What's in the water at the lake?

A brief review of water quality and limnology

You should not be surprised that there is an entire world to study just below the lake's surface. Whether it's whitecaps breaking during a stiff breeze on a warm summer afternoon or the water getting colder as you dive deep into your lake, there are complex physical processes at play in the water. Not only that, there are a myriad of chemical processes that control your lake's clarity and allow algae and other subsurface life to survive and grow. This subsurface life is part of an entire foodweb lurking under the lake's surface that includes a diversity of living things including bacteria, algae, zooplankton, insects, aquatic plants, and fish. The study of all of this, the physics, chemistry, and biology of lakes, is the main focus of a scientific field called **limnology**. In this booklet, we will give you a brief overview of limnology and show you how this connects to the quality of water in your lake.

Trent University has an active lake monitoring program that collects and analyzes water quality in the Kawartha-Haliburton region. As part of these efforts, the Frost laboratory at Trent University (frostlab.ca) began monitoring water quality of lakes in the Kawartha Region in 2015. After a year off, they collected samples yearly since 2017 and plan to continue this annual sampling for the foreseeable future.

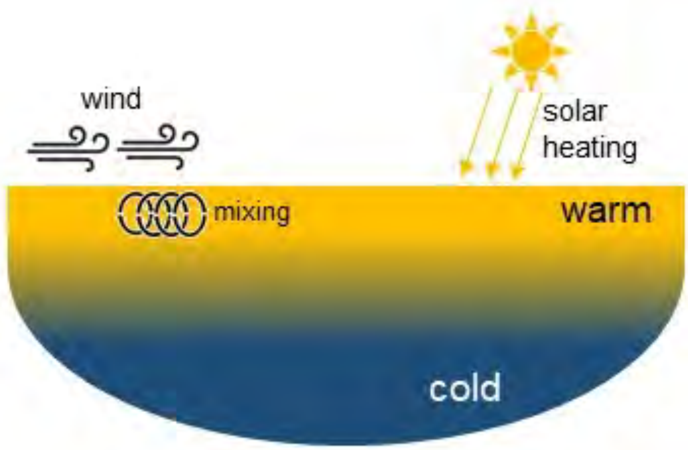
This sampling program is now completed as part of the **Trent Aquatic Research Program** (TARP; https://mycommunity.trentu.ca/tarp), which monitors lake health in the Kawartha-Haliburton region as part of its aquatic research and educational activities. The monitoring program provides a snapshot of health for selected lakes on an annual basis. Even more importantly, it will provide long-term information on water quality that is necessary for detecting and understanding trends over time. Having long-term information puts the data collected each year in context, which helps with the identification of current or emerging problems in lake health.

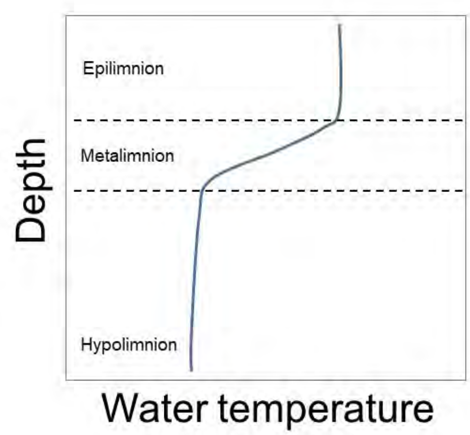
This booklet provides a short review of the primary water quality variables included in the TARP monitoring program and of interest to lake stewards, cottagers, and other stakeholders. The following sections of this primer briefly explains and reviews each of the variables that are normally measured and reported in our water quality reports on your lake.

Temperature

Background. Water temperature is a property that is probably familiar to most readers of this booklet. In the winter, a layer of ice and snow sit over frigid waters but by late summer you can enjoy a refreshing dip off the end of your dock. This seasonal pattern in temperature repeats each year with water warming up and cooling down on a seasonal cycle. These changes in water temperature affect the movement of water in the lake. As surface waters warm in spring, they become less dense and float on the top of colder, bottom waters. This warm-cold layering of water is called thermal stratification and generally lasts until fall, when the surface waters cool and begin to sink. This results in a thorough mixing of the lake's entire water column such that all layers intermix with each other. During this mixing period, you will find the same temperature from the top to the bottom of the lake's water column. Some lakes, including some in the Kawartha region, are too shallow for persistent thermal stratification to occur even in the middle of summer. In these lakes, the water column frequently mixes from top to bottom. In general, patterns of temperature, and particularly thermal stratification, control a lot of what happens to the lake ecosystem because these temperature layers affect oxygen exchange, water pH, the underwater light environment, and the availability of key nutrients. It is thus very important to know the lake's temperature, how much it changes over the year, and how it varies with depth.

Measurement. We have precise thermometers with long cords that allow us to measure the temperature from the surface all the way to the lake bottom. We typically see water temperatures at lake surface in 20-25°C during mid-summer, while temperatures near the lake bottom are much colder (<10°C).



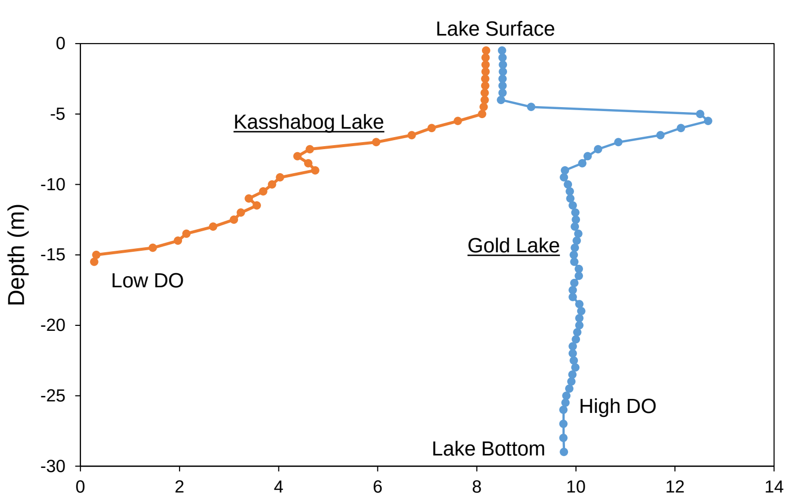


Summer thermal stratification is created by solar heating of lake surface waters. While this heat is redistributed by wind, the buoyancy of warm water keeps this warm water near the lake's surface. This creates three distinct layers in the lake. The epilimnion is the water surface layer. The metalimnion is the layer where temperatures change rapidly. The hypolimnion is the cold, bottom layer.

Dissolved Oxygen

Background. Just as we need to breathe oxygen in the atmosphere, many aquatic animals depend on the oxygen dissolved in water to survive. Fish, for instance, use gills to breathe in oxygen dissolved in the water and are quite sensitive to low oxygen concentrations. As limnologists, we are interested in the concentration of dissolved oxygen in lake water and how much it varies across the year and with depth of the water column. Generally in the middle of the summer, you will see high concentrations of dissolved oxygen in the water near the lake's surface. This oxygen is found in surface waters partly due to exchange with the atmosphere, but it can also be increased by algae and other aquatic plants, which release oxygen during photosynthesis. In fact, a high level of photosynthesis can oversaturate the water with dissolved oxygen and lead to its release from the lake into the atmosphere. On the other hand, many organisms in the lake require dissolved oxygen to maintain basic life processes, and all of this breathing can reduce dissolved oxygen concentrations. High levels of oxygen consumption lead to low concentrations in the lake, especially if the water is isolated from the atmosphere, which can happen in the cold bottom waters of lakes during the summer when warmer surface waters form a barrier to the atmosphere. Depending on the amount of biological activity, bottom waters can become nearly free of dissolved oxygen. This situation, which is called anoxia, may lead to fish death and can dramatically affect chemical processes in these waters. Oxygen is also a primary controller of lake chemistry and is thus especially important to measure in lakes.

Measurement. When we sample a lake for water quality, we use a carefully calibrated and highly precise dissolved oxygen meter attached to a long cord. This allows us to take measures at regular depth intervals, like every 1 meter, from the surface to the lake bottom. For most lakes in Ontario, dissolved oxygen concentrations will be found in the 7.5-10.5 mg/L range at the top of the lake and can vary between 0-10.5 mg/L at the bottom of the lake.

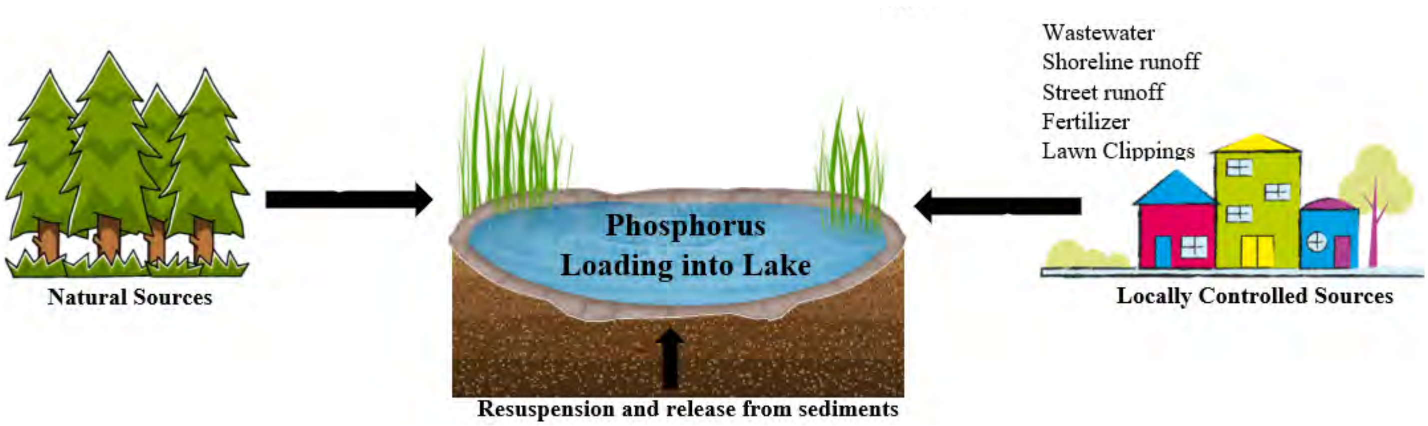


Dissolved oxygen concentrations in the water columns of two lakes, Kasshabog and Gold, during the summer of 2020. Gold Lake shows a high concentration of dissolved oxygen all the way from the surface to the bottom of the lake. The very high values at about 6 m is likely due to a layer of algae at that depth. Kasshabog Lake also has high dissolved oxygen concentrations in the surface waters but exhibits a steep decline in dissolved oxygen at deeper depths.

Phosphorus

Background. In many lakes, the addition of excessive nutrients has led to frequent and unsightly algal blooms. Because of its ability to promote excessive plant growth, there are many guidelines and efforts in place to reduce the amount of excess nutrients reaching lakes. These efforts largely focus on human sources who largely account for excessive phosphorus inputs. It is true that some of the phosphorus in our lakes come from natural sources, such as the slow dissolution of upstream rocks. However, there are many phosphorus sources that are associated with human activity. Our decisions about managing these sources of phosphorus can greatly impact the lakes we live and work around. It also means you might be able to identify sources that contribute phosphorus to your lake. Fertilizers and manure from farms or urban runoff from cities can both contribute phosphorus to streams and nearby lakes. Moreover, next time you flush a toilet at the cottage, think about where the nutrients associated with this human waste are headed. If poorly built or maintained, septic and sewage systems can allow phosphorus from human waste to seep into lakes. While being vigilant about external phosphorus sources is necessary, we can also track the amount of this important nutrient in the lake as an indicator of lake health because it is a key predictor of algal biomass, and it can tell us if the lake is receiving too much external phosphorus.

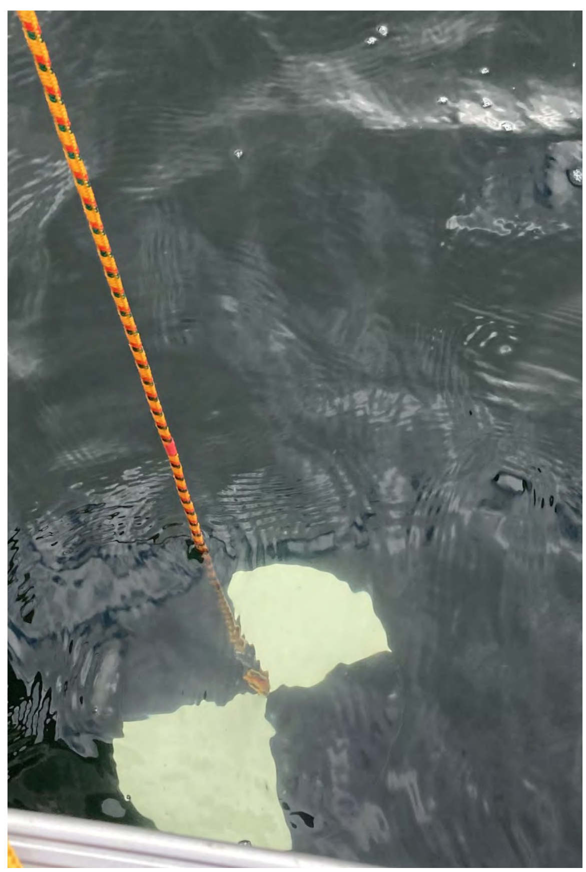
Measurement. The measurement of phosphorus can be relatively straight forward, but understanding phosphorus in lakes can be quite complicated. This is because there are different forms of phosphorus and it can cycle between these forms quite quickly. Usually, you will see total phosphorus reported, which is an estimate of all forms of phosphorus in the lake water. We measure total phosphorus by taking a water sample from near the lake's surface. A subsample is saved for a specific type of chemical analysis that turns blue if phosphorus is present. We use a machine in the lab to measure the level of blueness and compare with samples with known phosphorus concentrations. Most of the lakes in the Kawartha region have surface waters with phosphorus concentrations in the range of 5-10 µg/L with higher values sometimes found in the more southern Kawartha Lakes.



Water Clarity

Background. There are few moments more peaceful than gazing into the depths of a lake. Have you ever noticed that this view can vary substantially between lakes? In some lakes, you can see flashes of plant and animal life several meters below the surface, while in others the water is a murky green or brown and you can't see much of anything in the waters below. These differences are a matter of water clarity, which refers to how much light can pass through a given amount of water. Once past the surface of the lake, light penetrates deeper in the water column but is gradually removed and it becomes quite dark. The depth that light penetrates into the lake depends on how much and what type of material is present in the water. One situation that you don't want to witness first hand occurs during algal blooms when excessive growth of these planktonic algae clouds the water and absorbs most of the light near the lake's surface. This can greatly reduce water clarity and the depth that light can reach into the water column. While we often think of water clarity largely in terms of how it alters a lake's appearance, it has a number of other effects on the lake's ecosystem. For example, low water clarity can prevent plants and algae from growing on the lake's sediments. Water clarity also affects depth profiles of temperature and dissolved oxygen, determines the type of microbes you can find at the bottom of your lake, and controls many aspects of the lake food web.

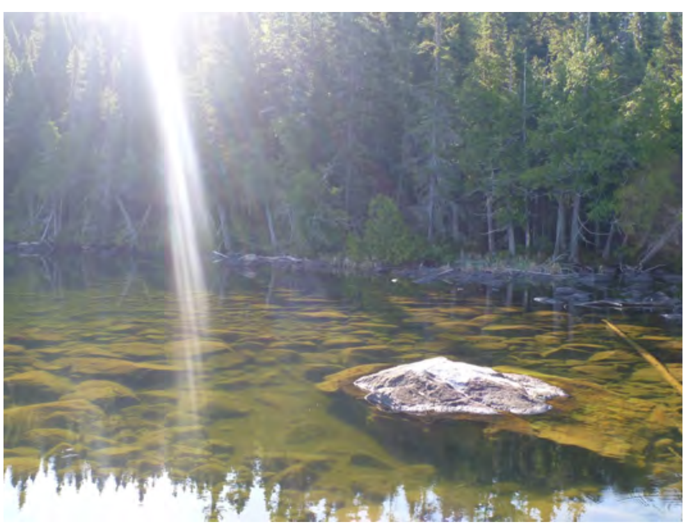
Measurement. We have different ways to assess water clarity. The easiest way and the one with which you might be familiar is to measure the Secchi depth. The Secchi depth is measured using a black and white disc attached to a rope. The disc is lowered into the lake until the disc is no longer visible in the water. Usually the Secchi depth is 4 or 5 meters, but in especially clear lakes it can reach 10 m or more. We can also measure water clarity using a sensitive light meter that we lower off the side of the boat. The light reaching a particular depth is then compared to that measured by a light sensor kept at the surface. By recording the amount of light at different depths, we can estimate how much is removed in the water column. We use these data to estimate the light attenuation coefficient, which describes how fast light disappears in the water column.

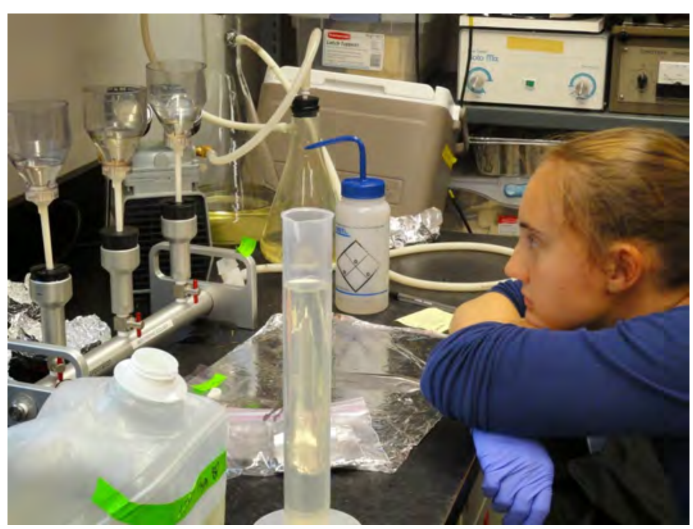


Chlorophyll

Background. Have you ever seen a really green lake? While this is usually portrayed in a negative light, these plants and algae nonetheless have important roles in our lakes. Floating algae produce oxygen, act as a source of food to small lake animals, and contribute nutrients to the lake when they decompose. Too much algae can be quite problematic for our lakes partly because this can lead to excessive decomposition and oxygen consumption in the lake's bottom waters. One relatively simple way to determine whether there is a healthy or unhealthy amount of algae in a lake is to measure the concentration of chlorophyll in the water. Chlorophyll is a green pigment that plants and algae use to carry out photosynthesis. The concentration of chlorophyll in lake water is often used to get an estimate of how much algae is contained in lake water. The amount of chlorophyll has been used in the past to classify lakes across the spectrum from clear and unproductive to green and highly productive. Generally, lower chlorophyll is associated with better water quality as it indicates better clarity and less nutrient-related pollution.

Measurement. The process of measuring chlorophyll involves collecting water samples and running this water through a filter. The filter collects the suspended algae from the water and then we measure the chlorophyll off the filter. These pigments are measured in the lab with a machine called a spectrofluorometer. Chlorophyll concentrations in many lakes will be found below 10 µg/L with exceptionally low values in our most clear lakes. Higher values (10-30 µg/L) are found in more productive lakes and are more typical of lakes experiencing algal blooms. Severe algal blooms typically will result in very high values (>30 µg/L), but these concentrations are not typically seen in lakes of our Kawartha region.





Lakes with high clarity have more of their shallow areas illuminated (left). These areas can become shaded when high chlorophyll concentrations reduce light penetration. **Filtering water samples** (right) to measure chlorophyll and other suspended matter uses vacuum pumps to collect particles on small paper filters. This can be a slow process and requires lots of patience.

Calcium

Background. If you were a small aquatic creature living in a lake, how do you think you would survive in a huge world teeming with danger? Would you swim fast? Would you hide among the rocks? Would you grow a tough protective shell to defend against being eaten? If you chose the option of producing a protective shell, you would be among good company, because this is a strategy employed by many invertebrates living in our lakes. To grow their shells, though, small lake animals need adequate supplies of dissolved calcium. Lately, there has been concern that certain lakes no longer contain enough calcium to support healthy populations of lake invertebrates. One possible outcome of declining calcium is that invertebrates which use less calcium will increase in prevalence. The invertebrates that thrive in calcium-poor conditions tend to have soft, jelly-like outer layers rather than hard, calcified shells. You may even have heard of a jelly-coated zooplankton, *Holopedium*, which may be increasing in prevalence in some Kawartha region lakes. Tracking calcium concentrations thus allow us to gauge whether a particular lake is at risk of calcium effects on food-webs and also tells us about the movement of this element through watersheds and catchments.

Measurement. When we measure calcium concentration, we start by collecting water samples at the lake and filtering this water in the lab. We then run small subsamples of this water through a machine called an X-ray spectrometer, which tells us the concentration of different elements, including calcium. Alternatively, calcium can be measured using other sophisticated analytical equipment. In the lakes of the Kawartha region, calcium concentrations vary widely depending on the size of the lake and the geology in its uplands. These values range from 2 mg/L to as high as 30 mg/L. Generally, you would not be concerned about calcium concentrations unless you found values lower than 3 mg/L.

Low Ca concentrations can affect the health of small aquatic animals. These animals are collected with a plankton net (left) and usually examined in the laboratory with a microscope. One planktonic animal that does well under low Ca conditions is *Holopedium*, which is a gelatinous crustacean that looks like small blobs of jelly (right).

Summary

Water scientists usually look at many factors when considering the health of a lake ecosystem. This is similar when you see a doctor and they assess your overall health during an annual check-up. The doctor might consider a number of variables including your weight, blood pressure, heartrate, and different aspects of your blood chemistry. Similarly for lakes, there are a few key variables we can look at to determine if there are desirable levels of algae and whether the lake is suitable for aquatic life. At the same time, these indicators are very useful to diagnose emerging water quality problems. For example, if you notice very green coloured water, we can measure the Secchi, chlorophyll, and total phosphorus to see if your lake is experiencing an algal bloom. The value of these diagnostics are increased when we have data from many lakes and over many years to use as comparison. The water quality we are collecting will be saved and used for this specific purpose.

For lakes in the Kawartha-Haliburton region, we generally ask two questions related to water quality: 1) is the water generally low in algae? And 2) is the dissolved oxygen at the bottom of the lake sufficient to support animal life? A third set of emerging issues that remain an area of concern include the slow decline of calcium concentrations and the ever-present threat of invasive species. Low calcium concentrations are present in very few of the lakes in our area but these lakes should be carefully monitored and tracked to see if this problem is becoming worse. Invasive species are more problematic because assessing their colonization and effects on a lake requires intenstive study of a lake's foodweb. Monitoring lake foodwebs is a expensive proposition if undertaken correctly. For example, tracking zooplankton populations requires multiple samples be taken about twice a month and each of these samples can take hours to sort and count. Zooplankton are just one small part of the foodweb so many changes to your lake may occur without anyone ever being able to notice. Future expansion of water quality monitoring should include foodweb monitoring so that any new arrivals can be detected promptly, which can help slow spread and reduce effects of invasive species.

What can you do to help? There are many things you can do to help protect the water quality of your lake. For one, you can adopt healthy shoreline practices to reduce your nutrient footprint on the lake. You can also become a steward and help collect water quality data used by various research and monitoring programs. Finally, you can support monitoring programs to collect data and have expertise to understand what these data means. To learn more about and help support the Trent Aquatic Research Program, please visit (https://mycommuity.trentu.ca/tarp), and/or contact Dr. Paul Frost at Trent University (paulfrost@trentu.ca).