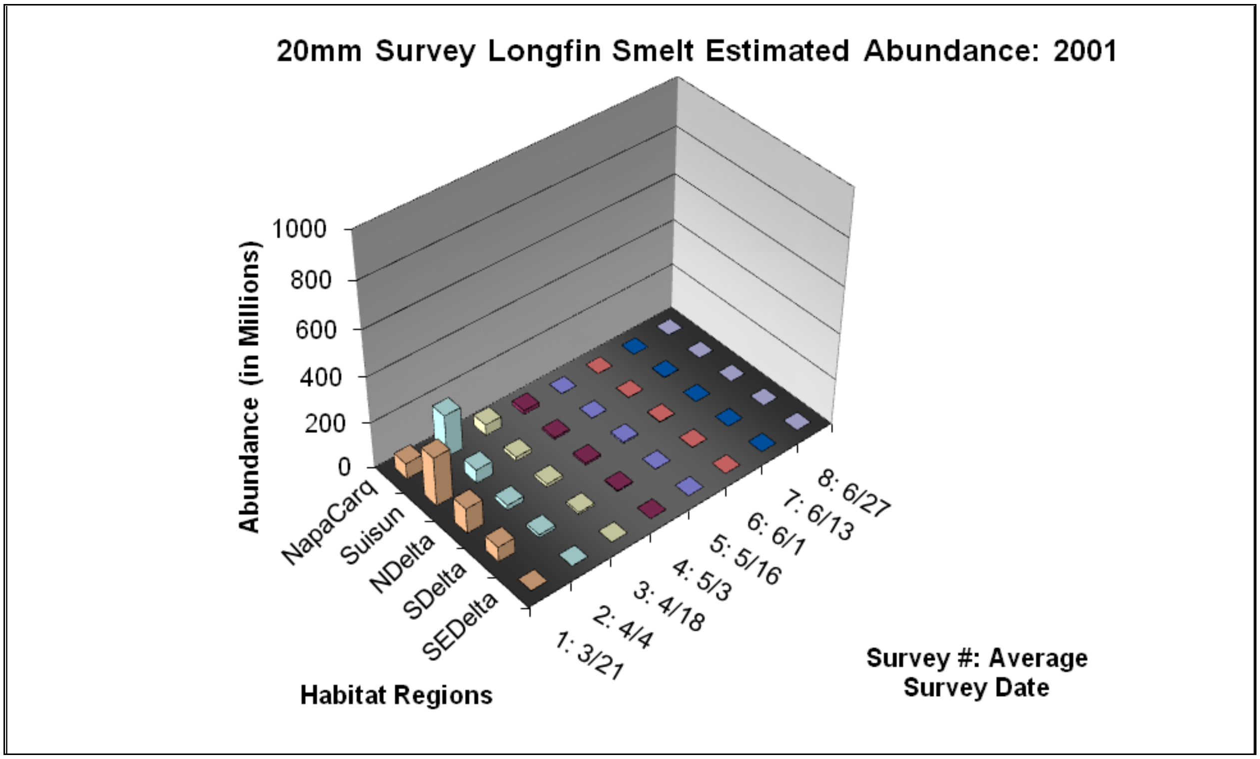
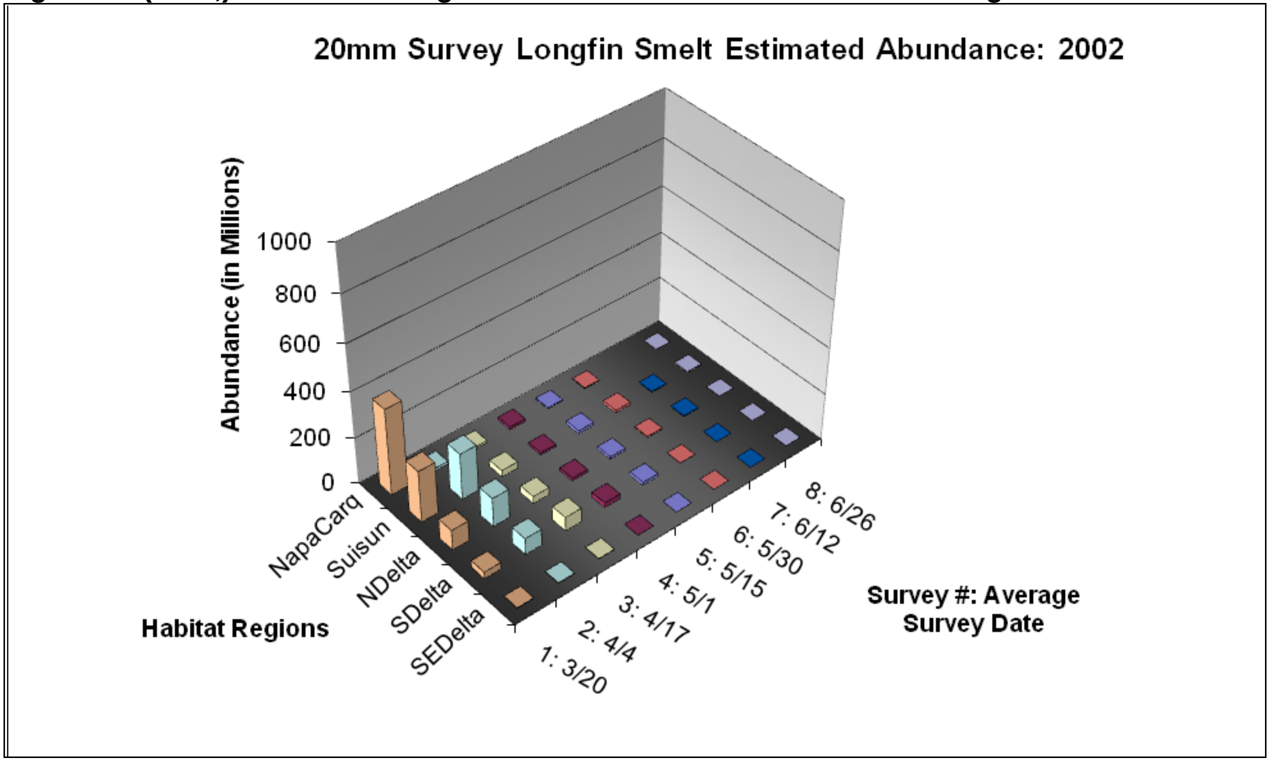


Figure 12 (cont,). Juvenile Longfin smelt abundance indices across regions.



<u>OTHER STRESSORS STRONGLY ASSOCIATED WITH THE FMWT LONGFIN SMELT ABUNDANCE INDEX.</u>

Other stressors besides losses at the pumps may be operating to control longfin abundance. Several potential stressors have been identified by the POD as potentially effecting longfin smelt (Baxter et al. 2008). New analyses of the longfin smelt abundance, as represented by its FMWT index show strong associations of this index with three independent factors:

- The average value of X2 during the winter/spring of the current year. The period February through April appears to account for the most variability. The X2 data used here was generated by applying the daily X2 equation to outflows in the DAYFLOW dataset.
- The average value of air temperature (F) at Davis from February through April of the current year. Regional air temperature, as represented by Davis air temperature, has an influence on water temperatures in the Delta and Suisun Bay and water temperature may influence species abundance. This temperature data can be found at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca2294.
- Average ammonia loading at Hood/Greenes
- Landing during March and September of the current and previous years. Loading can be estimated from DAYFLOW data and concentration data found at http://bdat.ca.gov/.

The data used for the correlations is given in Table 3. The data begins in 1977 because ammonia data is only available since 1975, while FMWT data is not available for 1976. Note that there is no FMWT available for 1979 either.

The time trends in X2, temperature, and ammonia loading are shown in Figure 13-15. X2 shows no time trend. Davis air temperature shows an upward trend at about 0.05 degrees F per year. Ammonia loading shows an upward time trend of about 10 Tons/m each year.

Table 3. Data used in evaluating other stressors.

Year	Longfin FMWT	Ln (LongfinFMWT)	Average February-April X2 (km)	Average Davis Air Temp February - April (F)	NH4-N Sacramento River at Hood/Greenes Landing (tons/month). Average of March and September for the Current and Previous Year
1977	210	5.3	91.0	53.6	143.0
1978	6619	8.8	56.9	54.1	175.0
1980	31184	10.3	53.7	53.9	165.2
1981	2202	7.7	70.3	54.1	167.8
1982	62905	11.0	51.6	51.7	192.5
1983	11864	9.4	44.0	52.5	206.9
1984	7408	8.9	61.0	54.2	240.6
1985	992	6.9	75.3	54.1	247.9
1986	6160	8.7	53.4	56.0	216.5
1987	1520	7.3	74.1	55.0	277.3
1988	791	6.7	84.5	55.4	288.3
1989	456	6.1	77.3	53.6	265.4
1990	243	5.5	86.8	54.4	295.2
1991	134	4.9	81.1	53.6	334.9
1992	76	4.3	76.1	57.3	369.8
1993	798	6.7	58.6	54.7	405.3
1994	545	6.3	74.6	54.1	399.9
1995	8205	9.0	50.8	53.7	316.4
1996	1346	7.2	54.0	55.9	249.9
1997	690	6.5	56.3	56.9	255.9
1998	6654	8.8	48.2	53.1	308.1
1999	5243	8.6	55.7	52.3	300.2
2000	3437	8.1	58.4	56.2	299.6
2001	245	5.5	72.0	54.9	358.0
2002	707	6.6	72.5	54.9	463.9
2003	467	6.1	67.3	53.9	512.7
2004	191	5.3	62.3	57.5	430.4
2005	129	4.9	64.7	55.9	459.8
2006	1949	7.6	50.6	52.7	438.9
2007	13	2.6	73.9	56.9	

Figure 13. Average X2 for February to April 1977-2006.

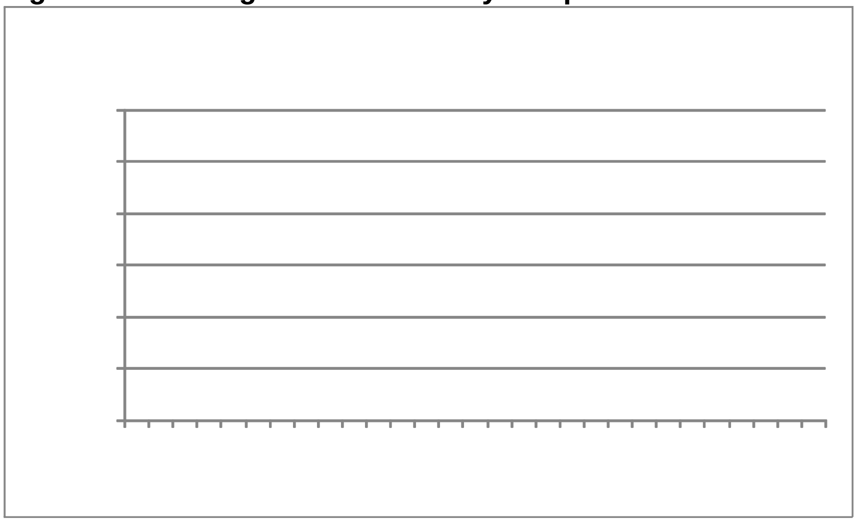


Figure 14. Average Davis air temperature for February to April 1977-2006.

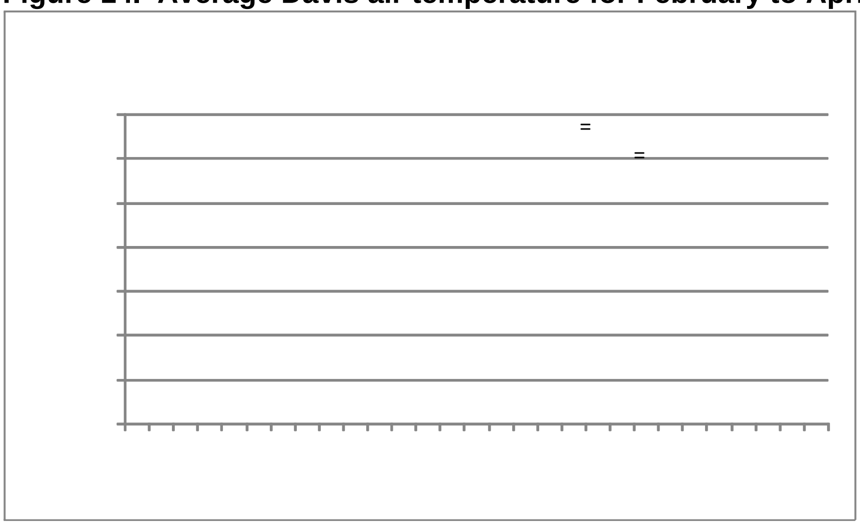
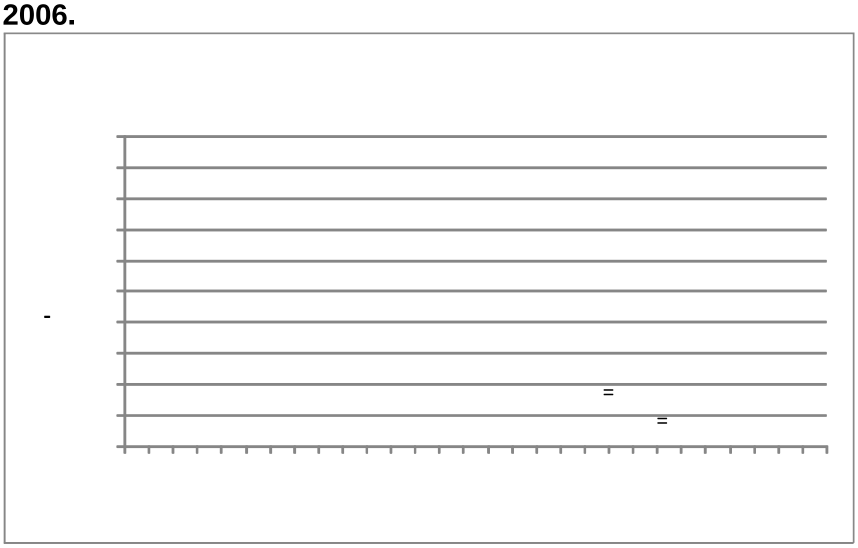


Figure 15. Average March and September ammonia loading at Greenes Landing 1977-2006.



The individual relationships between the X2, temperature, and ammonia variables and longfin FMWT index are shown below as Figures 16-18. One inference from the figures is that very high longfin abundances are rare when average X2 is greater than 65 km, when average Davis air temperatures are greater than 54.5 degrees F, or when average March/September ammonia loading is greater than about 250 tons per month.

Figure 16. Longfin FMWT and February to April X2.

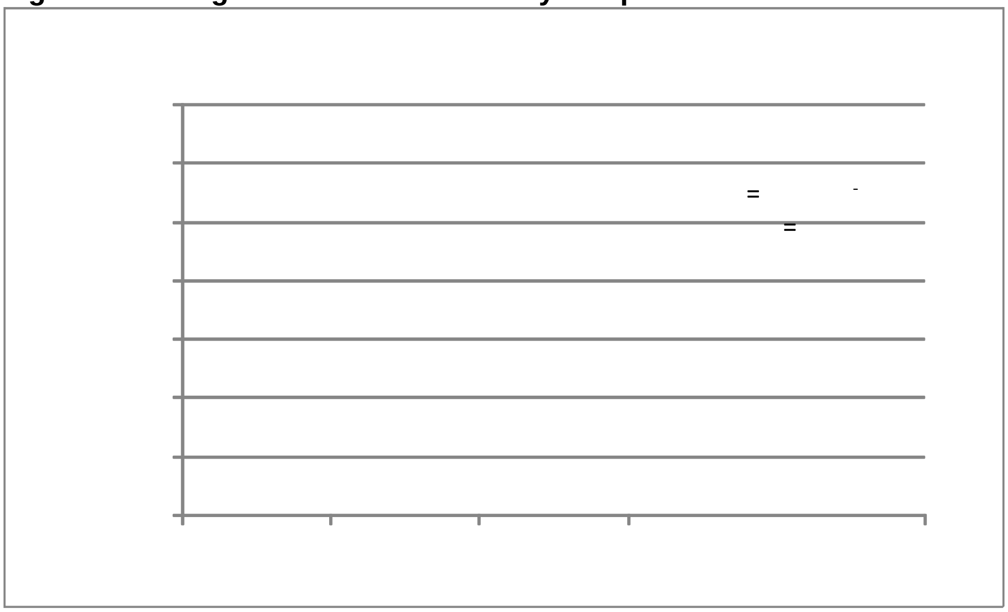


Figure 17. Longfin FMWT and February to April air temperature at Davis.

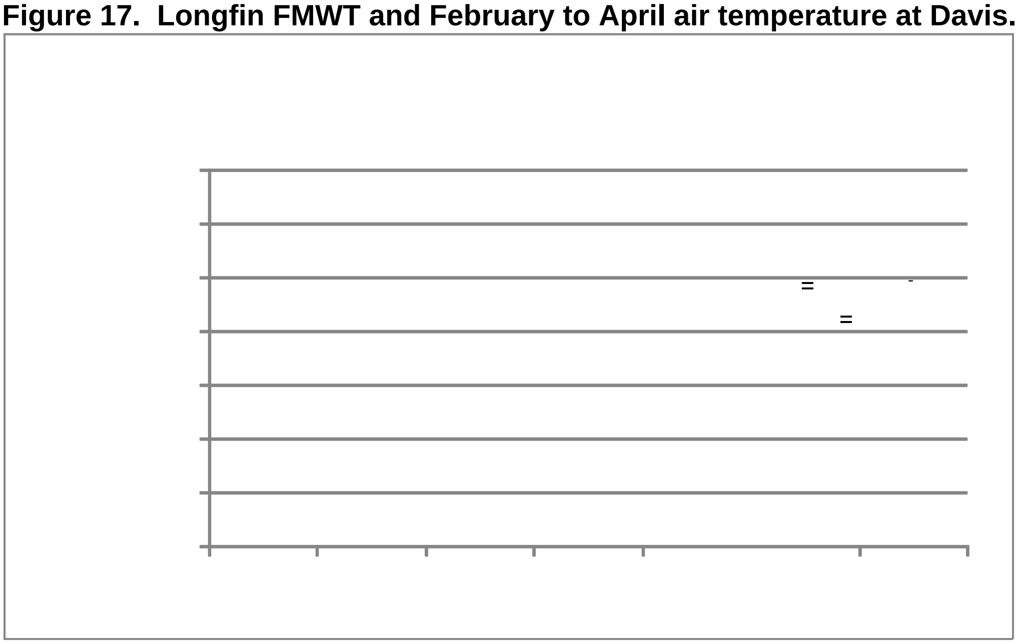
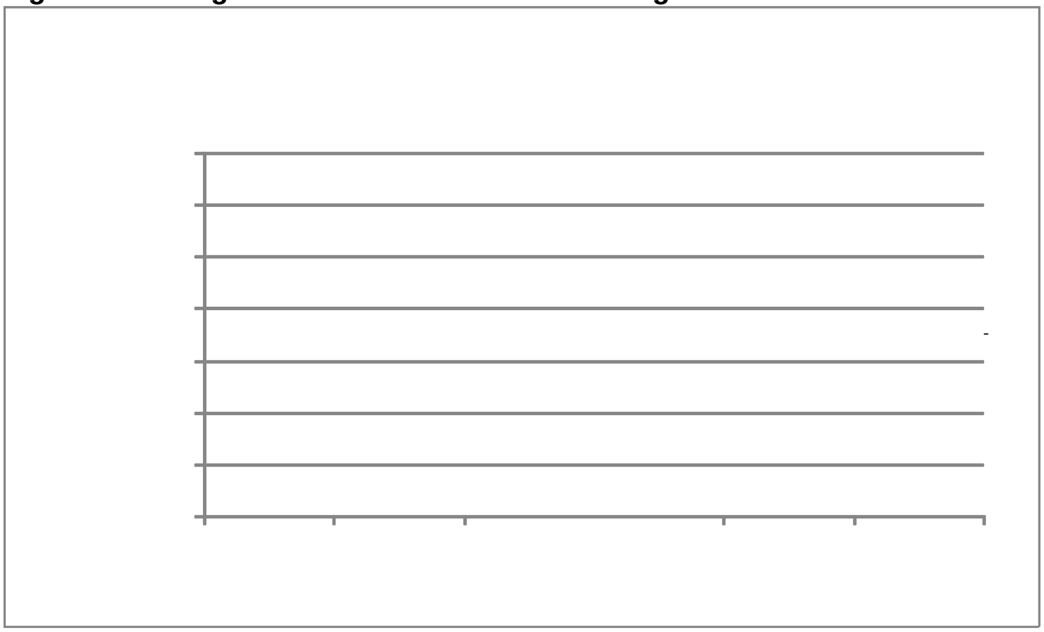


Figure 18. Longfin FMWT and ammonia loading.



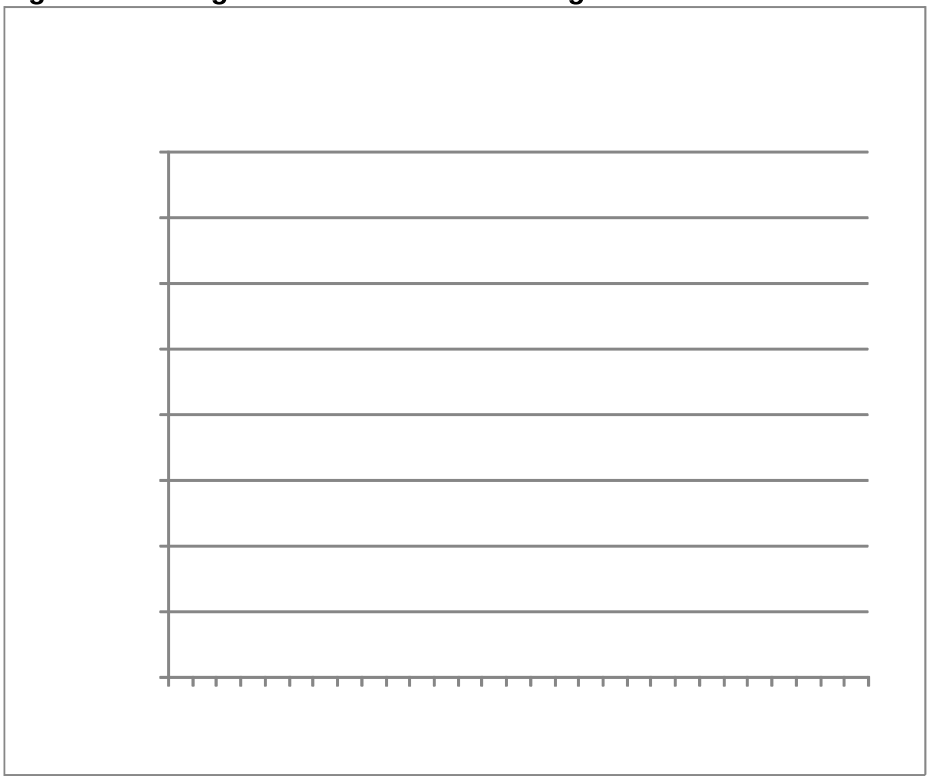
The effects of X2, Temperature, and Ammonia loading can be analyzed together using correlation. The natural log of the FMWT is used for purposes of the correlation to emphasize the percent change in abundance from year rather than the absolute change in population. Results are returned to arithmetic values for further interpretation. Note that 2007 is not included in Figure 19 due to the lack of ammonia data for 2007.A correlation of ln(FWMT) versus the X2, temperature, and ammonia data listed in Table 3 gives the following results:

- Ln(FMWT) = 35.2 - 0.087 (X2) – 0.37 (Temperature) – 0.0065 (Ammonia)
- R^2 0.82
- P values:
    - .0000002 for X2
    - .003 for temperature
    - .0006 for ammonia

Thus, the correlation both explains most of the variation in longfin abundance and is highly significant.

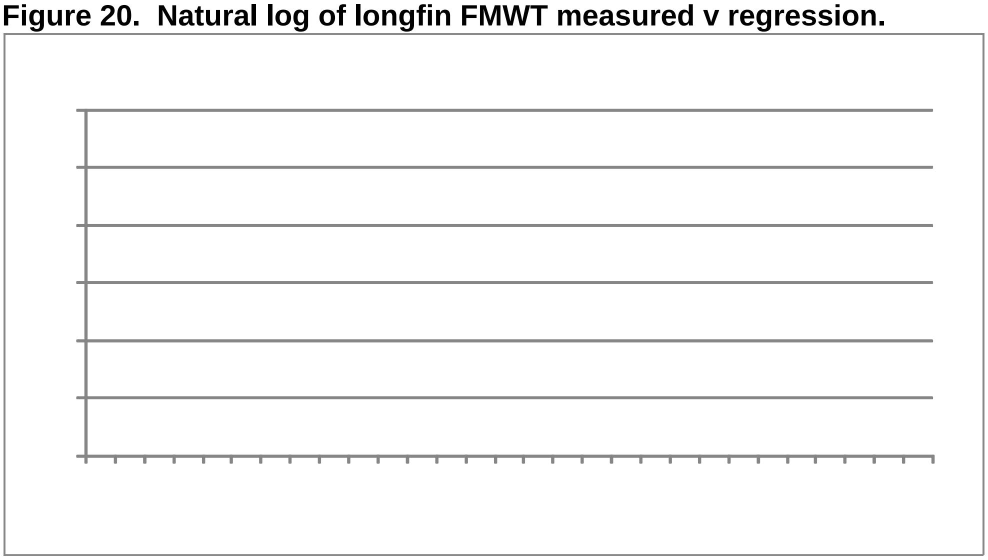
The fit between the regression and the measured FMWT values is shown in Figure 19

Figure 19. Longfin FMWT measured v regression.



The same data, but plotted using the natural logarithm of the FMWT is shown in Figure 20.

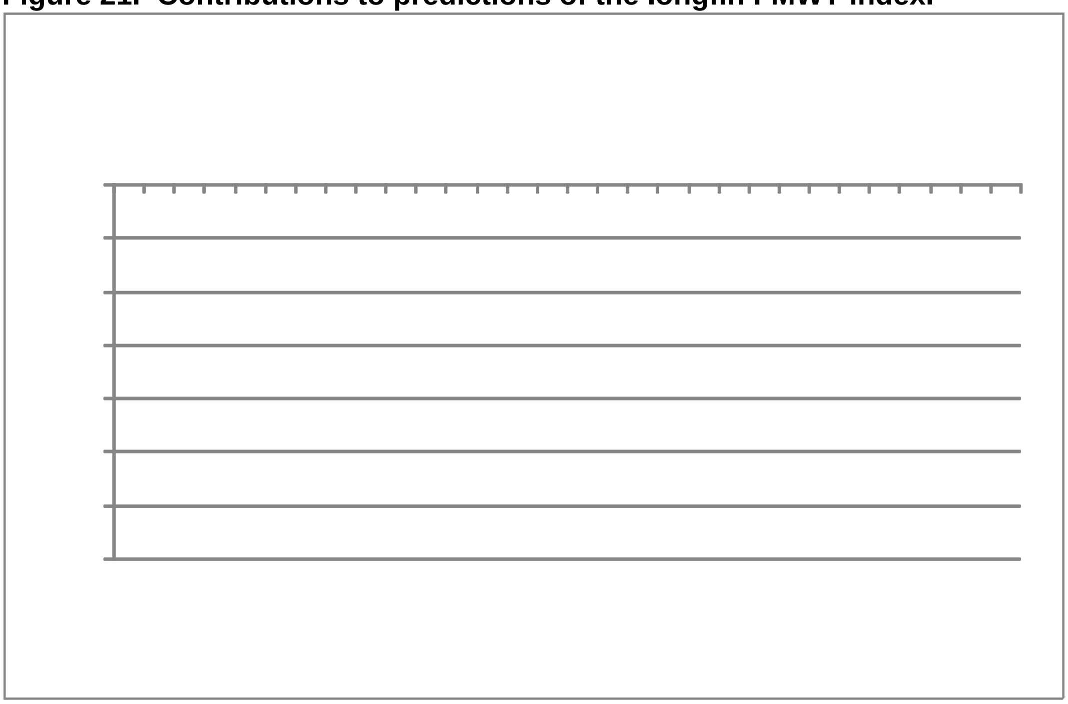
Figure 20. Natural log of longfin FMWT measured v regression.



All upward and downward spikes in abundance are captured since 1977. Although no ammonia data is available yet for 2007, if ammonia is close to the value from recent years, then the regression would correctly predict the major downward spike in abundance in the 2007 FMWT survey (2007 is discussed below and projected in Figure 21).

The relative contribution to declines in longfin abundance can be seen in Figure 21. The thickness of each band represents the degree to which that factor (X2, temperature, or ammonia) is dropping longfin abundance from the value it would have if each factor were at its optimum value over the period 1977 – 2006. If the thickness of any band is one, this means that longfin FMWT index has dropped by 2.7. If the thickness is 2, then FMWT index has dropped by 2.7 squared or about 7. A thickness of three means that FMWT index has dropped by a factor of 2.7 cubed or about 20. Figure 21 shows that in the 1970s, high longfin abundance was associated with low temperatures and low ammonia loading. Years when X2 was downstream were associated with extremely high longfin populations. Even years with high X2 had relatively good longfin abundance and temperature and ammonia are indicated as not suppressing the population. However, while X2 has remained generally stable since the 1970s, temperature, and particularly ammonia loading have increased. Now, even when X2 is far downstream, high temperatures and high ammonia loading could suppress population. When all three factors are unfavorable, then abundance can drop to very low levels. Figure 21 includes a projection for 2007 assuming that ammonia loading in 2007 is similar to levels of recent years. Thus, the extremely low longfin FMWT index in 2007 may represent the confluence of three separate factors X2, temperature, and ammonia acting together. Given low Delta outflow during 2008 and continued high ammonia loading, 2008 is also likely to have a low longfin FMWT index, though it does appear that Davis air temperatures were somewhat below average during 2008, which should help somewhat.

Figure 21. Contributions to predictions of the longfin FMWT index.



CONCLUSION

Although longfin smelt are entrained at the SWP and CVP facilities, historic data offer reasons to believe that very small portions of the widespread longfin population were involved. This applies to subadults and spawners, as well as larvae and juveniles at least during the spring. The fraction in the southeast Delta might be one of the metrics for assessing risks of entrainment at the Projects. Further, incremental changes in operations to protect longfin smelt beyond protections for delta smelt, probably would save some longfin smelt but not with detectable effects on the overall population. Finally, other environmental factors besides entrainment appear more likely to control the abundance of longfin smelt. Therefore, given the limited benefits to the longfin smelt population, additional water operations restrictions beyond those anticipated for delta smelt do not seem warranted.

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Baxter, R. et al. 2007. Pelagic Organism Decline Progress Report: 2007 Synthesis of Results. Interagency Ecological Program of the San Francisco Estuary. January.

Appendix A
Data Sources and Abundance and Salvage Analyses

Three sources were used for assessing longfin smelt abundances. These include the 20-mm survey, fall and winter midwater trawl (FMWT & WMWT), and spring Kodiak trawl (SKT). Additionally, salvage from the SWP Skinner Delta Fish Protective Facility and the CVP Tracy Fish Collection Facility are used to assess impact of exports on longfin smelt.

- Original 20mm agency data, stored in Microsoft Access, was downloaded from DFG's 20mm survey website, http://www.delta.dfg.ca.gov/data/20mm/, in November of 2007.
- Original MWT agency data, stored in Microsoft Access, was downloaded from DFG's FTP site, ftp://ftp.delta.dfg.ca.gov/, on 03/13/08.
- Original SKT agency data, stored in Microsoft Access, was downloaded from DFG's FTP site, ftp://ftp.delta.dfg.ca.gov/, in October of 2007.
- Salvage count data was downloaded from the DFG Central Valley Bay-Delta Branch Salvage FTP website, http://www.delta.dfg.ca.gov/Data/Salvage/, on 02/21/08 and length data was downloaded on 03/12/08.

Since datasets are managed with different software programs (e.g. Access, dBase, etc.), we used SAS software to consolidate the different datasets onto one platform so abundance programs and queries can be made efficiently. Output data is then copied into Excel for sharing and graphing. To make sure original data were not inadvertently modified during the conversion process to SAS, we subjected the SAS data to quality control measures and had independent reviewers check a random subset of the data. The SAS data were also subjected to a data quality QA/QC analysis for missing, extreme, and other questionable values.

Abundance Estimation

Abundance is the basic parameter used to assess population levels and dynamics. The basic estimation procedure was the same for the 20mm, MWT, and SKT surveys. The generic steps are as follows.

Length-specific catch, expressed as number of fish, was divided by net efficiency yielding an expanded catch. Net efficiency was determined separately for each survey net as described in detail below. Expanded catch was divided by the volume sampled per tow to determine densities. The sample volumes were computed from flow data obtained by DFG with a General Oceanics flow meter mounted in the mouth of the net. If more than one tow was taken, then densities were averaged over the replicate tows (varying between 1 and 3, depending on the survey) at each station for each sampling event. Station densities were averaged over sub-regions (Table A1 and Figure A1) and then multiplied by the sub-region's water volume over the whole water column to produce the sub-regional abundance estimates. Sub-regional water volumes, Table A2, were estimated by BJ Miller (unpublished). At this stage, the sub-regional abundances are still length-specific; hence total abundance is derived by summing overall length classes. For easier graphical interpretation, sub-regions were combined into five main regions, shown in Table A1 and main report Figure 4. All densities and abundances were calculated using SAS.

Table A1. Assignment of Sampling Stations to Regions for Each Survey.[1]

Regions	Sub-Region	20mm	Fall and Winter Midwater Trawl	Spring Kodiak Trawl
Napa-Carquinez	**Napa River**	340, 342, 343, 344, 345, 346	340, 341	340
	Carquinez Strait	405	401, 403, 404, 405, 406, 407, 408	405
Suisun	**Suisun Bay**	411, 418, 501, 602	409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 501, 502, 503, 515, 516, 517, 601, 602, 603, 604	411, 418, 501, 602
	Suisun Marsh*	606, 609, 610	605, 606, 608	606, 609, 610
North Delta	**Chipps Island**	504, 508, 519	504, 505, 507, 508, 509, 510, 518, 519	504, 508, 519
	Lower Sacramento River	513, 703, 704, 705, 706, 707	511, 512, 513, 701, 703, 704, 705, 706, 707	513, 704, 706, 707
	Cache Slough	716	713, 715, 716	713, 715, 716
	Upper Sacramento River	711	708, 709, 710, 711, 717, 724, 72	711, 712, 725
South Delta	**Lower San Joaquin River**	520, 801, 804	802, 804, 806, 807, 808	520, 801, 804
	Near Franks Tract	809, 812, 815, 901, 902, 906	809, 810, 811, 812, 813, 814, 815, 902, 904, 905, 906	809, 812, 815, 902, 906
	East-Southeast Delta	910, 912	908, 909, 910, 911, 912	910, 912
	East-Central Delta	919	903, 919, 920, 921, 922, 923	919, 920, 921, 922, 923
Southeast Delta	**Southeast Delta**	914, 915, 918	913, 914, 915	914, 915

[1] Every station was not sampled during each survey date

[2] Density at Cache Slough was assumed to be the same as at Upper Sacramento River

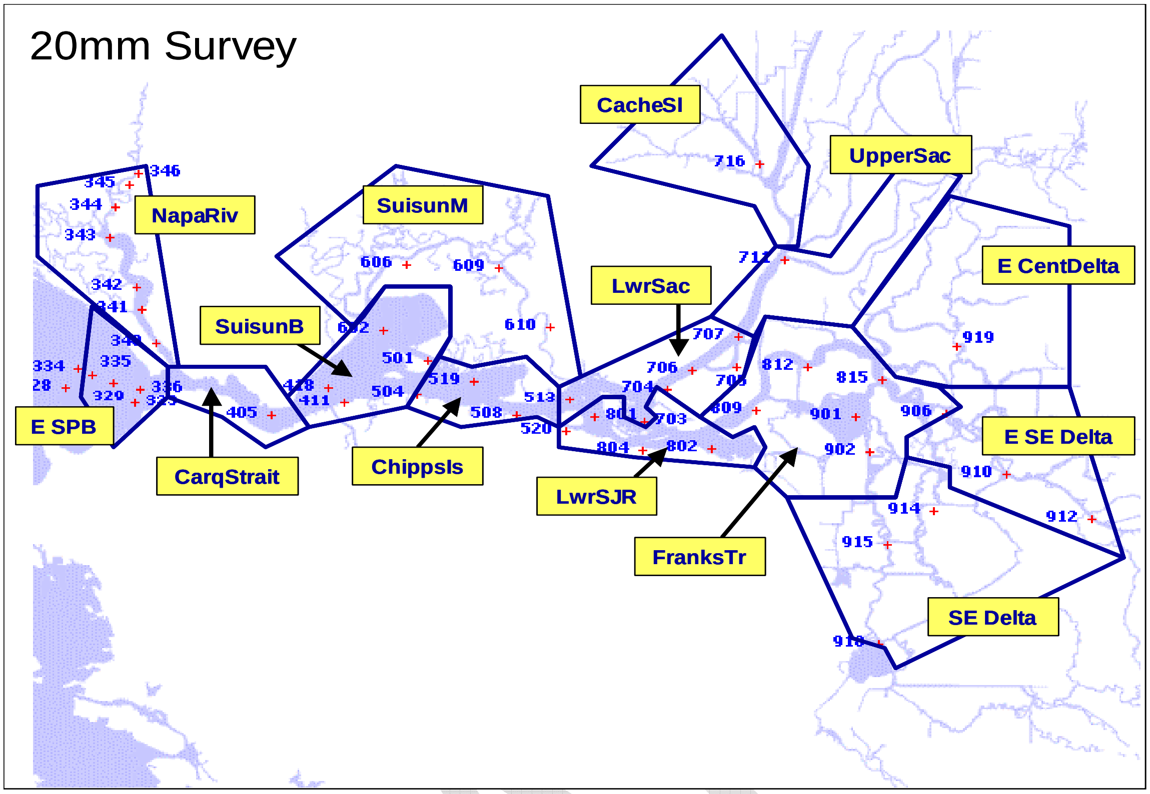


Figure A1. Sub-Regions Used for Abundance Calculations. 20mm survey station map used to illustrate regions for all surveys. ***(Map source: DFG 20mm website, http://www.delta.dfg.ca.gov/data/20mm/stations.asp)***

Table A2. Estimated Volume for 14 Regions of the Delta.[1]

Region	Full Depth Volume (m^3)
East San Pablo Bay	390,531,700
Napa River	59,440,550
Carquinez Strait	262,820,350
Suisun Bay	362,324,300
Suisun Marsh[2]	46,333,495
Chipps Island	125,562,450
Lower Sacramento River	187,942,300
Cache Slough	42,718,650
Upper Sacramento River	56,069,000
Lower San Joaquin River	132,873,650
Near Franks Tract	243,023,300
East-Southeast Delta	94,526,900
East-Central Delta	68,678,350
Southeast Delta	89,315,200
Total Volume	2,162,160,195

[1] Volumes are based on BJ Miller(unpublished)
[2] Suisun Marsh volumes only included Montezuma Slough, not smaller tributaries

The basic calculation steps for the abundance estimate require further steps to correct for sampling biases of the sampling nets. Since delta smelt and longfin smelt are similar in body shape (i.e. width to length proportion) and size, we applied net efficiency equations that were developed for delta smelt to longfin smelt abundance calculations. For the delta smelt net efficiency estimation, we collected available information about the mesh sizes of the survey nets and previous gear efficiency field studies. A summary of the net efficiency estimation procedure for each survey are described here.

MWT - A field study performed by DFG (Sweetnam and Stevens 1993) evaluated MWT net efficiency by placing a larger, finer mesh net outside of the standard MWT net to catch any fish passing through the standard net. Only results from the August 1991 experiment were evaluated, as the other experiment conducted in January 1992 collected few delta smelt. Catch values taken from published graphs were used to calculate the ratio of the standard net catch to the total catch. Resulting data showed a threshold point for retaining smelt at about 70mm. Hence, the net was assumed to be 100% efficient at retaining all delta smelt caught above a fork length of 70mm. Regression analysis was used to determine the best fit equation for net efficiencies for fork lengths below 70mm. A linear regression (Equation A1) had the best fit with a R^2 value of 0.67 and was selected for estimating the MWT net efficiency for delta smelt less than 70mm FL (Figure A2).

Equation A1 Net Efficiency = 0.0088 * Fork Length – 0.1422

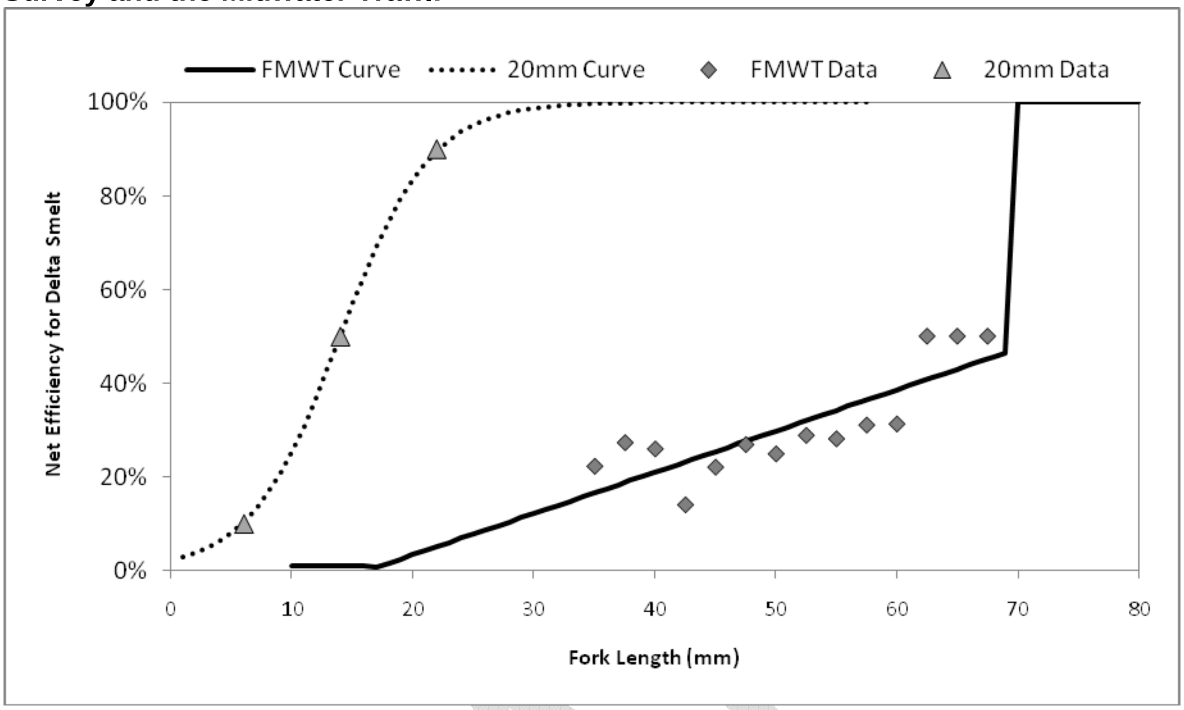
A second DFG field study was also performed in 2005 (unpublished). The second study also used a finer mesh outside net over the standard net. Since very few delta smelt were caught during the trawls, northern anchovies, which have a similar body shape and size, and were abundant, were used as a surrogate in the analysis for delta smelt net efficiencies. There was very little overlap in size of fish collected in the standard net catch versus the outside net catch, so no net efficiency curve could be generated. Still, the utility of this study was that it affirmed a threshold effect at about 70mm.

20mm Survey – Three data points were taken from an unpublished 20mm net efficiency graph[1] and a logistic equation was reconstructed from those points. The fitted logistic curve (Equation A2) was used for lengths up to 39 mm. For lengths 40 mm and greater, a gear efficiency of 100% was assumed (Figure A2).

Equation A2 Net Efficiency = (1 / (1 + EXP (-0.27 * (Fork Length – 14)))

[1] The unpublished graph is from one of the earlier drafts for Kimmerer (2008). The net efficiency curve in Kimmerer (2008) was updated from the draft efficiency curve. The update equation would have increased the 20mm longfin smelt abundance from levels in this report.

Figure A2. Regression relationships between net efficiency and fork length for the 20mm Survey and the Midwater Trawl.



<u>Kodiak</u> – No information was available to determine an efficiency curve or smelt size thresholds for the Kodiak trawl net, so no SKT efficiency was applied. The net was assumed 100% efficient.

Salvage by Life Stage Estimation

To estimate salvage by life stage, total daily salvage was divided into groups based on the measured lengths of longfin smelt. Since only a few salvaged longfin smelt were measured for length, the length data from 1993 to 2007 was pooled together and an average monthly life stage frequency was calculated. Life stage groups, based from data in Rosenfield and Baxter (2007), are defined here as 0-20mm for larvae, 20-59mm for juveniles, 60-89mm for subadults, 90-124mm for adults, and greater than 125mm for age2-adults. The monthly frequencies used to segregate daily salvage into life stage groups are listed in Tables A3 and A4.

Table A3. Monthly Life Stage Frequencies Averaged over 1993-2007 for SWP

	Larvae	Juvenile	Subadult	Adult	Age2Adult
January	0%	0%	53.57%	42.86%	3.57%
February	0%	0%	40%	60%	0%
March	0%	100%	0%	0%	0%
April	0%	100%	0%	0%	0%
May	0%	100%	0%	0%	0%
June	0%	100%	0%	0%	0%
July	0%	33.33%	66.67%	0%	0%
August	0%	0%	100%	0%	0%
September[1]	0%	0%	100%	0%	0%
October	0%	0%	100%	0%	0%
November[1]	0%	25%	50%	25%	0%
December	0%	50%	0%	50%	0%

[1] Although 41 fish were counted in salvage, no fish were measured for length, so the life stage frequency was estimated using the frequency of the previous and subsequent months.

Table A4. Monthly Life Stage Frequencies Averaged over 1993-2007 for CVP

	Larvae	Juvenile	Subadult	Adult	Age2Adult
January	0%	0%	46.15%	46.15%	7.69%
February	0%	0%	100%	0%	0%
March	2.22%	93.33%	4.44%	0%	0%
April	0%	99.88%	0.12%	0%	0%
May	0%	100%	0%	0%	0%
June	0%	100%	0%	0%	0%
July[2]					
August	0%	100%	0%	0%	0%
September[2]					
October[2]					
November[2]					
December	0%	25%	25%	25%	25%

[2] No fish were salvaged in the months of July, September, October, or November, so no life stage frequency needed.

References

Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science [Internet]. 6(2). http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art2/

Rosenfield and Baxter. 2007. Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary. Transactions of the American Fisheries Society **136**: 1557-1592.

Sweetnam and Stevens 1993. A status of the delta smelt (*Hypomesus transpacificus*) in California. Report to the Fish and Game Commission. Candidate Species Report 93-DS. 98 pp.

Attachment 4

Updates to Attachment 3

The following revisions were made and are provided on the pages that follow.

Page 12, para. 2,

line 3. Change "over 1.5" to "2.9" and "10s of" to "10s to a few 100s of"

Page 13, Figure 11.

Updated plots to reflect new abundance and fraction estimates due to recent publication of sampling gear efficiencies in Kimmerer (2008). (Full citation in figure header.) Abundance estimates are greater, as are some fractions in the southeast Delta, due to increased correction factors for poor gear efficiency at shorter lengths of longfin. The conclusion is the same, which is a small fraction of the population appears to inhabit the area near the pumps.

Pages 14-15, Figure 12.

Updated 3-dimensional bar charts to reflect new regional abundance estimates due to recent publication of sampling gear efficiencies in Kimmerer (2008). (Full citation in figure header.) Again, abundance estimates are greater, as are some fractions in the southeast Delta, due to increased correction factors for poor efficiency at shorter lengths of longfin. Again, the conclusion is unchanged, that most longfin smelt have been away from the pumps in the North Delta, Suisun Bay and Marsh, and Carquinez-Napa River regions.

Pages 15 -20.

A number of changes were made to the present a more refined correlation for longfin FMWT:

- *Switched from ammonia "loading" to ammonia "concentration" in presenting data. Ammonia concentration is what longfin actually see and is probably more credible.*
- *Table 3 and Figure 15 - Show that ammonia concentrations are increasing over time.*
- *Figure 18a added. Shows X2 and ammonia concentration are highly correlated. More outflow reduces concentration by reducing residence time.*
- *Figures 19 and 20. Since X2 and ammonia concentration are highly correlated, they cannot both be in the final correlation equation. X2 works better and so is*

retained in the equation. Further, since ammonia is not in the final regression, results all the way back to 1969 (instead of 1977) are shown.

- *The equation also now has a stock recruitment term – abundance two years ago. This type of term is frequently used to help compensate for the fact all things being equal, higher population in past years will be reflected in higher population in the current year.*
- *The overall regression is now better (in terms of r2) than before.*

Page 20.

Replaced second to last paragraph, and deleted the last paragraph entirely (Including text on page 21).

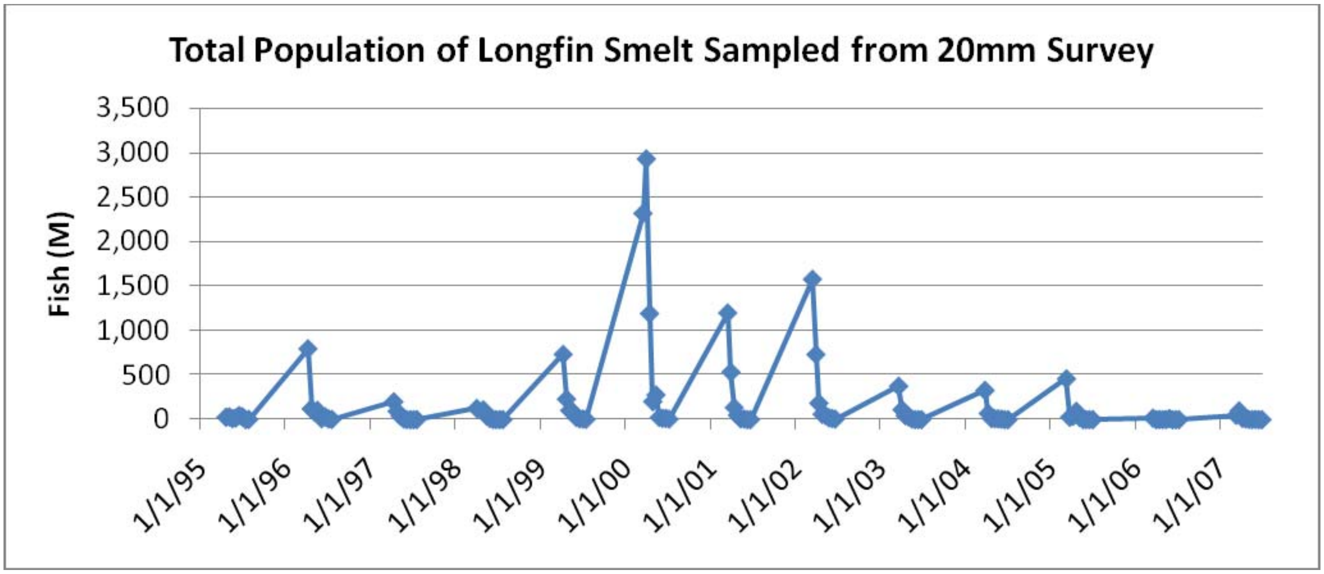
Page 21.

Deleted Figure 21.

Page A-4.

Replace the 20mmSurvey text with "20mm Survey net efficiency equation source is Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta smelt to Entrainment. San Francisco Estuary and Watershed Science. 6(2). At http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1115&context=jmie/sfews)"

Figure 11 (updated). Longfin smelt larval and juvenile abundance indices over all regions and the percent in the Southeast (SE) Delta. (Updated with gear efficiencies from Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta smelt to Entrainment. San Francisco Estuary and Watershed Science. 6(2). At http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1115&context=jmie/sfews)



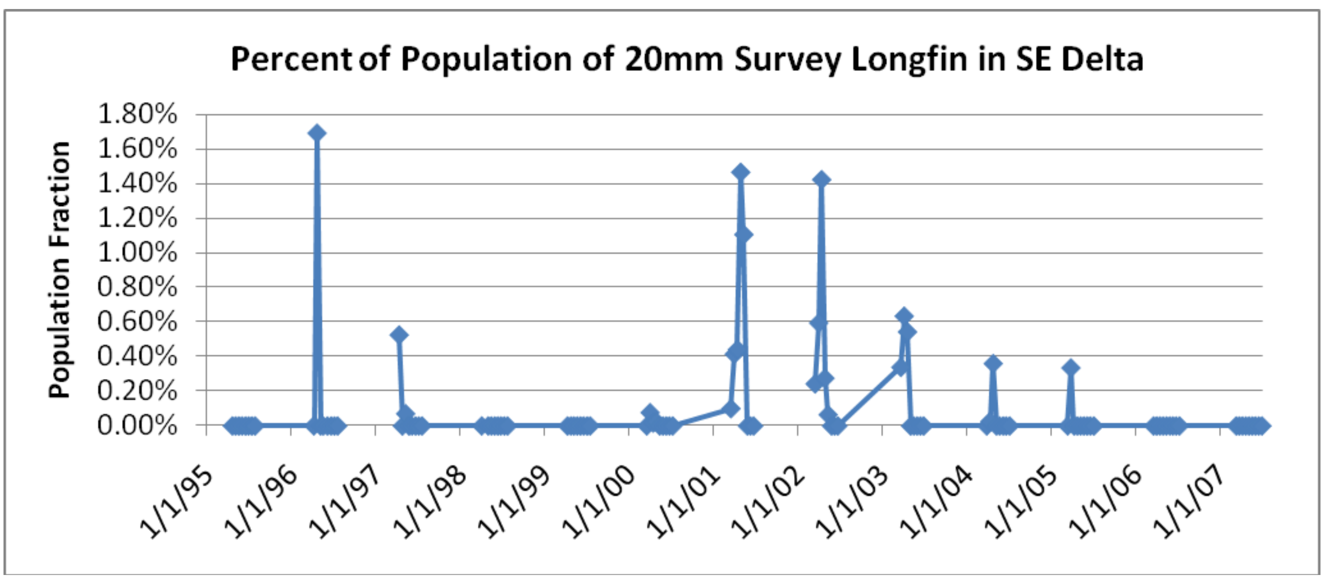


Figure 12 (updated). Larval and juvenile longfin smelt abundance indices across regions for 2000, 2001 and 2002. (Updated with gear efficiencies from Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta smelt to Entrainment. San Francisco Estuary and Watershed Science. 6(2). At http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1115&context=jmie/sfews)

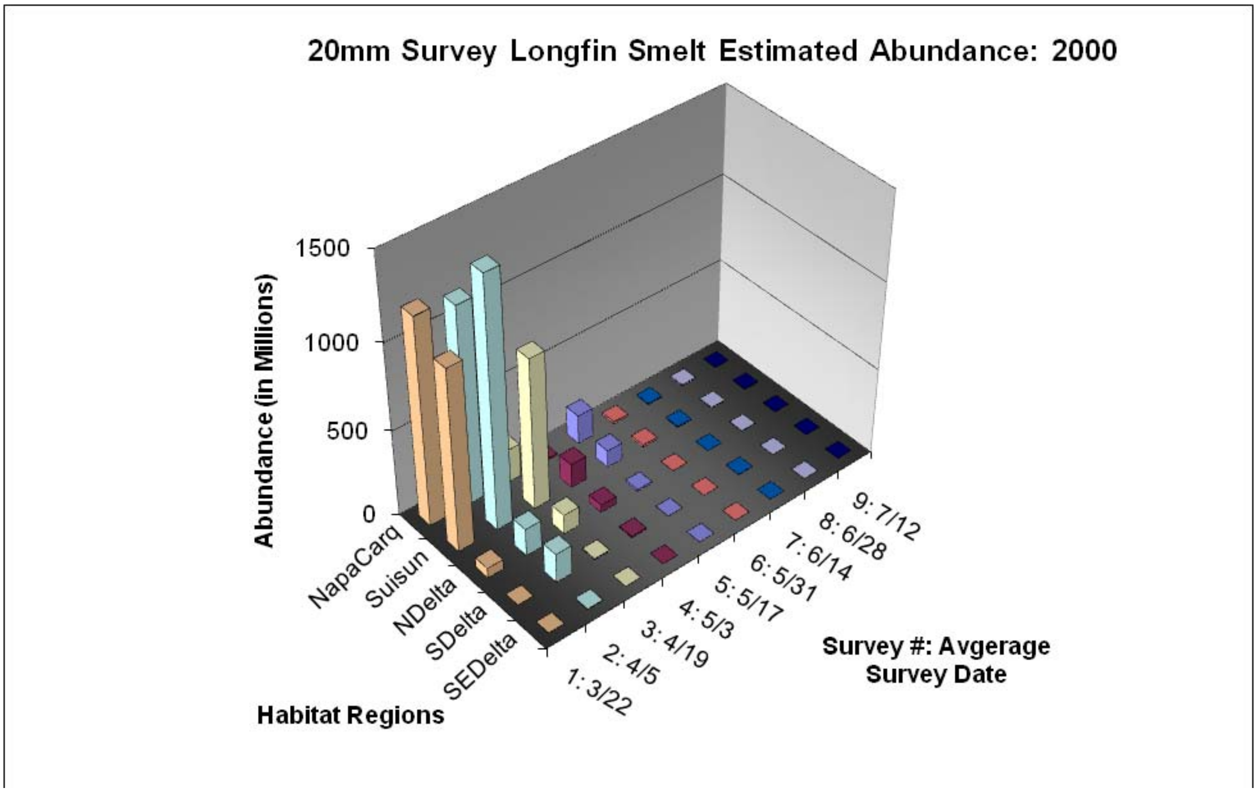
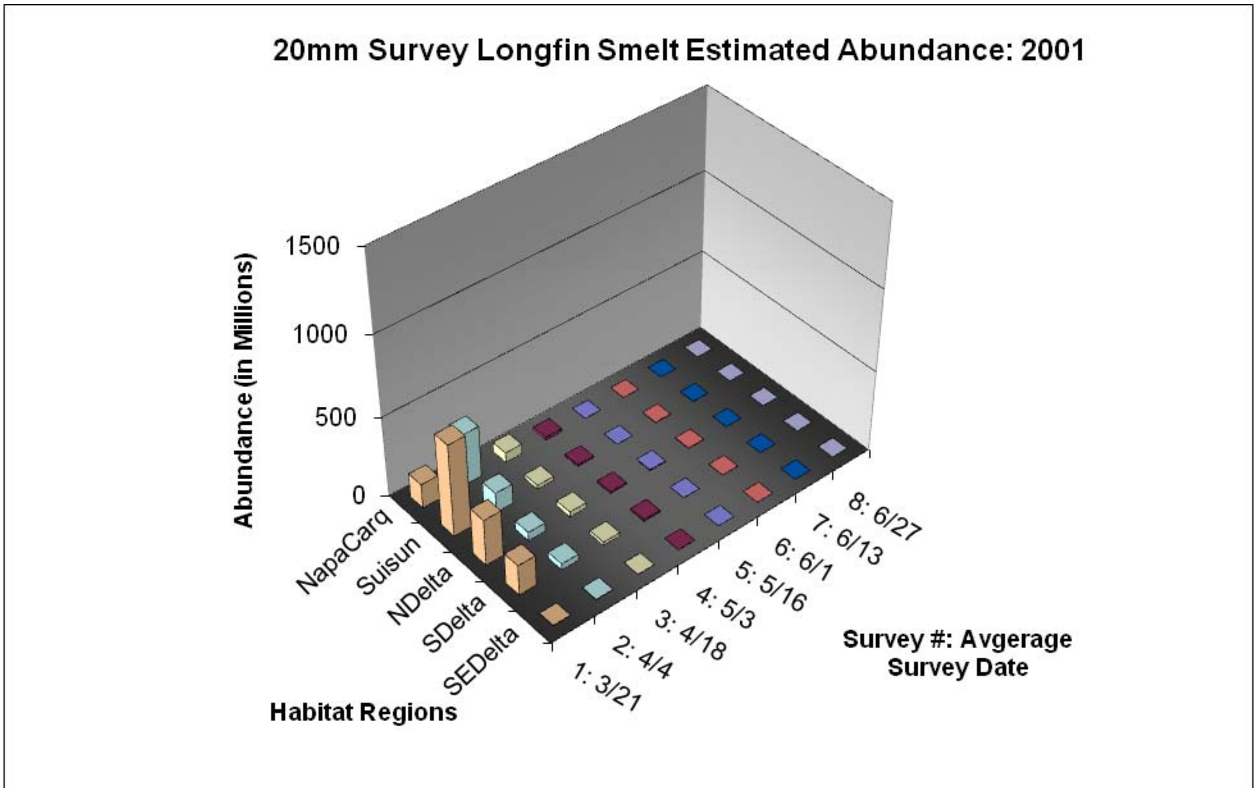
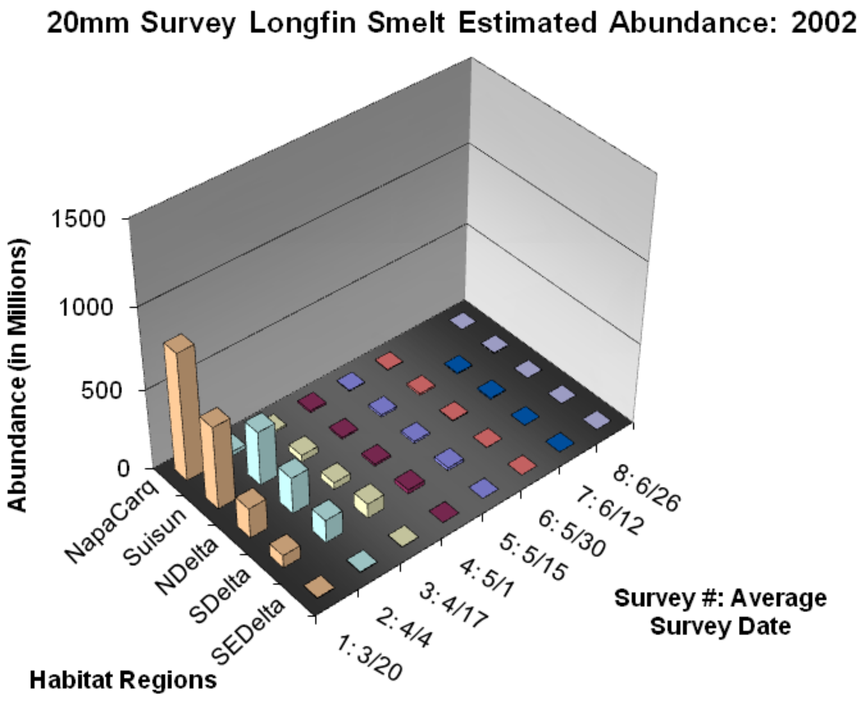


Figure 12 (Updated) (cont.). Larval and juvenile longfin smelt abundance indices across regions.





OTHER STRESSORS STRONGLY ASSOCIATED WITH THE FMWT LONGFIN SMELT ABUNDANCE INDEX.

Other stressors besides losses at the pumps may be operating to control longfin abundance.

Several potential stressors have been identified by the POD as potentially effecting longfin smelt (Baxter et al. 2008). New analyses of the longfin smelt abundance, as represented by its FMWT index show strong associations of this index with three factors:

- The average value of X2 during the winter/spring of the current year. The period February through April appears to account for the most variability. The X2 data used here was generated by applying the daily X2 equation to outflows in the DAYFLOW dataset.
- The average value of air temperature (F) at Davis from February through April of the current year. Regional air temperature, as represented by Davis air temperature, has an influence on water temperatures in the Delta and Suisun Bay and water temperature may influence species abundance. This temperature data can be found at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca2294.
- Average ammonia concentration at Bull's Head in Suisun Bay near Martinez. This data can be obtained on http://bdat.ca.gov/. Ammonia concentrations are closely related to X2, presumably because high outflow reduce residence time. Thus, it is not clear

whether X2 or ammonia concentrations are the key factor. In the regressions, X2 generates better statistical correlations than ammonia concentrations.

The data used for the correlations is given in Table 3. Data is missing for some variables for some years as shown.

The time trends in X2, temperature, and ammonia concentration are shown in Figure 13-15. X2 shows no time trend. Davis air temperature shows an upward trend at about 0.05 degrees F per year. Ammonia concentration shows an upward time trend of about .001 mg/l each year.

Table 3. Data used in evaluating other stressors.

Year	Longfin FMWT	ln(Longfin FMWT)	Average February-April X2 (km)	Average Davis Air Temp February - April (F)	Average NH4-N concentrations (mg/l) at Emmaton January – Jun
1969	59350	11.0	49.2	52.2	
1970	6515	8.8	55.3	54.1	
1971	15903	9.7	61.3	52.0	
1972	760	6.6	70.7	55.6	
1973	5896	8.7	54.3	54.1	
1975			51.8	52.6	
1975	2819	7.9	60.1	51.0	0.04125
1976			80.2	53.0	0.066667
1977	210	5.3	91.0	53.6	0.089
1978	6619	8.8	56.9	54.1	0.053333
1979			65.0	52.6	0.055833
1980	31184	10.3	53.7	53.9	0.053
1981	2202	7.7	70.3	54.1	0.066667
1982	62905	11.0	51.6	51.7	0.051667
1983	11864	9.4	44.0	52.5	0.036667
1984	7408	8.9	61.0	54.2	0.043333
1985	992	6.9	75.3	54.1	0.071667
1986	6160	8.7	53.4	56.0	0.063333
1987	1520	7.3	74.1	55.0	0.093333

1988	791	6.7	84.5	55.4	0.069167
1989	456	6.1	77.3	53.6	0.073333
1990	243	5.5	86.8	54.4	0.101667
1991	134	4.9	81.1	53.6	0.1275
1992	76	4.3	76.1	57.3	0.105
1993	798	6.7	58.6	54.7	0.063333
1994	545	6.3	74.6	54.1	0.111667
1995	8205	9.0	50.8	53.7	0.031667
1996	1346	7.2	54.0	55.9	0.048333
1997	690	6.5	56.3	56.9	0.056667
1998	6654	8.8	48.2	53.1	0.054
1999	5243	8.6	55.7	52.3	0.074
2000	3437	8.1	58.4	56.2	0.08
2001	245	5.5	72.0	54.9	0.125
2002	707	6.6	72.5	54.9	0.101667
2003	467	6.1	67.3	53.9	0.088333
2004	191	5.3	62.3	57.5	0.093333
2005	129	4.9	64.7	55.9	0.103333
2006	1949	7.6	50.6	52.7	0.046667
2007	13	2.6	73.9	56.9	

Figure 13. Average X2 for February to April 1977-2006.

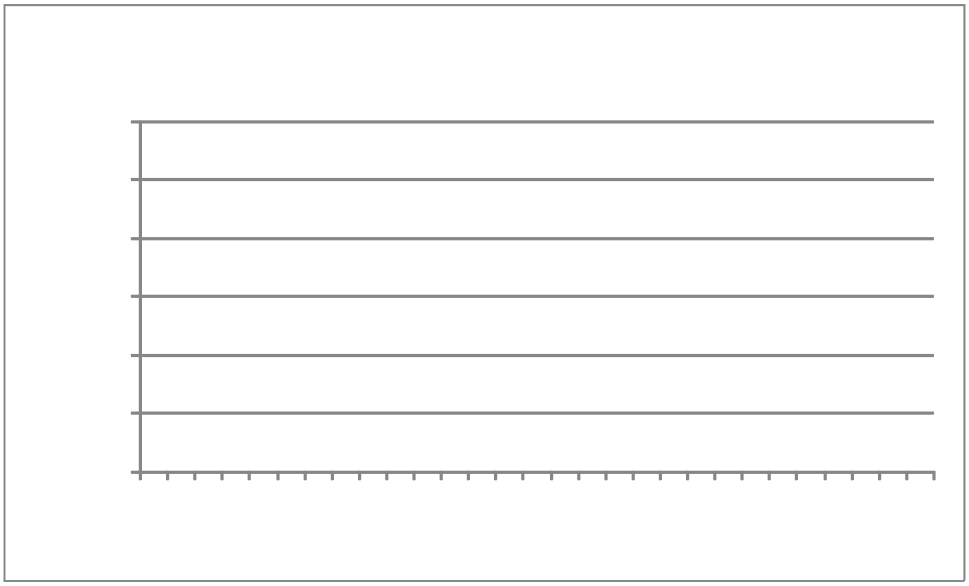


Figure 14. Average Davis air temperature for February to April 1977-2006.

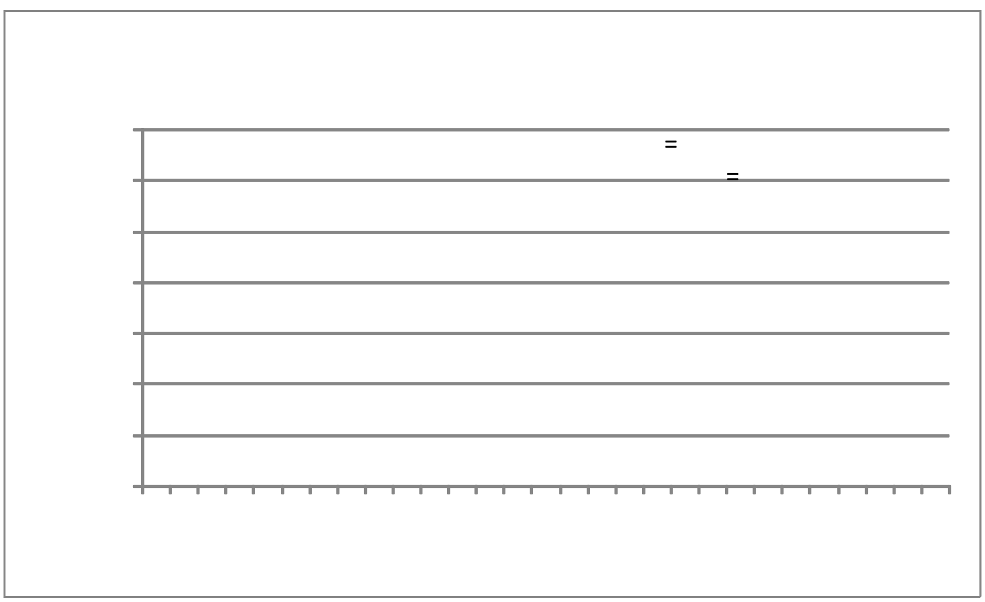
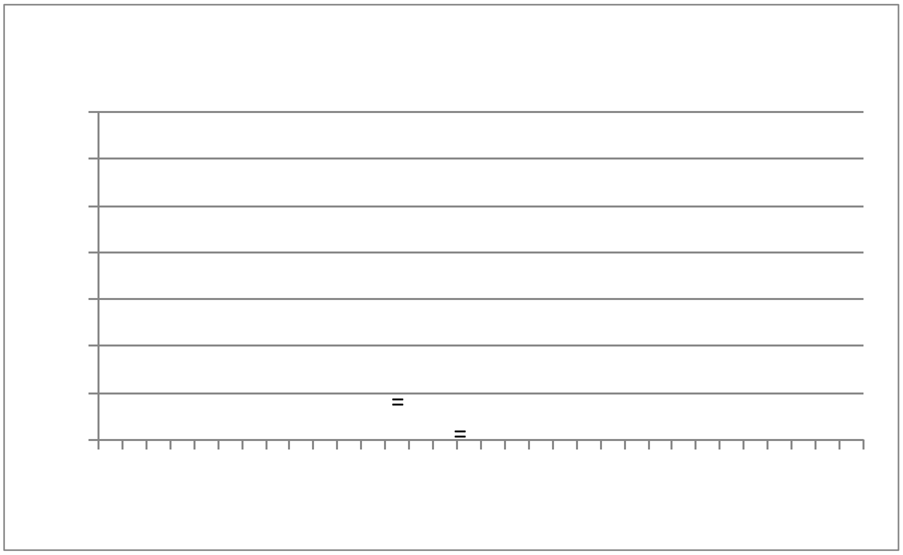
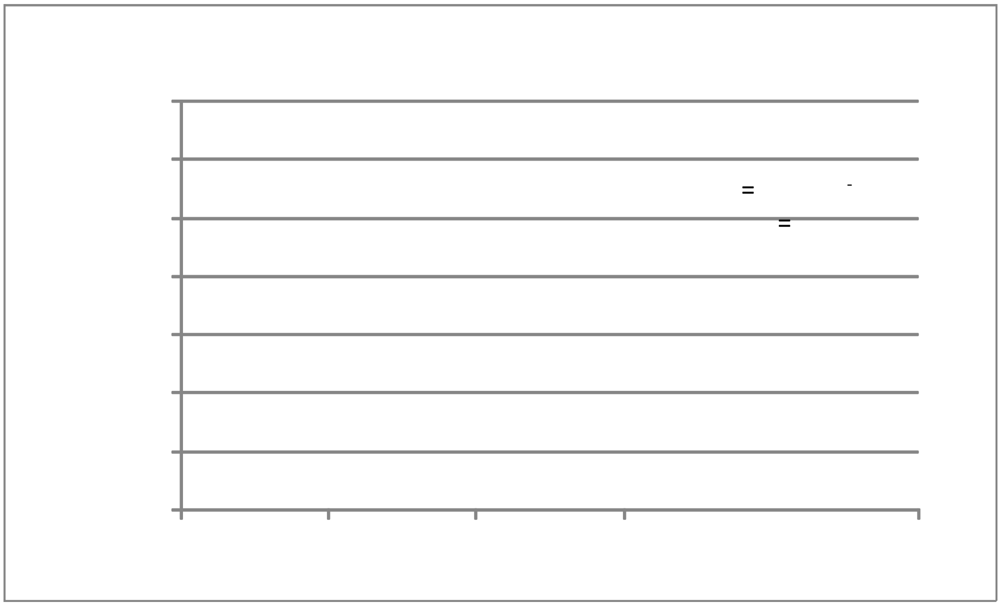


Figure 15. Average January – June Ammonia concentration (mg/l) at Emmaton 1977-2006.



The individual relationships between the X2, temperature, and ammonia variables and longfin FMWT index are shown below as Figures 16-18. One inference from the figures is that very high longfin abundances are rare when average X2 is greater than 65 km, when average Davis air temperatures are greater than 54.5 degrees F, or when average January to June ammonia concentrations are greater than about .07 mg/l. Figure 18a shows the high correlation between ammonia concentration and X2.

Figure 16. Longfin FMWT and February to April



X2.

Figure 17. Longfin FMWT and February to April air temperature at Davis.

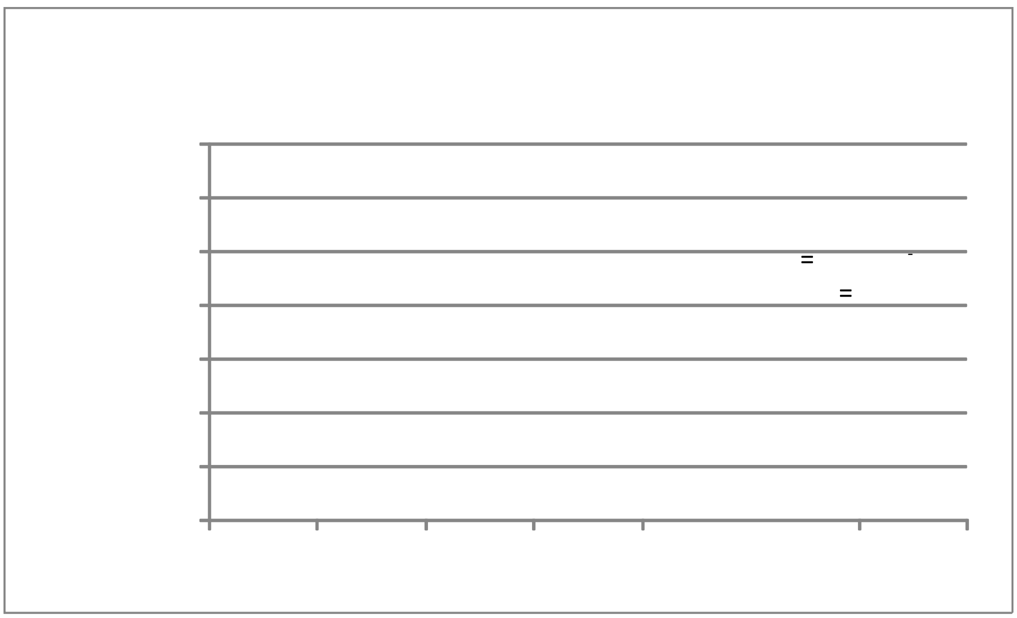


Figure 18. Longfin FMWT and ammonia concentration.

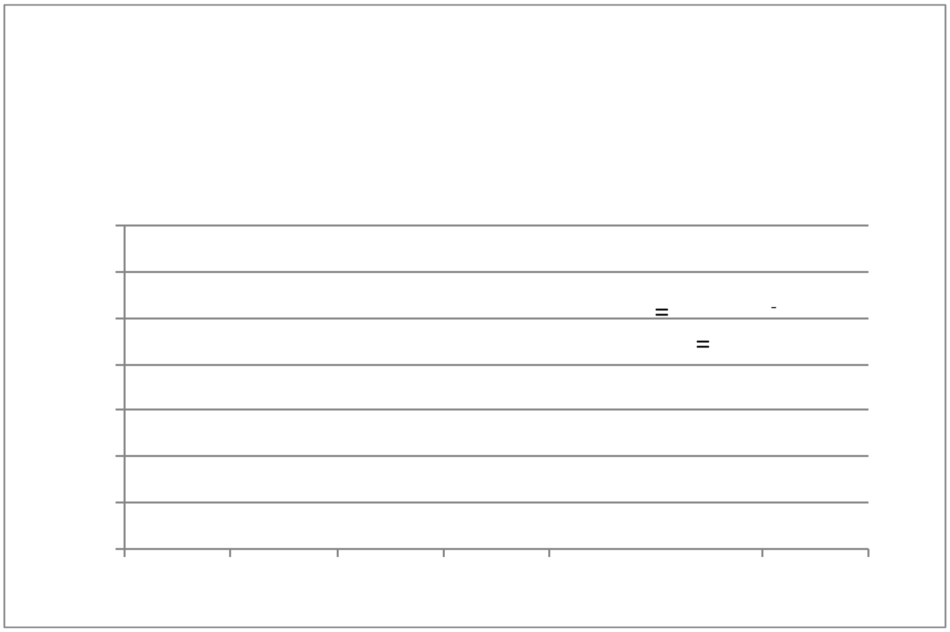
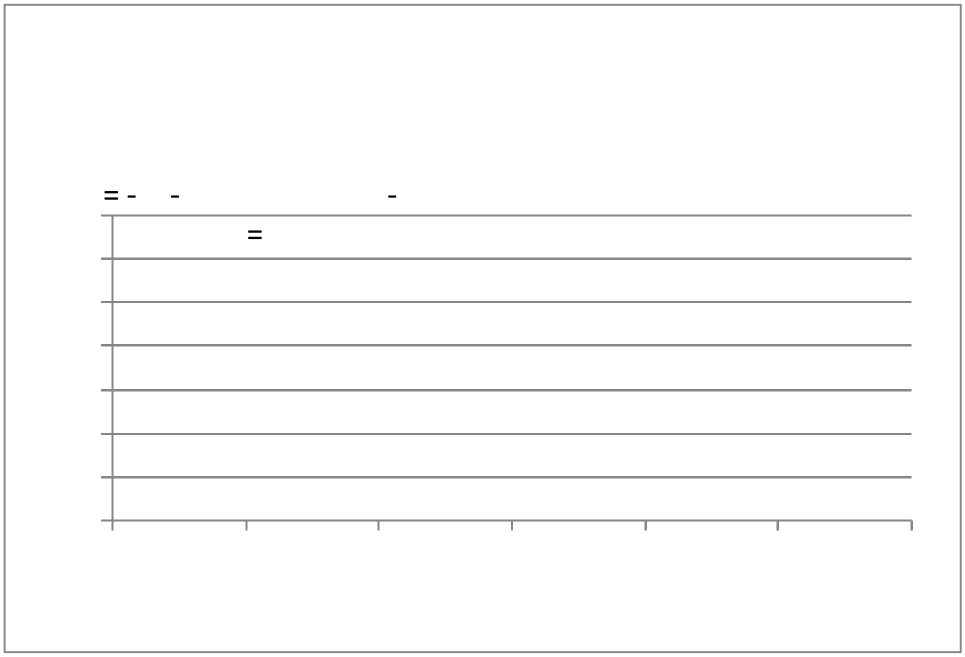


Figure 18a. January – June Ammonia Concentration at Emmaton v January – June X2.



The effects of X2, Temperature, and Ammonia loading can be analyzed together using correlation. The natural log of the FMWT is used for purposes of the correlation to emphasize the percent change in abundance from year rather than the absolute change in population. Results are returned to arithmetic values for further interpretation. A stock recruitment term using ln(FMWT from two years ago) also helps improve the correlation. As noted above X2 and ammonia concentration are highly correlated and are not both significant in the analysis. X2 gives a somewhat stronger correlation and is included below rather than ammonia concentration.

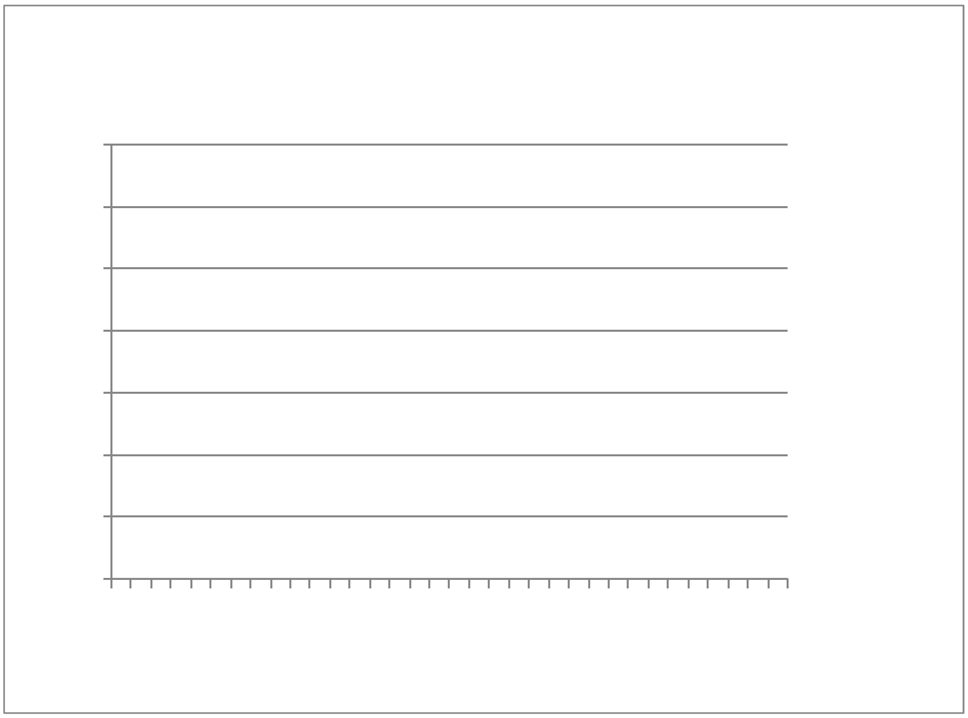
A correlation of ln(FWMT) using ln(FMWT from two years ago) and the X2 and temperature data listed in Table 3 gives the following results for the years 1969 - 2007:

- Ln(longfin FMWT) = 21.5 + .44*ln(longfin FMWT two years ago) - 0.0017*(X2-90.95)^2 – 0.35*(Temperature)
- R^2 0.85
- P values:
  - .000005 for ln(longfin FMWT two years ago)
  - .0007 for temperature
  - .00000008 for X2

Thus, the correlation both explains most of the variation in longfin abundance and is highly significant.

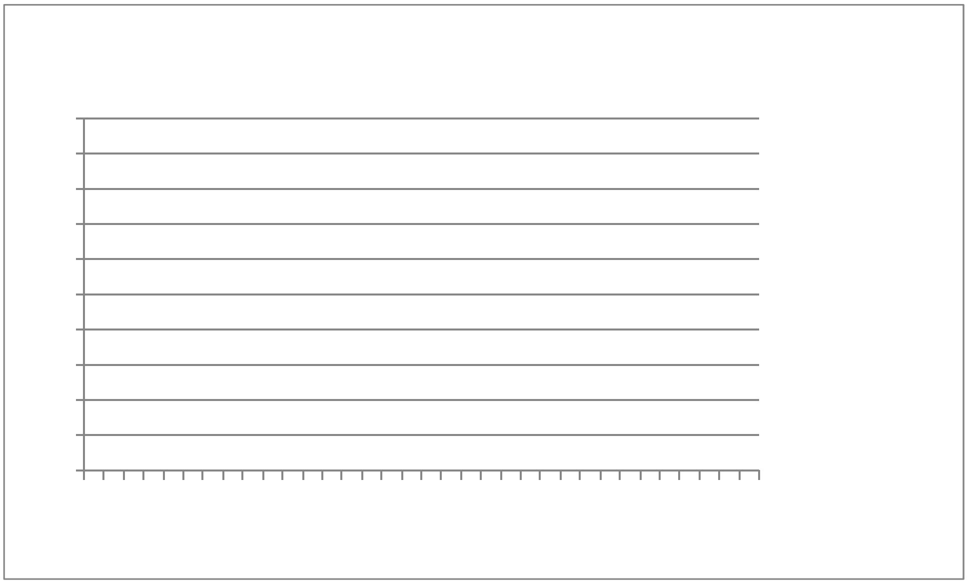
The fit between the regression and the measured FMWT values is shown in Figure 19.

Figure 19. Longfin FMWT measured v regression.



The same data, but plotted using the natural logarithm of the FMWT is shown in Figure 20.

Figure 20. Natural log of longfin FMWT measured v regression.



All upward and downward trends in abundance since 1969 are captured in this regression quite well.