DELTA SCIENCE PROGRAM

Sea Grant California

Plankton Dynamics in the Sacramento-San Joaquin Delta: Long-Term Trends and Trophic Interactions

Monika Winder, Delta Science Fellow, UC Davis

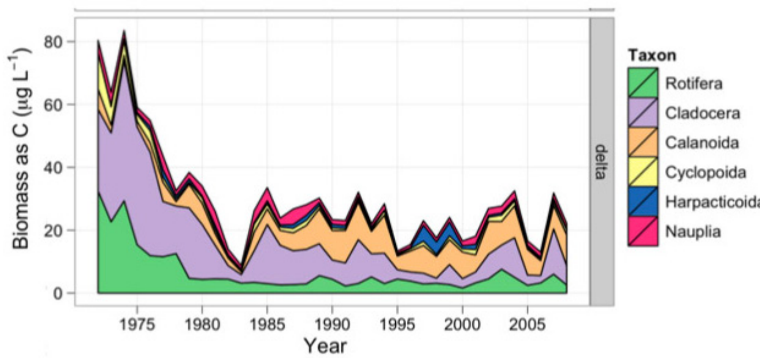
SUMMARY

Based on an analysis of a 37-year time series, zooplankton biomass and species composition appear to have changed profoundly in Suisun Bay and Sacramento-San Joaquin Delta, in response to invasive species introductions and hydrological conditions. Results are consistent with other studies linking a majority of species interactions in the upper San Francisco Estuary to non-native invasions. The Asian clam and several exotic zooplankton species appear to have capitalized, directly and indirectly, on the long drought from 1987 to 1994 and exacerbating water management practices. During this period of sustained high-salinity conditions, larger native copepods – the preferred prey of larval fishes – were replaced by smaller Asian zooplankton, notably *Limnoithona tetrapsina*, likely introduced via ballast water. In addition to the new species, total zooplankton biomass dropped significantly during the last four decades; however, the pace and timing of the decline does not explain the sudden collapse of pelagic fishes around 2002. While the shear abundance of smaller non-native zooplankton appears to have offset the loss of biomass from larger native zooplankton, it is plausible, even likely, that the new plankton community has degraded food quality for larval fishes. The Delta Science Fellow is currently exploring this idea and its link to larval fish survivorship.

PROJECT

Data analyzed for this study come from an unusually complete time series (1972-2008) of zooplankton and water quality collected by California Department of Fish and Game as part of Interagency Ecological Program for the San Francisco Estuary. For the purposes of this study, station data were acquired from 13 sites and grouped into two regions: downstream Suisun Bay (7 stations) and upstream Sacramento-San Joaquin Delta (6 stations).

Total zooplankton biomass and percent abundance by species were calculated for the bay and delta and plotted to document temporal trends, and their relation to other environmental variables such as salinity, flow rates and phytoplankton abundance. Because of the abrupt shift in zooplankton community structure from 1987 to 1994, zooplankton abundance and species composition were compared before and after the long drought. Another analysis focused on total zooplankton carbon before and after the "pelagic organism decline" in 2002.



Zooplankton biomass (excluding mysids) in the delta for major taxonomic groups. Credit: M. Winder

Because zooplankton themselves feed on phytoplankton, the fellow also looked at differences in availabilities of high-quality phytoplankton (diatoms) and low-quality microbial phytoplankton (flagellates and cyanobacteria) over time and in relation to proliferation of the Asian clam, a suspension feeder that competes with zooplankton for food.

The San Francisco Estuary has experienced many droughts in the past, and yet until the 1970s, these did not coincide with new zooplankton invasions. Another component of this project was to study relationships between species invasions and droughts, and mechanisms linking invader success with climatic and hydrological states.

RESULTS

Total zooplankton biomass showed high interannual variability and significant declining trends in both bay and delta regions. In the bay, total zooplankton biomass declined between 1972 and 1994 from about 30 to 10 µg C L−1 (micrograms carbon per liter) and recovered thereafter to about 20 µg C L−1; in the delta, zooplankton biomass dropped from approximately 60 µg C L−1 in the 1970s to 20 µg C L−1 after the early 1980s.

Mysids, historically a dominant part of the pelagic food web, dropped more than tenfold and their biomass comprised less than 4% of total zooplankton after 1994. In the bay, populations of larger copepods (calanoids and rotifers) declined abruptly in 1992 from 60% to less than 30% of total zooplankton biomass (excluding mysids).

In contrast, between 1972 and 2008, the biomass of introduced Limnoithona spp. increased about 11% annually in the bay, and 5% annually in the delta.

The overall pattern that emerges is the replacement of the historically dominant copepod species by newly introduced species. Some numbers highlight this: the native Eurytemora spp., Acartia spp., and Diaptomus spp. reached average annual biomasses in the bay of 4.9, 1.9, and 3.4 µg C L−1 respectively before the drought; from 1995 to 2008, their biomasses dropped below 0.9 µg C L−1 in both bay and delta, and the introduced *Pseudodiaptomus forbesi* and Acartiella spp. reached biomasses of 6.9 µg C L−1 in the delta.

From 1972 to 2009, there were 16 dry and 22 nondry years; all zooplankton invasions occurred in eight years, seven of which were dry. The high prevalence of invasion under dry conditions is believed to be at least partially related to the high salinities that prevail during these times.

The benthic grazing Asian clam (*Corbula amurensis*) proliferated during the long drought, and the fellow reports that the profound shift in crustacean zooplankton was mainly driven by the clam's population explosion in the 1980s. Chlorophyll-a concentrations dropped below 10 µg L−1 during this time, and zooplankton have likely been chronically food-limited since. The clam also consumes larval copepods, not just competing with but also directly reducing their numbers.

Further contributing to invasion success, and perhaps explaining patterns of zooplankton invasion, is the fact that the major dams on the Sacramento River were not completed until 1968. Dams and freshwater diversions both intensify drought-associated high-salinity conditions. The rise of international ship traffic in recent decades has also exposed the estuary to a continuous pulse of non-native species. The fellow reports that these factors and others likely precondition the estuary for a proliferation of exotics during dry years and can partially explain why exotic zooplankton were not documented in the upper estuary until the 1970s, when dams, water diversions and exposure to invasive species were all in play simultaneously.

MANAGEMENT APPLICATIONS

Zooplankton are an important trophic link to the upper food web and a key food for larval fishes in the San Francisco Estuary. Declines in populations of delta smelt, longfin smelt, striped bass and threadfin shad are believed to be largely attributable to poor survival and growth of larval and juvenile fish. The analysis presented in this project shows that there have been substantial declines in total zooplankton, and even greater declines in the preferred zooplankton prey (native copepods and mysids) for larval fishes over the last several decades. Overall, the food chain in the estuary is becoming progressively more reliant on the microbial food web (i.e., bacterial carbon), which is believed to be a lower-quality food for higher organisms.

Interestingly, since 1995 there have been no new zooplankton invasions in the upper estuary. A possible reason for this may be the 2000 regulation requiring ships entering California ports to exchange their ballast water at sea. The prevalence of well-established exotic zooplankton may also hinder would-be invaders. Perhaps most significantly, flow anomalies in the estuary have been somewhat muted in the last decade, as indicated by salinity measurements.

PUBLICATIONS

Winder M, Jassby AD, Mac Nally R (2011) Synergies between climate anomalies and hydrological modifications facilitate biotic invasions. *Ecology Letters*: doi: 10.1111/j.1461-0248.2011.01635.x.

Winder M, Jassby AD (2011) Shifts in zooplankton community structure: Implications for food-web processes in the upper San Francisco Estuary. *Estuaries and Coasts*. 34: 675-690. Recommended by Faculty of 1000 Biology

RESEARCH MENTORS

S. Geoffrey Schladow, Tahoe Environmental Research Center, UC Davis and Alan Jassby, John Muir Institute of the Environment, UC Davis

CONTACT

Monika Winder, Research Ecologist, Tahoe Environmental Research Center, UC Davis, mwinder@ucdavis.edu

Delta Science Fellow Monika Winder. Credit: UC Davis

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This publication is sponsored by a grant from the Delta Science Program, part of the Delta Stewardship Council, and is based on research findings from project R/SF-36. The views expressed herein are those of the authors and do not necessarily reflect the views of the Delta Stewardship Council or any of its sub-programs. This document is available in PDF on the California Sea Grant website: www.csgc.ucsd.edu. California Sea Grant, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, Dept. 0232, La Jolla, CA 92093-0232
Phone: 858-534-4440; Email: casgcomms@ucsd.edu