Magaguadavic Lake 2013-2022

Acknowledgements

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Magaguadavic Lake & Lakes Association

Magaguadavic Lake

Magaguadavic Lake is situated in the headwaters of the Magaguadavic river system. The lake drains in the southeast into the Magaguadavic river.

The lake is large but very shallow: It has an area of 26 km^2, a max depth of 11 m and a mean depth of ca 4 m. To put those numbers into some context you can compare the size of Magaguadavic with that of nine other NBALA lakes in Fig. 10. The deepest parts of the lake are found near the outlet.

The association monitors water quality at 5 stations (Fig. 1). The results in this report are based on ten years of data (2013 - 2022) from these stations.

Magaguadavic Lakes Association

The Magaguadavic Lakes Association (MLA) has been formed to:

- provide stewardship for the well-being of the ecosystem comprised of the lakes and their watershed;
- ensure the lakes' water levels are maintained in accordance with the 1978 St George Pulp and Paper Company/New Brunswick Department of the Environment agreement; and,
- ensure the lakes remain clean and healthy.

The overarching objective of the association is "*To ensure a healthy Magaguadavic Lakes ecosystem for the benefit of all users*"

For more information, visit magaguadaviclakesassociation.ca

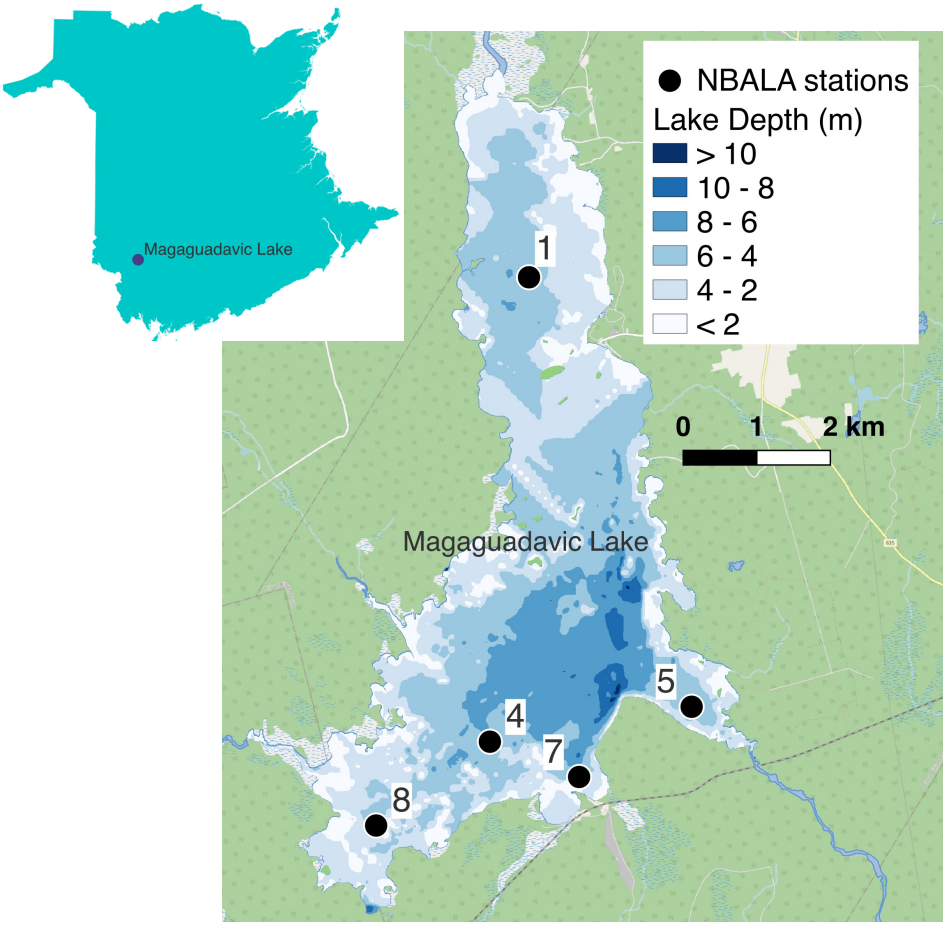


Fig. 1 Magaguadavic Lake and the location of sampling stations

Summary

What can the monitoring results tell us about the health of Magaguadavic lake?

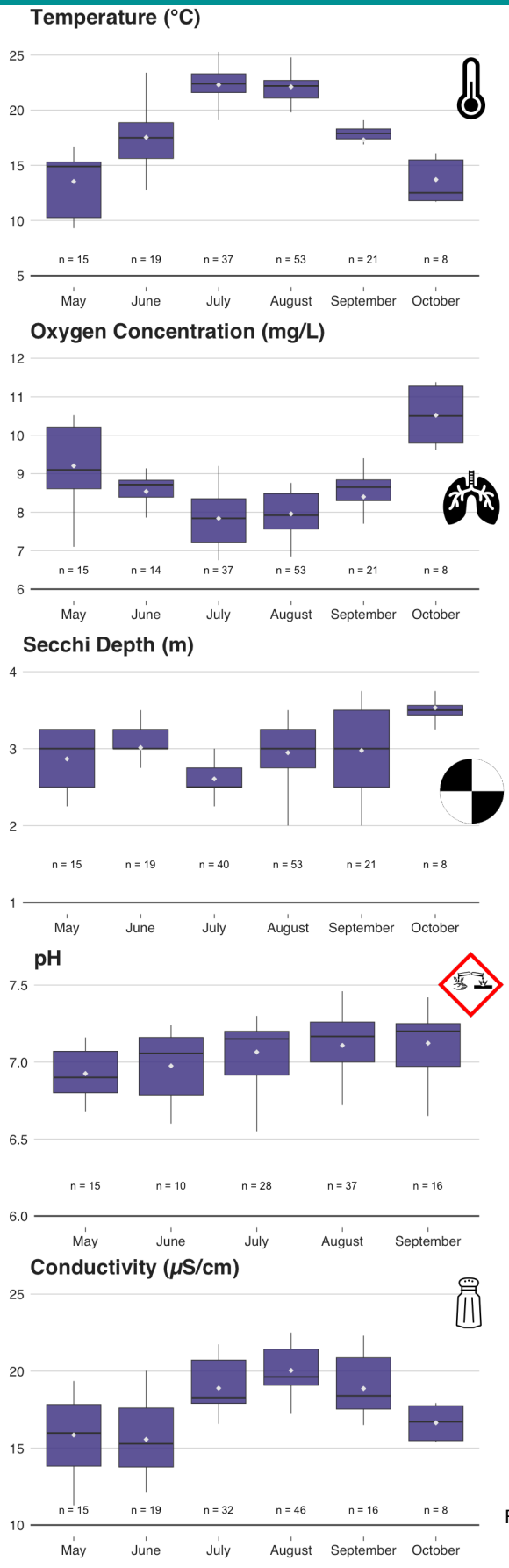
Magaguadavic Lake is large and shallow. These two factors, combined, makes it relatively easy for wind to mix the lake, preventing the formation of a stable thermal stratification.
Overall, I see no warning signs in the monitoring data. None of the parameters are “out of bounds” in relation to recommended values in the available guidelines provided by the Canadian Council of Ministers of the Environment (CCME).
Although the average oxygen concentration is the lowest of the nine NBALA lakes the concentration is fairly stable over time and never fall below levels of concern.
The one thing that stands out a little is the low transparency of the lake water. Secchi disk depth varies between two and three metres. While this does not give reason for concern, it is relatively low, and data on colour, turbidity and primary production could provide more insight.

…and what are they not telling us?

To really be able to see if there are any problems in the lake a wider suite of parameters would have to be investigated. For example, it would be pertinent to investigate concentrations of metals, commonly found toxic substances, and the nutrient status of the lake. Going one step further, the monitoring of plants and animals can show if human activities have significant effects on the inhabitants of the lake.

However, as stated above, it is possible to draw some conclusions from from the existing data, and the work done by the MLA can also give clues about what kind of monitoring efforts we might learn even more from in the future.
The MLA started monitoring of the lake a decade ago. Even with a modest number of parameters this means that the time-series in Magaguadavic Lake soon are long enough to start picking up on potential long-term trends of large-scale processes such as climate change.
Keep up the good work!

Seasonality in Magaguadavic Lake



The figures on the left show data from all stations and years grouped by month. The purpose with this presentation is to give an idea of how the monitored parameters vary over the growth season of plants animals in the lake, and what "normal" values look like in Magaguadavic Lake.

The parameters that fluctuate the most over the season in Magaguadavic Lake are conductivity, temperature, and oxygen.
Both conductivity and temperature increase from spring through summer and decrease again in fall. Oxygen shows an opposite pattern, as temperature increases, oxygen concentration decreases.
The pH is near neutral throughout the sampling season and Secchi disk readings stay at around three meter, but with some variation between stations or years.

What are those boxes in figure 2? -and what are they telling me?

In stead of just showing the average of each parameter for each month, I chose to present the data in a so-called "box plot". The strength of these are that they not only show an average value, but they also give you an idea of the variation around this value. The purpose of this is to give you a data-driven idea of what "normal" looks like in your lake!

To put it in terms that are in no way scientific but may be a useful rule of thumb: if during future years you find, for example, temperatures that fall above the box region for that month, you could refer to that as a "warmer than normal month". And if the temperature falls outside of the whisker region, it is fair to say that it is "extremely" or "unusually" warm or cold!

To learn more about how to interpret the boxplots, check out the glossary at the end of this report.

Fig. 2 Seasonal pattern of the investigated parameters in Magaguadavic lake

Stratification

Warm water is lighter than cold water.

During summer, the sun warms the surface of the lake. In lakes that are deep enough the lighter warm water forms a layer (epilimnion), separated from the cold, heavy water near the bottom (hypolimnion). Between these layers there is a transition zone where the temperature shifts drastically, the ”metalimnion”.
At what depth this metalimnion separates the two zones depends on how clear the lake is and the amount of wind mixing the water in the lake.

Why is this important?

A stratification acts as a barrier, so there is almost no transfer of nutrients and gasses, like oxygen, between the two layers. This means that the lake now has two habitats with very different temperature and potentially different chemistry.
The presence of cool bottom waters can be advantageous to cold water species. However, In nutrient rich lakes, oxygen can be depleted at depth due to decomposition processes.

Because no stratification was found in the data from Magaguadavic Lake, data from all depths are combined throughout this report.

Magaguadavic Lake does not stratify

Magaguadavic Lake is large and quite shallow, which means that it is easy for wind to mix the waters within, and the lake does not seem to establish a stable thermal stratification during summer.
In May, temperature is still relatively cool and oxygen levels indicate a slight undersaturation. (see the chapter on oxygen for more details on the relation between temperature and oxygen). By August, the temperature has increased but even if temperatures during warm days can get a bit warmer towards the surface wind mixing seems to prevent the formation of a proper thermocline. The fact that oxygen concentration does not decrease with the warmer temperature suggests that there is enough photosynthesis going on in the lake to bolster oxygen concentrations. In October temperatures are much lower and oxygen dissolves more readily from the air.

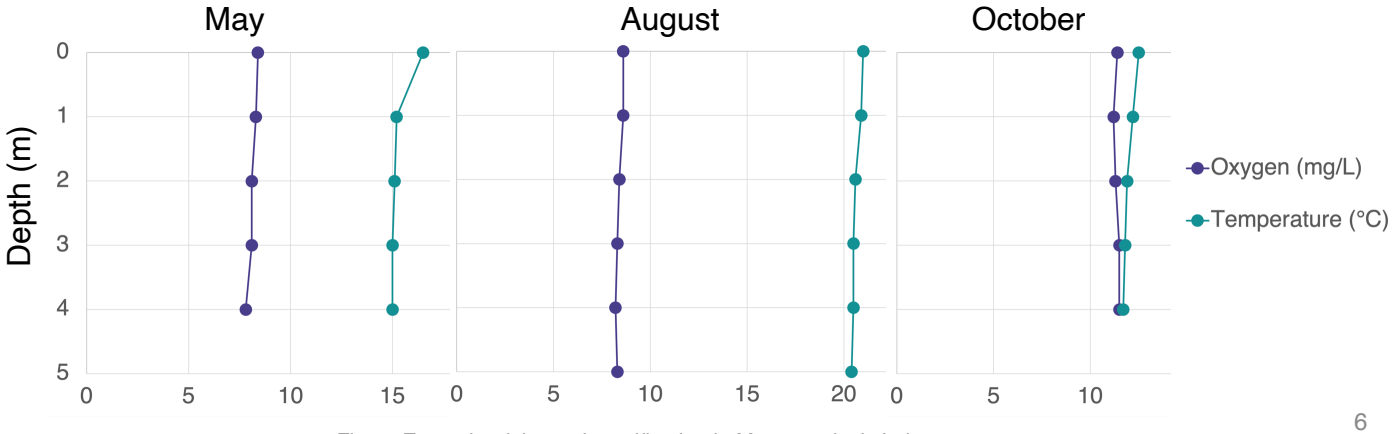


Fig .3. Example of thermal stratification in Magaguadavic Lake

Temperature

Temperature affects biological activity in a multitude of ways.

It influences for example, rates of chemical reactions and how well oxygen dissolves in water. Temperature also directly influence growth, respiration and even the behaviour of lake organisms. All plants and animals have a range of optimal temperatures in which they thrive. Cold water fish like salmonids are stressed already at 20 °C and when temperatures reach 23-25 °C prolonged exposure may lead to deaths. Fish like yellow perch also struggle in warm water while other species, like smallmouth bass do well at 25 °C. Another risk at higher temperatures is that some common harmful bloom-forming cyanobacteria like members of the genus Microcystis have optimum growth at temperatures over 25 °C.

Temperature in Magaguadavic Lake

Temperatures in Magaguadavic Lake hardly ever rise to levels that present any risks, except maybe for some cold-water species.

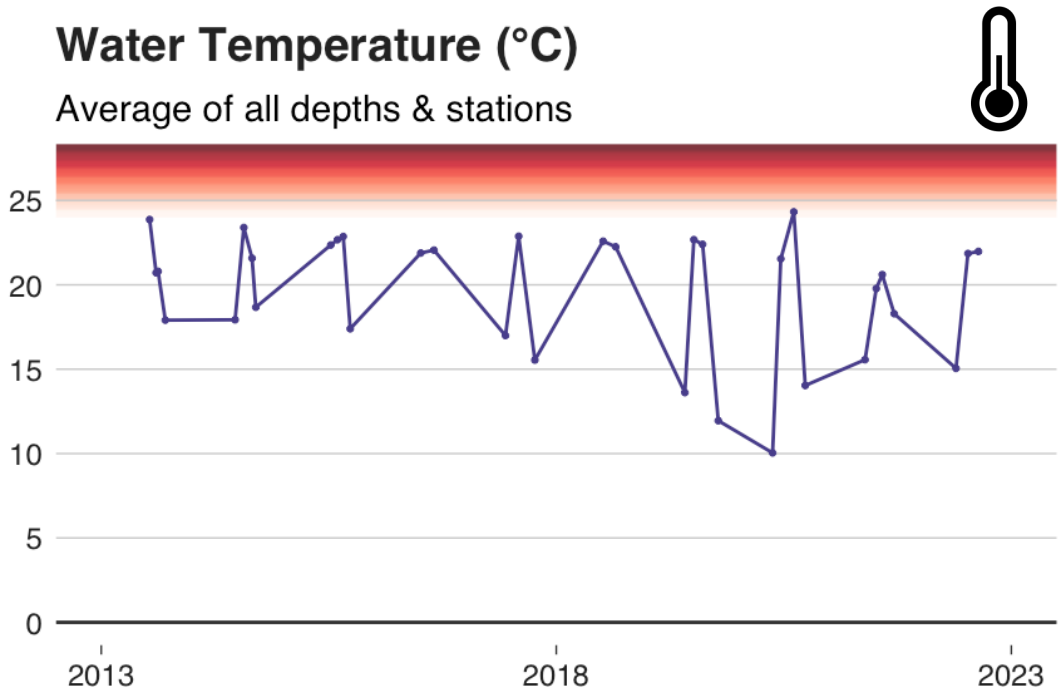


Fig. 4 Water temperature in Magaguadavic lake. The red gradient signifies increased risks associated with higher temperatures. No CCME guidelines are available.

Oxygen

Most organisms need oxygen to survive!

Even plants that produce oxygen need it during nights for respiration. Some species are more sensitive than others, and certain animals are adapted to life in environments with almost no oxygen.
Oxygen in the air dissolves in the water of a lake. How much oxygen that can be dissolved is influenced by the temperature of the water and the salinity. Colder water can hold more oxygen and salty water holds less. Oxygen can also be produced and consumed within the lake. For example, oxygen is produced by plants, algae and cyanobacteria in the lake, and it's consumed by respiration by animals and microorganisms.

Dissolved Oxygen in Magaguadavic Lake

The concentrations of dissolved oxygen (hereafter referred to as oxygen) registered in Magaguadavic Lake are rarely very high but also never low enough to give reason for concern. Oxygen concentration is never found to fall below CCME guidelines (Fig 5).
The shallow waters of the lake receive oxygen from the air and from photosynthesis by plants and algae in the water and the water is mixed by wind throughout the ice-free season.
It is interesting to note that even though the average concentration of oxygen is the lowest among the nine NBALA there is no reason for concern here whereas some of the lakes with a higher average have a higher variation over time and sometimes fall under the guideline values. This is a good example of how average values don't always tell the entire story.

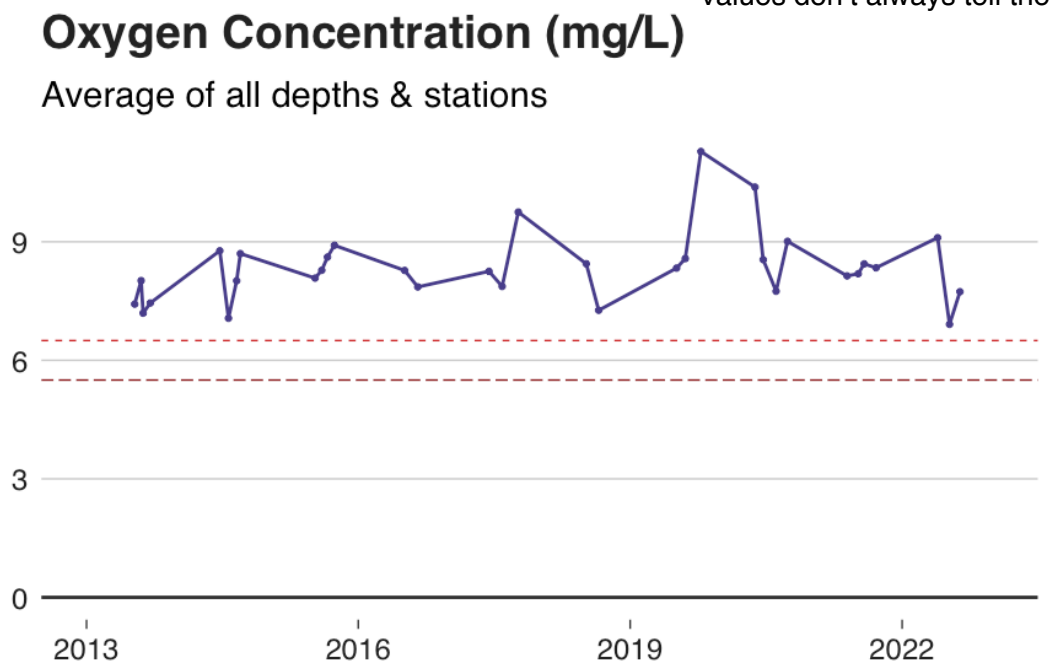


Fig .5 Dashed lines in the figure indicate lowest acceptable concentrations of oxygen for cold- (6.5 mg/L) and warm (5.5 mg/L) water species (CCME). Eggs and young individuals are generally even more sensitive.

Light (Secchi depth)

What does Secchi depth tell us about a lake?

Measuring secchi disk depth is an easy way to get an estimate of the light climate in a lake. Light is important because it is the source of energy for the plants and algae that make up the foundation of a lake ecosystem. It is also the primary source of heat in a lake. Lakes with many particles, algal blooms or high concentrations of humic matter washed in from the surrounding watershed all have reduced light conditions. The Secchi disk depth will not tell you the reasons for light attenuation but gives an estimate of how deep light penetrates. Generally, photosynthesis is found down to roughly 2-3 times the secchi depth.

Secchi readings in Magaguadavic Lake

There is no CCME guideline for aquatic life for Secchi disk depth, but Health Canada's guidelines for Canadian recreational water quality suggest that Secchi depth should be more than 1.2 metres in waters used for recreation.

Magaguadavic Lake Secchi readings are relatively low but never below the health guideline for recreational water. Data on turbidity/suspended solids, phytoplankton and water colour would be needed to say more about contributing factors restricting light in the lake.

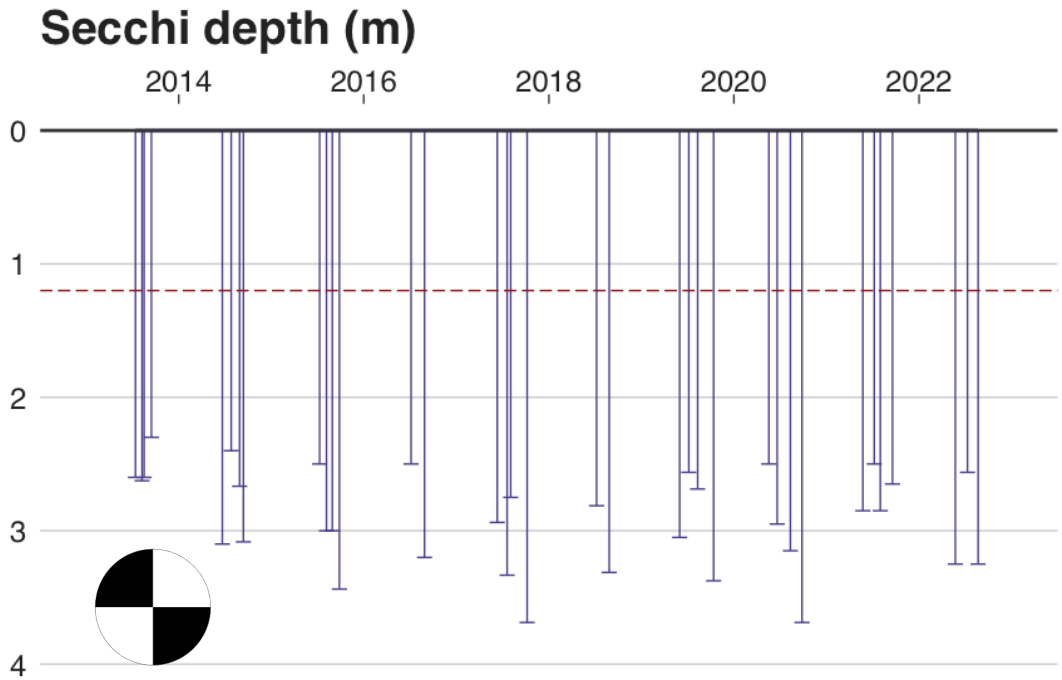


Fig. 6. Secchi depth in Magaguadavic Lake. Hatched line indicate level of concern according to CCME guidelines for recreational waters.

pH

Acidity, or alkalinity, is measured on the pH scale.

The lower the pH, the more acidic it is. The pH is a logarithmic scale so for every step in the scale, there is a tenfold difference. This means that pH 4 is 10 times more acidic than pH 5, and a 100 times more acidic than pH 6! If the pH is too high, or too low it has detrimental effects on lake plants and animals.
High pH can damage fish skin, eyes and gills of fish and increase the toxicity of ammonia. Acidification below pH 6 can directly harm organisms and lead to increased levels of dissolved aluminum & increased aluminum toxicity to fish.

pH in Magaguadavic Lake

The pH stays close to neutral during the entire period, with some fluctuation around pH 7. Values stay within the maximum and minimum recommended values according to CCME guidelines and I see no reason for concern with regards to pH in Magaguadavic Lake.

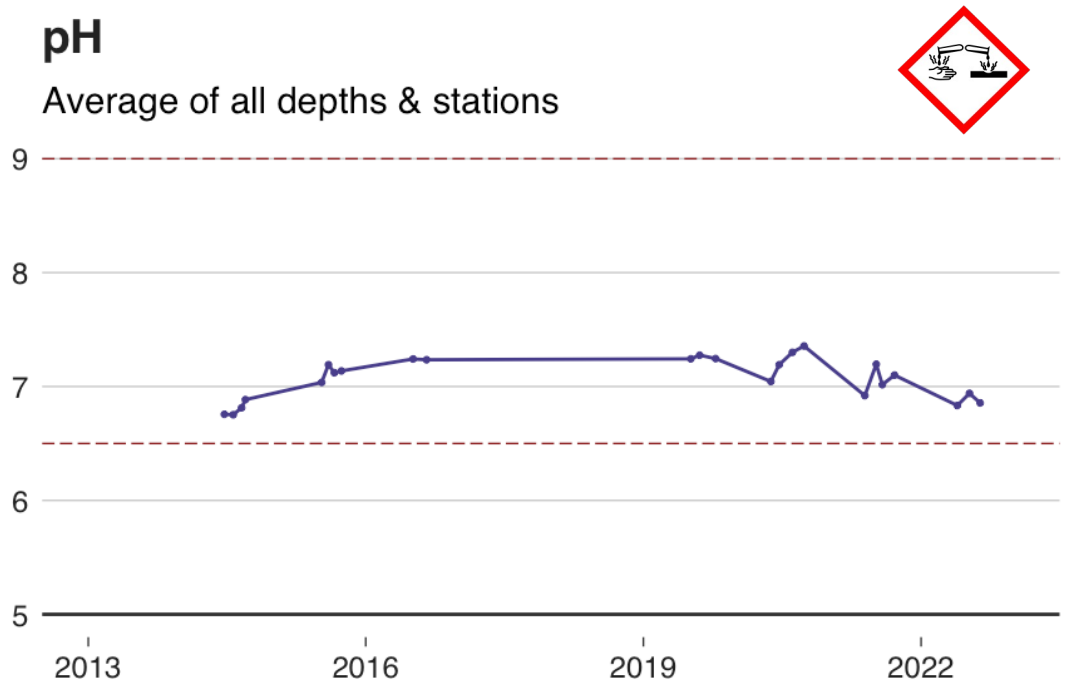


Fig. 7. pH in Magaguadavic Lake. Hatched lines indicate upper (pH 9) and lower (pH 6.5) levels of concern according to CCME guidelines.

Conductivity

Conductivity is an estimate of the total concentration of dissolved salts in a lake.

Conductivity is estimated by testing how well the water can conduct an electrical current. Higher concentrations of dissolved salts (ions) passes more electrical current. Elevated conductivity could indicate contaminated runoff. For example, runoff containing road salts can increase the salinity to levels where it is harmful for aquatic life.

Conductivity in Magaguadavic Lake

Conductivity in Magaguadavic Lake was among the lowest observed among the NBALA lakes, in the lower part of the range of background levels.

There are no CCME guidelines for conductivity and without knowing historical levels, it is impossible say if the conductivity in Magaguadavic Lake is elevated from natural conditions, but with such low values it seems unlikely, and I see no reason for concern in regard to conductivity.

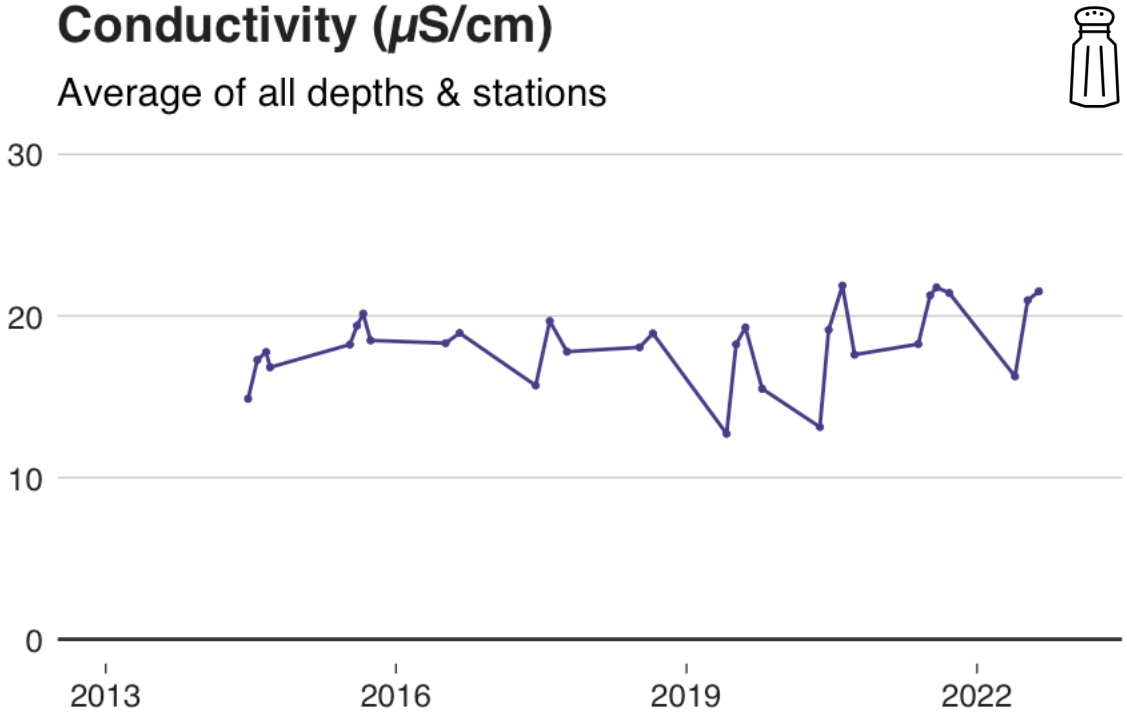
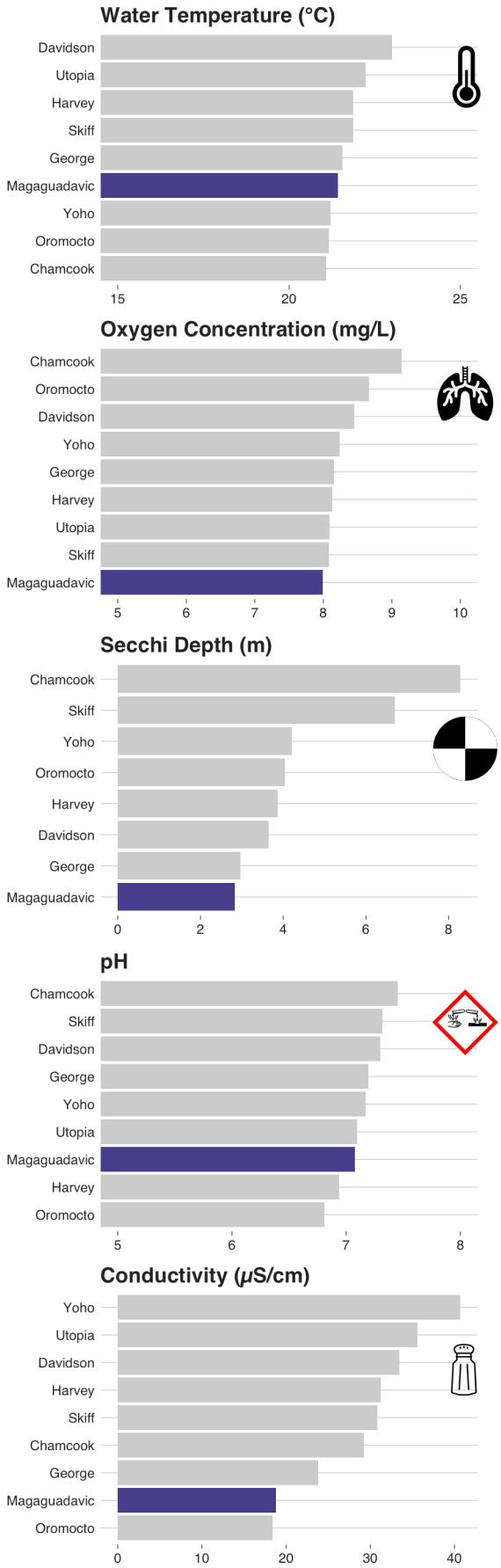


Fig. 8. Conductivity in Magaguadavic Lake from 2013 to 2022. No CCME guidelines are available.

A comparison of NBALA lakes



Is this a lot? …or little?

Most of us check the weather each day and have a reference system in our heads for what is considered a warm or a cold day. But very few spend every day looking at water chemistry data and thus have a hard time conjuring any sense of proportion when faced with a conductivity value.

This page is here to give some reference. As with many other things, what is considered extreme depends on what you compare with! Here I present the overall averages of the parameters monitored in the nine NBALA lakes analyzed in this project[1]. These lakes may not be representative for the full range found in New Brunswick lakes, but they will give you an idea of what you can expect in this part of the country and how your lake compares to the other NBALA lakes.

Magaguadavic is one of the larger of the NBALA lakes but also one of the shallowest. Oxygen is on average the lowest among the lakes, but not a reason for concern. The secchi disk depth is also the smallest among the lakes and it would be interesting to see what causes light attenuation in the lake.

[1]Average of values from depths above stratification for all data found within the period 2013-2022.

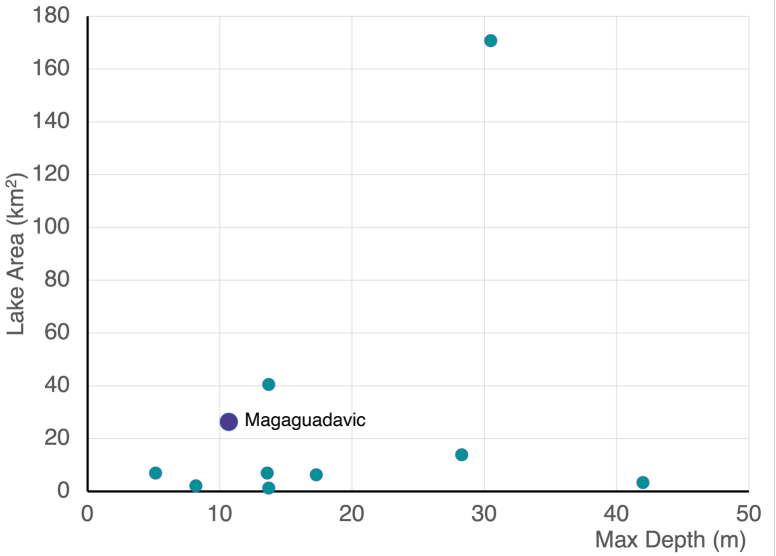


Fig. 10. The surface area and maximum depth of ten NBALA lakes. Magaguadavic lake is highlighted.

Fig. 9. Comparison between nine NBALA lakes for all investigated parameters.

Monitoring Strategies

Nature is in constant flux.

An ever-present question in all monitoring programs is whether to spend money and time on monitoring more often or to monitor more stations but not as frequently. There is no fits-all-sizes answer to this question. It depends on what parameter you are monitoring, in which ecosystem, and what the purpose of the program is.

Monitoring programs need to take into account that the lake environment changes. It changes from day to night, between days due to e.g., weather, between months due to seasonal changes and so on. The organisms living in the open water are also important in shaping the lake chemistry. Most of these are short-lived, fast growing, and abundances can change quickly.
When we monitor lakes, we take snapshots in time and space, hoping that samples will give us a good estimation of what's really going on.

Monitoring results vary both between places in the lake (spatial variation), and over time in the same place (temporal variation). These two sources of variation may not be equally important. The two extremes would be that if there is no variation in space (everything is exactly the same in all parts of the lake), it makes no sense to monitor several locations. Or, if there is no change over time, it makes no sense to monitor more often.

Which brings me back to the initial question. If the MLA wants to improve upon their estimates, Is it possible to give advice on whether they should sample more often or in more places?

Monitoring in Magaguadavic Lake

The MLA monitors five stations in the lake which have been visited around two times per year over the ten-year period. Enough data was found for two parameter to give some tentative suggestions about future efforts.
I made a preliminary analysis of spatial and temporal variation found in the MLA monitoring results. For each parameter I calculated the spatial and temporal variation expressed as the coefficient of variation (CV), see the glossary page for a brief explanation of methods.

The main conclusion is that for the two investigated parameters the data vary much more between dates than it does between stations (Fig. 11). This indicates that getting better coverage by sampling more often may give better estimates, or that maybe not all stations need to be sampled.
This is just a preliminary analysis. I would recommend a more careful look at the data and to consider what is practical for the volunteers before moving forward.

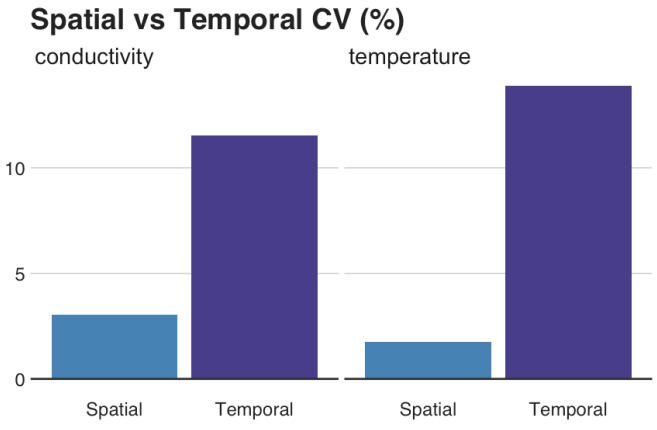


Fig. 11. Comparison of the relative variation between stations at any given date and the variation between dates for any given station.

Glossary

Catchment (area) the region around the lake that drains into the lake. (almost) Synonymous to watershed.
Coefficient of Variation is calculated by dividing the standard deviation by the mean. This gives a "relative" standard deviation that allows you to compare variation between parameters that have different units and ranges. It is often expressed as a percentage of the mean.
Epilimnion the warm, wind-mixed layer above the thermocline during thermal stratification..
Hypolimnion the layer of cooler water found under the thermocline during thermal stratification.
Metalimnion the layer between the epilimnion and hypolimnion where a rapid change in temperature is found with increasing depth.
Primary production the conversion of sun energy and carbon dioxide into organic compounds by plants, algae and cyanobacteria.
Standard Deviation is a measure of how large the variation is around a mean. A low standard deviation means that most data are close to the mean whereas a high standard deviation means that there is more spread out.
Thermocline synonym with metalimnion, sometimes referring to the depth where the maximum rate of change in temperature occurs.

Method description: analysis of spatial and temporal variation

I estimated the spatial variation by calculating the CV between stations for each date. I estimated the spatial variation per station by calculating the CV between dates within the period June-August. I then averaged both measures.
I limited the analysis to data data from years where at least three stations were visited at least three times (a bare minimum required to get an estimate of the standard deviation).
I also limited the analysis to data from the epilimnion because some NBALA lakes do not stratify, and the ones who do, typically only have data from the hypolimnion at one or two stations which is not enough. Finally, I excluded the secchi depth, because in many lakes it can not be measured properly at all stations, and there was not time to properly quality-control all secchi data.