Sea Grant California

What controls harmful algal blooms and toxicity in the Sacramento-San Joaquin Delta?

Cécile Mioni, Delta Science Fellow from 2008-2011, UC Santa Cruz

SUMMARY

This project shows that harmful algae like it hot. All things being equal, surface water temperature is the best predictor of whether a harmful algal bloom will form in the Sacramento-San Joaquin Delta, though flow dynamics, nutrient pollution and microbial associations also may play a role.

RELEVANCE

Harmful blooms of cynobacterial algae are becoming more common and more intense all over the world, including the San Francisco Estuary, to the extent that cyanobacterial poisoning has been implicated in human and animal illness and death in 36 states in the U.S., including California.

In the San Francisco Estuary, the dominant bloom-forming algae since 1999 has been a group of cyanobacteria known as Microcystis, which produce microcystins.

Microcystins are nasty compounds. At acute doses, they can cause liver failure and death. At chronic low doses below the World Health Organization's 1 microgram per liter (mg/L) threshold for drinking water, they may promote liver cancer, and possibly colon cancer.

While water treatment facilities may remove cyanobacterial toxins, crops may be irrigated with untreated water. There is a documented case of a beet field in Oregon dying after being sprayed with contaminated water. It is also known that microcystin is very stable (resisting both freezing and boiling) and can persist on produce for several weeks.

Surveys of drinking water reservoirs in California show that cyanobacterial toxins are diluted to non-detectible levels; however, continued human-induced stress on the delta, combined with warming and other impacts from climate change, could result in yet more frequent and more toxic blooms. This will likely have consequences for people and ecosystems.

In 2011, a new kind of bloom was detected in the Delta – the filamentous cyanobacteria Aphanizomenon. The round cells in the net are Microcystis. Credit: Cécile Mioni

Former Delta Science Fellow Cécile Mioni collects samples of a massive algal bloom in 2009 in the Sacramento-San Joaquin Delta. Credit: April Hennessy

PROJECT

The major goals of this project were to identify what seeds, triggers and fuels harmful cyanobacterial blooms in the eastern San Francisco Estuary, where the Sacramento and San Joaquin rivers join and freshwater is diverted for drinking water and irrigation.

Ultimately, scientists hope to be able to predict toxic blooms, including the species of algae that will dominate, based on environmental parameters already monitored in the delta. Predictive models would improve managers' ability to respond to and mitigate blooms, and reduce their particular threats to public health, water quality and wildlife.

METHOD

Water samples were collected monthly from September 2008 to December 2009 at 21 stations in the delta that are part of existing monitoring programs. Eight stations were monitored in the summer of 2010 and 2011, with additional support from the Delta Science Program and the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP).

Samples were tested for algae cell abundances and toxin concentrations. Nutrient levels, salinity, water clarity, irradiance, water temperature, and water residence time (flow) were also measured, as all may contribute to bloom formation.

RESULTS

A bloom of *Microcystis aeruginosa* was observed in 2009 but not the following summer, making 2010 the first "no bloom" year in the delta since the toxigenic algae were first detected in 1999.

Although there are no formal regulations in the U.S. for safe microcystin toxin levels in drinking water, the WHO's 1-mg/L advisory limit was exceeded in water samples collected from six stations during the 2009 bloom.

Levels of the liver-damaging toxin exceeded 5 mg/L at Antioch Bridge and Rancho del Rio at the bloom's peak in August. Notably, these elevated levels remained below the EPA's recreational water-contact exposure limit of 8 mg/L.

Analyses suggest temperature was the main "driver" of the bloom, as 2009 was a moderately strong El Niño year, and water temperatures were warmer than usual in the delta. Water temperatures dropped the following summer as the El Niño was replaced by the first strong La Niña episode since 1999. The theory is that the cold event suppressed algal growth.

Modeling suggests that a temperature threshold of 20ºC exists for the delta, above which blooms suddenly become more likely and intense. According to results from this project, the likelihood of a bloom increases from 10% to 50% when ambient surface water temperatures climb from 20ºC to 25ºC.

In the summer of 2011, another harmful algal bloom formed, as weakened La Niña conditions persisted. Much to the surprise of the scientists, a new kind of blue-green algae flourished, the saxotoxin-producing filamentous *Aphanizomenon flos-aquae*. (Saxotoxins are sodium-channel-blocking neurotoxins that accumulate in fish and shellfish, causing "paralytic shellfish poisoning.") Microcystis was detected at low levels only.

Since temperature alone cannot explain the species shift, the scientists involved in this project are exploring other explanations. One is based on the observation that concentrations of ammonia (a source of nitrogen) were lower than usual in 2011. Since Aphanizomenon is able to "fix" nitrogen from the atmosphere, while Microcystis cannot, Aphanizomenon may have outcompeted it under the relatively nutrient-poor conditions.

Ammonia levels overall – it should be noted – have more than doubled in some parts of the delta in the last two decades and may be connected to changes in the delta's food-web dynamics.

NEXT STEPS

The former Delta Science Fellow, Cécile Mioni, now a researcher at UC Santa Cruz, is currently working with Alex Parker, a marine microbial biogeochemist at the Romberg Tiburon Center, to explore why Aphanizomenon dominated in 2011. Were nutrient-poor conditions to blame? Or, was it because of the flip-flop in ocean conditions associated with El Niño and La Niña? Has there been some other shift in the delta? The first six months of 2012 have been warmer than normal, and if the warming continues into the summer and fall, it will allow them to further test and refine the hypothesis that temperature controls Microcystis blooms.

Mioni is also collaborating with UC Santa Cruz phytoplankton biologist Raphael Kudela to study the spatial and temporal (time) variability of toxin concentrations. Researchers have theorized that there are "seeding" grounds in the delta, where blooms form and are dispersed. Though this idea was not directly investigated during the Delta Science project, toxins level were observed to more than double, at a single site, over periods as short as a few hours. Algae cell counts could not explain the change. The scientists will be deploying an "artificial mussel" technology, known as SPATT (Solid Phase Adsorption Toxin Tracking), to record cumulative toxin exposure at a location.

With USC microbial chemist Sergio Sanudo-Wilhelmy, Mioni is also investigating the role of microbial symbiosis in regulating toxin production and algal cell growth in Clear Lake, Calif., the state's largest freshwater body. Microcystin contains a methane group, obtained from the amino acid methionine. Methionine contains cobalt and B12, which is produced only by bacteria. The scientists speculate that methionine and cobalt may be limiting compounds for microcystin synthesis and that microbial symbionts may help algae obtain the compounds they

RESEARCH MENTOR

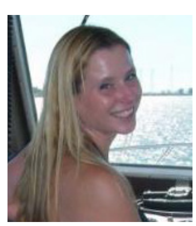
Adina Paytan, UC Santa Cruz

COMMUNITY MENTOR

Anke Mueller-Solger, Interagency Ecological Program

REPORT

Mioni, C.E., Kudela, R.M., Baxa, D. (2012) Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). Surface Water Ambient Monitoring Program (10-058-150). Final Report, March 31, 2012.



CONTACT

Cécile Mioni
UC Santa Cruz
T. 541-515-0425
E. cmioni@ucsc.edu

Sea Grant California

Delta Stewardship Council

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-35. 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

June 2012