CALFED Progress Report
California Sea Grant College Program

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Project Information

ProjectNo_2C: R/SF-35 StartDate_3a: 9/1/2008 EndDate_3b: 8/30/2010

ProjectTitle_4: Environmental Controls on the Distribution of Harmful Algae and Their Toxins in San Francisco Bay, California

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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 San Joaquin Delta). Surface water samples were collected monthly to determine: total toxins (Saxitoxins, Domoic Acid, Microcystins), harmful algae 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 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

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, I decided to stop collecting samples starting from January 2010. My community mentor suggested that I focus on the analysis of the samples collected in Fall 2008 and during the year 2009. I will also focus on the publication of my results for this time period.
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. The main producer of saxitoxins in the Bay is Alexandrium catenella. This harmful algae almost never dominate the assemblage during a bloom and therefore can be underestimated with traditional methods. Dr Silver provided me with a probe specific to this algae. This probe will be used in combination to epifluorescence microscopy to obtain a more accurate abundance of this algae. I am currently looking for funding that would allow me to purchase the reagents and materials necessary to complete this work. I am also trying to find funding to identify accurately Pseudo-nitzschia from June 2009 using SEM.

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

Domoic acid and saxitoxins do not appear to be endemic to the San Francisco estuary but rather appear to be introduced in the estuary through tidal forcing. Our results suggest that relaxation of the upwelling offshore may trigger outbreak of Alexandrium and Pseudo-nitzschia blooms and are followed by onshore transport during relaxation-favorable winds.
Our findings indicate that Microcystins are strongly correlated with surface water temperature which suggests 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 in this system.
Our results show that high risk levels of Microcystis and Microcytins are reached in the vicinity of the pumping station that are diverting water for agricultural, industrial & domestic uses. The concentrations of the cancer-promoting Microcystis toxin exceeded

(over 5 times higher) the World Health organization advisory limit for drinking water. Measures should be taken to monitor this toxin in the water diverted from the delta for domestic and agricultural uses. Indeed, daily exposure at a low dosage of MCs, which is similar with the natural route of potential presence of MCs in daily drinking water, is known to induce obvious oxidative stress in diverse organs of mammals (brains, liver, kidney; Zhao et al. 2009). Also, microcysitin can kill crops (Milligan, 2009).

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

Publications

I am currently working on the analysis of the data collected during the 2009 Microcystis bloom in the Delta. I expect to submit a paper within the next couple of months.

I also anticipate the publication of an article reporting elevated toxicity events that occured in the San Francisco Bay in Spring/Summer 2009. I am waiting for some data from collaborators: Pseudo-nitszchia and Alexandrium catenella abundance and trend over the past 15 years (Cloern group),Monterey Bay bloom in during the period of June 2009 - October 2009 (Kudela group).

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/]

Another article published this past year although not funded by this fellowship:
Milligan, A.J., Mioni, C.E., and F.M.M. Morel (2009), Response of cell surface pH to pCO_2 and iron limitation in the marine diatom Thalassiosira weissflogii. Marine Chemistry, 114: 31 – 36.

Meeting/Conferences/Workshops

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).

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)
* DWR - Environmental Monitoring Program staff (Scott Waller, Rich Breuer, & Karen Gehrts)
* Department of Fish & Game (Dave Crane Lab, Discount pricing on LC/MSMS analysis)
* UCSC Marine Analytical Lab (Rob Franks)
* UCSC Megamer Facility (Brandon Carter, Jon Zehr lab)
* Dr Steven Wilhelm (UT Knoxville, phylogenetic analysis)

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

2009 Lead Scientist – Peakwater organization (www.peakwater.org)
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, 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.

Milligan, A.J. (2009) Potential Impact of Cyanobacteria on Crop Plants. In: Pscheidt, J.W. and Ocamb, C.M. (eds.), 2009 PNW Plant Disease Management Handbook. Extension Services of Oregon State University, Washington State University, and University of Idaho. p. 38-39.

Zhao, Y.; Xie, P. and X. Zhang (2009) Oxidative stress response after prolonged exposure of domestic rabbit to a lower dosage of extracted microcystins. Environmental Toxicology and Pharmacology 27, 195-199.