Changes in Phytoplankton Community Composition and Biovolume during Prolonged Drought

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Phytoplankton are an important component of the San Francisco Estuary, comprising the base of the food web and sometimes forming nuisance blooms. Their community composition can vary widely under differing flow and nutrient conditions. Phytoplankton biovolume and biomass as chlorophyll-*a* represent what is directly available for consumption by higher trophic levels, and can vary by orders of magnitude among different taxa. DWR's Environmental Monitoring Program collects phytoplankton samples monthly to track changes in phytoplankton community and biomass. During the recent drought, the phytoplankton community in the Delta and Suisun Bay shifted dramatically to one dominated by small-celled cyanobacteria, considered a poor food source for zooplankton. Biovolume, however, varied widely between sites and years, with some large taxa such as diatoms representing over 50% of the biovolume but less than 10% of the organisms per milliliter. Possible reasons for these changes include changes to nutrient concentrations, fluctuations in temperature, and long residence times due to decreased flow.

Statement of Relevance: Drought is becoming the new normal for California and for the San Francisco Estuary in particular. Ongoing, multi-year droughts require understanding of how these conditions affect the phytoplankton community so that management tools can be developed to minimize nuisance blooms while maintaining a productive food web.

Keywords: phytoplankton, drought, community composition, biomass, biovolume
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The Impact of Two Years of Successive Drought on *Microcystis* Blooms in San Francisco Estuary

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Future climate change is expected to increase the frequency and intensity of drought in California and associated toxic cyanobacteria blooms in San Francisco Estuary. The droughts in 2014 and 2015 were the third and fourth most severe drought years in San Francisco Estuary, and provided the opportunity to test the hypothesis that successive drought years create environmental conditions that promote larger and more toxic *Microcystis* blooms in the estuary, than a single drought year. Field samples were collected at 10 stations semi-monthly during the bloom season in 2014 and 2015. Physical, chemical and biological factors were measured using a combination of YSI sonde and laboratory analyses of water samples. *Microcystis* colonies were quantified by surface net tow and their growth rate was measured by carbon uptake. Nitrogen sources were determined using stable isotope concentration and diffusion studies. Contrary to expectations, the more severe drought in 2015 was not associated with a larger *Microcystis* bloom than in 2014. Median chlorophyll *a* concentration for all stations was three times greater in August and September in 2014 than 2015. Most physical and chemical conditions and processes in the water column were similar in 2014 and 2015, including the presence of excess nutrients and use of ammonium as the primary nitrogen source. The difference in bloom magnitude between years was most closely associated with changes in the seasonal variation in streamflow and water temperature. Elevated water temperature extended the duration of the bloom into December in 2014, but only into October in 2015. Relatively high primary producer growth rate, in combination with low inflow and agricultural export, also enhanced the accumulation of bloom biomass more in 2014 than 2015. Knowing how drought impacts toxic cyanobacteria blooms can lead to better management of fishery resources in San Francisco Estuary.

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The Effect of Drought on Smelt: The Long-Term Ecological Response of Native Smelt in the San Francisco Estuary

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Problem Statement: In the San Francisco Estuary, two native osmerids, the Delta Smelt (*Hypomesus transpacifics*) and the Longfin Smelt (*Spirinchus thaleicthys*), have experienced population collapse, garnering significant attention by managers and spurring largescale ecological studies to determine the causes of decline. Approach: In this paper we examine the potential effects of drought on distribution, abundance and life history responses to gain a better understanding of how environmental variability influences the population response of these endangered fish. Results: Since the early 2000's we've documented changes in freshwater flows, temperature and food abundance for these fish. Concomitantly, we've observed a phenological shift in the spatial and temporal distribution, reduction in growth rates and declines to near zero abundance in recent monitoring surveys. Conclusions: Delta Smelt and Longfin Smelt respond rapidly to episodic drought conditions in the estuary, experiencing slower growth during the critical juvenile lifestage and poor recruitment success. Long-term trends suggest symptoms of an ecological syndrome is occurring, which is likely related to climate change. Significant changes to the management of freshwater flows is needed to provide population resilience to avoid extinction.

Keywords: Delta Smelt, Longfin Smelt, Drought, Climate Change, Extinction, Flow, Phenology
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Evidence of Regime Shift and Drought Impacts in the Sacramento-San Joaquin Delta Littoral Fish Community

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Various estuarine and freshwater ecosystems worldwide have undergone substantial changes in their ecological community due to multiple stressors that are often anthropogenic in origin. Over the past two decades, the Sacramento-San Joaquin Delta (Delta) saw a severe decline in pelagic fishes, a shift in zooplankton species composition, and rapid expansion of invasive aquatic vegetation. To evaluate whether major changes have also occurred in the littoral fish assemblage, we analyzed beach seine survey dataset collected regularly from 1995 to 2015 from 26 sites within the Delta. We examined changes in the littoral fish assemblage at three different ecological levels: species, community, and biomass, using clustering analysis, trend tests, and change-point analyses. We found that the annual catch for many introduced species and some native species have increased since 1995, while only a few have experienced decline. A consistent pattern of change over time in annual species community composition was also observed; a pattern which was primarily defined by a consistent increase in Centrarchid species abundance. However, the amount of freshwater input to the Delta also helped explain some of the interannual variation. Drought years were characterized by increased numbers of Mississippi Silverside *Menidia audens* and reduced catch of native cyprinid fish species such as the Sacramento Splittail *Pogonichthys macrolepidotus*. Lastly, we demonstrated that littoral fish biomass has essentially doubled over the 21-year study period, with Mississippi Silverside and the Centrarchidae family driving most of this increase. Overall, our results showed that drought years favor invasive species to the detriment of native species, and that a regime shift has occurred in the Delta littoral fish community. Furthermore, they indicated that the factors causing the decline in the pelagic food web could have been beneficial to the littoral community productivity.

Keywords: Regime Shift, Fish Community, Biomass, Time Series, Drought
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Winter-Run Chinook Salmon Responses to Drought: Impacts on Population Viability Criteria

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The effects of the 2014-2016 drought on viability of Winter-run Chinook Salmon (WRCS) is of intensive concern to agencies and stakeholders. During this period, unprecedented hydrometeorological challenges forced multiple temporary changes to CVP/SWP operational plans and state and federal regulations protecting environmental qualities and ESA-listed species. We performed a review of monitoring data from the Sacramento River and Bay Delta to evaluate the effects of the drought on the viable salmonid population criteria of WRCS. When reliable monitoring data were available, analyses were based on predictions from a conceptual model of drought operations and impacts on WRCS. By linking monitoring data with hypothesized mechanisms causing biological response, we integrated the droughts impact across life stages and habitats into a clearer picture of the plight of WRCS. We assessed various metrics for consideration of impacts from the drought's environmental and management drivers for brood years 2007 through 2012, between Water Year (WY) 2008 and 2013, of WRCS. We compared these years' measures with regard to the environmental conditions and operational events in their freshwater and estuarine life stages with similar measures from Brood Year (BY) 2013-2015 to determine if the salmon population was affected by the drought and management actions implemented during the drought period. Compilation of monitoring data showed measureable metrics reflecting abundance, distribution, and diversity were affected through the drought period and the degradation of these criteria will have consequences of the population's viability. A reduction in viability accelerates the need for greater management intervention to reduce endangerment of Winter-run Chinook Salmon.

Keywords: salmon, drought, temperature, outflow, viability criteria, monitoring, water operations
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