Florida Red Tide Mitigation and Technology Development Initiative
Project Executive Summaries

Mote Led Projects

Title: Development and Validation of New and Existing Technologies: Expanding PHySS's (Programmable Hyperspectral Seawater Scanner- PHySS(2.0)) Role in Mitigation of Harmful Impacts Caused by the Florida Red Tide
Principal Investigator: Dr. Sumit Chakraborty
Co-principal Investigators: R. Pierce, G. Kirkpatrick, V. Lovko, J. Hillier, K. Henderson, J. Turner
Summary: This project aims to continue development of the PHySS, which performs automated sampling and analysis of seawater and measures spectral absorption which is related to ancillary photopigments unique to *K. brevis*. The goals of the project include completing a hyperspectral library for different phytoplankton functional types, refining the algorithm by performing sensitivity and uncertainty analyses, and calibrating and validating PHySS on other platforms such as AUVs (gliders), field sampling and remote sensing data.

Title: Automated *in situ* Advanced Sensing Technology Development for Red Tide Mitigation and Control (PHySS-C)
Principal Investigator: Dr. William Haskell
Co-principal Investigator: R. Pierce, G. Kirkpatrick, J. Hillier, K. Henderson, C. Caredio, J. Turner
Summary: This project aims to produce new sensor technology to replace existing PHySS-2 sensors with next generation advanced technology multiuse, in situ sensors for red tide mitigation and control applications. The PHySS-C advanced sensing technology applications for red tide mitigation and control will include hyperspectral libraries of several phytoplankton species in addition to *K. brevis* to assess phytoplankton inter-species interactions related to red tide events. Sensors for water chemistry and physical parameters will allow for tracking of HAB dynamics. Data obtained from PHySS-C deployments will be utilized by collaborators for directing red tide bloom mitigation and control applications, and to assess the efficacy of red tide mitigation techniques.

Title: Testing the Efficacy of Products for Mitigating Harmful Effects of *Karenia brevis* Red Tide Events along the Florida Gulf Coast
Principal Investigators: Rich Pierce, Cindy Heil, Emily Hall, Vince Lovko, Jim Culter
Summary: The ability to apply successful products to the natural environment requires a host of additional studies to ensure efficacy in the field and that no further public health or ecological harm results from these mitigation applications. This project will accomplish the research required to answer the critical issues to 1) Test potential mitigation products to determine optimal product dosing concentrations and protocol, 2) establish product toxicity on other marine biota with standard EPA assays 3) determine production of toxic chemical degradation products impacts and half-lives in seawater, 4) determine sub-lethal impacts of these compounds on *K. brevis* and non-targeted organisms, 5) examine interactive compound effects on microbiota and nutrient cycling over short and long-term time scales (days to weeks)

in pilot mesocosm experiments, and 6) ultimately verify the efficacy and environmental compatibility of selected products with field applications during natural red tide events (when red tides occur during the study period).

Title: Developing UAV-based Red Tide Detection System
Principal Investigator: Dr. Vincent Lovko
Co-principal Investigators: S. Chakraborty
Summary: This project will examine the use of unmanned aerial systems (UAS) as an alternative method for detection of red tide blooms compared to vessel and satellite sampling. Although aircraft and satellite remote sensing can potentially help determine bloom presence and extent, it is often limited by lack of ground truthing and poor temporal resolution. Airborne hyperspectral sensors can provide high spatio-temporal resolution mapping of HABs at local scales. The project will aim to develop a hyperspectral database from UAS surveys to map red tide blooms using the Mote Airborne Red-tide Remote Sensing System (MARRSS).

Title: Beach Conditions Reporting System
Principal Investigators: Kevin Claridge
Co-principal Investigators: R. Pierce, S. Caywood, A. Cook
Summary: This project will work to improve Mote Marine Lab's Beach Conditions Reporting System (BCRS) website and smartphone app. The BCRS is an important resource for the public, providing information on beach conditions and alerting the community on HAB risks. Improvements to BCRS will include validation of citizen reports, integration and collaboration with outside data portals, and implementation of BloomZoom. The updates will allow fast communication of the most up-to-date information about red tide blooms and will give citizens easier access to reporting.

Title: BloomZoom: A Portable Phone-based Microscope for Quantitative Detection of *K. brevis* Through Citizen Science
Principal Investigator: Dr. Vincent Lovko
Summary: This project will focus on the development of a portable microscope to detect and quantify *K. brevis* concentrations. The microscope will be adapted to fit any phone, tablet or other portable device so that citizens can use the device to collect samples and report data on *K. brevis* blooms. This technology will enhance the accuracy of real-time information on red tide blooms and bloom forecasting.

Title: Citizen Science Detection and Quantification of Florida Red Tides via Personal and Smartphone-enabled PCR Technology
Principal Investigator: Dr. Cynthia Heil
Co-principal Investigators: P. Countway, N. Record (Bigelow Lab for Ocean Sciences)
Summary: This project focuses on the development and application of PCR technology to simultaneously identify and quantify *K. brevis* and *K. mikimotoi* in southwest Florida blooms and integrate it into Mote's Citizen Science Network. The project will compare two quantitative polymerase chain reaction (qPCR) units for efficacy and user-friendliness and select the better

fit to be used for *Karenia* detection. Once the technology is tested and verified, citizen scientists will be trained to use the PCR unit to monitor HABs.

Title: Evaluation of QUAT Efficacy for Florida Red Tide Mitigation
Principal Investigator: Dr. Cynthia Heil
Co-principal Investigators: E. Hall, A. Muni-Morgan, E. Cuyler
Summary: This project examines the effectiveness of quaternary ammonium compounds (QUATs) at removing *K. brevis* cells and brevetoxins. QUATs are known to bond to negatively charged bacterial and algal cell walls, resulting in enzyme inactivation and disruption of membranes and cell processes. The charged cell walls of *K. brevis*, combined with their bacterial symbioses, suggests that this is a potentially effective treatment of *K. brevis* blooms without attendant toxicity issues. Two commonly used QUAT compounds will be absorbed on both concrete and fiberglass substrates and tested to evaluate *K. brevis* removal as well as impacts QUATs may have on water quality and cell physiology.

Title: A Rapid Field Red Tide Toxin Biosensor for Commercially Important Shellfish and Seawater
Principal Investigator: Dr. Dana Wetzel
Co-principal Investigators: T. Sherwood, C. Miller
Summary: This project aims to develop a rapid red tide toxin field biosensor for commercially important shellfish and seawater. This will reduce the time needed to quarantine shellfish farms due to red tide toxins, which is based on time-consuming laboratory analyses. The project also plans to develop commercial application methods for depuration of red tide toxins from shellfish using a land-based recirculation system. These technologies will not only help the shellfish industry, they will also help reduce consumer risk and aid in red tide monitoring and research.

Title: Natural Compound Control and Mitigation for Red Tide
Principal Investigator: Dr. Dana Wetzel
Co-principal Investigators: T. Sherwood, A. Tarnecki, C. Miller
Summary: This project examines the algicidal properties of naturally occurring bacteria, macroalgae, grasses, seawater and other materials against *K. brevis*. Algicides can play a role in prevention, termination and regulation of HABs with lower risk of harmful side effects than other control measures due to their natural occurrence in the environment. Algicidal compounds collected from the Gulf of Mexico will be identified, characterized and evaluated for effectiveness against *K. brevis* in mesocosm studies.

Year 1 Partner Led Projects

Title: Optimizing Production of a Dinoflagellate–specific Algicide for Control of *Karenia brevis*
Principal Investigator: Dr. Kathryn Coyne (University of Delaware)
Co-principal Investigators: Dr. Dana Wetzel, Dr. Vincent Lovko (Mote Marine Laboratory)
Summary: Researchers already know that certain bacteria naturally produce compounds that are “algicidal”—lethal to at least some species of algae. This project focuses on optimizing

production of algicide by certain bacteria for use on the Florida red tide alga, *Karenia brevis*, identifying which bacteria-produced compounds are the most algicidal to *K. brevis* and evaluating the potential risks of applying the algicide, starting experiments with *K. brevis* algae cultured in the lab and then validating those results with natural communities of microscopic algae.

Title: Pushing *Karenia* Over the Edge with Beer Derived Flavonoids
Principal Investigator: Dr. Allen Pace (University of Maryland)
Co-principal Investigators: Taylor Armstrong (UMCES—IMET), Dr. Vincent Lovko and Dr. Richard Pierce (Mote Marine Laboratory)
Summary: This project will test natural compounds from "brewer's spent grain" (BSG)—a readily available byproduct of beer breweries—for their potential to fight *K. brevis* and degrade its brevetoxins. Scientists know that a related product, barley straw, produces compounds that can fight certain algal blooms as the straw decomposes over time. However, the slow release of compounds is not practical for *K. brevis* blooms that form in ocean waters offshore because it must be deployed well ahead of algal-bloom formation and remain near the bloom. Also, it is not clear that the barley straw would degrade or produce the same compounds in saltwater that it does in freshwater. In contrast, BSG has five times greater concentrations of certain barley compounds—phenolic acids and flavonoids—that can fight algae in the lab, and BSG is already releasing these compounds when it leaves the brewery, so project partners aim to assess its practical use for controlling *K. brevis* and its toxins.

Title: A Thin Shroud with Integrated Algaecide to Flocculate and Sink Karenia brevis
Principal Investigator: Dr. Vijay John (Tulane University)
Co-principal Investigators: Tim Mclean (Tulane University)
Summary: Project scientists aim to test an advanced technology designed to "smother" *K. brevis*, pull it to the bottom and treat it with algaecide in a targeted, controlled way. The technology is a super thin, environmentally benign shroud called a "metal phenolic network" that will be combined with clay particles to weigh down the shroud, and uniquely, will carry natural clay nanotubes with algaecide inside. This year-1 project focuses on testing the technology in the lab and in larger-scale "mesocosm" systems in collaboration with Mote, to understand its effectiveness, logistical and cost requirements, and potential side effects, such as release of toxins from dying *K. brevis* cells. If the project is successful in its first year, project leaders aim to transition to field experiments with Mote and FWC.

Title: Fate and Effects of *Karenia brevis* Cells, Toxins, and Nutrients Following Clay Application for Bloom Control
Principal Investigator: Dr. Don Anderson (Woods Hole Oceanographic Institute)
Co-principal Investigators: Dr. Richard Pierce, Jim Culter, Dr. Emily Hall and Dr. Vincent Lovko (Mote Marine Laboratory) and Dr. Kristy A. Lewis (University of Central Florida)
Summary: Laboratory studies suggest that kaolinite clay particles can "grab," sink, and destroy *K. brevis* algae, helping remove *K. brevis* cells and their toxins from water. Clays have been used to treat other algal blooms for more than 20 years in South Korea and China, often covering areas as large as 40 square miles, but further research is needed to transition clays for use in

the U.S. This new project will advance ongoing research of kaolinite clay as an effective and ecologically sound method for mitigating and decreasing the impacts of Florida red tide. The team will use large experimental systems called mesocosms to further investigate how clay affects *K. brevis* and organisms from Gulf of Mexico environments. For example, when the clay pulls *K. brevis* to the bottom, do its toxins harm bottom-dwelling marine organisms more than they would without the clay? Does the clay capture or release nutrients? What are the best locations and procedures for applying clay? These and other questions must be addressed to apply clays to Florida red tide.

Title: Examining the Feasibility of Removing and Composting Fish Carcasses to Mitigate Red Tide
Principal Investigator: Dr. Michael Parsons (Florida Gulf Coast University)
Co-principal Investigators: Dr. Cynthia Heil (Mote Marine Laboratory)
Summary: Florida red tide can cause large-scale fish kills—a major impact to coastal ecosystems and communities' quality of life—and decomposing fish release nutrients that *K. brevis* can use, possibly causing a positive feedback loop that could worsen red tide. This process should be better quantified (represented in terms of numbers/quantities) to understand its significance. This project aims to: better quantify the nutrient inputs to Florida red tide from fish kills in southwest Florida; conduct a cost/benefit analysis of removing dead fish to help mitigate red tide; and evaluate composting these fish (using a compost-accelerator compound) to produce fertilizer for local stakeholders.

Year 2 Partner Led Projects

Title: Microbe-Lift Mitigation 96 hour Testing with *Karenia brevis* (Red Tide)
Principal investigator: Ralph E. Elliott (Ecological Laboratories, Inc)
Co-principal investigators: Dr. Cynthia Heil (Mote Marine Laboratory)
Summary: The project will examine the efficacy of Microbe-Lift, a biotechnology created by Ecological Laboratories, Inc., that utilizes a series of cultured microbes to enhance and restore eutrophic aquatic ecosystems ranging from ponds, streams, rivers, and stormwater retention basins, and is commonly used in contained Koi and aquarium systems. This project will test the ability of Microbe-Lift to eliminate *K. brevis* cells and brevetoxins in laboratory experiments.

Title: A chemical-free Red Tide Mitigation Technology Utilizing UVC LEDs
Principal investigator: Neil Williams (nTecSolutions LTD)
Co-principal investigators: Dr. Kathleen Rein (Florida International University), Dr. Richard Pierce (Mote Marine Laboratory)
Summary: This project will examine the development of a field device that utilizes ultraviolet wavelengths from 260 nanometers to 280 nanometers (UVC) to prevent or mitigate algae blooms in small to medium scale aquatic ecosystems. UVC has been used in many industries for disinfection purposes, and UV lamps are frequently used in aquarium systems and small ponds to prevent the growth of algae. This project will investigate using solar panels to power a device that is triggered by specific levels of *K. brevis*, and will use UVC from light-emitting diodes to

maintain non-bloom levels of cells of *K. brevis*, with the goal of stopping a bloom before it develops or to halt an ongoing bloom.

Title: Controlled Release Oxidants for Red Tide Treatment and Mitigation
Principal investigator: Dr. Alexis Carpenter (AxNano, LLC)
Co-principal investigators: Dr. Cynthia Heil (Mote Marine Laboratory)
Summary: This project will utilize AxNano RemRx™ controlled release oxidant technology, which combines an oxidizing substance with an environmentally-friendly polymer and releases it in tunable, controlled doses. Originally developed for treating contaminated groundwater, these technologies may prove effective at eliminating or preventing algal growth. The controlled release properties are hypothesized to reduce the stress on the ecosystem and the amount of toxin released by *K. brevis* decomposition.

Title: A Preliminary Study to Assess the Feasibility of a Nantechnology Approach to the Removal of *Karenia brevis* cells and Brevetoxin from Estuarine and Marine Waters
Principal investigator: Dr. Jamie Lead (University of South Carolina SmartState Center for Environmental Nanoscience and Risk)
Co-principal investigator: Dr. Cynthia Heil (Mote Marine Laboratory)
Summary: This project proposes a nanotechnological approach to separate *K. brevis* cells and their toxins from seawater. Using an established strategy for oil and metal remediation, magnetic, polymer-coated nanoparticles will be tested to see if they can effectively attract both brevetoxins and *K. brevis* cells and remove them from the water.

Title: In-situ Mitigation of Florida Red Tide via Activated Carbon
Principal investigator: Dr. Regina Rodrguez (Carbonxt)
Co-prinicpal investigator: Dr. Vince Lovko (Mote Marine Laboratory)
Summary: This project will develop and investigate activated carbon products as both an adsorbent for brevetoxins and as an inhibitor for the spread of Florida red tide cells, *K. brevis*. Activated carbon is a highly versatile and widely-used product for filtering water and air. Activated carbon is well-suited for testing its application in controlling algae blooms due to its high affinity for contaminants, such as brevetoxins, and its ability to serve as a great substrate for impregnating with substances that can kill *K. brevis.*

Title: Efficacy of EVIE robot against *K. brevis*
Principal investigator: Dr. Annarie Lyles (Solaris Cybernetics)
Co-principal investigator: Dr. Richard Pierce (Mote Marine Laboratory), Rudy Behrens (Solaris Cybernetics)
Summary: A robotic vessel, nicknamed EVIE, will be tested in a mesocosm setting to determine its ability to a) find Florida red tide cells via a finely-tuned reflected-light sensor, and b) subsequently harvest cells via a nozzle, convert them to harmless biofuels, and store the product in the robot's holding tank.

Title: Isolation of Natural Algicidal Bacteria Associated with Harmful Algal Blooms to Develop a Mitigation Strategy for Florida Red Tide

Principal investigator: Dr. George P. Phillippidis (University of South Florida, Patel College of Global Sustainability)
Co-principal investigator: Dr. Vincent J. Lovko (Mote Marine Laboratory)
Summary: This project will screen the microbial community associated with *K. brevis* to identify natural bacteria that possess algicidal properties and can help mitigate blooms of Florida red tide.