**Florida Red Tide Mitigation and Technology Development Initiative**

**Project Executive Summaries**

**Title:** Evaluation of QUAT Efficacy for Florida Red Tide Mitigation

**Principal Investigator:** C. Heil (Mote Marine Laboratory)

**Co-principal Investigators:** E. Hall, A. Muni-Morgan, and E. Cuyler (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Summary:** This project is examining 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, suggest that this is a potentially effective treatment of *K. brevis* blooms without attendant toxicity issues. Two commonly used QUAT compounds are being 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:** Citizen Science Detection and Quantification of Florida Red Tides via Personal and Smartphone-enabled PCR Technology

**Principal Investigator:** C. Heil (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Co-principal Investigators:** P. Countway, N. Record (Bigelow Lab for Ocean Sciences)

**Summary:** This project is focusing 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 is comparing two quantitative polymerase chain reaction (qPCR) units for efficacy and user-friendliness and selects 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:** Beach Conditions Reporting System

**Principal Investigators:** K. Claridge (Mote Marine Laboratory)

**Co-principal Investigators:** R. Pierce, S. Caywood, and A. Cook (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Summary:** This project is improving 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 the BCRS will include validation of citizen reports, integration and collaboration with outside data portals, and implementation of BloomZoom (see project summary below). The updates are expediting communication of the most up-to-date information about red tide blooms and giving citizens easier access to reporting.

**Title:** Testing the Efficacy of Products for Mitigating Harmful Effects of *Karenia brevis* Red Tide Events along the Florida Gulf Coast

**Principal Investigators:** R. Pierce (Mote Marine Laboratory)

**Co-principal Investigator:** C. Heil, E. Hall, V. Lovko, and J. Culter (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Summary:** The ability to apply products to the natural environment requires studies to ensure efficacy in the field and that no further public health or ecological harm results from these mitigation applications. This project: 1) is testing potential mitigation products to determine optimal product dosing concentrations and protocol, 2) establishes product toxicity on other marine biota with standard EPA assays, 3) is determining production of toxic chemical degradation products impacts and half-lives in seawater, 4) is determining sub-lethal impacts of these compounds on *K. brevis* and non-targeted organisms, 5) is examining interactive compound effects on microbiota and nutrient cycling over short and long-term time scales (days to weeks) in pilot mesocosm experiments, and 6) verifies 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:** 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:** S. Chakraborty (Mote Marine Laboratory)

**Co-principal Investigators:** R. Pierce, G. Kirkpatrick, V. Lovko, J. Hillier, K. Henderson, and J. Turner (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Summary:** This project is continuing 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 project is 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:** Developing UAV-based Red Tide Detection System

**Principal Investigator:** V. Lovko (Mote Marine Laboratory)

**Co-principal Investigators:** S. Chakraborty (Mote Marine Laboratory)

**Project Date:** January 2020 - June 2021

**Summary:** This project is examining 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. This project is developing a hyperspectral database from UAS surveys to map red tide blooms using the Mote Airborne Red-tide Remote Sensing System (MARRSS).

**Title:** Pushing *Karenia* Over the Edge with Beer Derived Flavonoids

**Principal Investigator:** A. Place (University of Maryland)

**Co-principal Investigators:** T. Armstrong (University of Maryland Center for Environmental Science – Institute of Marine and Environmental Technology),V. Lovko, and R. Pierce (Mote Marine Laboratory)

**Project Date:** April 2020 - May 2021

**Summary:** This project is testing 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:** Fate and Effects of *Karenia brevis* Cells, Toxins, and Nutrients Following Clay Application for Bloom Control

**Principal Investigator:** D. Anderson (Woods Hole Oceanographic Institute)

**Co-principal Investigators:** R. Pierce, J. Culter, E. Hall, V. Lovko (Mote Marine Laboratory) and Dr. Kristy A. Lewis (University of Central Florida)

**Project Date:** May 2020 - June 2021

**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 project is advancing ongoing research of kaolinite clay as an effective and ecologically sound method for mitigating and decreasing the impacts of Florida red tide. The team is using 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:** M. Parsons (Florida Gulf Coast University)

**Co-principal Investigators:** C. Heil (Mote Marine Laboratory)

**Project Date:** May 2020 - June 2021

**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 is quantifying the nutrient inputs to Florida red tide from fish kills in southwest Florida; is conducting a cost/benefit analysis of removing dead fish to help mitigate red tide; and is evaluating composting these fish (using a compost-accelerator compound) to produce fertilizer for local stakeholders.

**Title:** A Thin Shroud with Integrated Algaecide to Flocculate and Sink Karenia brevis

**Principal Investigator:** V. John (Tulane University)

**Co-principal Investigators:** T. Mclean (Tulane University)

**Project Date:** May 2020 - June 2021

**Summary:** Project scientists are testing 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 will carry natural clay nanotubes with algaecide inside. This project focuses on testing the technology in the lab and in larger-scale “mesocosm” systems 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, project leaders aim to transition to field experiments.

**Title:** Optimizing Production of a Dinoflagellate–specific Algicide for Control of *Karenia brevis*

**Principal Investigator:** K. Coyne (University of Delaware)

**Co-principal Investigators:** D. Wetzel and D. Lovko (Mote Marine Laboratory)

**Project Date:** June 2020 - July 2021

**Summary:** Researchers already know that certain bacteria naturally produce compounds that are “algicidal”—lethal to at least some species of algae. This project is focusing 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:** A Rapid Field Red Tide Toxin Biosensor for Commercially Important Shellfish and Seawater

**Principal Investigator:** D. Wetzel (Mote Marine Laboratory)

**Co-principal Investigators:** T. Sherwood and C. Miller (Mote Marine Laboratory)

**Project Date:** July 2020 - June 2021

**Summary:** This project is developing 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 develops 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:** D. Wetzel (Mote Marine Laboratory)

**Co-principal Investigators:** T. Sherwood, A. Tarnecki, and C. Miller (Mote Marine Laboratory)

**Project Date:** July 2020 - June 2021

**Summary:** This project is examining 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 are being identified, characterized and evaluated for effectiveness against *K. brevis* in mesocosm studies.

**Title:** BloomZoom: A Portable Phone-based Microscope for Quantitative Detection of *K. brevis* Through Citizen Science

**Principal Investigator:** V. Lovko (Mote Marine Laboratory)

**Project Date:** July 2020 - June 2021

**Summary:** This project is developing 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 enhances the accuracy of real-time information on red tide blooms and bloom forecasting.

**Title:** Automated *in situ* Advanced Sensing Technology Development for Red Tide Mitigation and Control (PHySS-C)

**Principal Investigator:** W. Haskell (Mote Marine Laboratory)

**Co-principal Investigator:** R. Pierce, G. Kirkpatrick, J. Hillier, K. Henderson, C. Caredio, and J. Turner (Mote Marine Laboratory)

**Project Date:** July 2020 - June 2021

**Summary:** This project is producing a 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:** Controlled Release Oxidants for Red Tide Treatment and Mitigation

**Principal investigator:** A. Carpenter (AxNano, LLC)

**Co-principal investigators:** C. Heil (Mote Marine Laboratory)

**Project Date:** November 2020 - December 2021

**Summary:** This project is utilizing 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:** Efficacy of EVIE robot against *K. brevis*

**Principal investigator:** A. Lyles (Solaris Cybernetics)

**Co-principal investigator:** R. Pierce (Mote Marine Laboratory) and R. Behrens (Solaris Cybernetics)

**Project Date:** November 2020 - December 2021

**Summary:** A robotic vessel, nicknamed EVIE, is being 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:** Microbe-Lift Mitigation 96 hour Testing with *Karenia brevis* (Red Tide)

**Principal investigator:** R. Elliott (Ecological Laboratories, Inc. – Enviro Water Quality Restoration, LLC)

**Co-principal investigators:** C. Heil (Mote Marine Laboratory)

**Project Date:** November 2020 - December 2021

**Summary:** The project is examining 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:** In-situ Mitigation of Florida Red Tide via Activated Carbon

**Principal investigator:** R. Rodrguez (Carbonxt)

**Co-principal investigator:** V. Lovko (Mote Marine Laboratory)

**Project Date:** November 2020 - December 2021

**Summary:** This project is developing and investigating 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:** Isolation of Natural Algicidal Bacteria Associated with Harmful Algal Blooms to Develop a Mitigation Strategy for Florida Red Tide

**Principal investigator:** G. Phillippidis (University of South Florida, Patel College of Global Sustainability)

**Co-principal investigator:** V. Lovko (Mote Marine Laboratory)

**Project Date:** December 2020 - January 2021

**Summary:** This project is assessing the microbial community associated with *K. brevis* to identify natural bacteria that possess algicidal properties and can help mitigate blooms of Florida red tide.

**Title:** A Preliminary Study to Assess the Feasibility of a Nanotechnology Approach to the Removal of *Karenia* *brevis* cells and Brevetoxin from Estuarine and Marine Waters

**Principal investigator:** J. Lead (University of South Carolina SmartState Center for Environmental Nanoscience and Risk)

**Co-principal investigator:** C. Heil (Mote Marine Laboratory)

**Project Date:** January 2021 - February 2022

**Summary:** This project is using 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:** A chemical-free Red Tide Mitigation Technology Utilizing UVC LEDs
**Principal investigator:** N. Williams (nTecSolutions LTD)

**Co-principal investigators:** K. Rein (Florida International University) and R. Pierce (Mote Marine Laboratory)

**Project Date:** January 2021 - February 2022

**Summary:** This project is examining 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 is investigating 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.