# NCCOS FY18 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

**Total Approved Funding**: $655,336

**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

**Total Approved Funding**: $ 428,387

**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

**Total Approved Funding**: $690,759

**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

**Total Approved Funding**: $746,354

**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

**Total Approved Funding**: $ 743,882

**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

**Total Approved Funding**: $835,455

**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

**Total Approved Funding**: $ 843,931

**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.

## CHRP: AN ECOPHYSIOLOGICAL FRAMEWORK TO ASSESS BIOLOGICAL VULNERABILITY TO HYPOXIA IN THE CALIFORNIA CURRENT SYSTEM

**Institutions**: University of Washington, NOAA Northwest Fisheries Science Center, Southern California Coastal Water Research Project, University of California Los Angeles, University of South Florida

**Project Period**: September 2018 – August 2022

**Total Approved Funding**: $ 965, 418

**Project Summary**: The California Current System (CCS) is one of the most productive regions of the world ocean, but upwelling-driven hypoxia constrains available habitat for aerobic animals. The eastern North Pacific is predicted to undergo some of the most rapid rates of DO decline in the world's oceans, raising the potential for major ecosystem disruptions. Characterizing ecosystem vulnerability to multiple stressors, and the societal impacts of that vulnerability, is a critical line of investigation for fisheries, coastal resource, and water quality management. The goal of this project is to apply a combination of mechanistic ecophysiological frameworks and statistical species distribution models within a state-of-the-art earth systems model to evaluate species responses to temperature-dependent hypoxic habitat compression in the California Current Ecosystem. We will evaluate species responses to temperature-dependent hypoxic habitat compression in five major steps: (1) measure the temperature-dependent hypoxia tolerance for ~10 key species in the CCS; (2) compute historical habitat variability using ecophysiological and statistical models, ocean model hindcasts, and species distributions, (3) validate the modeling frameworks using ecological time-series observations of demersal fish and epibenthic invertebrate species; (4) project future changes in habitat constraints using downscaled climate change projections and (5) provide a visualization of hypoxia vulnerability for present-day and future conditions, with and without the contribution of terrestrial anthropogenic nutrients, with a particular emphasis on the differential exposure of the current network of MPAs.

## CHRP: LINKING EXPOSURE, IMPACTS AND ADAPTATION: ADVANCING FISHERY RESPONSE TO HYPOXIA INTENSIFICATION IN THE PACIFIC NORTHWEST

**Institutions**: Oregon State University

**Project Period**: September 2018 – August 2022

**Total Approved Funding**: $ 1,087,999

**Project Summary**: Wind-driven coastal upwelling links climate-mediated ocean deoxygenation and atmosphere changes to the intensification of hypoxia along the extensive continental shelves of the US West Coast. This is resulting in new challenges to ecosystem and fishery management as the episodic onset of hypoxic and anoxic threaten the sustainability and productivity of some of the region's most economically- and socially-important fisheries. The early impacts of hypoxia intensification are already being felt by the Dungeness crab fishery, as hypoxic zones increasingly form over traditionally productive fishing grounds. New information also suggests that by altering the behavior and distribution of fish, and importantly, their receptiveness to fishery-independent survey methods, hypoxia can also affect the performance of the very tools that are needed to support management as ocean conditions continue to change. Our project proposes to advance our understanding of fishery- and management-relevant exposure, impacts and adaptation alternatives through partnerships with stakeholders and state and federal agencies. First, we propose to develop and implement a cooperative hypoxia detection and monitoring program through the development of crab-pot deployable dissolved oxygen sensors for use by commercial fishermen. This effort, requested by commercial fishermen, will supply exposure data that will not only allow the fleet to adapt to the onset of hypoxia events, but will also 1) provide Oregon Department of Fisheries and Wildlife (ODFW) Shellfish Program managers with information to guide proactive in-season management measures, 2) enhance our ability to quantify thresholds for impacts, and 3) validate high resolution models necessary for defining exposure and vulnerability across the region. Secondly our effort will expand collaborations with NOAA's West Coast Ground Fish Trawl Survey, and Oregon Department of Fisheries and Wildlife (ODFW)'s Marine Resource Program. By integrating DO monitoring into survey methods, and by employing state-space population models, our objectives are to explicitly identify the effects of hypoxia on fishery independent survey data, and to develop generalized tools that would enable managers to account and adjust for the effects of hypoxia that propagated through stock assessment processes.

## CHRP ASSESSING HYPOXIA THREAT TO TROPICAL ECOSYSTEMS: A MULTI-STRESSOR FRAMEWORK TO SUPPORT CORAL RESTORATION EFFORTS

**Institutions**: University of Florida, Smithsonian Institution

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $ 698,795

**Project Summary**: Ocean deoxygenation poses a serious and escalating threat to marine ecosystems. While impacts of hypoxia have been well characterized for temperate systems, they remain poorly understood for tropical coastlines. Preliminary studies indicate that hypoxia has negative, species-specific consequences for coral health and reef diversity. The lack of a comprehensive and systematic assessment of the impacts of hypoxia on coral survivorship and performance limits the ability of coral reef managers and restoration practitioners to implement knowledge-based adaptive strategies to confront the hypoxia threat. The study will facilitate coral conservation by providing an understanding of the threat of hypoxia to corals in a multi-stressor context through three complementary research objectives: 1: Establish the state of knowledge and management needs of the hypoxia threat to coral reefs. Approach: Convene a working group to synthesize existing research, identify knowledge gaps, and establish a collaborative network of coral reef stakeholders. 2: Assess variation in the functional response of corals to hypoxia in a multistressor framework. Approach: Test how the separate and interactive effects of hypoxia and other stressors vary among coral restoration species and genotypes using laboratory experiments. 3: Quantify the relationship between coral performance and natural variation in oxygen and other water quality variables in a restoration context. Approach: Survey water quality and coral performance at restoration sites across an offshore-inshore gradient spanning reef microhabitats. The proposed research will support coral reef management and restoration by: (1) establishing the state of knowledge on the topic of hypoxia in coral reefs and developing strategies for effective communication and management of hypoxia impacts, (2) identifying indicator species and sublethal signs of hypoxic stress that will directly aid monitoring and restoration programs, and (3) establishing water quality criteria for healthy coral reefs, which will empower the selection of suitable sites and candidate species/genotypes for restoration.

## CHRP: CAUSES AND CONSEQUENCES OF HYPOXIC EVENTS IN LOW-INFLOW ESTUARIES

**Institutions**: University of California San Diego/Scripps Institution of Oceanography, Tijuana National Estuarine Research Reserve

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $823,466

**Project Summary**: While the dynamical drivers and consequences of hypoxic conditions in traditional estuarine systems have been studied, those in low-inflow estuaries (LIEs), typical of California, are very different and are less well understood. Tidal exchange, as mediated by the varying conditions of lagoon mouths, is a primary driver of dissolved oxygen concentrations, with closure of mouths by sand berms leading rapidly to hypoxic conditions in LIEs. Offshore hypoxia, storm overwash, beach replenishment, drought, wildfires, and urban drool are special features that can further affect hypoxia in LIEs. Climate change likely alters these factors. This project greatly expands the very limited understanding of the physical processes, including stratification, that lead to hypoxia development in LIEs, as well as identify their ecological consequences, with the goal of developing indicators of hypoxic state change and ecosystem vulnerability for use in LIE management. Key objectives are: (1) Evaluate how vertical stratification and the relative role of oceanic versus upstream water mass end members drive hypoxia dynamics in LIEs; (2) Define the different types of hypoxia regimes that develop in LIEs and assess how they influence shellfish health; and (3) Develop hydrodynamic and chemical indicators of imminent state change and ecological indicators of vulnerability, resistance and resilience to hypoxia-induced state changes in LIEs. We will combine historical hydrodynamic and water quality (especially oxygen) and benthos monitoring in two LIEs with very different mouth dynamics and management strategies: Tijuana Estuary and Los Peñasquitos Lagoon, with focused real-time hydrodynamic monitoring and biosentinel experiments over a 2- year period in these estuaries. Biological trait analysis of macrobenthos will be used to identify the suite of indicator traits that reflect different hypoxia states, the functional health of the estuary, the potential for recovery from hypoxic events, and science gaps that can guide future research in this area. This work will be accomplished in partnership with the Tijuana River National Estuarine Research Reserve, which has long-term research, management partnerships, and outreach programs associated with these systems. Outputs will include a LIE Management Transition Advisory Group, physical (stratification and mouth state) indicators, a hypoxia species watch list, and development of bivalves as biosentinels. Outcomes include a framework for coupled science and LIE management, improved implementation of LIE mouth management, better understanding of short- and long term faunal responses and enhanced and improved NERR monitoring capacity.

## REPP THRESHOLDS: CAN MEADOWS OF SUBMERGED AQUATIC VEGETATION (SAV) MITIGATE OCEAN ACIDIFICATION THRESHOLDS FOR EASTERN OYSTERS IN THE CHESAPEAKE BAY?

**Institutions**: College of William and Mary/Virginia Institute of Marine Science, Old Dominion University

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $937,693

**Project Summary:** Biological consequences of ocean acidification (OA) have been well established in the laboratory, but these effects may manifest in different ways in situ, as OA will co-occur with other stressors like ocean warming and hypoxia. There is a pressing and immediate need to understand the in situ consequences of OA against the backdrop of multiple stressors so that managers can act proactively to prevent ecosystem collapse and consequent negative impacts on coastal economies and human communities. Indeed, oysters, including the Eastern oyster Crassostrea virginica, respond negatively to conditions of OA, reaching physiological thresholds – conditions of seawater chemistry beyond they are able to grow or reproduce. One potential mechanism for mitigating OA impacts is to buffer the surrounding waters so that oysters will experience more muted, and possibly even beneficial, changes in carbonate chemistry conditions. Through their photosynthetic activities, submerged aquatic vegetation (SAV) could change surrounding water chemistry in a way that prevents or reduces the exposure of oysters to their physiological threshold of OA. However, these effects are not yet well quantified for translation into practical management tools. A proposed modeling approach will be used to quantify ecologically-relevant thresholds for the Eastern oyster in restoration and aquaculture contexts and evaluate the potential benefit of SAV restoration as a management tool for mitigating these thresholds. Scientific Objectives: 1) What is the OA threshold for the Eastern oyster in the Chesapeake Bay, and how is it modified by co-stressors? 2) Can SAV modify the surrounding carbonate chemistry and dissolved oxygen to benefit the Eastern oyster? 3) Under what conditions of OA will SAV restoration be a sustainable mitigation tool? Summary of Work: 1) Impacts of pH on oyster filtration, metabolism, and shell production will be incorporated mechanistically into EcoOyster, an ecosystem model, including Eastern oysters. OA thresholds for diploid and triploid oysters, defined as conditions beyond which net annual growth is negative, condition is poor, and time to harvest exceeds industry standards, will be identified by running the model using a range of pH values as well as co-stressor conditions. Formulations will be validated using laboratory measurements. 2) EcoOyster will then be coupled with GrassLight, a SAV bio-optical model, to allow the positive impacts of OA on SAV productivity to feed back to influence the carbonate chemistry conditions experienced by oysters. The coupled model will be validated using in situ measurements and run across a range of environmental conditions to assess the degree to which SAV meadows can mitigate the impacts of OA and associated stressors on oyster growth and survival. 3) With guidance from an Advisory Committee, the level of OA where mitigation using SAV meadows becomes unsustainable will be determined. The economic benefit of enhanced oyster performance will be compared to the cost of SAV restoration will be compared using results from the validated coupled model as well as information from restoration practitioners. Results will be applicable to co-restoration of SAV and oysters as well as SAV restoration adjacent to aquaculture.

## REPP THRESHOLDS: A GENERIC PREDICTIVE MODEL FOR OCEAN AND COASTAL ACIDIFICATION THRESHOLDS FROM LONG ISLAND SOUND TO THE NOVA SCOTIAN SHELF

**Institutions**: Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), New Hampshire Sea Grant, Mook Sea Farm, Gulf of Maine Research Institute, University of Massachusetts Dartmouth, University of New Hampshire, University of Maine, Wells National Estuarine Research Reserve

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $498,000

**Project Summary:** In recent years, Ocean and Coastal Acidification (OCA) has become an issue of significant concern. Policy-makers, as well as resource and environmental managers require not only information about biophysical changes, but how those changes impact various economic sectors, and how policy and management actions might respond accordingly (Mathis et al., 2015. New research has vastly improved our understanding of how ocean acidification responds to secular trends in atmospheric $CO_2$, and a scientific consensus about its possible devastating effects on calcifying organisms and the economies that depend on them is growing. However, we have limited understanding of how nearshore and coastal ecosystems will respond to OCA, how these impacts will affect human communities, and how society might cope with these unprecedented changes. An absence of actionable information and the dynamic nature of coastal carbonate systems pose major challenges to industry, resource managers, and coastal policy makers. The Northeast Coastal Acidification Network (NECAN) was established in 2013 to synthesize and disseminate regional acidification data and information. The proposed work seeks to fulfill NECAN's identified need for a regional OCA forecast model that can provide outputs as actionable guidance to managers. The project will expand the Northeast Coastal Ocean Forecast System (NECOFS) to include carbonate parameters. Input garnered from a series of workshops and focus groups will help define threshold detection and warning capabilities. These thresholds and warning capabilities are integral to developing a Management Transition Plan that utilizes NECOFS to ensure salient and legitimate decision-making support. Plan specifics will be co-constructed by researchers, an Advisory Committee of information users in government, industry, and non-profit sectors, and more specialized focus groups of information users experienced in three key decision areas of water quality management and monitoring, estuarine oyster aquaculture, and wild harvest shellfisheries. These three decision areas are ones in which OCA is already a salient issue, but with known or anticipated impacts that differ in time horizons, spatial patterns, ecological cascades, capital and labor investments, social-institutional contexts, and balance across public, private, and non-profit decision making. Information products and modeling capacity built during the project will be sustained into the future through inclusion in operations and maintenance activities of NERACOOS.

## REPP THRESHOLDS: IDENTIFYING THRESHOLDS IN COUPLED BIOGEOCHEMICAL-BIOLOGICAL-ECONOMIC SYSTEMS UNDER MULTIPLE STRESSORS

**Institutions**: University of Maryland Chesapeake Biological Laboratory, University of Delaware, University of Maryland Horn Point Laboratory, Oregon State University CEOAS

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $1,005,684

**Project Summary:** Aquatic ecosystems are complex environments characterized by a diversity of interactions between biological, chemical, and socio-economic processes. A wide-variety of these relationships are characterized by non-linear behavior, including the existence of thresholds, or points beyond which the fundamental relationship between processes is altered, and ecosystems may reach alternative stable states. While the study of non-linear dynamics remains to be somewhat theoretical, there are clear applications for this perspective in estuarine ecosystems where coupled geochemical, biological, and socio-economic processes overlap in a constantly changing environment. Concern for the potential interactive impacts of oxygen depletion and ocean acidification on key commercial estuarine organisms has led to substantial investment in the study of these processes, yet the potential non-linear response of organisms to these stressors and other environmental conditions has received less attention. Furthermore, the effects of future conditions within estuarine environments on key organisms are highly uncertain, not only because these conditions are difficult to predict (e.g., freshwater discharge), but also because the interactions between concurrently changing factors (temperature, nutrient loading, sea level) could lead to unexpected chemical, biological, and economic change. This challenge is particularly compelling for the shellfish aquaculture industry, which is growing globally, but is highly vulnerable to both environmental changes in growth areas and market changes within social-economic systems. In an environment where momentum is building for an ever-expanding and diverse aquaculture industry, sudden shifts in biogeochemical and physical conditions have the potential to create socio-economic disruptions associated with changes in commercial fisheries and recreation. Thus, the objective of this proposal is to make significant progress in our understanding of non-linear behavior within biogeochemical systems, the growth and survival of the eastern oyster, and the economic viability of an aquaculture industry toward to goals of understanding (1) biogeochemical interactions in oxygen, carbon, and nutrient cycles in response to long-term change and the discovery of non-linear behaviors, (2 ) how these nonlinear biogeochemical changes under historical and future atmospheric $CO_2$, nutrient loading, and climatic conditions conspire to amplify or suppress non-linear responses of oyster growth and survival to environmental conditions, and (3) how will the success of the eastern oyster under different conditions impact the economic feasibility of the young, but growing aquaculture industry in the Chesapeake Bay. We propose to address these questions by developing a coupled geochemical-biological-economic modeling system that integrates the project team's collective knowledge and quantitative tools toward linking biogeochemical cycling and physical forcing, oyster growth and survival, and economic profitability and constraints in the Chesapeake Bay ecosystem under past, current, and future conditions.

## REPP THRESHOLDS: THRESHOLDS IN A CHANGING OCEAN ENVIRONMENT: BIOECONOMIC IMPLICATIONS TO INFORM ADAPTATION DECISIONS FOR ALASKA'S SALMON FISHERIES

**Institutions**: University of Wyoming, NOAA Northwest Fisheries Science Center, NOAA Alaska Fisheries Science Center, University of Alaska, Alaska SeaLife Center, Alaska Ocean Observing System - Alaska Ocean Acidification Network, Alutiiq Pride Shellfish Hatchery

**Project Period**: September 2018 – August 2021

**Total Approved Funding**: $912,851

**Project Summary:** Alaska is expected to experience ocean acidification (OA) faster and more intensely than other parts of the globe, primarily due to its cold water which has a higher capacity to absorb $CO_2$. Yet, little is known about the way species in Alaska may respond to OA. Peer reviewed research has been conducted on only 14 of Alaska's marine species, and while this body of literature is growing, most commercial fish species have not been studied. With a $5.8 million seafood industry and a population reliant on healthy oceans for subsistence, nutrition, and livelihoods, OA is expected to have serious implications for the state. Among the concerns relating to OA, the potential impact to salmon has emerged as one of the top priorities, as identified during a 2016 statewide OA workshop and a recent OA stakeholder survey on information needs. The wholesale value of commercially caught Alaska salmon exceeded $1.2 billion since 2010 and Alaskans harvest over 12 million pounds for their own consumption annually. This is equal to one third of all wild foods they consume. However, despite salmon being the backbone of Alaska's fisheries, there are only two studies that have looked at salmon response to OA, both conducted outside of Alaska. Research shows that OA impairs coho salmon's olfactory senses and their ability to detect prey and negatively affects pink salmon growth rates. Other potential impacts to growth, metabolism, behavior and changes to prey quality and availability, remain unknown. For Alaskans dependent on salmon, understanding how they may fare in a higher-acidity environment, and the cultural and economic implications of their response, is critical. Formally evaluating the risks of OA and related thresholds to salmon fisheries, and assessing the benefits of pre-emptive human responses is needed for adaptation planning and decision making. This is particularly important in Alaska, as the state's constitution mandates salmon populations to be managed according to maximum sustainable yield, thereby providing less room for adaptive ecosystem-based management approaches such as the response to, or avoidance of, regime shifts. Therefore, understanding the legal and institutional barriers to implementing OA adaptation strategies is critical for a management transition. The project's objectives are to: A) leverage ongoing salmon data synthesis to identify critical ecosystem and socio-economic indicators, their current status and synergistic thresholds resulting in system-wide regime shifts; B) develop a dynamic ecological-economic model to simulate management scenarios with human-ecological feedbacks; C) reduce model uncertainty by conducting a laboratory study investigating the combined direct and indirect OA response in chum salmon as a case study; D) identify barriers to implementing adaptation and management transition plans; E) engage affected stakeholders and managers to guide the science and coproduce the plans; and F) communicate the project's scientific and planning results to legislative decision makers, fishermen, salmon-dependent communities, and wider scientific circles.

## REPP CORAL CONNECTIVITY: CONNECTIVITY OF CORAL ECOSYSTEMS IN THE NORTHWESTERN GULF OF MEXICO

**Institutions**: Lehigh University, Harvey Mudd College, Georgia Institute of Technology, NOAA National Centers for Coastal Ocean Science, NOAA Southeast Fisheries Science Center, U.S. Geological Survey, Smithsonian Institution/National Museum of Natural History

**Project Period**: September 2018 – August 2023

**Total Approved Funding**: $2,937,773

**Project Summary:** With continued anthropogenic threats in the marine environment, there is an urgent need to make decisions that will lead to the effective management and conservation of vulnerable coral ecosystems in the Gulf of Mexico (GoM). The establishment of marine protected areas (MPAs) is not only essential to protect and conserve coral ecosystems, but has been identified as one of the key restoration strategies for benthic communities impacted by the Deepwater Horizon (DWH) oil spill. The Flower Garden Banks National Marine Sanctuary (FGBNMS) has proposed to expand the boundaries of current protected areas to encompass additional coral sites. The goal of this proposal is to provide ecosystem connectivity information and tools to GoM resource managers, with a focus on the FGBNMS, the banks in the boundary expansion alternatives to the east of the sanctuary, and areas further afield in the GoM and the Caribbean. This project seeks to understand the processes that shape 3D connectivity networks in shallow (15-40m), upper mesophotic (40-85m), and lower mesophotic (85-150m) coral ecosystems of the northwestern GoM. To achieve these objectives, the team will integrate field sampling, state-of-the-art genetic chemical, and ecological analyses with high-resolution habitat suitability, oceanographic and larval dispersal modeling approaches. The team will work closely with managers to plan research activities and transfer knowledge and tools through online interactive products, reports, meetings and workshops. This collaborative effort links research outcomes, which will enhance our understanding of GoM ecosystems, with effective management of MPAs to restore of degraded coral communities, and preserve long-term viability of coastal ecosystems.