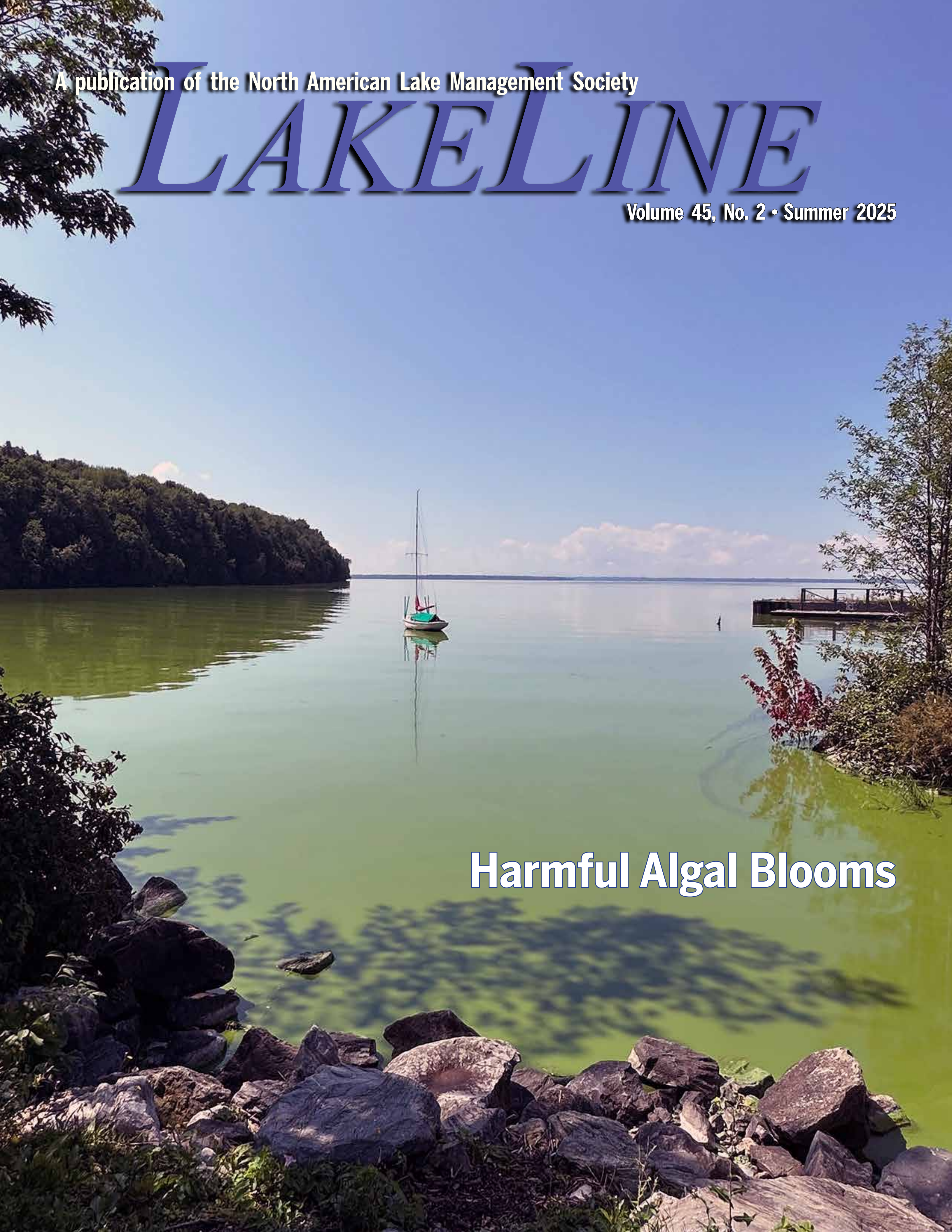
A publication of the North American Lake Management Society

LakeLine

Volume 45, No. 2 • Summer 2025



Harmful Algal Blooms

Visit Myrtle Beach

Navigating Change Together: Enhancing Lake, Reservoir, and Watershed Resilience

NALMS and the Board of Directors are pleased to invite you to join us at the beach for the 2025 Annual Symposium – Myrtle Beach, South Carolina. The annual conference returns to the southeastern United States and the timing is crucial as the region's coastal bay lakes face numerous ecological and anthropological challenges. Hazardous algal blooms, source water protection, fluctuating water levels, increased tropical storm frequency and strength and balancing reservoir needs for water supply and recreation are all topics of concern for natural resource managers. These topics and more will be deliberated during the conference, which will feature regional field trips, hands-on workshops, oral and poster presentations, and vendor displays.

We encourage you to explore the Myrtle Beach region and its abundance of outdoor recreation opportunities and tourist destinations before or after the conference. With numerous affordable lodging options, many world-class golf courses, and of course the beach, Myrtle Beach is a great base of operations for your explorations.

nalms.org/nalms2025

Contact Information

Sponsorship, Exhibition, Registration, and General Conference Information: NALMS Office • nalms2025@nalms.org
Conference Chair: Julie Chambers • Julie.Chambers@owrb.ok.gov
Conference Coordinator: Sara Peel • speel@arionconsultants.com
Program Co-Chairs: Chris Doyle • naiadconsultants@gmail.com & Amy Smagula • amy.smagula@des.nh.gov

Tentative Schedule

Tuesday, November 4
- Workshops
- Field Trips
- Exhibitor Set Up
- Welcome Event

Wednesday, November 5
- Opening Plenary Session
- Technical Sessions
- Exhibits Open
- Student Luncheon
- NALMS Membership Meeting
- Exhibitors Reception and Poster Session

Thursday, November 6
- Awards Plenary Session
- Technical Sessions
- Exhibits Open
- Clean Lakes Classic 5K
- Professional Certification Program Luncheon

Friday, November 7
- Technical Sessions
- Exhibits Open

#NALMS2025 • nalms.org/nalms2025

Photo: Todd Tietjen

Technical Program

The NALMS 2025 Program Committee has organized an excellent array of presentations on diverse aspects of lakes, ponds, reservoirs, their watersheds, and their many users and inhabitants. Below is a sample of session topics, but please check the symposium website regularly for complete program information.

Aquatic Invasive Species • Citizen Science • Climate • Drinking Water • Fisheries • Harmful Algal Blooms • Hydrology • Modeling • Nutrient Management • Oxygenation • Reservoir Management • Stormwater • Water Quality

Photo: Todd Tietjen

Workshops

We will be offering a full slate of full- and half-day workshops on Tuesday, November 4. These workshops provide attendees the opportunity for in-depth focus on a topic of interest, and many will provide hands-on experience.

Visit the conference website, www.nalms.org/nalms2025, for full details on workshop offerings. Conference registration is not required to attend a workshop.

Photo: Steve Lundt

Field Trips

The NALMS 2025 host committee has organized a series of educational field trips on Tuesday, November 4. Visit the conference website for more details on the available field trips. Space is limited.

Registration Fees

Add a 2026 NALMS membership to your registration and receive 20% off the membership!

	Early Bird by Sept 12	Regular by Oct 24	On-site after Oct 24
NALMS Member	$565	$625	$715
Non-Member	$695	$765	$855
Student	$315	$405	$485
Single Day	$285	$325	$395
Guest	$300	$330	$380

LakeLine

Contents

Volume 45, No. 2 / Summer 2025

On the cover:
"Blue Green Bay on Lake Champlain," photo by Fraces Pick, submitted as an entry to the NALMS 2023 photo contest. This photo was selected as Editor's Choice in the 2023 photo contest.

Published quarterly by the North American Lake Management Society (NALMS) as a medium for exchange and communication among all those interested in lake management. Points of view expressed and products advertised herein do not necessarily reflect the views or policies of NALMS or its Affiliates. Mention of trade names and commercial products shall not constitute an endorsement of their use. All rights reserved.

ISSN 0734-7978

P.O. Box 14 • Caledonia, MN 55921
(All changes of address should go here.)

Address all editorial inquiries to:
Amy P. Smagula
29 Hazen Drive
Concord, NH 03301
Tel: 603/419-9325
LakeLine@nalms.org

Address all advertising inquiries to:
Alyssa Anderson
North American Lake Management Society
PO Box 14 • Caledonia, MN 55921
aanderson@nalms.org

Payments:
PO Box 7276 • Boulder, CO 80306-7276
Tel: 608/233-2836

From Amy P. Smagula the Editor

The summer 2025 issue of *LakeLine* focuses on topics related to "Harmful Algal Blooms," including various aspects of blooms, from forecasting to causal agents, and special characteristics of cyanobacteria. Our "Lakespert" reminds us that cyanobacteria are a natural part of our plankton community that sometimes manifest as blooms under various circumstances.

Blake Schaeffer, **Michael Paul**, **Donald Benkendorf**, **Gregg Serenbetz**, **Deron Smith**, and **John M. Johnston** provide a brief overview of cyanobacteria and harmful algal blooms, and problems posed by blooms to the functional values of our surface waters. They go on to discuss a unique and valuable bloom forecasting approach to help identify harmful algal blooms before they become worse in a waterbody. With the aid of models and satellite data, scientists at EPA, along with other federal partners, built a predictive forecasting tool to help lake managers and others determine if a bloom is imminent in larger waterbodies across the United States. A future focus is to expand this forecasting tool to smaller waterbodies as well.

Gertrud Nürnberg highlights a number of simple approaches to determining if and how often cyanobacteria and HABs are occurring in a particular waterbody. She focuses on mostly surface blooms and includes a variety of tools or existing data sources that are readily available. Even simple data gathered by grassroots efforts can inform scientists of trends occurring within waterbodies.

LakeLine encourages letters to the editor. Do you have a lake-related question? Or, have you read something in *LakeLine* that stimulates your interest? We'd love to hear from you via e-mail, telephone, or postal letter.

In this issue, **Elizabeth Kelly** shares what happens to downstream waters when two hurricanes make landfall over parts of Florida, bringing with them large amounts of rainfall. Due to high water levels, releases from Lake Okeechobee in Florida were made to downstream waters. Elizabeth's article focuses on the time lapse between flood water release events, and downstream water quality parameters, including cyanobacteria populations.

George Knoecklein reviews the evolution of the science and understanding of gas vacuoles in cyanobacteria cells, as they relate to cyanobacteria buoyancy in the water column. He also discusses the impacts of climate change on cyanobacteria blooms.

In this issue, we have a guest "Lakespert," Madeline Reilly, who is serving as the 2025 NALMS Education, Communications, and Outreach (ECO) intern. Madeline tackles the topic of cyanobacteria from an education and outreach perspective, to share facts and information about cyanobacteria and causes of blooms.

Also in this issue, our NALMS Executive Director, Philip Forsberg, prepared a conference preview for the NALMS 2025 Annual Symposium, to be held in Myrtle Beach, South Carolina, from November 4-7, 2025. To learn more about the conference, find the layout in this issue, or visit https://www.nalms.org/nalms2025/. Also, remember to snap some photos this summer, and submit your best shot to the NALMS 2025 Photo Contest. Details on the contest are also included in this issue.

NALMS President, Victoria Chraibi, reminds us to spend time appreciating the values of our lake resources, whatever or wherever they. NALMS celebrates July as Lakes Appreciation Month and encourages everyone to take some time in or by a favorite lake.

We hope you enjoy this issue and have a great summer!

Amy P. Smagula is the Chief Aquatic Biologist and Director of the Jody Connor Limnology Center at the New Hampshire Department of Environmental Services.

Letter to Editor

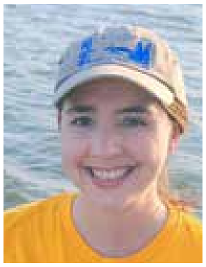
Reading through the Spring 2025 issue of *LakeLine* (Watershed Work – Little Things Add Up) brought back a nagging peeve – we lack a meaningful critique of and guidance for the role of watershed management in restoring lake quality.

From the beginning (of NALMS and lake management categorically), it has been presumed that managing a watershed was a critical and necessary element of good lake management. While there is plenty of credible evidence that watershed disturbance and development has caused lake impairments (for nutrients and sediments mostly), there is little evidence that reversing the process using a "little things add up approach" or best management practices (BMPs) results in tangible, meaningful improvements to lake quality. To the contrary, the record suggests watershed management requires substantial pollution reductions involving major engineering interventions to achieve

***(Letter to the Editor**, continued on p. 29 . . .)*

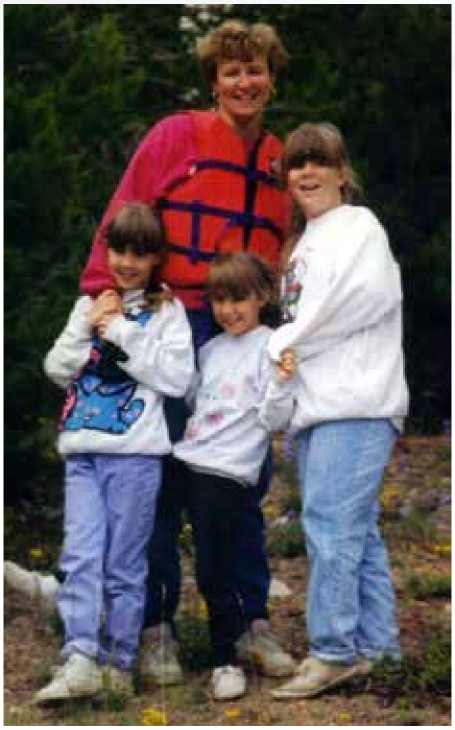
From Victoria Chraibi the President

My childhood in Colorado was imprinted by two annual lake traditions: Every summer, my family

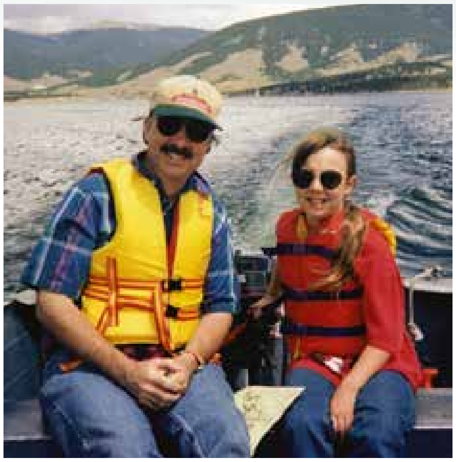


would rent a boat to cruise Lake Dillon (see images at right), a reservoir that provides drinking water to Denver. Each fall, my family would visit Echo Lake in the mountains to enjoy the changing colors of the aspens. My mom snapped a photo of the three kids on a log during an early visit that we replicated every year until we dispersed for college (see below). These outings marked the changing seasons and the progression of our lives. I invite you to take some time this July for Lakes Appreciation Month to remember the lakes that have shaped your life past and present. Your research and management sites, your favorite spots for boating, fishing, birding, hiking, or picnicking with family and friends, or the bridge you drive over every day – whatever it may be! Lakes often provide the backdrop for our fond memories, family traditions, and daily routines.

Even so, lakes deserve to be more than a backdrop, and we at NALMS encourage you to consider lakes as a main character in your summer outings. Enjoying lakes and



conserving lakes go hand in hand. As David Attenborough riffed on the common saying, "No one will protect what they don't care about; and no one will care about what they have never experienced." To this end, NALMS spends this month focused on raising both the awareness and appreciation that underlies management and conservation. The K-12 lake poster contest invites youth to express their opinions and values of lakes. The Libraries Love Lakes program provides outreach materials for summer readers. The Robert Carlson Secchi Dip-In rallies volunteers to gather valuable data while putting community members in touch with the waters they live near and the consideration of the water quality relevant to their community. NALMS members put in the time and effort to request their states recognize lakes as economically, socially, culturally, and environmentally important during the month of July.



Through art, science, advocacy, and the simple act of spending time on our lakes, we fortify the importance of lakes in our lives and communities. For NALMS and our members, this mission continues throughout the year. Right now, we can particularly revel in it. I hope you and your loved ones enjoy a summer of sun, splashing, and Secchi discs.

Victoria Chraïbi is a tenured associate professor of aquatic ecology at Tarleton State University and the assistant director of Timberlake Biological Field Station, for which she coordinates educational outreach programming and manages student research initiatives. She holds a B.A. in biology and Spanish from Hanover College, Indiana; a Fulbright scholarship to McGill University, Quebec; an M.S. in water resources science from the University of Minnesota Duluth; and a Ph.D. in earth and atmospheric sciences from the University of Nebraska-Lincoln. As a paleolimnologist, past research includes Lake Memphrémagog, Lake Superior, and Yellowstone National Park. As a phycologist, current research focuses on Texas streams and reservoirs. Victoria joined NALMS as a student member in 2011, and has been a member of the Board of Directors since 2018.

The future of water quality is here: Forecasting cyanobacterial harmful algal blooms

Blake Schaeffer, Michael Paul, Donald Benkendorf, Gregg Serenbetz, Deron Smith, & John M. Johnston

Lakes and reservoirs across the United States offer a reliable source of drinking water, recreation, and natural beauty. For a lot of people, summertime means swimming, fishing, and boating, while for water managers it means working quietly behind the scenes to keep those experiences safe.

Harmful algal blooms

Each summer, some lakes can turn a blueish-green color due to the growth of cyanobacteria, also called blue-green algae. When cyanobacteria grow to excess, they can potentially produce toxins, and are then called cyanobacterial harmful algal blooms, or cyanoHABs. The toxins can cause serious health effects including respiratory issues, and skin irritation and illness in humans and animals. In addition to being a threat to public health, cyanoHABs can cause taste and odor issues, impact aquatic life, and negatively impact the economy. CyanoHABs have become a persistent, nationwide health concern, and public health advisories are sometimes needed to protect people and their pets from exposure. Water utilities also need to be on alert to treat water that is sourced from rivers and lakes or reservoirs to remove these toxins.

Forecasting blooms

Managing cyanoHABs requires early detection, quick response, and ideally the ability to anticipate cyanoHABs before they worsen. Until recently, consistent forecasting of cyanoHAB levels wasn't possible at a national scale. That gap in capability reached a turning point when Congress authorized the Harmful Algal Bloom and Hypoxia Research and Control Act, funding federal agencies to research, monitor, and forecast these events. The U.S. Environmental Protection Agency was ready for the challenge. What followed was a scientific effort to answer the difficult question: can we forecast cyanobacterial harmful algal blooms like we forecast the weather?

The task was complex because cyanoHABs don't behave the same way in every lake. Blooms can develop during the spring through late fall. Some persist for weeks, while others may rapidly form and fade within a few days. Each event is shaped by local environmental conditions, including waterbody size and depth, nutrient concentrations, rainfall, watershed characteristics, and temperature. In addition, existing cyanoHAB models typically focused on a few well-studied lakes that require continuous and intensive field sampling. Therefore, scaling from a single lake to the entire nation was difficult.

Modeling and testing

To tackle this, Environmental Protection Agency (EPA) scientists turned to a new modeling framework and leveraged satellite data. The Cyanobacteria Assessment Network (CyAN; www.epa.gov/cyanoproject – a multi-agency collaboration including EPA, National Aeronautics and Space Administration (NASA), National Oceanic Atmospheric Administration (NOAA), and United States Geological Survey (USGS) focused on identifying cyanobacteria blooms across the largest 2,192 U.S. lakes using data from the European Space Agency's Sentinel-3 Ocean and Land Colour Instrument (OLCI). The OLCI measures light reflected by water on the Earth's surface. The presence of cyanobacteria creates a unique signature in the light reflected from surface waters, which can be detected by the Sentinel-3 OLCI. Scientists developed an algorithm to convert the detected wavelengths of reflected surface light into an estimated abundance of cyanobacteria dominated chlorophyll-a. From this process, the CyAN team quickly amassed a huge dataset of cyanoHAB observations for all of the targeted lakes. By combining the satellite observations with predictors like water temperature, precipitation, lake size and depth, the EPA team built a national forecasting model that can be updated weekly without the need for constant field observations at every lake (Schaeffer et al. 2024). We can now monitor real-time cyanoHAB conditions with satellites and forecast the probability that a cyanoHAB event will occur the following week.

The team tested the model across all 2,192 lakes from 2021-2023. Each week we compared the predicted bloom probabilities with the satellite observations for every lake. The results were promising; the model correctly identified cyanoHAB conditions with 90 percent accuracy. It also worked across a diverse range of locations, from Florida to Utah. This approach filled the critical gap in the capability of forecasting cyanoHAB occurrence.

Accessing the forecasts

Water managers can now access the forecasts through the EPA HABs forecast website (www.epa.gov/habs/hab-forecasts), which displays a national map of cyanoHAB probability with weekly updates. Users can also view maps by week (Figure 1), explore trends in individual lakes (Figure 2), and download data. The EPA HABs forecast website is available to everyone – including local health departments and state environmental agencies.

Where once, decisions had to be reactive – made after cyanoHABs formed and toxins were possibly present – this new forecasting service makes it possible to act earlier. Now, public health advisories, drinking water protection, and additional field monitoring can be more targeted based on what is likely to happen, not just what has already occurred.

Continued challenges

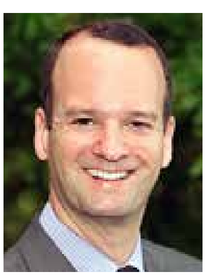
The challenges of addressing cyanoHABs are not over. For example, the current model can forecast the presence of cyanobacteria blooms, but it cannot determine whether the bloom is toxic or exactly where it will occur in the waterbody. Future improvements include higher resolution imagery to provide forecasts for smaller lakes and waterbodies. But thanks to the combined effort of satellite remote sensing experts, field scientists, modelers, GIS scientists, and web design staff, a major piece of the cyanoHAB puzzle has fallen into place for public health protection. The EPA team continues to provide reliable forecasts while the next generation of improved forecasting models are developed.

Just like weather forecasts change how we plan our summer days, this new forecasting ability can change the work that water managers do behind the scenes to keep us safe. When combined with real-time satellite monitoring and field observations, this approach can help identify large lakes in a state or region at risk of exceeding thresholds for cyanoHABs. Local and state water quality managers can use the forecast to make faster and better-informed management decisions regarding recreational and drinking water safety. Innovative prediction tools like this empower decision-makers to protect people before problems reach the shoreline. The future of water quality isn't just about detecting what has already happened – it's about seeing what is coming next. And now, we can.

Reference

Schaeffer, B.A., N. Reynolds, H. Ferriby, W. Salls, D. Smith, J. Johnston, and M. Myer. 2024. Forecasting freshwater cyanobacterial harmful algal blooms for Sentinel-3 satellite resolved U.S. lakes and reservoirs. *Journal of Environmental Management*. 349: 119518.

Dr. Blake Schaeffer is an EPA research scientist in Durham, N.C. His research focus is on the use of satellite remote sensing technology to monitor water quality in coasts, estuaries, and lakes. His interests generally include integrating remote sensing technologies into water quality management frameworks. You can contact Blake at schaeffer.blake@epa.gov.



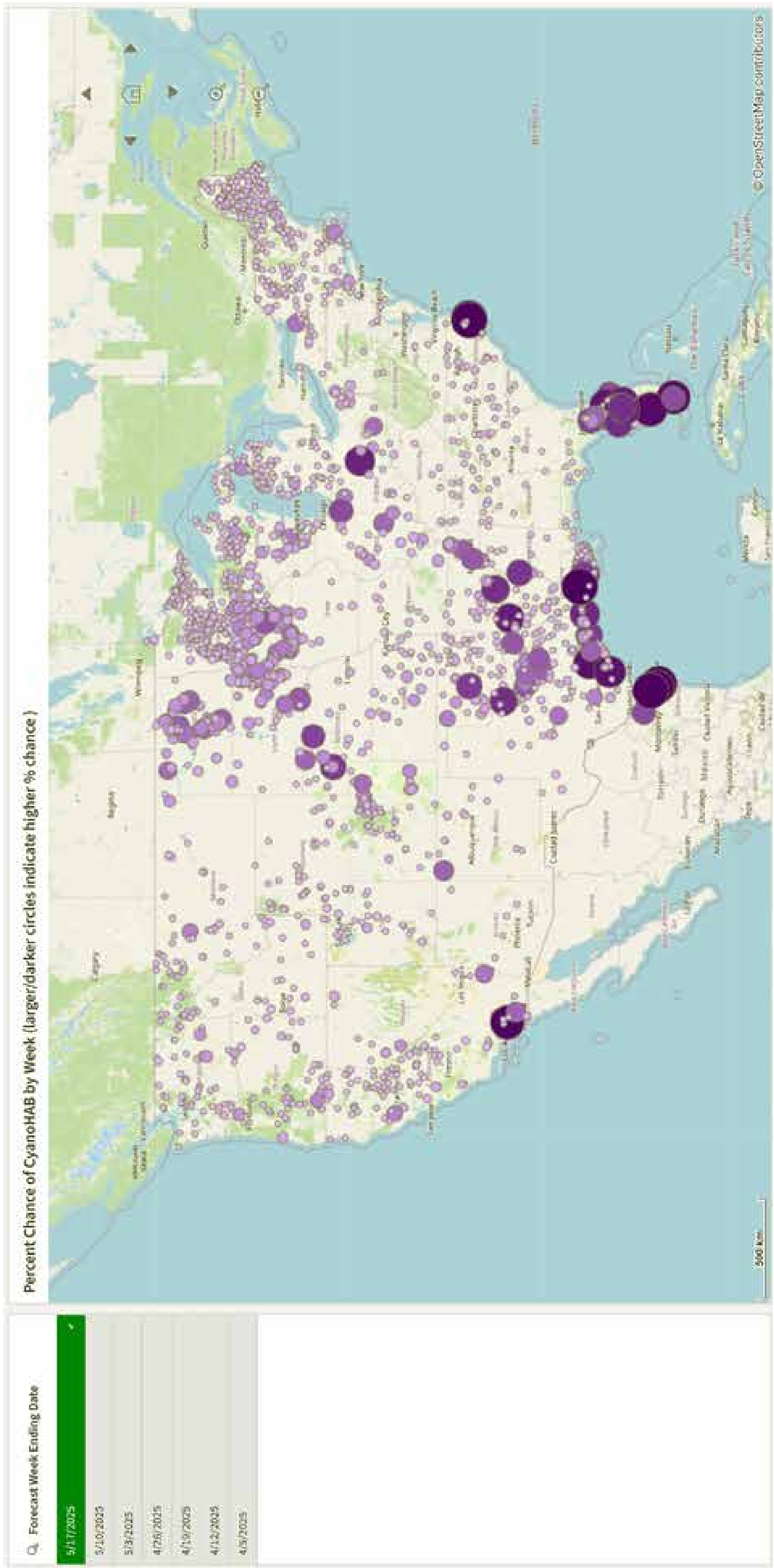


Figure 1. Public website example forecast map for the week ending on May 17, 2025. Larger and darker circles indicate a higher probability of a bloom.

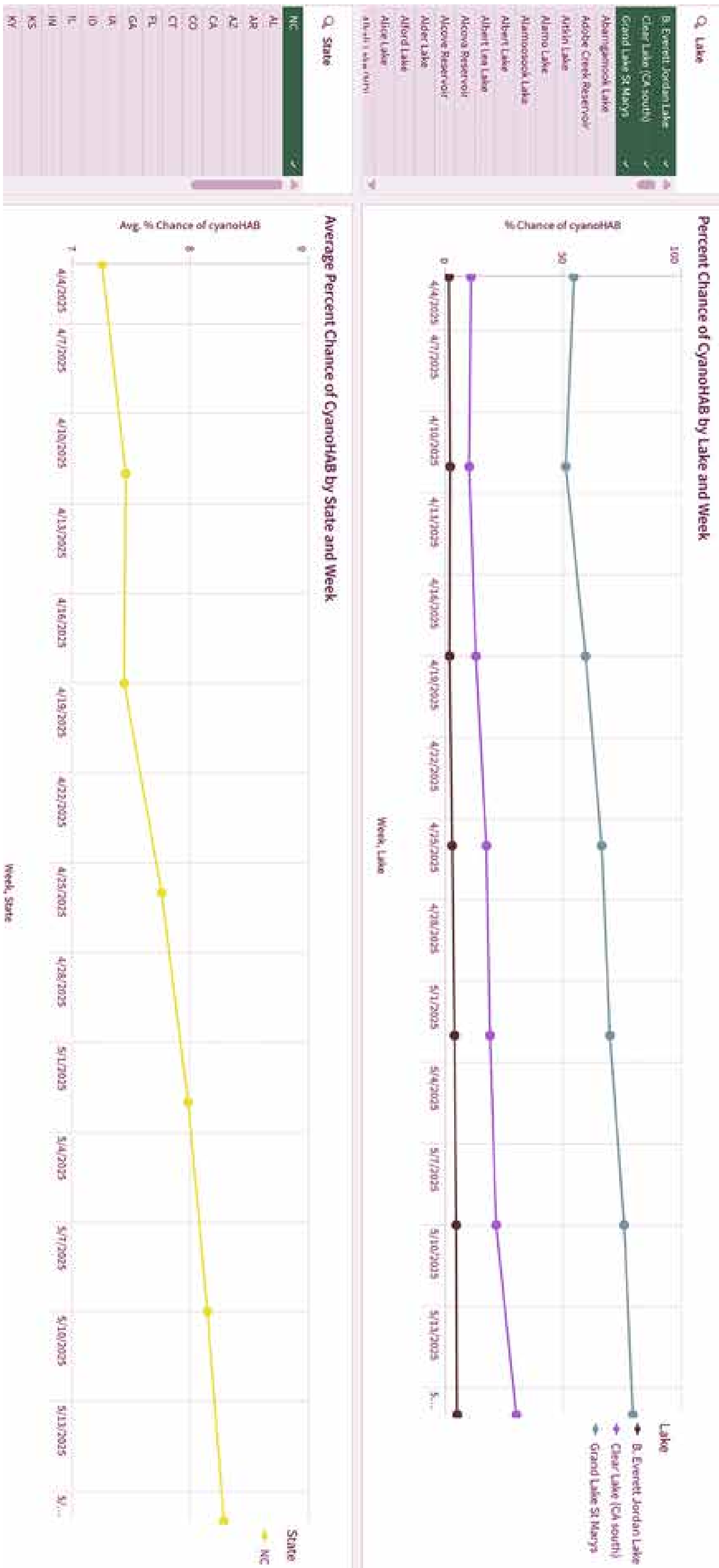
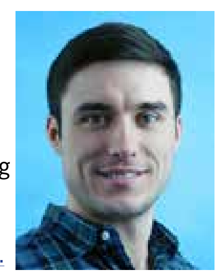


Figure 2. Public website time series of weekly lake (top) and state (bottom) averaged probabilities for April 5 through May 17, 2025.

Dr. Michael Paul is the EPA National Harmful Algal Bloom Program Lead, responsible for coordinating all HAB related activities across the agency. He also supports the nutrient and biological criteria development programs in the Office of Water. Mike has more than 30 years of experience in the research and management of aquatic ecosystems, including 20+ years in water quality criteria development across the nation. He can be reached at paul.michael@epa.gov.

Dr. Donald Benkendorf is an EPA physical scientist in Washington, DC. He works on the National Aquatic Resource Surveys team and has broad research interests in the areas of monitoring and assessment of aquatic resources. You can contact Donald at benkendorf.donald@epa.gov.

Gregg Serenbetz is an EPA Environmental Protection Specialist in Washington, DC. He works on the National Aquatic Resource Surveys team with a focus on wetland monitoring and analysis. He can be reached at serenbetz.gregg@epa.gov.



Deron Smith is an EPA Information Technology Specialist in Athens, GA. His work has focused on applied scientific software applications, cloud computing architectures, and machine learning models. He can be reached at smith.deron@epa.gov.

Dr. John M. Johnston is an EPA supervisory ecologist in Athens, GA. His research focus is on water quality monitoring and modeling to forecast ecosystem services and their influence on human health. His interests include life cycle impact assessment, remote sensing, spatial modeling, and sustainability analysis. Current projects include forecasting lake cyanobacterial bloom probability and urban storm water management and reuse. He can be reached at johnston.johnm@epa.gov.

UPCOMING IN *LAKELINE*

Fall 2025: Tire Toxins and Other Emerging Contaminants

Fall is a good time to check in on emerging contaminants of concern in our waterbodies, after a spring and summer of field work to monitor water quality data across many of our waterbodies. In particular, tire wear particles can influence the health of our aquatic systems. Leached chemicals from tires, including the compound 6PPD-quinone, as well as microplastics can be harmful to aquatic life and water quality. When these particles break down on land they are flushed into aquatic systems through runoff patterns. Once in a waterbody they can affect these systems in a variety of ways. Articles focusing on the breakdown of tire material and transport of these particles and chemicals to aquatic systems (fate and transport) as well as documented impacts to aquatic systems and water quality will be the focus on this issue. If you have been working on topics related to this issue, or other emerging contaminants, please consider submitting an article for fall *LakeLine*.

Draft articles are due by September 15, for publication in the fall issue in mid-October 2025.

Winter 2025: National Aquatic Resource Surveys

This issue will focus on data from federal National Aquatic Resource Surveys, including the National Lake Assessment. Articles related to this type of monitoring, including overviews, survey results, methods, interesting findings by state or region are welcome, as well as federal perspectives related to monitoring and data.

Draft articles for winter issue are due by December 15th, for publication in January.

Spring 2026: Volunteer Monitoring

There are many volunteer monitoring programs out there focusing on collecting chemical, physical and biological data from our surface waters. The focus of this issue will be to feature the work of some of those programs, including any novel methods as well as data collected as part of these monitoring efforts. Values and uses of these data, engaging volunteers, and leveraging support for these programs are all topics of interest.

Drafts for spring issue are due by March 30, for publication in April.

Summer 2026: DNA Barcoding in Lake Studies

More and more we are hearing about the use of DNA barcoding, eDNA, and metabarcoding to monitor our surface waters. What is it, how is it used, what is it used for, and who's using it? These are all topics that are being sought for articles to round out this issue. Are you working with DNA barcoding in your lake(s)? Please consider submitting an article about your work!

Draft articles are due by June 30, for publication in July.

Please contact Amy Smagula, *LakeLine* Editor, with any questions, or to propose an article for one of the above-listed themes. Do you have a topic that doesn't match a theme? That's ok, we can include the article in any of these issues or use it to build a themed issue. Amy can be reached at **lakeline@nalms.org**.

Determining the rise & possible causes of cyanobacteria blooms **with limited means**

Gertrud K. Nürnberg

Which information can a lake champion assemble with few resources?

This article is about simple approaches for finding out how often and why there are cyanobacteria and even harmful algal blooms (HABs) in a specific lake. This information can inform more costly, separate studies that determine how to abate cyanobacteria under specific circumstances.

Such knowledge can be developed by a type of cause determination or "system analysis" to determine the mechanisms of the main players driving water quality, while considering lake specific characteristics. In this article, system analysis helps determine the likelihood of present and future HABs development.

Mainly surface blooms are addressed here, as they are most obvious. Other cyanobacteria groups that are usually below the mixed layer and can come to the surface at times (e.g., red cyanobacteria under ice that turn the water dark red in the spring) are not considered.

Potential approaches should include the following characteristics to maximize effectiveness:

1. Scientific (evidence-based) and defensible
2. Permit easy application, high method availability, and low error-proneness
3. Low cost or high grant possibilities
4. Expected community acceptance and endorsement
5. Close collaboration and follow-up by knowledgeable professionals

A simple homemade adjustment of the well-known suspended Secchi disk is shown in Figure 1. In murky hypereutrophic waters and in fast flowing systems, a Secchi disk on a broomstick provides more detailed depths recordings than a classic Secchi disk deployed on a line. Also, inexpensive thermometers (bath thermometer and one provided by citizen science projects) can record the lake surface temperature (at arm's length) at the same time of taking Secchi readings.

Determine current and past prevalence of cyanobacteria

Any observed cyanobacteria proliferation can trigger such an investigation. To begin, any increase of the obvious presence of cyanobacteria should be described and quantified, and long-term cyanobacteria records assembled. Past official records on the occurrence of cyanobacteria are often unavailable but extremely important for further studies. Such information can be garnered from past residents and users of the lake, including written (newspaper articles, state/provincial health notices including beach closures for cyanotoxins, often on websites) and orally transmitted histories (e.g., by members of the First Nations and old family members of lake residents). For example, a Rowers Club's notebook turned out to be crucial to determining the recent location and timing of cyanobacteria in the Ontario Thames River Reservoir, Fanshaw Lake.

Several states and Canadian Provinces have programs where volunteers take water samples or Secchi disk readings in the summer (e.g., Secchi Dip In, https://www.nalms.org/secchidipin/, the Ontario Lake Partner Program, https://www.ontario.ca/data/ontario-lake-partner, and many other state- or Province-wide programs (Preece

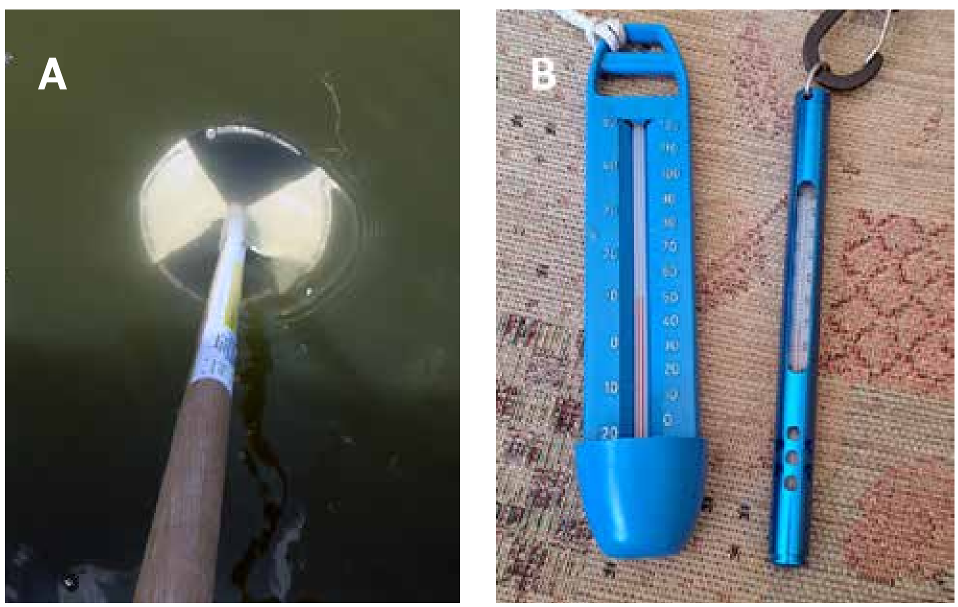


Figure 1. Simple tools available to Lake Champions on the lake: (A) A simple homemade adjustment of the well-known suspended Secchi disk. In murky hypereutrophic waters and in fast-flowing systems, a Secchi disk on a broomstick provides more detailed depths recordings than a classic Secchi disk deployed on a line. (B) Inexpensive thermometers (bath thermometer and one provided by citizen science projects) can record the lake surface temperature (at arm's length) at the same time of taking Secchi readings.

and Hardy 2021). In addition to the useful data such programs create by the interaction of volunteers and governmental or commercial laboratories, the volunteers could report any occurrence and spread of algal scum (likely by cyanobacteria) at the same time.

Most relevant are recorded observations of the temporal and spatial scum variation in the summer growing period for as many growing periods as possible. Even simple devices, such as the Secchi disk, can provide detailed and predictive records of cyanobacteria distribution (Box 1 below). Such records can also be compared to climate variables that are readily available on governmental websites (i.e., maximum and minimum or average air temperature and precipitation volume for specific months, see below).

Other methods that are less accessible include historic satellite imaging, genetic determination of cyanobacteria distribution, and sediment-based paleolimnological determination of past lake characteristics (e.g., temperature, stability and nutrient and oxygen content). A detailed description of helpful approaches to cyanobacteria monitoring with different resources is available in the 2023 *LakeLine* summer issue (Wilkinson et al. 2023).

What can cause HABs?

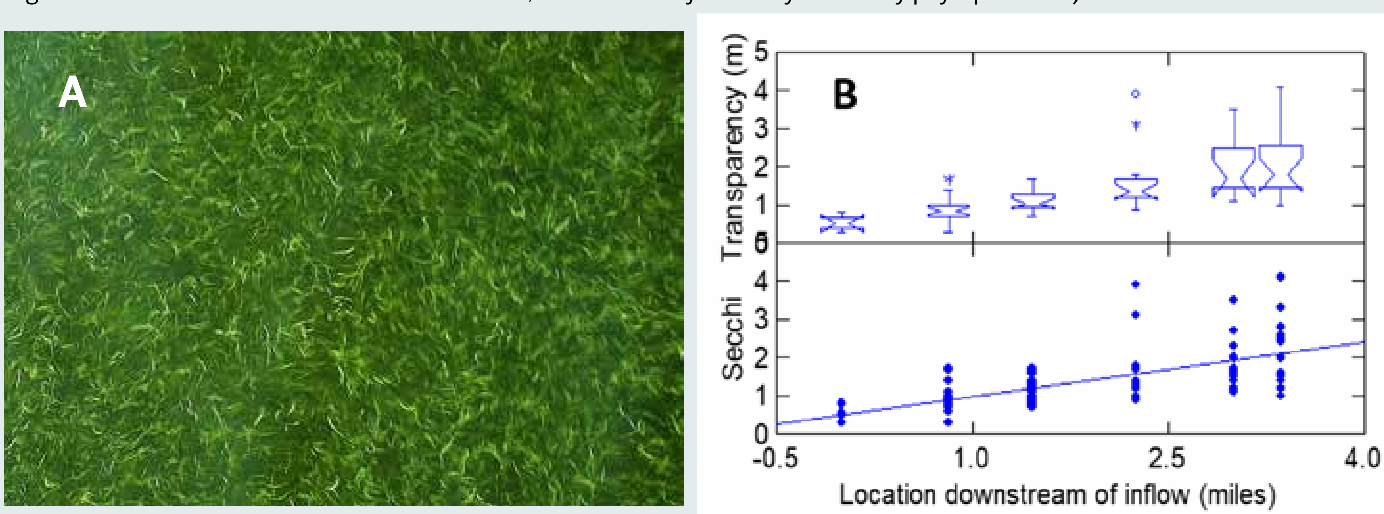
There are several known causes for the rise of cyanobacteria but increased nutrients, especially the increase of phosphorus (P), is the most important. Elevated P can originate either outside the lake (i.e., in the catchment basin or watershed, as point sources from streams fed by wastewater effluents, and from atmospheric deposition) or inside it (mainly from the lakebed sediments), and often stems from both sources.

Therefore, it is useful to determine any obvious **external P** sources, first. Of the many possible sources, some are described here that I have experienced in my studies involving lake associations (Figure 2 A-D).

- Access by livestock (cattle, horses), and waterfowl (Canada Goose, Swan) (left).
- Inflow from nutrient rich and polluted small drain (upper right).
- Upstream beaver dam (lower right): When there is a breach of an old dam – Nutrient export can be extremely high from a wetland pond and its

Spatial variation of cyanobacteria

Water quality and cyanobacteria distribution is often larger in certain areas, e.g., in bays and shallower sections compared to the main open deep sites that are preferentially monitored. In water systems with obstructed outflow, like in man-made reservoirs but also in natural lakes affected by ponding caused by downstream beaver dams, spatial changes along the way from inflow to outflow can be large and are best monitored at several sites. For example, in the South Dakota reservoir, Lake Mitchell, Secchi transparency increased along the way from inflow to outflow, as happens often in riverine reservoirs formed in former riverbeds. The simple measurements of Secchi transparency in the summer were correlated with the more costly and effort-requiring determination of the phytoplankton pigment, chlorophyll-a, here mainly from *Aphanizomenon*, so that Secchi served well for the documentation of this cyanobacteria. (The depth of Secchi disk transparency measures algae biomass in clear lakes, unstained by organic acids and in lakes with known color values, where turbidity is mainly caused by phytoplankton.)



Secchi disk transparency (correspondent to the cyanobacteria, *Aphanizomenon,* (A), along sampling stations starting at the inflow (mile = 0) for Lake Mitchell, SD, 2001, (B).

Lower panel: Individual data points and regression line for all stations. Upper panel: medians and non-parametric confidence bands. The horizontal lines are upper hinges or 75th percentile, and lower hinges or 25th percentile, respectively. The narrow "waist" represents the median, the vertical line the range, except that star and circle represent outliers. The slanted lines off the median represent 95% non-parametric confidence bands.

When spatial variation is determined by simple methods, costly monitoring and system analysis involving specialists can be conducted more efficiently and economically.

bottom sediments after the breach of a beaver dam. Beaver dam ruptures were mentioned in several small lakes in northern Ontario and in British Columbia with likely recent occasional HABs and their potential negative effects on downstream waters *(studied in mesocosms)*. Historic records and current inspections including photographic evidence help define this potential nutrient source for downstream water systems.

Internal P sources mainly occur in regions with long-term previous human development or naturally enriched soils, and they include elevated phosphorus in the lake bottom sediment. Whether and how much of such sediment P is released into the water (as internal P load) depends on lake characteristics and requires intensive monitoring of water and sediment. Signs and characteristics that facilitate the occurrence of internal P loading from lake sediments include thermal stratification and low dissolved oxygen in the stagnant regions (the bottom waters of thermally stratified lakes), harder-to-detect warming and oxygen depletion at the sediment-water interface in mixed regions, and elevated P in both these water systems (Sidebar 2, following page).

In contrast to external P load, internal P load is in a chemical form similar to fertilizers so that it is almost totally available to the biota. Importantly, internal loading appears to be on the rise in many freshwater systems, and there are known reasons for such increases. The tell-tale signs of rising sediment derived P (mostly from iron-associated components or settled organic matter) as internal load include physical changes in the lake ecosystem especially those affecting lake stability and warming.

Lake depth and thermal stratification are important influences and have to be considered first.

- Lengthy duration of thermal stratification in a deep lake.
- Lengthy duration and widespread oxygen depletion (a) in bottom waters in deep lakes or (b) at the sediment-water interface in shallow, occasionally mixed lakes.
- Increased epilimnetic total phosphorus concentration (a) in late summer and fall in (deep) lakes that stratify and (b) throughout the growing period in (shallow) lakes that often mix.
- Increased whole lake (water column volumetric average) total phosphorus concentration throughout the summer in any lake.

Climate change influences, easily determined

The long-term variability of the period and extent of internal P loading and associated cyanobacteria proliferation much depends on the weather; therefore, climate variables and their variation due to anthropogenic climate change can help to trace and explain an increase in internal P load.

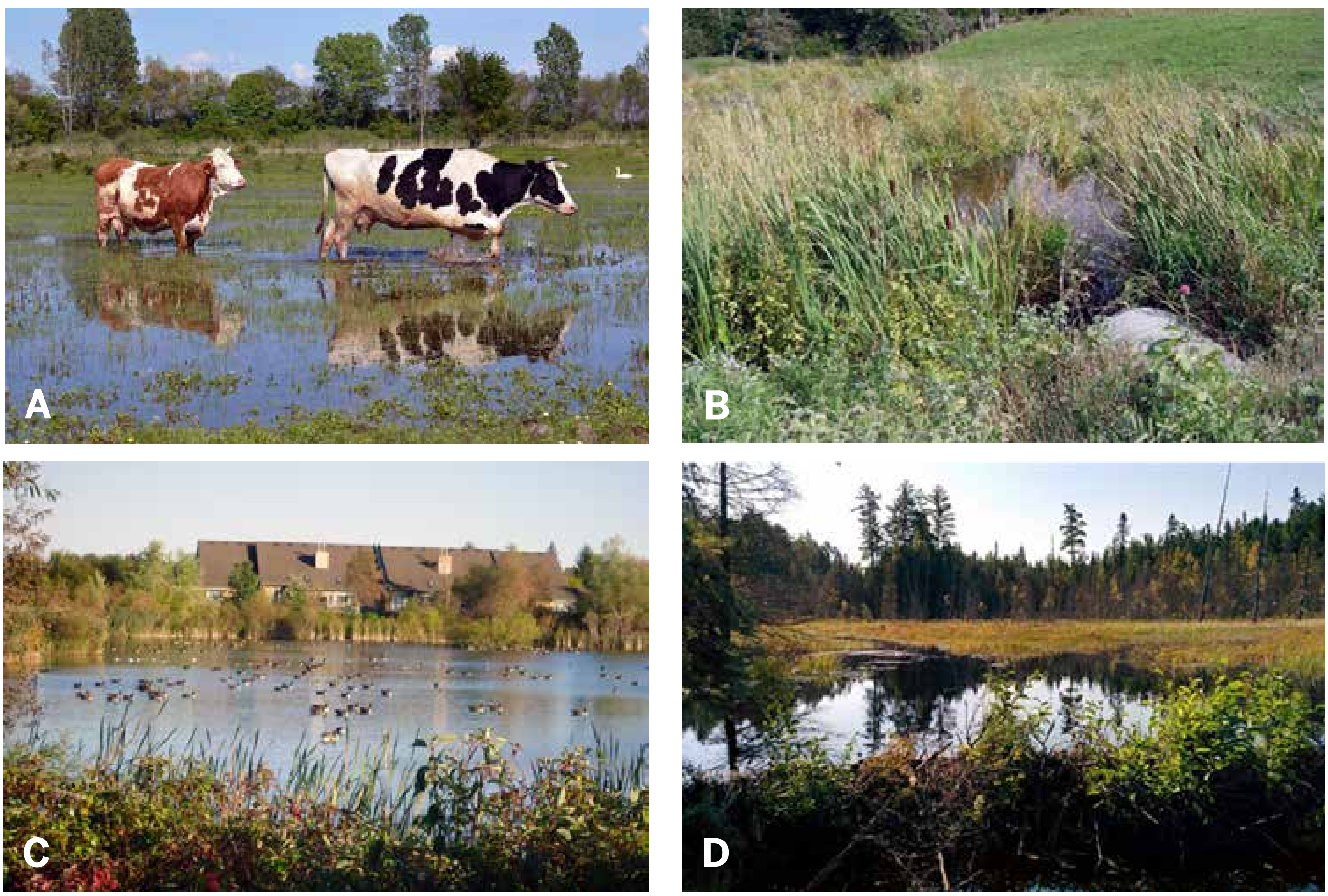
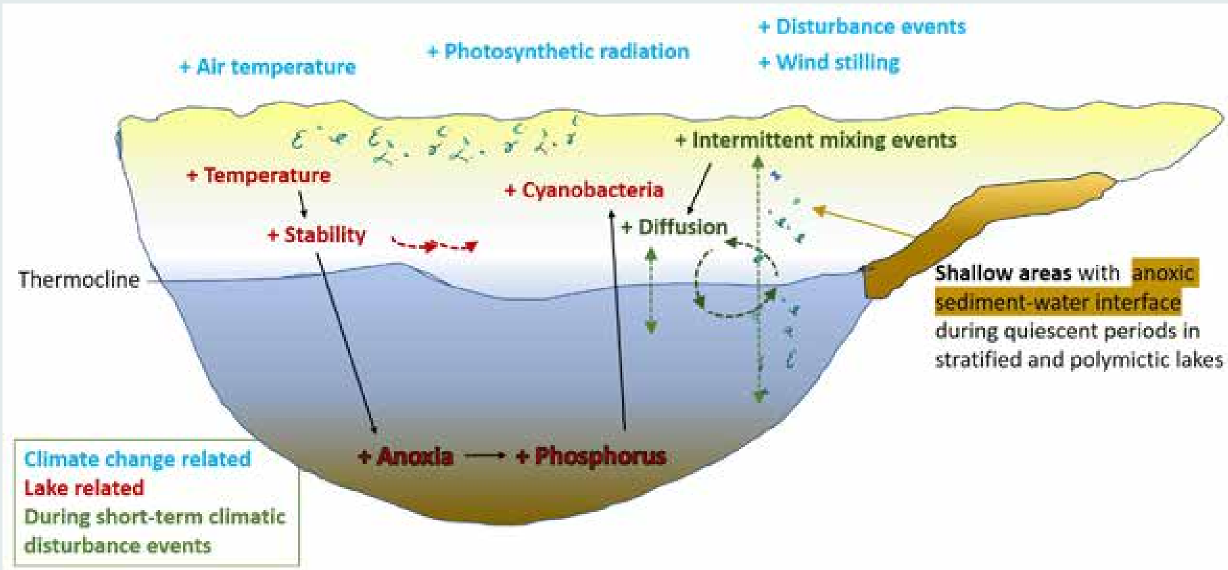


Figure 2 A-D. Examples of external sources, discovered by simple sight inspection. Photos taken by the author, except 2A, courtesy of Pexels.

Possible climate effects on cyanobacteria and internal P load. (Abbreviated text and Figure 5.15 from Nürnberg 2025 with permission)

Positive interactions between climate change trajectories (blue), internal P load, and cyanobacteria. Increased stability with related lake variables (red) is interrupted by increased frequency of climatic disturbance events (green). Arrows indicate potential influences that can be bidirectional.



"The lake-mixing state, either polymictic in a shallow lake or stratified in a deep lake, and gradations between these extremes (quantifiable from lake area and its depth) regulate hypoxia and the influence of internal load on cyanobacteria. Climate change (warmer and dryer and wind stilling, blue variables) increases lake temperature and hypoxia, which is related to increases in both internal P load and cyanobacteria biomass (perhaps except in very deep lakes) (red variables). ... Influences of drought, resuspension, and lake stability or mixing state on cyanobacteria, can at least partially be explained by internal P loading effects."

The climate change especially affects lakes of medium stability. Such lakes are usually of medium depth with variable thermal stability between and within years. They can be mixed during the warm season in some years (polymictic) and stabilize in others (stratified). Here, any warm and dry weather favors internal loading and cyanobacteria (Figure 3).

I have experienced many climate-related relationships of cyanobacteria proliferation and internal P load variability in my studies involving lake associations and municipalities. Such relationships have also been found globally throughout the Americas, Europe, Asia, Australia, and Africa (Nürnberg 2025).

Climate variables are recorded by many jurisdictions and governmental agencies so that related information is readily available on the internet. Long-term records exist for air temperature, precipitation, and other weather-related variables (e.g., NOAA, the National Oceanic and Atmospheric Administration for the USA; ECCC, Environment and Climate Change Canada for Canadian locations). Flow gauges can provide publicly accessible flow records reflecting the watershed conditions with respect to runoff and moisture content (e.g., the Canadian HYDAT and websites of many regulated reservoirs).

In addition, there are records of climate indices that summarize climate conditions in specific regions (e.g., the El Niño – Southern Oscillation (ENSO) index that is based on temperature changes in the tropical Pacific Ocean, the North Atlantic Oscillation (NAO) index that is based on sea-level pressure differences, and the Pacific Northwest Index (PNI) that is based on three terrestrial climate variables in the northwestern United States). Many established climate indices are related to lake hypoxia (Nürnberg 2025) and thus are useful for the investigation of internal load.

For example, just by listing summer averages of maximum air temperature and precipitation volume it became clear that slightly elevated air temperature (2% and 4% above average of previous 11 summers) together with low precipitation (57% and 67% below average) compared to the previous 11 years coincided with regional blooms in a mesotrophic drinking water reservoir (Figure 4). Additional studies (supported by the reservoir owner) revealed that internal P load was elevated in those years.

Further, lake responses to the climate variables can be determined from simple, low-cost water monitoring devices. For example, a simple bath thermometer used every time when Secchi readings were taken, can indicate summer variability of the surface temperature within and among years (taken "at arm's length" about 30 cm below the surface, Figure 5).

In situations with cyanobacteria blooms, it helps to know whether thermal stratification and bottom water anoxia has changed in recent summers and falls, which can cause increases in internal P load (Sidebar 2, previous page). Relatively

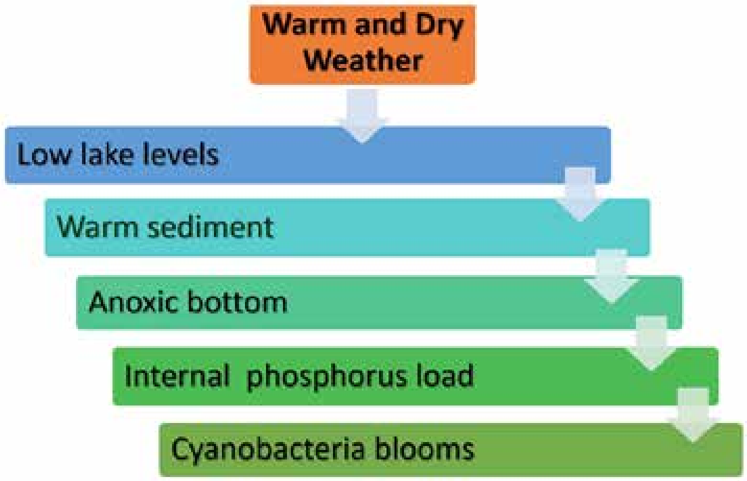


Figure 3. Schematic and generalization of changes in occasionally mixed lakes for warm and dry climate conditions.

costly temperature and dissolved oxygen probes take depths profiles down to the bottom at specific times from a boat. In addition (or instead of), and with little manpower, the computer-savvy lake champion can determine the water temperature and stratification variability even at deeper depths by inexpensive temperature probes deployed at several depths throughout the water column. For the recording of oxygen concentrations, more expensive dissolve oxygen recording probes exist, ready to be installed close to the sediment in mixed lakes and higher above in stratified lakes to determine the development of oxygen depletion. Data accumulated during deployment, typically in the summer and fall, can then be transferred to computer, plotted, and analyzed (Figure 6).

Another easily recorded climate-related variable in northern lakes includes ice phenology. Long-term records of ice-in and ice-out document the effects of air temperature changes on winter ice cover in specific regional settings. Because these variables dictate lake stability over the year, they can also influence internal P loading.

Finally, chemical water monitoring variables, including phosphorus (total), which may be available in provincial and federal programs and on websites (in addition to Secchi and chlorophyll, dissolved oxygen and temperature), could be another source of data needed to confirm internal P loading.

Observations accrued by simple, cost-effective monitoring efforts can provide a starting point for more in-depth, academic studies. For example, paleolimnological investigation as part of a doctoral thesis selected specific lakes from such citizen-based studies. The sediment-derived information on previous lake conditions supported the likelihood of increasing internal P load in several lakes in the Algoma District, Central Ontario, by presenting evidence for the increased duration of stratification and oxygen depletion in these lakes (Favot 2021, Queen's University, Kingston Ontario, Canada). Similarly, an internship as part of a master's thesis provided sediment P fractionation results for lakes with various acid rain exposure. These studies determined a decrease in phosphorus retention in the lake sediments indicating increased internal load (Nürnberg et al. 2018).

Bottom line (conclusions)

- In situations with cyanobacteria blooms, detailed limnological investigation have often shown signs of internal P loading (Nürnberg 2025).
- Limited data (observations) combined with long-term available weather records can demonstrate relationships between cyanobacteria and climate conditions and its change.
- Novel insights about past and present conditions obtained by observant members of the public (citizen scientists)

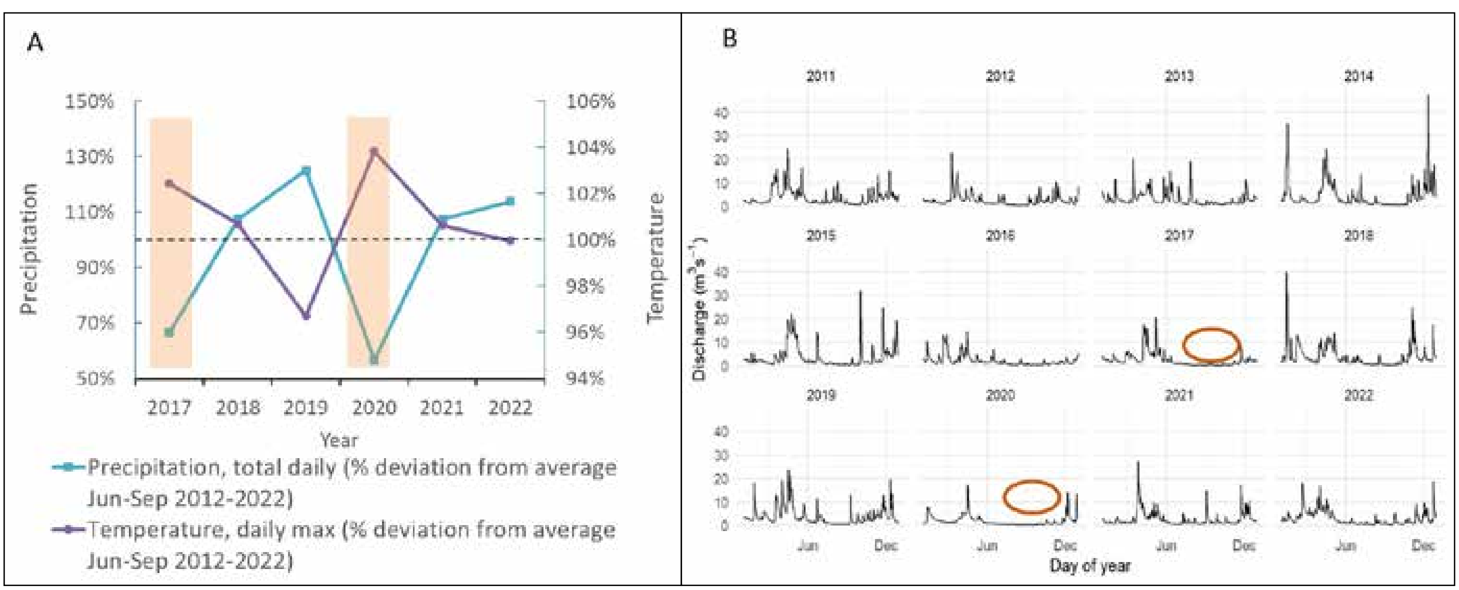


Figure 4. Cyanobacteria (orange shading) were detected (only) during warm and dry summers in an eastern Canada mesotrophic reservoir (A) when discharge was low (B, orange ovals). (Bloom monitoring started in 2017.)

in combination with governmental and regulatory agency surveys and consultants pave the way for more detailed study projects, including academic investigations.

- The lake champion to-do list: Be a detective of nutrient sources, external, and internal. Find historic records of cyanobacteria blooms. Record current lake conditions: temperature, Secchi, cyanobacteria presence/absence and have the accumulated data reviewed by a limnological professional.
- This way important information can be provided as background to supplement more detailed analyses of the lake in question.
- Combined efforts by the citizen scientist and the professional lead to better management and more options for abatement.
- Such endeavours enhance community spirit and environmental awareness.

News and references

For "cyano" news hot of the press, both in the general news media and in peer-reviewed publications, subscribe to this informative week-monthly newsletter *Eutrophication, Cyanobacteria & Cyanotoxins Research Newsletter / Bulletin de recherche sur l'eutrophisation, les cyanobactéries et les cyanotoxins.* An e-mail to info@blue-leaf.ca will get you on the mailing list.

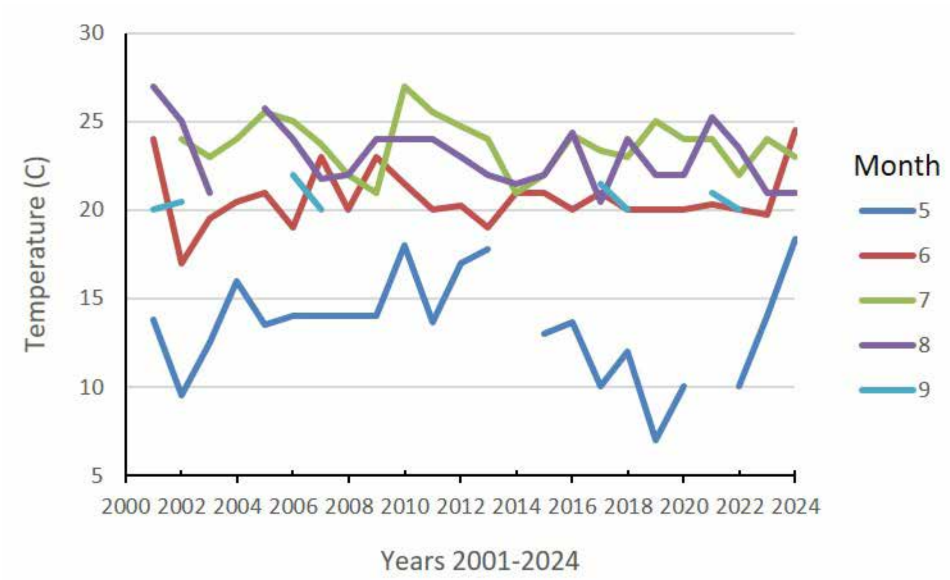


Figure 5. Nutrient-poor Grandview Lake temperature taken with a simple bath thermometer (Figure 1) averaged for months May (5) to September (9).

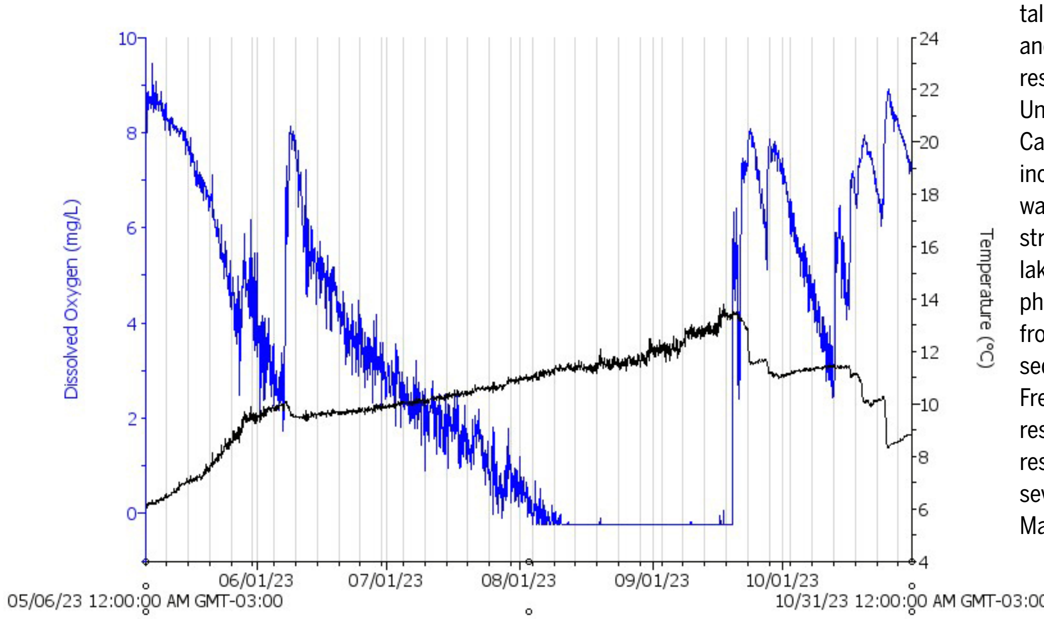


Figure 6. Temperature and dissolved oxygen 2.0 m above bottom from HOBO sensors deployed at the deep location close to the reservoir dam.

Chorus, I. and M. Welker (Eds.). 2021. Toxic cyanobacteria in water; a guide to their public health consequences, monitoring and management; second edition. 2nd ed. London, doi.org/10.1201/9781003081449: World Health Organization.

Nürnberg, G.K. 2025. Lake Functioning: Internal phosphorus loading, cyanobacteria, and climate change. CRC Press. https://www.routledge.com/9781032294407

Nürnberg, G.K., R. Fischer and A.M. Paterson. 2018. Reduced phosphorus retention by anoxic bottom sediments after the remediation of an industrial acidified lake area: Indications from P, Al, and Fe sediment fractions. *Science of the Total Environment* 626, 412-422. https://doi.org/10.1016/j.scitotenv.2018.01.103

Preece, E.P. and F.J. Hardy. 2021. Regional differences in CyanoHAB outreach methods in the US. *LakeLine* 41-2, 28-31. https://www.nalms.org/wp-content/uploads/2021/07/41-2-8.pdf

Wilkinson, A., D. Lofton, D. and K. Kemmitt. 2023. Blind spots in CyanoHAB monitoring. *LakeLine* 43-2, 12-16. https://www.nalms.org/wp-content/uploads/2023/07/43-2-4.pdf

Gertrud K. Nürnberg has been an environmental scientist for more than 40 years studying and modelling the geochemistry of lakes and reservoirs. She holds a Ph.D. (1984) from McGill University, Montreal, Canada. Main interests include the sediment-water interactions in stratified and polymictic lakes, especially phosphorus release from lake bottom sediments. As head of Freshwater Research, she has focused on the restoration and modeling of eutrophic lakes and reservoirs. Her efforts have been recognised by several awards from the North American Lake Management Society (NALMS.org).

A flood of concern: Effects and recovery in the St. Lucie River and Estuary following releases from Lake Okeechobee

Elizabeth Kelly

From February 17, 2024, until March 30, 2024, the US Army Corps of Engineers released water from Lake Okeechobee to the St. Lucie River and Estuary and the Caloosahatchee River. In this study, the effects of these flows into the St. Lucie River and Estuary are analyzed through flow data collected from local water control structures, salinity from estuarine stations, and the resulting Fecal Indicator Bacteria (FIB) enterococci (recommended instead of E. coli per EPA standards for saline/brackish water) and microalgae/cyanobacteria levels in the River and Estuary.

The period of study was 66 days, beginning on February 14th, before the first release, continuing through the time period during which the releases occurred in the St. Lucie River and Estuary, until April 19th, to measure the recovery period. Our observations revealed that when the flow increased, salinity decreased and counts of enterococci and cyanobacteria (some expressing toxins) increased. Whether salinity, enterococci, or cyanobacteria were analyzed in this study, the parameters responded fairly quickly (approximately one day) to the changing ecosystem as the Lake flowed through the river and estuary; after all three releases, it took approximately two weeks to one month for these parameters to return to the levels at which they were in early February.

Introduction

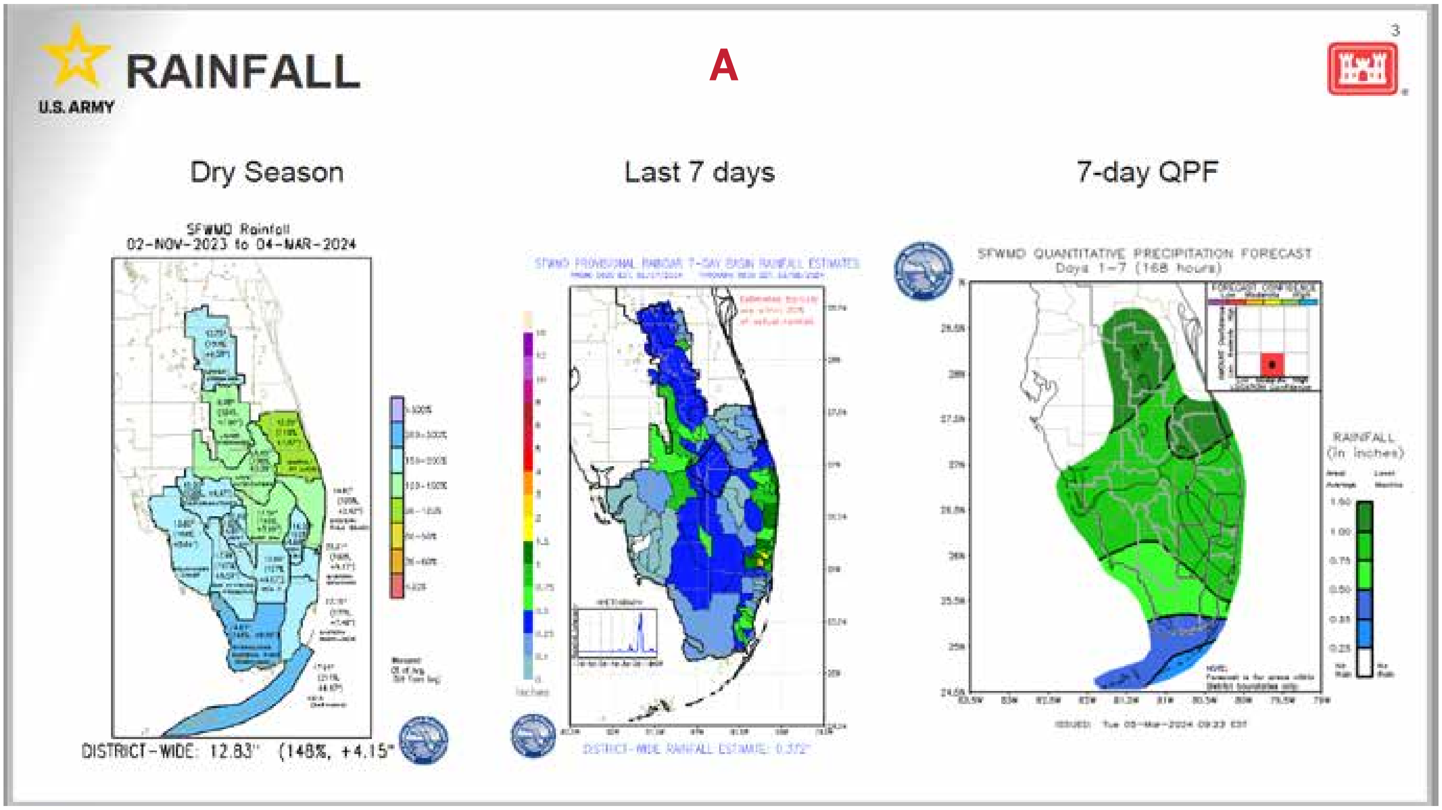
Lake Okeechobee is a large, shallow eutrophic lake located in subtropical south-central Florida. It is designated a Class I water (potable water supply). It is a large multipurpose lake providing drinking water for urban areas, irrigation water for agricultural lands, recharge for aquifers, freshwater for the Everglades, habitat for fish and waterfowl, flood control, navigation, and many recreational opportunities. High phosphorus loadings resulting from man-induced hydrologic and land-use modifications over the past 60 years have degraded the water quality of the lake (FDEP TMDL). One of the man-induced hydrologic modifications was a connection, known as the C-44 Canal, created from the lake to the St. Lucie River and Estuary. This connection was designed to allow the lake to drain during high-water conditions such as hurricanes or other major rainfall events.

The connection is managed by the US Army Corps of Engineers (USACE) through a series of gates, one that manages flow out of the lake and into the C-44, and a second one that allows flow out of the C-44 and into the south fork of the St. Lucie River. While hydrologic flow is carefully managed near the lake and into the C-44, the resulting nutrients, enterococci, and cyanobacteria (along with other microbes and chemical compounds), and their effects on water quality in the St. Lucie River and Estuary are not well understood.

During the fall of 2022, Hurricanes Ian and Nicole made landfall on the state of Florida in September and November per the National Oceanic and Atmospheric Administration's National Hurricane Center (NOAA NHC), dropping large amounts of rainfall over Lake Okeechobee and the watersheds that flow into the lake (United States Army Corps of Engineers [USACE]). During 2023, the normal wet season contributed water, followed by an unusually wet dry season resulting from El Niño conditions in late 2023 and early 2024 (USACE).

Per USACE, rainfall in the South Florida Water Management District was 143 percent of the amount normally received between November 2 and February 13. By March 4th, the amount had increased to 148 percent, and by March 25, it had further increased, to 151 percent of the normal volume (Figure 1). By February 14, 2024, the Lake elevation was 16.37 feet (South Florida Water Management District [SFWMD]). From February 17, 2024, until March 30, 2024, the US Army Corps of Engineers released water from Lake Okeechobee to the St. Lucie River and Estuary and the Caloosahatchee River. On March 26, 2024, Lake Okeechobee's elevation was 15.42 feet. As this elevation is below the intermediate guidance for the Central and Southern Florida Project 2008 Lake Okeechobee Regulation Schedule (LORS08) maintenance schedule, the releases to the St. Lucie River were discontinued on March 30th. Releases to the Caloosahatchee River continue around 2,000 CFS per day.

Neither the Caloosahatchee River nor the St. Lucie River have natural connections to Lake Okeechobee. Freshwater inputs to the St. Lucie River and Estuary only come from the watershed surrounding the North Fork and South Fork of the river. The two forks of the river meet in the estuary, which then flows out to the southern Indian River Lagoon and the coastal zone. The river is 35 miles long; the watershed encompasses about 781 square miles (SFWMD Water Supply Department). Freshwater inputs beyond what comes out of the watershed affect the natural balance of the ecosystem, bringing both natural and anthropogenic pollution with the flows, including fecal indicator bacteria (FIB) and microalgae, which includes harmful algal blooms (HABs) such as cyanobacteria. Maintaining normal



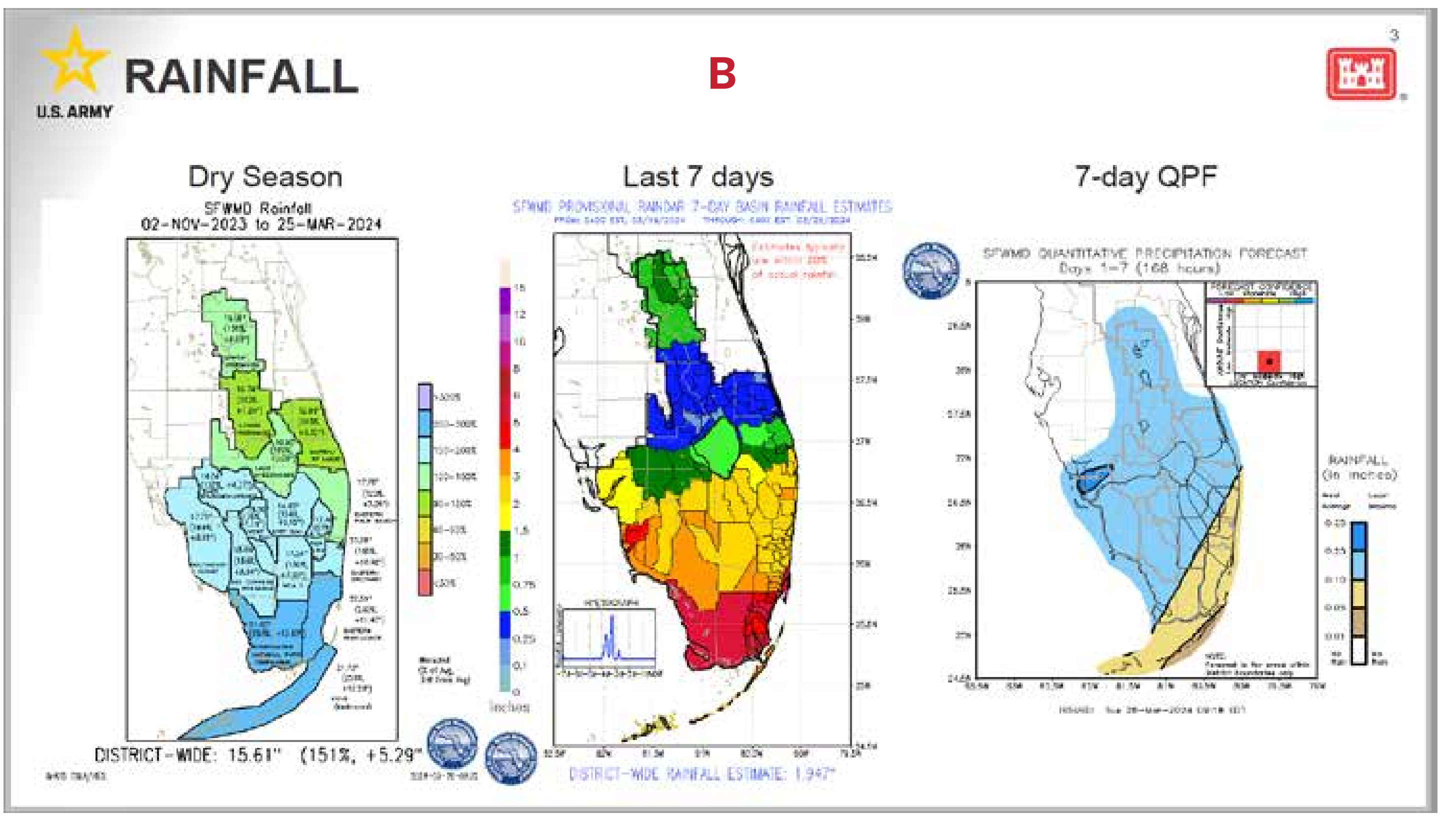
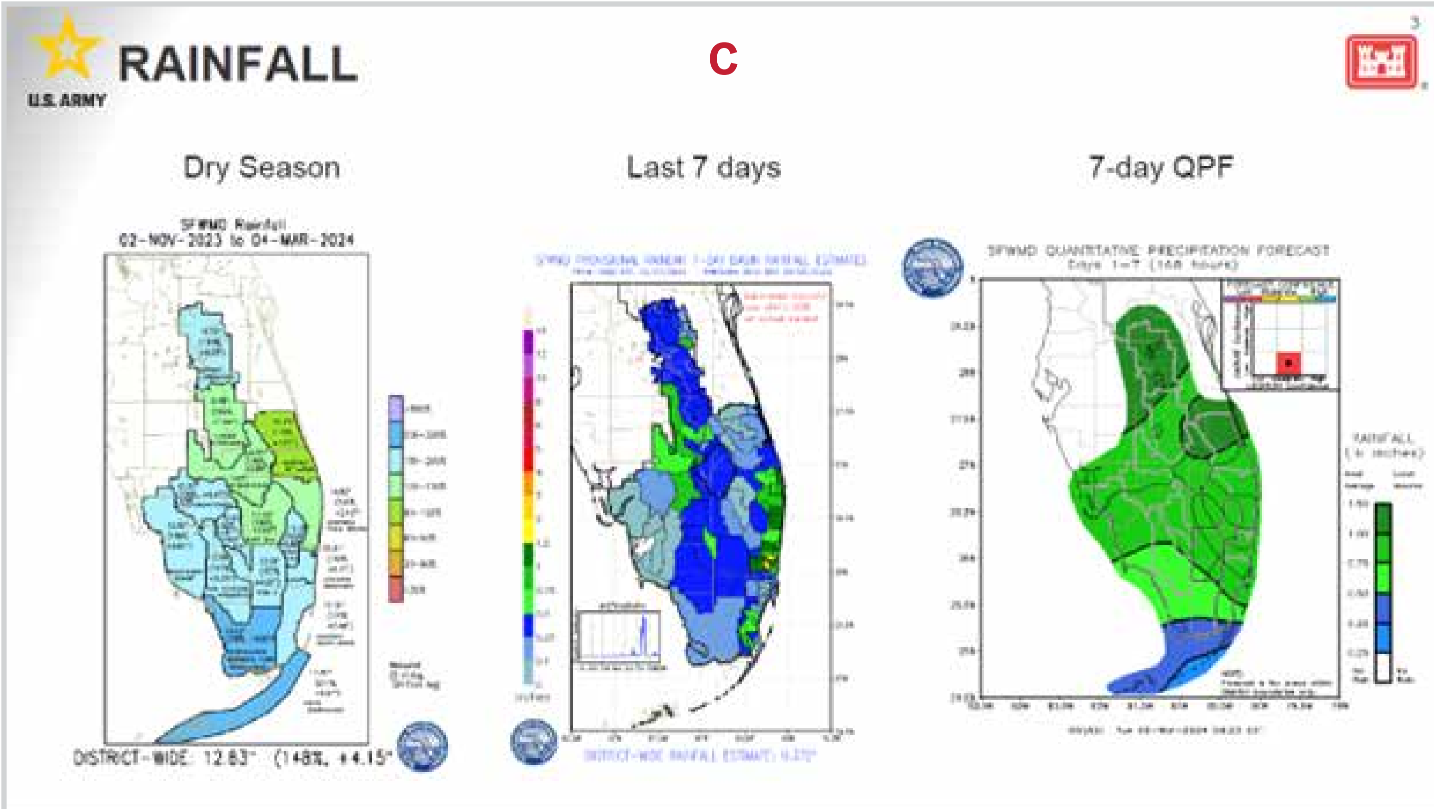


Figure 1 A and B. Rainfall over the South Florida Water Management District, November 2, 2023 - March 2024 (continued on page18).



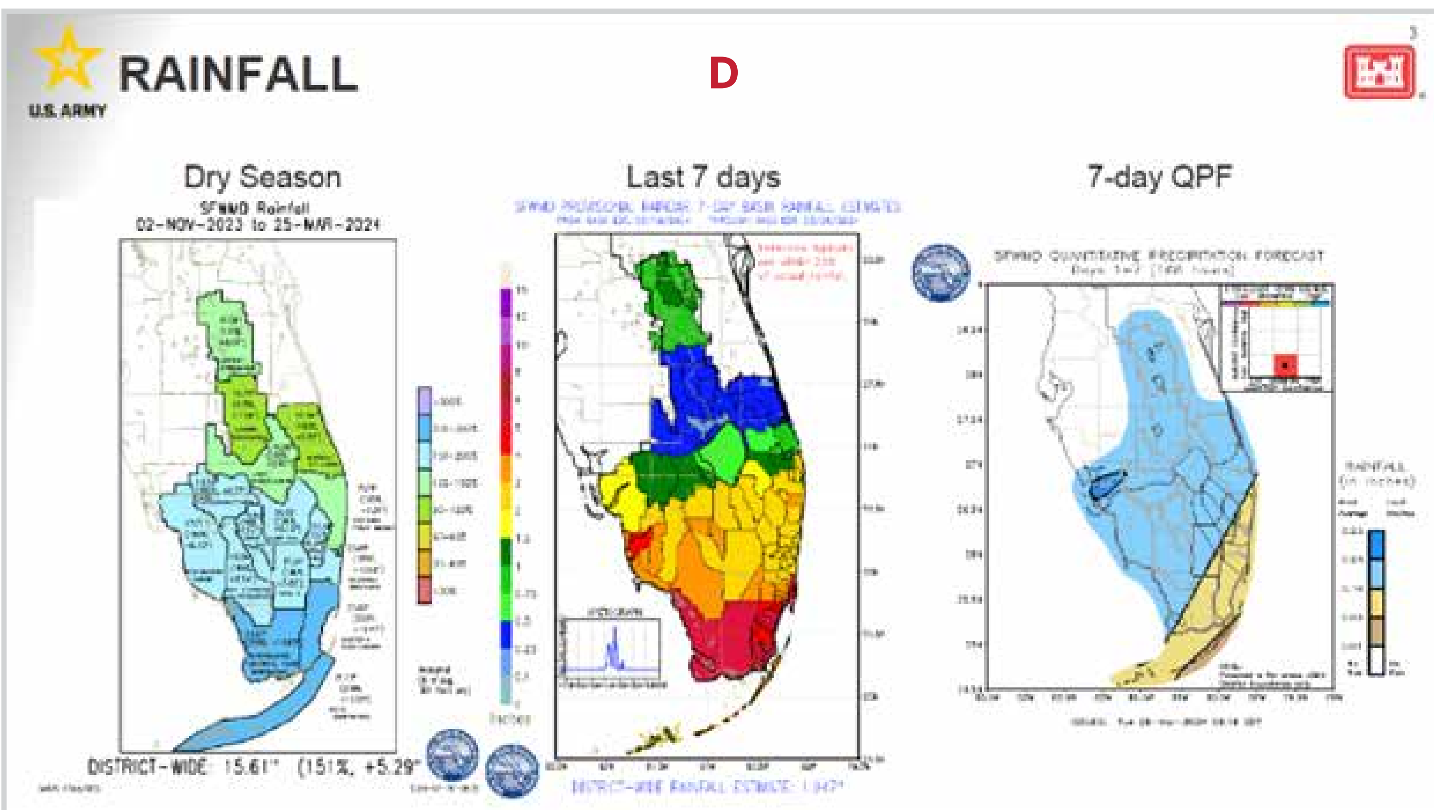


Figure 1 C and D. Rainfall over the South Florida Water Management District, November 2, 2023 - March 2024 (continued from page 17).

salinity is important to the estuary for the survival of oysters and seagrass, which are impacted by the changes in salinity along with the pollution.

This study is designed to analyze the effects of these flows into the St. Lucie River and Estuary, through flow data collected from local water control structures, salinity from estuarine stations, and the resulting FIB enterococci (recommended instead of E. coli per EPA standards for saline/brackish water) and algae/cyanobacteria levels in the River and Estuary, as collected through grab samples in the field, which are then analyzed in the laboratory. The period of study was 66 days, beginning on February 14, a few days before the first release, continuing through the time period during which the releases occurred in the St. Lucie River and Estuary (February 17, 2024, through March 30, 2024), until April 19th to measure the recovery period. The salinity data were analyzed in comparison to flow rates, as well as for the time period over which the salinity returned to post-release rates.

Methods

Methods used in this study involved the collection and review of both "historical" data (beginning in early February 2024, to provide an idea of pre-release water conditions) and "real-time" data (downloaded daily or weekly per collection/analysis schedule and the source agency). Data were collected on flow, salinity, enterococci, and cyanobacteria from the sources listed below. These data were then combined into an Excel spreadsheet to develop a database, and graphs were developed to perform evaluations. Maps were also consulted to reference sample collection locations.

Flow was evaluated in (1) the C-44/South Fork St. Lucie River [a] per the schedule provided by USACE, [b] from SFWMD's DBHYDRO data from the S-80 station on the C-44, and [c] from the USGS station 2276998 before the S-80. Flow was evaluated (2) from the watershed through [a] the C-23 Canal at S-97_S, through the [b] C-24 Canal at S-49_S, and at [c]) Ten Mile Creek through the Gordy Road structure (GORDY_S). These data are provided daily, most at 15-minute intervals. For these sites, a daily average was created for use in this analysis.

Salinity was measured through the USGS 0227710 Station (STL_RIVER) at Roosevelt Bridge and at the St. Lucie Estuary at USGS 02277110 Station (STL_A1A). These are measured via sonde. These data are provided daily.

Enterococci data comes from the Martin County Department of Health (DOH). Samples are collected once per week at each site. If the site exceeds the threshold, a follow-up sample is collected as soon as possible after the initial collection and analysis, until the samples collected no longer demonstrate exceedance. Exceedance of enterococci is determined to be bacterial counts greater than 70 MPN (EPA). Most Probable Number (MPN) indicates that analysis was performed in the laboratory using a statistical method to estimate the numbers of bacteria via a series of dilutions. The diluted samples are then incubated for 24 hours at 41+/-5 degrees Celsius with a nutrient substrate targeted for enterococci. The nutrient substrate includes a fluorescent indicator that fluoresces blue when metabolized by enterococci. The numbers of blue squares are then counted, recorded, and reported to the public and to the state DOH Environmental Health office. See Appendix C for the full dataset from the period of study.

Cyanobacteria data on algae samples were collected from the Florida Department of Environmental Protection Blue-Green Algae Dashboard (FDEP). Samples are collected at the location of any sighting of possible algae reported to FDEP. Sample collection is not regular; FDEP responds to reports of possible cyanobacteria made by the public through their Algae Bloom Monitoring and Response website (https://www.surveygizmo.com/s3/3444948/Algal-Bloom-Reporting-Form).

Algae are first speciated via microscope to determine the type of algae present. The sample is then analyzed to determine whether the toxins microcystin (from *Microcystis aeruginosa*) or CYN (*Cylindrospermopsin raceborskii*) are being expressed. Florida's current guidelines for toxin levels are to report to the public if any toxins are detected. Once the samples are collected and the dominant species is determined to be Microcystin, a caution is issued by the DOH at that location. If the microcystin is found, through laboratory analysis, to be expressing the microcystin toxin, a health alert is issued, and signage is placed at the area to avoid swimming or other contact with the water.

Results

Flow from all stations generally followed the schedule set by USACE. There were three release periods (February 17-March, March 2-March 15, and March 29). These release periods appear as peaks on the flow graph (Figure 2). Flow in the first release period as scheduled by USACE started at 3,200 cubic feet per second (CFS), peaked at 3,600 CFS, and then tapered to 1,300 CFS, followed by four days of 0 CFS for recovery of the estuary. The second release period started at 2,000 CFS, increasing to 3,500 CFS during the middle. It then tapered off to 1,000 CFS, ending in 0 CFS for the last three days of the schedule. The third release period started with three days of 0 CFS, building to 3,500 CFS, and ending on March 29 with 2,000 CFS. Flows remained at 0 CFS from March 30 onward; they are to remain there in the future unless a major rainfall event occurs.

Flow data per the USACE schedule and the flow out of the C-44 at the S-80 should be the same, but in comparison, the actual flow out of the S-80 does not match the schedule. This created some differences that were reflected in the graph (Figure 2). The combined watershed data also generally followed the USACE schedule, but the results were higher than what was scheduled during the first two releases. The combined watershed and the C-44 S-80 were both lower than the schedule at the peak and tapered off at the same rate to 0 CFS. The combined watershed has had releases of 74.53 CFS since March 31st due to the constant flow from Ten Mile Creek at Gordy Road.

Flow and Salinity. In comparing the flow to the salinity, increase in flow, both on the USACE schedule and the flow through

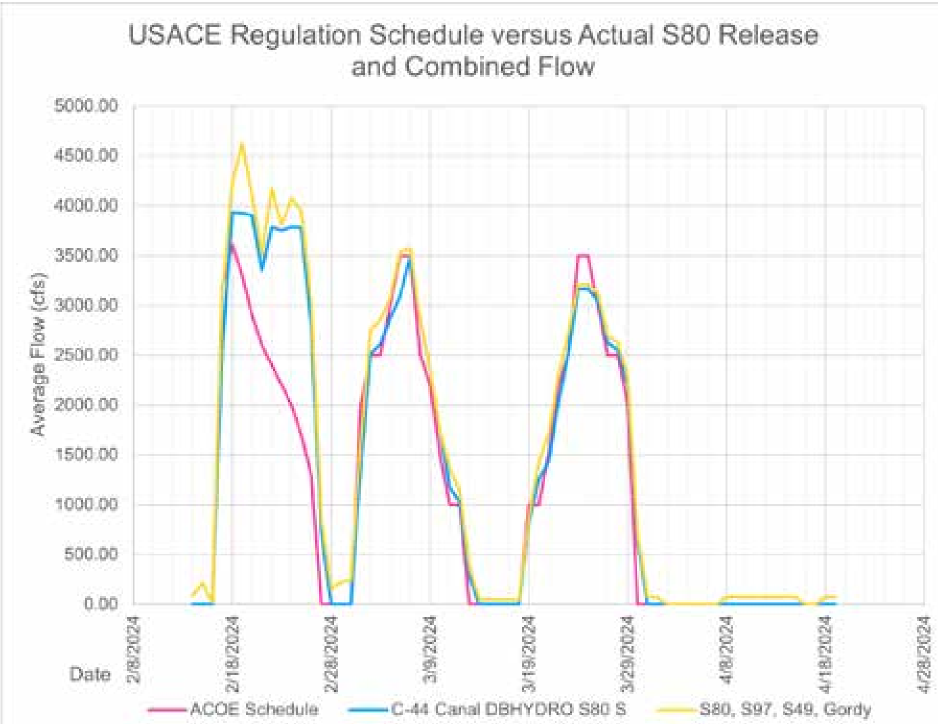


Figure 2. Flow via USACE Schedule, C-44 at S-80 per SWWMD, and combined flow from the watershed (S-80, S-97, and Gordy Road).

the S-80 structure, correlated with a decrease in salinity. Salinity ranged from 5.6 Practical Salinity Units (PSU) to 22 PSU (average of 13.37 PSU) at the Roosevelt Bridge (STL_RIVER) and 8.8 PSU to 30 PSU (average of 18.38 PSU) at the Estuary (STL_A1A). The indirect relationship can be seen in Figure 3; as the flow increases, reaching its highest levels, the salinity decreases, reaching its lowest levels. The rest periods between releases are also reflected as the salinity rebounded.

As can be seen in Figure 4, salinity levels dropped to stressful and harmful levels for oysters and seagrass. For the estuary near Roosevelt Bridge, the "stressful" level was reached for seagrass and oysters, and the "harmful" level for oysters was reached during the lowest salinity levels. In the St. Lucie Estuary near A1A (Figure 5), the "stressful" level was reached for both seagrass and oysters.

Flow and Enterococci. The flows also corresponded with increases in exceedances of enterococci (more than 70 MPN/CFU) and increases in reports of cyanobacteria confirmed by laboratory analysis. At the Roosevelt Bridge site (1 on Figure 6), results of laboratory analysis revealed that enterococci levels were 10 MPN for both February 5 and February 12 (Figure 7). On February 19, enterococci levels were 99 MPN; on February 21, enterococci levels remained high at 150 MPN. Levels dropped to 10 MPN on February 26, March 4, and March 11, but returned to 64 MPN ("moderate" water quality, which does not warrant a resample) on March 18. After lower levels on March 21st and March 25, there was an increase to 53 MPN (again, moderate water quality) on April 1. Enterococci levels returned to 10 MPN on April 8 and April 15. At Leighton Park, (3 on Figure 6), enterococci levels were 53 MPN and 20 MPN for February 5th and February 12, respectively (Figure 7). On February 19, enterococci levels were 150 MPN; on February 21, enterococci levels remained high at 178 MPN. Levels dropped to a "moderate" 64 MPN on February 26 and March 4. On March 11, levels rose to 53 MPN.

On March 18, enterococci levels were 238 MPN. After lower levels on March 21 (42 MPN), the counts rose to 64 MPN for March 25 and April 1. Enterococci levels returned to 10 MPN on April 8 and April 15.

Flow and Cyanobacteria. Cyanobacteria were reported, analyzed, and confirmed at multiple sites throughout Martin County during the period of study (Figure 8). The first confirmed location was on the north side of the estuary on February 29; while

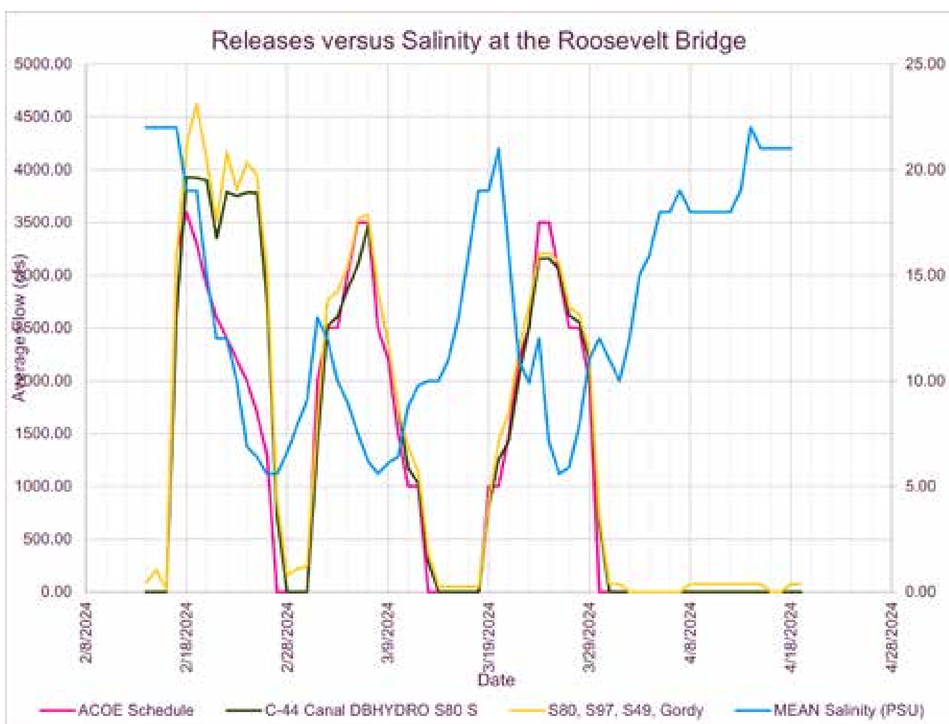


Figure 3, Flow from USACE Schedule, C-44 at S-80 per SWWMD, and combined flow from the watershed (S-80, S-97, and Gordy Road) versus mean salinity at Roosevelt Bridge.

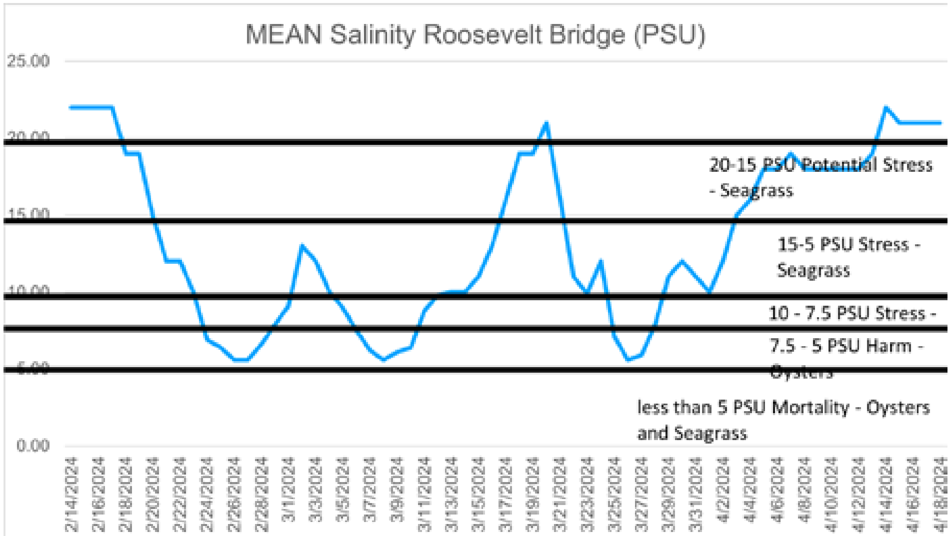


Figure 4, Mean Salinity at Roosevelt Bridge 2/14/2024 – 4/18/2024. Information on seagrass and oyster stress courtesy of Florida Oceanographic Society, personal communication *2024.*

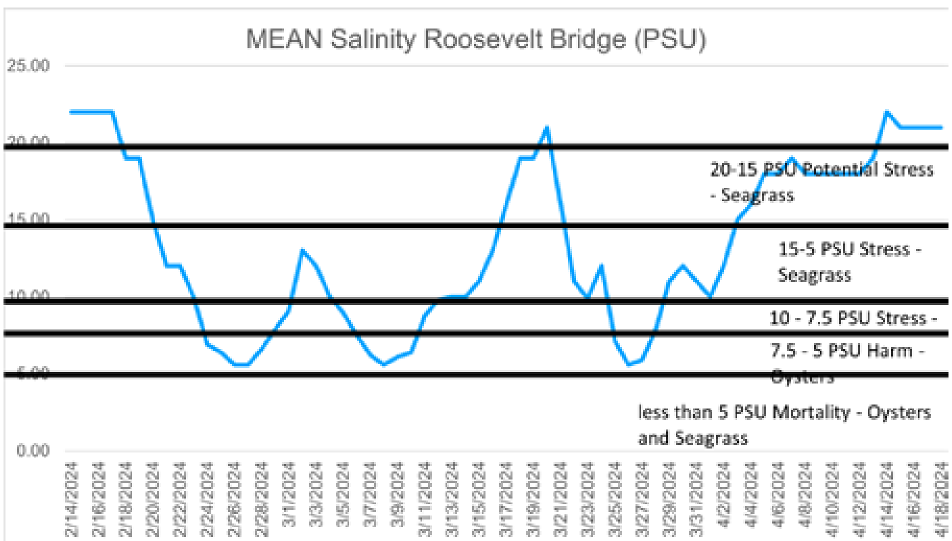


Figure 5. Mean Salinity at the St. Lucie Estuary at A1A 2/14/2024 - 4/18/2024. Information on seagrass and oyster stress courtesy of Florida Oceanographic Society, personal communication *2024.*

Microcystis aeruginosa was the dominant taxon, the toxin microcystin was not being expressed. On March 25- 28, five additional sites were found to have *Microcystis aeruginosa* as the dominant taxon, with four of them expressing microcystin. Two were below detectable limits, and two were above the EPA standard of 8 µg (11 µg and 17 µg). Between April 2 and April 9, three more sites had the presence of *Microcystis aeruginosa* confirmed as the dominant taxon, with no microcystin detected. On April 16, five more sites were reported, but only one (located at the S308 lock) had *Microcystis aeruginosa* as the dominant taxon. In total, nine sites had confirmed microcystin (Figure 9). The others were mixed species. All blue sites in Figure 8 had *M. aeruginosa* as the dominant taxon at least once during the study period.

Discussion

In comparing any of the variables against the flow data, a pattern begins to emerge. At the beginning of the dataset, the variables are at a baseline for this study. While it is necessary to keep in mind that large amounts of unseasonable rainfall and a very high lake were the reasons that flows from the lake to the St. Lucie River and Estuary and the Caloosahatchee River were necessary, it is also important to note that releases had not been made to the St. Lucie River except in small increments to equalize the head in the C-44 canal and the Lake (SFWMD).

As the ecosystem received only small amounts of lake water (which likely remained in the C-44 as it did not pass through the locks at S-80) since January of 2023 in response to Hurricane Ian, a baseline had been established. As we have no way of knowing what the conditions would have been in the river and estuary before the connection to the lake was established, we can utilize the conditions that existed before the S308 and S-80 were opened on February 17, 2024.

The variables (salinity, enterococci, and cyanobacteria) demonstrate their changes fairly quickly after the releases. Salinity near the Roosevelt Bridge began to drop about a day after releases began and fell from 22 PSU to 5.6 PSU in about 10 days. Salinity remained around that level, where seagrass is stressed and oysters are harmed, until the flows decreased. A break between February 27 and March 1 allowed for the salinity to increase to 13 PSU. A decrease back to 5.6 PSU was followed by a longer break, which allowed for an increase to 21 PSU on March 20. The final releases began on March 19 and concluded on March 29. In turn, the salinity levels fell back to 5.6 PSU on March 26 and returned to 22 PSU on April 14.

During these salinity fluctuations, the enterococci levels were also responding. Enterococci counts were measured at 10 MPN at Roosevelt Bridge on February 5 and 12t. On February 19th, bacterial counts had increased to 99 MPN and 150 MPN on February 21. During the break from flows, the levels return to 10 MPN on February 26 and March 11. On March 18, following the second round of releases, the levels are a moderate 64 MPN. They decreased to near 0 MPN on March 21st before rising to 20 MPN on March 25 during the third round of releases, and 53 on April 4. With no additional releases, enterococci levels at the Roosevelt Bridge have remained at 10

Figure 6. Sample collection locations on the St. Lucie River for enterococci by Martin County Department of Health. Roosevelt Bridge is station 1 and Leighton Park is station 3.

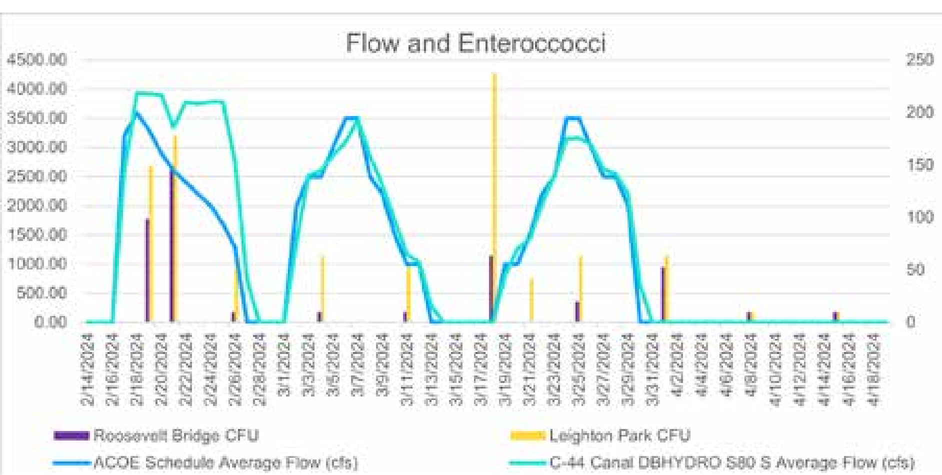


Figure 7. Flow data and resulting enterococci during the period of study.

MPN through collections on April 8th and April 15. Leighton Park followed a pattern similar to that of Roosevelt Bridge but reached its peak exceedance during the second round of releases (178 MPN on February 21 and 238 on March 18.) The third round of releases brought a moderate 64 MPN for March 25th and April 1. It has also remained at 10 MPN since April 8 at the time of this writing (4/25/24).

Reports of cyanobacteria also increased during the period of study. During 2024, it had been fairly inactive for cyanobacteria in January and early February, as would be expected under normal dry season conditions, despite the excessive rainfall that occurred to the El Niño event. There was a report of cyanobacteria at the S-308 (Port Mayaca) lock that separates Lake Okeechobee from the C-44, but there had been no occurrences in the C-44 or the St. Lucie River and Estuary. On February 26 and February 29, the first reports of possible cyanobacteria in the South Fork (near Leighton Park) and in the North Fork (by Roosevelt Bridge) were investigated. While both were found to have no dominant species and no toxins, over the next month (2/29/2024 – 3/28/2024), confirmed cyanobacteria were found in the C-44 near the S-80 and in the South Fork. Cyanobacteria persisted at these sites until April 9.

Per USACE, the releases to the St. Lucie River and Estuary resulted in 86 percent of the Total Daily Inflow to the watershed being contributed from Lake Okeechobee between January 16 and March 28th, 2004 (Figure 10). Whether analyzing salinity, enterococci, or cyanobacteria, the variables responded fairly quickly to the changing ecosystem as the lake flowed through the river and estuary; it took these variables a while to return to the levels at which they were in early February.

Conclusions

During the period of study, the St. Lucie River and Estuary ecosystem changed in response to the flows out of Lake Okeechobee. Salinity decreased, stressing oysters and seagrass; and both enterococci and cyanobacteria increased, causing a risk to human health as well as to environmental health. While the entire ecosystem from the North and South Fork,

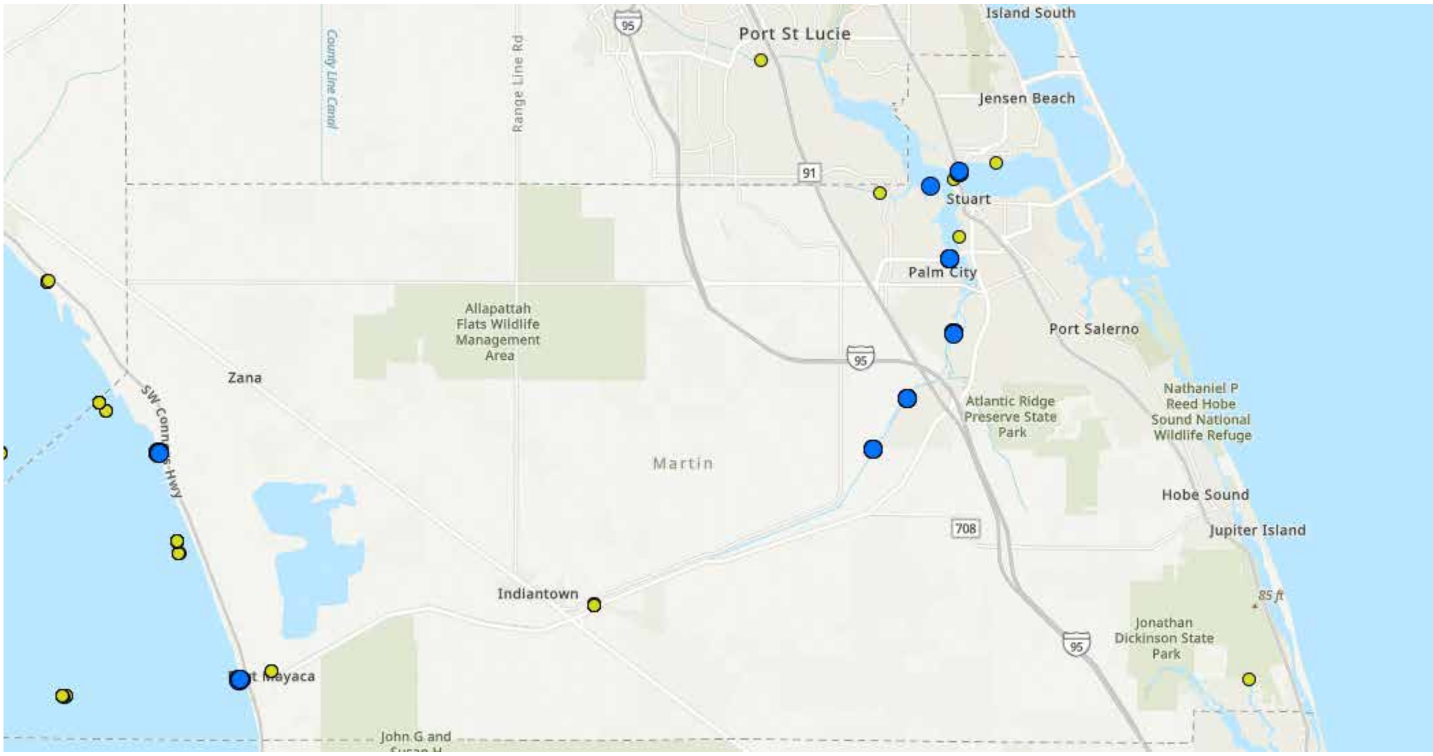


Figure 8. Location of laboratory confirmed cyanobacteria per FDEP (blue circles). Lake Okeechobee is on the left and the St. Lucie River and Estuary are on the upper right. The yellow circles indicate locations at which samples were collected, but cyanobacteria were not detected. As FDEP returns to sites to resample following the detection of cyanobacteria, the yellow circle may be the last in a series of samples, indicating that cyanobacteria had been detected in the past, but is no longer at this location.

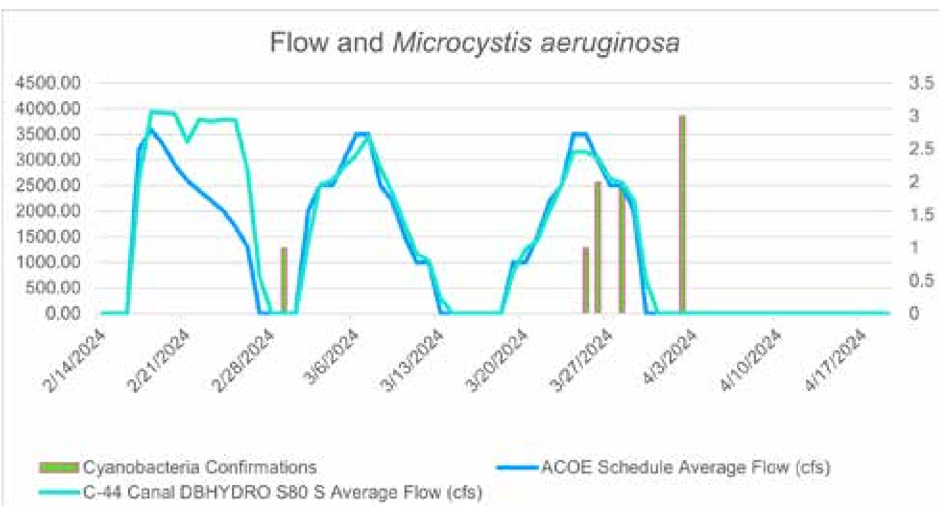


Figure 9. Flow data per USACE and SFWMD and confirmed cyanobacteria (microcystis aeruginosa) in the C-44 and the St. Lucie River and Estuary during the period of study.

all the way through the estuary to the Indian River Lagoon and the coastal zone demonstrated effects, the South Fork and the mid-estuary (near Roosevelt Bridge to Rio) demonstrated the strongest effects: the lowest salinities and the highest enterococci and cyanobacteria levels. This is likely due to the close location of these areas to the S-80, making these areas the first to receive the flow and to receive it full-force, sometimes at 3,500 CFS per day. Such a large volume of water, entering a small watershed at 1,000 – 3,500 CFS per day, can change the microbiome, nutrient balance, and other physical-chemical characteristics of the watershed. While the period of study is short, the data provided will be used to guide future work in characterizing the St. Lucie River and Estuary watershed, and in planning for resilience strategies for the ecosystems. We will continue to build upon these data through the upcoming wet season and beyond, investigating the connections among the microbiome, the nutrient balance, and the physical-chemical characteristics of the ecosystems in the watershed, and the resulting water quality.

References cited

DBHYDRO – South Florida Water Management District DBHYDRO Environmental Database. 2024. https://my.sfwmd.gov/dbhydroplsql/show_dbkey_info.main_menu

DOH – Martin County Department of Health. 2024. https://martin.floridahealth.gov/programs-and-services/environmental-health/beach-and-river-sampling/results/index.html

FDEP TMDL – Total Maximum Daily Load for Total Phosphorus, Lake Okeechobee, Florida 2001. https://floridadep.gov/sites/default/files/Lake_O_TMDL_Final.pdf

FDEP – Florida Department of Environmental Protection Algal Bloom Dashboard. 2024. https://floridadep.gov/AlgalBloom

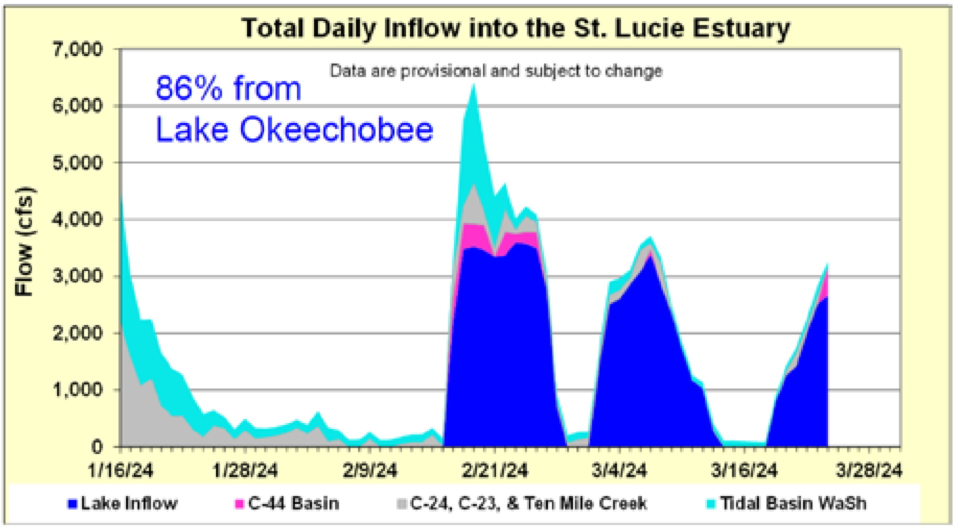


Figure 10. US Army Corps of Engineers Total Daily Inflow estimate to the St. Lucie Estuary, 1/16/24 - 3/8/24.

FOS – Florida Oceanographic Society, *personal communication*, February 2024.

LORS 08 – Central and Southern Florida Project 2008 Lake Okeechobee Regulation Schedule, 2008.

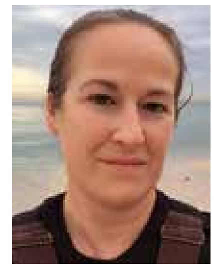
NOAA NHC – Bucci, L., L. Alaka, A. Hagen, S. Delgado and J. Beven. 2023 National Hurricane Center Tropical Cyclone Report Hurricane Ian April 2023. Retrieved April 24, 2024. https://www.nhc.noaa.gov/data/tcr/AL092022_Ian.pdf

NOAA NHC – Beven, J. and L. Alaka. National Hurricane Center Tropical Cyclone Report Hurricane Nicole March 2023. Retrieved April 24, 2024. https://www.nhc.noaa.gov/data/tcr/AL172022_Nicole.pdf

SFWMD – South Florida Water Management District. 2024. Lake Okeechobee and Water Conservation Area Daily Status. https://w3.saj.usace.army.mil/h2o/reports/StatusDaily.htm

SFWMD – Water Supply Department – Technical Documentation to Support Development of Minimum Flows for the St. Lucie River and Estuary May 2002. Retrieved April 24, 2024.

USACE – US Army Corps of Engineers, Periodic Scientists' Call meetings and presentations. February 2024-April 2024.



Elizabeth Kelly, Ph.D., PWS, is an environmental scientist at the Martin County Department of Public Works, Environmental Resource Division. She specializes in microbial ecology, soils, and hydrology. Her research focuses on water quality in freshwater, coastal, and estuarine environments, specifically involving the study of fecal indicator bacteria (FIB), cyanobacteria (blue-green algae), and nutrients.

The discovery & history of investigations into gas vacuoles & buoyancy control in cyanobacteria

Geoerge W. Knoecklein

Introduction

Cyanobacteria blooms are regularly featured in the news and many bloom watch forecasting and tracking systems and networks are now in place, with only more to follow. Tracking blooms worldwide may finally answer long-standing questions for lake managers: Are blooms becoming more frequent, longer lasting, and more intense? Blooms could be linked to climate change, with warmer weather, a longer growing season, and higher CO2 all favoring higher numbers of cyanobacteria.

Some cyanobacteria have gas vacuoles – manufactured empty places in the cell consisting of many very tiny hydrophobic cylinders constructed of long chains of nitrogen – carbon molecules. Gas vacuoles decrease the density of the cell. When present, gas vacuoles seemingly guarantee that cells will remain at or near, the surface. While scums do form, the buoyant cyanobacteria genera have an elegant mechanism to generally keep this from happening. The "light:dark cycle", as I refer to it in this article, describes how cells manipulate gas vacuole creation and destruction to maintain a specific density.

This process was discovered in the 1970s based on work initially done in the late 1890s but largely forgotten until recently. The history of the research into what gas vacuoles are, how they function, and what purpose they play is a fascinating one that weaves together years of solid laboratory and in-situ results on how cyanobacteria regulate their own buoyancy. That research will help direct future research into how cyanobacteria with gas vacuoles will respond to changes in their environment.

Historical discoveries

In the late 1800s, cyanobacteria blooms were known as flos-aquae or water blossoms. By that time, there were well documented diel migrations of cyanobacteria up and down in the water column; however, these observations were not yet linked to the organisms' ability to regulate their own buoyancy with gas vacuoles.

Membrane-bound organelles, called vacuoles, were discovered in the 1660s by Antonie van Leeuwenhoek, who conducted the first microscopic examination of living organisms. He referred to the "reflective granules" as "pseudovacuoles", with the prefix "pseudo-" used to distinguish them from the membrane vacuoles that hold fluids and other cellular materials. Klebahn later coined the term "gas vacuoles" for these structures, recognizing their unique composition and function related to buoyancy rather than storage.

Investigating pseudovacuoles in blue-green algae (cyanobacteria were referred to as blue-green algae), Hans Klebahn, a microbiologist in Germany discovered how bizarre these brightly glowing structures were. Working with *Gloeotrichia* cells collected from a surface scum on Lake Plon, magnification revealed that the glowing structures were reflective granules that appeared as gas bubbles. The initial experiments involved attempts to pop the gas bubbles inside the cells. The first experiment involved pumping air into a filled, airtight bottle containing *Gloeotrichia*, thereby increasing the internal pressure several times. This failed to "pop" the gas bubbles, leading him to conclude that they were not "bubbles" after all. He then struck the cork stopper with a hammer (*author note: maybe he was unhappy with this result, or maybe like everything else here on Earth, you have to hit it to make it work*). Klebahn reported the occurrence of three unusual changes to the algae suspension after the hammer strike. First, the algae changed in appearance from milky green to a dark translucent. Second, air bubbles collected at the top under the cork. Third, the algae sank to the bottom of the bottle.

He successfully popped the bubbles that he just concluded didn't exist. Under magnification, he found that the alga had lost the reflective granules that these cells possessed before the experiment and that other, untreated alga from the same bloom still possessed. He concluded that the shock of the hammer somehow succeeded in releasing gas from the granules when increasing the pressure in the fluid didn't. He also surmised that the volume of gas that collected at the top of the jar would be equal to what was in the granules before the strike, and that this volume of gas was what the cells required to remain buoyant, since the algae sank without these granules.

Klebahn reasoned, after numerous experiments, that the gas vacuoles were surrounded by a rigid and impermeable membrane. He believed this because ordinary bubbles disappear in a vacuum, while the cyanobacteria gas vacuole "bubbles" remain unchanged in a vacuum. His reasoning proved incorrect unfortunately, focusing attention on a dead end that persisted for over 50 years.

Cyanobacteria buoyancy in the first half of the 20th Century

The findings of Klebahn seemed to go unrecognized for many years. This is not an exhaustive search but two important early century limnology textbooks, Paul Smith Welch in 1935, and Franz Ruttner in 1953, have scant information on cyanobacteria (referred to at the time as 'blue-green algae') and neither mention gas vacuoles.

In 1941, British biologist G. E. Fogg published a critical review of the existing knowledge on what he referred to as the "variously termed gas vacuole" and the so-called "water bloom algae." Fogg concluded that, although it was generally accepted that gas vacuoles were required for cells to float, there was a contrary argument that contended benthic cyanobacteria often have these structures but are never buoyant – suggesting that the role of vacuoles in buoyancy regulation was inconclusive. He goes on to state that no experiments on the effect of external conditions of the formation of gas vacuoles had been carried out.

Basically, at the time of his writing, the gas vacuole was barely understood. G.E. Hutchinson, in *Treatise of Limnology, Volume 2: Introduction to Lake Biology and the Limnoplankton* (1957), lists the cyanobacteria that are buoyant (Table 1) and briefly considers the fraction of the cell needed for gas vacuole space necessary for the cell to become buoyant, reasoning that the empty space inside the cell decreases the cell density. He was able to show that a gas vacuole volume of 0.8 percent of the total cell volume would render the cell neutrally buoyant. He speculated that gas vacuoles function was to provide needed buoyancy to lift plankters out of the anoxic water at the bottom of the hypolimnion. He explains that the sudden appearance of cyanobacteria at the surface of lakes is due to induced gas vacuole formation in populations previously in deeper water.

Table 1. Cyanobacteria genera reported to possess gas-vacuoles by Fogg (1941) and Hutchenson (1957).

Fogg 1941	Hutchenson 1957
Anabaena	*Anabaena*
Anabaenopsis	*Anabaenopsis*
	Anacystis
Aphanizomenon	*Aphanizomenon*
Calothrix	*Calothrix*
Coelosphaerium	
Gloeotrichia	*Gloeotrichia*
	Gomphosphaeria
Lyngbya	*Lyngbya*
Microcystis	
Nostoc	*Nostoc*
Oscillatoria	*Oscillatoria*

Beginning of modern research

In 1965, 70 years after Klebahn's work was published, C.C. Bowen and T.E. Jensen investigated Klebahn's cyanobacteria gas vacuoles using electron microscopy. They found that the vacuoles were composed of many minute hollow cylindrical structures which they called vesicles. Each cylinder was 6 µm wide and at least 200 µm in length with conical end caps. These elements resembled a unit membrane, in that they appeared to be composed of two layers about 2µm wide. These were later confirmed to consist completely of tiny protein molecules with walls only one molecule thick and an hydrophobic inner surface that restricts water molecules from entering the vesicle. Cells that were subjected to sudden pressure were found to be slightly smaller in diameter than control cells. The smaller cells were found to contain, in the place of vacuoles, many short, flat, membranous elements. Cells that were subjected to this pressure treatment and then placed in a freshwater lake were found to recover some gas vacuoles after 9 hours, with extensive recovery after 24 hours. The membranes of the gas vesicles could not be preserved by fixation with potassium permanganate, a method that was typically used to preserve unit membranes, indicating that it was not a typical plasma membrane that is composed of a bilayer of phospholipids.

The Bowen and Jensen paper brought gas vacuoles to the attention of Anthony Edward Walsby who basically picked up where Klebahn had left off. Walsby was a student of G.E. Fogg who three decades earlier stated that no experimental data on the effect of external conditions on the formation of gas vacuoles had been done, began asking those questions. Walsby began publishing papers on gas vacuole research in the mid-1960s and continued until his death in 2024.

Walsby was initially intrigued by the possibility that only the inert gas argon was present inside the vacuole, believing they were rigid impermeable membranes. To solve this, he performed a series of experiments with a Warburg respirometer, which provides critical measurements of changes in gas and heat. Walsby learned five important things: (1) vacuoles are rigid structures but are permeable to any gas; (2) vacuoles are not permeable to water; (3) vacuoles are breathable structures; (4) the volume of gas in the vacuoles is measurable; and (5) vacuoles collapse only under a sudden increase in pressure – if pressure builds up slowly, the pressure in the vacuole maintains equilibrium with outside pressure.

Together, these findings created a paradigm shift from the solidly held belief through the first half of the twentieth century that the vesicle membrane is impermeable, to the reverse reality that the membrane is permeable and breathable to all gases. By the end of the 1970s, the question of what gas was inside the vacuole was no longer of any interest because any ambient gas in the cell could be present in the vacuoles (N2, O2, CO2, COH2, Ar, and CH4 were found to pass through a vesicle).

Walsby subjected cells to a range of artificially increased turgor pressures and was able to measure the necessary pressure to collapse vesicles. Turgor pressure is the internal osmotic pressure caused by diffusion of water into the cell due to increased photosynthetic metabolites. Each vesicle has a critical pressure that, if exceeded, will collapse walls. Walsby found that the pressure inside vesicles was always equal to the hydrostatic pressure on objects in the water column due to the atmosphere (ATM) – a constant 1 ATM to a depth of 10 meters. He found that the internal turgor pressure increases consistently with increasing photosynthetic rate, reaching several ATM – high enough to collapse vesicles and cause loss of buoyancy and cell sinking.

Oscillatoria was found to have the highest critical pressure of 0.9 MPa. Microcystis was also found to have strong vesicles, requiring a pressure of 0.75 MPa. Most bloom species, Anabaena, Gloeotrichia, Nostoc, and Aphanizomenon have been found to require a median critical pressure of 0.6 MPa. Walsby (1980) and Walsby and Booker (1983) proposed a buoyancy regulation model in which plankters, Oscillatoria (initially), could either maintain a distinct position in the mid-depth of a water column or move to the surface at night and early morning and descend by noon. The cycle begins when vacuoles are created in the dark, leading to buoyancy. The buoyant cells float up toward the light. The cells experiencing higher light levels photosynthesize at higher rates, creating ballast and increasing turgor pressure. At higher rates, cells replicate, causing vacuole dilution. With both increased turgor pressure and a diluted number of vesicles, the cells sink, ending the cycle.

Buoyancy regulation

The light:dark cycle suggests that cells can regulate their location in the water column by creating and destroying vacuoles. Essentially, cells moving toward the light lose buoyancy while cells moving away from light gain buoyancy, referred to here as the light:dark cycle. *Oscillatoria* has been shown to maintain itself at the most favorable depth in the thermocline (the best light) by adjusting buoyancy to fine-tune its density. The genera use orchestrated sinking when cells get too buoyant and vesicle creation when light levels diminish, returning some buoyancy. Using continuous iterations of this on a small scale allows the cells to maintain position in the thermocline. This light:dark cycle accounts for the observed diurnal migration where cyanobacteria migrate up at night and down in growing daylight. Empirical studies have shown diurnal migrations of *Oscillatoria*, *Microcystis*, *Anabaena*, *Aphanizomenon*, and *Gloeotrichia*. However, *Microcystis*, with the stronger vesicles, was found to not sink as readily as other forms under higher photosynthetic rates.

Bloom formation and climate change

The light:dark cycle describes mid-depth blooms and diurnal migrations but doesn't explain how surface blooms can be sustained in the presence of high CO_2 and high light; normally causing sinking, but they do not; instead, they form a surface scum.

It turns out there are at least three short circuits to the light:dark cycle. The first is the distance sinking cells need to go for low light conditions. Initially, this distance is probably measured in meters but increasing cell density in the surface water causes water clarity to decline, shortening the depth cells need to go to find low light. During a dense bloom cell self-shade causes adjacent cells to be in low light conditions, allowing for gas vacuole creation. The second is the ammonia supply; without ammonia, cells in low or no light conditions either don't create gas vacuoles or do so more slowly. Given high ammonia levels cells dramatically increase the rate of vesicle formation. Moreover, high ammonia also allows vesicle formation in higher light and higher CO_2 conditions, where vesicle formation would otherwise be prohibited. With high ammonia in the water column, cells can remain buoyant. A third short circuit is higher levels of phosphate in the epilimnion has been shown to allow cells to remain buoyant during high photosynthesis.

Global warming is occurring due to increased levels of CO_2 in the atmosphere causing higher CO_2 in lake water. Research into gas vacuoles and turgor pressure has shown that high CO_2 causes increased rate of photosynthesis in cyanobacteria, suggesting that as carbon dioxide in the atmosphere and hence lake water increases, the presence of cyanobacteria will also increase. Higher ammonia and/or phosphorus will assist in retaining buoyancy. The longer growing season and warmer temperatures result in a longer period of stratification, giving cyanobacteria with gas vacuoles the edge while other phytoplankton sink. Sustained warmer temperatures will allow longer periods of highest growth of cyanobacteria. Combine this with the effects of eutrophication, increased nitrogen and phosphorus, and with anoxic bottom water increasing ammonia and phosphate, both will allow cyanobacteria to remain buoyant in the surface water for longer periods of time.

George Knoecklein earned a doctorate under Peter Rich at the University of Connecticut in 1997. Prior education includes a master's degree from Michigan State University in 1981 and a two-year degree from Unity College in 1973. George is the founder and principal limnologist of Northeast Aquatic Research (NEAR), a Mansfield, Connecticut-based lake management consulting firm founded in 1997. Through NEAR, George has been studying the causes, consequences, and controls of cyanobacteria in regional lakes . His research includes interactions between cyanobacteria and aquatic plants; specifically, how invasive aquatic plants could contribute to cyanobacteria abundance.

YOU could be the winner of the 2025 NALMS Annual Photo Contest!

Two winning images will be selected, a Member's Choice winner selected by Symposium attendees and an Editors' Choice winner selected by the editor and production editor for the entry that will make the best *LakeLine* cover. Prizes will be awarded to the contest winners, and your favorite lake or reservoir photo could grace a cover of *LakeLine*!

Entries will be judged during the 2025 NALMS Symposium in Myrtle Beach, South Carolina.

How to Participate:

- You must be a NALMS member to submit an entry.
- Only electronic submissions will be accepted.
- Photos should be of sufficient resolution to print from ‘ (at least 300 dpi at 8.5" x 11"). Portrait or landscape orientation are welcome.
- A caption for the photo must be included.
- One entry per person.

Entries must be received by Friday October 17, 2025.

Email your entry to:
Amy Smagula, LakeLine Editor
LakeLine@nalms.org

(*Letter to the Editor*, *continued from p. 4 . . .)*

measurable, meaningful and durable improvements in lake condition.

The four featured articles describe various watershed and shoreline improvement projects and programs. However, the articles provide little, if any quantitative context. I have no critique of the kind of work described in this issue – minimizing turf grass, stabilizing shorelines, watershed best management practices (BMPs) and stream restoration – all are all good things. These efforts have benefits beyond watershed pollution mitigation. So, while good, we don't know if they are good enough (singly or cumulatively) in these (and most other) cases.

We have known for a quarter-century or more that watershed BMPs are not effective in reversing eutrophication (Welch and Jacoby 2001). I published an article almost a decade ago that underscored the tradeoffs of watershed versus in-lake management (Osgood 2018). Further, I published an assessment of what we can expect of BMPs with respect to the impacts of phosphorus reductions on eutrophic lakes (Osgood 2017).

NALMS has no position on watershed management.

NALMS as an organization ought to provide clear and quantitative guidance on how watershed management is helpful (or not) in improving lake quality, so we all have a better idea of how these "little things" fit into a larger management context.

Sorry, still peeved.

Dick Osgood, retired, Life Member, NALMS past-president, and past-Certified Lake Manager

References

Richard A. Osgood. 2017. Inadequacy of best management practices for restoring eutrophic lakes in the United States: guidance for policy and practice, Inland Waters, DOI:10.1080/20442041.2017.1368881.

Osgood, D. Guidance for Managing In-Lake or In-Watershed. *LakeLine* Fall 2018.

Welch, E.B. and J.M., Jacoby. 2001. On determining the principal source of phosphorus causing summer surface algal blooms in western Washington lakes. *Lake Reserv Manage.* 17:55–65.

Reply to Letter to the Editor

Thank you for your Letter to the Editor feedback on the "Watershed Work – Little Things Add Up," spring 2025 issue of *LakeLine*. The magazine is a great opportunity for all members of NALMS (and non-members) to share their work related to our freshwater resources. The issue included articles from wholly volunteer groups to professionals working in watershed management, and we thank them for their contributions.

While watershed efforts may not rehabilitate a lake alone, they can contribute to preventing or minimizing future nutrient and sediment loads to our lakes, educating watershed residents, building community engagement, and encouraging good watershed stewardship.

Further, the Letter to the Editor was shared with the NALMS Board, and board members have agreed to begin discussions of a workgroup to revisit the topic of watershed management, including a white paper and position statement in the future.

If anyone is interested in serving on a NALMS subcommittee to evaluate the subject of watershed management, and ultimately contribute to a white paper and position statement generated by NALMS, please contact the NALMS board at https://www.nalms.org/contact-us/.

Amy P. Smagula,
Lakeline Editor

NALMS Membership Form

Mailing address

Name

Company

Address

City | ST/Prov. | Postal Code

Country

Phone

Email

Billing address ❑ check if same as above

Name

Company

Address

City | ST/Prov. | Postal Code

Country

Phone

Email

I am ...

❑ ... a New Member ❑ ... a Renewing Member ❑ ... purchasing a gift

Individual

- ❑ College Student $45
- ❑ Early Career* $85
- ❑ Professional $140
- ❑ Lake Leader $75
- ❑ Emeritus** $75

*For individuals with less than 5 years in the field - the stepping stone to the Professional level!
**For individuals who are retired, over the age of sixty, and have maintained a membership for five years.

Organization

- ❑ Affiliate $330
- ❑ Lake/Watershed Association*** $165
- ❑ Non-Profit**** $330
- ❑ Corporate $650

*** For organizations with a yearly budget of under $50K
****For organizations with a yearly budget of over $50K

Do you want to help protect lakes? A donation will help ensure that NALMS' mission to foster the management and protection of lakes continues.

Eberhardt Memorial Student Fund .... $______

G. Dennis Cooke Symposium Fund .... $______

Lake Givers Club (for general donations) .... $______

Payment Information

☐ Check or money order enclosed in the amount of US$____________

☐ Charge the amount of US$ ______________ to the following credit card: ☐ VISA ☐ MasterCard | Is this a business card? ☐ Yes ☐ No

Card Number | Exp. Date | V-code*

PRINT Card Holder's Name

X____
Card Holder's Signature

**The 3-digit verification code is located on the back of your card in the signature box.*

Mail application and payment in US funds to:

NALMS, PO Box 14, Caledonia, MN 55921

Rev. 1/19

"Lakespert" –

Hear Me Out: Stop Blaming Cyanobacteria

Madeline Reilly /
Steve Lundt, CLM

Let me introduce you to our guest "Lakespert" for this summer issue of LakeLine*. Madeline lives in Vermont and is NALMS' 2025 Education, Communications, and Outreach (ECO) Intern. She'll be working on education and outreach projects and is interested in full-time work in this field. Take it away, Madeline . . . .*

~ Steve Lundt

Thanks, Steve! Over the last two years I worked as an environmental educator in the Lake Champlain Basin, which spans 8,234 square miles across parts of Vermont, New York, and Québec. During that time, I had countless conversations with the public about cyanobacteria blooms (or HABs: harmful algal blooms). For locals and tourists alike, Lake Champlain's beaches are a quintessential part of summertime in our region. Yet with warming summers and more frequent severe storms, beach closures due to HABs are becoming part of our summer routine. Smaller ponds and lakes throughout the watershed are now regularly affected by blooms, too.

In response, our region has a robust network for monitoring cyanobacteria and streamlining data into real-time maps and resources (read more in *Lakeline*'s Summer 2019 issue!). While public communications around HABs appropriately focus on mitigation and safety, many people still don't know much about cyanobacteria and why blooms form. As an educator, I'm always seeking ways to deepen public understanding of environmental issues in ways that empower people to take action. How we talk about HABs greatly impacts this understanding. As blooms affect more lakes, opportunities arise to educate people not only on how to stay safe, but how they can help prevent blooms.

When talking with people, I observed a sense of contempt toward cyanobacteria, as well as alarm over cyanotoxins. When summer plans are foiled by pea soup water and "BEACH CLOSED" signs, it's understandable why people assume the fault lies in front of them rather than in our lawns, our farms, stormwater and wastewater infrastructure, or severe storms. And when cyanobacteria are perceived as toxic nuisances, it overshadows the reality that they are native and essential members of our ecosystems. To fill in these gaps, I've thought of two ways to enrich existing messaging: (1) highlighting the ecological role of cyanobacteria; and (2) emphasizing how human behavior and landscape change are driving blooms.

#1: Let's start with a refresher on cyanobacteria – they're quite fascinating! Similar to algae in function but taxonom-

Figure 1. Microcystis aeruginosa *(bottom) and* Aphanizomenon flos-aquae *(top right) from a bloom in Barr Lake near Denver, CO (microscopic images). They're among species known to produce cyanotoxins, but let's zoom out to understand why HABs aren't really their fault.* Photo: Abbie Culbertson.

ically distinct, cyanobacteria are single-celled organisms that produce oxygen through photosynthesis (Figure 1). They're the ancestors of chloroplasts in photosynthetic plants, meaning they predate the oxygen-rich atmosphere that supports life today. Cyanobacteria belong in our waters and serve as essential building blocks of our ecosystems. Without them, life as we know it likely wouldn't exist.

#2: By changing the narrative around cyanobacteria being the primary source of "harm" in HABs, we can encourage behavioral changes that address the root causes. Yes, HABs can be toxic because certain species produce cyanotoxins. However, a fuller explanation considers that cyanobacteria are always present, and human activities create the conditions for potentially toxic blooms. For disappointed beachgoers, a HAB may be their first up-close-and-personal experience with nonpoint-source pollution; while the problem manifests on the water, the "blame" is spread out over topography and time. Here's our teaching opportunity: use what we know about cyanobacteria to explain why our actions are to blame. An informed public helps us shift from simply managing the problem to being proactive.

In fact, despite their frustration, most people I spoke with wanted to help. We know it's not a cure-all for landowners to plant vegetative buffers or reduce their use of fertilizer, but we also know that every action has an impact that can be scaled up. And we certainly have more agency than our resident cyanobacteria. While they can only respond to changing conditions, our choices on land determine those conditions.

How do we put this into practice? Organizations that monitor HABs can hold community awareness events to share the fuller story. Use newsletters and digital communications to share bite-sized information. Connect with libraries and schools. Alongside safety tips, beach signage can include the roles of cyanobacteria and our actions. Does your municipality share information in multiple languages? Recruit interpreters to translate signage and written materials, and artists to create visuals. The simplest way: talk to your lake-loving friends and neighbors! Share what you know and ask them to do the same. Now is the time to spread the word and expand our thinking to reach more people. Thanks for hearing me out.

Madeline Reilly is the 2025 NALMS Education, Communications, and Outreach (ECO) Intern. She holds a B.S. in Environmental Studies from the University of Vermont and has worked with all ages as an environmental educator focusing on the Lake Champlain watershed. As the ECO Intern, she is developing a webinar targeting the needs of early career members and supporting NALMS communications. Feel free to reach out to her at mreilly@nalms.org!

Steve Lundt, Certified Lake Manager, has monitored and worked to improve water quality at Barr Lake (Denver, Colorado) for over 20 years. Steve is active with the Colorado Lake & Reservoir Management Association and is a past Region 8 director for NALMS and an active member since 1998.