LTMS Longfin Smelt
Literature Review and Study Plan

Final Technical Report

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for Dredged Materials in San Francisco Bay
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1. Introduction

In recent decades, the longfin smelt (*Spirinchus thaleichthys*) has experienced significant declines in abundance in the San Francisco Estuary and throughout California. On March 4, 2009, the California Department of Fish and Game (CDFG) listed the longfin smelt as threatened under the California Endangered Species Act (CESA; Fish and Game Code §§ 2050 et seq.). Under the CESA listing, the species is protected throughout its range in California. In response to the state listing of this species, CDFG stated that longfin smelt “take” assessments must be conducted for dredging projects in San Francisco Bay.

The Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (LTMS) funded this review of the current scientific literature in order to provide better information upon which to base CDFG take assessments, and protect longfin smelt. The LTMS is a collaborative partnership of the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), the State Water Resources Control Board (State Water Board), the San Francisco Bay Regional Water Quality Control Board (San Francisco Bay Water Board), and the San Francisco Bay Conservation and Development Commission (BCDC).

The remainder of this report includes three sections. Section 2 is a literature review on longfin smelt life history and ecology, with particular focus on habitat and distribution. Section 3 reviews risks of dredging and other threats to longfin smelt. Sources for the literature review in Sections 2 and 3 include peer reviewed published literature, agency reports and other gray literature, presentations from the Longfin Smelt Symposium held by the San Francisco Estuary Institute (SFEI) in 2009 (Stanford et al. 2009), personal communications with experts, and unpublished data. Section 4 is a study plan for longfin smelt. This study plan proposes five potential studies to address key data gaps identified in this report. The study plan builds on the discussion between scientists and dredgers about future study needs that was started at the 2009 Longfin Smelt Symposium (Stanford et al. 2009).

2. Longfin Smelt Life History and Ecology

The longfin smelt is a small fish in the family Osmeridae. It is adapted to a wide range of salinities (i.e., euryhaline), and travels from fresh to marine waters over its life cycle (i.e., anadromous). The geographic range of the species extends from Alaska to California, with longfin smelt in the San Francisco Estuary[a] representing the southern-most spawning population within the species range. Historically, this species was found in three estuaries in California: the San Francisco Estuary (hereafter, the Estuary), Humboldt Bay, and the Klamath River Estuary. Incidental catch of longfin smelt in Humboldt Bay and the Eel River confirms their continued presence in these areas, however the size of the population is unknown (Cannata and Downie 2009). No recent sampling has been conducted in the Klamath River that could detect longfin smelt (Cannata and Downie 2009).

The longfin smelt was once considered two separate species, with the San Francisco Bay population referred to as Sacramento smelt (*S. thaleichthys*), and the remaining populations regarded as longfin smelt (*S. dilatus*; Moyle 2002). McAllister (1963) grouped the Sacramento smelt and longfin smelt together after concluding that meristic differences between the species were the result of a north-south gradient, rather than a discrete set of traits. This grouping was further supported by allozyme analysis (Stanley et al. 1995).

Recognition of the Estuary population as a genetically distinct population could result in a Federal decision to list the population (The Bay Institute et al. 2007). Previously the U.S. Fish and Wildlife Service (USFWS) declined to list the Estuary population of the longfin smelt, citing a lack of evidence demonstrating the population's genetic distinction from other populations within the species range (USFWS 2009). In November 2009, a suit was filed by the Center for Biological Diversity, The Bay Institute, and the Natural Resources Defense Council to challenge the federal decision not to list the longfin smelt. In February 2011, USFWS agreed to conduct a range-wide 12-month review of the longfin smelt status, with the findings to be published by September 30, 2011. Recent research performed by Israel and May (2010) compared genetic sequences from microsatellite DNA in longfin smelt from Lake Washington (Seattle, WA) and the San Francisco Bay-Delta. This study found that while the majority of the genetic variation was within rather than between the collection locations, it was still possible to distinguish between the two locations. The study also found no evidence of recent gene flow between the locations. These findings suggest that

[a] In this report, the San Francisco Estuary (i.e., the Estuary) is defined to include the estuarine waters that ultimately drain through the Golden Gate. The Estuary includes San Francisco Bay, the Sacramento-San Joaquin Delta (i.e., the Delta), and estuarine tributaries of these waters. San Francisco Bay (i.e., the Bay) is the more marine portion of the Estuary, and includes five segments: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay.

the San Francisco Estuary and Lake Washington represent two genetically distinct populations.

2.1 Life history

Longfin smelt are found throughout the San Francisco Estuary, occupying different regions of the Estuary throughout the year. Most longfin smelt exhibit a two-year semelparous[b] life cycle, spawning and dying in their second year. In good growth years, however, longfin smelt can spawn at the end of their first year, and three year old smelt have also been observed. Longfin smelt are anadromous fish that spawn in freshwater and disperse to marine environments as they mature (Moyle 2002).

Longfin smelt undergo a protracted period of spawning that ranges from November to June, though the majority of spawning occurs between February and April (Moyle 2002). Spawning locations have been inferred from the distribution of larvae to occur at the interface between fresh and brackish water. This mixing zone provides nursery habitat for many native fishes (Dege and Brown 2004; Hobbs 2009). Longfin smelt have adhesive eggs and are assumed to spawn over rocky/sandy substrate, similar to other smelt species. However, larvae monitoring has been limited to offshore stations in San Francisco Bay and the West Delta, and there are no published observations of spawning activity or egg location. Because spawning has not been directly observed anywhere in the Estuary, there is some uncertainty about the exact microhabitat requirements for spawning (Rosenfield 2009). Within the Estuary there is substantial sandy substrate, which likely provides spawning habitat (Baxter 2009).

Egg development lasts approximately one month (CDFG 2009). The young smelt then hatch and exist as yolk-sac larvae for one to two weeks. The yolk-sac larvae are positively buoyant, floating near the water surface, and moving with the prevailing current. Larvae are found in increasing numbers in January, peak in February, and decline in abundance between March and May. This is evident in elevated capture frequency of larvae in plankton nets in winter and spring, with almost no capture in summer or autumn (Figure 1). As post-yolk-sac larvae develop air bladders, when they reach a length of 10-12mm, they adjust their depth in the water column to maintain their position relative to the moderately saline productive zone near X2 (the 2 psu isohaline, as measured by its distance from the Golden Gate Bridge; (Jassby et al. 1995; Kimmerer 2002)). The area near X2 has historically been an area of high productivity, providing good nursery habitat for larval fish of several species, including longfin smelt (Hobbs 2009). Larvae grow at a rate of 0.12 to 0.23 mm/day, reaching juvenile length ($\geq$ 20mm) approximately 90 days after hatching (CDFG 2009).

Longfin smelt grow to standard lengths of 60 to 70 mm in the first year of life, followed by a second period of growth in the summer and fall of the second

[b] That is, a single reproductive episode during its life span

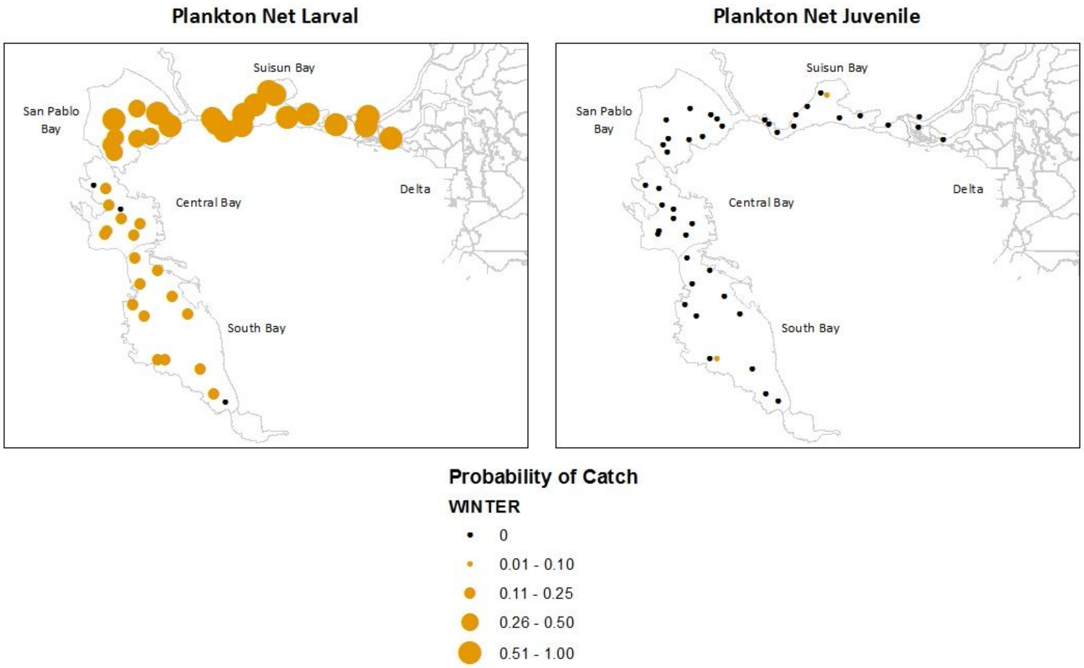

Figure 1a[c]. Larval and juvenile catch probability in the winter. Results compiled from 1980–1987 plankton net survey.

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[c] **Note on Figures 1 and 2:** Data on longfin smelt distribution were collected by CDFG's San Francisco Bay Study and the IEP for the San Francisco Estuary. These figures used the CDFG San Francisco Bay Study Longfin Smelt Dataset, with data uploaded by SFEI staff from the study ftp site: ftp://ftp.dfg.ca.gov/BayStudy/LongfinSmelt/. Figures were developed based on these data using ArcGIS 10. Probability of catch was based on the frequency with which longfin smelt of the given age class were present, across all sampling events for a given site and season. Seasons represent 3-month blocks as follows: Dec–Feb (Winter), Mar–May (Spring), Jun–Aug (Summer), and Sep–Nov (Autumn).

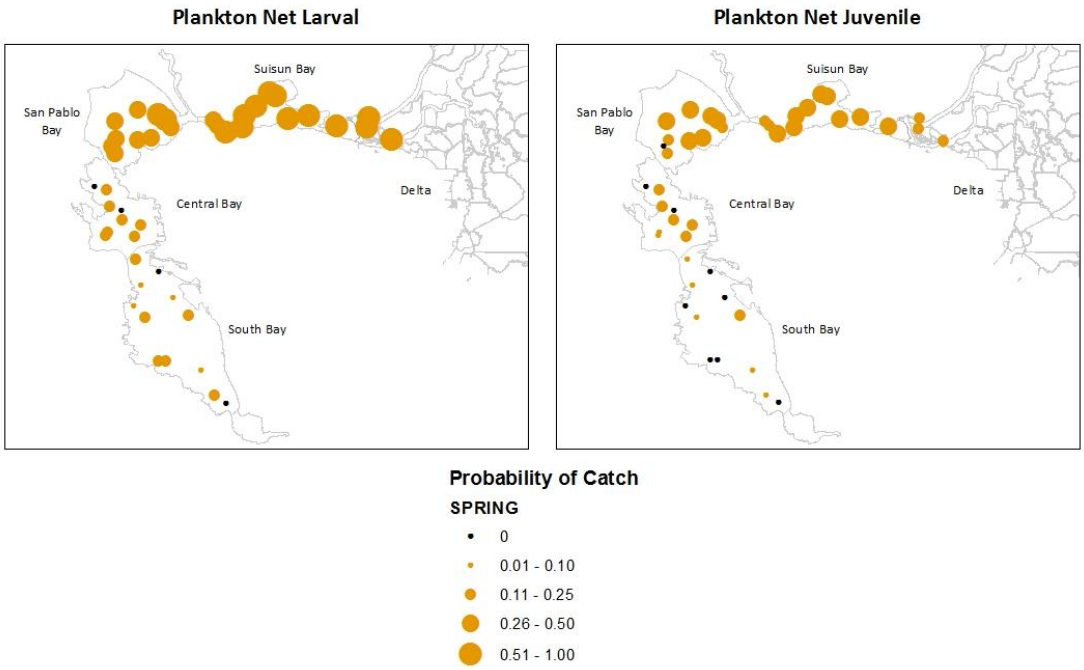

Figure 1b. Larval and juvenile catch probability in the spring. Results compiled from 1980–1987 plankton net survey.

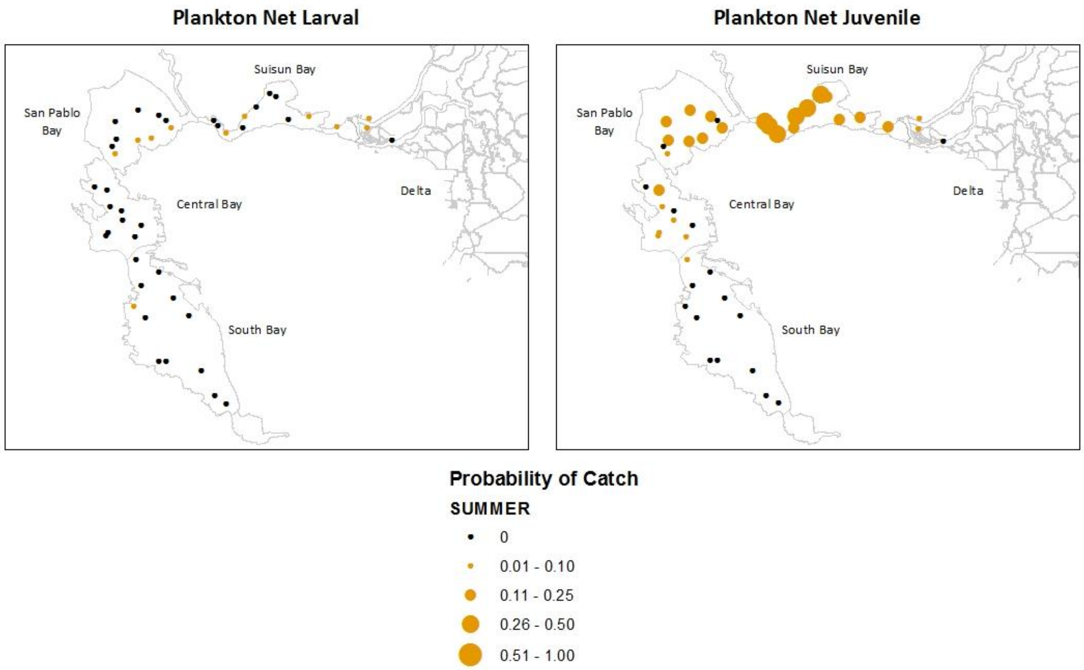

Figure 1c. Larval and juvenile catch probability in the summer. Note that many larvae recruited to juveniles. Results compiled from 1980–1987 plankton net survey.

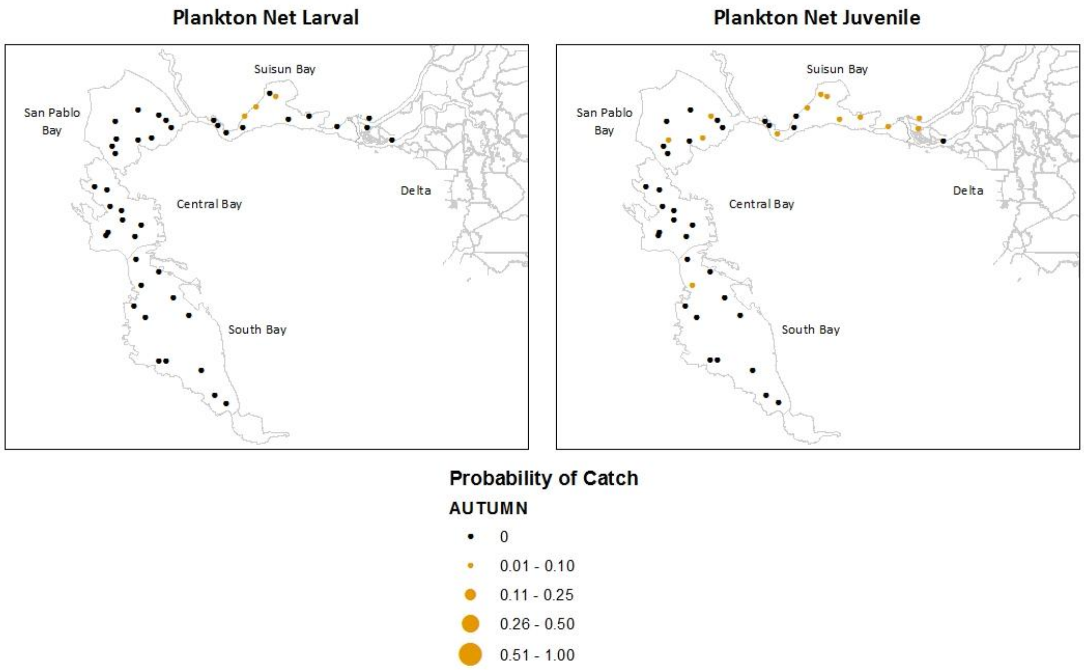

Figure 1d. Larval and juvenile catch probability in the autumn. Results compiled from 1980–1987 plankton net survey.

year, to obtain standard lengths of 90 to 111 mm. Rarely, individuals will spawn after one year. The majority of individuals die before reaching year three (Moyle 2002). Those individuals that do survive to year three reach lengths of 120 to 150 mm standard length. Females lay 2,000 to 18,000 eggs, with fecundity increasing exponentially with age (CDFG 2009). In otter trawl and midwater trawl sampling, age 1 fish are caught most frequently and with the widest distribution during the winter, followed by spring (Figure 2). However, over the course of all sampling, some age 1 fish have been caught in all San Francisco Bay segments (South Bay, Central Bay, San Pablo Bay, and Suisun Bay) year round (Figure 2).

Smelt larvae and young juveniles feed predominantly on calanoid copepods, including *Eurytemora affinis* (S. Slater, CDFG, unpublished data, as reported in Baxter et al. 2010). Older juveniles and adults feed principally on opossum shrimp, *Acanthomysis spp.* and *Neomysis mercedis*, when available, and copepods when shrimp are not available (Feyrer et al. 2003) (Hobbs et al. 2006). The invasion of the overbite clam (*Corbula amurensis*) has reduced the availability of planktonic algae that form the base of the food web for the longfin smelt (Moyle 2002). The Lake Washington population exhibits daily vertical migrations, appearing higher in the water column at night and lower during the day, related to the movement of their prey (Moyle 2002). Smelt in San Francisco Bay undergo tidal migration to maintain their position relative to habitat (Bennett et al. 2002).

Historically, longfin smelt were an important component of the food web in the San Francisco Estuary. However, the high proportion of non-native fish and other species currently inhabiting the Estuary (Cohen and Carlton 1995, 1998) suggest that competition or predation by non-natives may play a role in the declining numbers of longfin smelt.

2.2 Distribution in San Francisco Bay

Several long-term monitoring programs provide data on the abundance and distribution of the longfin smelt. As part of the Interagency Ecological Program (IEP) the CDFG conducts four studies in which longfin smelt are collected: the Fall Midwater Trawl, the Bay Study, the Smelt Larvae Study, and the 20mm study. UC Davis also conducts an annual survey of fish in Suisun Marsh as part of the IEP. These studies provide long term datasets on the distribution and abundance of longfin smelt (Rosenfield and Baxter 2007).

Longfin smelt occupy different portions of the Bay throughout the year. There is also significant interannual variation in their distribution, which is strongly correlated with freshwater outflow in the Delta (Baxter 2009). Specifically, in years with higher freshwater outflow, larvae and juvenile smelt are generally distributed further downstream (i.e., closer to the Golden Gate) than years with low freshwater outflow (Dege and Brown 2004).

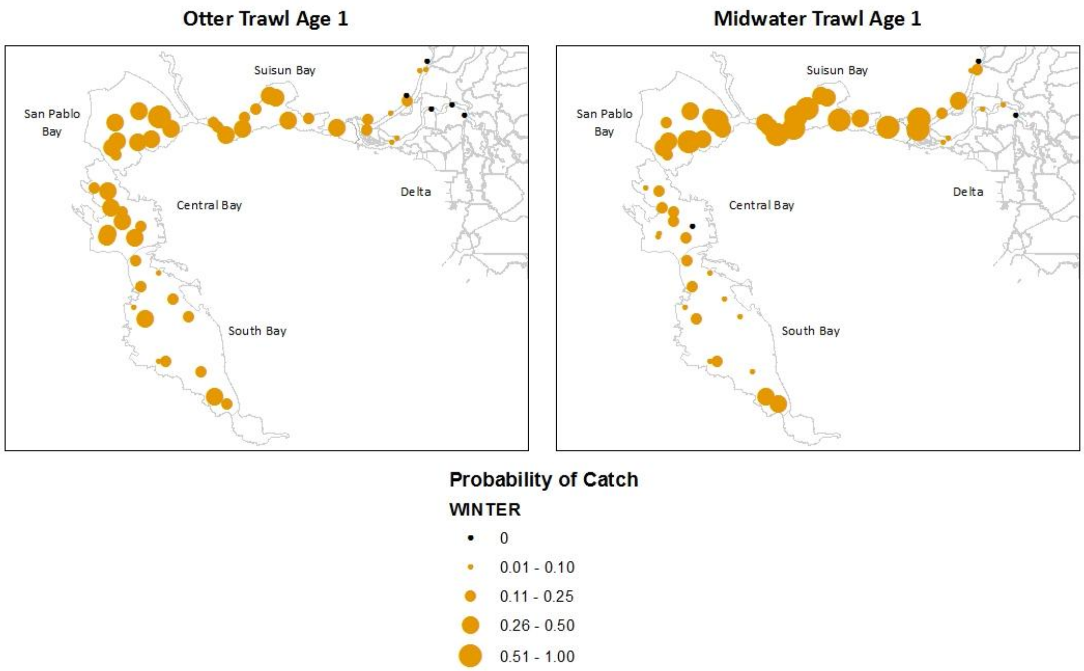

Figure 2a. Age 1 longfin smelt in the winter. Results compiled from 1980–2008 otter trawl and midwater trawl survey.

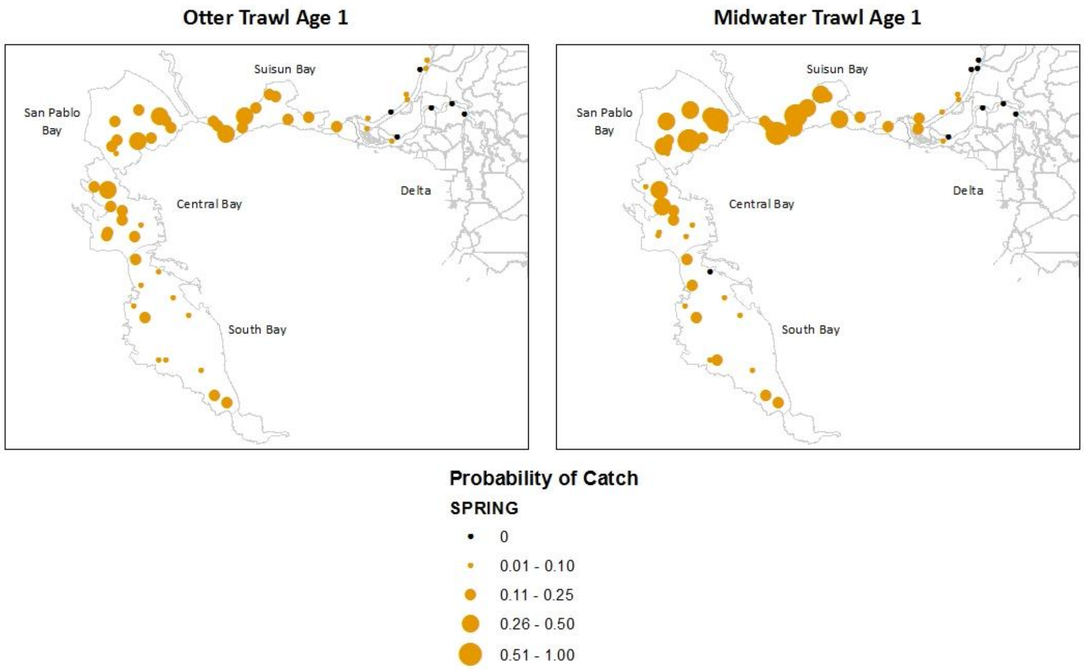

Figure 2b. Age 1 longfin smelt in the spring. Results compiled from 1980–2008 otter trawl and midwater trawl survey.

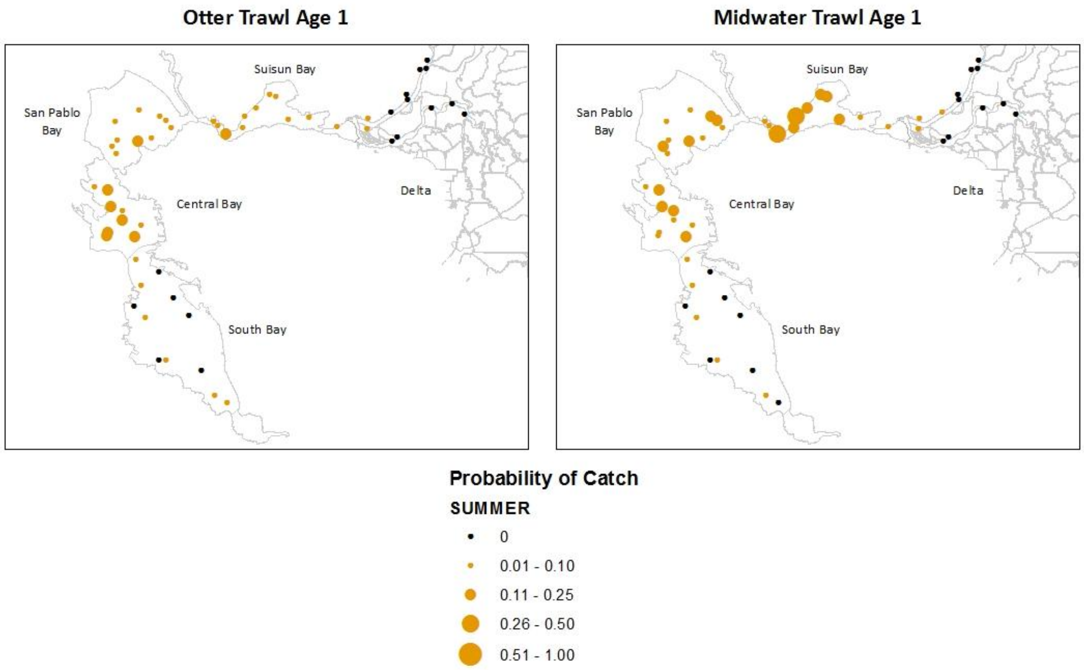

Figure 2c. Age 1 longfin smelt in the summer. Results compiled from 1980–2008 otter trawl and midwater trawl survey.

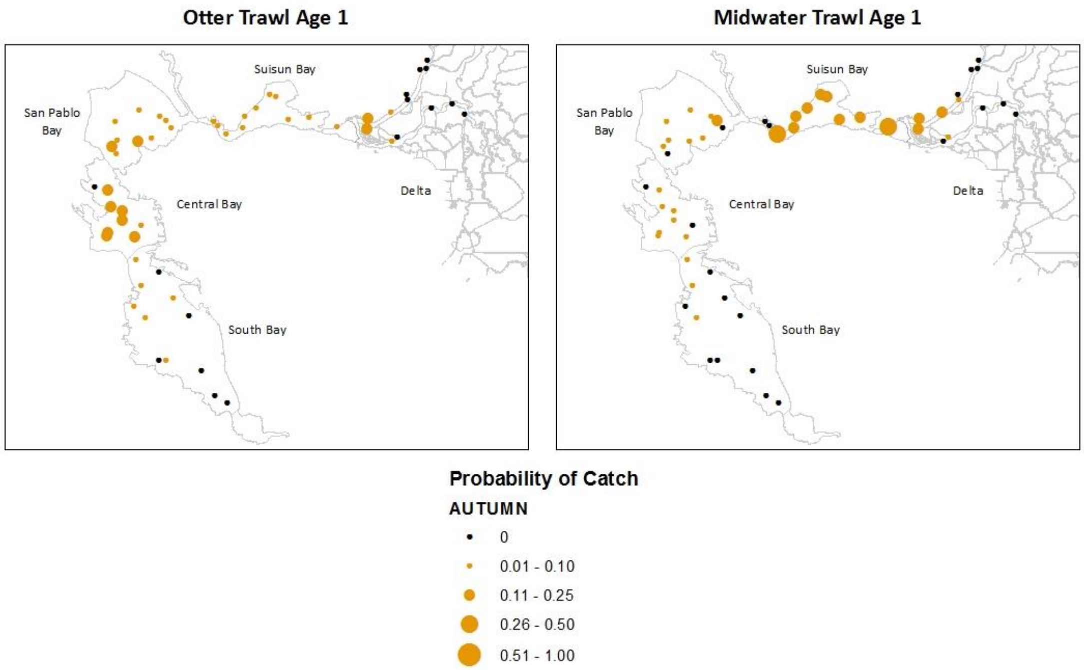

Figure 2d. Age 1 longfin smelt in the autumn. Results compiled from 1980–2008 otter trawl and midwater trawl survey.

2.2.1 Adult distribution

Adult longfin smelt have been collected as far upstream as the lower Sacramento River, including the Yolo bypass and Cache Creek complex, the Mokelumne River to Hog Slough, and the San Joaquin River near Rough and Ready Island. Smelt are more commonly found near this upstream end of their range in low- and moderate-outflow years (CDFG 2009). Distribution of adult longfin smelt changes seasonally, with the majority of adults found in Central Bay, San Pablo Bay and Suisun Bay in the summer, and moving upstream in early fall. Adult distribution is the most widespread in the winter and spring, extending from the South Bay through the Delta, with the greatest concentrations in San Pablo Bay, Suisun Bay, and the West Delta (Rosenfield 2009) (see Figure 2). Both juveniles and adults are uncommon in the Delta in the fall (CDFG 2009).

Knowledge of longfin smelt use and distribution in tributaries feeding into the Bay, such as Coyote Creek, and the Napa and Petaluma Rivers, is limited. Longfin smelt use of bay tributaries is likely related to the extent of a freshwater signal in the Bay right before and during the longfin spawning migration (Baxter, pers. comm.). Sampling done in the Lower South Bay, near Coyote Creek in Feb 2010, found high numbers of longfin smelt in Coyote Creek, Alviso Slough, and nearby salt ponds (James Hobbs, unpublished data). Bay Study data shows spawner use of Coyote Creek (adults then larvae in the South Bay) in 1982 and 1983, both very high outflow years. Similar effects are likely for the Petaluma River. Shrimp trawling data suggests longfin smelt are present at the mouth of the Petaluma River (Swedberg and Zentner 2009), but the extent to which smelt use upstream habitat is unknown. Abundance of larval and juvenile fish caught in the Napa River in CDFG's 20mm survey is high (CDFG, unpublished data), but adult distribution in the Napa River is not well known (CDFG unpublished data; Stillwater Sciences 2006). High larval densities in the Napa River are likely a result of both local spawning in wet years and tidal effects pushing larvae that hatched in the Delta or Suisun Bay into the lower Napa system (Baxter pers comm).

Longfin smelt abundance in the bay, as measured by the CDFG surveys, changes throughout the lifecycle of the fish (Figure 3). Fish become large enough to be sampled in the IEP otter trawl and midwater trawl surveys in April, and abundance increases through December. Abundance is lowest in the second summer of the smelt's life, and increases again in the second fall and winter (Rosenfield and Baxter 2007). This pattern indicates longfin smelt are leaving the Bay in their second summer, as part of their anadromous life cycle.

2.2.2 Spawning distribution

Spawning of longfin smelt in the San Francisco Estuary has not been observed directly and has been estimated from the distribution of yolk-sac larvae. The upper limit of the spawning distribution is thought to be Medford Island in the

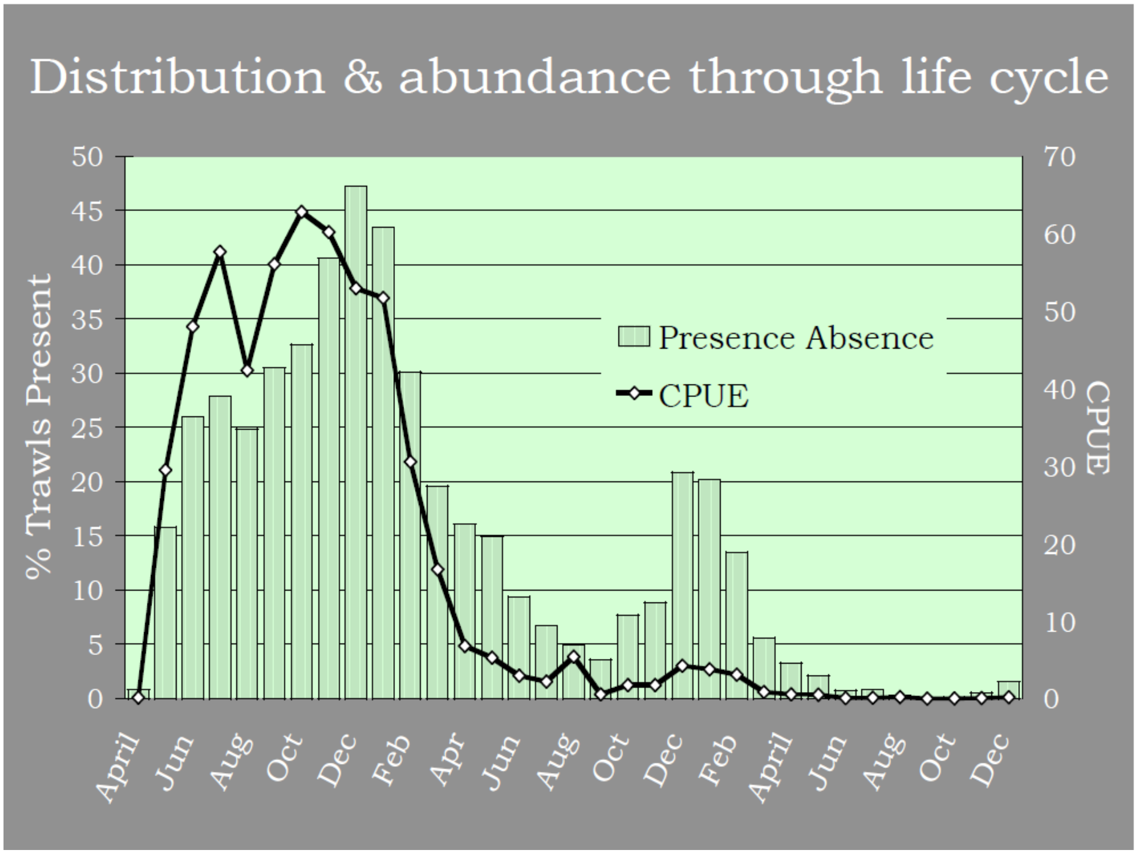

Figure 3. Abundance in the Estuary throughout the lifecycle of a cohort of longfin smelt. Estuary abundance is lowest in the second summer and increases again in the second fall and winter, indicating that longfin smelt are leaving the Bay in their second summer, as part of their anadromous life cycle. Abundance data are from the CDFG Bay Study (Rosenfield 2009).

San Joaquin River and as far north as Upper Cache Slough and the Deep Water Ship Channel in the Sacramento River Basin. (Moyle 2002). Yolk-sac larvae are abundant near X2, which is evident from higher capture frequencies in Suisun Bay, and adults found upstream of X2 are thought to be spawning adults (Baxter et al. 2010). Spawning in other longfin smelt populations occurs at night, so the abundance of spawning adults in freshwater may be underestimated by daytime sampling (Baxter 2009).

2.2.3 Larval and juvenile distribution

Distribution of larvae is strongly influenced by freshwater outflow to the Delta (Baxter 1999; Dege and Brown 2004). In low-outflow (dry) years, larvae are concentrated primarily in the West Delta and Suisun Bay. In high outflow (wet) years larvae are found throughout the Estuary, from South Bay through the West Delta, with the greatest concentrations in San Pablo and Suisun Bay early in the season and into the Central Bay later in the season (Rosenfield 2009).

Wang et al. (1991) examined interannual variation in larval distribution in the Delta. In 1989-1990, larvae were found upstream to Medford Island and the Sacramento River below Rio Vista, from April to July. In 1990, with less outflow, larvae were found further south to near the Central Valley Project and State Water Project pumping stations. Sampling by the 20mm survey consistently found low numbers of larvae in the South Delta (CDFG 2009).

High numbers of larvae and young juveniles are found in the Napa River in most years by the CDFG 20mm survey (CDFG, unpublished data). The Napa Fisheries Monitoring program consistently found low numbers of larvae in March-May of 2001-2005, with a spike in abundance in 2003 (Stillwater Sciences 2006).

The distribution of juveniles is initially similar to that of larval fish, but with juveniles moving further downstream with age, occupying the entire upper estuary through Central Bay during their first summer and expanding throughout the estuary by the following winter (CDFG 2009).

2.3 Habitat requirements

The longfin smelt is primarily a pelagic to demersal, open water species (Moyle 2002). However, longfin smelt are also found in lower densities in Suisun Bay marshes (seasonally), comprising six percent of the total otter trawl catch over monthly sampling from 1979 to 1999 (Matern et al. 2002). Although their sometimes frequent occurrence in Suisun Bay marshes suggests general occurrence in shallow and nearshore locations, systematic sampling across these areas has not been conducted. The fish are found across a wide range of temperatures and salinities, depending on life stage and season. In Lake Washington tributaries, longfin smelt spawned in areas with sandy substrates and low velocity flows; favorable substrate and flow conditions are assumed to be similar in the San Francisco Estuary (CDFG 2009).

2.3.1 Salinity

Juvenile and adult longfin smelt tolerate a wide salinity range, occurring in salinities ranging from seawater to freshwater throughout their life cycle. Adults, prior to their spawning migration, prefer salinities of 15 to 30 ppt and early life stages have a lower salinity tolerance (Moyle 2002). Adult preferences for mesohaline and polyhaline salinities are illustrated by the relatively high frequency of occurrence in South Bay, Central Bay, and San Pablo Bay, in comparison to Suisun Bay and the Delta (Figure 2).

Baxter (2009) suggests that longfin smelt require freshwater to spawn, because very young larvae have a low salinity tolerance. Kimmerer et al.(2009) found that larvae and young juveniles were most abundant at 2 ppt and declined rapidly as salinity increased to 15 ppt. Larvae in the Napa River were also captured at salinities of 0.4 to 5.6 ppt, when the water was the freshest (Stillwater Sciences 2006). Freshwater flow in the Delta during incubation and the larval rearing period is a strong correlate of longfin smelt abundance, likely because high flow increases the volume of brackish water preferred by larval and juvenile smelt (Baxter et al. 2010). Nevertheless, plankton tows performed from 1980 to 1987 also captured larvae in higher salinity regions, including Central and San Pablo Bays (Figure 1), during years of higher outflow (Baxter 1999).

Otolith microchemistry indicates that, in recent years, larvae that survived to adulthood predominantly occurred in low salinities (average 2 ppt), whereas the average salinity at which all larvae were found, by 20mm survey, was higher. This finding suggests that larval distribution may have been shifted to suboptimal salinity conditions, potentially causing a substantial reduction in recruitment success (Hobbs et al. 2010). However, interannual variations in survival and distribution may occur, which have not been thoroughly evaluated (Baxter, pers. comm.).

2.3.2 Temperature

Adult longfin smelt prefer water temperatures of 16 to 18°C or below but will occupy waters as warm as 20°C in the summer (Baxter 1999). Far fewer fish are found above 22°C (Figure 4). Temperatures come close to or exceed this upper limit in the summer and early fall in the Delta and South Bay (Baxter 2009). Moyle (2002) suggests that longfin smelt use of deepwater habitat, and marine migrations in the summer may be a method of escaping higher temperatures. In the nearshore waters of Suisun Marsh, elevated temperature was negatively associated with occurrence of adult smelt (Matern et al. 2002). Moyle (2002) reports spawning temperatures of 7-14.5°C in San Francisco Bay. CDFG (2009) reports that spawning begins when water temperatures drop below 16°C and becomes consistent when water temperatures drop below 13°C.

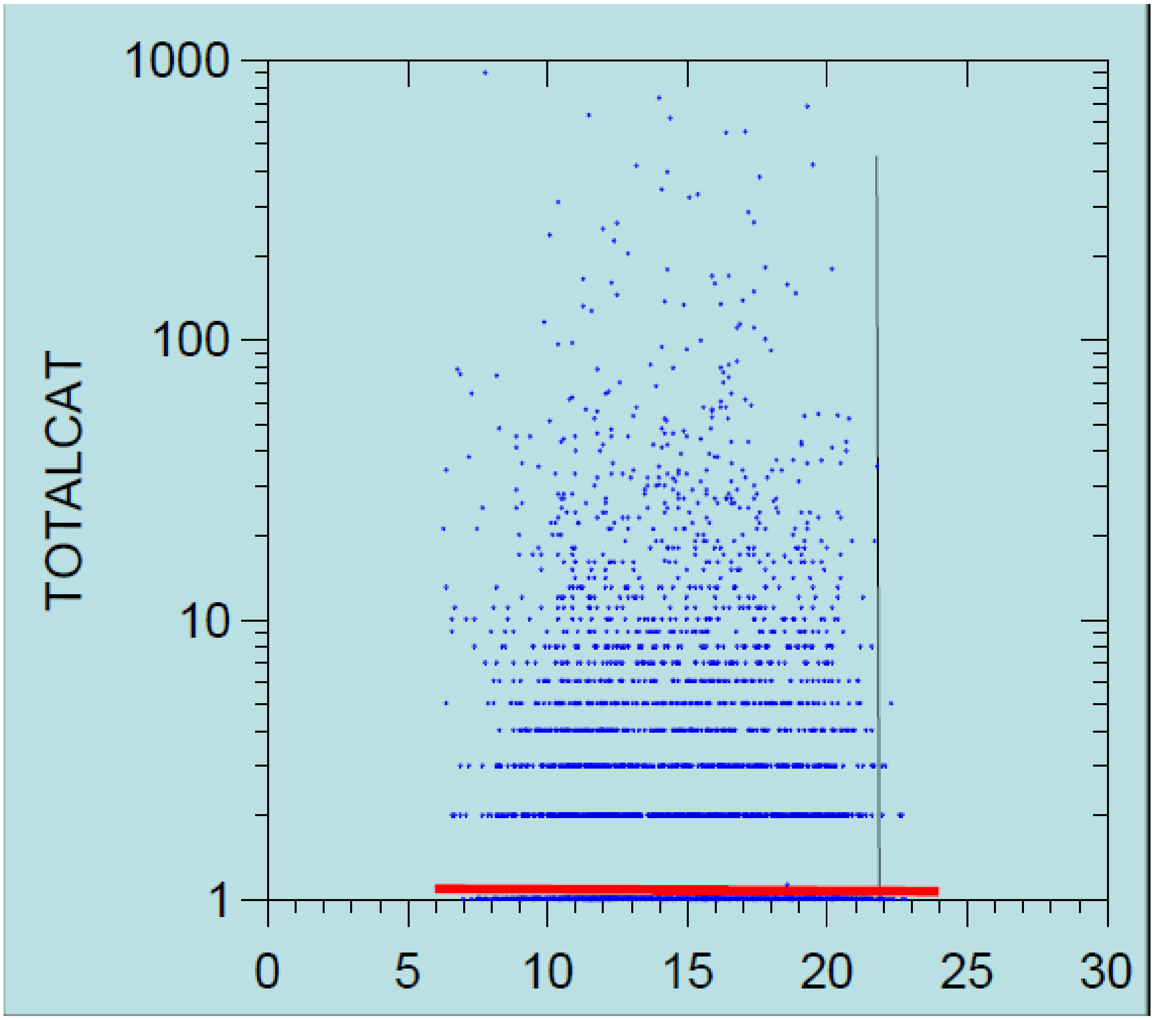

Figure 4. Temperatures at which longfin smelt were captured. Data taken from the CDFG Bay Study. Capture rates decline sharply above 20°C, and smelt are rarely found at temperatures >22°C (Baxter 2009).

2.3.3 Water depth

For adults and juveniles, water depth can vary as a function of vertical migration to maintain longitudinal position in the channel. In deep channels, fish are higher in the water column when moving upstream on the flood tide and lower in the water column when moving downstream on the ebb tide. This vertical migration allows the smelt to maintain position relative to optimal salinity habitat (Hobbs 2009). In nearshore areas, existing data suggests that they remain in deeper channels (e.g., sloughs) (Rosenfeld and Baxter 2007); however, the potential for them to be exposed to shallower conditions exists.

The ratio of fish caught by midwater trawl versus otter trawl in the IEP Bay Sampling Program decreased downstream of San Pablo Bay, suggesting that fish further downstream prefer to be lower in the water column (Baxter 2009).

Overall, longfin smelt densities have been found to be greater above deepwater channels than above the shoals (Rosenfield 2009). However, the extent to which smelt are present in nearshore locations and shallow areas has not been systematically evaluated.

2.3.4 Turbidity

Turbidity is an important part of longfin smelt larval habitat (Kimmerer et al. 2009), possibly providing a competitive foraging advantage or means of predator avoidance. Smelt have excellent olfaction, allowing them to forage effectively at night or in turbid environments (Baxter et al. 2010). Smelt are found at higher densities in turbid water, although there is some evidence that turbidity may negatively affect growth and condition. In Suisun Bay, comparison of longfin smelt in the shallow, less turbid northern channel versus the deep, more turbid southern channel revealed greater abundance in the southern channel, but also lower feeding and growth rates (Hobbs 2009).

2.3.5 Spawning substrate

Spawning has not been observed in San Francisco Bay, so the exact microhabitat preferences of local longfin smelt are unknown. Longfin smelt in Lake Washington are known to spawn on sand or gravel, with a preference for sandy substrate (CDFG 2009).

2.3.6 Use of tidal marshes

Longfin smelt have been observed in Suisun Marsh surveys since 1980, with sharp declines in abundance observed since the early 1980s (Matern et al. 2002). Monthly trends in abundance generally followed trends seen in other IEP surveys (Bay Study, FMWT). As in these other surveys, differences in abundance by year were also strongly correlated with water outflow (Rosenfield and Baxter 2007). Connectivity between the tidal marsh and tidal sloughs is likely the most important driver in determining the benefit of tidal marsh habitat to longfin smelt (Raabe et al. 2010). Temperature is also likely to be a factor (Baxter pers. comm.).

2.4 Species decline and current threats

The longfin smelt was once one of the most abundant fish in the San Francisco Estuary. The species has experienced severe declines in abundance in recent decades. Previous declines (mid-1970s, 1990s) were strongly correlated with low Delta water outflow (Figure 5). However, recent declines have persisted even in years of high Delta outflow (Moyle 2002, Rosenfield 2009). These recent declines, beginning in the early 2000s, are considered part of the Pelagic Organism Decline (POD) in the Delta, and mirror trends seen in the delta smelt (*Hypomesus transpacificus*), threadfin shad (*Dorosoma petenense*), and juvenile striped bass (*Morone saxatilis*) (Armor et al. 2006, Thomson et al. 2010). Major causes believed to be contributing to the recent decline of the longfin smelt are reduced freshwater outflow during the incubation and larval rearing period, entrainment of larvae and adults in water delivery intakes (i.e., pumping stations), and the changing of the food web due to introduced species. Other factors potentially important in the decline of the longfin smelt include climate change, shrimping by-catch, and changes in water quality (turbidity and contaminants) (Moyle 2002, The Bay Institute et al. 2007, CDFG 2009, Baxter et al. 2010).

Reduction in Delta outflow is believed to be the biggest factor affecting longfin smelt abundance in the Estuary (Moyle 2002); (CDFG 2009). Longfin smelt abundance shows a strong, positive, multi-decadal correlation with freshwater outflow (Rosenfield and Baxter 2007, Baxter 2009, Baxter et al. 2010). Otolith microchemistry shows that smelt occupied a narrower salinity range in 2000 to 2007, and more saline water overall, indicating that availability of brackish habitat for smelt has been reduced (Hobbs 2009).

Water diversions by the State Water Project (SWP) and Central Valley Project (CVP) have contributed to lower Delta outflow. Such diversions also pose a threat to longfin smelt because of their potential to entrain longfin smelt, particularly larvae and juveniles, in pumping stations (Kimmerer and Nobriga 2008). Risk of entrainment was fairly constant over the last 50 to 100 years until the SWP and CVP increased diversions and potential for entrainment (Moyle 2002).

The introduction of the overbite clam, *Corbula amurensis*, in the late 1980s changed the benthic community and is likely responsible for the observed step-decline in mysid shrimp, which are an important prey item for longfin smelt. The introduction of non-native copepods may have further reduced the quality of prey available (Baxter et al. 2010). While introduced predators such as striped bass do not appear to be a threat to adult longfin smelt (Baxter 2009), egg and larval predators such as the Mississippi silverside (*Menidia audens*) may pose a threat (Moyle 2002).

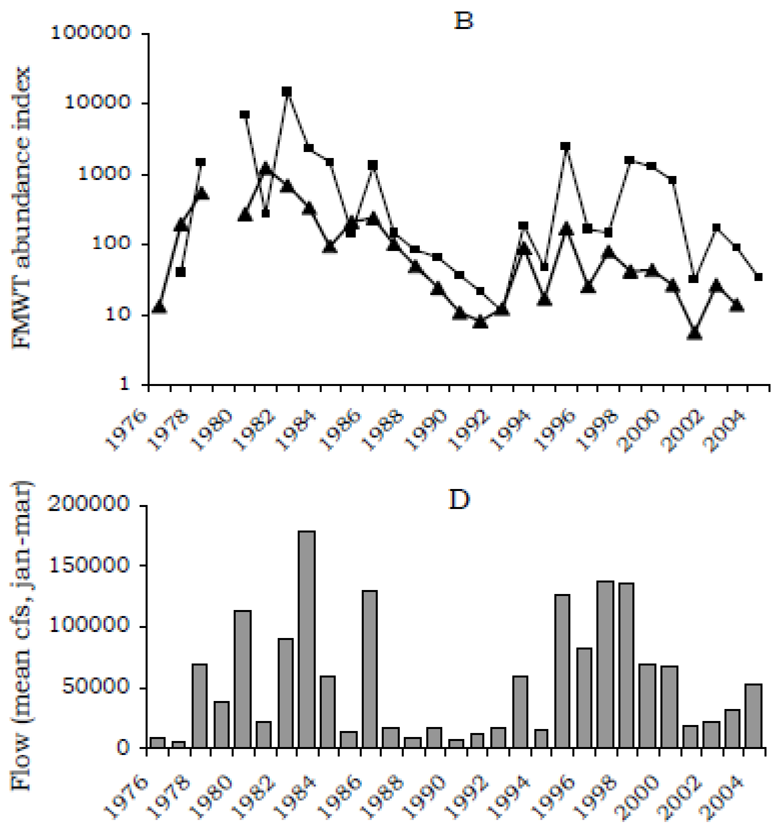

Figure 5. Abundance of longfin smelt population has correlated positively over time with freshwater flows (Rosenfield 2009). Abundance data are taken from the CDFG Fall Midwater Trawl surveys (FMWT).

Contaminants in urban and agricultural run-off and in wastewater treatment plant discharges have the potential to be toxic to longfin smelt. Pyrethroid contamination may be less of a problem for longfin smelt compared with other Delta species, because spawning occurs early in the year before much of the pesticide application. However, when the timing does coincide, larvae could be susceptible, and effects might be hard to detect (Moyle 2002). The short life and low trophic position of the smelt also lessen concerns about bioaccumulation and biomagnification. However, the relative sensitivity of longfin smelt to contaminants, compared to other species, has not been studied. Delta smelt are known to be much more sensitive than Mississippi silverside (Baxter 2009). Water quality is of greatest concern in Suisun Bay and the Delta, as this is where spawning and early larval development take place and early life stages are most vulnerable to contaminants. Given the long incubation period and close proximity to sediment, eggs may be at risk of exposure to sediment-associated contaminants, and surface-oriented early-stage larvae would be particularly vulnerable to pulse-flow transported contaminants (Baxter et al. 2010).

Increasing water temperatures may be contributing to the decline of the smelt as well. San Francisco Bay represents the southernmost extent of population and, therefore, the species is likely to be close to the upper end of its temperature tolerance (Rosenfield 2009). Warm temperatures are believed to make parts of the Bay uninhabitable to the longfin smelt in the summer months (Baxter 2009).

Changes in turbidity have been proposed as a potential threat to longfin smelt. Reduced turbidity in recent years, due to sediment retention in upstream reservoirs and by invasive aquatic plants, may reduce the availability of ideal habitat, as smelt show a preference for turbid waters (Baxter et al. 2010).

Longfin smelt are a known by-catch of shrimp trawling in the Bay (Baxter 2009). Shrimp trawling is not allowed in spawning areas. However, it is responsible for some adult mortality.

CDFG (2009) described the greatest threats to longfin smelt as reduced inflows, entrainment, climatic variation, toxic substances, predation, and introduced species. Dredging has also been listed as a concern for the species and is considered in detail below. In the CDFG report on Delta organism stressors (CDFG 2010), dredging was listed as a Priority 3 (low priority) stressor because of its localized and limited impacts to species of concern. However, given the state of the population, even small effects could be damaging (Rosenfield 2009).

3. Dredging and Longfin Smelt

3.1 Potential impacts of dredging

Potential impacts of dredging include direct mortality due to entrainment or burial of eggs, removal of spawning habitat, changes in water quality due to increased suspended sediment, and indirect effects resulting from habitat alteration.

Entrainment by hydraulic dredging has been directly monitored in several studies, and little to no entrainment has been observed. Swedberg and Zentner (2009) filtered 65,000 cubic yards of dredged material from the Port Sonoma project at the mouth of the Petaluma River. While large numbers of longfin smelt were caught in the area when trawling for shrimp (establishing presence), no longfin smelt were found in the dredged sediment in 2007. One longfin smelt was entrained in 2006 while the dredge head was running above the sediment surface, emphasizing the importance of correct dredging technique, which could have prevented entrainment of that fish. This study was conducted in late autumn and winter when relative risk of adult entrainment in San Pablo Bay is believed to be low. Gold (2009) performed an entrainment study using a custom-built entrainment screen. In this study, 725 fish of 15 species were captured. The majority of the catch were non-native, benthic species including shimofuri goby, channel catfish, and white catfish. No longfin smelt were captured. Similarly, monitoring of a hopper dredging project in Pinole Shoal Channel found no entrainment of longfin smelt (McGowan 2010). In combination, these findings suggest very low entrainment rates for adult or juvenile longfin smelt due to hydraulic dredging.

Dredging in spawning habitat poses a risk of removing eggs or spawning habitat directly, burying eggs, or increasing suspended sediment to an extent that prevents the adhesion of eggs to proper substrate (USACE 2004). Across fish species, suspended sediments may cause alarm reaction, cover abandonment, or attraction (as a potential food source or cover). There are also changes in light penetration/scattering that could cause increased swimming, altered school behavior, avoidance, displacement, attraction, and changes in prey capture rates (Anchor Environmental CA et al. 2003). Although all of these effects could potentially occur, none have been evaluated or documented for longfin smelt.

Although dredging associated turbidity has been raised as a potential concern for aquatic species in the Bay (Jabusch et al. 2008), it is unlikely that turbidity would have adverse impacts to adult or juvenile longfin smelt. Longfin smelt are an estuarine species, adapted to turbid waters and changing water clarity. Increased turbidity may have a positive effect on longfin smelt, with higher densities of longfin smelt in more turbid waters. This finding suggests that longfin smelt appear to seek refuge from predators in turbid waters (Hobbs 2009). In addition to increased turbidity, there is also concern that resuspension of contaminated sediment could increase the availability and uptake of heavy metals and organic contaminants in longfin smelt (Baxter, pers. comm).

For new dredging projects, changes to hydrodynamics and habitat have the potential to benefit or harm longfin smelt, depending on the project-specific outcome. Longfin smelt may be particularly sensitive to changes in hydrodynamics, as they appear to use channel depth and the pattern of water flow through a channel to maintain position near the entrapment zone. Substantial channel deepening could conceivably increase stratification and consequently affect the ability of longfin smelt to maintain longitudinal position by vertical migration (Hobbs 2009). Conversely, substantial disposal of dredge material in deepwater locations near the entrapment zone could reduce the ability of smelt to maintain position. Depending upon where channel deepening occurs changes in water velocity or salinity may also occur (Baxter, pers. comm.).

Potential indirect effects of dredging pertain to the creation and maintenance of shipping channels. These channels may facilitate the introduction of invasive species, as well as harm by commercial vessel wave action and propeller damage.

3.2 Avoidance, minimization and mitigation of impacts to longfin smelt

3.2.1 Work windows

The interannual variation in spatial distribution of longfin smelt makes it difficult to avoid potential impacts of aquatic activities using a fixed work windows-based approach. Alternative methods that account for interannual variation in spatial distribution merit consideration.

The LTMS established work windows in the LTMS Environmental Impact Statement/Report and Record of Decision (EIS/R & RoD). At that time, longfin was a candidate for listing and therefore not considered in the 1999 LTMS biological opinion. However, the LTMS EIS & RoD did provide work windows for some candidate species of concern, including longfin, and those work windows are still in place (LaCivita pers comm). Work windows limit work to the period of June to October in the Delta and South San Francisco Bay, September to November between the Carquinez Bridge and Collinsville, and from August to January in San Pablo Bay (LTMS 2004).

The 2009 LTMS Longfin Smelt Symposium facilitated discussion on work windows for longfin smelt. Members of the expert scientific panel did not support establishing work windows for this species. The basis for not supporting a windows approach was the widespread use of the Bay by longfin smelt throughout the year and the high degree of interannual variation in distribution (Stanford et al. 2009). Examination of seasonal and spatial patterns in IEP Bay Study data (Figures 1 and 2) indicate widespread distribution of longfin smelt. More detailed summaries also indicate the species to be present throughout the Bay, with some risk of occurrence year round (Baxter 1999, Rosenfield and Baxter 2007).

3.2.2 Minimization and mitigation in recent projects

Current dredging projects have minimized impact to longfin smelt larvae by timing and dredge placement location and to adults by dredging methods and equipment. A dredging project on the Pinole Shoal Channel in San Pablo Bay by hopper dredge reduced the risk of dredging to longfin smelt by limiting all priming, cleaning, and pumping of water to within three feet of the bottom (McGowan 2010). Monitoring of this project found no entrainment of longfin smelt. The Chevron Long Wharf project minimized impact through use of a clamshell dredge with a cable arm. The project report (Arcadis 2009) indicated that this method “minimize[d] sediment dispersion through engineered vents to decrease downward water pressure that roils bottom materials as the bucket approaches. Using a controlled descent speed also reduces the potential for direct contact between the bucket and marine life and reduces sediment dispersion.”

Allied Defense Recycling and Lennar Mare Island plan to conduct maintenance dredging of the Mare Island Dry Docks. To mitigate for potential impacts to Delta smelt and longfin smelt, mitigation will be conducted in the form of acquiring, restoring, and preserving five acres of tidal shallow water habitat (San Francisco Bay Conservation and Development Commission 2010).

4. Study Plan

4.1 State of knowledge and information gaps

The basic life history of longfin smelt is well understood, largely from studies done in the Lake Washington area (Moulton 1974, Chigbu and Sibley 1998, Chigbu 2000, Moyle 2002). Some knowledge gaps exist on aspects of life history specific to San Francisco Estuary populations. These include spawning locations and habitat, use of marshes and nearshore areas, and extent of migration to marine locations. Long-term monitoring by the IEP has provided useful information regarding spatio-temporal patterns in longfin smelt abundance and mechanisms to explain declines (Baxter 1999, Armor et al. 2006, Rosenfield and Baxter 2007, Baxter 2009, Baxter et al. 2010, Thomson et al. 2010). Similar trends across all monitoring programs suggest we are capturing trends in abundance and distribution of this species (Rosenfield and Baxter 2007).

Understanding of potential effects of dredging is limited by a lack of systematic data collection in many locations where dredging projects may occur. Areas where longfin smelt distribution is not well understood include: shallow water, nearshore habitat, the Lower South Bay, Bay tributaries (e.g., the Napa and Petaluma Rivers and Coyote Creek), and marine waters outside of the Bay. A better understanding of how longfin smelt are associated with habitat parameters may also help identify areas where it is safe to dredge. Of these, temperature, salinity, and depth are particularly promising as variables to potentially explain short-term patterns in distribution of the species (Baxter 2009). Effects of dredging on water quality (Jabusch et al. 2008) and suspended sediment (Anchor Environmental CA et al. 2003) have been studied in general, and these results can potentially be applied to predict the response of longfin smelt. While the potential risk of contaminants on fish have been considered generally, both from runoff (Moyle 2002) and resuspension of contaminated sediments (Jabusch et al 2006), specific studies of contaminant effects on longfin smelt have not been conducted. Since non-dredging threats such as climate change and shrimp trawling are not well understood, the ability of the LTMS to ameliorate these issues is not clear. Based on their pelagic life history, reduction of shrimp trawling activity holds potential promise as a means to reduce impacts to longfin smelt.

The POD team of the IEP oversees many studies related to the decline of longfin smelt and other fish species in the Delta. The 2010 POD work plan includes 39 continuing study elements and 32 new elements (Baxter et al. 2010). Proposed studies related to longfin smelt will investigate population genetics, otolith biogeochemistry, salinity tolerance, and food web changes (see Table 1 for a complete list of POD studies that relate to the longfin smelt).

One conclusion among participants at the 2009 LTMS Longfin Smelt Symposium was that real-time monitoring at the individual project level might be valuable for large-scale projects but is too costly for smaller projects. Furthermore, results from one project would not necessarily be applicable to other projects (Stanford et al. 2009). These findings suggest that a large-scale Bay-wide program might be more effective for evaluating distribution and potential risks to longfin smelt.

Dredgers at the Symposium also voiced a desire for more specific guidance from the State on how to meet the requirements for avoidance, minimization and mitigation. Other stakeholders also expressed frustration at the lack of guidance on meeting permitting requirements (Stanford et al. 2009). These findings suggest the need for development of a systematic and consistent approach for managing longfin smelt at the project level.

Table 1. Study elements in the 2010 Pelagic Organism Decline Workplan that relate directly or indirectly to longfin smelt (Baxter et al. 2010).

Study Element	New or ongoing work
Development and implementation of IBM of striped bass and longfin smelt	Ongoing work
Estimation of pelagic fish population sizes	Ongoing work
Zooplankton fecundity and population structure	Ongoing work
Phytoplankton primary production and biomass	Ongoing work
NCEAS - synthetic analyses of fish and zooplankton	Ongoing work
Fish diet and condition	Ongoing work
Trends in benthic macrofauna abundance and biomass	Ongoing work
Corbula salinity tolerance	Ongoing work
Field survey of Microcystis bloom biomass and toxicity	Ongoing work
Food web support for delta smelt and other estuarine fishes	Ongoing work
Investigation of power plant impacts	Ongoing work
SAV abundance and distribution	Ongoing work
Fish facility history	Ongoing work
Contaminants and biomarkers work	Ongoing work
Feasibility of using towed imaging systems	Ongoing work
Use of acoustics to measure trawl openings	Ongoing work
Effects of the Cache Slough complex on north Delta habitat	Ongoing work
Population genetics and otolith geochemistry of longfin smelt	Ongoing work
Effects of waste water management on primary productivity	Ongoing work
Effects of Microcystis on threadfin shad	Ongoing work
Contaminant synthesis 2 – impacts of contaminants and discharges	Ongoing work
Spatial and temporal variability of Delta water temperatures	Ongoing work
Plankton dynamics in the Delta: trends and interactions	Ongoing work
Environmental controls on the distribution of harmful algae and their toxins in the San Francisco Bay	Ongoing work
Comparison of nutrient sources and phytoplankton growth and species composition	Ongoing work
Spatial and temporal quantification of pesticide loadings	Ongoing work
Acute and chronic toxicity of contaminant mixtures and multiple stressors	New IEP, new CALFED/Delta Science Program or expanded IEP work
Advancing procedures for extracting and recovering chemicals of concern from sediment interstitial water	New IEP, new CALFED/Delta Science Program or expanded IEP work
Comparison of 1- and 2-D hydrodynamic and water quality models of the Delta	New IEP, new CALFED/Delta Science Program or expanded IEP work
Spatial and temporal variability in nutrients in Suisun Bay in relation to spring phytoplankton blooms	New IEP, new CALFED/Delta Science Program or expanded IEP work
Experimentally determining early life-stage sensitivity to salinity for longfin smelt	New IEP, new CALFED/Delta Science Program or expanded IEP work
Remote sensing mapping and monitoring of Microcystis and turbidity in the upper SFE	New IEP, new CALFED/Delta Science Program or expanded IEP work
Metabolic responses to variable salinity environments in field acclimatized Corbula amurensis	New IEP, new CALFED/Delta Science Program or expanded IEP work
Causes of seasonal and spatial variations in NH4 sources, sinks, and contributions to algal productivity using a multi-isotopic approach	New IEP, new CALFED/Delta Science Program or expanded IEP work
Longfin smelt bioenergetics	New IEP, new CALFED/Delta Science Program or expanded IEP work
OP and pyrethroid use in the Sacramento River and Delta	New IEP, new CALFED/Delta Science Program or expanded IEP work
Ammonia literature review	New IEP, new CALFED/Delta Science Program or expanded IEP work

4.2 Proposed studies

Based on information gaps identified in this literature review, and management needs discussed at the Symposium, five studies are proposed for consideration by the LTMS Science Workgroup (Table 2).

4.2.1. Thermal tolerance

Cost: $25,000-$100,000

Duration: 1-2 years

Question: What is the thermal tolerance of longfin smelt? Is there a temperature threshold at which the species can be assumed to be absent from an area?

Summary:

Temperature has been proposed as a major factor limiting the southern distribution of the longfin smelt, and explaining their summer movement into deeper waters (Baxter 2009). Establishing the thermal tolerance of the species could allow identification of areas in the San Francisco Estuary where it would be safe to assume no take of longfin smelt from dredging would occur. Further, understanding how growth and condition are affected by elevated temperatures could help to predict how climate change will impact future survival and distribution of the species.

These questions could be answered by laboratory studies examining the growth and survival of longfin smelt at different temperatures, using acclimated chronic exposure methods with fish fed to saturation daily to establish peak growth temperatures in addition to lethal thresholds (e.g. Swanson and Cech 1995, Swanson et al. 2000; Selong et al. 2001). Such studies should establish thermal tolerance for larval and juvenile fish as well as adults.

Laboratory studies will compliment data from continued IEP monitoring programs (Bay Study, Fall midwater trawl survey) which measure temperature at each station in each survey.

As part of this study the relationship between water depth and temperature could be examined to determine whether high temperatures preclude longfin smelt presence in certain areas of shallow water.

4.2.2. Mechanical dredging

Cost: $100,000 - $250,000

Duration: 1 year

Question: What is the risk of direct mortality from clamshell dredging, versus other methods, for longfin smelt and other species of management concern?

Summary:

Clamshell dredging is widely employed as a method that minimizes effects to aquatic resources. Escapement and avoidance is believed to be greater employing clamshell dredges than other methods, such as suction dredges. Although other dredge methods have been evaluated in the Bay, direct measurement of mortality due to clamshell dredging has not been performed.

A study is recommended to measure entrainment levels from clamshell dredging as compared to other methods, to establish the relative impact to longfin smelt and other sensitive aquatic species. This would aid in understanding the potential benefits of clamshell dredging as a minimization activity, as well as providing additional information on the actual risk posed by other dredging activities.

The presumed cost estimate for this study assumes that it would be performed in tandem with maintenance or navigation dredging activities underway. A portion of the study effort would be in developing appropriate techniques for quantitatively collecting fish entrained or disturbed by the dredging activity. This could include sorting through dredged sediment, as was performed previously (Gold 2009, Swedberg and Zentner 2009), and placement of nets in the dredging area to document fish present during the activity.

The study would preferably be conducted during a period and location where longfin smelt of various life stages were expected to be abundant. Though high abundance would present a short term risk to the species, this would be ameliorated by the long term benefits of better understanding the hazards of these activities under worst-case scenario conditions. Previous studies recorded no impacts to longfin smelt (Gold 2009, Swedberg and Zentner 2009), likely due to very low abundance of the species in the study area. Additional species captured should also be carefully recorded to document potential impacts to other species of concern (e.g., green sturgeon (*Acipenser medirostris*), pacific herring (*Clupea pallasi*)) as well as invasive species.

Ideally, an experimental approach would be employed in which multiple dredging methods were applied on-site, and at varying times of day and tidal conditions. A replicate statistical design is recommended to include varying combinations of dredge method, time, and tidal cycle. This would facilitate statistical analysis of potential factors leading to elevated entrainment or mortality by dredging activities. However, if costs for concurrent studies of multiple dredging methods are prohibitive, studies of clamshell dredging alone could be conducted and results compared to previous studies for hydraulic dredging.

4.2.3. Distribution in nearshore areas, tributaries, and Lower South Bay

Cost: $100,000-$250,000

Duration: 3 years or ongoing

Question: How do longfin smelt use habitats currently not monitored? Are there locations not currently monitored where it would be safe to dredge?

Summary:

One of the uncertainties identified by researchers working with longfin smelt is their use of shallow and nearshore locations where many maintenance dredging projects and restoration activities occur (Randy Baxter, pers. comm.). There is also limited understanding of their presence and abundance within the Lower South Bay and the Petaluma River (Figures 1 and 2). Rather than an ad-hoc project-specific approach, the most effective approach to further understand the biology of this species is a systematic status and trends monitoring program, such as that employed by the IEP. Another advantage of a programmatic study approach (rather than project-specific) is a greater ability to systematically integrate and interpret data regarding the needs, habitat use, and impacts to the species (Baxter 1999, Matern et al. 2002, Rosenfield and Baxter 2007, Thomson et al. 2010). This would aid in development of a Decision Support System for evaluating the effects of dredging (Study 4.2.5).

Currently, in collaboration with other agencies, the IEP performs extensive fish monitoring in multiple offshore locations throughout the Estuary. However, monitoring in nearshore locations where dredging activity and dredge material placement frequently occur is limited to a set of stations in Suisun Marsh (Matern et al. 2002). Systematic monitoring is also lacking in the Lower South Bay and Petaluma River, despite the occurrence of longfin smelt in these waters.

The LTMS could work in coordination with IEP to develop a sampling program covering shoreline habitat across the Bay, in order to increase understanding of longfin smelt use of shallow areas. Although information is lacking throughout the year, of particular interest is spawning activity and larval development, which occur between January and June. Although useful information could be obtained in 3 years or less, additional long term study could be performed to evaluate interannual variation and long-term trends in abundance and distribution of longfin smelt and other species.

A probabilistic survey design is recommended to best understand the spatial and temporal patterns in fish abundance and distribution (Stevens and Olsen 2004). Such approaches have been useful in understanding spatial patterns in benthic condition and contaminant concentrations in the Bay and Delta. Targeted sampling could also be included to evaluate use of the Lower South Bay, Petaluma River, other Bay tributaries where dredging is commonly performed, and areas with major planned restoration activity (e.g., Hamilton Wetlands Restoration Project).

Ancillary parameter information should also be collected to aid in determining factors that influence the abundance and distribution of longfin smelt, in addition to other species of interest. Of particular interest are water temperature, salinity, turbidity, tidal condition, depth, benthic habitat type (e.g., sediment composition), and shoreline condition. This would enable statistical modeling of drivers of smelt presence and abundance (Matern et al. 2002). For example, correlational data relating water depth, temperature, and species presence could be used to evaluate a potential interaction between nearshore water (7 m to shoreline) elevated water temperatures, and reduced longfin smelt abundance. Such a finding would indicate very limited or no risk of take to the species for projects occurring in such conditions. Since longfin smelt inhabit deeper water and tend to avoid water temperatures in the >20 deg C range, depth and temperature could work additively to reduce risk.

4.2.4. Spawning Locations and Habitat

Cost: $25,000-$100,000

Duration: 3 years

Question: Where specifically are longfin smelt spawning in the Bay? What are the important habitat requirements for spawning?

Summary:

Although spawning activity has been documented in the Lake Washington population (Moulton 1974), actual spawning has not been observed in San Francisco Bay. Based on observations of distribution of spawning aged adults, and yolk-sac larvae, local biologists have hypothesized that spawning occurs at the freshwater/brackish water interface, with sandy sediments in deeper channels favorable for spawning (Moyle 2002, Rosenfield and Baxter 2007, CDFG 2009, Baxter et al. 2010). However, with no direct evidence of the locations or habitat preferences for spawning, these hypotheses remain speculative. Spawning is believed to occur within the Delta and possibly within tributaries such as the Petaluma and Napa Rivers, and Coyote Creek, areas where dredging projects might potentially occur. Removal or alteration of spawning habitat as a result of dredging would negatively impact reproductive success of the longfin smelt.

A better understanding of appropriate spawning habitat would enable the LTMS to determine whether particular habitat types (e.g., sandy sediments), channel depths, or locations within the Estuary are likely to contain longfin smelt. The potential presence of spawning adults, eggs, or yolk-sac larvae would aid in determining the potential hazard of a proposed project. This would further aid in development of a Decision Support System for evaluating the effects of dredging (Study 4.2.5)

The proposed study would evaluate multiple locations within the Estuary to determine appropriate spawning habitat for longfin smelt. The study approach would be a field survey, targeting gravid females in addition to eggs. To reduce costs, the study could be performed in coordination with the survey of abundance and distribution (Study 4.2.3). Current sampling for native and alien fish eggs in the Sacramento River and Yolo Bypass uses plankton sampling (Sommer et al 2004), which is inappropriate for detecting the adhesive eggs of longfin smelt. Substrate sampling or artificial substrates is needed to detect the spawning locations of longfin smelt (Baxter, pers. comm.). Statistical modeling techniques would be used to compare egg presence information to environmental factors of potential interest (e.g., depth, salinity, time of year, flow, and location).

4.2.5. Decision system for adaptive response to longfin smelt spatial and temporal patterns

Cost: $100,000-$250,000

Duration: 2 years

Question: What is an appropriate method to reduce hazards to longfin smelt, based on spatiotemporal distribution and habitat preferences?

Summary:

Longfin smelt occur throughout San Francisco Bay, with spatial distribution varying seasonally and across years, due to riverine flow and other factors. LTMS participants and other stakeholders have requested development of a clear and consistent approach for management of this species. To address these needs, we recommend a study to develop an approach to manage potential impacts of sediment management activities on longfin smelt.

The study would focus on developing a decision support system for longfin smelt management. This will require integration of both technical (e.g., longfin smelt biology) and organizational (e.g., effective interagency communication) information. It would need to occur in collaboration with LTMS participating agencies and would require investment of time and coordination. As an initial conceptual model, the following three components would be incorporated into the decision support system: 1. A tool or method for obtaining real-time information on longfin smelt abundance and distribution in the Bay; 2. A standardized methodology for management decision-making based on current dredging activities and results of 1; and 3. A set of standardized avoidance, minimization and mitigation measures.

The first component, a method for obtaining real-time information on abundance or distribution, is needed to address the substantial interannual and seasonal variation in regional abundance of longfin smelt. Currently, IEP monthly collections provide general information about Bay-wide movement of the species. Additional data collection undertaken as part of Studies 4.2.3 and 4.2.4, may provide further necessary insight into the abundance and distribution of the species. The data synthesis and integration method would entail development of a data query tool and an efficient interagency relationship and communication strategy. This approach must provide a rapid and reliable method to access, interpret, and disseminate the longfin smelt distribution data in a standardized fashion appropriate for LTMS use.

The second component, a standardized methodology for management decision-making, should be a decision tree or other system to efficiently and consistently answer two questions: 1. will a dredging or other management activity substantially spatially and temporally overlap with longfin smelt? and 2. what is the extent to which that activity is likely to pose a threat to individuals within the population? The outcome of the decision should depend on type of dredge employed (or other management activity); expected or observed abundance (i.e., current overall abundance level); and distribution of the species recorded near the activity, duration of the activity, and other factors expected to affect longfin smelt occurrence and entrainment risk. Ultimately, the system must be straightforward to employ, enabling consistent outcomes. A subtask for developing the methodology would be developing statistical models of likelihood of smelt occurrence, based on environmental parameters measured at the site and expected to influence the species (e.g., temperature, salinity, depth), and field testing of those models.

The third component is a set of standardized minimization and mitigation measures that may be employed to ameliorate potential effects to longfin smelt when there is a high risk of negative effects. This component is needed to rapidly and consistently determine appropriate measures when smelt are likely to be present in a project area. Possible measures include monitoring for the species, setting up barrier devices to reduce exposure to the species, changing the dredging methodology to lower-risk practices (e.g., clamshell dredging), restoration or enhancement of nursery habitat in appropriate locations, or other practices as determined by the study. The extent of mitigation or minimization required should be scaled in a consistent fashion, based on the magnitude of hazard as defined in the second component.

For this study to have benefit, key agencies should commit to participating and allocate adequate staff support (some of which could be funded as part of the study budget). At a minimum, workgroup participants should include a staff member from USACE, BCDC, CDFG permitting, and two biologists familiar with longfin smelt (e.g., Randy Baxter, Kathy Hieb, Jim Hobbs, or Josh Israel).

Table 2. Studies proposed for consideration by the LTMS Science Workgroup.

Proposed Studies			
Proposed Study Name	**Cost**	**Duration**	**Questions to be answered**
Thermal tolerance	$25,000-$100,000	1-2 yrs	What is the thermal tolerance of longfin smelt? Is there a temperature threshold at which the species can be assumed to be absent from an area?
Mechanical dredging	$100,000-$250,000	1 yr	What is the relative risk of direct mortality from clamshell dredging, versus other methods, for longfin smelt and other species of management concern?
Distribution in nearshore areas, tributaries, and Lower South Bay	$100,000-$250,000	3 yrs	How do longfin smelt use habitats currently not monitored? Are there locations not currently monitored where it would be safe to dredge?
Spawning locations and habitat	$25,000-$100,000	3 yrs	Where specifically are longfin smelt spawning in the Bay? What are the important habitat requirements for spawning?
Decision system for adaptive response to longfin smelt spatial and temporal patterns	$100,000-$250,000	2 yrs	What is an appropriate method to reduce hazards to longfin smelt, based on spatiotemporal distribution and habitat preferences?

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