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

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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

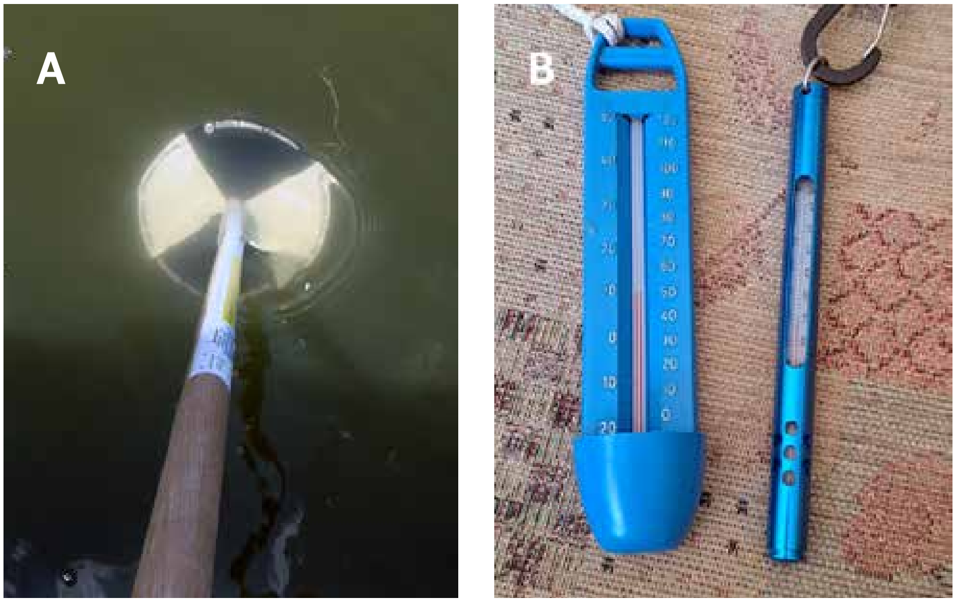


Figure 1. Simple tools available to Lake Champions on the lake: (A) A simple homemade adjustment of the well-known suspended Secchi disk. In murky hypereutrophic waters and in fast-flowing systems, a Secchi disk on a broomstick provides more detailed depths recordings than a classic Secchi disk deployed 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?

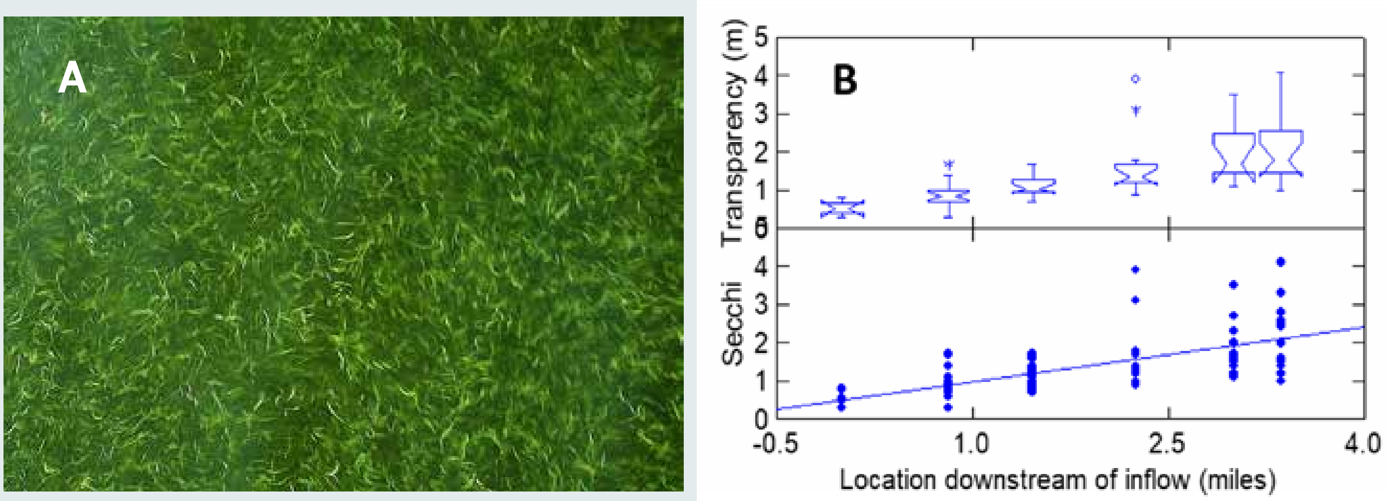
There are several known causes for the rise of cyanobacteria but increased nutrients, especially the increase of phosphorus (P), is the most important. Elevated P can originate either outside the lake (i.e., in the catchment basin or watershed, as point sources from streams fed by wastewater effluents,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

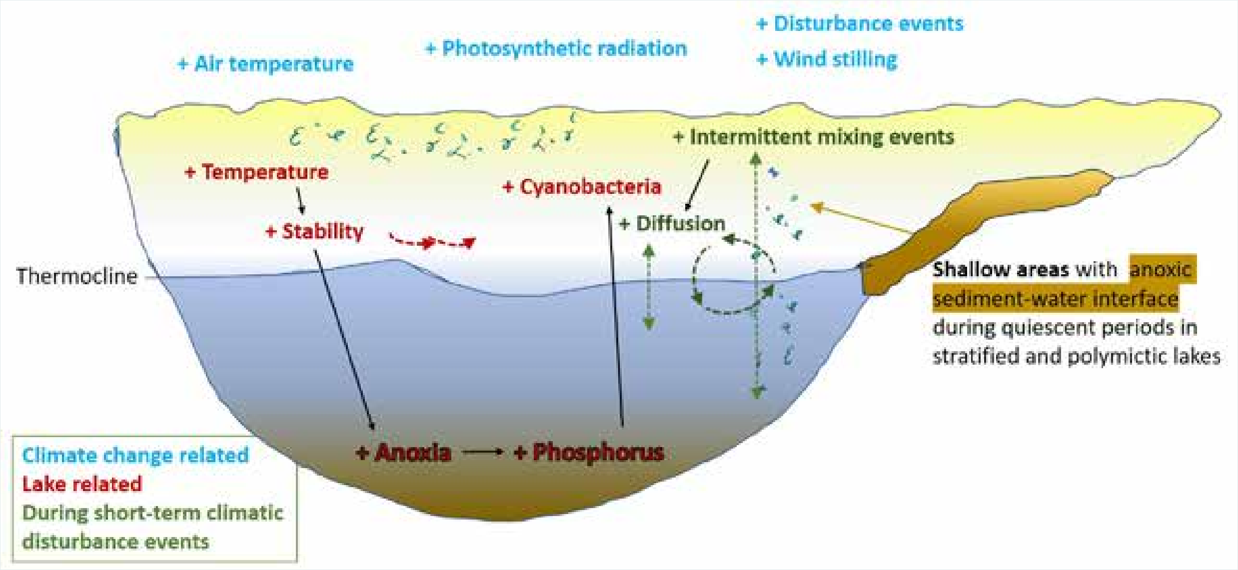
Climate change influences, easily determined

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

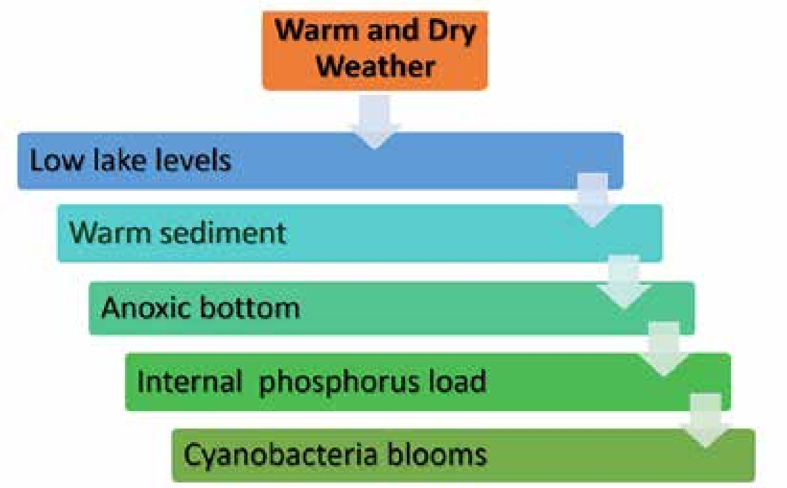


Figure 3. Schematic and generalization of changes in occasionally mixed lakes for warm and dry climate conditions.

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)

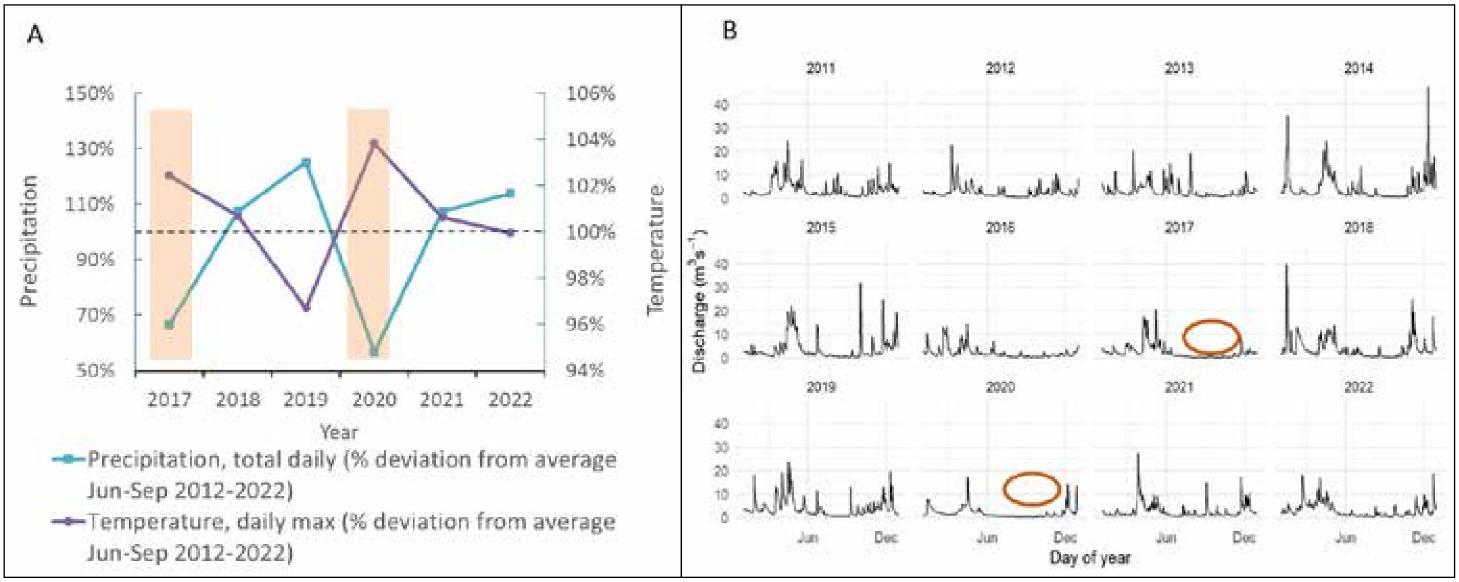


Figure 4. Cyanobacteria (orange shading) were detected (only) during warm and dry summers in an eastern Canada mesotrophic reservoir (A) when discharge was low (B, orange ovals). (Bloom monitoring started in 2017.)

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.

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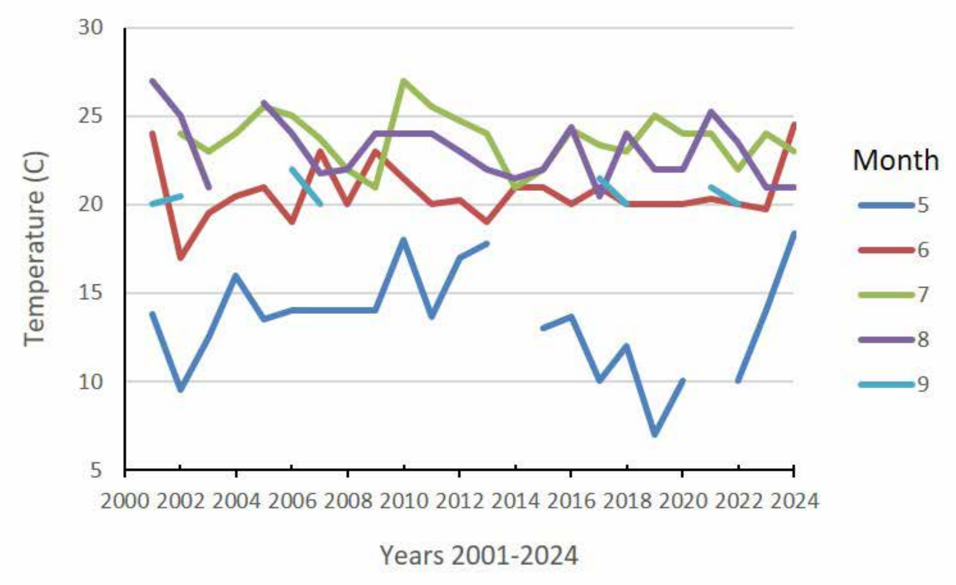

Figure 5. Nutrient-poor Grandview Lake temperature taken with a simple bath thermometer (Figure 1) averaged for months May (5) to September (9).

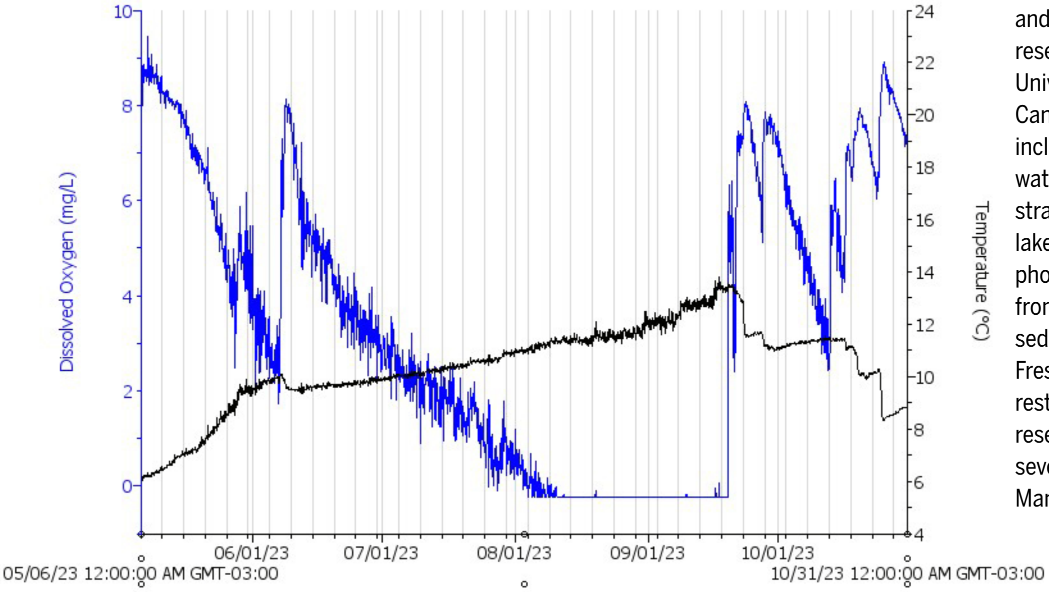

Figure 6. Temperature and dissolved oxygen 2.0 m above bottom from HOBO sensors deployed at the deep location close to the reservoir dam.

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). ✺