

Mote staff joins Blue Green Water Technologies and Emerge Marine on the *Guardian* for a field deployment

## FLORIDA RED TIDE MITIGATION AND TECHNOLOGY DEVELOPMENT INITIATIVE 379.2273(2)(d)

# ACCOMPLISHMENTS AND PRIORITIES REPORT

JANUARY 2026

Red tides, or red tide harmful algal blooms (HABs), are a higher-than-normal concentration of microscopic alga that occur in ocean and coastal waters. Red tides in Florida have been documented since the 1500's and their likely impacts date back to records from Spanish explorers. In Florida, the toxin producing *Karenia brevis* is the species causing most red tides. These blooms can harmfully affect sea life, lead to massive fish kills, cause human respiratory problems, close beaches, and significantly impact shellfish, fishing, hotel, restaurant, recreational, and tourism industries. This report is being provided to meet the requirement of 379.2273(2)(e) Florida Statutes, which states: "Each January 15 until its expiration, the initiative shall submit a report that

contains an overview of its accomplishments to date and priorities for subsequent years to the Governor, the President of the Senate, the Speaker of the House of Representatives, the Secretary of Environmental Protection, and the executive director of the Fish and Wildlife Conservation Commission."

### MITIGATING RED TIDE IMPACTS FOR FLORIDA

The Florida Red Tide Mitigation and Technology Development Initiative is a partnership between Mote Marine Laboratory (Mote) and the Florida Fish and Wildlife Conservation Commission (FWC), Fish and Wildlife Research Institute (FWRI), codified under 379.2273 Florida Statutes that establishes an

independent and coordinated effort among public and private research entities to develop prevention, control and mitigation technologies and approaches that will decrease the impacts of Florida red tide on the environment, economy and quality of life in Florida. The goal of the Initiative under 379.2273(2)(b) is “to develop, test, and implement innovative, effective, and environmentally sustainable technologies and approaches for controlling and mitigating the impacts of red tide.”

The Florida Legislature recognized the importance of continuing the Initiative through in-water deployment testing and clarifying the Initiative regulatory direction during the FY2023-2024 Session under 379.2273(2)(c): “Upon successful completion of science-based laboratory testing of prevention, control, and mitigation technologies and approaches, the initiative shall develop recommendations for field trial deployment of the technologies and approaches in state waters. The initiative shall submit a report on its findings and recommendations to the department, the commission, the Department of Agriculture and Consumer Services, and other state agencies with regulatory oversight of field trial deployment of the technologies and approaches in state waters. The department shall evaluate the technologies and approaches and identify all existing state permits Mote Marine Laboratory may use to deploy and test the technologies and approaches in state waters. The department shall submit its evaluation to Mote Marine Laboratory within 60 days after receipt of the report. If the department determines existing state permits may not be used, the department shall amend its regulatory or permitting processes to ensure the timely deployment of any red tide or similar harmful algal bloom mitigation and control technologies and approaches recommended by the initiative. Upon successful testing of the technologies and approaches, the department shall expedite regulatory reviews for the recurring use of the technologies and approaches



Dead fish found in Venice, FL canals during a bloom in February 2025

in state waters to control and mitigate the impacts of red tide or similar harmful algal blooms.”

### **STATE OF FLORIDA RED TIDE RESEARCH PROVIDING LOCAL CONTROL OPTIONS**

Mote is an over 70-year leader of independent, entrepreneurial and nonprofit marine research and FWC’s Fish and Wildlife Research Institute is the primary state-government entity focused on red tide. This Initiative builds upon the ongoing and highly productive FWC-Mote cooperative red tide research and monitoring program, while also leveraging state appropriations of \$3-million each year with Mote’s ability to secure additional private and federal funding in order to:

- Bring together the best and brightest scientists from Florida and around the world;
- Utilize innovative approaches and technologies to determine the most effective and ecologically sound methods for mitigating adverse impacts from red tide;
- Test technologies with combinations of lab-based, large-scale mesocosm and pilot-scale field studies ultimately leading to permitting for large-scale field testing and application;
- Develop novel detection systems to support public red tide forecasting, emergency response, and implementation of control strategies;

- Enhance public health protection with expansion of the Beach Conditions Reporting System ([visitbeaches.org](http://visitbeaches.org)), local community outreach and engagement; and
- Develop new technologies for smartphone apps to engage citizen science information collaborations and commercial fisherman reporting of red tide toxin concentrations.



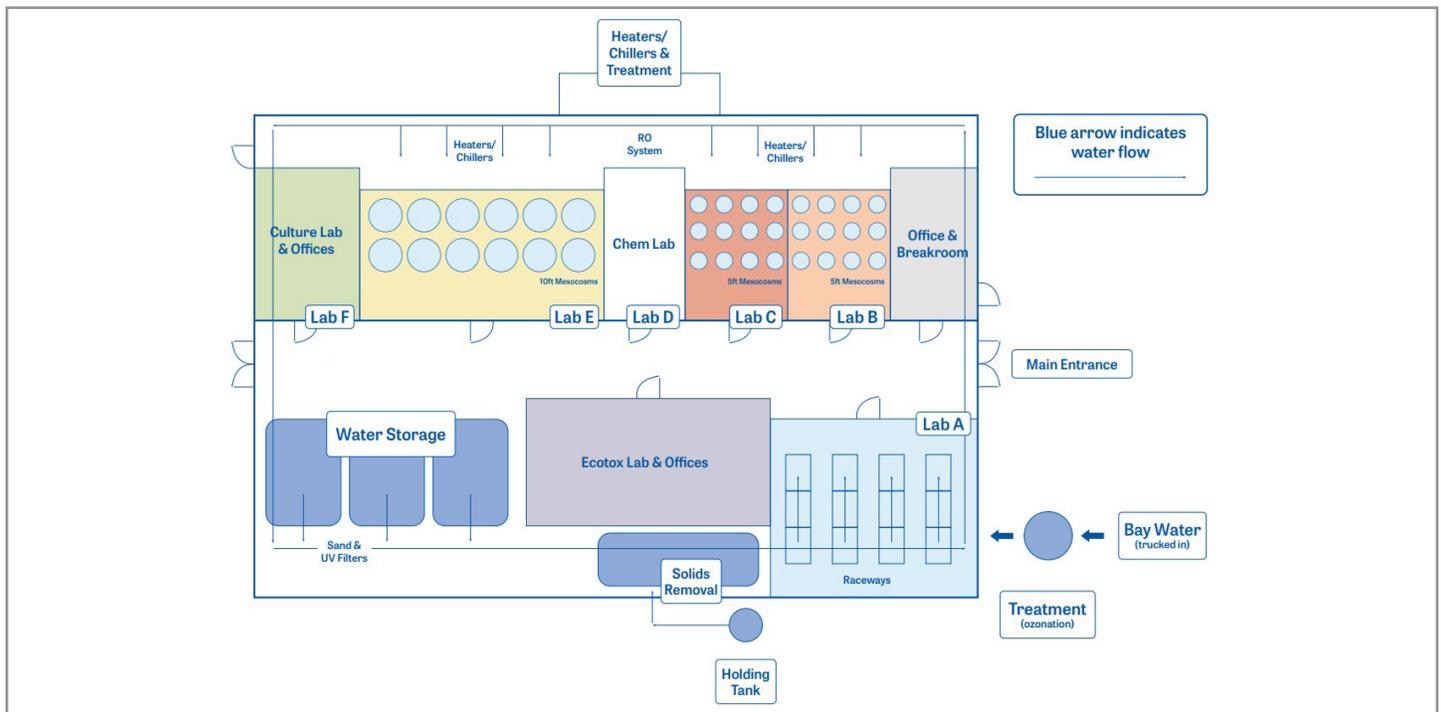
A sea urchin is exposed to curcumin to assess ecological impacts in a mesocosm experiment

## PIONEERING RED TIDE TECHNOLOGY TESTING FACILITIES

A key part of furthering red tide research is the need to safely test coastal ecosystem components with mitigation compounds and technologies through a multi-tiered approach (peer reviewed published literature or lab based, mesocosms/raceways, then offshore) using red tide culture. Thus, Mote created a cutting-edge red tide mitigation testing facility at the Mote Aquaculture Research Park (MAP) in Sarasota, approximately 15 miles inland from the coast. The facility uses over 150,000 gallons of treated and recirculated seawater stored in large holding areas for research raceway tanks and 5-foot and 10-foot



Clams and other shellfish are often used in mitigation experiments to monitor the uptake and depuration of brevetoxins in tissues



Schematic of Red Tide Mitigation and Technology Development Testing Facility

mesocosms, along with ample lab space for water quality, marine species, and toxin testing. The unique testing facility and unprecedented quantities of *K. brevis* culture are free for use by initiative scientists, allowing for safe and controlled setting tests prior to pilot field implementation.

### **TECHNOLOGY ADVISORY COUNCIL**

Mote has conducted ten Technology Advisory Council (TAC) Meetings (including three Workshops with TAC members attending) in compliance with 379.2273(3) which states: “There is established within the initiative, the Initiative Technology Advisory Council, an advisory council as defined in s. 20.03(7), that includes marine science, technology development, and natural resource management representatives from governmental entities, private organizations, and public or private research institutions. The council shall meet at least twice annually.” These public meetings have provided overviews of the administrative structure developed to run the initiative, public records laws, projects underway, proposals being considered, and planned next steps. Short biographies of the council members, presentations, and meeting minutes are on the Mote Red Tide Initiative website ([www.mote.org/redtideinitiative](http://www.mote.org/redtideinitiative)).

### **LEVERAGING WITH PRIVATE AND FEDERAL FUNDS**

In accordance with 379.2273(2)(d)(3) which states: “The initiative shall leverage state-appropriated funds with additional funds from private and federal sources”, Mote has successfully synergized and expanded initiative funding capabilities and impacts. For example, Mote has leveraged initiative appropriations with private business funds for water/algal treatment infrastructure developed by Prescott Clean Water Technologies, a generous donation from the Andrew and Judith Economos Foundation for

numerous mitigation compound studies, funding from the Southeast Coastal Ocean Observing Regional Association to support initiative reporting technology improvements, NOAA Ecology and Oceanography of HABs funding to assist mitigation tool development, and combined competitive USDA and NOAA grants as part of the initiative shellfish biosensor research. Mote is also leveraging funding, regulatory process understanding, and scientific research being conducted through the US Harmful Algal Bloom Control Technologies Incubator (US HABCTI), which is a Mote partnership with NOAA and the University of Maryland to provide proof-of-concept funding support for, and assess feasibility of innovative HAB control tools and technology development projects applicable to HABs that affect coastal and Great Lakes waters around the United States. Mote also includes undergraduate research experiences in the Red Tide Initiative through funding secured by the National Science Foundation and philanthropy to broaden opportunities for students participating in marine science STEM fields.

### **MOTE RED TIDE EXPERTISE**

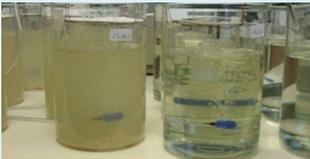
Mote brought together an experienced team of field and laboratory ocean and coastal scientists and resource management experts to lead Florida harmful algal bloom science and guide the initiative work. Mote utilized its in-house decades of red tide monitoring and innovative control techniques and engaged valuable expertise from the private, academic, and public sectors to work collaboratively while expanding and strengthening the red tide scientific network. Mote has also incorporated training for the next generation of scientists via undergraduate internships, graduate fellowships and postdoctoral research opportunities. And despite many challenges including supply shortages, staffing hurdles, and partner delays due to COVID-19 and hurricanes over the past six years, Mote’s

independent organizational framework has allowed for consistent mitigation testing progress.

## RED TIDE INITIATIVE PRODUCTIVITY

Initiative funding has enabled Mote to expand critical testing of mitigation products aimed at reducing *K. brevis* by identifying options that effectively kill the algae, minimize the impact of brevetoxins, and avoid additional human health or ecological harm. To date, Mote has evaluated more than 300 chemicals and compounds, and over 40 projects have been completed or are currently underway. While most projects have focused on natural, manmade, and technological mitigation techniques, several have also advanced public communication and monitoring tools designed to reduce the impacts of red tide. These efforts include updating the Programmable Hyperspectral Seawater Scanner; developing an in situ biosensor for shellfish farmers to detect brevetoxins; conducting a cost-benefit analysis of removing red-tide-impacted fish for use as fertilizer; deploying an unmanned aerial system for nearshore red tide reporting; enhancing the Beach Conditions Reporting System (now with more than 100 reporting locations); and creating smartphone-based citizen science tools for red tide detection.

Each mitigation project follows a tiered testing approach—peer reviewed published literature and/or lab based (Tier 1), mesocosms/raceways (Tier 2), and nearshore field sites (Tier 3). Projects in Tier 2 testing at the Red Tide Mitigation and Technology Development Facility focus on integrating mitigation techniques while monitoring natural ecosystem components – including impacts on water quality and keystone animals such as blue crabs, sea urchins, clams, oysters and shrimp. This ensures mitigation products have minimal adverse impacts to natural communities, which is essential data needed for projects to receive Federal, State, and local permitting approvals. As shown in the Project Status Diagram, most projects have completed Tier 1 and 2 testing, with several currently refining dosage or deployment methods before advancing to Tier 3. However, some products have encountered significant permitting challenges. Although these products have demonstrated strong performance in the lab, Tier 3 testing cannot proceed without extensive—and costly—toxicity evaluations required by the Environmental Protection Agency (EPA). Projects that have received the necessary permits for field trials either involved products already registered with the EPA or those classified as minimum-risk. Additional details on these projects can be found in the Appendix.

TIER 1	TIER 2	TIER 3	TIER 4
			
<b>Laboratory Experiments &amp; Literature Search</b>	<b>Mesocosms Raceways • Collaborations</b>	<b>Canals / Marinas Nearshore • Offshore</b>	<b>Commercialize Monitor</b>
<ul style="list-style-type: none"> <li>• Effects on the Cells and Toxins in the Lab</li> <li>• Previous Uses Worldwide</li> <li>• Existing Regulatory Approvals</li> </ul>	<ul style="list-style-type: none"> <li>• Effective with Natural Communities</li> <li>• Ecological Impacts</li> <li>• Human Health Concerns</li> <li>• Logistical Issues</li> <li>• Economically Feasible</li> </ul>	<ul style="list-style-type: none"> <li>• Pilot Studies &amp; Field Demonstrations</li> <li>• Federal/State/Local Regulatory Approvals</li> <li>• Engineering Needed</li> <li>• Public Interactions</li> </ul>	<ul style="list-style-type: none"> <li>• Customers</li> <li>• Intellectual Property</li> <li>• Efficiency Scaling</li> <li>• State/Local Budgets</li> <li>• Deployment Contractors</li> </ul>

## RED TIDE INITIATIVE PROJECTS

Mitigation Science, Deployment and Monitoring, Scalability, Environmental Compliance, Intellectual Property and Economic Feasibility

PROJECT TOPICS*	TIER 1	TIER 2	TIER 3	TIER 4
Smartphone PCR Technology <sup>1</sup>	Completed	Completed	Completed	Completed
Beer Derived Flavonoids <sup>2</sup>	Completed	Completed	Completed	Completed
PHySS Upgrades <sup>3,25</sup>	Completed	Completed	Completed	Completed
Bacterial Compounds <sup>4,7</sup>	Completed	Completed	In Progress	In Progress
Shellfish/Water Biosensor <sup>6,13,16</sup>	Completed	Completed	In Progress	Completed
Controlled Release Oxidants <sup>8</sup>	Completed	Completed	Completed	Completed
Fish Carcass Use <sup>9</sup>	Completed	Completed	Completed	Completed
UV LEDs <sup>10</sup>	Completed	Completed	Completed	Completed
QUATs <sup>11</sup>	Completed	Completed	Completed	Completed
UAV Detection System <sup>12</sup>	Completed	Completed	Completed	In Progress
RAS Brevetoxin Elimination <sup>14</sup>	Completed	Completed	In Progress	In Progress
Humic Acid Compound <sup>15</sup>	Completed	Completed	Completed	Completed
Deployment Platform <sup>17</sup>	Completed	Completed	Completed	Completed
EVIE Robot <sup>18</sup>	Completed	Completed	Completed	Completed
Activated Carbon/Algacide <sup>19,30</sup>	Completed	In Progress	Completed	Completed
Microbe-Lift <sup>20</sup>	Completed	Completed	Completed	Completed
Plasma <sup>21</sup>	Completed	Completed	Completed	Completed
Clay w/Biochar <sup>22</sup>	Completed	Completed	Completed	Completed
Nanotechnology Approach <sup>23</sup>	Completed	Completed	Completed	Completed
De-Oil-it/RTF3 <sup>24</sup>	Completed	Completed	Completed	Completed
BloomZoom <sup>26</sup>	Completed	Completed	In Progress	In Progress
Clay w/Oxidant <sup>27</sup>	Completed	Completed	Completed	Completed
Ultra-Archaea <sup>28</sup>	Completed	Completed	In Progress	In Progress
AUV <sup>29</sup>	Completed	Completed	In Progress	In Progress
Biokos <sup>31</sup>	Completed	Completed	Completed	Completed
Minimum Risk Products <sup>32</sup>	Completed	Completed	Completed	Completed
Curcumin <sup>33</sup>	Completed	Completed	In Progress	In Progress
Lake Guard Oxy <sup>34</sup>	Completed	Completed	Completed	Completed
Electromagnetic Energy <sup>35</sup>	Completed	Completed	In Progress	In Progress
Xtreme <sup>36</sup>	Completed	Completed	Completed	Completed
Ozonix <sup>37</sup>	Completed	Completed	Completed	Completed
Clay <sup>5,38</sup>	Completed	Completed	In Progress	In Progress
BCRS Upgrades <sup>39</sup>	Completed	Completed	Completed	Completed
Natural Plant Compounds <sup>40</sup>	Completed	Completed	Completed	Completed

\*For more information please see the Referenced Number in the Appendix Project Summaries.



Completed



In Progress

## TIER 3 FIELD DEPLOYMENTS

During the past year, the Initiative directed its efforts toward transitioning mitigation tools and technologies that have completed Tier 2 testing into pilot-scale deployments within the natural environment. Mote collaborated with federal and state permitting agencies to identify the regulatory requirements governing red tide mitigation activities and to establish a clear pathway for projects to follow to ensure full compliance. Projects are subject to regulations enforced by EPA under the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Food Drug and Cosmetic Act; US Army Corps of Engineers; Florida Department of Environmental Protection; Florida Department of Agriculture and Consumer Services; and Florida Fish and Wildlife Conservation Commission. Depending on the product's composition and origin, navigating these regulatory steps can be lengthy and, in some cases, may hinder progression to Tier 3 testing.

Despite these challenges, several products—including Clear, Xtreme, LakeGuard Oxy, Ozonix, and clay—have successfully completed the regulatory process and secured the permits needed for field testing. However, additional work was still required to address the logistical challenges and operational procedures essential for effective red tide mitigation. To meet these needs, Mote partnered with specialists from related emergency-response disciplines to develop advanced field technologies capable of deploying mitigation tools safely and efficiently.

Mote contracted Emerge Marine to assist four of the five permitted projects, excluding clay. Emerge Marine provides critical support for these projects, including the fabrication of sprayers and other dispersal systems for liquid, powder, and pelletized materials; the provision of a fleet of vessels and licensed crew for field deployments; and the evaluation of deployment limitations, operational costs, and procedures to inform future mitigation



Deployment logistical tests often include the use of dyes to visualize how a mitigation product is distributed in the water



A barge is equipped with a tote and liquid sprayer to transport and disperse products Xtreme and Clear in two separate canals



Staff take water samples to analyze the impact of the product on water quality, nutrients, *Karenia brevis*, and toxins



Lake Guard Oxy, a sodium-percarbonate based product, is deployed near Sapphire Shores Park in Sarasota, Florida



Lake Guard Oxy floating on the surface of the water immediately after deployment



Mote staff process water samples on the *Guardian*

efforts. Emerge also retrofitted the 110' marine vessel *Guardian* to accommodate a floating lab for researchers. This lab space is essential for analyzing water samples in real time during Tier 3 testing to determine impacts from the mitigation product. Since early 2025, Mote has conducted three field deployments: (1) Clear and Xtreme were applied on February 14th in red tide-impacted canals in Venice, Florida; (2) Lake Guard Oxy was applied on November 12th in the waters adjacent to Sapphire Shores Park in Sarasota, Florida; and (3) a logistical deployment of the Ozonix technology was conducted in December near Fort Myers, Florida. The

February deployment occurred during an active red tide bloom, allowing researchers to evaluate impacts on *K. brevis* cell concentrations and toxin levels. The subsequent deployments, conducted in the absence of a bloom, focused on addressing logistical challenges, refining response protocols, and improving readiness for future mitigation events. Continued field research is needed for all tools and technologies to better understand how natural environmental conditions influence product performance—and how these products affect the environment. Additional deployments are planned throughout 2026.

## SUMMARY OF INITIATIVE PROGRESS

- Statutory, Administrative, FWC Contract and Partner Subcontract Structure
- Red Tide Mitigation and Technology Development Initiative Website
- Cutting-Edge Red Tide Mitigation Testing Facility
- 5 Requests For Proposals, 4 Partner Webinars
- 40+ Initiative Projects Concluded or Underway
- 50+ Funded External Partners
- Examined over 300 compounds and technologies
- Strategic Selection of Technologies to Fast Track
- 10 Public Technology Advisory Council Meetings
- Numerous meetings with local communities and regulatory partners for upcoming mitigation deployments
- Hosted 3 Workshops
- Leveraged Initiative Funding With Private and Federal Sources
- 6 Annual Progress Reports to Governor, Legislature and Agencies



2025 Red Tide Initiative Workshop

local government representatives; business partners; intellectual property experts from the law firm Burr Forman; pesticide regulatory experts from Conn & Smith; and state of Florida emergency deployment experts (e.g. oil spill technologies). These events provide the opportunity to review project progress, regulatory requirements, deployment technologies and property access, scalability, and financial feasibility. Mote plans to host another workshop to advance and expedite these issues in late Spring 2026.

Complementing this regulatory and technical coordination, Mote also recognizes that transparency and public communication are essential when conducting field trials. In January 2025, Mote hosted a media day to showcase the mitigation tools preparing for Tier 3 testing, and has since continued working closely with local governments, homeowners' associations, waterkeepers, and other community partners to keep the public informed on deployments and the results.

## RESEARCH PARTNERSHIPS

Another important part of the initiative was included under 379.2273(2)(d)(1), which states: "Mote Marine Laboratory may, with the concurrence of the Fish and Wildlife Research Institute, use a portion of the awarded funds to facilitate additional engagement with other pertinent marine science and technology development organizations in this state

## RED TIDE INITIATIVE WORKSHOP & COMMUNITY OUTREACH

Mote regularly coordinates with state and federal agencies on required pesticide and environmental resource regulations and permitting, as well as with key partners on early commercialization steps. To encourage and socialize these important but complex processes for red tide mitigation, Mote has hosted three Workshops (August 2022, August 2023, and January 2025), each bringing together more than 75 participants- including scientists; federal, state, and

and around the world to pursue applied research and technology for the control and mitigation of the impacts of red tide.” Mote embraced this opportunity with the careful guidance to partners that any developed mitigation technology must not cause greater harm to human health or the Florida coastal ecosystems than the red tide itself.

To date, Mote has conducted five “Requests For Proposals” and review processes, highlighted the initiative at many conferences and meetings, hosted four public webinars, and led countless video/phone calls which ultimately have generated well over 100 mitigation technology development proposals. The initiative funding opportunities have been open to any and all interested parties and Mote has received widespread local, state, national and international interest. Mote convened highly qualified research proposal review panels composed of representatives from multiple federal and state agencies, several

universities, Florida National Estuary Programs and private industry. The use of MAP red tide technology testing facilities at no charge was encouraged, but not required, and subcontracts were limited to 12 months (with ability to apply each subsequent year depending on previous year outcomes) to expedite and better guide research findings. A select group of proposals has been presented at the regular TAC meetings for recommendations and have been open to public comment.

A complete list of project titles, principal investigators and summaries are attached as an Appendix to this report and can also be found on the Mote Red Tide Initiative website ([www.mote.org/redtideinitiative](http://www.mote.org/redtideinitiative)). Mote has subcontracted and partnered on a variety of research and regulatory issues with 50+ different private business, agency and academic partners, as demonstrated by their logos below:



## APPENDIX

### FLORIDA RED TIDE MITIGATION AND TECHNOLOGY DEVELOPMENT INITIATIVE PROJECT EXECUTIVE SUMMARIES

**1. Title:** Citizen Science Detection and Quantification of Florida Red Tides via Personal and Smartphone-enabled PCR Technology

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

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

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

**Summary:** This project focused on the development and application of qPCR technology to simultaneously identify and quantify the two dominant *Karenia* species, *K. brevis* and *K. mikimotoi*, present in southwest Florida blooms and integrate this technology into Mote's Citizen Science Monitoring Network. Molecular detection has advantages over traditional microscopic identification as it does not require specialized taxonomic and microscopic training and is able to rapidly detect extremely low cell concentrations. The project compared two quantitative polymerase chain reaction (qPCR) units for efficacy and user-friendliness, selected the better fit to be used for *Karenia* detection and trained Mote Citizen Scientists in their routine use. The technology was tested and verified during the 2020-2021 red tide and has also been utilized by other states for *Karenia* detection in their coastal waters.

**2. 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 – January 2022

**Summary:** This project tested 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 was not clear that the barley straw would degrade or produce the same compounds in saltwater than 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 assessed its practical use for controlling *K. brevis* and its toxins.

**3. 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 – March 2022

**Summary:** This project was 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 was completing a hyperspectral library for different phytoplankton functional types and refining the algorithm by performing sensitivity and uncertainty analyses.

**4. Title:** Optimizing Production of a Dinoflagellate-specific Control of *Karenia brevis*

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

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

**Project Date:** June 2020 – September 2022

**Summary:** Bacteria naturally produce compounds that are “allelopathic”— lethal to at least some species of algae. This research has focused on the bacterial allelochemicals produced by *Shewanella* sp. IRI-160. Researchers worked to optimize the production of the chemicals, identify the compounds, and test those on *K. brevis*. The project continues under funding separate from the Initiative with partners from NOAA and ERDC. The team has developed a product called DinoSHIELD, which contains the algicidal bacteria in a non-toxic hydrogel preventing the bacteria from releasing into the water column but allowing the algicidal compounds to dissolve and mitigate red tide. Future collaboration with Mote is anticipated as the project continues testing, prepares for field deployment, and navigates regulatory hurdles.

**5. 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 K. Lewis (University of Central Florida)

**Project Date:** May 2020 – October 2022

**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 was needed to transition clays for use in the U.S. This project was 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 used the red tide facility mesocosms to test clay treatments on Gulf of Mexico ecosystem components and research included limnocorral studies to work with captured natural planktonic and benthic communities. This project was answering such questions as: 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. This research is continuing under another project (#38) to combine clay with other algicides, and is also leveraging funding from federal NOAA PCMHAB grants and Florida Sea Grant.

**6. Title:** Enabling Accurate Field-based Testing for Shellfish Farmers with Optimized Toxin Extraction and Stable Standards

**Principal Investigator:** J. McCall (University of North Carolina Wilmington)

**Co-Principal Investigators:** D. Wetzel and T. Sherwood (Mote Marine Laboratory)

**Project Date:** October 2021 – November 2022

**Summary:** This project aimed to help shellfish farmers by producing a user-friendly extraction and test kit that can detect brevetoxins in shellfish. The shellfish farming industry must regularly monitor for toxic shellfish, which can lead to human illness if consumed. Currently, shellfish farmers rely on laboratory testing to know if their product is toxic due to red tide, which can take days. The test kit produced in this study will allow farmers to perform the toxin tests in the field and to be better informed about the status of their product. This project is closely coordinating with the Mote Rapid Field Red Tide Toxin Biosensor project.

**7. Title:** Red Tide Mitigation through Natural Bacteria Suppression of *K. brevis* during HAB Progression

**Principal Investigator:** G. Philippidis (University of South Florida)

**Co-Principal Investigators:** V. Lovko (Mote Marine Laboratory) and A. Tarnecki (Auburn University)

**Project Date:** December 2020 – December 2022

**Summary:** This project aimed to understand the relationship between *K. brevis* and allelopathic bacteria. There is little known about the interactions between these bacterial species and *K. brevis*, therefore researchers monitored a red tide bloom throughout its progression, before the bloom started and after it dispersed. Bacteria and the rest of the microbial community were profiled and identified. The data allowed researchers to determine some of the conditions that favor suppression of *K. brevis* and moved science closer towards a realistic bacterial mitigation strategy based off those conditions. The data also contributed to Mote's microbiological library, which is now being used to explore algicidal bacteria against other HABs, including *Alexandrium* and *Pseudo-nitzschia sp.* under a US HABCTI grant.

**8. Title:** Controlled Release Oxidants for Red Tide Treatment and Mitigation

**Principal Investigator:** J. Darcy (AxNano, LLC)

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

**Project Date:** November 2020 – March 2023

**Summary:** AxNano tested their groundwater remediation product, RemRx™ CRP (Controlled Release Pellets), for mitigating *K. brevis*. RemRx™ CRP is formulated to gradually release oxidants into the water over time. A sustained oxidant source is hypothesized to be successful in treating and subsequently mitigating red tide blooms in surface waters. In addition, the controlled release functionality of RemRx™ CRP is hypothesized to decrease stressors on the surrounding ecosystem. Initiative research has demonstrated that the active oxidant in RemRx™ CRP is lethal to *K. brevis* and can degrade brevetoxins. Testing in the red tide facility's mesocosms yielded insight into the effect of RemRx™ CRP on other aquatic species. Future testing may include the optimal depth of oxidant release in the water column, and explore combinations of fast release and slow release RemRx™ CRP percarbonate required for treatment and mitigation of *K. brevis* in dynamic systems.

**9. Title:** Examining the Feasibility of Removing and Composting Fish Carcasses to Mitigate Red Tide

**Principal Investigator:** M. Parsons (Florida Gulf Coast University)

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

**Project Date:** May 2020 – March 2023

**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 project quantified the nutrient inputs to Florida red tide from fish kills in southwest Florida; conducted a cost/benefit analysis of removing dead fish to help mitigate red tide; and evaluated composting these fish (using a compost-accelerator compound) to produce fertilizer for local stakeholders. Nitrate, nitrite and urea concentrations (and release rates) were found to be negligible likely due to microbial processes and ammonium was the major nitrogen-based inorganic nutrient released by the decaying fish (and/or transformed by microbial processes). This project found that fish decay may be a more important nitrogen source than previously believed; fish decay may be a less important phosphorus source than previously believed; and nutrient release rates generally stabilized within 2 and 7 days after fish decay commenced. Next steps for this project include commercialization of fish clean-up for beneficial use.

**10. 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 – March 2023

**Summary:** This project was examining the development of a field device that utilizes ultraviolet wavelengths (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 has been 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 *K. brevis*, with the goal of stopping a bloom before it develops or to halt an ongoing bloom. Researchers have concluded mesocosm testing, though some device and non-target species investigations continue, and engineering/scalability work is being considered.

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

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

**Co-Principal Investigators:** E. Hall, J. Frankle, and S. Klass (Mote Marine Laboratory)

**Project Date:** January 2020 – March 2023

**Summary:** This project was 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 were 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. The mitigation findings from this project are now being utilized in the *Karenia* Mitigation Platform Project (#17) for deployment testing. There are also ongoing examinations into the EPA regulatory perspectives for QUATS as HAB mitigation tools.

**12. Title:** Developing UAV-based Red Tide Detection System

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

**Co-Principal Investigator:** S. Chakraborty (Mote Marine Laboratory)

**Project Date:** January 2020 – March 2023

**Summary:** This project was 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 has been developing protocols for data collection and a hyperspectral database from UAS surveys to map red tide blooms as well as other phytoplankton blooms as they occur.

**13. 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 – March 2023

**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 based on time-consuming laboratory analyses. Synthetic aptamers have been made to be used in the rapid field test kit. Multiple formats for the field kit are being evaluated, including lateral flow, fluorescent aptamer assay, and agarose bead technology. The project is also developing commercial application methods for depleting red tide toxins from shellfish using a land-based recirculation system. A series of oyster, clam, and sunray venus clam red tide uptake exposures and subsequent depuration studies have been completed. The results have shown that at red tide toxin accumulation levels of over 4.0 ppm, depuration to below regulatory limits was achieved in less than 24 hours, confirming that land-based depuration is a suitable mitigation strategy for red tide-contaminated shellfish. These technologies will not only help the shellfish industry, but they will also help reduce consumer risk and aid in red tide monitoring and research. This project is leveraging funding from NOAA, USDA, and FMRI.

**14. Title:** Flushing Out Red Tide: Investigating Recirculating System Technologies for Brevetoxin Elimination from Shellfish

**Principal Investigator:** N. Rhody (Mote Marine Laboratory)

**Project Date:** April 2022 – March 2023

**Summary:** Due to the risk of neurotoxic shellfish poisoning caused by consuming shellfish contaminated with brevetoxins, the Florida Department of Agriculture and Consumer Services continually monitors and evaluates shellfish harvesting areas during red tides. Red tide related closures to these harvesting areas have resulted in millions of dollars of lost revenue for the commercial shellfish industry. One solution to mitigate these catastrophic economic losses is to use land-based recirculating aquaculture systems (RAS) to purge or eliminate brevetoxins from shellfish harvested out of areas impacted by red tide. The post-harvest process of depuration involves placing shellfish into tanks of high-quality seawater to purge any contaminants stored in their tissues thus, rendering them safe for human consumption. Historically, wet storage systems have been used only for removing bacterial contaminants (*Vibrio* sp.) and, at present, there are no federally approved

protocols for use of these systems for toxin removal. This research aimed to assess the utilization and efficacy of RAS systems for rapid elimination of brevetoxins from shellfish tissues following exposure to *K. brevis*.

**15. Title:** Mitigation of Brevetoxin Aerosolization by Dissolved Humic Substances

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

**Project Date:** April 2022- March 2023

**Summary:** Inhalation of aerosolized brevetoxins impacts huge numbers of both tourists and residents during *K. brevis* blooms. Prior and current options for mitigation of aerosolized HAB toxins are indirect and focus on either the elimination of HAB cells and toxins within the water or on education, outreach and behavioral modification to minimize exposure. This project focused on a method by which humic acids - naturally occurring, chemically complex mixtures of organic acids resulting from plant degradation - are added to waters containing a HAB to reduce production of aerosolized toxins. Application of dissolved humic compounds to *K. brevis* cultures in preliminary experiments have been shown to reduce the production of aerosolized brevetoxin by >99%. This project sought to identify a low-cost humic acid compound effective in mitigating the production of brevetoxin aerosols. Next steps include investigating the regulatory requirements needed to conduct field trials and registration with the EPA.

**16. Title:** Mitigation, Regulation, and Assessment of the Toxicity of Individual Brevetoxins: Protecting Human Health while Maintaining a Viable Economy

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

**Co-Principal Investigator:** T. Sherwood, C. Miller (Mote Marine Laboratory)

**Project Date:** April 2022- March 2023

**Summary:** Neurotoxic shellfish poisoning (NSP) in humans is caused by consuming shellfish that have bioaccumulated red tide toxins. To reduce the risk of NSP, shellfish farms are monitored and regulated to determine whether shellfish are below toxicity levels during a red tide event. Current US regulatory agencies rely solely on the mouse bioassay (MBA) for determining brevetoxin toxicity in shellfish and for closures and openings of shellfish farms. The MBA is time-consuming, costly, and does not directly measure toxin levels. This project aimed to develop a new method for testing brevetoxin toxicity in place of the MBA using neuroblastoma cell lines.

**17. Title:** *Karenia* Mitigation Platform: Means and Method for Enhancing, Vetting, and Deploying Red Tide Mitigation Technologies within Open Water Conditions

**Principal Investigator:** J. Ivey (University of South Florida)

**Co-Principal Investigators:** M. Diedzic (BlackRock Energy Corporation), C. Heil and R. Pierce (Mote Marine Laboratory)

**Project Date:** December 2021- March 2023

**Summary:** This project is focused on the development of an adaptable floating platform to deploy mitigation compounds safely and efficiently. The platform will float on an aluminum work barge and will house a pumping, treatment and monitoring system that can work with different red tide mitigation technologies including nanoparticles, ozone and clays. Researchers tested the efficiency of the platform using QUATs, a mitigation technique currently being explored in another Initiative project. As more mitigation products

enter Tier 3 testing in the field, they can be combined with the platform as a deployment method and allow for integrated water quality and HAB monitoring and mitigation all in one system.

**18. Title:** Optimizing the EVIE Robot Technology to Mitigate *K. brevis*

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

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

**Project Date:** November 2020 – March 2023

**Summary:** A robotic vessel, nicknamed EVIE, is being tested in mesocosm and stormwater pond settings. Mesocosm testing determined its ability to identify *K. brevis* cells via a finely-tuned reflected-light sensor and subsequently harvest cells via a nozzle, convert them to harmless biofuels, and store the product in the robot's holding tank. Results exhibited successful destruction of *K. brevis* cells, however EVIE was not as effective at toxin degradation. Researchers intend to modify EVIE's nozzle to optimize the reduction of red tide toxins in future tests and research will continue under non-Initiative support for freshwater HAB use.

**19. Title:** In situ Mitigation of Florida Red Tide via Activated Carbon

**Principal Investigator:** R. Rodriguez (Carbonxt)

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

**Project Date:** November 2020 – September 2023

**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*. Researchers have identified a combination of activated carbon and luteolin, a plant-derived flavonoid, that work together to reduce *K. brevis* cells and toxins. This research is continuing under another project (#30) to combine activated carbon with other algicides.

**20. Title:** Simulated field study (mesocosm and nearshore) of Microbe-Lift PBL plus Microbe-Lift SA or single product ML/RTM3322 on *Karenia brevis*

**Principal Investigator:** S. Xu (Ecological Laboratories, Inc.)

**Co-Principal Investigator:** C. Heil and R. Pierce (Mote Marine Laboratory)

**Project Date:** November 2020 – September 2023

**Summary:** This project examined 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. Researchers tested the ability of Microbe-Lift to eliminate *K. brevis* cells and brevetoxins in laboratory and mesocosm experiments. Ecotoxicology tests were also performed on a variety of marine organisms with promising results. Researchers will continue to focus on optimizing the formula and dosage of Microbe-Lift for field deployment as well as combinations with other Initiative tools/technologies being developed.

**21. Title:** Plasma-Assisted Destruction of *Karenia brevis*

**Principal Investigator:** J. Mangum (Southwest Research Institute)

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

**Project Date:** October 2022 – September 2023

**Summary:** This project investigated plasma-based mitigation of red tide cells and toxins on a laboratory scale. Plasma is an electrically charged gas, naturally found as lightning or static electricity. In recent years, plasma technology has been found to act as a microbiological decontaminant, and has been used to treat algal blooms and disinfect fruits and vegetables. When plasma interacts with water, it creates many reactive and oxidative species that can potentially eliminate red tide cells and toxins. Researchers developed a portable plasma system to examine the best method to apply plasma treatments to *K. brevis* in beaker-sized experiments. It was found that plasma could rapidly destroy *K. brevis* cells and toxins in a matter of minutes and that destruction efficiency was impacted by how the plasma interacts with the water. Additional collaboration on plasma-based research for *K. brevis* and other harmful algal blooms is under consideration.

**22. Title:** Adsorption of Brevetoxins on Low-Cost Biochar

**Principal Investigator:** T. Reza (Florida Institute of Technology)

**Co-Principal Investigator:** S. Fire (Florida Institute of Technology), V. Lovko (Mote Marine Laboratory), and D. Anderson (Woods Hole Oceanographic Institute)

**Project Date:** September 2022 – October 2023

**Summary:** This project investigated the use of clay modified with biochar to remove red tide cells and toxins. Biochar is a carbon-rich solid product traditionally used for carbon sequestration and water purification, but has recently been shown to absorb toxins from harmful algal blooms. Previous studies confirm that clay can effectively remove *K. brevis* cells during flocculation, however brevetoxin concentrations remain high. The addition of biochar is anticipated to remove the remaining toxins from the water column. Researchers tested two types of biochar, a commercially available product and one developed in the lab by the PI's, and initial results demonstrate both are effective at removing toxins. The team will continue to test biochar with other agents, including poly-aluminum chloride, on *Karenia brevis* and other HABs under a USHABCTI grant.

**23. 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)

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

**Project Date:** January 2021 – December 2023

**Summary:** This project was 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 were being tested to see if they can effectively attract both brevetoxins and *K. brevis* cells and remove them from the water. Significant progress has been made on the synthesis of polymer-coated magnetic iron oxide nanoparticles and characterization of their physico-chemical properties. The team also conducted mesocosm tests to determine efficacy on red tide cells, as well as the deployment and removal logistics of the nanoparticles. Results from the study will help researchers determine best practices for real-world implementation.

**24. Title:** Mitigation of *Karenia brevis* cells and toxins using De-Oil-It RTF3 Formula

**Principal Investigator:** D. Schillaci (Greenworld Environmental Alliance)

**Co-Principal Investigators:** C. Heil, R. Pierce, and E. Hall (Mote Marine Laboratory)

**Project Date:** August 2022 – September 2024

**Summary:** This project examined the use of De-Oil-it, a hydrocarbon biodegrader solution, as a mitigation product for red tide. De-Oil-It is typically used to break down oil and fuel spills by degrading hydrocarbons into less toxic chemicals. Greenworld Environmental Alliance tested a diluted version of De-Oil-It called RTF3 on red tide cultures, successfully eliminating both cells and toxins. These tests will help address environmental safety concerns through EPA approved toxicity tests on shrimp and fish, as well as determine the best application/deployment method of RTF3. This project completed mesocosm tests in early 2024 and is navigating the permitting process with EPA for field use, however the current ingredients in RTF3 may require extended review by the EPA so the team is looking into alternative compounds that are EPA approved.

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

**Principal Investigator:** J. Langan (Mote Marine Laboratory)

**Co-Principal Investigators:** R. Maguire and K. Henderson (Mote Marine Laboratory)

**Project Date:** July 2020 – June 2025

**Summary:** This project is producing a new sensor technology to replace existing PHySS-2 sensors with next generation advanced technology multi-use in situ sensors for red tide mitigation and control applications. The PHySS-C advanced sensing technology applications 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 to inform the public of red tides, direct red tide bloom mitigation and control applications, and to assess the efficacy of red tide mitigation applications/techniques.

**26. 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 2025

**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. Researchers have now constructed a working prototype housed in a commercially available insulated metal water bottle that can be disassembled, greatly assisting in the construction and assembly of the BloomZoom. Additional work is needed to optimize the device, including the development of an application (for multiple mobile platforms) to control the device and integration of data streaming from BloomZoom to BCRS.

**27. Title:** A New Approach to the Flocculation, Sinking and Targeted Destruction of *Karenia brevis*

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

**Co-Principal Investigators:** V. Lovko (Mote Marine Laboratory), and T. Mclean (Tulane University)

**Project Date:** May 2020 – June 2025

**Summary:** This project started by testing an advanced technology designed to “smother” *K. brevis*, pull it to the bottom and treat it with peroxide in a targeted, controlled way. The technology is a super thin, environmentally benign shroud called a metal phenolic network (MPN). Test results concluded that MPNs are effective at flocculating the cells, however it was not possible to target and kill *K. brevis* cells in the floc with a peroxide. Therefore, researchers decided to use polyaluminum chloride in place of the MPN to act as the flocculant, and sodium percarbonate, which releases hydrogen peroxide, or calcium peroxide. The project is focusing on optimizing the formula for the controlled release of peroxide in polyaluminum chloride-based flocs to rapidly kill red tide cells. Researchers are also investigating regulatory approvals with the EPA for field testing and long-term registration. This project received funding from the US HABCTI to test on freshwater HABs.

**28. Title:** Ultra-Archaea Bioremediation Product for Red Tide Mitigation

**Principal Investigator:** M. Clancy (UltraTech International)

**Co-Principal Investigators:** M. Shaw (UltraTech), R. Pierce and J. Toyoda (Mote Marine Laboratory), and W. Baird (WEB Engineering/Microsorb)

**Project Date:** September 2023 – June 2025

**Summary:** This project is investigating the efficacy of Ultra-Archaea to mitigate red tide and brevetoxins. Ultra-archaea is a collection of over a hundred species of the domain Archaea, unicellular prokaryotic organisms that thrive in extreme environments. This colony is a naturally occurring bioremediation culture used for environmental clean-up applications such as oil spills, livestock waste, and sewage treatment for over 40 years. Ultra-Archaea are also on the EPA National Contingency List as a bioremediation product. Researchers are conducting tabletop range-finder and mesocosm tests to determine the correct dosing concentration to mitigate *K. brevis* and reduce brevetoxins while investigating any non-target marine organism impacts.

**29. Title:** Innovative integration of autonomous marine technologies to enhance the monitoring and management of harmful algal blooms

**Principal Investigator:** J. Langan (Mote Marine Laboratory)

**Project Date:** September 2023- June 2025

**Summary:** This project focuses on the integration of autonomous marine technologies to enhance the monitoring and management of *Karenia brevis*. Central to this effort is the acquisition of the Lightfish, a cutting-edge autonomous surface vessel equipped with the proprietary PHySS sensor system, developed in an earlier project. The PHySS sensor utilizes advanced 4th derivative spectral analysis to detect subtle variations in phytoplankton composition, providing rapid and accurate indications of *K. brevis* presence. This precision tool allows for targeted investigations in areas of interest, significantly improving the efficiency of monitoring efforts. By combining advanced autonomous technologies, this project bridges the gap between large scale environmental surveillance and localized ecological assessment. This capability not only enhances our understanding of *K. brevis* dynamics but also strengthens our capacity to provide timely alerts and responses to harmful algal blooms, benefiting marine ecosystems, safeguarding coastal communities, and supporting effective resource management strategies.

**30. Title:** Pelletization of algicide and activated carbon for mitigation technology

**Principal Investigator:** R. Rodriguez (Carbonxt)

**Co-Principal Investigators:** D. Contrino (Carbonxt) and V. Lovko (Mote Marine Laboratory)

**Project Date:** July 2024 – June 2025

**Summary:** This project investigated commercialization and agglomeration methodologies to mix activated carbon with an EPA approved, or likely to be approved, algicidal compound. Activated carbon has been tested as a mitigation product in another Initiative funded project, and works well when combined with an algicide. Mixing activated carbon with an EPA-approved compound will reduce regulatory hurdles for field testing and real-world application for red tide mitigation, therefore making it easy for this project to fast track through tiered testing with successful results.

**31. Title:** Biokos - a natural solution for the treatment of Red Tide

**Principal Investigator:** G. Salerno (Sundew)

**Co-Principal Investigator:** J. Toyoda (Mote Marine Laboratory)

**Project Date:** December 2024 – June 2025

**Summary:** This project was focused on validating a new Biokos based formulation against *K. Brevis*. Biokos is a cyclic lipopeptide made by a natural strain of *Pseudomonas* sp. H6 that interacts with cellular membranes of certain organisms, until the membranes lose functionality and the cells die. It shows little or no activity on bacteria or environmental key species of green algae, cyanobacteria or daphnia, and it degrades to its constituent amino and fatty acid residues. Biokos is currently sold in the ornamental market for use as an antiparasitic across the globe. The aim of this project was to develop a formulation of Biokos that specifically targets *K. brevis* and determine the proper dosage for larger scale applications. While initial results showed a significant reduction in cells, further research is needed to understand the impact on the microbial community and other organisms.

**32. Title:** Tier 1 Testing of Active Ingredients Eligible for Minimum Risk Pesticide Products with *Karenia brevis*

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

**Project Date:** July 2024- June 2025

**Summary:** State and federal permitting requirements remain a major barrier to advancing potential *K. brevis* mitigation compounds from laboratory research to in situ testing, making it essential to identify options that qualify for the U.S. EPA's streamlined Minimum Risk Pesticide (FIFRA-exempt) pathway. To support this effort, researchers reviewed FIFRA-exempt active ingredients for evidence of algicidal, antiviral, antibacterial, or antiparasitic activity and selected five commercially available, literature-supported compounds for Tier 1 laboratory testing. The project conducted range-finding and definitive Tier 1 experiments to evaluate cell removal and brevetoxin reduction, refine dose ranges, and identify candidates for Tier 2 mesocosm trials. Based on literature review and extensive laboratory testing, cinnamon oil and thyme oil emerged as the most effective compounds, consistently reducing *K. brevis* cells and brevetoxins within 24 hours, with essential oil formulations outperforming powders due to stronger activity and easier solubilization.

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

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

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

**Project Date:** January 2020 – June 2025

**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. After testing numerous compounds, researchers found curcumin to be the most effective at removing *K. brevis* cells and toxins. Curcumin, an extract of turmeric root, is used in aquaculture facilities as a dietary supplement for fish and has many health benefits. The project conducted mesocosm tests to determine the impacts of curcumin on multiple marine organisms, and is now navigating the permitting process for field trials. Researchers are investigating different forms of curcumin that would be approved for mitigation use in coastal waters by the EPA. Once a final product is selected, the project intends to complete field trials with the appropriate permits.

**34. Title:** Efficacy of Lake Guard Oxy Against *Karenia brevis* Development

**Principal Investigator:** J. Frost (BlueGreen Water Technologies)

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

**Project Date:** August 2023 – June 2026

**Summary:** This project is investigating the use of Lake Guard Oxy, a product developed by BlueGreen Water Technologies, to mitigate red tide blooms. Currently, Lake Guard Oxy is used to improve water quality conditions and remediate harmful algal blooms around the world in freshwater systems. The product is eco-friendly, specially formulated to float with time-release application, and is approved by the EPA for marine use. When Lake Guard Oxy comes into contact with water, it releases hydrogen peroxide and creates a chain of reactions that can be detrimental to the growth and function of many algae cells. Researchers completed Tier 1 and 2 tests to determine the efficacy of different doses of Lake Guard Oxy on *K. brevis* and toxicity tests on key species. In November 2025, the project completed its first marine field trial with Lake Guard Oxy in Sarasota, FL, following approval from the relevant regulatory agencies. This deployment provided valuable insights into the logistical considerations of applying the product with an agricultural sprayer in a semi-enclosed cove. A second deployment is planned for early 2026 and will proceed if and when a red tide bloom is present, allowing researchers to evaluate the product's effectiveness under natural conditions.

**35. Title:** Red Tide Mitigation with Low-Energy Electromagnetic Treatment

**Principal Investigator:** G. Philippidis (University of South Florida)

**Co-Principal Investigators:** V. Lovko (Mote Marine Laboratory)

**Project Date:** December 2022 - June 2026

**Summary:** This project aims to use low electromagnetic (EM) energy to restore water bodies with low oxygen and excess nutrients back to healthy aquatic systems, thereby mitigating red tide blooms. The EMF1000 is a lightweight solar-powered, free-floating, and remotely-controlled device that generates electromagnetic energy to continuously aerate water, restoring its natural properties and making it inhospitable to *K. brevis*. The EM technology has already been successfully deployed in water reservoirs, lakes, and ponds, where it controlled algal growth, reduced odor, and restored and maintained aquatic health. Researchers conducted preliminary testing of the EMF1000 in saltwater at Mote's mesocosm facility to examine potential adverse impacts to non-target organisms. The project aims to deploy multiple devices during early 2026 after PI's have acquired the necessary permits.

**36. Title:** Non-toxic Biodegradable Formulation for Mitigation of Red Tide Cells and Toxins

**Principal Investigator:** S. Rowley (Heartland Energy Group, Ltd.)

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

**Project Date:** August 2022 – June 2026

**Summary:** This project will investigate the effectiveness of Xtreme, a natural non-toxic product developed by Heartland Energy Group, on reducing red tide cells and toxins. Xtreme is currently used for water purification and quality improvement applications, and has been shown to control blue-green algae blooms. Initial testing at Mote determined Xtreme significantly reduced red tide cells and toxins. A mesocosm experiment was conducted to verify the dosage range needed for successful mitigation and to conduct toxicity tests on commercially important clams. Xtreme was determined to be exempt under EPA and DACS pesticide regulations and has received verification of DEP exemption. After acquiring the necessary permits, researchers conducted multiple field trials to assess deployment strategies and determine the impacts of Xtreme on natural red tide blooms. In February 2025, the team used a barge-mounted sprayer to treat a one-acre canal in Venice, Florida during an active red tide bloom, and subsequent results indicated a reduction in red tide cells. However, the influence of environmental factors—such as tidal movement, wind, and other dynamic conditions—on both the product and the bloom requires further study. Additional deployments are planned for 2026 to investigate these outlying questions.

**37. Title:** Innovative Use of Advance Oxidation, Nanobubble-Cavitation for Rapid Deployment to Restore Severely Impacted Red Tide Areas Back to Natural Conditions

**Principal Investigator:** T. Charanda (Prescott Clean Water Technologies LLC)

**Co-Principal Investigators:** R. Pierce, V. Lovko and E. Hall (Mote Marine Laboratory)

**Project Date:** July 2021 – June 2026

**Summary:** This project is testing the OZONIX® Advanced Oxidation Process technology as a mitigation method for red tide. OZONIX® is a patented chemical free water treatment technology that uses four processes- hydrodynamic cavitation, ozone injection, ultrasonic acoustic cavitation, and electrochemical oxidation- to treat contaminated water. The technology has been used for cleaning cyanobacteria blooms, contaminated water supplies, and agricultural farm waste. Tests for effectiveness at destroying *K. brevis* cells and toxins were conducted using the OZONIX® Mobile Water Treatment Unit, a 53ft trailer that houses the water treatment system. Results from these studies validated the technology's ability to eliminate cells

and toxins without harming live organisms. Researchers are also exploring technology improvements of the system that would reduce operation costs and non-target impacts. The team has acquired the necessary Federal, State, and local permits to conduct field trials and began testing at Centennial Park in Sarasota to develop deployment strategies. In December 2025, researchers conducted a logistical deployment to ensure the OZONIX technology could be utilized on a barge and the team plans to conduct another deployment in early 2026 to evaluate the practicality of maneuvering the trailer-barge system through confined areas such as canals. These assessments are critical for determining where the OZONIX technology can be effectively accessed and deployed during a red tide event.

**38. Title:** Double Indemnity for Karenia: Modifying Clay for Improved Cell and Toxin Removal

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

**Co-Principal Investigators:** E. Hall, C. Heil, V. Lovko, R. Pierce (Mote Marine Laboratory) and K. Lewis (University of Rhode Island)

**Project Date:** August 2022 – June 2026

**Summary:** This project will combine natural plant derived flavonoids with clay particles as a new approach to red tide mitigation. It is well known that positively charged clay particles flocculate algal cells and that clays are used as a mitigation strategy for HABs in other parts of the world. Additionally, flavonoids have been found to work allelopathically by inhibiting algal physiology. Both clay and flavonoids are natural products that are available at low cost, which reduces concern for environmental harm compared with other mitigation strategies. The removal and destruction of red tide cells and toxins would be amplified as the clay/flavonoids work together to flocculate and kill the cells. Initial testing analyzed the effectiveness of two flavonoids, curcumin and luteolin, that were both combined with clay. The top-performing clay/flavonoid mixture was selected for a mesocosm experiment to examine potential impacts on water quality and animals (crabs, urchins and clams). The project also received a US HABCTI grant to clarify EPA requirements for field trials and pesticide registration. As a result, researchers are now positioned to conduct a field trial using a selected clay formulation, supported through both Red Tide Initiative and NOAA PCMHAB funding. Researchers intend to test the formula during an active bloom.

**39. Title:** Beach Conditions Reporting System

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

**Co-Principal Investigators:** A. Cook (Mote Marine Laboratory)

**Project Date:** January 2020 – June 2026

**Summary:** This project is improving the Mote 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 directly through the app and website and through FWC public reports. Improvements to the BCRS have included validation of citizen reports, integration and collaboration with outside data portals, adding educational video components, and expanding to new reporting locations, which now cover 100+ locations. The updates are expediting communication of the most up-to-date information about red tide blooms and will be helpful in deploying mitigation tools/technologies.

**40. Title:** Natural Compound Control and Mitigation for Red Tide

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

**Co-Principal Investigators:** R. Medvecky (Mote Marine Laboratory)

**Project Date:** July 2020 – June 2026

**Summary:** Plant-derived biological compounds have shown promise as potential algal bloom suppressors in marine and freshwater ecosystems. Natural chemicals can prevent, terminate, and regulate HABs with a lower risk of harmful/non-target side effects than other control measures due to their existing environmental occurrence. This project has identified and characterized algicides from marine, freshwater, and terrestrial plants, which can be used as natural compounds for red tide mitigation and control. Time series dose-response cell counts of *K. brevis* culture to 40 unique plant extracts and pure compound candidates have been conducted to determine the lowest effective concentration needed to mitigate red tide in the shortest exposure time. Two candidates were selected for further development, and two end-use product formulations were created: 1) engineered particles for rapid and slow release of algicides, and 2) an aqueous solution that can be applied below the surface directly into a bloom. Dispersion dynamics, toxicity testing, and stability assessments have been performed. All federal and state permits, registrations, and approvals have been obtained. A pilot application of the aqueous algicide in a coastal canal was successfully carried out during an active bloom in February 2025, and field deployments with the different formulations are now being designed and planned for early 2026.



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