



CALFED Progress Report
California Sea Grant College Program

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 TypeQuestionnaire_2B Interim Report

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Project Information

ProjectNo_2C R/SF-35 StartDate_3a 9/01/2010 EndDate_3b 2/28/2011
 ProjectTitle_4 Environmental Controls on the Distribution of Harmful Algae and Their Toxins
in San Francisco Bay, California

CALFed Fellow contact information

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Additional Research Mentors and Community Mentors

Additional Research Mentors_8

Dr. Raphael Kudela (UCSC).....
 Dr. Mary Silver (UCSC).....

Additional Community Mentors_9

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Project Objectives: Please type your responses, and answer the questions in a style appropriate for laymen.

ProjectObjectives_10

The major goals of this project are to elucidate the role of physical (temperature, light, turbulence, salinity, hydrodynamics), chemical (inorganic and organic nutrients, dissolved organic carbon, trace metals) and biological (phytoplankton abundance) drivers on the distribution, growth, and toxicity of harmful algae in SF Bay and to enhance our understanding of the relationships between these parameters and the occurrence and consequences of HABs. This information will aid in predicting and mitigating HAB events in the future.

Research is guided by the following motivation:

A combination of environmental factors (biotic and/or abiotic) has precluded toxic blooms from occurring frequently in SF Bay despite their prevalence in the adjacent coastal ocean. Future anthropogenic or natural climatic changes in the Bay (particularly warming and water stratification) may alter this unique situation resulting in more frequent blooms and negative impacts on human and ecosystem health.

We believe that determining the combination of parameters that enhance seeding, growth and toxicity of harmful algae in this system can be used to predict and prevent HABs from occurring and will serve as an important tool for managers and regulators. Our ultimate goal was to establish a baseline of conditions in the Bay and to determine the stressors controlling growth and toxicity in the natural population of harmful algae with a special focus on the cyanobacterium *M. aeruginosa*.

Summary of progress in meeting each of these goals and objectives

ProgressSummary_11

In an effort to characterize the harmful algae distribution, toxicity and their origins, we monitored 21 stations throughout the San Francisco Estuary from September 2008 to December 2009 in collaboration with preexisting monitoring programs (USGS water quality from South Bay to the Sacramento River, DWR Environment Monitoring Program in the Delta). We also monitored 8 stations in the Delta over summer 2010. Surface water samples were collected monthly to determine: total toxins (Saxitoxins, Domoic Acid, Microcystins), algal composition and abundance, nutrients (ammonia, nitrate+nitrite, phosphate), dissolved organic carbon, and trace metals.

****Amnesic Shellfish Poisoning (ASP)****

Low concentrations of domoic acid were detected in the surface waters of the San Francisco estuary throughout the study period except in June 2009. Elevated concentrations of ASP toxins (>0.3ug/L) were detected at 5 stations located from South Bay (USGS 24) to San Pablo Bay (USGS 13). At the northern stations (Delta) the levels of these toxins were below detection limit. Preliminary results suggest that these increased concentrations were not endemic to the SFBD but rather associated to the intrusion of offshore oceanic waters inside the Bay. Indeed, this elevated ASP toxins levels coincided with a Pseudo-Nitzschia outbreak in the Monterey Bay which resulted in the death of many sea lions (Melissa Miller, pers. com.). Offshore Pseudo-Nitzschia blooms may have been favored by large scale forcing such as El Nino/winds upwelling relaxation (Kudela et al. 2004).

****Paralytic Shellfish Poisoning (PSP)****

Low concentrations of saxitoxins were detected in the surface waters of the San Francisco estuary throughout the study period except in August 2009. Elevated concentrations of PSP toxins were detected in central Bay (station USGS 18 > 0.3 ug/L, Station USGS 21 > 0.2 ug/L August 09) and in San Pablo Bay (station USGS 13 > 0.2 ug/L). At the northern stations (Delta) the levels of these toxins were below detection limit (<0.02ug/L). Preliminary results suggest that these increased concentrations were associated to the intrusion of offshore oceanic waters inside the Bay. Indeed, on the West coast, PSP outbreaks typically initiate with the increase of *A. catenella* in offshore waters followed by onshore transport during relaxation-favorable winds (Anderson et al. 2008, Langlois & Smith 2001). Offshore dinoflagellate blooms may have been favored by several consecutive days of warm weather, stratified water and large scale forcing (El Nino/winds upwelling relaxation, Anderson et al. 2008).

**** Microcystins ****

We monitored a bloom of *Microcystis aeruginosa* in the San Francisco estuary during Summer/Fall 2009. High levels of Elevated concentrations of the cancer-promoting toxin, Microcystin, were detected at most stations of the San Joaquin delta from July to September 2009. The level of Microcystins exceeded the World Health Organization advisory limit for drinking water (1ug/L) at most stations, the highest concentrations being recorded at Old River (5.89ug/L) and Antioch Bridge (6.46ug/L) during the month of August. These elevated toxin concentrations were comparable to that detected in October 2008 (Old River station: 5.81ug/L). These levels are 3 orders of magnitude higher than that previously reported for the same study area (Lehman et al. 2008, 2010). All our

samples with elevated levels of total microcystins were sent for validation to an independent lab (Dave Crane, Department of Fish and Game) and analyzed by LC/MSMS. No Microcystis bloom was observed and no toxins were detected in surface water samples collected during Summer 2010.

PROJECT MODIFICATIONS: Please explain any substantial modifications in research plans, including new directions pursued. Describe major problems encountered, especially problems with experimental protocols and how they were resolved. Describe any ancillary research topics developed.

Modifications_12

Due to funding issues, no samples were collected between January 2010 and June 2010. We also decided to focus our efforts on the Delta stations over the summer 2010.

The methodology for the taxonomy analysis of my samples was modified with the guidance of Dr. Kudela and Dr. Silver. Different methods are being applied to identify the different harmful algae of interest. Microcystis aeruginosa cells were enumerated from raw surface water samples preserved with 4% formaldehyde and counted using a Zeiss Axioplan epifluorescence microscope. Phycoerythrin and Chl a were used to visualize Microcystis cells by epifluorescence microscopy using green excitation (Zeiss filter set 20, excitation 546-nm bandpass, and emission 575-640-nm bandpass filters) and a 40x objective.

BENEFITS AND APPLICATIONS: Suggest the relevance of these new findings to management. Describe any accomplishment, that is significant effects your project has had on resource management or user group behavior. CALFED is looking for "management cue" (see <http://science.calwater.ca.gov/pdf/soemgmtcues.pdf>).

BenefitsApplic_13

High risk levels of Microcystis and Microcystins were reached at several stations in the Delta during summer 2009. The concentrations of cancer-promoting microcystin exceeded (over 5 times higher) the World Health organization advisory limit for drinking water but remained lower than the advisory limit for recreational water ($\leq 8 \mu\text{g/L}$). Comparative analysis between summer 2009 (Microcystis bloom) and summer 2010 (no bloom) suggests that surface water temperature was the main driver of Microcystis bloom in the Delta. Our logistic modeling results suggest that the probability of Microcystis bloom increases from 10% to 50% when surface water temperature increases from 20C to 25C. Indeed, our findings suggest that global warming could result in an increase in the frequency and amplitude of this toxic cyanobacterium in the Delta. Our results do not indicate that nutrient loading has a significant impact on Microcystis growth and toxicity within this system in 2009 and 2010. However, preliminary results from the Aphanizomenon bloom of summer 2011 suggest that lower than usual NH_4 levels might be competitively disadvantageous to Microcystis as compared to nitrogen-fixing cyanobacteria such as Aphanizomenon.

In line with our CALFED objectives, data obtained through this project are being shared with Dr. Lucas (USGS) to develop a prediction model that will have the ability to forecast cyanobacteria abundance and toxicity in the SFBDD under various climate and development scenarios.

PUBLICATIONS: List any publications, presentations, or posters that have resulted from this funded research. Give as many details as possible, including status of paper (e.g., in review; in press), journal name, conference location and date of presentation. Please note (as outlined in the conditions of the award) that each fellow is required to submit an abstract for an oral or poster presentation at each State of the Estuary conference and CALFED Science Conference during the duration of the fellowship.

Publications 14

- Mioni, C.E., Lucas, L., Grimaldo, L., Thompson, J., Mueller-Solger, A., Waller, S., Sakata, B., and A. Paytan (2011) Environmental controls on potentially harmful cyanobacteria abundance and toxicity in the San Francisco Estuary (in prep.). This article will compile the data collected during the CALFED fellowship and compare summer 2009 (Microcystis bloom), summer 2010 (no bloom), and summer 2011 (Aphanizomenon/Microcystis mixed assemblage).
- Some of my nutrient data were used and published in this report:
Kuwabara, J.S.; Topping, B.R.; Parchaso, F., Engelstad A.C. and V.E. Greene. 2009. Benthic Flux of Nutrients and trace metals in the Northern component of San Francisco Bay, California. US Geological Survey Open file Report 2009-1286, 14p. [http://pubs.usgs.gov/of/2009/1286/]
- Meeting/Conferences/Workshops (oral presentations to disseminate my CALFED findings)
- Mioni, C.E. 2011. What controls Microcystis bloom and toxicity in the San Francisco Estuary? Water Resource Discipline Webinar series, USGS Menlo Park, CA. May 19, 2011 (invited, video can be viewed by going to the following link: <http://www.wrcamnl.wr.usgs.gov/wrdseminar/pastseminars2011.html>)
- Mioni, C.E. 2010. What controls harmful Microcystis Bloom and toxicity in the San Francisco Bay-Delta? Bay-Delta Science Conference, Sacramento CA. September 2010. (Science News spotlight presentation).
- Mioni, C.E. 2010. What controls harmful algae and phytotoxins in the SF Bay? Oceans Colloquium, Hopkins Station. April 2010. (selected Speaker)
- Mioni, C.E. 2010. Environmental controls on Microcystis & microcystins in San Francisco estuary. CSU Monterey Bay, April 2010. (invited seminar).
- Mioni, C.E. and A. Paytan. 2010. Environmental Controls on harmful algae & their toxins in San Francisco Estuary. USGS Menlo Park. January 2010. (Invited seminar)
- Mioni, C.E. and A. Paytan. 2009. Environmental Controls on Microcystis and Microcystins production in San Francisco Estuary. California State Water Resources Control Board – “Cyanobacteria & Cyanotoxins” Contracts meeting, Long Marine Laboratory. Santa Cruz, CA. December 2009. (Invited)
- Mioni, C.E. and A. Paytan. 2009. Does Ammonium control harmful algae abundance & toxicity in the San Francisco Estuary, CA? CALFED Bay-Delta Ammonia Summit. Rancho Cordova, CA. August 2009. (Invited).
- Mioni, C.E. and A. Paytan 2009. Environmental controls on the distribution of harmful algae and their toxins in San Francisco Estuary. Interagency Ecological Program – “Monitoring & Food Web” workshop. Sacramento, CA, June 2009. (invited).
- Mioni, C.E. and A. Paytan, A. 2009. Environmental controls on the distribution of harmful algae and their toxins in San Francisco Bay, CA. ASLO Aquatic Sciences meeting Nice (France), January 2009. (oral).
- Other publications submitted/published although not funded by this fellowship:
- MacKey, K.R., Mioni, C.E., Ryan J.P. and A. Paytan (2011) Phosphorus cycling in the red tide incubator region of Monterey Bay in response to upwelling. *Frontiers in Microbiology* (accepted, in review).
- Mioni, C.E., Smythe, T., and R. Kudela (2010) Harmful cyanobacteria and cyanotoxins in Clear Lake, CA (report)
- Jonhson, Z.I., Shyam, R., Ritchie, A.E., Lin, Y., Mioni, C.E., Lance, V.P., Murray, J.W., and E. Zinser (2010) The Effects of iron- and light- limitation on phytoplankton communities of deep chlorophyll maxima of the Western Pacific Ocean. *Journal of Marine Research*, 68(2): 283 – 308.

Milligan, A.J., Mioni, C.E., and F.M.M. Morel (2009). Response of cell surface pH to pCO₂ and iron limitation in the marine diatom *Thalassiosira weissflogii*. *Marine Chemistry*, 114: 31 – 36.

COOPERATING ORGANIZATIONS: List those agencies and/or persons who provided financial, technical or other assistance to your project since inception. Describe the nature of their collaboration.

CoopOrganiz_15

Collaborators/Technical assistance:

- * USGS - SF Bay Water Quality Monitoring group (Cloern lab, ship time and assistance with data analysis)
- * DWR - Environmental Monitoring Program staff (Scott Waller, Rich Breuer, & Karen Gehrts, ship time, data sharing)
- * Department of Fish & Game (Dave Crane Lab, LC/MSMS analysis for data validation)
- * UCSC Marine Analytical Lab (Rob Franks)
- * UCSC Megamer Facility (Brandon Carter, Jon Zehr lab)
- * Dr. Steven Wilhelm (UT Knoxville)

Financial assistance awarded to the fellow:

- 2009 California State Water Resources Control Board Award (\$2,700)
- 2009 Sacramento County Sanitation District fellowship (\$23,211)
- 2009 ASLO Early Career Travel Award, Aquatic Sciences Meeting (1,000\$)

AWARDS: List any special awards or honors that you, or mentor or members of the research team, have received during the duration of this project.

Awards_16

- 2011 Hewlett-Packard award (co-PI: Cecile Mioni, Lead PI: Raphael Kudela, \$17,617, awarded in 2010 to develop new toxin tracking tools)
- 2010 Selected speaker (Cecile Mioni), 2010 Oceans Colloquium, Stanford University – Hopkins Station, Monterey, CA
- 2009 California State Water Resources Control Board (provided \$2,700 for the analysis of some of my CALFED toxin samples using LC/MSMS for validation- Dave Crane's lab)
- 2009 Sacramento County Sanitation District fellowship (\$23,211)
- 2009 ASLO Early Career Travel Award, Aquatic Sciences Meeting (1,000\$)

KEYWORDS: List keywords that will be useful in indexing your project.

Keywords_17

Harmful Algae Bloom, harmful cyanobacteria, Toxins, Microcystins, Domoic Acid, Saxitoxins, Amnesic Shellfish Poisoning, Paralytic Shellfish Poisoning, San Francisco Estuary

PATENTS: List any patents associated with your project.

Patents_18

N/A

Additions: Additional information can be added here. Please begin the text with the number of the question you are adding to.

Additions_19

References:

Anderson, D.M.; Burkholder, J.M.; Cochlan, W.P. et al. (2008) Harmful algal blooms and eutrophication: examining linkages from selected coastal regions of the United States. *Harmful algae* 8, 39-53.

Kudela, R.M.; Cochlan, W.P. and A. Roberts (2004) Spatial and temporal patterns of *Pseudo-nitzschia* spp. in central California related to regional oceanography. In: K.A. Steidinger, J.H. Landsberg, C.R. Tomas and G.A. Vargo, Editors, *Harmful Algal Blooms 2002. Proceedings of the X International Conference on Harmful Algae Florida Fish and Wildlife Conservation Commission and Intergovernmental Oceanographic Commission of UNESCO (2004)*, pp. 347–349.

Langlois, G. and P. Smith (2001) Phytoplankton. In: Karl, H.A., Chin, J.L., Ueber, E., Stauffer, P.H., Hendley III, J.W. (Eds.), *Beyond the Golden Gate—Oceanography, Geology, Biology and Environmental Issues in the Gulf of the Farallones*. U.S. Geological Survey Circular 1198, pp. 123–132.

Lehman, P.; Teh, S.J.; Boyer, G.L. et al. (2010) Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food webs in the San Francisco estuary. *Hydrobiologia* 637, 229-248.

Lehman, P.; Boyer, G.; Satchwell, et al. (2008) The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. *Hydrobiologia* 600, 187-204.