Sea Grant Florida

State of the Science for Cyanobacterial Blooms (*Microcystis* species) in Florida

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

Image: Cyanobacterial bloom in Lake Okeechobee
Credit: L. Krimsky, Florida Sea Grant

TESI Thompson Earth Systems Institute

UF IFAS UNIVERSITY of FLORIDA

Contents:

Prepared by:

Rebecca Burton, Thompson Earth Systems Institute
Lisa Krimsky, UF/IFAS Extension Florida Sea Grant
GiGi Novak, Florida Sea Grant
Rhett Register, Florida Sea Grant
Betty Staugler, UF/IFAS Extension Florida Sea Grant

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.*

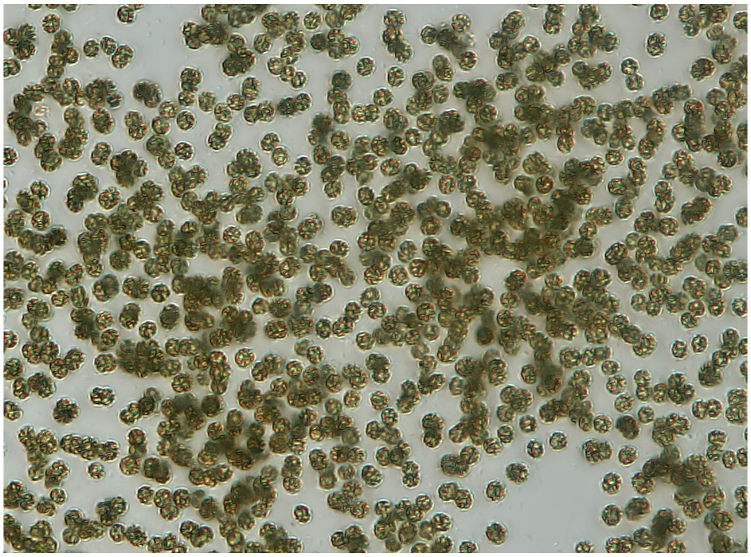

Image: Microcystis aeruginosa
Credit: B. Rosen, Florida Gulf Coast University

Current Understanding

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

Bloom Initiation, Development and Termination

Cyanobacteria are bacteria that can carry out photosynthesis, which is why they are often referred to as blue-green algae even though they are not true algae.

Cyanobacteria are present in freshwater, brackish and marine environments, depending on the species. But, the species that form harmful algal blooms are primarily found in freshwater. These include *Microcystis* species.

Cyanobacteria need a few specific ingredients and conditions to grow: nutrients, sunlight and carbon dioxide; blooms also require relatively calm water. At any given time, a variety of algae and cyanobacteria, including those species that form blooms, are suspended throughout the water column, but the factors that allow one species to form a bloom over another species are complex.

Cyanobacteria prefer warm waters and excess nutrients, including nitrogen and phosphorus. These conditions allow them to multiply quickly.

Blooms often contain more than one species and shifts in the dominant species may occur with bloom progression. One advantage some cyanobacteria have over other phytoplankton is the ability to regulate their buoyancy. In other words, they can use gas vesicles to move vertically throughout the water. This movement allows them to travel up and down the water column where they can either optimize their light capture or sink to the sediments where nutrients lie.

The ever-changing availability of nutrients and light, water column stability and species interactions make it difficult to predict the timing and magnitude of a cyanobacterial bloom. It is also important to note that blooms are not always visible from the surface. Bloom initiation and maintenance may occur at midwater or on the bottom, depending on the species, water clarity, and density variation throughout the water column.

Microcystis is a type of cyanobacteria that contains many species, including *Microcystis aeruginosa*, and is responsible for the fluorescent green blooms in Lake Okeechobee in recent years. *Microcystis* can regulate their buoyancy to gain a competitive advantage, leading to bloom initiation. Although *Microcystis* is a freshwater organism, it can tolerate salinity up to 18 ppt, though this tolerance depends on the exact species and strain. *Microcystis* populations originate from the sediments, where they spend the winter. Resuspension of these populations are triggered by increases in temperature, light, and anoxic, or oxygen deplete, conditions.

Rainfall, and associated increases in nutrient flow, can trigger bloom formation. The main nutrients cyanobacteria like *Microcystis* need to survive are nitrogen and phosphorus. Some species are also able to fix nitrogen from the atmosphere, meaning they have an endless supply. *Microcystis* cannot fix atmospheric nitrogen, and therefore requires another source of nitrogen to fuel a bloom.

Many external and internal sources of nutrients can fuel cyanobacterial blooms in Florida. In the Lake Okeechobee basin, legacy nutrients, or those that remain in the sediments from past contributions, are a particularly important source of nitrogen and phosphorus.

Microcystis blooms may sometimes produce toxins called microcystin, though not all blooms are toxic. Producing these toxins is a big energy burden on the organisms. These toxins are about 14% nitrogen by mass, whereas *Microcystis* cells are approximately 7% nitrogen by mass. Thus, *Microcystis* needs excess nitrogen to produce toxins. Scientists do not quite understand the reasons as to why or when *Microcystis* produces these toxins. And, the link between *Microcystis* biomass and toxin concentration is not clearly defined.

The mechanisms that trigger the end of a bloom are not fully known. There are always cells dying in a colony that release nutrients into the water column for others to utilize, creating a seemingly endless nutrient supply. Scientists know that cooler temperatures are important in bloom termination, but the role of other factors, such as bacteria, predation, leaking cells and cell death, are not well understood.

Public Health

Although cyanobacteria can produce a variety of toxins, not all blooms do. It is impossible to determine whether a bloom contains toxins based on appearance alone. Additionally, the toxicity of cyanotoxins and their effects on different organs in the human body differ based on the type of toxin. Therefore, public health messaging in Florida follows the precautionary principle, which is to avoid all waters where a bloom is present. These warnings are simply based on presence or absence of a bloom, not numeric thresholds.

If a bloom is toxic, several exposure pathways exist for toxins to impact humans and animals: direct skin contact, incidental ingestion and inhalation of aerosols.

The most common way the public comes in contact with cyanotoxins is through direct skin contact that might happen during recreational activities like swimming.

The exposure pathway that poses the highest risk is incidental ingestion. This can occur through activities like swimming, eating contaminated fish and shellfish or drinking contaminated water. Fortunately, in Florida most drinking water is from groundwater where toxic cyanobacterial blooms are not an issue. But, the safety of drinking water is becoming more of a concern as reliance on surface water for drinking increases.

Cyanotoxins tend to concentrate in the internal organs of fish and shellfish, with lower levels present in the muscle. Bivalve shellfish that are eaten whole (e.g., oysters, clams, mussels) are a potential source of exposure to concentrated cyanotoxins, especially when harvested illegally. In Florida, freshwater shellfish are not commercially harvested. Recreational shellfish harvest is prohibited outside of approved areas, which are all estuarine or marine. Still, *Microcystis* blooms can be present in estuarine harvest areas. At this time, there are no U.S. regulatory guidelines regarding cyanotoxins in shellfish; however, the Florida Department of Agriculture and Consumer Services has in the past closed estuarine shellfish harvesting areas when cyanobacteria blooms were present. Cyanotoxins do not tend to accumulate in edible portions of finfish to the same degree as in their internal organs. Eating finfish may still result in exposure to cyanotoxins, possibly above World Health Organization guidance levels under the right conditions. Many questions regarding seafood consumption during a bloom still need to be answered and this is a focus for research.

Exposure can happen from aerosol inhalation. When algae cells are disrupted at the surface from activities like boating and jet skiing, cyanotoxins may be released in the air and therefore can be inhaled.

Cyanotoxins can also contaminate soil. This exposure can happen when dried toxin cells are used as fertilizer or when crops are irrigated with toxin-contaminated water. Some agricultural crops can take in microcystin, which can inhibit plant growth and lower crop yields. These exposed soils, as well as consumption of contaminated crops, can lead to human exposure to toxins.

Image: Cyanobacterial bloom at Port Mayaca
Credit: L. Krimsky, Florida Sea Grant

In Florida, most data are from self-reported exposures and illnesses, and the most common symptoms reported are skin rashes and eye, nose and throat irritation. Additionally, decomposing cyanobacteria can emit hydrogen sulfide, which can also cause some of these reported symptoms. As a result, it is difficult to distinguish whether symptoms are directly from acute exposure to cyanotoxins.

Scientists do not know much about the long-term health impacts of cyanotoxins. One such example is beta-Methylamino-L-alanine (BMAA), an amino acid produced by cyanotoxins that has been suggested to cause amyotrophic lateral sclerosis (ALS) and other neurological diseases. This is a controversial topic and is a concern of the general public; however, data are still insufficient to understand this possible connection and research is ongoing.

Evaluating the impact of cyanobacterial blooms on human health is challenging. Some of the many challenges include:

- Symptoms are not specific to HAB exposure.
- We have a limited understanding of exposure dose through different pathways.
- Currently there are no FDA approved clinical laboratory tests for exposure.
- There are few health care professionals with expertise in HAB-related illnesses.
- The migration of people in and out of affected areas, scarcity of air monitoring data, and the expense and time of conducting long-term, human health studies exacerbate these challenges.
- Current human health research priority areas for the state include prevention, treatment, addressing health disparities, and improving screening detection and accuracy.

Bloom Prediction and Modeling

Satellites and other remote sensing tools can be used to detect and quantify the presence of cyanobacteria. They do this by estimating the amount of chlorophyll in the water. Chlorophyll is a pigment found in photosynthetic organisms and is a proxy for the amount of algae. Chlorophyll biomass can be seen and quantified from satellites and satellite data can be useful for building and validating bloom models. Using biomass and lake circulation data, current bloom models can forecast blooms three days out. Scientists are also working on a metric that would measure the severity of a bloom.

Satellites are more sensitive than the human eye to low chlorophyll levels. As a result, cyanobacteria can be detected by satellites at concentrations that may pose a risk but would typically not otherwise be noticeable. However, satellites cannot measure the toxicity of a bloom, which varies widely. In general, the spatial resolution of satellites is low, roughly the size of a football field. Some satellites have higher spatial resolution (10-20 m), but trade-offs exist. For example, they cannot specifically identify cyanobacteria and glint from the sun may block image detail for a few months around the solstice. It is important for scientists to properly interpret bloom imagery when sharing with the public so that the limitations are understood.

Bloom Detection and Monitoring

Blooms are detected through multiple channels: through routine surface water sampling programs, through NOAA satellite imagery and through the algal bloom hotline, where the general public can notify officials when they see a bloom. Once a bloom is detected, state agencies have multiple ways to receive notifications regarding the bloom. These notifications are assessed daily during the bloom season.

Sampling efforts are coordinated between various agencies: Florida Department of Health, Florida Fish and Wildlife Conservation Commission and the Florida Department of Environmental Protection. Sampling locations are prioritized based on the potential for human exposure and harm, the number of bloom reports, previous sampling history and toxin analysis and the availability of personnel. Samples are collected primarily to assess public risk, to protect aquatic resources and to guide management decisions. These data may also be used to determine the factors that are contributing to the occurrence, persistence and severity of the bloom, information that can help predict and mitigate future blooms.

In Florida, bloom samples are collected from the environment and are analyzed for cyanotoxins, chlorophyll a and nutrients. Lake Okeechobee is routinely monitored due to its propensity to experience cyanobacteria blooms, including *Microsystis aeruginosa* blooms. Previously within the lake, 17 monitoring sites, including eight nearshore and nine pelagic, were monitored monthly for a suite of physical, chemical and bloom conditions. The monitoring program has recently been expanded and now includes more sites and twice-monthly sampling. During blooms, additional samples may be collected and analyzed for dominant species identification and microcystins.

Routine monitoring is useful for providing general trends on localized bloom conditions, but may be somewhat limited in scope. New tools are supplementing routine water quality monitoring data by providing instantaneous water condition measurements. These tools will allow for timelier management decisions.

Bloom Mitigation and Control

A variety of management approaches are used to control cyanobacterial blooms, including *Microcystis aeruginosa*. Proactive approaches to controlling blooms may include long-term management strategies, such as mitigating nutrient inputs and/or the impacts of climate change, and should be a part of any bloom management strategy. Bloom control efforts can also include direct, short-term options designed to prevent a cyanobloom before it begins. But reactive approaches are more common and are meant to control the rate of a bloom or remove algae from surface waters.

Before a control approach is selected, managers should consider several important factors:

- Size, type and water quality of the affected waterbody
- Type of bloom
- How the control measure might impact the ecosystem or introduce pollutants
- Scalability of the control effort

It is also important for managers to realize that species composition may shift throughout the lifespan of a bloom and one approach may not work for all species. Managers must also understand that bloom management does not necessarily equate to toxin management.

Bloom control efforts can be classified into a few basic categories: physical, biological and chemical.

Physical control methods remove the cyanobacteria from the waterbody using tools like harvesters, rakes and surface skimmers. Other physical control strategies are designed to disrupt the cyanobacteria's ability to migrate throughout the water column. These techniques include aeration, mechanical mixing and sonication. Physical control can also be achieved by hydraulic or hydrologic manipulations.

Biological control methods use algicidal bacteria, plant bioactive compounds, enzymes, and herbivorous fish, such as grass carp and tilapia, to remove algae. But compared to other microalgae, cyanobacteria are not as appetizing to fish.

Chemical control methods may be proactive. For example, barley straw can be placed in the water to inhibit the growth of cyanobacteria. Blue dyes can also be used to inhibit light penetration, block photosynthesis and reduce algae growth. Chemical control methods can also be reactive. For example, the addition of coagulants or flocculants can bind to the cyanobacteria cells making them sink to the bottom. Many algicides and aquatic herbicides that are currently registered by the U.S. Environmental Protection Agency may be used to kill an existing cyanobacteria bloom in fresh water. While algicides are a relatively rapid method, the fate of the chemical and the toxin from broken algae cells remains unknown. Treatment effectiveness may also vary by species and bloom. Scientists need more data to assess the feasibility and costs of many of these control options. Long-term data are also needed to assess how these chemicals would impact the environment and other non-target organisms.

The takeaway message is that not all waters and not all blooms are the same; what works in one may not work in another.

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 state's 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 cyanobacterial blooms.

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.*

This publication was supported by the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), Grant No. NA 18OAR4170085. The views expressed are those of the authors and do not necessarily reflect the view of these organizations. Additional copies are available by contacting Florida Sea Grant, University of Florida, PO Box 110409, Gainesville, FL, 32611-0409, (352) 392.2801, www.flseagrant.org. November 2020, SGR 138