Sea Grant Florida

State of the Science for *Karenia brevis* (Red Tide) in Florida

A summary document from the 2019 Harmful Algal Bloom State of the Science Symposium

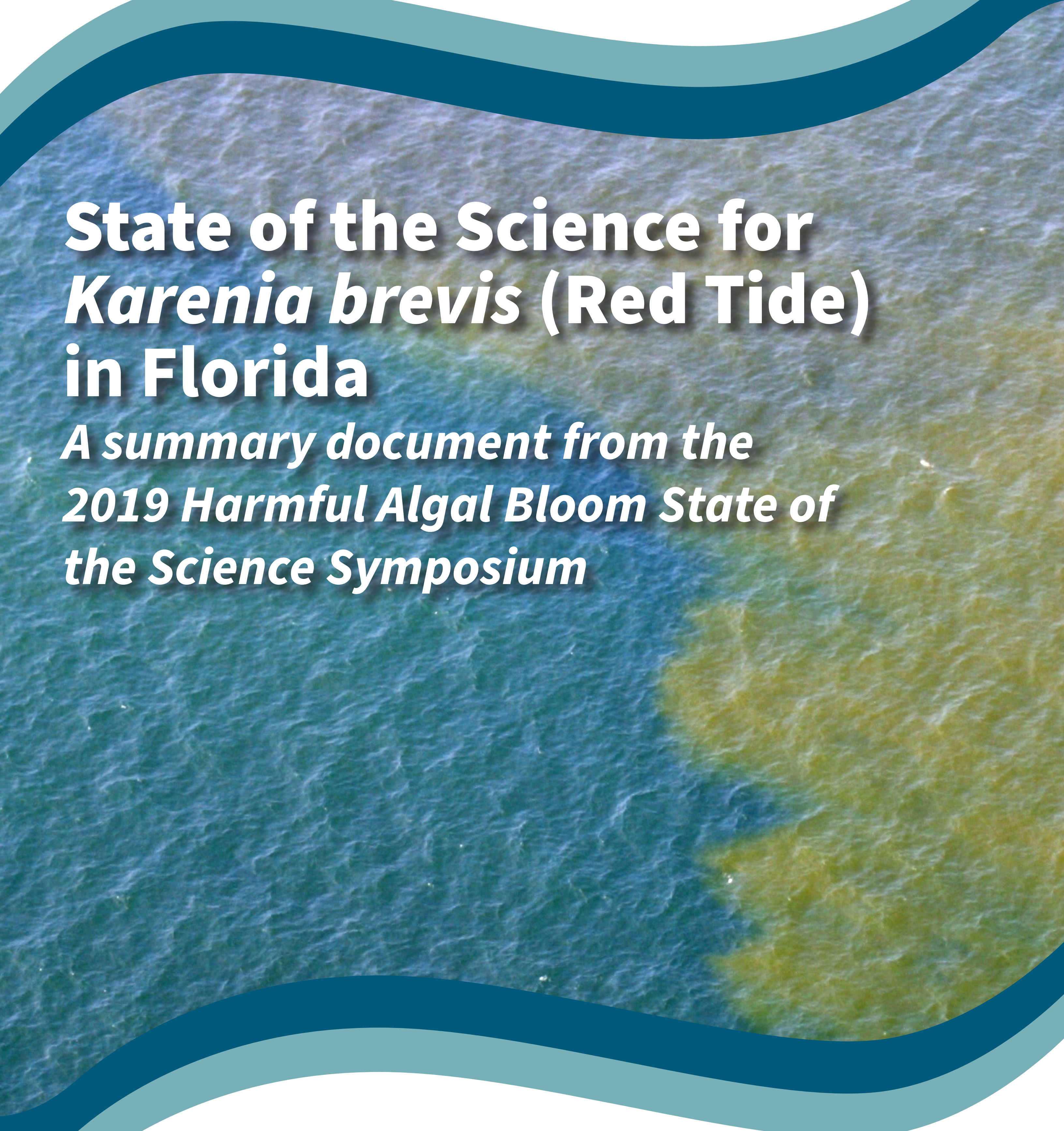

Image: K. brevis *bloom*
Credit: FWC Fish and Wildlife Research Institute

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Introduction

In recent years, intense blooms of *Karenia brevis* red tide and *Microcystis aeruginosa* cyanobacteria, known commonly as blue-green algae, have plagued Florida waterways, impacting the state's economy, environment and public health. Though notable in their duration and intensity, these harmful algal blooms, or HABs, are not uncommon. Florida experiences a variety of HABs in its marine and fresh waters.

In 2019, Governor Ron DeSantis' Executive Order 19-12 established the Blue-Green Algae Task Force and revived the state's Harmful Algal Bloom Task Force to provide technical expertise and recommendations to reduce the adverse impacts of future blooms.

This fact sheet represents the latest science-based information cultivated during the 2019 HAB State of the Science Symposium hosted by the University of Florida Institute of Food and Agricultural Sciences and Florida Sea Grant. The Symposium's 75 participants represented 27 unique institutions encompassing academia, nonprofit organizations, local, state and federal agencies, allowing for a diverse and comprehensive assessment of the scientific research arena.

For a more in-depth explanation, visit the symposium consensus publication: *State of the Science for Harmful Algal Blooms in Florida:* Karenia brevis *and* Microcystis *spp.*

Image: Red tide fish kill
Credit: Mark Winfrey via Shutterstock

Current Understanding

The consensus summaries presented here represent the current state of knowledge for *Karenia brevis*, as identified by symposium participants during the presentations and facilitated discussion.

Bloom Initiation, Development and Termination

Initiation

K. brevis red tide blooms in Florida are not new and occur regularly along the Southwest coast of Florida. This is because the Gulf of Mexico's natural conditions are favorable to blooms, which typically begin offshore along the West Florida shelf in the fall, though the timing can vary from year to year.

Although multiple *Karenia* species can be involved in blooms, the naturally occurring and always toxic dinoflagellate *K. brevis*, is the primary player in Florida's red tide. Scientists do not currently know what role other *Karenia* species play or why *K. brevis* is the dominant species in Florida.

The initiation of a red tide bloom can be triggered by physical, chemical and biological drivers. Because the West Florida Shelf is characterized as nutrient poor, or oligotrophic, bloom initiation is dependent on nutrients that are found in deeper waters. This occurs through a physical process known as upwelling, a process in which deep nutrient rich water rises to the surface.

Image: K. brevis *bloom near a Florida beach*
Credit: Paul Schmidt, Sun Coast Media Group

Ocean circulation and winds determine the movement of red tide blooms. They transport *K. brevis* from offshore to nearshore waters where they can become a nuisance to people. During the maintenance stage, *K. brevis* cells are dispersed alongshore expanding their geographic range and can be transported to locations beyond where the bloom initiated.

K. brevis is ecologically flexible, meaning it can grow in a broad range of temperatures, salinity and light. Like all plants, it requires nitrogen and phosphorus to grow. Ammonia is *K. brevis*'s preferred form of nitrogen, though it will use nitrate and urea when ammonia is limited. *K.* can get these nutrients from at least 13 sources, including fish decomposition and estuarine runoff. Scientists don't quite understand the importance of each nutrient source for growth as this can vary by location and time.

While offshore, one of those sources of nutrients is a type of cyanobacteria called *Trichodesmium*, which has the ability to obtain nitrogen from the air and convert it into a form of nitrogen that can be used by *K. brevis*.

Cyanobacterial blooms like those caused by *Trichodesmium* are increasing with climate change, leading to a possible impact on red tide initiation. Human-caused influences like climate change and increased nutrient inputs may also have direct and indirect impacts on the formation, length and duration of a red tide event.

A bloom is in the termination phase when the population of cells has decreased to background levels or is transported out of the area. Although some progress has been made, scientists are still trying to understand the exact mechanisms underlying each bloom stage and the transition from one stage to the next.

Public Health

K. brevis produces a neurotoxin called brevetoxin, which poses risks to humans and wildlife. Exposure pathways for *K. brevis* include direct skin contact, ingestion of food, incidental ingestion, and inhalation of aerosols.

The symptoms of exposure to aerosolized toxins from *K. brevis* blooms are most severe for persons with respiratory illness, such as asthma. Respiratory irritation may linger in such susceptible populations, whereas acute symptoms in healthy people mainly subside as soon as they leave the exposure area.

Brevetoxins produced by *K. brevis* can be found in shellfish, leading to foodborne illness, but incidence of this is low because of ongoing shellfish monitoring in the state. In Florida, human illnesses from neurotoxic shellfish poisoning (NSP), which can be caused by *K. brevis*, are a required reportable disease. To date, there have been no known documented human fatalities from NSP.

There also have been no documented NSP illnesses due to the consumption of legally harvested bivalves in Florida. However, NSP cases resulting from harvesting gastropods or from illegal recreational harvesting of bivalves have been reported. Potential victims of NSP are likely to be non-English speakers or visitors to the area unaware of the potential risks.

There are gaps in public health research as they relate to detection, prevention and long-term impacts of brevetoxin exposure. The following priorities were identified: 1) prevention and improved treatment of impacts from exposure to *K. brevis* toxins; 2) reducing impacts from exposure to *K. brevis* toxins resulting from health disparities due to race, ethnicity or income; 3) improving diagnostic testing accuracy; 4) identifying high-risk subgroups; and 5) improving early detection and prevention of *K. brevis*-related illness.

Bloom Prediction and Modeling

As mentioned, bloom initiation, development and transport are dependent on physical, chemical and biological factors associated with upwelling conditions, winds and ocean currents. Tracking and predicting red tide blooms require understanding, observations and models of these factors. Some of the parameters that are collected are: temperature, salinity, chlorophyll, colored dissolved organic matter (CDOM), and oxygen, which are parameters that may influence blooms and are necessary to better understand where the blooms originate. Currently, autonomous glider surveys can provide this data. Improvements to tracking and prediction methods could be made by supplementing glider surveys with ship-based research and strategically placed moorings to provide quantitative real-time nutrient and cell-count data.

Current models allow for geographically specific, short-term *K. brevis* red tide forecasting. However seasonal forecasts are still in development and forecasting model accuracy can be improved. This would need to incorporate irregular events like storms, simulation data and biological measurements into models.

Satellites can be used to estimate the amount of chlorophyll in the water. Chlorophyll is a pigment found in photosynthetic organisms and is a proxy for the amount of algae in the water. Satellite imagery can provide important information for various models, although there are some limitations that need to be recognized. For example, satellites cannot detect low concentrations of cells in the water and imagery is not useful for tracking the distribution of *K. brevis* below the surface.

Another limitation with satellite data is that chlorophyll is not specific to *K. brevis* — other diatoms and dinoflagellates share similar pigments that cannot be distinguished with existing imagery.

Currently, satellite imagery is best used for supporting monitoring and input into other models, and for blending with field observations to identify or confirm bloom patches as *K. brevis*.

Bloom Detection and Monitoring

Due to widespread impacts to fish, wildlife and humans, a comprehensive monitoring system has been developed to determine the effects on ecological and human health. This system has been developed and adapted over time as our knowledge of *K. brevis* has improved. Routine monitoring occurs year-round statewide and sampling efforts increase around bloom events.

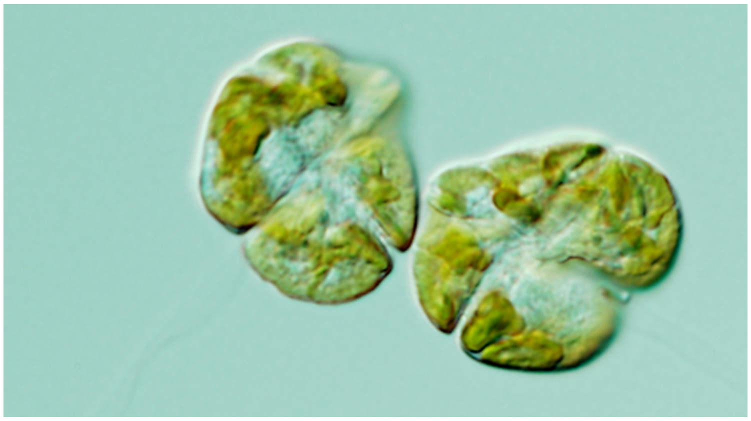

Image: Karenia brevis *(light micrograph)*
Credit: FWC Fish and Wildlife Research Institute

Routine monitoring provides information for forecasts that help the public avoid respiratory exposure and informs resource managers who take actions to protect the public from seafood poisonings. Because these data can help us take steps to avoid potential exposure, monitoring is also considered a form of mitigation.

Outputs from this system are used by state agencies like the Florida Department of Agriculture and Consumer Services to determine closures of shellfish harvest areas, which are required when cell counts reach a certain density.

Scientists agree that the best monitoring tools are those that are the most affordable with the highest degree of specificity, meaning they can determine the species of the bloom. Microscopy is currently the gold standard for evaluating *K. brevis* cell concentrations, however this method is very time and labor intensive. New tools and technologies are being developed that can provide underwater and real-time data to help researchers better understand the *K. brevis* life cycle and differentiate between *Karenia* species. These tools are in various stages of testing, development and implementation. Some will allow partners and citizen volunteers to participate in bloom detection and monitoring, which can improve the timeliness of water sample collection and analysis.

Real-time HAB sensors are a priority; however, the tool used should be dependent on who the audience is and what the data are to be used for. For instance, the Beach Conditions Reporting System, a service that lists beach conditions in southwest Florida and the Panhandle, is not specific enough for scientific purposes, but it is very useful for beachgoers. Future *K. brevis* monitoring and detection approaches should link these different tools and datasets together.

Weaknesses in current *K. brevis* monitoring include the lack of a central repository for monitoring data, which is critical for moving *K. brevis* science forward. The Gulf of Mexico Coastal and Ocean Observing System (GCOOS) has a promising existing repository that can aggregate and provide quality controlled, open-access data for public dissemination.

Future monitoring efforts should prioritize capturing baseline and background ecological data during non-bloom periods and these efforts should extend into the offshore regions. Below surface, offshore observations are also critical for predicting bloom initiation as blooms occurring at or near the bottom are not detected by routine monitoring.

Bloom Mitigation and Control

The public would like to see some level of action to prevent, mitigate or control blooms. Successful mitigation and control strategies to minimize cells, toxins and impacts must be both ecologically sound and economically feasible. Blooms can be controlled using one or more of four strategies: avoidance, chemical, biological and physical.

Avoidance

Avoidance is a key factor in reducing the impact of respiratory irritation and other health risks associated with blooms. The most common assumption is that if red tide is present, then the beach should be avoided. Aerosol impacts can vary widely from one beach to another and over the course of a day. This is due to the interaction of prevailing winds with tides and currents, that tends to bring blooms onshore in localized patches. Consequently, beaches a mile or two apart may experience very different toxic aerosol levels. The best protection from *K. brevis* toxic aerosol exposure is improved information in the form of easily accessible daily, beach-specific respiratory forecasts.

Tools are being developed to refine the geographic scale of the red tide. The existing NOAA HAB Bulletin provides a day-by-day, county-wide assessment detailing whether someone might be at risk of low or high respiratory irritation today or tomorrow. However, these forecasts are correct at individual beaches only 20% of the time. A newer method, called the HABscope forecast, uses detailed daily cell counts at individual beaches with improved models to give hourly forecasts at those beaches. This method is only available at a limited number of beaches, but is currently being expanded.

Chemical Control

Chemical bloom mitigation and control efforts include cleansing agents and algicides. Challenges to chemical mitigation and control are that methods may be toxic to other marine life. A chemical's persistence in the environment may lead to public health risks associated with bioaccumulation in animals. Additionally, lysing, or breaking down, of *K. brevis* cells could lead to a massive release of brevetoxin into the ecosystem. Previous attempts at large-scale chemical control have resulted in widespread deaths of invertebrates or have been too expensive for widescale field application.

Biological Control

Biological bloom mitigation and control includes living docks and shorelines, co-existence of certain macroalgae species, HAB-specific parasites and algicidal bacteria. To date there have been no tests of biocontrol using introduced pathogens in the field. But research has shown high host specificity and rapid proliferation of some pathogens against some HAB species in lab studies. Challenges to biological mitigation and control include adverse risks to other marine life and resulting poor water quality. Additionally, when *K. brevis* cells are broken down, brevetoxin can be released and their fate is unknown by scientists.

Physical Control

Physical bloom mitigation includes removal of cells or nanobubbles and bubble curtains — physical barriers to keep HABs out of confined areas such as canals. Cell and toxin removal using clay is probably the most viable physical control method at the present time. The combination of the clay particles and the ionic strength of seawater makes the cells aggregate. The resultant clay flocculant binds to *K. brevis* cells making them sink to bottom, thereby removing the cells and a large percentage of the brevetoxin as well. Variations on this method have been successfully used against other types of HABs in Korea and China with low environmental impact.

Future Research

Although promising red tide control strategies are currently in use in other countries, they may not apply in Florida since *K. brevis* is a part of the Gulf of Mexico's natural system. Scientists need to better understand the role it plays so control methods do not negatively impact the ecosystem. In other words, the cure should be no worse than the bloom-associated impacts. To move forward, a standard protocol for testing bloom mitigation strategies should be developed.

Continuous monitoring is needed to develop a toolbox of potential mitigation strategies to minimize impacts to the public and to inform resource managers. Scientists agree that large-scale application likely will not be possible, but targeted applications should be considered at critical times and places.

Next Steps

Symposium participants also described and prioritized outstanding questions related to red tide in Florida. To learn more about the scientists' research priorities, visit: *State of the Science for Harmful Algal Blooms in Florida:* Karenia brevis *and* Microcystis *spp.*

Conclusion

The 2019 HAB State of the Science Symposium brought experts together to join forces in addressing harmful algal blooms in Florida. Proceedings from the meeting are being used by the governmental task forces and university researchers working on this issue.

Florida Sea Grant and UF/IFAS are committed to continuing these discussions. Future efforts will assess progress on research questions outlined here and facilitate communication between the disparate groups working to better understand red tide.

To be involved in the conversation and receive the latest updates, visit the Florida Sea Grant Harmful Algal Bloom webpage at: *www.flseagrant.org/habs*.

Image: K. brevis *and* Trichodesmium *bloom in Gulf of Mexico*
Credit: FWC Florida Wildlife Research Institute

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