Great Lakes Harmful Algal Blooms: Current Knowledge Gaps

Freshwater Harmful Algal Blooms (HABs) pose serious risks throughout the world to drinking water, recreation, and ecosystem health. The Laurentian Great Lakes of North America, which contain nearly 20% of the world's available surface freshwater, have been experiencing an increase in HABs since the 1990s. Knowledge gaps relating to HABs remain even after extensive and ongoing research efforts. These knowledge gaps are presented below for the benefit of water resource managers, state, tribal, and federal agencies, legislators, and others involved in the development of policies to address HABs throughout the Great Lakes.

Background

HABs and less severe nuisance algal blooms (NABs) have significant impacts on human use and enjoyment of riverine and coastal communities. In addition to recreational impacts such as poor aesthetics and beach closures, the toxins produced by HABs impact human health, drinking water treatment, and can be a contributing factor in pet and wildlife mortality.

Algal blooms result from a combination of factors. When excessive nutrients—principally phosphorus and nitrogen—are discharged from various human activities on the landscape, they make their way to the rivers feeding our Great Lakes and cause algal blooms in rivers and coastal areas. The changing climate in the region is causing an increase in intense storm events and overall precipitation, leading to more intense and flashier flows, which introduce more nutrients into streams, rivers, and coastal areas. Higher summertime temperatures can lead to algal blooms earlier in the season for longer durations. This altered hydrology and increase in temperature also affect the mobilization of legacy phosphorus (i.e. phosphorus that has accumulated over a number of years) residing in

farm fields, ditch and stream beds, and lake sediment. These impacts from our changing climate are compounded by the effects of invasive species: profuse invasive mussels in coastal areas increase the depth light penetrates into the water column and invasive Phragmites affects the ability of native coastal wetlands to remove nutrients from the water column. These disruptions create a snowball effect leading to economic losses and societal impacts in lakeshore communities.

Common HAB Knowledge Gaps across all Great Lakes

These knowledge gaps were identified in a consensus based process by a subset of HABs Collaborative members, including both scientists and practitioners, that convened throughout 2020.

Watershed Runoff and Tributary Nutrient Loading Processes:

- Cost and effectiveness of agricultural management practices for reducing the loss of phosphorus (especially dissolved reactive phosphorus) and nitrogen at a watershed scale.
- Cumulative effects of multiple agricultural management practices for nutrients.
- Optimal location for specific types of management practices.
- Relative importance of different nutrient sources (e.g. farm field runoff, animal waste discharge, streambank erosion) on HAB formation.
- The effect of climate change on the effectiveness of management practices (e.g., relative impact of evaporation, snow cover and/or frozen soil periods, storm intensity, temperature, etc).
- Changes in soil chemistry and nutrient cycling due to changes in temperature and water availability.
- The movement of legacy nutrients (e.g., phosphorus and nitrogen in farm fields, streambanks, and streambeds) throughout a watershed.
- The fate and transport of phosphorus and nitrogen within streams.
- Cost and effectiveness of in-stream nutrient abatement practices (e.g., phosphorus filters).
- Relative importance of interannual variability in tributary nutrient loading on HAB formation.

In-Lake Processes and Bloom Development:

- Release of nutrients from sediments in small lakes, embayments, rivers, and streams.
- Relative importance of nutrient loading from tributaries versus in-lake processes on HAB formation.
- Predicting movement of HABs within a lake, from formation to algae deposition.
- The effect of changing atmospheric carbon levels on algal dynamics.
- The effect of climate on coastal and open-lake currents and water column stability.
- Refinement of remote sensing and the feasibility of the use of drones for smaller scale monitoring.
- Evaluation and optimization of existing and emerging HAB control strategies (e.g. algaecides, cyanophages, harvesters, etc.)
- Importance of phosphorus and nitrogen forms, ratios/proportions, and timing of delivery (i.e., when tributary nutrient loading occurs) on HAB formation.
- Evaluation of the ability for HABs to respond to differing nutrient concentrations and forms of nutrients.

Bloom Toxicity:

- Environmental signals or covariates that differentiate between toxic versus non-toxic HABs.
- Methods to detect a broader range of HAB toxins and related compounds.
- Evaluation of viruses that affect HABs and their potential role in releasing toxins.
- Relationship of toxicity to algal bloom size.
- Importance of phosphorus and nitrogen forms, ratios/proportions and timing of delivery on toxin formation.
- Drivers of toxin production and understanding of conditions that promote more toxic strains of cyanobacteria.
- Evaluation of benthic and epithetic (i.e. growing on other plants) algae in toxin formation and challenges for monitoring.

Negative Impacts to Humans, the Ecosystem, and the Economy:

- Effect of toxin exposure on humans through inhalation, fish consumption, and skin contact.
- The relative importance of toxicity and algal blooms size in protecting human health.
- Effect of related chemicals produced by HABs (e.g. anabaenopeptins, β-methylamino-L-alanine (BMAA), and euglenophycin) on humans.
- Impact of exposure to mixtures of multiple toxins and related chemicals on humans.
- Evaluation of toxins in fish tissue, plants, and other products consumed by humans and/or livestock.
- The effects of HABs and associated toxins on aquatic habitats and food web.
- The interaction between HABs and conditions of hypoxia in thermally stratified waterbodies.
- Secondary impacts on tourism, recreation, fishing, and whether those are disproportionately impacting people of color and socioeconomically disadvantaged communities.

HABs Knowledge Gaps by Great Lake

In addition to the general knowledge gaps across all the Great Lakes, each lake has unique knowledge gaps related to HABs. Green circles indicate known areas of HABs formation according to the 2017 report, **Harmful Algal Blooms and Hypoxia in the Great Lakes Research Plan and Action Strategy: An Interagency Report** (DOI: 10.13140/RG.2.2.33266.20167), with additional areas added by the authors based on more recent observations.

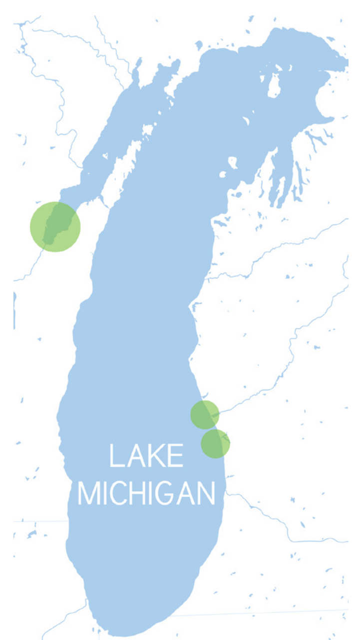
Lake Superior

Lake Superior has the lowest nutrient concentrations of all the lakes and experiences the least intense HABs, which are shorter in duration and typically appear in the nearshore western region. Knowledge gaps for Lake Superior include the following:

- Determine why HABs appear despite conditions being unfavorable (e.g. cool temperatures and lower nutrient concentrations).
- Identify the nutrient sources supporting HABs since the surrounding watershed is relatively undeveloped.
- Relationship between ice cover and HAB formation.
- Origin of seed source for localized HABs.

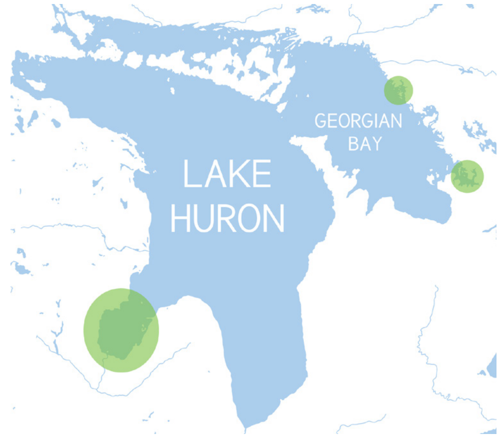
Lake Michigan

Lake Michigan experiences HABs in Green Bay at the outlet of the Fox River in Wisconsin and in other shallow embayments, such as drowned river mouths on the eastern shore. HABs occur with the highest intensity in the southern portion of Green Bay. Knowledge gaps for Lake Michigan include the following:



- Drivers of cyanobacteria toxins in Green Bay.
- Causes of variation in size, intensity, and duration of a HAB.
- Determine nutrient targets to mitigate harmful algae, while still maintaining a healthy fishery.

Lake Huron



Lake Huron experiences both HABs and benthic NABs in Saginaw Bay and the nearshore of Georgian Bay. Knowledge gaps for Lake Huron include the following:

- Drivers of nuisance organic material washing up on shores of public beaches.
- Appropriate nutrient targets that mitigate nuisance and harmful algae while maintaining a desired fishery production.

Lake St. Clair

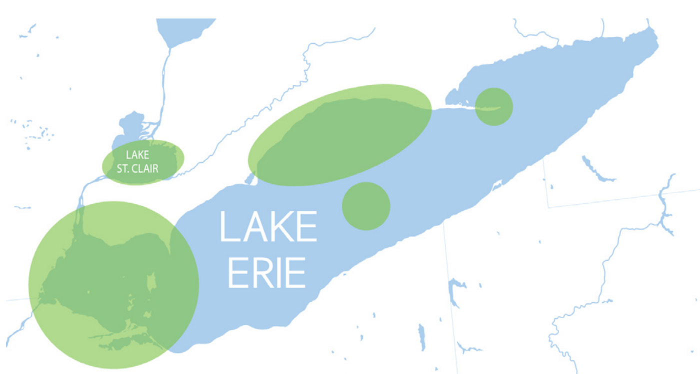
While not typically included as a Great Lake, Lake St. Clair experiences HABs each year mostly in the southern portion of the Lake off the Canadian coast and is part of the complex of connecting water moving from Lake Huron to Lake Erie. Knowledge gaps for Lake St. Clair include the following:

- Drivers of size and duration of HAB and comparison between years.
- Drivers of cyanobacteria toxins and location of those toxins within the lake.
- Determine fate of HABs and HAB toxin that are transported through the Detroit River to Lake Erie.
- Quantify nutrient loads from currently unmonitored tributaries to Lake St. Clair.

Lake Erie

Lake Erie experiences annual HABs that usually occur from July through October. The predominate HAB occurs in the western portion of the Lake, however HABs also occur elsewhere in the Lake along the north shore. HABs are also a contributing factor in hypoxic conditions in the Lake's central basin near Cleveland, Ohio. Knowledge gaps for Lake Erie include the following:

- Effect of timing of runoff events (i.e. when tributary nutrient loading occurs) and contribution of legacy phosphorus and nitrogen.
- Importance of phosphorus and nitrogen forms and ratios as drivers of HABs.
- Quantification of nutrients released from sediments and role in bloom dynamics.
- Predicting how toxic a Lake Erie bloom dominated by the cyanobacteria *Microcystis* will be and what drives toxin concentration.
- Modeling and prediction of nearshore blooms outside of the western Lake Erie basin that can impact recreation and drinking water quality (and potential linkages to western Lake Erie basin blooms).
- Prediction of Sandusky Bay bloom flushing events and their downstream impacts on Lake Erie beaches and water supplies. Sandusky Bay is the long bay at the southeast edge of the western basin of the Lake.
- The importance of benthic cyanobacteria and their toxin formation.



Lake Ontario

Lake Ontario experiences sporadic HABs in bays and harbors along the US and Canadian coast as well as nuisance algal blooms in the nearshore zone. Knowledge gaps for Lake Ontario include the following:

- Relative importance of phosphorus and nitrogen loading from tributaries versus point sources and contributions from Lake Erie.
- The role of internal loading of nutrients. Although listed in the Common Knowledge Gaps section, this is considered very important to understanding blooms occurring in bays and harbors in Lake Ontario.
- The effect of climate on currents and water column stability. Although listed in the Common Knowledge Gaps section, this is considered very important to better understand HABs in Lake Ontario.

References

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