Lakes Environmental Association

Keoka Lake Water Quality Report

2020

Table of Contents

About LEA	Page 1
2020 Water Quality at a Glance	Page 2
LEA Service Area	Page 4
2020 Volunteer Monitors and Interns	Page 5
Lake Stratification 101	Page 6
A Year in the Life of a Lake	Page 7
Water Quality Testing Parameters	Page 8
2020 as a Year	Page 9
Interpreting the Summary	Page 10
Water Testing Data Summary	Page 11
High-Resolution Temperature Monitoring	Page 13
High-Resolution Temperature Monitoring Summary	Page 16
Fluorometric and Algae Monitoring	Page 17
Fluorometric and Algae Monitoring Summary	Page 18

About LEA

The Lakes Environmental Association (LEA) is a non-profit organization founded in 1970 with the goal of preserving and restoring the high water quality and the traditional character of Maine's lakes, watersheds and related natural resources. Headquartered in Bridgton, Maine, LEA focuses its efforts on 6 towns in the western Maine Lakes Region, although its reach and influence extends across the whole state.

Invasive Plant Program

LEA's Milfoil Control Team successfully eradicated invasive Variable Leaf Milfoil from Brandy Pond and the Songo River in 2015, after over a decade of hard work. The focus shifted to Sebago Cove in 2016, where a dense infestation threatens nearby waterbodies, and in 2017 they began work on Long Lake after an infestation was found there. LEA's program has been a model for the entire state.

Environmental Education

LEA offers environmental education programs to local elementary, middle, and high schools, reaching over 1,000 students annually. LEA also hosts educational programs for all ages at the Holt Pond Preserve, Highland Lake Preserve and Pondicherry Park, all of which LEA played a key role in establishing.

Lake Water Testing

Water testing on over 40 lakes and ponds in the area occurs every year through traditional and advanced testing initiatives. The results are presented in this report.

Landowner and Municipal Assistance

LEA provides technical assistance to residents interested in preventing erosion on their property. This service helps educate landowners about simple erosion control techniques and existing land use regulations. LEA also works with municipalities on comprehensive planning, natural resources inventories and ordinance development.

Courtesy Boat Inspections

Every summer, LEA hires over 30 courtesy boat inspectors to educate boaters at public boat launches about invasive plants and help them perform inspections on their watercraft. This program, begun by LEA, has been adopted across the state.

Maine Lake Science Center

Opened in 2015, LEA's Maine Lake Science Center is a hub for lake research in the state. The center regularly hosts researcher retreats and other events at its remodeled and renovated energy-efficient headquarters located in Bridgton.

Please Join LEA!

LEA is a primarily member-funded operation. If you swim, boat, fish or simply believe Maine wouldn't be Maine without clear, clean lakes and ponds, please join the Lakes Environmental Association and protect Maine's lakes now and for future generations.

You can become an LEA member with a donation of any amount. Just mail a check to LEA, 230 Main St., Bridgton, ME 04009 or join online at www.mainelakes.org.

Water Quality at a Glance — Biweekly Monitoring

Lake	2020 Avg . Clarity	2020 Avg. Phosphorus	2020 Avg. Chlorophyll-a	Clarity Trend .	Phosphorus Trend	Chlorophyll-a Trend
ADAMS POND	High	Moderate	Low	Increasing	Stable	Stable
BACK POND	Moderate	Moderate	Low	Increasing	Decreasing	Stable
BEAR POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
BRANDY POND	Moderate	Low	Moderate	Stable	Stable	Stable
CRYSTAL LAKE	Moderate	Moderate	Moderate	Decreasing	Stable	Stable
FOSTER POND	Moderate	Moderate	Moderate	Decreasing	Stable	Stable
GRANGER POND	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
HANCOCK POND	Moderate	Low	Moderate	Increasing	Stable	Decreasing
HIGHLAND LAKE	Moderate	Moderate	Moderate	Increasing	Stable	Decreasing
ISLAND POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
KEOKA LAKE	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
KEYES POND	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
LITTLE MOOSE	Moderate	Moderate	Moderate	Stable	Stable	Stable
LONG LAKE	Moderate	Moderate	Moderate	Stable	Stable	Decreasing
LONG LAKE	Moderate	Moderate	Moderate	Stable	Stable	Stable
LONG LAKE	Moderate	Low	Moderate	Stable	Decreasing	Stable
McWAIN POND	Moderate	Moderate	Moderate	Stable	Decreasing	Decreasing
MIDDLE POND	Moderate	Moderate	Moderate	Increasing	Stable	Decreasing
MOOSE POND	High	Low	Moderate	Stable	Decreasing	Decreasing
MOOSE POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
MOOSE POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
PEABODY POND	High	Low	Moderate	Increasing	Stable	Stable
SAND POND	Moderate	Moderate	Moderate	Decreasing	Stable	Stable
STEARNS POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
TRICKEY POND	High	Low	Low	Decreasing	Decreasing	Increasing
WOODS POND	Moderate	Moderate	Moderate	Stable	Increasing	Stable

Key to Water Quality at a Glance Table

Chlorophyll-a and Phosphorus Trends: Available data from 1996-2020 were analyzed to determine if chlorophyll-*a* and phosphorus trends indicate increasing, decreasing, or stable concentrations over time. Both chlorophyll-*a* and phosphorus are measured in parts per billion (ppb).

Increasing = more chlorophyll-*a* or phosphorus in lake water samples over time

Stable = neither more nor less chlorophyll-*a* or phosphorus in lake water samples over time

Decreasing = less chlorophyll-*a* or phosphorus in lake water samples over time

Clarity Trends: Available data from 1996-2020 were analyzed to determine if clarity trends indicate increasing, decreasing, or stable depth trends over time. Clarity is measured in meters (m). Higher numbers indicate clearer water.

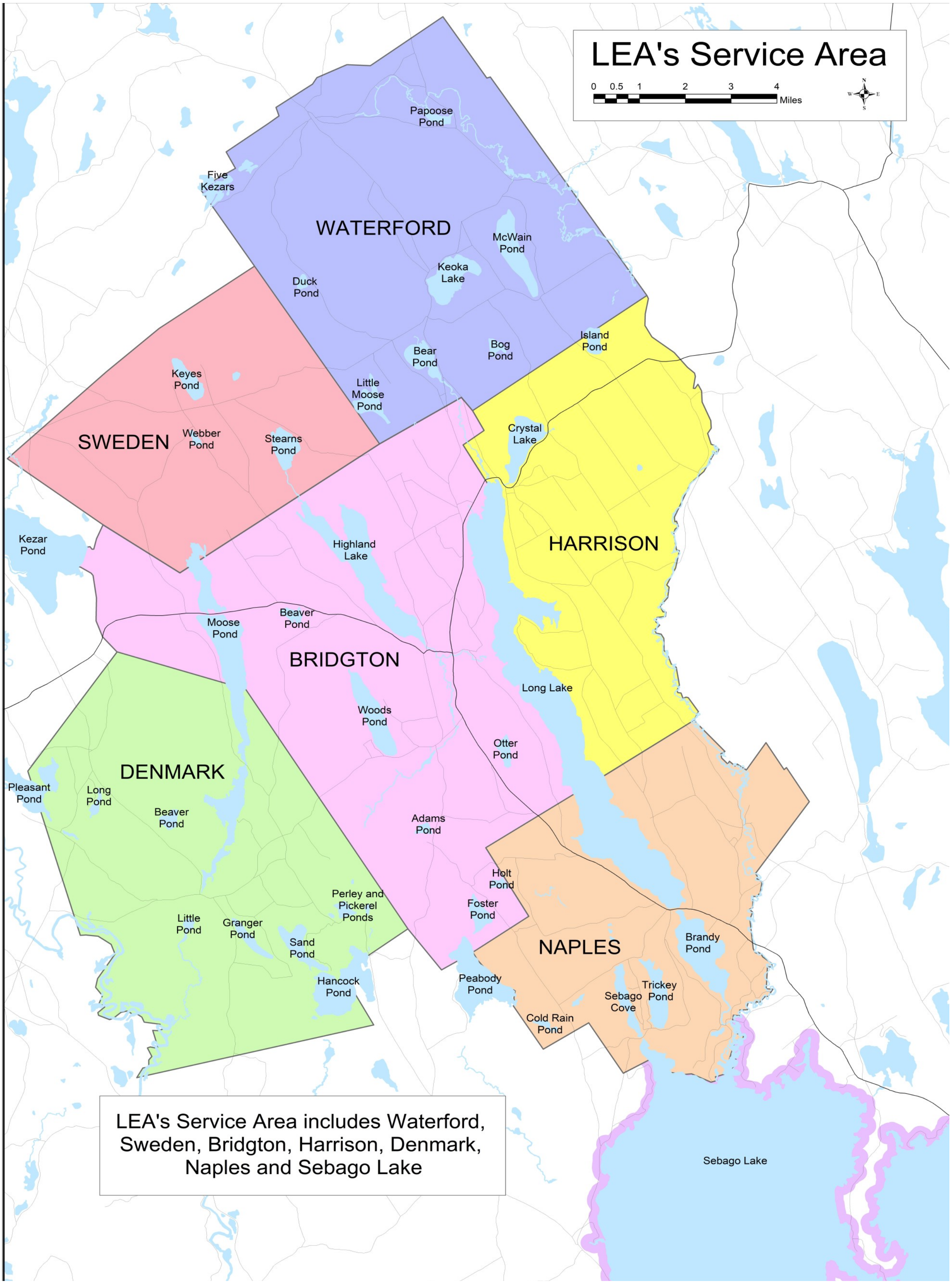
Increasing = deeper clarity readings over time

Stable = clarity readings are neither deeper nor shallower over time

Decreasing = shallower clarity readings over time

2020 Average Chlorophyll-*a* concentrations, Phosphorus concentrations, Color and Clarity readings: Chlorophyll-*a* and phosphorus concentrations throughout the 2020 monitoring season were averaged and classified according to LEA's water quality index outlined below.

Clarity in meters (m)	Phosphorus in parts per billion (ppb)	Chlorophyll-*a* in parts per billion (ppb)	Color in Standard Platinum Units (SPU)
10.0 + Very high	less than 5.0 Low	less than 2.0 Low	Less than 10.0 Low
7.1 – 10.0 High	5.1 – 12.0 Moderate	2.1 – 7.0 Moderate	10.1 - 25.0 Moderate
3.1 – 7.0 Moderate	12.1 – 20.0 High	7.1 – 12.0 High	25.1 - 60 High
less than 3.0 Low	20.1 + Very high	12.1 + Very high	60.1+ Very high



LEA's Service Area includes Waterford, Sweden, Bridgton, Harrison, Denmark, Naples and Sebago Lake

LEA would not be able to test the 41 lakes and ponds of this area without strong support from our surrounding community. Every year, we rely on volunteer monitors, lakefront landowners, summer interns, and financial support from lake associations and the towns of Bridgton, Denmark, Harrison, Naples, Sweden, and Waterford to continue to monitor and analyze lake water quality. **Thank you for all your help!**

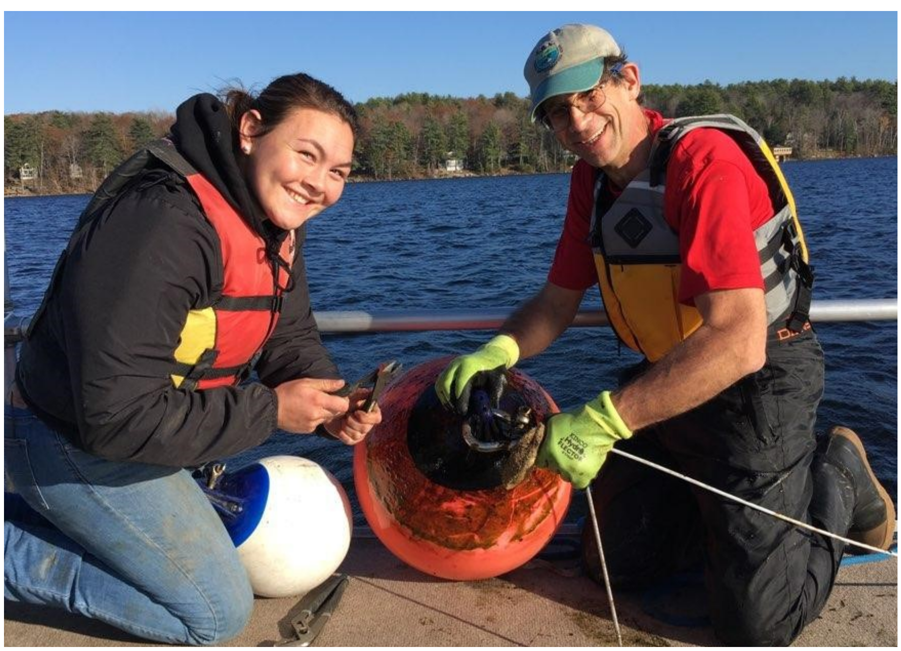
2020 Volunteer Monitors and Lake Partners

Richard and Andy Buck	Ethan Judd	Nancy Pike
Papoose Pond Campground	Bill Ames and Paulina Knibbe	Jean Preis
Steve Cavicchi	Bob Mahanor	Jean Schilling
Jeff and Susan Chormann	Amy March	Linda and Orrin Shane
Janet Coulter	Julie and Dan McQueen	Foster and Marcella Shibles
Joe and Carolee Garcia	Bob Mercier	Bob Simmons
Carol Gestwicki	Michael Neilson	Tom Straub
Shelley Hall	Barry and Donna Patrie	Don and Pat Sutherland

Five Kezar Ponds Watershed Associa-	Keoka Lake Association	Moose Pond Association
Hancock and Sand Ponds Association	Keyes Pond Environmental Protection Association	Peabody Pond Protective Association
Island Pond Association	McWain Pond Association	Trickey Pond Environmental Protection Association
	Woods Pond Water Association	

2020 Water Testing Crew

Shannon Nelligan Addie Casali Garrett Higgins



Lake Stratification 101

To understand much of LEA's water quality data, you must understand the concept of lake stratification.

Lake stratification is when the water column separates into distinct layers. This is caused by density differences in water at different temperatures. However, wind also plays a key role in maintaining and breaking down stratification. This layering happens in both the summer and winter and breaks down in the spring and fall, allowing for "turnover" — full mixing throughout the water column.

In Maine, three layers often form; the epilimnion, metalimnion (aka thermocline), and the hypolimnion.

The epilimnion is the warm surface layer of the lake and the hypolimnion is the cold bottom layer. The thermocline is a narrow zone in between these layers where temperature and oxygen levels change rapidly. The exact depths of each layer change over the course of the summer and from lake to lake and year to year.

Due to the nature of stratification, which does not allow for exchange between the top and bottom layers, oxygen and nutrient concentrations often differ significantly between the upper and lower portions of a stratified lake. This is especially true in late summer.

This has several consequences for the lake. Light penetration is greatest near the top of the lake, meaning that algae growth primarily occurs in the epilimnion. Algae growth will sometimes peak near the thermocline, often in lakes with deep light penetration and higher hypolimnetic phosphorus levels.

Oxygen levels in the epilimnion are constantly replenished through wind mixing, but the hypolimnion is cut off from the atmosphere, leaving it with a fixed volume of oxygen which is slowly used up over the summer. This can affect coldwater fish species in some lakes.

Phosphorus, the limiting element controlling algae growth in our lakes, is often more abundant in the hypolimnion because it is stored in sediments.

When oxygen levels are low at the bottom of the lake, as often happens later in the summer, a chemical reaction occurs that releases stored phosphorus from sediments. However, due to the density barrier at the metalimnion, these nutrients do not move easily into the epilimnion. This often causes a buildup of phosphorus in the hypolimnion.

Smallmouth Bass

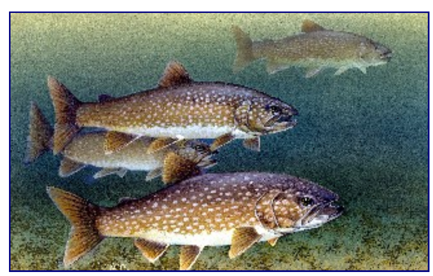
Epilimnion

The warm upper waters are sunlit, wind-mixed and oxygen rich.

Landlocked salmon

Metalimnion

This layer in the water column, also known as the thermocline, acts as a thermal barrier that prevents the interchange of nutrients between the warm upper waters and the cold bottom waters.



Lake trout, also known as togue

Hypolimnion

In the cold water at the bottom of lakes, food for most creatures is in short supply, and the reduced temperatures and light penetration prevent plants from growing.

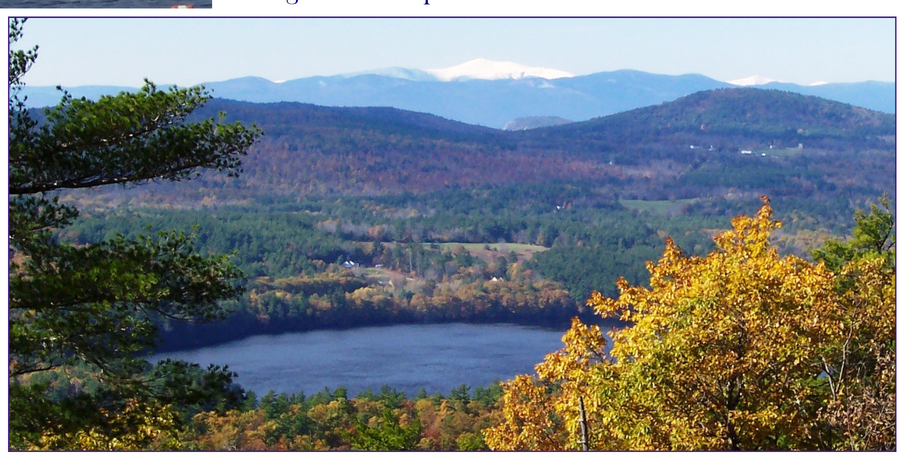
A year in the life of a lake

Winter is a quiet time. Ice blocks out the sunlight and also prevents oxygen from being replenished in lake waters because there is no wind mixing. With little light below the ice and gradually diminishing oxygen levels, plants stop growing. Most animals greatly slow their metabolism or go into hibernation.

Spring is a period of rejuvenation for the lake. After the ice melts, all of the water is nearly the same temperature from top to bottom. During this period, strong winds can thoroughly mix the water column allowing for oxygen to be replenished throughout the entire lake. This period is called spring turnover. Heavy rains, combined with snow melt and saturated soils are a big concern in the spring. Water-logged soils are very prone to erosion and can contribute a significant amount of phosphorus to the lake. Almost all soil particles that reach the lake have attached phosphorus.

Summer arrives and deeper lakes will gradually stratify into a warm top layer and a cold bottom layer, separated by a thermocline zone where temperature and oxygen levels change rapidly. The upper, warm layers are constantly mixed by winds, which “blend in” oxygen. The cold, bottom waters are essentially cut off from oxygen at the onset of stratification. Coldwater fish, such as trout and landlocked salmon, need this thermal layering to survive in the warm summer months and they also need a healthy supply of oxygen in these deep waters to grow and reproduce.

Fall comes and so do the cooler winds that chill the warm upper waters until the temperature differential weakens and stratification breaks down. As in Spring, strong winds cause the lake to turn over, which allows oxygen to be replenished throughout the water column.



Water Quality Testing Parameters

LEA's testing program is based on parameters that provide a comprehensive indication of overall lake health. Tests are done for transparency, temperature, oxygen, phosphorus, chlorophyll-a, color, conductivity, pH, and alkalinity.

Clarity is a measure of water transparency. It is determined with a Secchi disk and measured in meters. Clarity is affected by water color and the presence of algae and suspended particles.

Temperature is measured at one-meter intervals from the surface to the bottom of the lake. This data is used to assess thermal stratification. Lakes deep enough to stratify will divide into three distinct layers: the epilimnion, metalimnion and hypolimnion. The epilimnion (upper layer) is comprised of the warm surface waters. The hypolimnion is made up of the deep, colder waters. The metalimnion, also known as the thermocline, is a thin transition zone of rapidly decreasing temperature between the upper and lower layers. Temperature is recorded in degrees Celsius.

Chlorophyll-a is a pigment found in all algae. Chlorophyll (the –a is dropped for simplicity) sampling in a lake is used to estimate the amount of algae present in the water column. Chlorophyll concentrations are measured in parts per billion (ppb). Samples are collected with a core tube and are made up of water from the top layer (epilimnion) of a lake.

Phosphorus is a nutrient needed by algae to grow. It is measured in order to determine the potential for algae growth in a lake. Like chlorophyll-a, phosphorus is measured in ppb. Surface-layer phosphorus samples are taken in the same manner that chlorophyll samples are collected, while deep-water phosphorus samples are taken at individual depths using a grab sampler. Surface-layer samples tell us how much phosphorus is available for algae in the sunlit portion of a lake, where the algae grow. If deep-water samples show high phosphorus, this is an indication that sediments are releasing phosphorus and that the lake is more susceptible to future algae blooms.

Dissolved oxygen is measured at one-meter intervals from the surface to the bottom of the lake. It is measured in parts per million (ppm). Over the course of the summer, oxygen in the bottom waters is consumed through organic matter decomposition. If dissolved oxygen concentrations reach zero at the bottom of the lake, phosphorus can be released into the water column from bottom sediments, which can cause increased algal growth that fuels further oxygen depletion. Phosphorus release is inhibited in lakes with high sediment aluminum levels. Oxygen depletion can be a natural occurrence in some lakes. It is a special concern in lakes that support coldwater fish, because they are an important part of lake food webs. In this report, "oxygen depletion" refers to dissolved oxygen levels below 4 ppm. During the fall, cooler temperatures and winds cause the lake to de-stratify and oxygen is replenished in the deep waters as the lake mixes.

Other Measurements: We collect data on these parameters, but they tend to remain stable over long periods time. They are not reported on unless unusual conditions were observed.

> **Conductivity** measures the ability of water to carry electrical current. Pollutants and minerals in the water will generally increase lake conductivity.
>
> **Color** is a measure of tannic or humic acids in the water.
>
> **pH** is used to measure the level of acidity in lake water, which affects the species makeup and availability of micronutrients in a lake.
>
> **Alkalinity** measures the capacity of lake water to buffer changes in pH.

2020 as a Year

Despite an array of challenges presented by the COVID-19 crisis, our 2020 summer water testing interns embraced coronavirus safety protocols and diligently collected: 292 secchi readings; 231 oxygen and temperature profiles; 231 hypolimnetic core samples (all of which were analyzed for color, pH, conductivity, alkalinity, total phosphorus concentration, and chlorophyll concentration); 64 fluorometer profiles, 149 deep water total phosphorus samples; and deployed 17 high resolution temperature monitoring buoys containing 120 individual temperature sensors. Our data collection efforts provide water quality information from 44 basins on 41 waterbodies within the LEA service area. What an accomplishment during times marked by social distance and public health crisis!

COVID aside, 2020 saw warmer than average air temperature, highly variable wind patterns, with stronger winds coming from the NW and SE. The 2020 water testing season began after a low-snowfall winter, which contributed to early season drought conditions. We did receive substantial rainfall and stormy weather in June, July, and August, which helped ease drought conditions in mid-summer; however, dry conditions returned in September.

In 2020, 85% of the lakes we monitor bi-weekly had either stable or increasing (deeper) clarity trends, 96% had either stable or decreasing total phosphorus trends, and 96% had either stable or decreasing chlorophyll-*a* trends. Of the lakes we monitor once annually, 84% had either stable or increasing (deeper) clarity trends, 89% had either stable or decreasing total phosphorus trends, and 95% had either stable or decreasing chlorophyll-*a* trends.

The water testing results for 2020 show a great year for water quality in the Lakes Region. This is likely due, in large part, to the drought. Rainfall and storm events bring nutrients and sediments into lakes so water quality often improves in dry periods.

Interpreting the Summaries

Water Quality Classification

Each lake's clarity, chlorophyll, and phosphorus readings will be discussed in the lake summaries. These three measurements are the basis for determining water quality classification. Most lakes in LEA's service area are in the moderate range for all three parameters. The following table shows the range of values in each category for each parameter. Water color is also included in the table because it affects clarity.

Clarity in meters (m)	Phosphorus in parts per billion (ppb)	Chlorophyll-*a* in parts per billion (ppb)	Color in Standard Platinum Units (SPU)
10.0 + Very high	less than 5.0 Low	less than 2.0 Low	Less than 10.0 Low
7.1 – 10.0 High	5.1 – 12.0 Moderate	2.1 – 7.0 Moderate	10.1 - 25.0 Moderate
3.1 – 7.0 Moderate	12.1 – 20.0 High	7.1 – 12.0 High	25.1 - 60 High
less than 3.0 Low	20.1 + Very high	12.1 + Very high	60.1+ Very high

Table 1. Numeric values used to determine water quality in waterbodies monitored by LEA

Trends and Long-Term Averages

Lake summaries include an explanation of clarity, chlorophyll, and phosphorus trends. Trends are determined for each lake that has been visited bi-weekly for multiple years in a row. These trends are a regression analysis of all data that has been collected by LEA on that lake or pond since 1996 (or later if data is unavailable for earlier years). If the p-value of the regression is less than 0.05, it is an increasing or decreasing trend (depending on the direction of the trend). If the p-value is above 0.05, there is no significant trend and that parameter is considered stable. These trends show water quality changes over time.

On lakes that are only visited once annually, the long term average is compared to current water quality conditions. The long-term average is a simple mean of all the data we have on record for each parameter (clarity, chlorophyll, and phosphorus). The long-term average uses all the data available rather than just data collected in or after 1996. The long-term average doesn't tell us specifically how each parameter changes over time; it is instead used to see how the current year's data compares to historical values. A t-test was used to compare 2020 average values against long-term average values. This shows us if 2020 data is significantly different than historic data. If the p-value is above 0.05, there is no significant difference between 2020 averages and long-term averages. If the p-value is below 0.05, there is a significant difference between 2020 averages and long-term averages.

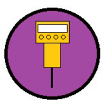
Coldwater Fish Habitat

Suitable habitat is defined as being below 15.5 °C and above 5 ppm dissolved oxygen. Marginal habitat is between 15.5 and 20 °C and above 4 ppm oxygen. Coldwater fish habitat is considered a water quality issue in lakes with coldwater fisheries that do not have at least 2 meters' worth of suitable habitat at all times during the testing season.

Individual Lake Summaries

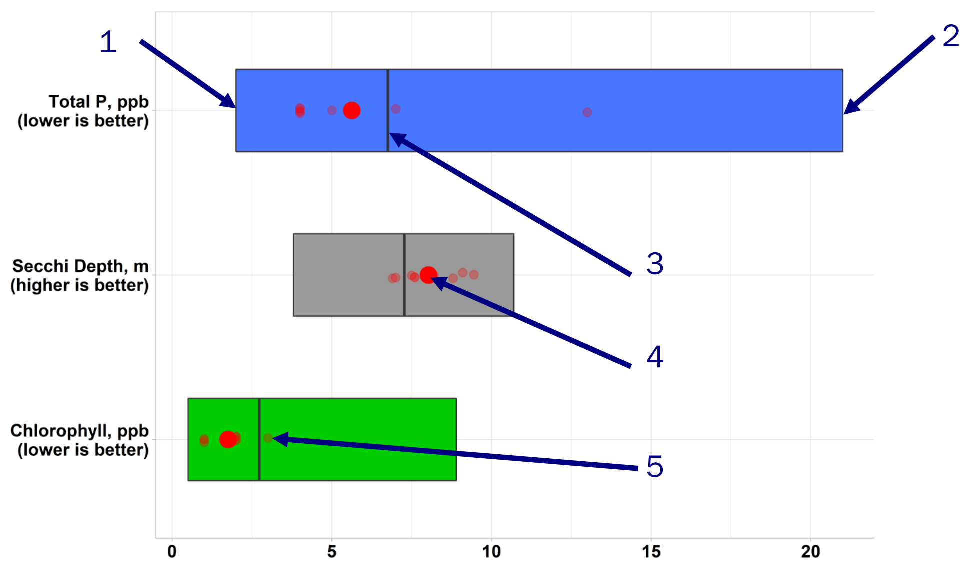
The following pages present 2020 routine monitoring data by lake. Graphs or charts have been included in the individual summary information to help show particular conditions or trends. You will also see the following symbols in the top right corner of some pages. These symbols indicate that additional data for that lake is available in chapters 2—4.

This symbol indicates that a series of temperature sensors was deployed in the lake in 2020. More information is available in Chapter 3.



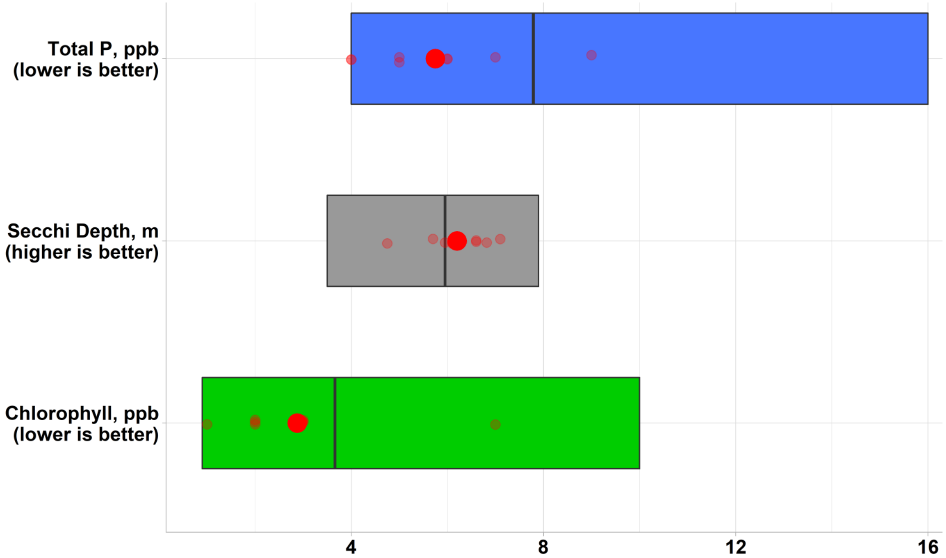
This symbol indicates that fluorometer profiles were taken from the lake in 2020. Fluorometer results are discussed in Chapter 4.

Reading and Interpreting Graphs



1. Lowest value in the data set—far left edge of colored rectangle
2. Highest value in the data set—far right edge of colored rectangle
3. Average value in the data set—black bar bisecting rectangle
4. Current year's average value—large red dot
5. Past year's average values—smaller red dots

Keoka Lake



Surface Area:	460 acres
Maximum Depth:	42 feet
Mean Depth:	25 feet
Volume:	10,569 acre-feet
Watershed Area:	3,808 acres
Flushing Rate:	0.7 flushes per year
Elevation:	492 feet

Keoka Lake surface water chlorophyll, phosphorus, and Secchi depth data summary
Colored boxes represent the long-term range of values, from minimum to maximum, obtained on Keoka Lake. The line represents the long-term average value and the dot represents 2020's average value. The small red dots represent individual readings taken in 2020.

2020 Water Quality Highlights

The average Secchi disk reading for 2020 was 6.20 meters, fell into the moderately clear range, and was deeper than the long-term average of 5.97 meters. The average total phosphorus reading of 6.00 ppb fell into the moderate range and was less than the long-term average of 8.00 ppb. The chlorophyll -a average of 2.90 ppb fell into the moderate range and was lower than the long-term average of 3.66 ppb. Long-term trend analysis indicates chlorophyll–a concentrations in Keoka Lake are stable, total phosphorus concentrations are decreasing, and clarity readings are increasing. The average color reading for 2020 was 19.00 SPU, indicating that water in Keoka Lake is moderately colored. Suitable coldwater fish habitat was present through June. As water temperatures increased and deep water oxygen was consumed, coldwater fish habitat became moderate in July and became unsuitable from August through September.

Keoka Lake's 2020 Quick Stats

	Water Color (SPU)	Clarity Trend	Phosphorus Trend	Chlorophyll-a Trend
Analysis Result	19.00	Increasing	Decreasing	Stable
Interpretation	Water was moderately colored	Deeper clarity readings over time	Less phosphorus in water over time	Neither more nor less chlorophyll over time

Introduction to High-Resolution Temperature Monitoring

LEA began using in-lake data loggers to acquire high resolution temperature measurements in 2013. The loggers, which are also interchangeably referred to as HOBO sensors, temperature sensors, or thermistors, are used to provide a detailed record of temperature fluctuations within lakes and ponds in our service area. This information allows for a better understanding of the thermal structure, water quality, and extent and impact of climate change and weather patterns on the waterbody tested.

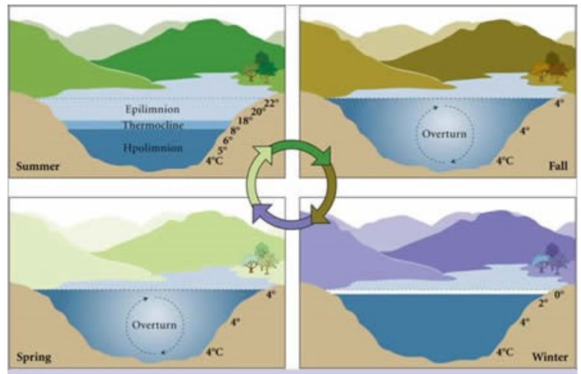
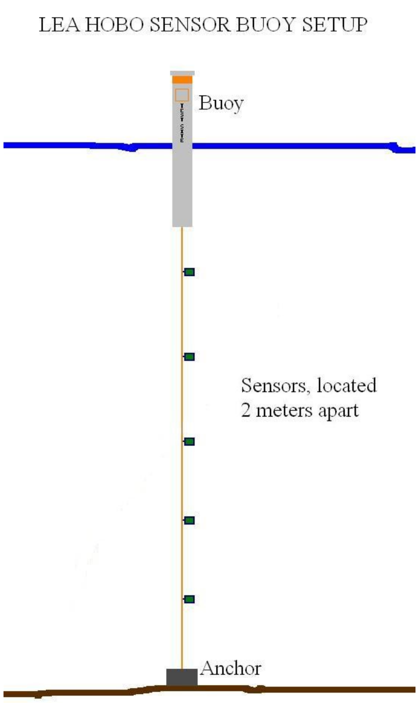


Diagram of Seasonal Stratification and Lake Mixing
Young, M. (2004). *Thermal Stratification in Lakes*. Baylor College of Medicine, Center For Educational Outreach.

Each year, we attempt to capture the entire stratified period within the temperature record, from when stratification begins to form in the spring to when the lake mixes in the fall. Stratification refers to the separation of lake waters into distinct layers, and is a natural phenomenon that has important consequences for water quality and lake ecology. See page 6 for more information about stratification.

Water temperature is critical to the biological function of lakes as well as the regulation of chemical processes. Lake temperature and stratification are greatly influenced by the weather. Air temperature, precipitation, and wind speed and direction can all affect water temperature and stratification patterns from year to year. Lake size, depth, and shape also greatly impact stratification timing and strength. The larger the difference in temperature between the top and bottom layers of the lake, the stronger the stratification is.



With funding and support from local lake associations, LEA has deployed temperature sensors at sixteen sites on thirteen lakes and ponds. Sensors are attached to floating line held in place by a regulatory-style buoy and an anchor. The sensors are attached at 2 meter intervals, beginning 1 meter from the bottom and ending approximately 1 meter from the top. Each buoy apparatus is deployed at the deepest point of the basin it monitors. The setup results in the sensors being located at odd numbered depths throughout the water column (the shallowest sensor is approximately 1 meter deep, the next is 3 meters, etc.).

Temperature sensors are programmed to record temperature readings every 15 minutes. LEA has for many years used a handheld YSI meter to collect water temperature data.

However, this method is time consuming, resulting in only 8 temperature profiles per year. While temperature sensors require an initial time investment, once deployed, the sensors record over 15,000 profiles before they are removed in the fall. This wealth of data provides much greater detail and clarity than the traditional method ever could. Daily temperature fluctuations, brief mixing events caused by storms, the date and time of stratification set up and breakdown, and the timing of seasonal high temperatures are all valuable and informative events that traditional sampling can't accurately measure.

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2020 Monitoring Season

This year, water temperatures increased greatly in late June and stayed high through mid-August. The highest recorded temperatures across all lakes were between July 28th and August 14th. This is inconsistent with the usual timing of the peak in temperature, which is typically in late July. Temperatures gradually cooled throughout late summer and fall. The timing of mixing depended greatly on lake depth, size and shape.

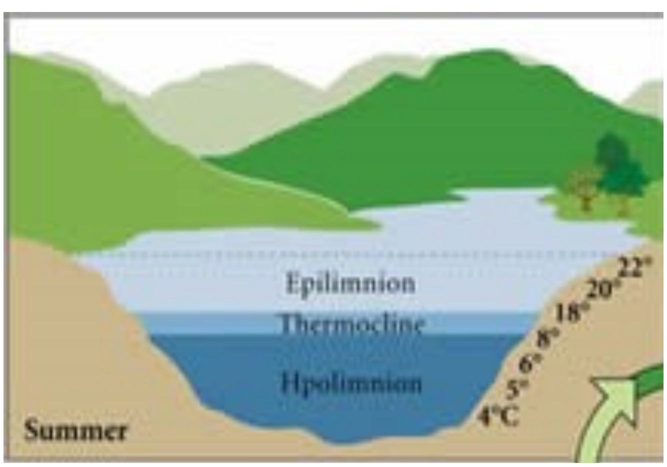
A HOBO temperature sensor

Lack of significant summer rainfall, coupled with high temperatures, led to very low lake levels throughout much of the summer season. Water levels did not recover until fall. This is noteworthy because fluctuations in water levels affect the relative depth of the temperature sensors.

High-Resolution Temperature Monitoring: How to Read the Graph

The temperature monitoring summary includes a graph that displays all the data collected in the 2020 season. These graphs can be tricky to understand, so here are a few pointers:

- Each colored line represents the temperature over time at a specific depth in the water. The topmost lines represent water near the top of the lake (red = 1 meter below the surface, etc.), with a difference of 2 meters (approx. 6 feet) in depth between each line.
- The graph shows temperature change over time – The horizontal axis (left to right) shows the date, while the vertical axis (up and down) shows the temperature (in degrees Celsius).
- Generally, the lines are close together on the left side of the graph because temperature is fairly uniform throughout the water column (late April/early May), then widen out (June-August), then come back together on the right side of the graph when temperature is again uniform (September-November). The top few lines may stay close to each other when the graph widens out, indicating these depths are within the epilimnion (see below). Then, there is often a gap in the middle, indicating the rough position of the thermocline. Most of the time, the bottom lines stay relatively flat, indicating that they are within the hypolimnion.
- Large gaps between lines means there is a large temperature difference between depths.
- The pattern in temperature displayed by the top line (the sensor nearest to the lake's surface) is strongly influenced by air temperature.
- During stratification, the epilimnion does not easily mix with the hypolimnion (hence, these lines do not touch each other). It is only when the temperature of the upper water cools down that the lake can fully mix. You can see this process happening on each graph: the temperatures near the surface get cooler and the deeper waters get warmer as the barrier between the two layers weakens and the waters begin to mix. The lines converge one by one until the temperature is the same at each depth. This is known as lake turnover or destratification.



Stratification Terms

Epilimnion: The warm, top layer that forms when a lake stratifies. It is heavily influenced by air temperature and is well mixed by wind.

Thermocline: A zone of rapid temperature and density change that separates the epilimnion from the hypolimnion.

Hypolimnion: The cold, bottom layer that forms when a lake stratifies. This layer is cut off from the surface layer and cannot mix with it until stratification breaks down.

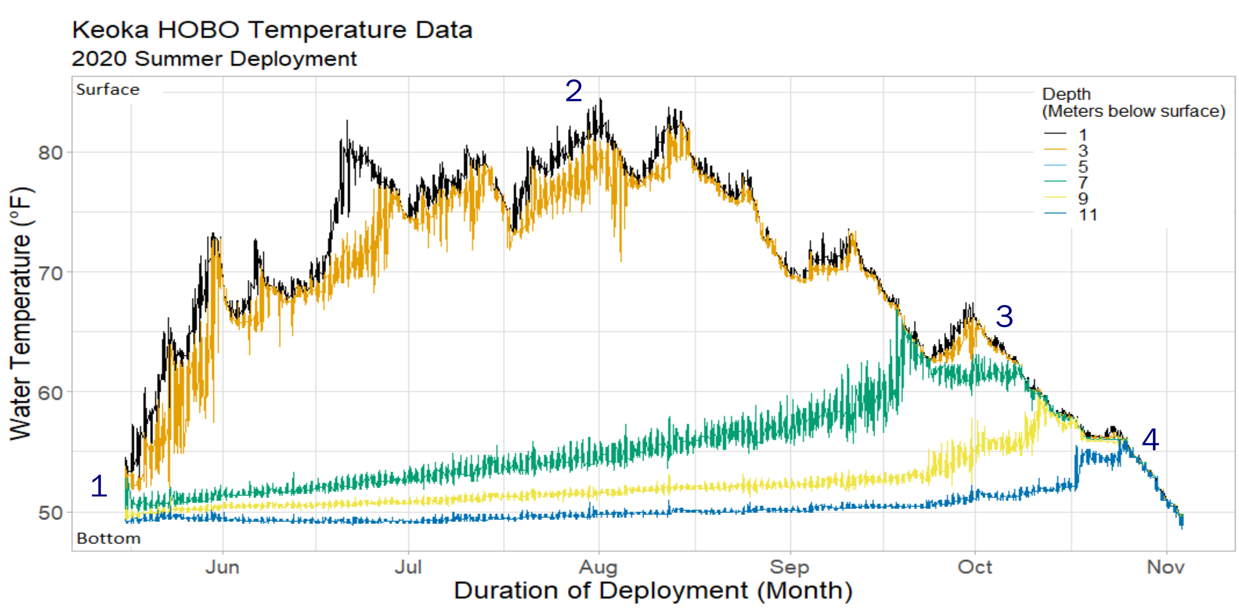
Keoka Lake

Summary

Note that the 5-meter sensor malfunctioned during the season. We can use temperature data collected during our regular monitoring efforts to help fill in the information gaps left by the broken sensor. When sensors were deployed on May 15, the water column of Keoka Lake had begun to divide into layers based on temperature (stratified). Keoka Lake had distinctly and strongly stratified by mid-June. The wide gaps between the 3-meter and 7-meter lines indicate that for much of the season the thermocline was between these depths. The depths above and below the thermocline are markedly different. Temperature differences like this prevent colder, deeper waters from mixing with warmer, shallower waters, thus reducing the chance that nutrient-rich deep waters could mix with the surface waters and feed algae populations. As water temperature began to cool further in September and October, waters down to 9 meters began to mix with shallower waters. Full mixing occurred on October 25.

The following events can be seen in the graph below:

1. Keoka Lake had started to stratify when sensors were deployed on May 15.
2. While surface waters were warm from late June through mid-August, the peak in temperature of 84.47 °F occurred on August 1.
3. After a warm spell in early October, waters between 1—7 meters briefly re-stratified.
4. Full mixing occurred on October 25.



Deployment Date	Peak Temperature (°F)	Full Mixing	Retrieval Date
5/15/2020	84.47	10/25/2020	11/4/2020

LEA's Algae & Fluorometric Chlorophyll Monitoring Programs

Sample Sites
Back Pond
Hancock Pond
Keoka Lake
Keyes Pond (fluorometer only)
McWain Pond
Middle Pond
Moose Pond (Main Basin)
Moose Pond (North Basin)
Moose Pond (South Basin)
Peabody Pond
Sand Pond
Trickey Pond
Woods Pond

Chlorophyll-a is a pigment found in all plants, including algae. Because all algae contain chlorophyll-a, it can be used as a proxy for algae abundance. Algae use this pigment during photosynthesis which produces oxygen as a by-product. Monitoring is essential to understanding the water quality status of lakes since high chlorophyll-a concentrations can indicate algae blooms and declining water quality conditions.

Traditional sampling measures chlorophyll-a from a composite sample of the top layer of the lake, so any variability with depth cannot be seen. When lakes stratify in the summer they have a top layer — the epilimnion — which is the warm, sunlit mixed layer. The middle layer, or thermocline, is a zone of rapid temperature and density change. The bottom layer is known as the hypolimnion and is cold, dark, and in many lakes, prone to oxygen depletion.

The fluorometer, which is calibrated to measure chlorophyll-a, works by emitting blue light at a specific wavelength designed to cause the chlorophyll -a molecules to enter a high-energy ("excited") state. When the molecules return to their normal state, they give off light (fluoresce) at a different wavelength. The instrument measures the strength of this return wavelength. The stronger it is, the more chlorophyll-a there is. However, fluorometer readings can be affected by water temperature and light levels. According to the fluorometer manufacturer, chlorophyll fluorescence decreases by 1.4% for every 1°C rise in temperature. Algae respond to low light levels by pushing chlorophyll-a to the surface of their cells, which means that a reading in low light may actually fluoresce more than in bright light, when the algae don't have to work as hard to photosynthesize.

The fluorometer reports result in Relative Fluorescence Units (RFUs). This measurement result is not a direct comparison to data obtained through the chlorophyll sampling done on each lake during regular water testing. The fluorometer provides qualitative data, rather than quantitative. Data collected by the fluorometer must therefore be treated as estimates, which are very useful for viewing trends and comparing among lakes.

Monthly fluorometer profiles were collected from each lake and pond in this chapter for five months. Each summary contains a graph of the lake's results. Many lakes contain a chlorophyll maximum near the thermocline. There are a few reasons why this tends to happen. One is that there is a large density difference between the warm upper-layer water and cold bottom-layer water, so algae that sink down from the upper layer tend to be slowed down here and accumulate. Another reason is that some algae actually preferred the area near the thermocline. While the thermocline is a common place to see algae, algae can, and do, grow deeper in the water column where there are often more nutrient resources.

Keoka Lake

Summary

Each month, a fluorometric profile was taken to identify approximate chlorophyll-a concentrations via strength of fluorescence signal. An increase in fluorescence (and therefore chlorophyll-a) near the thermocline (the zone of rapidly changing temperature and density that separates a lake's upper and lower layers during stratification) is seen most months. This phenomenon is common in many of the lakes we monitor and is likely a result of algae "sitting" on top of the denser cold water and continuing to photosynthesize. Although the fluorescence signal is less strong in warmer waters, these temperatures are more conducive to fast-growing algae, and for this reason, we see the highest readings in August.

The following events can be seen in the graph below:

1. Early season fluorescence peak likely due to stronger flurometric signal in colder water.
2. Peak chlorophyll fluorescence occurred in August.
3. The spike in fluorescence seen near the pond bottom is likely caused by interference from bottom sediments.