Yoho Lake
2013-2022

Acknowledgements

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Yoho Lake & Yoho Lake Association

Yoho Lake

Yoho Lake is situated in the northwest part of the Oromocto River sub-catchment of the Wolastoq/St John River. It drains into the North Branch of the Oromocto river via Yoho stream.

It is a small and shallow lake: It has an area of 1.3 km^2, a max depth of ca 14 m and a mean depth of ca 6 m. To put those numbers into some context you can compare the size of Yoho with that of nine other NBALA lakes in Fig. 10.

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

Yoho Lake Association

The Yoho Lake Association (YLA) was founded in 1991 and has many goals, a few of which are:

- Protect the local environment and safeguard quality of life around the lake
- Provide an avenue for discussing common issues
- Act as an organized voice when dealing with government and other agencies
- Inform our community about environmental and other matters

For more information, visit yoholake.ca

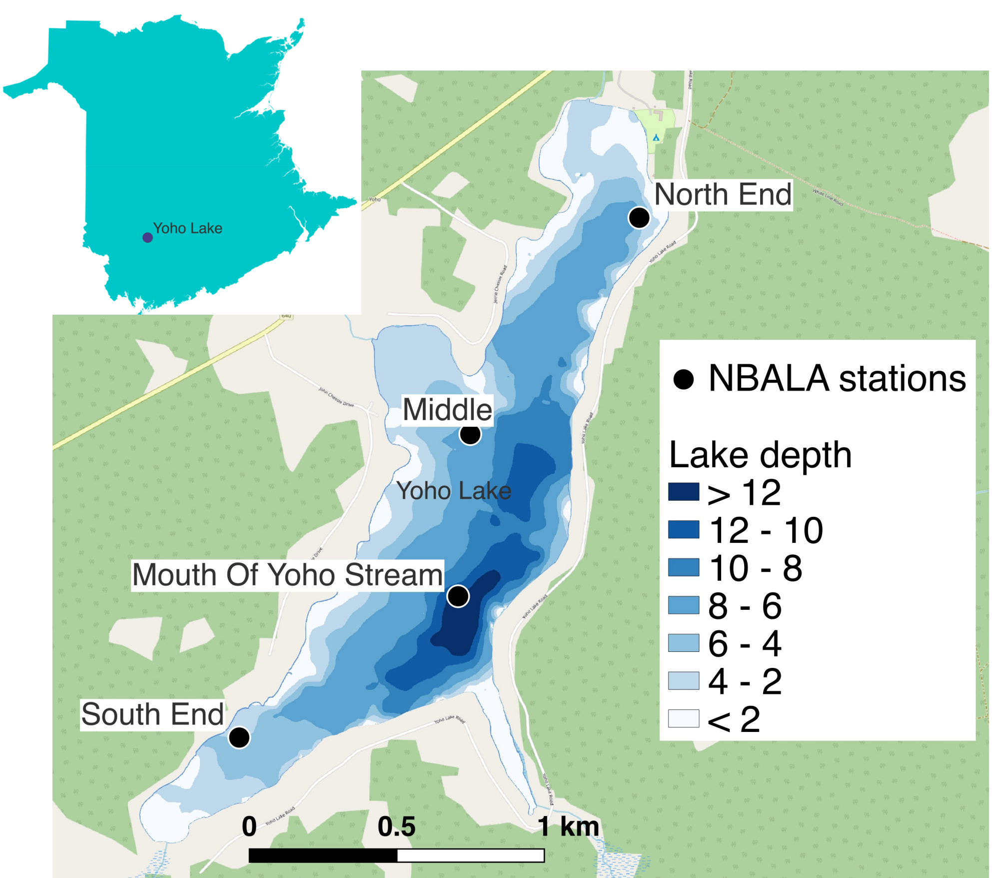


Fig. 1 Yoho Lake and the location of the YLA sampling stations

Summary

What can the monitoring results tell us about the health of Yoho Lake?

Yoho Lake is small, and even if though is not very deep a thermal stratification develops every summer. The lake is then divided into a warmer upper layer and a cooler layer, below the thermal stratification. Most years this deeper layer, the hypolimnion, is found at depths exceeding ten metres. Only a small part of the lake is that deep which means that most of the lake is made up of the warmer shallower waters.

In the shallow parts of the lake, none of the investigated parameters give reason for concern and rarely exceed available guidelines provided by the Canadian Council of Ministers of the Environment (CCME). Temperatures are not extreme but could at times possibly be stressful for cold-water species of fish. Conductivity data suggest a possible increasing trend of salinity in the lake and although levels are well within the range of background levels, the association may want to keep tabs on future development.

Below the thermocline, the oxygen and pH levels both fall under the levels of concern found in CCME guidelines and create an environment that is unsuitable for many species. For both parameters, the decline is likely caused by respiration and decomposition processes. When such processes are able to almost completely deplete oxygen levels, as is the case in Yoho Lake, this can be an indication of nutrient pollution. As a first step in figuring out more about what's going on, I would suggest to check to see if the provincial government has nutrient and phytoplankton production data.

…and what are they not telling us?

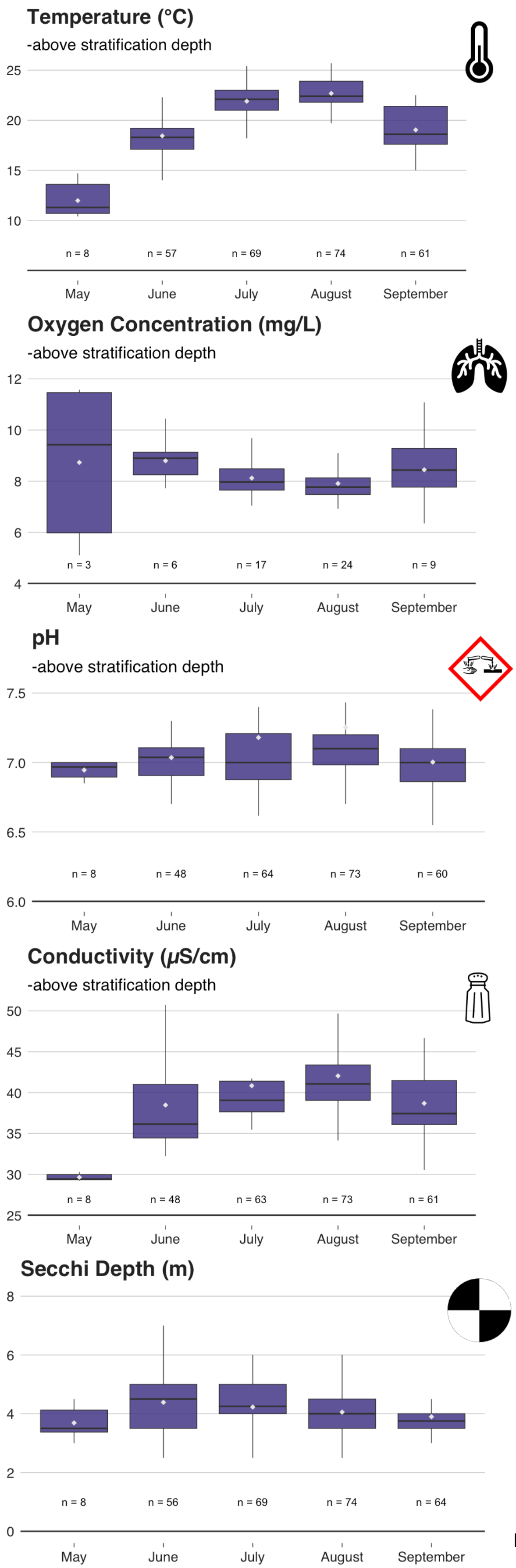
To really be able to see if there are any problems in the lake a wider suite of parameters would have to be investigated. For example, it would be pertinent to investigate concentrations of metals, commonly found toxic substances, and the nutrient status of the lake. Going one step further, the monitoring 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 YLA can also give clues about what kind of monitoring efforts we might learn even more from in the future.

Finally, it is noteworthy that the YLA has now monitored the lake for over a decade. Even with a modest number of parameters this means that the time-series in Yoho Lake soon are long enough to start picking up on long-term trends of large-scale processes such as climate change.

Keep up the good work!

Seasonality in Yoho 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 Yoho Lake.
To avoid variation caused by the presence or absence of a thermal stratification, only data from the top five metres of the lake was combined per station and date before averaging per month.

The parameters that fluctuate the most over the season in Yoho Lake are temperature and oxygen and they show opposite patterns: as temperature increases, oxygen concentration decreases.
Both pH and conductivity increase a bit over the course of the summer and then decline again in September, but the changes are not big enough to be of great importance to plants and animals.
Secchi readings are the highest in early summer and variation is highest in June which may be caused by differences in how warm spring has been in any given year.

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 patterns of the investigated parameters in Yoho 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.

To account for variation caused by stratification, the sampling data in this report are often divided into shallow water (0-5 metres depth) and deep water (more than 10 metres depth).

Example of stratification in Yoho Lake

The series of graphs below depict a typical year in Lake Yoho, (all data except May are from a single year). Beginning in late spring (May), temperature is still cool and the water oxygen rich (see the chapter on oxygen for more details on the relation between temperature and oxygen).
In June, the temperature is increasing in the upper part of the lake, and it becomes hard for wind to mix the entire lake. A thermal stratification has been created.
As summer progresses, the temperature in the upper layer continues to increase while the temperature below stays almost the same leading to a more defined stratification.
In September when temperatures cool down, the wind is able to circulate water almost throughout the entire lake. At this point, the stratification is almost completely gone.

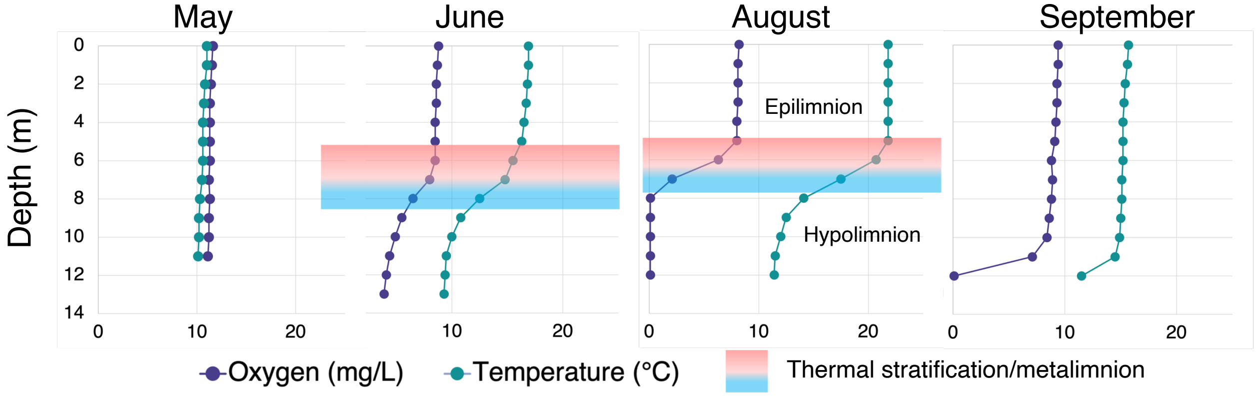


Fig .3. Example of thermal stratification in Yoho Lake

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 Yoho Lake

Temperatures in Yoho Lake sometimes rise to levels that present risks for some cold-water species.
Organisms like fish that can move around the lake may seek refuge in deeper, cooler waters under the thermal stratification if they are stressed by higher temperatures during summer.
However, the quality of deeper waters as a refuge is degraded by the low oxygen levels found in this part of the lake (see next page).

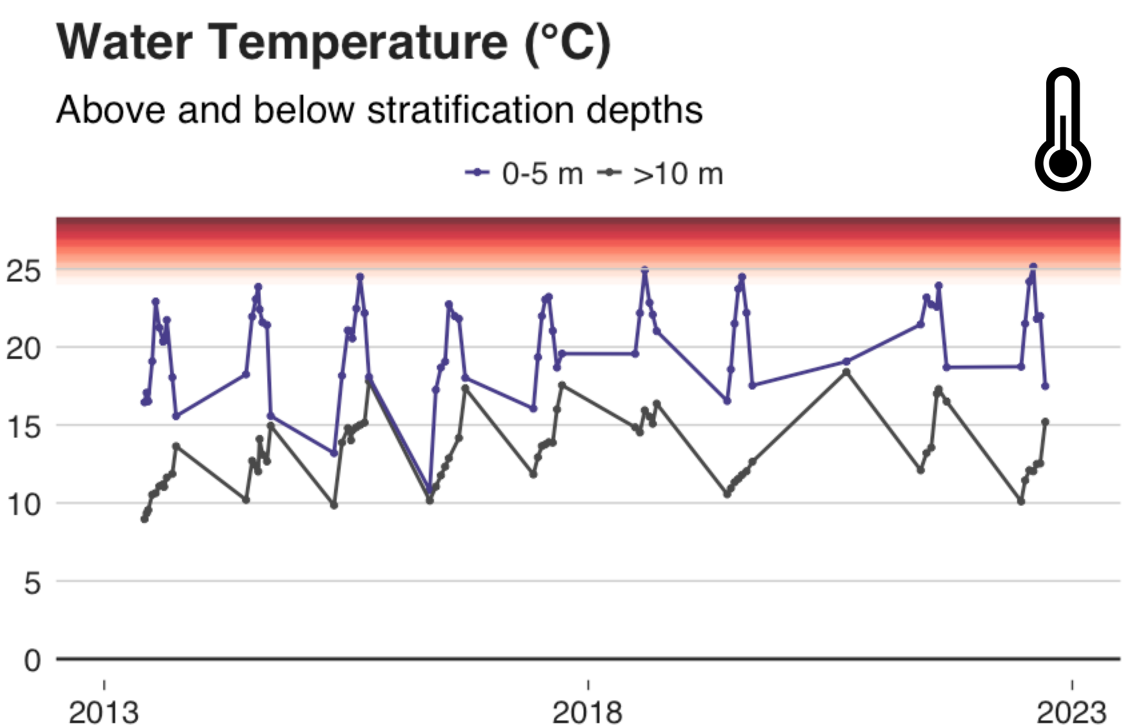


Fig. 4 Water temperature in Yoho Lake from 2013 to 2023. The red gradient signifies increased risks associated with higher temperatures. No CCME guidelines are available.

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 Yoho Lake

Concentrations of dissolved oxygen (hereafter referred to as oxygen) in the top five meters of Yoho Lake are generally good. These shallow waters receive oxygen from the air and from photosynthesis by plants and algae in the water. In contrast, oxygen concentrations decline continuously during summer under the thermal stratification. Concentrations in this part decline to near zero most years. Very few species can survive in such conditions.
Low oxygen concentrations in the hypolimnion are caused by the continuous consumption of oxygen by respiration and decomposition processes. This indicates that Yoho is relatively productive. If it is not already known, I recommend looking into whether this is natural or if nutrient concentrations are elevated due to human activity. A relatively small area of the lake is deep enough to see these conditions, but that area could be important as a refuge from high water temperatures.

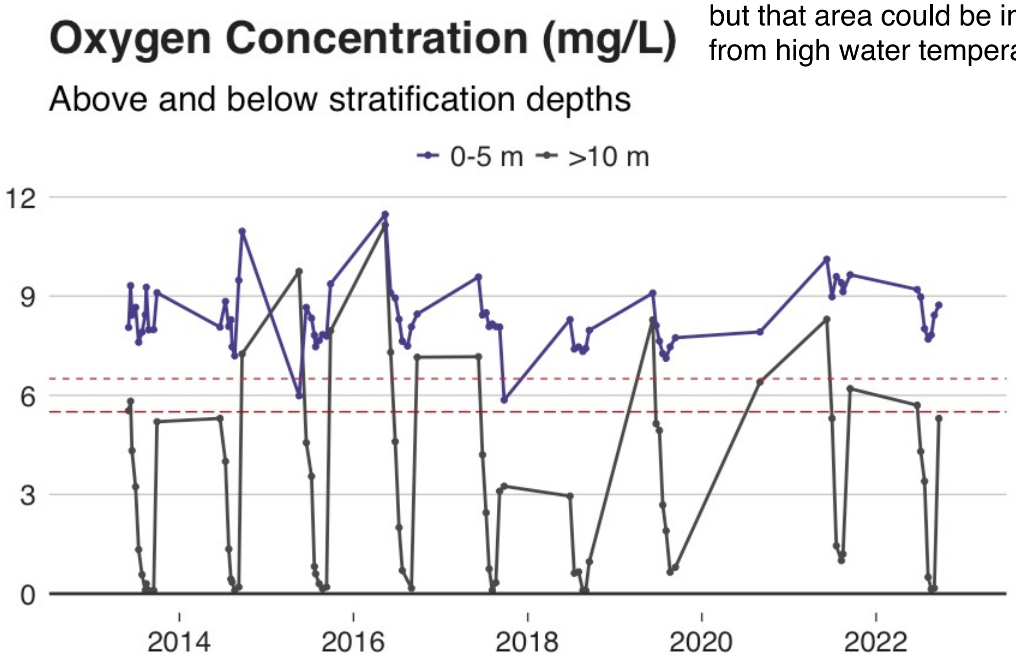


Fig .5 Dashed lines in the figure indicate lowest acceptable concentrations of oxygen for cold- (6.5 mg/L) and warm (5.5 mg/L) water species (CCME). Eggs and young individuals are generally even more sensitive.

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 Yoho 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.

Yoho Lake mostly has a relatively clear water, exceeding the health guideline depth, allowing for the potential of rooted plants to be found throughout most of the lake.

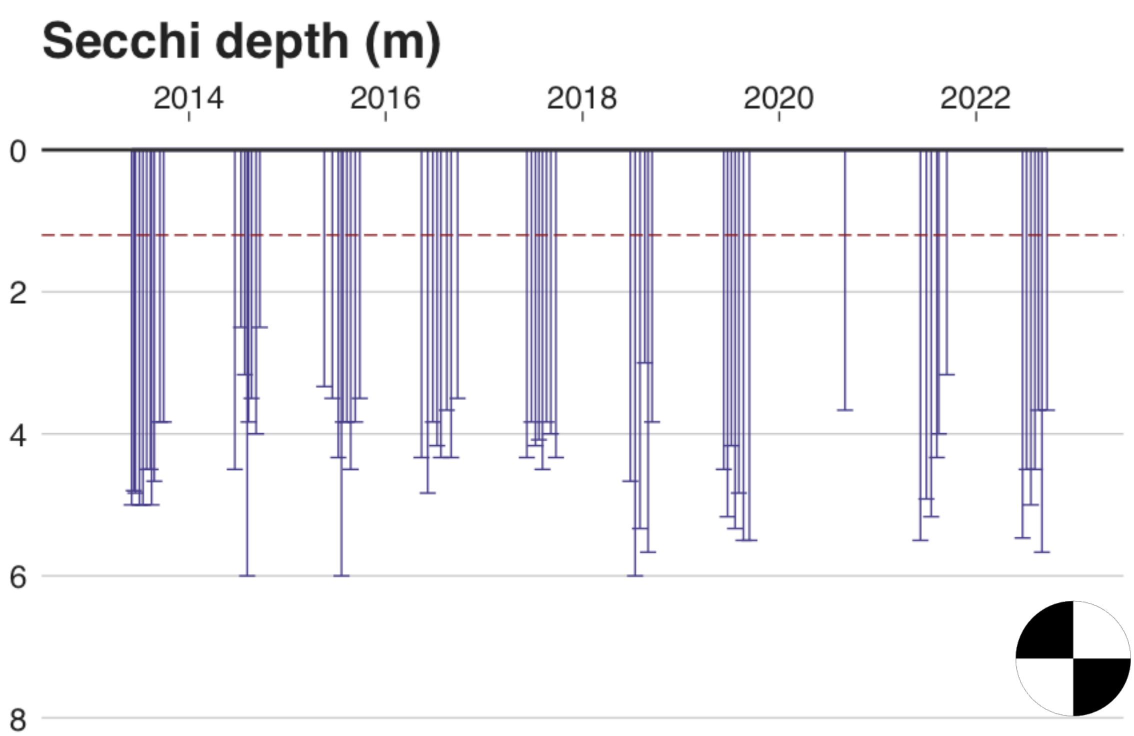


Fig. 6. Secchi depth in Yoho Lake. Hatched line indicate level of concern according to Health Canada guidelines for recreational waters.

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 Yoho Lake

The pH of the surface waters, above the thermal stratification is more or less neutral with some fluctuation around pH 7. The pH seems to be less stable in recent years compared to the beginning of the period. The pH in the deeper parts of Yoho Lake does periodically drop under the lower levels recommended by the CCME. This could affect some species but likely not severely. At around pH 6.5 some sensitive species of fish and invertebrate are beginning to be affected, but many species do just fine until pH goes below 5.5-6. At pH under 5 most fish are severely negatively affected.
The difference in pH between the shallow and deep waters can be caused by natural processes. pH can decrease during the decomposition of organic material in the deeper waters and photosynthesis can increase pH in the upper layer.
If there are data available on the alkalinity in Yoho it could be informative. Alkalinity is a measure of the lake's buffering capacity against acidification.

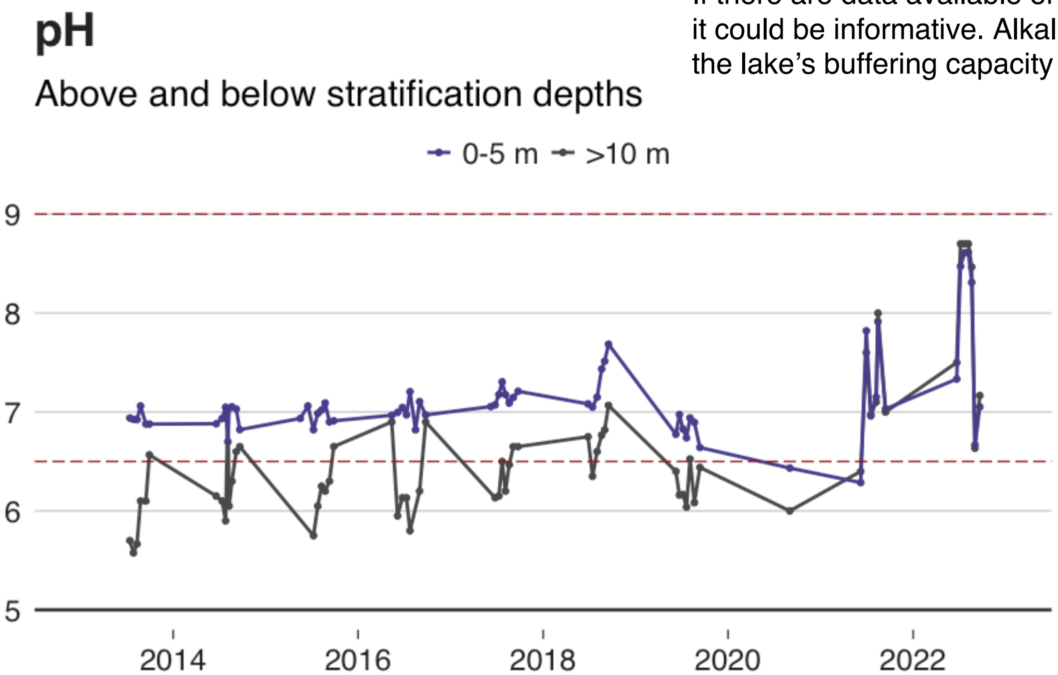


Fig. 7. pH in Yoho Lake from 2013 to 2022.
Hatched lines indicate upper (pH 9) and lower (pH 6.5) levels of concern according to CCME guidelines.

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 Yoho Lake

Conductivity in Yoho Lake was the highest observed among the NBALA lakes but still well within the range of background levels and most likely not a cause for concern. There are no CCME guidelines for conductivity and without knowing historical levels, it is impossible to say if the conductivity in Yoho Lake is elevated from natural conditions.
Conductivity appears to be higher in later years and it could be worth looking out for a possible continued trend in the future.
The higher conductivity at greater depths is likely caused by remineralization of salts during decomposition of organic material. These salts accumulate until the unravelling of the stratification in fall allows for wind to mix the lake water.

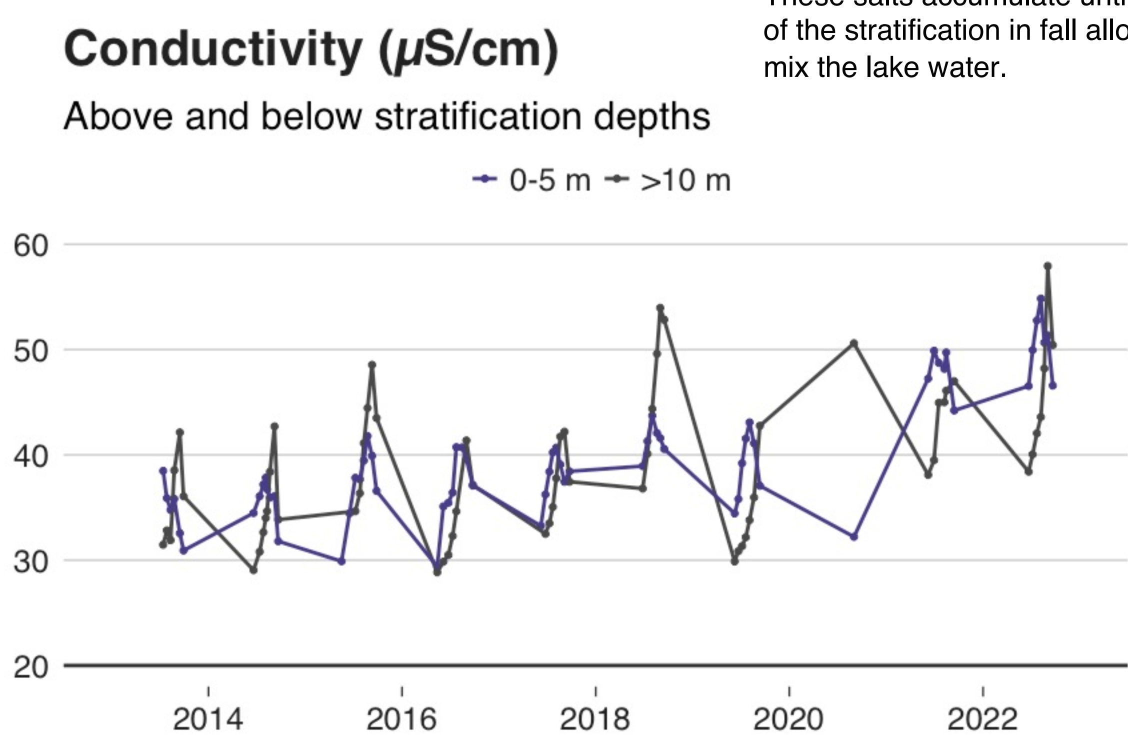


Fig. 8. Conductivity in Yoho Lake from 2013 to 2022. No CCME guidelines are available.

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.

Yoho Lake has the smallest surface area of the nine lakes but is not the the shallowest. Apart from conductivity, for which Yoho has the highest average, all parameters are towards the middle of the range of values.

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

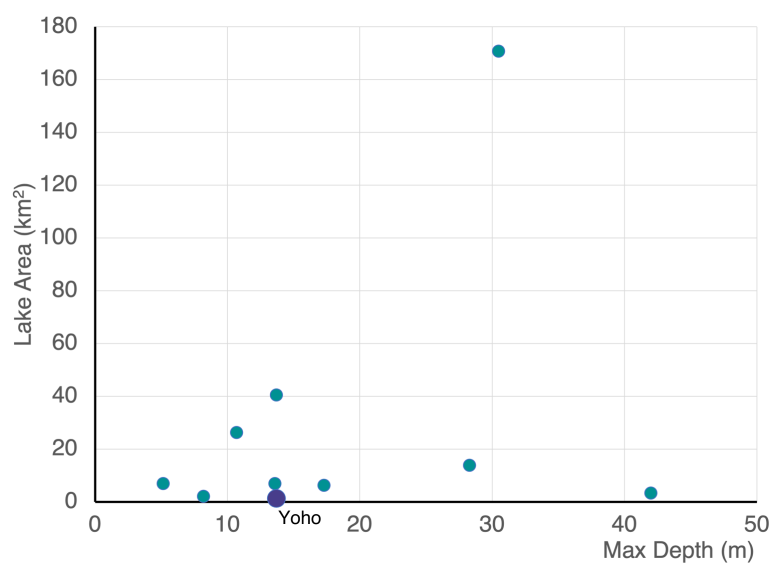


Fig. 10. The surface area and maximum depth of ten NBALA lakes. Yoho Lake is highlighted.

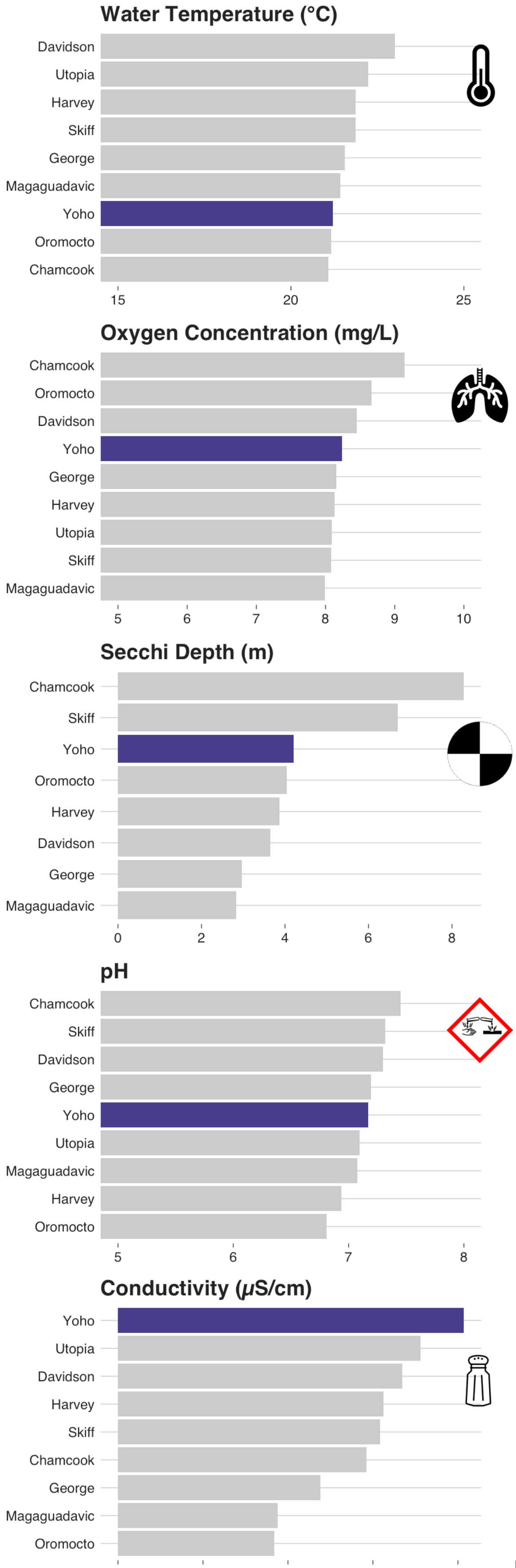


Fig. 9. Comparison between nine NBALA lakes for all investigated parameters.

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 YLA 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 Yoho Lake

The YLA monitors 4 stations in the lake which have been visited around five times per year over the ten-year period. This is a good body of data that can be evaluated in order to give some tentative suggestions about future efforts. I have made a preliminary analysis of spatial and temporal variation found in the YLA 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 all parameters the data vary 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.

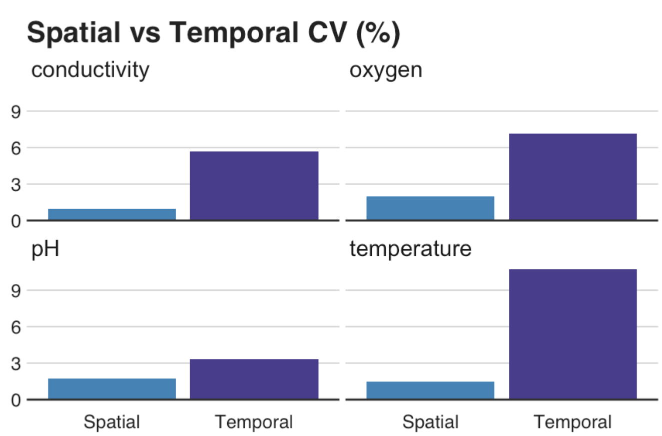


Fig. 11. Comparison of the relative variation between stations at any given date and the variation between dates for any given station.

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.