

# Science Foundation Chapter 3

## Appendix 3.1 – Case Study

### Longfin Smelt (*Spirinchus thaleichthys*)

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#### DESCRIPTION OF THE SPECIES

The longfin smelt is an anadromous Osmerid native to the San Francisco Estuary (Moyle 2002), which is home to its southern-most reproducing population (Rosenfield and Baxter 2007). Historically, the longfin smelt was one of the most abundant pelagic species, supporting a commercial “white bait” fishery (Skinner 1962). Since the 1960s, the abundance of longfin smelt in the San Francisco Estuary has declined consistently and precipitously except during brief periods of higher outflow (Thompson et al. 2010). In the early 2000s, the abundance of longfin smelt, and 3 other upper estuary pelagic fishes, took another sharp decline that has yet to be fully explained (Thompson et al. 2010, Mac Nally et al. 2010). This simultaneous multi-species decline has come to be known as the Pelagic Organism Decline (Sommer et al. 2007). The longfin smelt is classified as ‘threatened’ under the California Endangered Species Act (OAL 2010) and the San Francisco Estuary component of the west coast population was assessed as warranting federal threatened status, but its listing was precluded due to higher priority work (USFWS 2012).

Within the San Francisco Estuary, increased outflow (or reduced X2 position) during its spawning and early rearing periods (i.e., December through June) continues to produce a significant increase in longfin smelt abundance (Sommer et al. 2007, Kimmerer et al. 2009, Baxter et al. 2010), but more recent analyses suggest that increased flows during spring (March-May) produce the strongest effect (Mac Nally et al. 2010, Thompson et al. 2010, Nobriga and Rosenfield unpublished). Longfin smelt abundance is also significantly influenced by adult spawner number (Baxter et al. 2010, Nobriga and Rosenfield unpublished). This outflow-abundance relationship remains the strongest and most consistent of those observed for organisms within the estuary (Kimmerer et al. 2009). Future water management in support of this relationship will likely benefit longfin smelt and a suite of other estuarine and anadromous fishes, as well as some invertebrates (see Kimmerer 2002, CDFG 2010).

In tributaries to the San Francisco Estuary, longfin smelt probably seek sand or gravel substrates not far above brackish water (CDFG 2009a&b) and spawn, incubate and hatch during the coldest period of the year (Baxter 1999, CDFG 2009a&b). Using the presence of newly hatched larvae and projecting back in time, assuming a 25-day incubation duration, CDFG (2009a) estimated that longfin smelt spawn from November through April and that spawning is initiated about when water temperatures drop below 16°C and becomes widespread at water temperatures < 13°C. After a long incubation (ca. 25-40 days; CDFG 2009a), longfin smelt hatch into buoyant larvae that are dispersed by tides and outflow such that the distribution of late stage larvae and young juveniles centers around 2 psu salinity (Dege and Brown 2004, Hobbs et al. 2010, Kimmerer et al. 2009). With growth and development, longfin smelt disperse broadly throughout the Estuary, including to marine waters (Baxter 1999, Moyle 2002), but avoiding regions where water temperature exceeds 22°C (CDFG 2009a). In recent years this movement by young of the year longfin smelt (though both age classes show shift) to more marine rearing habitat appears to be the

dominant life history strategy as exemplified by both a higher salinity distribution (Figure 10, Contreras et al. 2011) and proportionally many more fish being caught in central San Francisco Bay than more upstream embayments (Baxter et al. 2010). It's unclear whether the observed distributions represent an actual shift, possibly in response to poor upper Estuary feeding conditions as argued for northern anchovy (see Kimmerer 2006) or result of better survival in marine regions. Earlier migration to marine waters could be one means of avoiding increasing summer temperatures in the upper Estuary.

Considering the use of marsh habitats, Brown (2003) described longfin smelt as a transient species found almost exclusively during the cooler winter and spring periods of the year. He described longfin smelt as migrating through the Suisun Marsh to spawn upstream. However, both Brown (2003) and CDFG (2009b) present information indicating that freshwater sources, within marshes, that flow substantially during winter and spring can attract adults during their spawning migrations; presence of adults and, later in the year, larvae strongly indicated that spawning took place in Cordelia Slough or its tributary Green Valley Creek within western Suisun Marsh (CDFG 2009b); similarly, Meng and Matern (2001) found longfin smelt larvae most abundant in Cordelia Slough, and their abundance associated with low temperatures and high outflows. Thus, some marshes may be seasonally important to longfin smelt.

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## LIKELY CLIMATE CHANGE IMPACTS AND RISKS

As global air temperatures increased in the past several decades, so have surface water temperatures (see summary in Cloern et al. 2011). Scaled to the San Francisco Estuary, model projections indicate variable but significant future increases in Delta water temperatures, sea level and salinity, and concurrent significant declines in precipitation and runoff, both only in the more severe temperature increase scenario (Cloern et al. 2011). These scenarios suggest four primary modes of effect on longfin smelt: 1) increasing water temperatures reduce the length of the spawning period; 2) increasing winter and spring water temperatures potentially create a metabolic demand among larvae prior to food availability; 3) increased summer and fall water temperatures reduces habitat quality of the upper Estuary in general and marshes in particular; and under the more extreme temperature change scenario, 4) reductions in runoff, particularly in spring, causing a negative effect on recruitment.

Warming winter water temperatures in the range of 1.5 to 4°C, depending upon model assumptions, could reduce the duration of the longfin smelt spawning period by 2-3 weeks, as inferred from modeling results depicting earlier spring warming (cf., delta smelt mean spawning window date; Brown et al. 2013) and an assumption that fall cooling would not be similarly affected (e.g., no increase in stress temperatures, Brown et al. 2013). It's not clear whether this reduction in the longfin smelt spawning window (longfin smelt likely spawn in water temperatures <16°C, CDFG 2009a) would have a population level effect -- longfin smelt spawning and early rearing would remain synchronous with earlier outflows projected by models-- but it would affect the temporal range available for reproductive hedge-betting.

Metabolic demand in fishes is in part a function of water temperature (Adams and Breck 1990). Increased winter and spring temperatures can be inferred from model projections of 2 -3+ week earlier mean dates of the delta smelt spawning window (Brown et al. 2013). Such temperatures will increase the metabolic demand of longfin smelt larvae, but it's unclear whether future patterns of lower trophic bloom timing will support this higher demand. Even small changes in early survival are likely to have profound affects on abundance.

Negative effects on summer and fall longfin smelt habitat quality in the upper Estuary can be inferred from Cloern et al. (2011) and Brown et al. (2013), both of whom projected substantial increases in the number of high mortality days (>25°C) within the Delta under all future scenarios. Although longfin smelt tolerate higher salinity and are found farther down in the Estuary, it is likely that these high temperatures will propagate downstream (see Shellenbarger and Schoellhamer 2011) and negatively affect longfin smelt habitat. Unlike delta smelt, longfin smelt juveniles and sub-adults have the option to move to cooler marine waters (Baxter 1999). This temperature effect on habitat suitability will likely be more pronounced in shallow, marsh waters where volume is low, heat exchange is high, and water exchange is limited.

Finally, predicted changes in runoff -- shifting from spring to winter, increased variability and a potential for decline under certain scenarios (Cloern et al. 2011) -- does not bode well for longfin smelt whose reproductive success is strongly tied to high winter and spring outflows (see Kimmerer et al. 2009 and references therein). A shift in runoff from spring to winter will likely continue to associate high flow periods with the more restricted longfin smelt reproductive window, possibly maintaining the current beneficial associations. Increased outflow variability, given the species current extremely low abundance, places additional stress on the already stressed population, particularly in the case of a protracted drought. In the absence of a drought, if the future includes a general decline in runoff, it's also likely to include an increased human demand (Cloern et al. 2011), resulting in greater pressure to allocate the reduced flow to uses outside the Estuary, producing negative effects on the longfin smelt population.

These conclusions should be viewed as inferentially based individual- or population-level responses derived from examining modeled subsets of possible future environmental outcomes and using best professional judgment of the author; they should not be construed as predictions. Our understanding of the temperature tolerances of longfin smelt life stages is extremely limited, and we know nothing of their metabolic demands, so inferences in these areas are highly speculative.

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## LITERATURE CITED AND RESOURCES

Adams, S. M., and J. E. Breck. 1990. Bioenergetics. Pages 389-415 in C. B. Schreck, and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Baxter, R. D. 1999. Osmeridae. Pages 179-216 in J. Orsi, editor. Report on the 1980-1995 fish, shrimp and crab sampling in the San Francisco Estuary. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Technical Report 63.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, K. Souza. 2010. Interagency Ecological Program 2010 Pelagic organism decline work plan and synthesis of results through August 2010. Interagency Ecological Program for the San Francisco Estuary.

Brown, I. R. 2003. Will tidal wetland restoration enhance populations of native fishes? San Francisco Estuary and Watershed Science 1(1):43 pages.

Brown, L. R., and coauthors. 2013. Implications for future survival of delta smelt from four climate change scenarios for the Sacramento-San Joaquin Delta, California. *Estuaries and Coasts* DOI 10.1007/s12237-013-9585-4.

California Department of Fish and Game (CDFG). 2009a. Report to the Fish and Game Commission: A status review of the longfin smelt (*Spirinchus thaleichthys*) in California. 46 pages

California Department of Fish and Game (CDFG). 2009b. Effects Analysis -- State Water Project Effects on longfin smelt. California Department of Fish and Game. 58 pages plus appendices.

California Department of Fish and Game. 2010. Effects of Delta inflow and outflow on several native, recreational and commercial species. Written submission to the State Water Resources Control Board March 22, 2010 prepared for the informational proceeding to develop flow criteria for the Delta Ecosystem. 41 pages

Cloern, J. E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger, T.L. Morgan, D.H. Schoellhamer, M.T. Stacey, M. van der Wegen, R.W. Wagner, A.D. Jassby. 2011. Projected evolution of California's San Francisco Bay-Delta-River system in a century of climate change. *Plos ONE* 6(9):1-13.

Contreras, D., V. Afentoulis, K. Hieb, R. Baxter, and S. Slater. 2011. 2010 Status and Trends Report for pelagic fishes of the upper San Francisco Estuary. *IEP Newsletter* 24(2):27-38.

Dege, M., and L. R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Pages 49-65 in F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. *Early life history of fishes in the San Francisco Estuary and watershed*, 39 edition. American Fisheries Society, Bethesda, Maryland.

Hobbs, J. A., L. S. Lewis, N. Ikemiyagi, T. Sommer, and R. D. Baxter. 2010. The use of otolith strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) to identify nursery habitat for a threatened estuarine fish. *Environmental Biology of Fishes* 89:557-569.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series* 243:39-55.

Kimmerer, W. J. 2006. Response of anchovies dampens effects of the invasive bivalve *Corbula amurensis* on the San Francisco Estuary foodweb. *Marine Ecology Progress Series* 324:207-218.

Kimmerer, W. J., E. S. Gross, and M. L. Mac Williams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? *Estuaries and Coasts*. DOI 10.1007/s12237-008-9124-x.

Mac Nally, R., J.R. Thomson, W.J. Kimmerer, F. Feyrer, K.B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S.D. Culberson, G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). *Ecological Applications* 20(5):1417-1430.

Meng, L., and S. A. Matern. 2001. Native and introduced larval fishes of Suisun Marsh, California: the effects of freshwater outflow. *Transactions American Fisheries Society* 130:750-765.

Moyle, P. B. 2002. *Inland Fishes of California*, 2nd edition. University of California Press, Berkeley, California.

Office of Administrative Law (OAL). 2010. File #2010-0127-02. Fish and Game Commission. List longfin smelt as a threatened species. Effective 04/09/2010. California Regulatory Notice Register NO. 12-Z. March 19, 2010. page 437

Rosenfield, J. A., and R. D. Baxter. 2007. Population dynamics and distribution patterns of longfin smelt in the San Francisco Estuary. *Transactions American Fisheries Society* 136:1577-1592.

Shellenbarger, G. G., and D. H. Schoellhamer. 2011. Continuous salinity and temperature data from San Francisco Estuary, 1982-2002: trends and the salinity-freshwater inflow relationship. *Journal of Coastal Research* 27(6):1191-1201.

Skinner, J. E. 1962. *An Historical Review of the Fish and Wildlife Resources of the San Francisco Bay Area*. California Department of Fish and Game - Water Projects Branch, 1.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. *Fisheries* 32(6): 270-277.

Thomson, J. R., W.J. Kimmerer, L.R. Brown, K.B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, E. Fleishman. 2010. Bayesian change-point analysis of abundance trends for pelagic fishes of the upper San Francisco Estuary. *Ecological Applications* 20(5):1431-1448.

United States Fish and Wildlife Service. 2012. *Endangered and Threatened Wildlife and Plants; 12-month finding no a petition to list the San Francisco Bay-Delta population of the longfin smelt as endangered or threatened*. Federal Register 50 CFR Part 17(Docket No. FWS-R8-ES-2008-0045):155 pages.