



Knowledge Gaps Update: In-lake Conditions

Background

In the late 1990's, harmful algal blooms (HABs) re-emerged as a complex problem for lakes of all sizes in the Great Lakes region. Voluntary measures to curb "nonpoint" nutrient losses from agriculture fields have accelerated, yet few concrete improvements have been made to the duration and intensity of HABs in the Great Lakes and smaller, inland lakes and rivers. This fact sheet articulates current knowledge gaps regarding in-lake conditions. A companion fact sheet (Knowledge gaps: nature-based solutions to manage runoff) considers scientific support for promising watershed management solutions.

What is known and unknown

More than **20% of the world's fresh surface water is contained within the Great Lakes basin**. More research is needed to stay ahead of changes within this ecosystem that provides drinking water to nearly 40 million people in the United States and Canada and forms the backbone of a \$9 trillion economy.

KNOWN

In the Great Lakes basin, HABs are formed by several different types of cyanobacteria (blue-green algae). The cyanobacteria are not a single species growing in a similar way; rather, the cyanobacteria are one part of a complex mix of microorganisms that scientists refer to as a "phycosphere."

Like phosphorus, nitrogen is a nutrient which plays a role in the production of algal toxins.

HABs produce toxins which impact wildlife and can kill animals, including pets, each year in the Great Lakes basin.

The Great Lakes and inland waters in the basin are warming, and long-range forecasts predict more high-intensity rainfall events and less consistent ice cover.

NOT KNOWN

It is not known how the growth and toxicity of HABs is influenced by phycosphere composition. To manage HABs, scientists must better understand differences in phycosphere composition in lakes that experience HABs and lakes that do not. The increased presence and rate of HABs across the Great Lakes basin, including in cold and nutrient-poor waters, demonstrate that additional factors can influence development. An understanding of these factors would assist in mitigation and treatment of HABs.

It is unknown how specifically nitrogen affects the formation and toxicity of HABs. To protect drinking water and public health, more research is needed to identify how certain factors impact the toxicity of HABs.

The short and long-term health effects tied to HABs are unknown, especially for long-term consumption of fish impacted by HABs. Currently, there are no state health-based guidelines for consuming fish from water affected by a HAB.¹

It is unknown what impact these changes will have on the freshwater ecosystem including HABs. HABs may also be influenced by the presence of invasive mussels, loss of winter, and changing water chemistry.

¹ Wisconsin Harmful Algal Blooms Program, guide for safe fishing practices and safe fish consumption in Wisconsin's lakes and rivers. <https://www.dhs.wisconsin.gov/publications/p03625.pdf>, accessed April 29, 2025.

What is needed

- Fund research on HAB formation and toxicity factors including the phycosphere and nitrogen effects
- Create fish consumption guidelines for HAB-affected waters and fund research on human health effects
- Establish a program for HAB monitoring inclusive of climate impacts

Current research highlights



Aphanizomenon spp. collected from a small, late-season bloom in the Duluth-Superior harbor. Photo credit Cody Sheik.

Lake Superior is considered the most “pristine” of the Great Lakes due to its lack of productivity, which stems from an extreme imbalance of excess nitrogen and limited phosphorus. Scientists believe that blooms are driven by heat² and excess nutrients; however, cyanobacterial blooms have begun appearing across the globe in waters in suboptimal temperature³. In Lake Superior, blooms have been observed for over 50 years; however, they have been short-lived and often mistaken for other⁴ natural materials in the water, like pollen. To date, blooms, primarily species of *Dolichospermum*, have been concentrated in the western arm of Lake Superior, especially near the Apostle Islands and the Duluth/Superior harbor.

The drivers of these blooms are currently unknown; however, *Dolichospermum*⁵ populations constantly

move with currents⁶ and thus, many factors must converge for a bloom to develop. Within the watershed, blooms of *Microcystis*, *Aphanizomenon*, and other *Dolichospermum* have been observed, but the extreme conditions of Lake Superior may have thus far kept species from migrating into the lake. However, Lake Superior continues to change, thermally and chemically, and it is difficult to predict the future of blooms⁷.

The University of Toledo’s solar-powered **GLAMPER (Great Lakes Atmospheric Monitoring & Protection Environmental Research unit)** is a mobile, shoreline lab that measures lake spray, aerosols, weather, and water where people live, work, and recreate. GLAMPER’s high-resolution environmental data feed directly into **GLAMR (Great Lakes Aerosol Monitoring Research)**, a multi-year community health study that follows volunteers before, during, and after bloom season. By pairing simple health checks (symptoms, lung function, and optional biosamples) with real-time environmental measurements, the team is determining when and how algal toxins become airborne,

² Paerl, H. W. & Huisman, J. Blooms Like It Hot. *Science* 320, 57–58 (2008).

³ Reinl, K. L. et al. Blooms also like it cold. *Limnology and Oceanography Letters* 8, 546–564 (2023).

⁴ Lafrancois, B. M. & Reinl, K. L. Lake Superior cyanobacterial bloom reports, 2012 - present ver 1. <https://doi.org/10.6073/pasta/89d1b199d4bdb8d82847c7f39d1018be> (2024).

⁵ Wood, A. W. et al. Spatiotemporal dynamics of cyanobacterium *Dolichospermum lemmermannii* populations in a bloom-prone region of Lake Superior. *Journal of Great Lakes Research* 51, 102455 (2025).

⁶ Wood, A. W. et al. Spatiotemporal dynamics of cyanobacterium *Dolichospermum lemmermannii* populations in a bloom-prone region of Lake Superior. *Journal of Great Lakes Research* 51, 102455 (2025).

⁷ Sheik, C. S. et al. *Dolichospermum* blooms in Lake Superior: DNA-based approach provides insight to the past, present and future of blooms. *Journal of Great Lakes Research* 48, 1191–1205 (2022).



Dr. David Kennedy (left) and Dr. Kennedy Doro (right) with GLAMPER. Photo credit Daniel Miller/ The University of Toledo.

their partners at the **NOAA Great Lakes Environmental Research Laboratory (NOAA GLERL)**, CIGLR operates a water quality monitoring program in Lake Erie that includes over a decade of water quality measurements. Weekly water quality data from western Lake Erie support HABs forecasts that inform water resource managers on the development, location, and hazards of the current bloom. CIGLR's and NOAA's monitoring work is supported by the Great Lakes Restoration Initiative. The HAB resurgence in the 1990s led to the establishment of CIGLR's and NOAA

GLERL's western Lake Erie monitoring program. This program has grown to generate real-time data, produce seasonal and near-term forecasts, create a consistent long-term dataset, and provide information for NOAA's biweekly **Lake Erie HAB Bulletin** that reaches thousands of stakeholders across Michigan and Ohio each season. These measurements help scientists better understand how nutrients, specifically phosphorus and nitrogen, influence the size, duration, and severity of HABs.

The data collected from each HAB season informs forecast models used by key Great Lakes stakeholder groups, such as drinking water managers. Effective management of Great Lakes ecosystems requires

timely and continuing predictions of ecosystem change. "Year after year, we've observed variations in western Lake Erie HABs, with consistent monitoring proving to be a critical tool in discerning these changes," said CIGLR 'Omics Research Technician Paul Den Uyl. "The water quality monitoring program in Lake Erie produces both up-to-date data, made available to the public just days after sampling, and a consistent long-term dataset. Those two aims place different requirements on the researchers and delivering on both would not be achievable without the professional science staff at CIGLR," said CIGLR Assistant Research Scientists Casey Godwin, PhD.



Photo courtesy of CIGLR, available through the 2023 edition of their annual magazine, *The Ripple Effect*.

Contact us at www.glc.org/work/habs