Florida Harmful Algal Bloom Task Force
Consensus Document #2:

Progress and Recommendations Regarding Red Tide (*Karenia brevis)* Blooms

DECEMBER 2021
MyFWC.com/HABTaskForce

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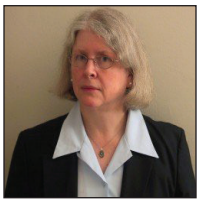

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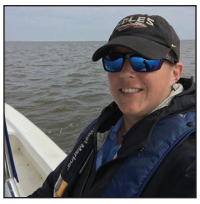

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On January 31, 2020, the Harmful Algal Bloom (HAB) Task Force recommended several actions to improve our ability to manage red tide and its harmful effects in a "Consensus Document #1: Initial Recommendations Regarding Red Tide (*Karenia brevis*) Blooms."

The consensus document contained key background information and made recommendations focused on Public Health, Communications, Management and Response, and Research. This second consensus document builds on the first, providing updates on actions to address the initial recommendations and identifying additional actions that will advance management of red tide.

The HAB Task Force continues to recommend actions that create improved understanding of red tide and translate it into enhanced management. Like its predecessor, this document is not intended to provide an exhaustive list of useful actions. The recommendations are meant to complement and support other efforts to set long-term goals and implement specific actions that minimize the harmful effects of red tide as well as a variety of other HABs that impact Florida, such as the work of the Blue-Green Algae Task Force.

Background

The severity, duration, and spatial extent of red tide blooms caused by *Karenia brevis* vary widely from event to event and, unlike most severe weather events, cannot be forecast accurately. In fact, blooms can persist through all seasons, survive tropical storms and hurricanes; coincide with other HAB events (spatially and temporally) in marine, estuarine, and freshwater systems; and result in human respiratory irritation and widespread reports of fish, sea turtle, marine mammal, and other wildlife mortalities. The scales of responses needed for events also vary, and responses involve numerous agencies and partners, new strategies, and extensive communication efforts. There is a continued need for more intensive and comprehensive monitoring and improved responses that span blooms and their impacts. These efforts generate critical data necessary to document variation in bloom intensity and severity and to better understand the complex mechanisms underlying bloom development, intensification, maintenance, and decline, as well as impacts on human, wildlife, ecosystem, and socioeconomic health.

Severity can be based on a diversity of metrics. Recent events have highlighted the need to define and document severity over time, to look at drivers individually and holistically, and to approach issues in a systematic way that facilitates historical comparisons and improves forecasts and hindcasts. There also is an ever-growing need to communicate results quickly and effectively across many domains, spanning management to the public. There are challenges and successes associated with all elements of monitoring, event response, and research; and each event provides novel insight that helps inform the implementation of new and existing tools, including those that may help mitigate the impacts or severity of HAB events in Florida.

Multiple events demonstrate progress since Executive Order 19-12 was enacted in January 2019. Key efforts relate to identified priorities of the HAB Task Force, and they include complementary initiatives led by partners, such the Center for Red Tide Research and the Florida Red Tide Mitigation and Technology Development Initiative.

June 2019: Inaugural meeting of the Blue-Green Algae Task Force

- Florida Red Tide Mitigation and Technology Development Initiative established with Mote Marine Lab (F.S. 379.2273)
- FWC Center for Red Tide Research established
- Two public meetings of the HAB Task Force
- Blue-Green Algae Task Force presents Consensus Document #1

2019

January 2020: HAB Task Force endorses and supports the recommendations of the Blue-Green Algae Task Force Consensus Document #1 and presents its own Consensus Document #1: Initial Recommendations Regarding Red Tide (*Karenia brevis*) Blooms

August 2019: HAB Task Force reactivated

- Five public meetings of the HAB Task Force
- FWC Center for Red Tide Research expands cooperative monitoring and research program for 5-years with Mote and USF
- Mote Initiative supports 12 red tide mitigation and technology projects
- FWC HAB Grants program funds three projects: one red tide communications and two real-time detection projects
- HAB Communication Working Group is established

December 2021: HAB Task Force presents Consensus Document #2

2021

2020

- Red tide research facility opened at Mote
- Six public meetings of the HAB Task Force
- Florida HAB Monitoring and Observing Network Steering Committee established
- Resource Guide for Public Health Response to HABs in Florida, version 2, 2021 published
- HAB Communications Working Group initiates work on a statewide public communications plan
- Multiple projects funded through the Mote Red Tide Mitigation and Technology Development Initiative, the FWC Center for Red Tide Research, and the FWC HAB Grant Program

Measuring the cost of inaction

Addressing issues surrounding red tides and other HABs will require a commitment of funds and other scarce resources, but the costs of not acting are substantial. Past studies have estimated sizable economic impacts on public health, recreation and tourism, and commercial fisheries and shellfisheries. The detrimental effects of the prolonged 2017–2019 red tide event in Florida, which co-occurred with blue-green algal bloom in Lake Okeechobee, were felt by residents and tourists and across multiple counties and business sectors. Final estimates of economic, social, and ecological impacts of the 2017–2019 event are still being calculated, but losses to front-line sectors – commercial and recreational fishing, beach and coastal recreation, and waterfront hotels, restaurants and marinas – were substantial and sustained. The Balmoral Group (2020) estimated total losses of nearly **$1 billion** dollars in revenue and an additional loss of **$178 million** in tax revenue in 23 Gulf Coast counties.

Any estimates of impacts are likely underestimates due to complex interactions among the economy, society, and ecology. Nevertheless, researchers are using new data and approaches to detail the multi-millions of dollars in economic value lost by individuals, the negative impacts on local economies, and the additional unanticipated costs borne by state and local governments as a result of the 2017–2019 event. Some preliminary estimates from new data and approaches are:

- **$184 million** in reduced spending because visitors cancelled Airbnb reservations in Southwest Florida, which in turn caused total economic impacts of: **$317 million** in sales revenue; **$195 million** in total value added; **$120 million** in total income associated with labor; **$45 million** in total federal, state, and local taxes; and nearly **3,000 job-years** (Court et al. 2021)

FWC manatee rescue field staff respond to a manatee with signs of red tide. (Susan Smart)

- **$3 million** in lost value to anglers when boat ramps were closed and boaters in Lee County had to find alternative access (Alvarez et al. 2019)
- **$198 million** willing to be paid by the public to avoid the stranding of **152 marine mammals** (The Balmoral Group 2020)
- **nearly $10 million** in state funds was provided to counties to cleanup and dispose of over **2,400 tons** of debris (Shafer and Shafer 2020)

An ability to assess the relative costs of action and inaction would be improved by rapid, accurate, and comparable estimates of economic losses. Development and implementation of such an approach forms the basis for a recommendation from the HAB Task Force.

A goliath grouper is removed from Madeira Beach. (Pinellas County)

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HAB Task Force Recommended Actions

Red tide and other harmful algal blooms create a complex set of ongoing challenges. The HAB Task Force sees considerable value in a long-term vision paired with significant and sustained investments that reduce risks to public health, ensure successful communication, and employ adaptive management and response. Investments are more likely to yield societal value if they are based on research that fills gaps in knowledge and increases understanding. The vision and investment should include complementary and interconnected actions because no single or isolated effort will suffice. Adaptive management allows us to cope with inevitable uncertainty by assessing effectiveness and making prudent adjustments. Furthermore, some investments will yield value in the short term, whereas others will require more time to yield optimum return.

The HAB Task Force and its partners have addressed the recommendations in the 2020 consensus document (Appendix A P1–P10). Based on this progress and more deliberation, the HAB Task Force recommends the following actions.

Summary Recommendations

Public Health

Provide DOH with resources needed to make multiple improvements in protection of public health.

Communications

Provide the HAB Communications Working Group with the resources needed to take key actions that improve communications about red tide and other HABs.

Management and Response

Provide the HAB Task Force, state management entities, and other relevant groups with the resources needed to reduce harm from red tide and other HABs.

Research

Progress

See Appendix A for progress updates addressing initial recommendations.

Public Health

Public health includes the physical, social, and mental health of residents and visitors; safe recreation opportunities and working conditions; consumption of safe seafood; and protection of their pets and domesticated animals. Public health sustains the quality of life for people in Florida and makes the state an attractive and safe place to live and work.

Provide DOH with resources needed to make multiple improvements in protection of public health.

DOH should collaborate with professional health associations to develop a training program for the state's health care professionals that improves diagnosis, treatment, and reporting of red tide and other HAB-related illnesses.

DOH will coordinate with experts and stakeholders, and an updated Resource Guide for Public Health Response to Harmful Algal Blooms in Florida will support the training.

DOH and relevant partners should develop guidelines, protocols and related training that will protect the health of people who work near blooms regularly.

The effects of long-term and repeated exposure to blooms are not well known, and they may create a need for protective equipment or protocols to prevent illness.

Public Health Research

DOH should begin to create a framework that minimizes harm from red tide by identifying and prioritizing unknowns related to short-term and long-term health problems caused by brevetoxins and seeking collaborators and resources to address those gaps.

Exposure to brevetoxins includes contact with skin, swallowing, and inhaling, and the framework should address pathways for exposure, risks of disease, and strategies to minimize harmful exposure.

Communications

Communications refers to free movement of information among diverse stakeholders to encourage them to support key actions and engage in behavior that minimizes the detrimental effects of blooms. Communications incorporate productive interactions among those with responsibilities related to red tide, timely and targeted responses that protect people and ecological systems without causing undue anxiety, education that is accessible and easy to understand, and feedback that ensures accountability and leads to improvements.

Provide the HAB Communications Working Group with the resources needed to take key actions that improve communications about red tide and other HABs.

The HAB Communications Working Group should build on recent evaluations of existing communications to develop and begin to employ a strategy and associated tactics that enhance alerts and education related to red tide and other HABs to enhance public awareness and minimize harm.

P3 P4

DEP, FWC, DOH, DACS, the HAB Communications Working Group, and other partners who respond to red tide should build on the "Protecting Florida Together" dashboard and other trusted sources of information to convey the status of HABs more effectively, efficiently, and comprehensively so that people can access the information they seek.

The working group will coordinate experts and stakeholders, and the strategy will outline actions to 1) identify hazards, convey risks, and deliver alerts; 2) begin a long-term campaign to increase awareness, understanding, and safe behavior across all age groups and demographics; 3) create and maintain a repository of shared resources that promote accurate and consistent messaging; and 4) seek feedback to guide improvements.

Recent evaluations suggest that a network of websites is needed to provide timely, accurate, and comprehensive information on the status of HABs, with multiple levels of detail tailored to different groups of stakeholders.

Communications Research

The HAB Communications Working Group should collaborate with experts to develop a program that will evaluate the short-term to long-term outcomes of communication as a guide for future improvements.

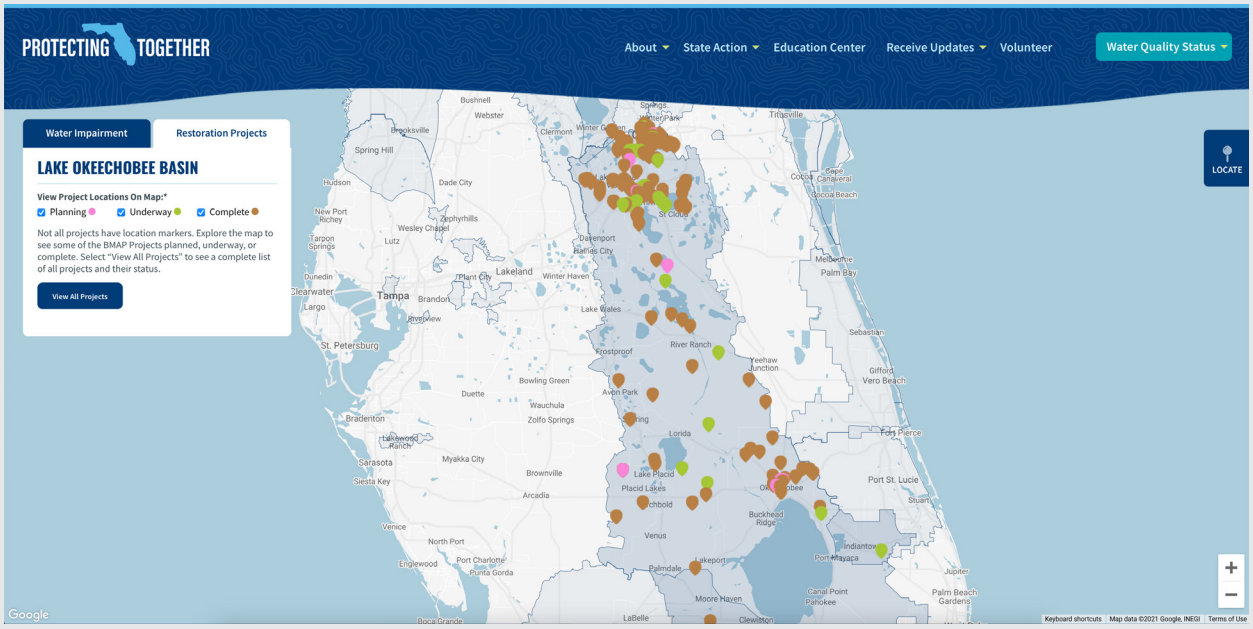
Ongoing evaluations are critical to verify the effectiveness of communication and change approaches as audiences gain awareness and understanding.

Nutrients

Nutrients play a necessary role in the environment; however, excessive nutrients can cause an imbalance. This imbalance can increase the frequency, duration, and intensity of certain HABs in Florida, resulting in detrimental effects on natural systems, the economy, and public health.

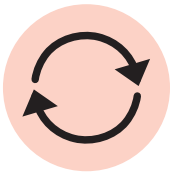
Knowing how nutrients feed HABs, particularly in marine systems, will provide a better understanding of how blooms form, grow, and eventually end. Identifying how nutrient inputs and nutrient recycling affect both offshore and nearshore blooms is a complex issue and continues to be a research priority of the HAB Task Force. The HAB Task Force understands that nutrients are not the sole influence affecting red tides or other HABs, but reducing inputs of nutrients to our freshwater and coastal systems is an important step in reducing HABs. The HAB Task Force also recognizes that addressing Florida's nutrient enrichment problem will require improvements to existing regulatory programs and implementation of new and innovative ways to manage nutrients.

Numerous recommendations to reduce nutrients were included in the Blue-Green Algae Task Force's Consensus Document #1. These recommendations stimulated development of Florida's Clean Waterways Act of 2020. The HAB Task Force supports the efforts of the Blue-Green Algae Task Force to ensure that the Clean Waterways Act achieves its goals of reducing inputs of nutrients and improving water quality. In particular, we support efforts to verify and improve the effectiveness of Total Maximum Daily Loads, Basin Management Action Plans, permits to discharge stormwater, agricultural best management practices, and prevention of discharges from wastewater treatment plants. As research identifies problematic sources of nutrients that feed harmful algal blooms, the Blue-Green Algae and HAB Task Forces will collaborate to prioritize needs and ways to address them.



Screenshot from the Protecting Florida Together website, showing Basin Management Action Plan projects for the Lake Okeechobee Basin.

Management and Response



Management and response seek to minimize the harm caused by algal blooms, which will remain an ongoing need because algal blooms will continue to occur. Management and response include detection of blooms, assessment of hazards and risks, issuing of suitable warnings, actions that prevent or alleviate detrimental effects, and evaluation and revision of all efforts.

Provide the HAB Task Force, state management entities, and other relevant groups with the resources needed to reduce harm from red tide and other HABs.

FWC, DEP, DOH, DACS, local governments, and other partners and stakeholders should review current practices and develop a comprehensive response plan supported by monitoring and streamlined permitting for control and mitigation.

P1 P5 P6

The response plan should address 1) tiers of routine and event-driven monitoring; 2) communication during emergencies that links federal, state, and local groups; 3) triggers for issuing warnings, initiating control, commencing mitigation, and taking other actions that can be tailored for localities and affected industries; 4) best practices that define roles and responsibilities; and 5) resources needed and ways to garner them.

FWC, DEP, DOH, DACS, water management districts, partners in the integrated ocean observing system, local governments, and other stakeholders should review and document current practices to detect red tide and other HABs, opportunities for improvement, and resources required to provide earlier and more accurate warnings.

P7

Ultimately, monitoring should 1) draw on existing and emerging technologies to enhance detection and tracking of algal cells and toxins in water, air, and seafood; 2) span freshwater, estuarine, and marine locations where HABs occur; 3) track and assess loads and cycling of nutrients that fuel HABs; 4) assess the effectiveness of efforts to manage those loads; and 5) provide early warning of HABs.

DEP should streamline permitting for testing and applying technologies to control or mitigate red tide and other HABs.

P6

Key considerations include benchmarks for development and testing, special needs during a state of emergency, facilitating communications with relevant federal agencies, and requirements specific to large-scale efforts.

Management and Response Research

FWC, DEP, DOH, DACS, DEO, and other partners and stakeholders should engage with scientific, health and economic specialists to improve our ability to evaluate the severity of red tides and the broad socioeconomic impacts from blooms across years.	This information is needed so that long-term trends and progress in reducing bloom impacts can be evaluated. The approach should include a set of rigorous and comparable methods, tools, and metrics, which are based on currently available information whenever possible.
FWC, with existing and new partners, should document and build on available information to design investigations that will yield an understanding of red tide sufficient to guide effective and adaptive management. P7	The program should include multiple, large-scale surveys spanning nearshore and offshore waters, and it will require consistent and sustained funding over the long-term to address factors that initiate red tide and control bloom dynamics.
FWC, with existing and new partners, should develop a suite of models that predict the initiation, progress, and termination of *K. brevis* blooms and their impacts so early warnings can be evaluated and potential improvements to management can be evaluated. P7 P8	These tools are needed so that early warnings can be generated and potential improvements to management can be evaluated. Models should address short-term (days) and long-term (seasonal) dynamics of blooms, onshore and inland transport of brevetoxins in air, and the roles of nutrient inputs, nutrient cycling, and climate change in exacerbating blooms and their impacts.
FWC, with existing and new partners, should foster projects that will improve early detection of *K. brevis* and brevetoxins to enhance rapid response. P8 P9	The goal is to detect *K. brevis* in water and brevetoxins in water, air, and seafood rapidly and accurately.
The Red Tide Mitigation and Technology Development Initiative and other partners should continue to evaluate strategies and approaches to control blooms and mitigate their detrimental impacts. P10	Evaluations require sustained funding to ensure they are rigorous and cover multiple temporal and spatial scales.

The HAB Task Force recommendations address immediate needs to better understand and minimize the negative effects of red tide on Florida's residents and visitors. In the future, the HAB Task Force will address other HAB species and events impacting Florida coastal waters. Without hard work and careful planning, the challenges created by HABs are likely to worsen due to the influences of other environmental stressors associated with climate change and Florida's growing population.

Scientific research suggests that the impacts of climate change may promote HABs through a complex variety of mechanisms including warmer water temperatures, changes in salinity, changes in rainfall patterns, increased atmospheric carbon dioxide concentrations, coastal and ocean acidification, changes in coastal upwelling, and sea level rise. The State of Florida is taking action to better understand coastal vulnerabilities and identify strategies to build resilience in both natural and human communities. Some large-scale climate trends may be impossible to change, but continuing investments made by the state to build coastal resilience in our communities is an important first step. Partnerships and coordinated actions among all Floridians will be essential to success. In addition to the immediate benefits provided by development of innovative strategies to managing red tide blooms and their impacts, the actions we take now can decrease community vulnerability and build resilience in our coastal infrastructure. A comprehensive and strategic approach to address the issues will strengthen the economic resilience of Florida's human-built infrastructure, nature-based economy, and the ecological resilience of our diverse coastal ecosystems. Investments made today will deliver significant return on investment in the long run.

(FWC)

Investing in Red Tide Monitoring, Response and Mitigation

The State of Florida is making historic investments to manage harmful blooms of *Karenia brevis* that include improved detection, enhanced responses, effective control, prudent mitigation, and increased understanding of bloom dynamics. The HAB Task Force is dedicated to providing scientific support to guide those investments. Florida's HAB and water quality problems are large and complex. Solutions will require long-term dedicated investments for projects, focused programs, dedicated facilities, and additional experienced and dedicated staff to effectively respond to the growing challenges and needs.

Algal blooms are part of healthy and productive coastal and oceanic systems. However, when conditions are right, algal blooms can become intense, long-lasting, expansive, and sometimes toxic to both wildlife and humans. When this happens, HABs become a threat to wildlife, people, our coastal economy, and our quality of life. One example of a vulnerable sector is saltwater recreational fishing. In Florida, this industry generates an estimated $9.2 billion annually and employs 88,501 people (American Sportfishing Association and Southwick Associates, based on USFWS 2011 survey data updated to 2020; FWC 2021). The future of this industry and Florida's global brand as the "fishing capital of the world" are threatened by fish kills, respiratory distress, and other problems arising from HABs.

Federal investment in *Karenia brevis* research and response

Federal investment to tackle the complex problem of *Karenia brevis* blooms in Florida has a long history. Federal agencies began funding efforts to understand, predict, and monitor *Karenia* blooms and its toxins, in the late 1940s, and support increased in the 1990s. From these efforts, which include development and application of new tools and approaches, we have learned a considerable amount about red tides, especially regarding the complexity that surrounds how blooms start, continue, and end. In addition, we have learned the value that could be added by having access to a consistent level of resources over the long term. Current and recent projects received funding from various offices and programs in the National Oceanographic and Atmospheric Administration, the National Institute of Health National Institute of Environmental Health, and the Centers for Disease Control and Prevention.

See Appendix B for a listing of projects.

Water is collected by an FWC researcher on the aft deck of the R/V Walton Smith during a week-long research survey along the West Florida Shelf. Water samples are ultimately analyzed to determine a variety of things, including red tide cell abundance. (FWC)

Increased severity and frequency of HABs can be driven by nutrient enrichment, with the exact relationships for specific HABs being a focus of research. Florida is addressing nutrient enrichment with a historic and comprehensive "all hands on deck" approach. For example, scientists are working throughout the state and nation to better understand the complex physical, chemical, and biological factors that combine to initiate, sustain, and terminate red tide blooms.

Solutions will require multiple approaches because nutrient enrichment comes from long-term, low-level, diffuse inputs, as well as major events associated with aging, inadequate, and vulnerable wastewater and stormwater infrastructure. One recent example is the discharge of approximately 215 million gallons of process water and 205 tons of total nitrogen from the Piney Point gypsum stack into Tampa Bay in 2021. That increased nutrient load fueled algal blooms in the waters of lower Tampa Bay, and there may be long-term challenges to estuarine restoration that still are not fully understood.

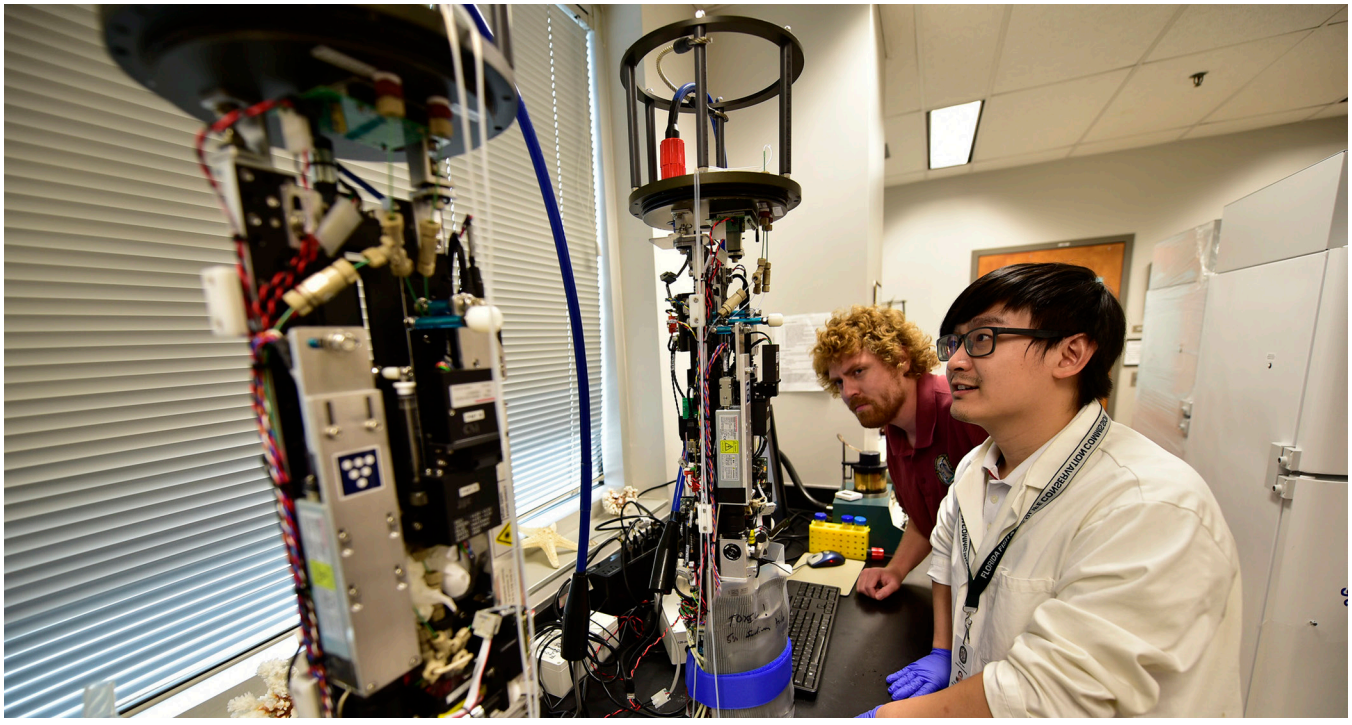
To complement solutions to the nutrient problem, the Florida Red Tide Mitigation & Technology Development Initiative (a partnership between Mote Marine Laboratory and the FWC) seeks to develop technologies for HAB prevention, control and mitigation that decrease the impacts of red tide on the environment, economy, and quality of life in Florida. This coordinated effort among public and private research entities brings together the best and brightest scientists from Florida and around the world, attracted by world-class research facilities funded by Governor DeSantis and the Florida Legislature in 2019. Much has been learned since the start of the initiative. The HAB Task Force is looking forward to this initiative producing innovative strategies that lessen a variety of risks associated with HABs.

In summary, Florida is making progress, but much work remains. Problems will not be solved by a single "silver bullet." Instead, community leaders, industry leaders, regulators, policy makers, scientists, and citizens must resolve to work together on delivering a portfolio of innovations, science-based policy decisions, and financial investments that ensure Florida remains a world-class destination to live, work, and play.

Long-Term Focal Areas

The HAB Task Force has adopted broad, long-term focal areas within which it will evaluate existing approaches or knowledge; pinpoint gaps in our efforts or understanding; and build a prioritized portfolio of strategies and actions to fill those gaps by assessing their benefits and feasibility. The HAB Task Force will prioritize and recommend:

- actions to reduce excess loads of nutrients entering our freshwater and coastal systems developed in collaboration with the Blue-Green Algae Task Force, relevant entities identified in Executive Order 19-12, and other stakeholders;
- improvements to current policies and procedures that prevent or mitigate the impacts of harmful algal blooms on public health, ecosystem sustainability, economic viability, and other valued facets of society;
- enhancements to communication, coordination, cooperation, and collaboration among stakeholders charged with responding to harmful algal blooms and their effects; and
- strategic research into the biology and ecology of species creating harmful algal blooms; detection, tracking, modeling, and prediction of blooms; fate of algal toxins; impacts of blooms on valued facets of society; prevention, control and mitigation of blooms; and other key issues.



FWC has deployed an Imaging Flow Cytobot in Tampa Bay – an instrument that continuously images water samples to identify red tide cells – which has provided unprecedented information about not just how many red tide cells there are at a given time, but also about their behavior. (FWC)

Appendix A

The following initiatives and activities address the initial recommendations of the HAB Task Force.

P1) Resource Guide for Public Health Response to Harmful Algal Blooms in Florida

P1

The *Resource Guide for Public Health Response to Harmful Algal Blooms in Florida*, was originally developed in 2009 to support the HAB Task Force's legislative mandate (F.S. 379.2271). The report expanded on and updated information identified in the Task Force's 1999 white paper *Harmful Algal Blooms in Florida*. In addition, it provided technical information and presented a methodology to help county health departments and local and state agencies develop integrated public health environmental monitoring response plans to HABs. The reinstated HAB Task Force identified the need to update the guide to reflect current knowledge and practices in HAB science and management, and a 2021 edition has since been published. This user-friendly resource guide has two major components. The first provides background information to guide the development of local response plans and quick reference guides for responses to public health threats from HABS. The second component presents a method for developing flowcharts and further technical information related to responses to HABs. The guide will be reviewed regularly and updated to incorporate new information and materials that facilitate the development of local response plans.

P2) DOH HAB-health initiatives

P2

In 2020–21, $1 million was appropriated by the legislature to the DOH for projects to improve management of long-term health impacts from cyanobacteria and *K. brevis*. The DOH established a HAB-health working group in 2021 to identify research needs and associated improvements to surveillance, reporting, and education. The DOH, with partners and stakeholders, have been developing information and tools needed to effectively address recommendations from the working group and the HAB Task Force.

P3) HAB Communications Working Group

P3

The HAB Communications Working Group resolves issues surrounding communication about HABs. It achieves this goal by tackling barriers to effective communication as identified by the HAB Task Force and state agencies, providing input on initiatives funded by the FWC HAB Grant Program or other sources, and guiding development of statewide communication plans and long-term educational campaigns to better inform the public about HABs. The working group has members from government agencies, academia, industry, and non-governmental organizations, and it is coordinated by FWC-FWRI and co-chaired by two members of the HAB Task Force. In 2020–21, the working group identified and began to work on a set of priorities. It developed a list of first points of contact for questions regarding HABs, and that list will be distributed to stakeholders who field calls from the public. The working group began and will continue a review of answers to frequently asked

questions conveyed to the public through various means, and it will review a report describing a long-term strategy for multi-lingual and multi-modal communication about red tide submitted in September 2021 by the University of Florida/ Florida Sea Grant.

P4) Developing a communications plan for red tide in Florida

P4

The FWC HAB Grant Program funds projects that address priority recommendations of the HAB Task Force. In 2020–21, funding was awarded to UF/Florida Sea Grant to advance red tide communications. The project conducted focus groups and social science studies to identify red tide information needed by the public and the most effective models for messaging and dissemination. In September 2021, a final framework was proposed to the HAB Communications Working Group that aligns practitioner needs with end-user wants. Anticipated benefits of the red tide communication plan include improved understanding of red tide and increased access to timely information to mitigate health risks, protect the economy, and instill confidence in Florida's red tide monitoring and management. These benefits will arise from clear, credible, coordinated, and consistent messaging through appropriate methods accessible to diverse audiences. This project will result in a framework for implementing a multimodal, multilingual, coordinated statewide communication plan for red tide.

P5) FWC Center for Red Tide Research

P5

The FWC Center for Red Tide Research provides the backbone to both enhance existing partnerships and develop new ones, bringing together state and local government, university, private sector partners, and citizen scientists to enhance statewide red tide monitoring and conduct applied research. Various projects that address specific recommendations of the HAB Task Force associated with tracking, predicting, and mitigating effects of red tide were initiated in 2020–21 and continued efforts are underway to further address next steps and priorities in 2021–22. These include more than 14 interdisciplinary research projects focused on advancing technology for monitoring and observational datastreams (including cells, toxins, nutrients, and impacts).

P6) DEP HAB initiatives

P6

The DEP Division of Water Resource Management has drafted and provided FWC, Mote, and other stakeholders with draft Non-Point Source Discharge Elimination (NPDES) permit language related to a Generic Permits for the application of red tide mitigation products that qualify as pesticides. The Generic Permit conditions outline the informational needs and conditions that must be met by the permittee and will speed up the process of obtaining DEP permitting approval during red tide mitigation pilot projects in waters of the state. In addition to the draft Generic Permit language, the DEP continues to develop, improve, and expand the Protecting Florida Together website to better assist the public and stakeholders with finding red tide-related information, regardless of which state agency is responsible for producing the content.

P7) Florida HAB Monitoring and Observing Network Steering Committee

P7

In response to both the need to design and implement a robust, statewide, integrated coastal and ocean monitoring and observation system that feeds into a suite of existing and future predictive models that deliver value to multiple stakeholders, a steering committee was

established to plan a workshop. The committee consists of seven members, including state and federal representatives and members of both SECOORA and GCOOS, the two IOOS Regional Associations in Florida. The workshop being planned for 2022 will build awareness across the research and stakeholder communities regarding new and existing data streams; new or collective assets; comprehensive consideration of impacts; gaps in knowledge, data, or technology; the short-term and long-term need for expanded modeling and technology; methods to convey risks effectively, approaches to improve management of ecosystem and public health; and the value of a tiered approach to funding.

P8) Field deployable measurement of aerosolized brevetoxins from *Karenia brevis* using colorimetric immunoassay

P8

The FWC HAB Grant Program funds projects that address priority recommendations of the HAB Task Force. In 2020–21, funding was awarded to the University of Florida to advance real-time detection of red tide toxins. The project aims to develop a field-deployable colorimetric immunoassay that measures aerosolized brevetoxins. In the first year of the project, investigators developed and tested two methods of aerosol sampling that are faster and simpler than the high-volume air samplers traditionally used. A novel enzyme-linked immunosorbent assay based on magnetic nanoparticles is being optimized. The project lays the foundation for development of a field-deployable tool for monitoring aerosolized toxins during red tide blooms and explores how long brevetoxins remain in aerosols and how they are degraded over time. This project will result in an improved ability to keep communities informed and implement effective responses to reduce impacts of red tide on public health.

P9) An in situ holographic imaging system for measuring distributions of *Karenia brevis*

P9

The FWC HAB Grant Program funds projects that address priority recommendations of the HAB Task Force. In 2020–21, funding was awarded to Florida Atlantic University to improve real-time detection of red tide in water. To date, the project has achieved the following: 1) demonstrated the ability of digital holography to image *K. brevis*, 2) successfully tested the AUTOHOLO system as a means of documenting distributions of *K. brevis* populations in three dimensions, and 3) developed a database of over 22,000 *K. brevis* images for training convolutional neural networks to automate detection and classification. This novel imaging technology could improve in situ, real-time detection of *K. brevis* and interactions with associated communities via horizontal towing, vertical profiling, and/or deployment at a fixed location.

P10) Florida Red Tide Mitigation and Technology Development Initiative

P10

In 2019, Florida Statute 379.2273 was signed into law, and it established the Florida Red Tide Mitigation and Technology Development Initiative as an independent and coordinated effort among public and private research entities. Approximately $3 million a year for six years is appropriated to FWC and awarded to Mote Marine Laboratory to lead the development of innovative technologies and approaches that are critically needed to address the control and mitigation of red tide and its impacts. Since 2019, a state-of-the-art research facility was constructed to safely test tools for mitigation and over 25 projects involving more than 20 private business, government, and academic partners are examining over 125 potentially useful compounds in work that will proceed from lab to mesocosm to coastal waters.

Appendix B

Current and recent federally funded projects in *K. brevis* research and response

Agency	Program	Project Title	Lead Institutions
NOAA	NCCOS CRP ECOHAB	A mechanism-based intervention for brevetoxin induced oxidative stress	Florida International University
NOAA	NCCOS CRP ECOHAB	Life and death of *Karenia brevis* blooms in the eastern Gulf of Mexico	Mote Marine Laboratory and Aquarium
NOAA	NCCOS CRP PCMHAB	Implementing the *Karenia* "tricorder" to improve red tide monitoring and management in the Gulf of Mexico	University of South Florida
NOAA	NCCOS CRP PCMHAB	Seasonal forecasting of *Karenia brevis* red tide blooms in the eastern Gulf of Mexico	University of South Florida
NOAA	NCCOS CRP PCMHAB	Integration of alternative methods of analysis into the Neurotoxic Shellfish Poisoning monitoring and management framework	FWC
NOAA	NCCOS CRP MERHAB	Implementing *Karenia brevis* respiratory risk forecast system in the Gulf of Mexico	Texas A&M University
NOAA	NCCOS CRP PCMHAB	DinoSHIELD: A slow-release natural algicide produced by *Shewanella* sp.IRI-160 for management of red-tide	NCCOS

Agency	Program	Project Title	Lead Institutions
NOAA	NCCOS CRP PCMHAB	Application of clay flocculation for removal of *Karenia brevis* cells and toxins in Southwest Florida coastal waters	Woods Hole Oceanographic Institution
NOAA	NCCOS CRP HAB Event Response	Response to quantify toxin accumulation in seabirds and prey fish	University of Florida
NOAA	NCCOS Intramural Research	Development of a HAB forecast for the Gulf of Mexico	NCCOS
NOAA	NCCOS CRP & GCOOS Socioeconomic Impacts of HABs	GCOOS 2020: Assessment of the short- and long-term socioeconomic impacts of Florida's 2017–2019 red tide event	University of Florida
NOAA	NCCOS CRP & GCOOS Socioeconomic Impacts of HABs	Estimating economic losses and impacts of Florida red tide	University of Central Florida
NOAA	IOOS HAB Pilot Program	HABScope	GCOOS
NOAA	IOOS Fill the Gaps	Glider efforts for HAB detection and tracking	GCOOS & University of South Florida
NOAA	IOOS Fill the Gaps	Glider efforts for HAB detection and tracking	GCOOS & Mote Marine Laboratory
NOAA	IOOS	Support of the operational PHYSS	GCOOS & Mote Marine Laboratory
NOAA	IOOS	Beach Conditions Reporting System	GCOOS & Mote Marine Laboratory
NOAA	IOOS	3 day forecast for *Karenia brevis* blooms	SECOORA & University of South Florida

Agency	Program	Project Title	Lead Institutions
NOAA	IOOS Fill the Gaps	Harmful algal bloom observation & forecast system for the eastern Gulf of Mexico	SECOORA & FWC
NOAA	Florida Sea Grant	Citizen science detection and quantification of Florida red tides via personal smartphone-enabled PCR technology	Mote Marine Laboratory
NOAA	National Sea Grant	NOAA HAB liaison for OAR, NOS and NESDIS	Florida Sea Grant
NOAA	Florida Sea Grant	A promising Florida red tide control strategy: combining stakeholder input and benthic surveys to evaluate impacts of clay flocculation	University of Central Florida
NOAA	Florida Sea Grant	Controlling *Pyrodinium* outbreaks in the Indian River Lagoon Estuarine System (IRLES) using low-cost biochars prepared from *Sargassum*	Florida Institute of Technology
NOAA	Ocean Acidification Program	Evaluation of ocean acidification impacts to plankton and fish distributions in the Gulf of Mexico during GOMECC-4 with a focus on HAB-interactions	AOML, University of Louisiana-Lafayette, North Carolina State University
NOAA & State of Florida	Intramural Research & FWC-FWRI	South Florida ecosystem restoration and red tide research cruises (SFER)	AOML & FWC

Agency	Program	Project Title	Lead Institutions
NOAA & Florida Commercial Watermen's Conservation (FCWC)	Internal Funding	Commercial fisheries oceanographic monitoring for red tide	AOML, SEFSC, and FCWC
NIH NIEHS	Exploratory/ Developmental Research Grant (R21)	Assessment of neurological impacts of brevetoxins in humans	Roskamp Institute
CDC	Intramural Research	Exploring the use of electronic health records with environmental data to predict HABs posing public health risks	CDC National Center for Environmental Health
CDC	Intramural Research	One Health Harmful Algal Blooms System (OHHABS) for disease surveillance	CDC National Center for Emerging and Zoonotic Diseases

Program Acronyms

AOML, NOAA OAR Atlantic Oceanic and Meteorological Laboratory
CDC, Centers for Disease Control and Prevention
CRP, Competitive Research Program
ECOHAB, NOAA NCCOS Ecology and Oceanography of Harmful Algal Blooms
Florida Sea Grant Program, NOAA OAR
GCOOS, NOAA NOS IOOS Gulf of Mexico Coastal Ocean Observing System
IOOS, NOAA NOS Integrated Ocean Observing Systems Program
MERHAB, NOAA NCCOS Monitoring and Event Response for Harmful Algal Blooms
National Sea Grant Program, NOAA OAR
NCCOS, NOAA NOS National Centers for Coastal Ocean Science
NIH NIEHS , National Institute of Health National Institute of Environmental Health Sciences
NMFS, NOAA National Marine Fisheries Service
NOAA, National Oceanographic and Atmospheric Administration
NOS, NOAA National Ocean Service
OAR, NOAA Oceanic and Atmospheric Research
PCMHAB, NOAA NCCOS Prevention, Control, and Mitigation of Harmful Algal Blooms
SECOORA, NOAA NOS IOOS Southeast Coastal Ocean Observing Regional Association
SEFSC, NOAA NMFS Southeast Fisheries Science Center

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