Microcystis Drought Response Program Collaborative Research Summary

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Cyanobacteria blooms are often toxic and affect the health and survival of aquatic species in the San Francisco Estuary and are expected to increase with the increased frequency and intensity of droughts associated with climate change in California. The 2014 and 2015 droughts provided an opportunity to test the hypothesis that the amplitude and toxicity of *Microcystis* blooms will increase with successive years of drought. As a part of the California Drought Response Program, a suite of studies were conducted in 2014 and 2015 to characterize the blooms, determine causal factors and identify biological community impacts. This poster summarizes the collaborative field and laboratory research conducted by researchers at the California Department of Water Resources, University of California at Davis, San Francisco State University, California Maritime Academy and the University of Georgia. Research included quantifying the magnitude, toxin concentration, growth rate, nitrogen sources, fish toxicity, and biological community impacts of the *Microcystis* blooms in 2014 and 2015.

Keywords: Cyanobacteria, *Microcystis*, toxin concentration, nitrogen sources, biological community impacts

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

Sampling and Analyses Conducted for the 2014 and 2015 *Microcystis* Drought Response Program

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The severe drought in 2014 and 2015 provided favorable conditions for blooms of the toxic cyanobacteria harmful algal bloom (CHAB) species, *Microcystis aeruginosa*. As part of the *Microcystis* Drought Response Program, a study was conducted semi-monthly from July to December in 2014 and August to November in 2015 at ten stations located in the central and south delta of the San Francisco Estuary. The objective of the study was to measure the impact of drought conditions on the toxin production and abundance of *Microcystis,* as well as physical, chemical and biological conditions in the Delta ecosystem. *Microcystis* and zooplankton mass were collected with net tows, and the samples were identified and enumerated using a Flowcam, a digital imaging flow cytometer. Physical and chemical properties of the surface water were measured at each station using a YSI water quality sonde, and subsurface irradiance was measured with a LiCOR quantum sensor. Surface water samples were also collected for nutrient and suspended solids concentration, cyanobacteria toxins, DNA, and isotope analyses. The study is significant as water quality conditions and the phytoplankton communities in the Delta are likely to be impacted by more frequent and severe drought conditions.

Keywords: *microcystis*, drought, toxin, cyanobacteria bloom

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

The Impact of Successive Drought Years 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 the history of 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 alone. Field samples were collected at 10 stations every other week 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 for toxin, chlorophyll *a*, nutrient, phytoplankton taxa and suspended sediment concentration. *Microcystis* colony biomass on the surface of the water column was measured 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.

Keywords: cyanobacteria, *Microcystis,* drought, climate change, blooms

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

Rates of Primary Production for the 2015 *Microcystis* Bloom in the San Francisco Estuary

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The goal of the 2015 *Microcystis* Drought Response Program was to assess the amplitude, duration and toxicity of Delta *Microcystis* blooms as well as gain insight into potential impacts of *Microcystis* on water quality associated with multi-year drought conditions. As part of this study, we measured primary production twice monthly from August to November at 10 stations throughout the Delta, where *Microcystis* has historically been abundant. Water quality parameters including light attenuation were measured at all stations. Near-surface water samples were inoculated with ^{14}C labeled bicarbonate and incubated for 24 hours at four light levels (50, 25, 10 or 5% of surface irradiance). Primary production (PP) rates were calculated as 1) light saturated (i.e., PP at 50% of surface irradiance), 2) biomass-specific (i.e., normalized to chlorophyll-a) and 3) depth–integrated through the photic zone. Depth-integrated PP was highest at stations located in the southeastern Delta (Rough and Ready Island, Old River, Mildred Island, San Joaquin River, Victoria Canal) compared to stations in the western Delta (Antioch, Browns Island, Collinsville, Franks Tract and Jersey Point). The difference likely reflects more favorable irradiance conditions that were found in the southeastern Delta. Light-saturated and biomass-specific PP were also generally higher in the southeastern stations and may too reflect adaptations to higher light conditions or differences in species composition. Taken together, these results suggest that differences in algal carbon physiology influence patterns in algal biomass during drought conditions. The rates presented will help inform future drought management.

Keywords: *Microcystis*, Primary Production, Drought, Water Quality,

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

Abundance of Key Cyanobacteria Species and Cyanotoxin Concentrations during Severe Drought Years, 2014 and 2015

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Cyanobacteria, also known as blue-green algae, are photosynthetic aquatic microorganisms of major public health concern due to the deterioration of water quality through the production of toxic and odorous chemicals. Various cyanobacterial species flourish in warm water, therefore elevated water temperature due to drought could provide favorable conditions for *Microcystis* and other harmful cyanobacterial species to thrive. Despite the deleterious effects of cyanobacterial harmful algal blooms (CyanoHABs) on human and aquatic environments, field data are still limited and little is known about how drought conditions may alter cyanobacterial species assemblages and their abundances in the Sacramento-San Joaquin Delta. To better understand the effect of drought conditions to CyanoHABs in the Delta, we measured the abundance of three cyanobacterial species (*Microcystis*, *Aphanizomenon* and *Anabaena*) by qPCR and their associated cyanotoxin concentrations using enzymatic and immunological assays in the summers of 2014 and 2015, record severe drought years. Our results indicate that the abundance of cyanobacteria, particularly *Microcystis aeruginosa*, was extremely high in the summer of 2014. Interestingly, the abundance of total cyanobacteria, including *M. aeruginosa,* was significantly lower in 2015 compared to 2014 even though the basic water quality parameters, including water temperature, were generally similar in both years. Other potential cause(s) contributing to the differences in the cyanobacteria species abundance between 2014 and 2015 will be discussed.

Keywords: Drought, Cyanobacteria, Abundance, qPCR, Cyanotoxin

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

2014 and 2015 Critical Drought Effects on Zooplankton Composition during *Microcystis* Blooms

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In 2014 and 2015 California experienced two of the driest years on record, resulting in increased residence times and water temperatures in the San Francisco Estuary. Such conditions are favorable for cyanobacterial harmful algal blooms (CHAB), including *Microcystis aeruginosa*, a known toxic cyanobacteria. A drought response study investigated the distribution, abundance, genetic composition, toxin production and food web impact of *Microcystis* spp. in the San Francisco Estuary. The goal of this study was to compare the abundance and distribution of key zooplankton taxa as it relates to *Microcystis* spp. blooms during the critical drought years of 2014 and 2015. *Microcystis* spp., zooplankton, water quality, and ambient water samples were collected biweekly from ten stations in the San Francisco Estuary from July to December in 2014 and August through November in 2015. Zooplankton samples were preserved in 70% ethanol and were identified by taxa and enumerated for biomass using a FlowCAM digital imaging flow cytometer. For both drought years, copepod and cladoceran species were the most abundant zooplankton during the CHAB. Sites along the inner delta yielded the highest biomass and diversity of zooplankton. As an effect of global climate change, the frequency and intensity of drought is expected to increase in California. The findings are significant because prolonged droughts are likely to change water quality conditions, increase CHABs, and ultimately cause adverse impacts on the Sacramento-San Joaquin aquatic food web.

Keywords: Drought, Zooplankton, *Microcystis*, Harmful Algal Blooms, Food Web

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research

Characterizing Biodiversity and Relative Abundance of Cyanobacteria by Shotgun Metagenomic Sequencing Analysis

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Harmful cyanobacteria blooms are ubiquitous around the world and are of global concern due to their ability to produce toxins, which are known to cause cancers in wildlife and humans. Drought conditions and overall global temperature increases provide favorable growing conditions for toxic cyanobacteria, causing these blooms to become more frequent and intense. However, little is known about the biodiversity of cyanobacteria assemblages and their toxicity in drought conditions in aquatic ecosystems. To address this gap in knowledge, we evaluated the biodiversity of cyanobacteria as well as other microscopic organisms in the Sacramento-San Joaquin Delta by shotgun metagenomic sequencing analysis. Data from this analysis detected over 30 genera of cyanobacteria, *Microcystis* spp. being the most dominant genus. This data also demonstrated the first appearance of *Anabaena circinalis*, a possible neurotoxin producer, in the San Joaquin River in 2014 a year of serious drought. A characteristic geographical pattern was observed amongst the sampling sites; *Microcystis* and other cyanobacteria were dominant at the three sampling stations in the confluence (Antioch and Collinsville) and Franks Tract while bacteria accounted for over 50% at Mildred Island and San Joaquin River. Interestingly, the highest percentage of phytoplankton and zooplankton was observed at Rough 'n Ready, suggesting the site is more productive than the other locations. Our results indicate that shotgun metagenomic sequencing analysis is a powerful tool to understand biodiversity and relative abundances of wide range of aquatic organisms.

Keywords: Cyanobacteria, Bacteria, Biodiversity, Abundance, Functional Analysis, Metagenomics

Poster Cluster: *Microcystis* Drought Response Program Collaborative Research