# Fish Biomass in the Upper San Francisco Estuary, 1980-2006

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## Introduction

In recent years, abundance of delta smelt (*Hypomesus transpacificus),* longfin smelt (*Spirinchus thaleichthys*), striped bass (*Morone saxatilis)*, and threadfin shad (*Dorosoma petenense)* has declined dramatically in the upper San Francisco Estuary. There has also been a decline in the use of the low salinity areas in the estuary as rearing habitat by northern anchovy (*Engraulis mordax*) (Kimmerer 2006). A hypothesis for this pelagic organism decline (POD) is that the feeding conditions in the upper estuary have declined, partly due to the presence of the bivalve *Corbula amurensis,* changes in zooplankton composition, and environmental conditions (IEP 2006).

If food limitation is a stressor occurring in the San Francisco Estuary, it would be reasonable to expect declines in productivity via fish biomass. Biomass estimates were made during the summer months of June through October for the following species: American shad (*Alosa sapidissima*), Chinook salmon (*Oncorhynchus tshawytscha*), delta smelt, jacksmelt (*Atherinopsis californiensis*), longfin smelt, northern anchovy, Pacific herring (*Clupea pallasii*), plainfin midshipman (*Porichthys notatus*), shiner perch (*Cymatogaster aggregata*), splittail (*Pogonichthys macrolepidotus*), striped bass, threadfin shad, white croaker (*Genyonemus lineatus*), and yellowfin goby (*Acanthogobius flavimanus*). The objectives of this study were to investigate if there has been a change in biomass of open water fishes on temporal and regional scales in the upper reach of the estuary and if so, to quantify the biological and environmental factors associated with any changes in biomass.

## Methods

Young fish biomass was calculated from catch data provided by the Interagency Ecological Program and Department of Fish and Game's (DFG) San Francisco Bay Study (Bay Study). The Bay Study samples with a midwater trawl on a monthly basis at 19 open water sites upstream of Central Bay (Figure 1). No sampling occurred in 1994. The 14 most abundant fishes (99% of the midwater trawl catch) were used to calculate biomass estimates by the following steps:

- Wet weight in grams (g) of each fish was calculated from fork lengths (mm) using the relationship $W = a{*}FL^b$, which was generated for each species from the DFG Length-Weight Special Study.
- Biomass-per-unit-effort (BPUE) of each species at each station was calculated as: BPUE = (Sum of wet weight (g) /Tow volume ($m^3$) ) * 10,000.
- Wet weight was converted to carbon weight using the ratio: carbon weight (g) = wet weight (g) * 0.15 (Hanson et al. 1997).
- Carbon BPUE + 1 was log-transformed and the mean June-October values were reported.

Outflow data reported by the Department of Water Resources (DWR) was acquired at: http://www.iep.ca.gov/dayflow/index.html. Bivalve data collected by the DWR Environmental Monitoring Program (EMP) benthic study was acquired from: http://baydelta.ca.gov/. Copepod density data was provided by the DFG Zooplankton Study and converted to biomass by use of mean carbon weight (g) estimates developed during the POD Condition and Diet Study (unpublished). All copepods were sampled using a Clarke-Bumpus net with the exception of the smaller *Limnoithona spp.,* which was collected using a pump sample.

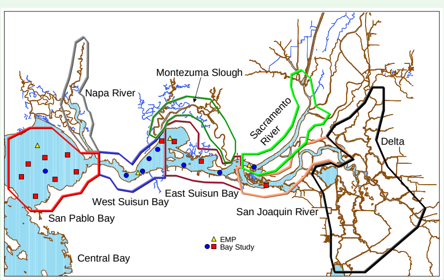


Figure 1. Location of sampling sites in the upper San Francisco Estuary.

## Results

The sum of young fish biomass has declined over time in the low- (0.02-9.99 ppt) and intermediate-salinity (10.0-19.99 ppt) regions of the upper estuary (Figures 2A and 2B), but not in the high-salinity (>=20.0 ppt) region (Figure 2C). Biomass of individual species declined for nearly all fishes with the exception of American shad, which appears to have remained relatively stable. The low- and intermediate-salinity regions are inclusive of a large portion of the upper estuary, including the lower Sacramento and San Joaquin rivers, the western and eastern stretches of Suisun Bay, and San Pablo Bay in high outflow years (Figure 3).

## Results cont.

The trend of decline in biomass of fishes was similar in both low- and intermediate-salinity regions following the introduction of *C. amurensis* in 1987 (Figure 2A and 2B). There appears to be a step decline in fish biomass that began in 1987, with periods of extremely low biomass in 1988-1992 and 2002-2005, which coincide with low summer outflow (Figure 4) and high densities of *C. amurensis* (Figure 5).

The adult copepod biomass composition has changed over time with a decline in calanoid copepods and an increase in the cyclopoid copepod *Limnoithona tetraspina* (Figure 6). The biomass of calanoid copepods of dietary importance to young fishes, including *Eurytemora affinis* and *Sinocalanus doerrii,* declined dramatically following 1987 and *Pseudodiaptomus forbesii* declined during 2001-2005 (Figure 6).

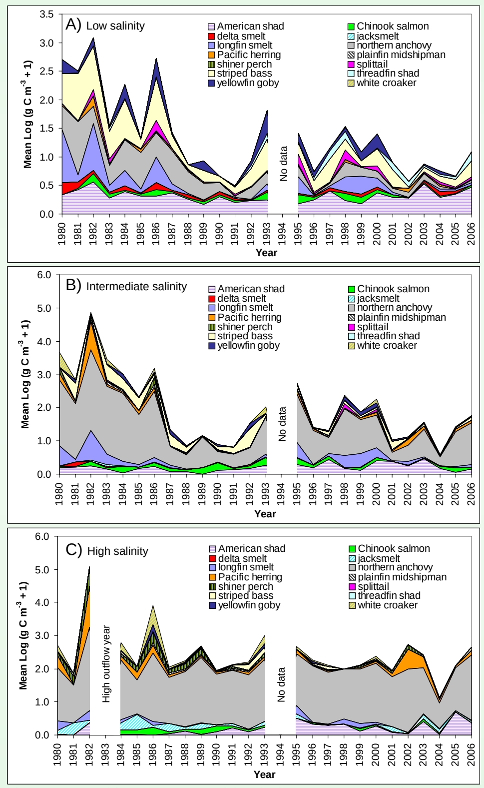


Figure 2. Mean biomass of young fishes in the upper San Francisco Estuary during June-October for three salinity ranges A) 0.02-9.99 ppt, B) 10-19.99 ppt, and C) >=20 ppt. No sampling occurred in 1994.

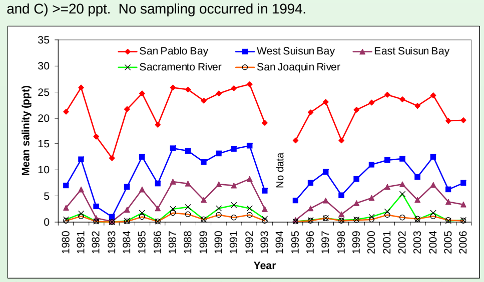


Figure 3. Mean salinity (ppt) in various regions of the upper San Francisco Estuary during June-October. No sampling occurred in 1994.

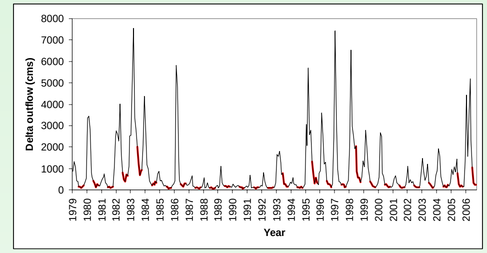


Figure 4. Mean monthly freshwater outflow (cms) during January-December, with June-October months highlighted in red.

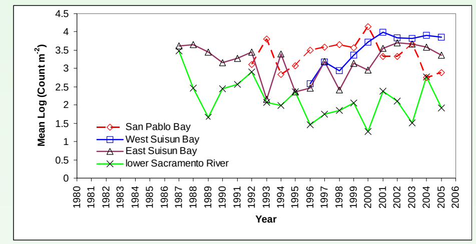


Figure 5. Mean abundance of *Corbula amurensis* in various regions of the upper San Francisco Estuary during June-October. Years sampled vary among regions.

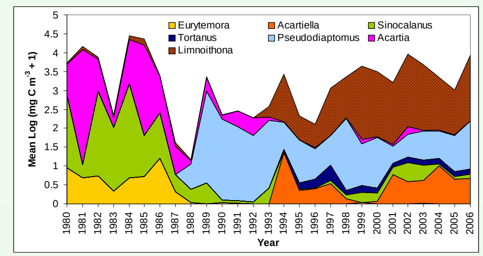


Figure 6. Mean biomass of adult copepods in the upper San Francisco Estuary during June-October.

## Discussion

The biomass of nearly all young fishes in the low- and intermediate-salinity regions has declined, and although total copepod biomass does not appear to have declined, the biomass of calanoid copepod species of dietary importance to young fishes has decreased. These declines have occurred primarily in Suisun Bay and the lower Sacramento and San Joaquin rivers; regions that have historically been productive nursery areas for young fishes. Declines in biomass, most notably for fish in 1988-1992 and 2002-2005, coincide with periods of low outflow and increased densities of *C. amurensis*, which are reported consumers of chlorophyll and copepod nauplii (Kimmerer and Orsi 1996, Kimmerer 2006). This study will continue to investigate the impact of *C. amurensis* densities, copepod composition, and environmental conditions on young fish production, as well as develop biomass trends for demersal fishes in the upper reach of the estuary.

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### References

Hanson, P. C, T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish Bioenergetics 3.0. University of Wisconsin Sea Grant Institute, Madison, WI.

IEP (Interagency Ecological Program for the San Francisco Estuary). 2006. Interagency Ecological Program 2006-2007 Work Plan to Evaluate the Pelagic Organism Decline in the Upper San Francisco Estuary. Available at: http://science.calwater.ca.gov/pod/pod_documents.shtml

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. and J. J. Orsi. 1996. Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam *Potamocorbula amurensis*. Pages 403-424 in J. T. Hollibaugh, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco.

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