NEW NCCOS FY18 HARMFUL ALGAL BLOOM PROGRAM AWARDS

ECOHAB : TOWARDS A PREDICTIVE UNDERSTANDING OF OUR ECOSYSTEMS: MICROCYSTIS BLOOMS AND TOXIN PRODUCTION

Institutions: Northeastern University, University of Tennessee

Project Period: September 2018 – August 2021

FY18 Funding: $225,050

Project Summary: Cyanobacteria blooms and toxin production are urgent contemporary problems in the US and worldwide. Water quality models are important environmental engineering tools for managing these problems, but the available operational models are based on old biology (i.e., Monod kinetics), do not include many important processes (e.g., overwintering in the sediment bed) and do not make predictions of important parameters (e.g., toxin production). This limits their utility for management and research. This project aims to take a significant step towards remedying this situation by developing a modern model for *Microcystis* growth and toxin production, which will resolve intracellular mechanisms of metabolism and toxin production at the gene, transcript, protein and metabolite level. The model will be developed based on available laboratory data, integrated into an existing water quality model of western Lake Erie and compared to field observations of *Microcystis* and toxin concentrations. Further, the model will be used to explore hypotheses about the ecological role of toxins, including as a grazing deterrent or to protect against redox damage.

ECOHAB: A MECHANISM BASED INTERVENTION FOR BREVETOXIN INDUCED OXIDATIVE STRESS

Institutions: Florida International University, Mote Marine Laboratory and Aquarium

Project Period: September 2018 – August 2021

FY18 Funding: $148,329

Project Summary: The endangered Florida manatee, *Trichechus manatus latirostris*, inhabits coastal environments in which blooms of the toxic dinoflagellate, Karenia brevis, frequently occur. K. brevis produces a suite of polyether neurotoxins, collectively called brevetoxins, that result in massive fish kills, contamination of shellfish, and respiratory effects. Due to its full-time residency in areas where frequent blooms occur, the manatee is highly susceptible to the harmful effects of red tide blooms. Substantial evidence exists suggesting that the toxins produced by these blooms can impact immune function in this marine mammal as well in as other species. The most recent evidence suggests a role for oxidative stress in brevetoxicosis through a specific inhibition of the enzyme thioredoxin reductase (TrxR) which is involved in alleviating the effects of oxidative stress. Additionally, manatees and sea turtles exposed to red tide toxins consistently show signs of oxidative stress at the functional, cellular, and genetic levels. The research we propose focuses on evaluating the potential for antioxidants to reverse or reduce the effects of brevetoxin-induced oxidative stress. Mammalian cell lines will serve as a model system for evaluating effects of antioxidants (selenium, ascorbic acid and trolox) and antiinflammatory agent (ketoprofen) on minimizing effects of toxin (PbTx-2)-induced oxidative stress. Additionally, oxidative stress in immune cells collected from rescued manatees will also be evaluated before and after in vitro antioxidant treatment. Finally, oxidative stress in the immune system of rescued manatees will be evaluated before, during, and after current treatment protocols being followed for brevetoxin exposure in rehabilitation facilities. Specific oxidative stress markers will include evaluation of activities of the enzymes thioredoxin reductase and superoxide dismutase which are both involved in oxidative stress. Results will include an assessment of whether antioxidant treatment has the potential to serve as a beneficial treatment protocol for manatees being treated for brevetoxicosis in rehab facilities. Our overall goal is to improve treatment options and enhance success of returning animals to the wild.Domoic acid (DA) poisoning is a pervasive problem in the coastal oceans of the Northeast and Northwest United States. Discovered in 1987 from algal bloom forming diatom *Pseudo- nitzschia*, the trigger for its production and the chemical and molecular mechanism for its biosynthesis is still not completely understood to date. Although several physical and biological factors have been implicated for the production of DA, bacterial metabolites as potential triggers for DA synthesis has not been investigated. The overarching goal of this proposal is to gain an understanding of the biosynthetic machinery of domoic acid in *Pseudo-nitzschia* and the influence of marine bacteria that leads to the synthesis of domoic acid and other kainoid families, which will provide fundamental new insights about chemical, molecular and biotic factors at work during *Pseudo-nitzschia* bloom. `

ECOHAB : ARE GROWTH AND TOXICITY OF THE DINOFLAGELLATE ALEXANDRIUM CONTROLLED BY GRAZER-INDUCED DEFENSE?

Institutions: University of Connecticut

Project Period: September 2018 – August 2021

FY18 Funding: $222,793

Project Summary: Blooms of the toxigenic dinoflagellate *Alexandrium fundyense*, which are common throughout New England waters, result in economic losses to fisheries and aquaculture, and pose public health risks. To date, however, there is no full mechanistic understanding of the factors that govern *Alexandrium* bloom dynamics. The typical modeling approach assumes that growth rate and cell toxicity depend only on environmental factors such as light, temperature, and nutrients. However, novel evidence shows that grazers (copepods, mussels, clams, and ascidians) can induce increases in toxin production of *A. fundyense* by up to ~ 500%. Induction occurs even when *Alexandrium* cells are separated from grazers. Induction of toxin production also significantly decreases cell growth rate. Hence, in addition to grazing losses, grazer-induced toxin production results in an additional fitness penalty for *A. fundyense*. The controls of this tradeoff between grazer-induced toxin production and reduced cell growth are not well understood, nor currently recognized in HAB population dynamics models. The goal of this project is to determine the controls of grazer-induced toxin production on cell toxin content and cell growth of *Alexandrium fundyense* . The hypothesis is the degree of grazer-induced toxin production is directly proportional to grazing risk and inversely proportional to cost of toxin production.

ECOHAB : THE ROLE OF NITRIC OXIDE IN PROMOTING HETEROSIGMA BLOOMS

Institutions: University of Delaware, Boston University

Project Period: September 2018 – August 2021

FY18 Funding: $249,635

Project Summary: *Heterosigma akashiwo* is a globally distributed HAB species, with blooms recorded in temperate, subtropical, and tropical coastal regions of both Pacific and Atlantic Oceans. It produces an as-yet-unknown toxin or suite of toxic compounds that have been implicated in extensive mortality of finfish and shellfish. Laboratory culture experiments examining the growth and physiological response of *Heterosigma* to nitrogen source have focused on its ability to utilize nitrate, ammonium and urea. Other nitrogen sources, such as nitric oxide (NO) may be an important but overlooked source of nitrogen to Heterosigma productivity in the natural environment. The ability to use NO as a nitrogen source adds a previously unknown dimension to the range of biochemical mechanisms employed Het+F18erosigma to access nitrogen in marine environments, potentially providing this species with a competitive advantage and contributing to the formation of harmful blooms. This project is a multidisciplinary, hypothesis-driven approach with both laboratory culture experiments and field studies to (1) empirically assess the molecular and biochemical responses of *Heterosigma* to NO input, (2) determine the effects of other nitrogen sources on uptake and assimilation of NO, (3) Measure changes in NO flux from coastal sediments when *Heterosigma* is present, and (4) evaluate the contribution of NO to species selection during the early stages of a *Heterosigma* bloom.

ECOHAB : LIFE AND DEATH OF A KARENIA BLOOM

Institutions: University of Texas Austin, Texas A&M University College Station

Project Period: September 2018 – August 2021

FY18 Funding: $245,732

Project Summary: In contrast to the Eastern Gulf of Mexico (GoM), much less is known about *Karenia brevis* blooms that affect the western GoM, even though they appear to be occurring with increasing frequency along the lower Texas coast. As a result, almost all hypotheses regarding K. brevis bloom processes are derived from studies in the eastern GoM (or in the lab); their relevance to the western GoM remain untested. Blooms in Texas and Florida appear to start from the same offshore source population and experience similar light, temperature, and salinity conditions. Historically, Texas blooms occurred less frequently, but are more common in recent years, implying that different processes drive *K. brevis* blooms in the western and eastern GoM. There is a management need for better forecasting of *K. brevis* blooms. While an existing physical model does well at predicting initiation, this work would further improve the model and develop indicators of bloom persistence and termination that would aid management. The overall goal of this project is to determine the processes that drive K. brevis blooms in the western GoM. While physical processes are a primary determinant of bloom initiation in the western GoM, other factors may modify its effects or act at later stages of the bloom life cycle, e.g. termination. We hypothesize that: 1 – *K. brevis* is subject to lower grazing pressure than the community as a whole 2 – *K. brevis* blooms occur under low DIN:P conditions and an abundance of organic N 3 – Endogenous cell death contributes to bloom decline in *K. brevis*

Proposed work: A combination of detection by an Imaging FlowCytobot and forecasting by physical models will be used to identify the earliest stages of a K. brevis bloom. Observations and experiments will commence at bloom initiation and continue through termination, including analysis of nutrients, microzooplankton grazing, cell death markers, and gene expression. The results will be used to modify the existing individual based model of K. brevis blooms, which will be validated against field observations. Project results will identify both the unique and shared drivers of K. brevis blooms across the GoM.

ECOHAB : TOWARD A PREDICTIVE UNDERSTANDING OF COCHLODINIUM AND ALEXANDRIUM BLOOMS IN LOWER CHESAPEAKE BAY

Institutions: Old Dominion University

Project Period: September 2018 – August 2022

FY18 Funding: $199,412

Project Summary: Massive, months-long blooms of the dinoflagellate, *Cochlodinium polykrikoides* have occurred throughout lower Chesapeake Bay and its tributaries in most of the last 20 years and for the last 8 years, subsequent blooms of the ichthyotoxic *Alexandrium monilatum* have been increasing in intensity and duration. Despite their widespread and annual occurrence, efforts to prevent, control or mitigate blooms of these species have been stymied because of limited understanding of how and where blooms initiate and the factors that contribute to their ecosystem domination once blooms emerge. While mitigation and control of HAB proliferation is difficult in most situations, the localized nature of *C. polykrikoides* and *A. monilatum* bloom initiation provides the possibility mitigation strategies to prevent these blooms. However, this requires understanding the factors contributing to bloom initiation, transport, magnitude, and duration. To address fundamental gaps in our knowledge, a combined observational and modeling study of a mid-Atlantic estuarine system impacted by blooms of *C. polykrikoides* and *A. monilatum* will be undertaken to: 1) determine meteorological, nutritional, and physical parameters governing bloom initiation, growth and proliferation of these organisms in a lower Chesapeake Bay estuary; 2) ascertain environmental triggers for excystment in laboratory and natural populations of *C. polykrikoides* and *A. monilatum*; 3) determine how behaviors, alternative metabolisms, and bottom-up controls contribute to initiation and maintenance of *C. polykrikoides* and *A. monilatum* blooms under field and laboratory conditions; 4) determine how grazing and top-down control modulates *C. polykrikoides* and *A. monilatum* population growth and expansion; 5) determine how climate variability affects bloom initiation, magnitude and duration. To do this, field and laboratory components will provide quantitative measures to parameterize the conceptual bloom cycle andcombined a one-dimensional model to address hypotheses related to the above five objectives. Based on experimental results of key physical and physiological processes, a one-dimensional coupled physical-biological model will be developed and used to conduct diagnostic studies using data collected from this project and other longer-term regional databases

ECOHAB : INTEGRATED MODELING OF THE HARMFUL GENUS PSEUDO-NITZSCHIA SPP. TO SUPPORT ECOSYSTEM PREDICTION AND ENVIRONMENTAL MANAGEMENT IN THE SOUTHERN

Institutions: University of California Los Angeles, Southern California Coastal Water Research Project (SCCWRP), Southern California Ocean Observing System (SCOOS), University of California Santa Cruz, University of Washington

Project Period: September 2018 – August 2021

FY18 Funding: $287,450

Project Summary: Within the California Current System (CCS), the toxigenic harmful algal diatom genus *Pseudo-nitzschia* (PN), and its potent neurotoxin domoic acid (DA), are now considered to be the leading HAB and conservation issues for much of the U.S. West Coast. The connection between HABs and anthropogenic nutrient enrichment, coastal processes (e.g. upwelling), and climate forcing at the land-sea interface are critical lines of investigation, yet the relative importance of these drivers has not been systematically evaluated. However, such an evaluation is key to a cost-effective strategy to manage water quality coastal resources at local scales. Development of the pre-operational application system California Harmful Algae Risk Mapping (C-HARM) for the Southern CCS predicts toxin and PN blooms as a function of statistical relationships with temperature, salinity, and optical variables. Absence of near real-time nutrient measurements hinders the ability to include nutrient variables in this modeling system, and thus a good deal of information relevant to bloom formation and DA production is ignored. In order to establish a state-of-the-art system built on first principles of PN physiology, this project intends to build a modeling system in parallel with C-HARM that leverages previous studies on the nutrient response by PN populations. This project will: 1) Develop an end-to-end predictive capacity for PN and DA production in the southern CCS (Baja Mexico to California-Oregon Border) that: a) builds upon an existing mechanistic model of DA production parameterized from laboratory experiments with toxigenic PN, b) adapts Biogeochemical Elemental Cycling (BEC) model construct to explicitly represent PN biomass and DA production, c) is coupled to a realistic regional physical- biogeochemical model, and d) can be evaluated against observational data; 2) Use the integrated model to investigate the relative importance of anthropogenic inputs and temperature on the frequency and severity of PN blooms and associated DA events in the Southern CCS; and 3) Transmit these findings to coastal zone managers and help them explore their implications for marine resource management and pollution control.