Lakes Environmental Association

Hancock Pond and Sand Pond

Water Monitoring Report

2021

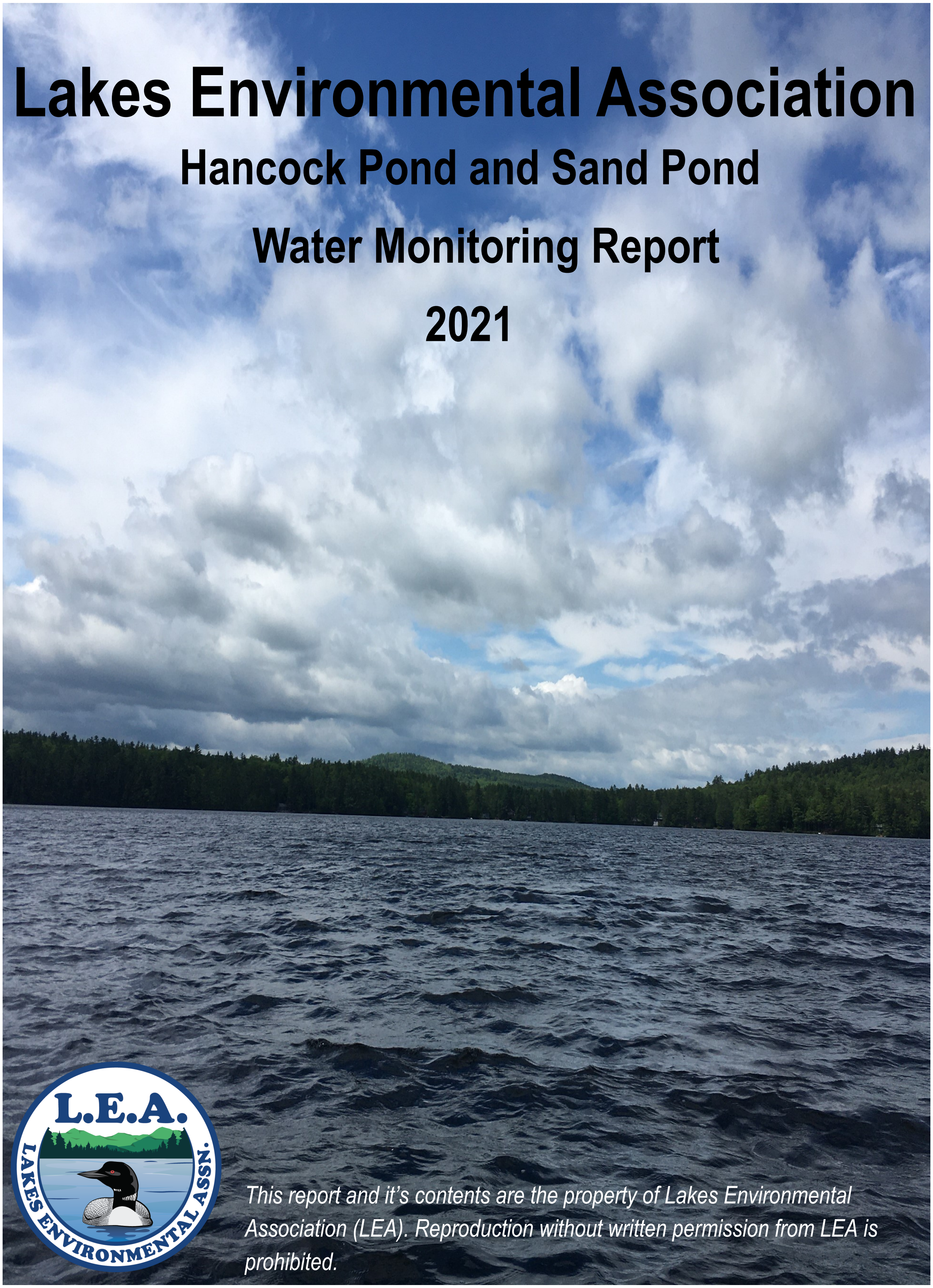


Table of Contents

About LEA

The Lakes Environmental Association (LEA) is a non-profit organization founded in 1970. LEA's mission is to preserve and restore the exceptional water quality of Maine's lakes, ponds, rivers, streams, and wetlands and the integrity of their watersheds. Headquartered in Bridgton, Maine, LEA's service area includes six towns in the western Maine Lakes Region, although its reach and influence extends across the whole state.

Lake Water Testing

Water testing on 41 lakes and ponds in LEA's service area occurs every year through traditional and advanced testing initiatives. Data collected and presented in this report contributes to our long-term understanding of lake/pond behavior and health. Our data are available to the public through Maine's Department of Environmental Protection and on LEA's website.

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 Research Forest, and Pondicherry Park, all of which LEA played a key role in establishing.

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!

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	2021 Average			1996—2021 Trend		
	Clarity	**Phosphorus**	**Chlorophyll-*a***	**Clarity**	**Phosphorus**	**Chlorophyll-*a***
ADAMS POND	High	Low	Low	Increasing	Stable	Stable
BACK POND	Moderate	Moderate	Low	Increasing	Stable	Stable
BEAR POND	Moderate	Moderate	Moderate	Stable	Decreasing	Stable
BRANDY POND	Moderate	Moderate	Low	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	High	Moderate	Moderate	Increasing	Decreasing	Decreasing
HIGHLAND LAKE	High	Moderate	Moderate	Increasing	Decreasing	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	High	Moderate	Low	Stable	Stable	Stable
LONG LAKE (North)	Moderate	Moderate	Moderate	Stable	Stable	Decreasing
LONG LAKE (Middle)	Moderate	Moderate	Low	Stable	Stable	Decreasing
LONG LAKE (South)	Moderate	Moderate	Moderate	Stable	Decreasing	Decreasing
McWAIN POND	Moderate	Moderate	Moderate	Stable	Decreasing	Decreasing
MIDDLE POND	Moderate	Moderate	Moderate	Increasing	Decreasing	Decreasing
MOOSE POND (Main)	High	Moderate	Moderate	Stable	Stable	Decreasing
MOOSE POND (North)	Moderate	Moderate	Moderate	Stable	Stable	Stable
MOOSE POND (South)	Moderate	Moderate	Moderate	Stable	Increasing	Stable
PEABODY POND	High	Moderate	Moderate	Increasing	Stable	Stable
SAND POND	Moderate	Moderate	Moderate	Decreasing	Stable	Stable
STEARNS POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
TRICKEY POND	High	Moderate	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 1996-2021 were analyzed to determine if chlorophyll-*a* and phosphorus concentrations are changing 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 1996-2021 were analyzed to determine if water clarity is changing over time. Clarity is measured in meters (m). Higher numbers indicate clearer water.

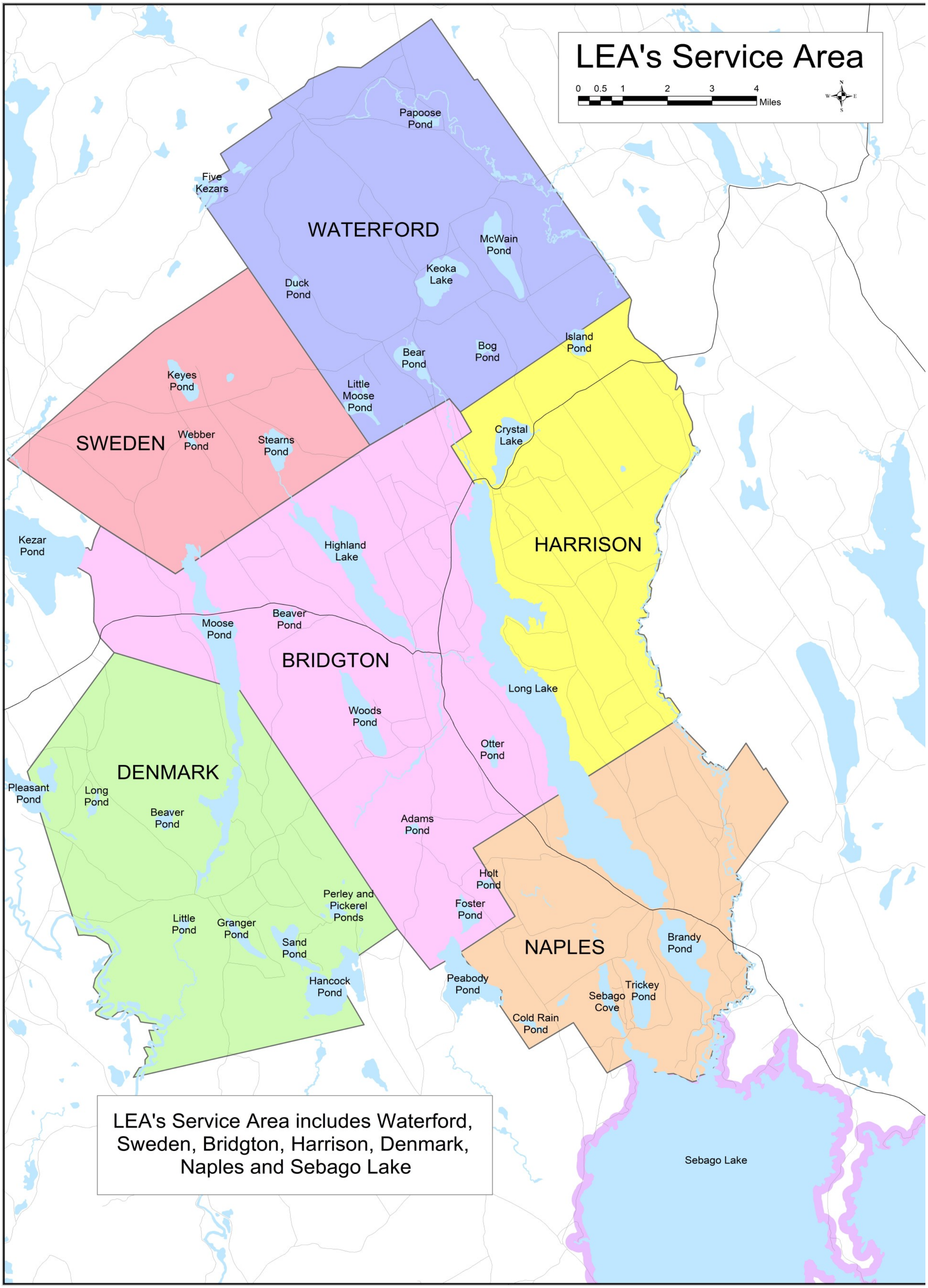
Increasing = higher clarity readings over time

Stable = clarity readings are neither higher nor lower over time

Decreasing = lower clarity readings over time

2021 Average Chlorophyll-*a* concentrations, Phosphorus concentrations, Color and Clarity readings: Chlorophyll-*a* and phosphorus concentrations throughout the 2021 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	Color in Standard Platinum Units (SPU)
10.1 + Very high	less than 5.1 Low	less than 2.1 Low	Less than 10.1 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 3.1 Low	20.1 + Very high	12.1 + Very high	60.1+ Very high


LEA's Service Area
0 0.5 1 2 3 4
Miles
WATERFORD
SWEDEN
BRIDGTON
HARRISON
DENMARK
NAPLES
Papoose Pond
Five Kezars
McWain Pond
Keoka Lake
Duck Pond
Island Pond
Bog Pond
Bear Pond
Keyes Pond
Little Moose Pond
Crystal Lake
Webber Pond
Stearns Pond
Kezar Pond
Highland Lake
Moose Pond
Beaver Pond
Long Lake
Woods Pond
Otter Pond
Pleasant Pond
Long Pond
Beaver Pond
Adams Pond
Holt Pond
Foster Pond
Perley and Pickerel Ponds
Little Pond
Granger Pond
Sand Pond
Brandy Pond
Hancock Pond
Peabody Pond
Trickey Pond
Sebago Cove
Cold Rain Pond
LEA's Service Area includes Waterford, Sweden, Bridgton, Harrison, Denmark, Naples and Sebago Lake
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!**

2021 Volunteer Monitors and Lake Partners

Richard and Andy Buck
Papoose Pond Campground
Steve Cavicchi
Jeff and Susan Chormann
Janet Coulter
Joe and Carolee Garcia
Carol Gestwicki

Bill Ames and Paulina Knibbe
Bob Mahanor
Amy March
Julie and Dan McQueen
Bob Mercier
Barry and Donna Patrie
Nancy Pike
Shelley Hall

Jean Preis
Jean Schilling
Linda and Orrin Shane
Foster and Marcella Shibles
Bob Simmons
Tom Straub
Don and Pat Sutherland

Five Kezar Ponds Watershed Association
Hancock and Sand Ponds Association
Island Pond Association

Keoka Lake Association
Keyes Pond Environmental Protection Association
McWain Pond Association
Woods Pond Water Association

Moose Pond Association
Peabody Pond Protective Association
Trickey Pond Environmental Protection Association

2021 Water Testing Crew

Shannon Nelligan Erin Antosh Hanna Holden

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.

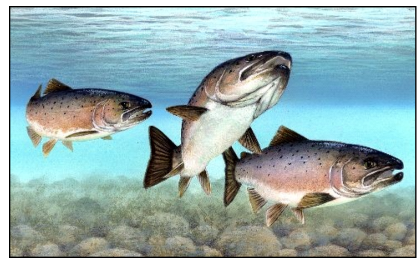
Phosphorus, the limiting element controlling algae growth in our lakes, is often more abundant in the hypolimnion because it is stored in sediments.

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

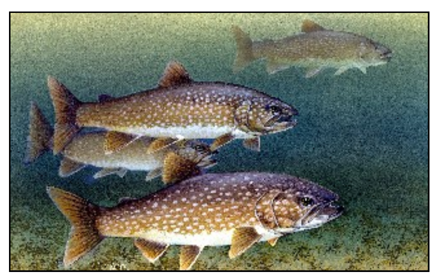
The warm upper waters are sunlit, wind-mixed and oxygen rich.



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.

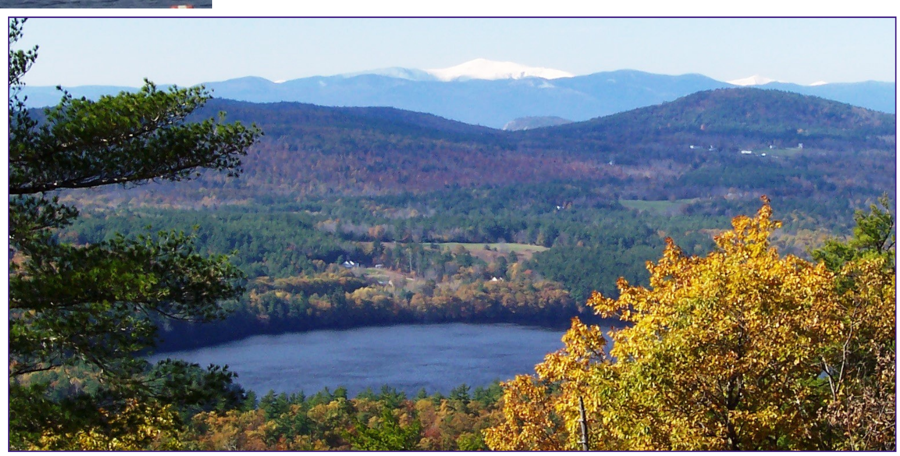
A year in the life of a lake

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.



Lakes Environmental Association

2021 Water Testing Report

Chapter 1 — Water Quality Monitoring

Water Quality Testing Parameters

LEA's testing program provides a comprehensive assessment of general lake health. Tests are conducted for clarity, color, temperature, chlorophyll-*a,* phosphorus, dissolved oxygen, conductivity, pH, and alkalinity.

Clarity is a measure of water transparency. Clarity is measured with a Secchi disk and is reported in meters. Higher Secchi values indicate clearer water. Clarity is affected by water color and the presence of algae and suspended particles.

Color is a measure of tannic or humic acids in the water. Color affects water clarity and is reported in Standard Platinum Units (SPU). Higher values indicate darker water.

Temperature is measured at one-meter intervals from the surface to the bottom of the lake. Temperature data are used to assess thermal stratification. Temperature is recorded in degrees Celsius.

Chlorophyll-*a* is a pigment found in all algae. Chlorophyll (the –*a* is dropped for simplicity) 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 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. Phosphorus is measured in parts per billion (ppb). Phosphorus samples are collected from the lake's upper layer (epilimnion) while deep-water phosphorus samples are collected at individual depths using a grab sampler. Upper-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 (10 ppb or higher than upper-layer phosphorus samples), this is an indication that sediments are releasing phosphorus and that the lake is potentially 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 could fuel 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.

Other measurements: We collect data on these parameters, but they tend to remain stable over long periods of 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.
>
> **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.

Interpreting Data Summaries

Water Quality Classification

Each lake's clarity, chlorophyll, and phosphorus results will be discussed in the following 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.

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

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 5.1	Low	less than 2.1	Low	Less than 10.1	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 3.1	Low	20.1 +	Very high	12.1 +	Very high	60.1+	Very high

Trends and Long-term Averages

Lake summaries include a summary of clarity, chlorophyll, and phosphorus trend analysis. Trends are determined for each lake that has been visited bi-weekly for multiple years in a row and includes data from 1996—2021. These trends help us estimate the relationship between a water quality variable and time. For example, on any given lake we plot all of the clarity readings we have collected for that lake since 1996 and plot each of them on a graph with time on the horizontal axis and Secchi depth on the vertical axis. We then fit a 'best fit' line through the data. If the direction of the line trends up, it is a positive trend, while a flat line or a downward line indicate either stable rend, or a decreasing trend respectively. This shows us how water clarity readings are changing over time on that lake.

The long-term average is compared to current water quality conditions for all lakes visited. The long-term average is a simple mean of all the data we have on record for each reported 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.

Coldwater Fish Habitat

Suitable habitat is defined as being below 15.5^{o} C and above 5 ppm dissolved oxygen. Marginal habitat is between 15.5 and 20^{o} 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. Suitability of coldwater fish habitat is estimated by using temperature and oxygen data collected during bi-weekly visits. Temperature and oxygen data are analyzed at each depth and categorized as either: suitable, marginal, or unsuitable based on the parameters discussed above.

2021 as a Year

Our 2021 summer water testing interns continued to embrace coronavirus safety protocols while they diligently collected: 278 Secchi readings; 227 oxygen and temperature profiles; 227 hypolimnetic core samples (all of which were analyzed for color, pH, conductivity, alkalinity, total phosphorus concentration, and chlorophyll concentration); 64 fluorometer profiles, 124 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 that continue to be marked by public health crisis!

2021 began with shallow snow pack and dry conditions. As a result, the water testing season began during mild drought conditions. The National Weather Service reported record high air temperatures in June, which resulted in a few of LEA's lakes recording their warmest surface water temperatures in June. The National Weather Service also reported record low temperatures and record high precipitation levels in July. July's high rainfall saw the end of drought conditions for our area. Air temperatures (and water temperatures) rose again in August and persisted through the end of the testing season in late September.

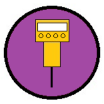
In 2021, 85% of the lakes we monitor bi-weekly had either stable or increasing clarity trends, 92% had either stable or decreasing total phosphorus trends, and 96% had either stable or decreasing chlorophyll-*a* trends. Of the lakes we monitor once annually, 84% had either stable or increasing clarity trends, 90% had either stable or decreasing total phosphorus trends, and 95% had either stable or decreasing chlorophyll trends. In 2021, periods of high rain were often followed by lower Secchi readings and higher phosphorus concentrations. This is likely due, in large part, to nutrients and sediments washed into lakes by the rainfall events. Nevertheless, water testing results for 2021 show a great year for water quality in the Lakes Region.

Thanks to those who facilitate our work by providing lake access and boat access to LEA staff!

Interpreting Data Graphics

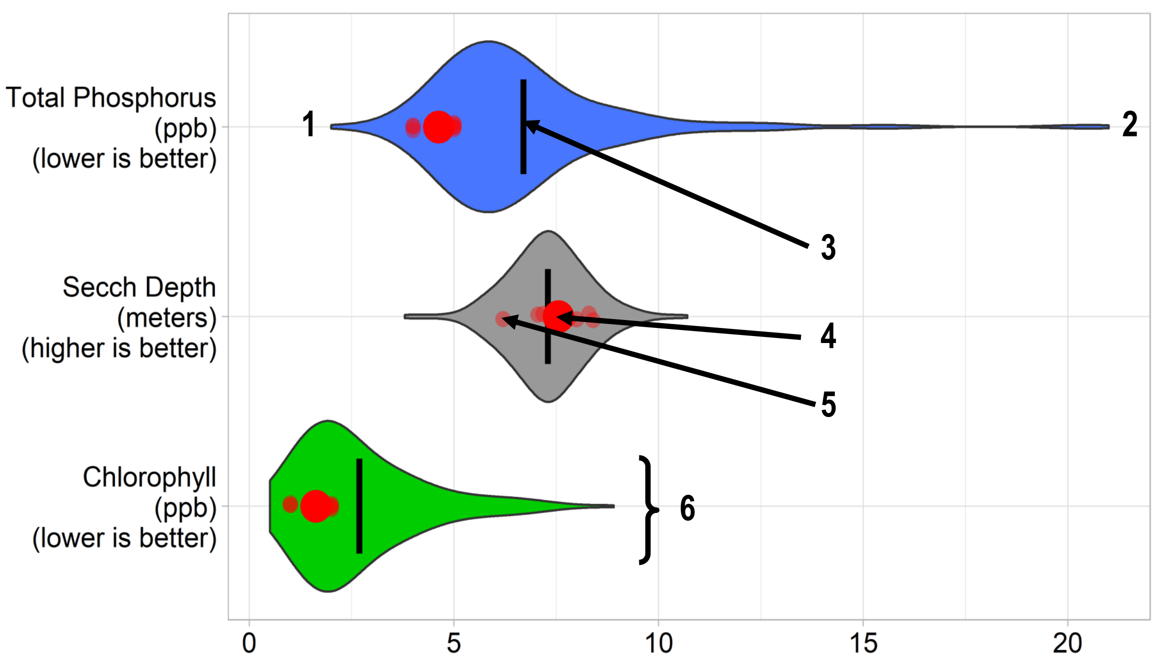
The following pages present 2021 routine monitoring data by lake. The following symbols in the top right corner of some pages indicate that additional data for that lake is available in chapters 2 - 3.

This symbol indicates that high resolution temperature sensors was deployed in the lake in 2021. More information is available in Chapter 2.



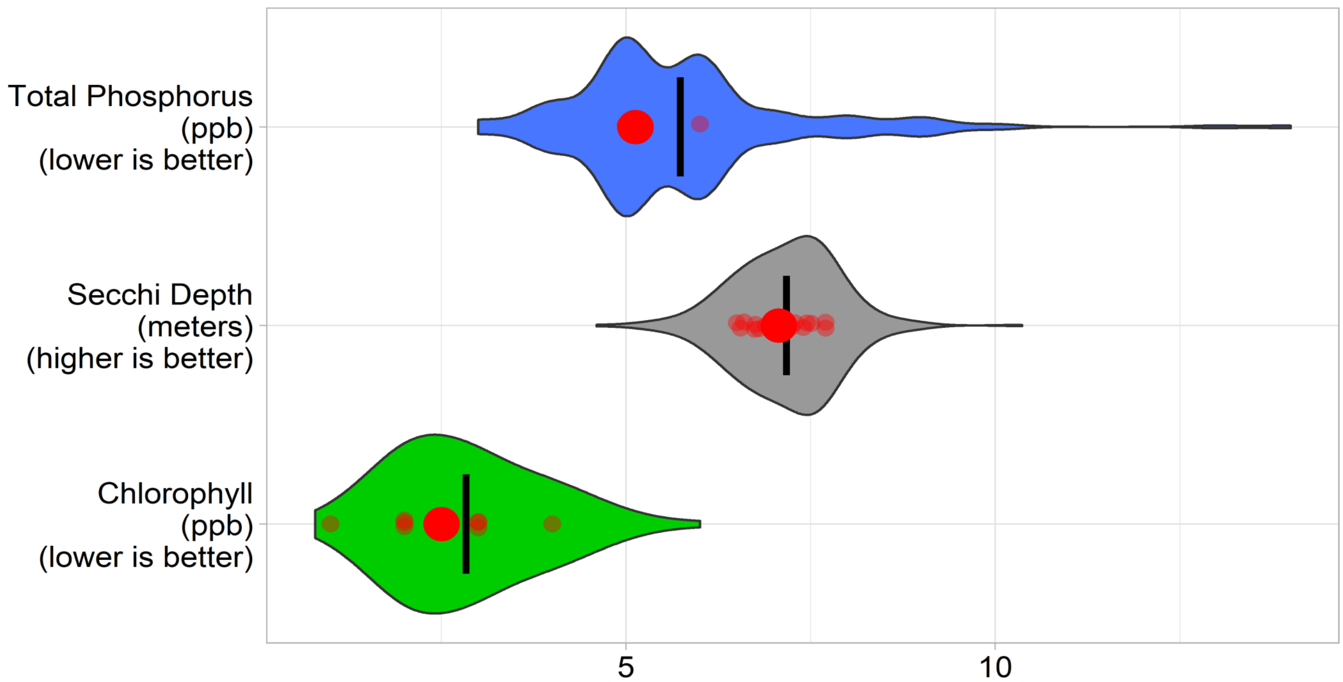
This symbol indicates that fluorometer data were taken from the lake in 2021. Fluorometer results are discussed in Chapter 3.

Graphs have been included for each test site to visually compare 2021 data to historic data (1996—2021). The vertical axis (y-axis) indicates the condition while the horizontal axis (x-axis) represents reported values. Three different conditions are being reported on the same graph, which results in the value units for the horizontal axis varying, based on condition. Condition units are noted in parentheses under the vertical axis label. Area thickness increases as more measurements are reported at that value. Thus, thicker areas indicate that several measurements have been reported at that value, while thinner areas indicate that fewer measurements have been reported at that value.



1. Long-term minimum value — far left edge of colored area
2. Long-term maximum value — far right edge of colored area
3. Long-term average value — vertical black bar bisecting colored area
4. Reporting year's average value — large red dot
5. Reporting year's raw values — smaller red dots
6. Thickness of colored area — frequency of past measurements at specific values

Hancock Pond



Hancock Pond's surface water chlorophyll (ppb), phosphorus (ppb), and Secchi depth (meters) data comparison. Colored areas represent the long-term range of values, from minimum to maximum. Area thickness indicates frequency of measurements at that value. Area thickness increases as more measurements are reported at that value. The vertical black line represents the long-term average value. The large red dot represents 2021's average value. The small red dots represent individual readings taken in 2021.

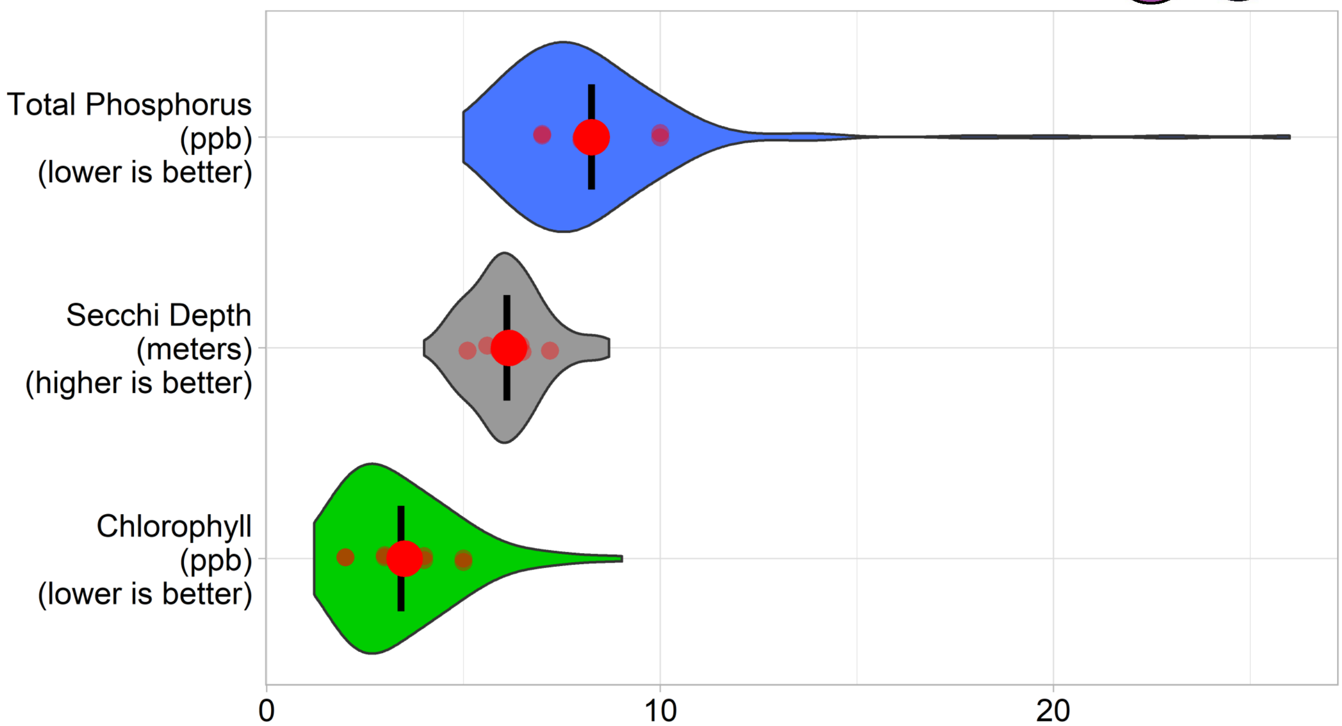
2021 Water Quality Highlights

The average Secchi disk reading for 2021 is 7.1 meters, which falls into the moderately clear range. The average total phosphorus reading of 5.1 ppb falls into the moderate range. The average deep water phosphorus value was not significantly above surface water phosphorus values, which suggests phosphorus recycling is not problematic. The chlorophyll-a average of 2.5 ppb falls into the moderate range. Long-term trend analysis indicates chlorophyll–a concentrations in Hancock Pond are decreasing, total phosphorus concentrations are decreasing, and clarity readings are increasing. The average color reading for 2021 is 25.3 SPU, indicating that water in Hancock Pond is highly colored. Suitable coldwater fish habitat was present from June through July. Coldwater fish habitat became marginal in August and unsuitable in September.

Hancock Pond's 2021 Quick Stats

	Average Deep Water Phosphorus (ppb)	Water Color (SPU)	Clarity Trend	Phosphorus Trend	Chlorophyll-a Trend
Analysis Result	8.6	25.3	Increasing	Decreasing	Decreasing
Interpretation	Within acceptable range	Water was highly colored	Deeper clarity readings over time	Less phosphorus in water over time	Less chlorophyll in water over time

Sand Pond



Sand Pond's surface water chlorophyll (ppb), phosphorus (ppb), and Secchi depth (meters) data comparison. Colored areas represent the long-term range of values, from minimum to maximum. Area thickness indicates frequency of measurements at that value. Area thickness increases as more measurements are reported at that value. The vertical black line represents the long-term average value. The large red dot represents 2021's average value. The small red dots represent individual readings taken in 2021.

2021 Water Quality Highlights

The average Secchi disk reading for 2021 is 6.2 meters, which falls into the moderately clear range. The average total phosphorus reading of 8.3 ppb falls into the moderate range. The average deep water phosphorus value was not significantly above surface water phosphorus values, which suggests phosphorus recycling is not problematic. The chlorophyll-a average of 3.5 ppb falls into the moderate range. Long-term trend analysis indicates chlorophyll–a concentrations in Sand Pond are stable, total phosphorus concentrations are stable, and clarity readings are decreasing. The average color reading for 2021 is 25.3 SPU, indicating that water in Sand Pond is highly colored. Suitable coldwater fish habitat was present through June. In July, warming water temperatures and decreasing deep water oxygen concentrations resulted in coldwater fish habitat becoming marginal and then unsuitable. Unsuitable conditions persisted through September.

Sand Pond's 2021 Quick Stats

	Average Deep Water Phosphorus (ppb)	Water Color (SPU)	Clarity Trend	Phosphorus Trend	Chlorophyll-a Trend
Analysis Result	11.0	25.3	Decreasing	Stable	Stable
Interpretation	Within acceptable range	Water was highly colored	Shallower clarity readings over time	Neither more nor less phosphorus in water over time	Neither more nor less chlorophyll in water over time

Lakes Environmental Association

2021 Water Testing Report

Chapter 2—High-resolution Temperature Monitoring

Introduction to High-resolution Temperature Monitoring

LEA began using in-lake temperature sensors to acquire high-resolution temperature measurements in 2013. The sensors, which are also interchangeably referred to as HOBO sensors, are used to provide a detailed record of temperature fluctuations within lakes and ponds in our service area. High-resolution temperature data allows for a better understanding of a water body's thermal structure, water quality, and the possible influence of climate change.

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 Chapter 1, page 7 of the Water Testing Report for more information about stratification.

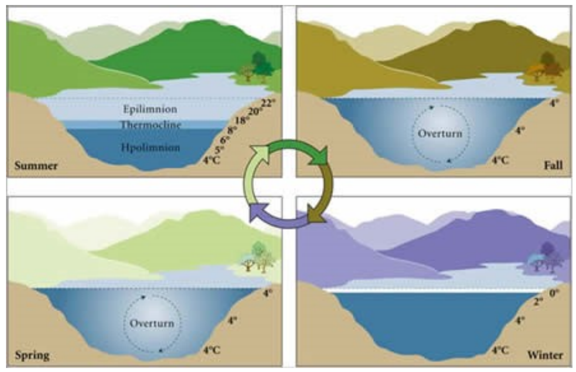
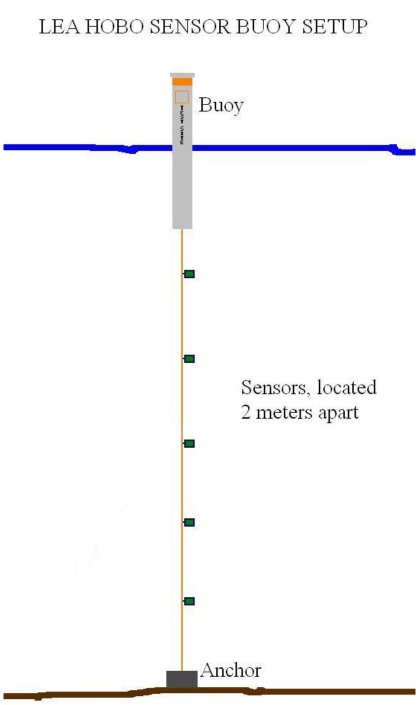


Diagram of Seasonal Stratification and Lake Mixing
Young, M. (2004). *Thermal Stratification in Lakes*. Baylor College

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 seventeen sites on thirteen lakes and ponds. Sensors are attached to a floating line held in place by a regulatory-style buoy and an anchor. The sensors are attached at 2-meter intervals, beginning one meter from the bottom and ending approximately one 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 eight 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.

2021 Monitoring Season

2021 began with shallow snow pack and dry conditions. Spring ice-out occurred on most lakes in early April. Temperature sensors were deployed in mid-May. Shallow snow pack prior to ice-out, coupled with dry conditions, contributed to low water levels and mild drought conditions, which persisted through mid-July.

Early season air temperature fluctuations resulted in many lakes distinctly warming in late May, visibly cooling in early June, re-warming in late June, and cooling again in early July. Surface water temperatures followed a more typical warming pattern from mid-July through August before beginning to cool in early September.

The National Weather Service reported record high air temperatures in June, which resulted in a few of LEA's lakes recording their warmest surface water temperatures in June. The National Weather Service also reported record low temperatures and record high precipitation levels in July. July's wet conditions saw the end of drought conditions for our area. Peak water temperatures generally occurred in mid to late August; however, the late August temperature peak was often within two degrees of readings from June.

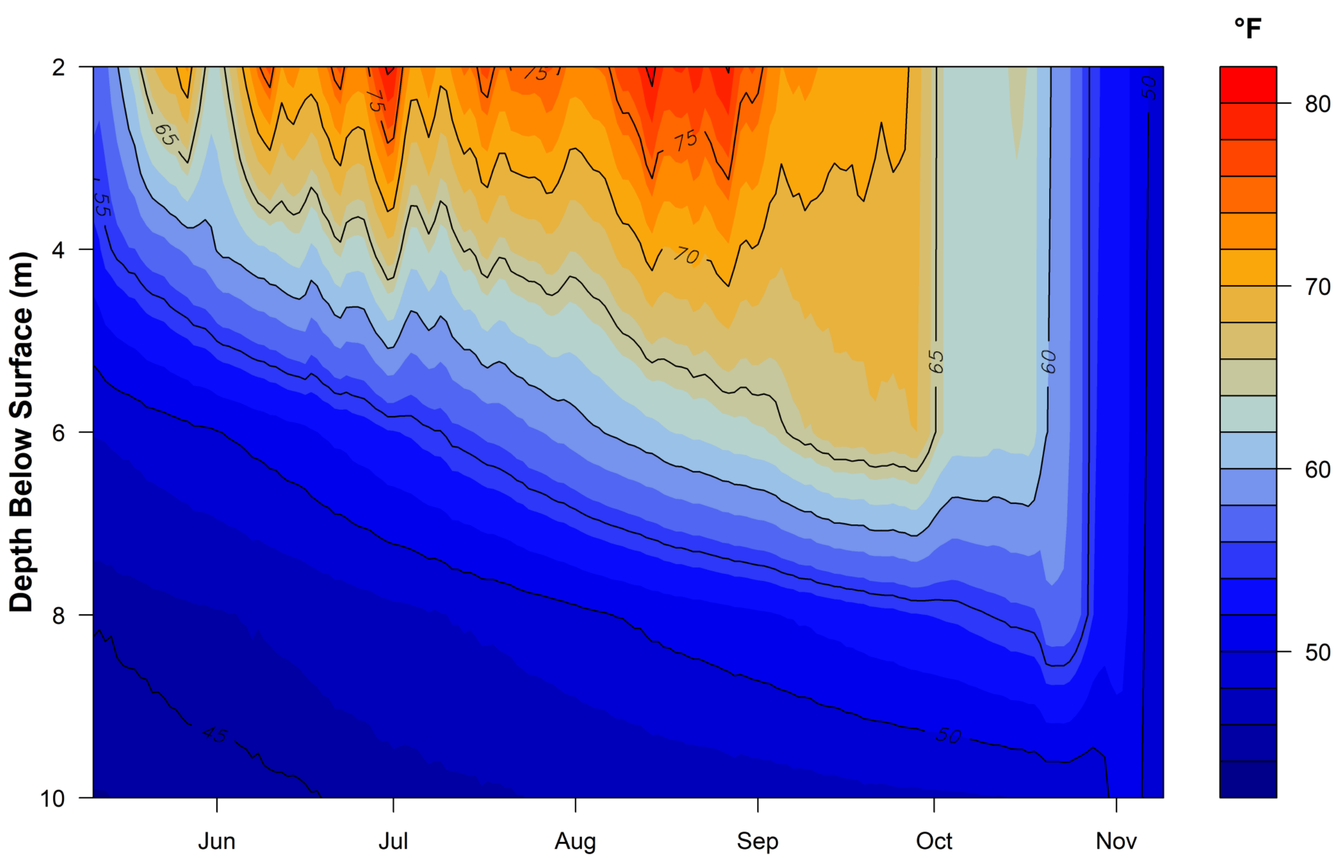
A HOBO temperature sensor

High-resolution Temperature Monitoring: How to Read the Graphs

Temperature monitoring summaries on the following pages include a temperature map for each lake, displaying all the data collected in the 2021 season. Temperature maps were generated using daily mean temperature values, which help determine temperature across depth and time. Temperature is represented by colored contours, where the red to blue color range corresponds to a high to low temperature range. The vertical bar on the right side of the temperature map indicates the temperature each color represents in degrees Fahrenheit (°F). The horizontal axis shows the months sensors were deployed, while the left hand vertical axis shows sensor depth (meters) below the water's surface.

Temperature stratification shows up as areas of the plot where colors change in the vertical direction and contour lines are tilted more towards horizontal (from June through early November). The area where temperature changes most rapidly with depth is often referred to as the thermocline. Vertical contour lines indicate mixed conditions, and areas of a single color from top to bottom (such as late-October into November) indicate completely mixed conditions. Warm, stratified conditions stand out as darker red areas. Large gaps between lines means there is a large temperature difference between depths.

During stratification, the shallower waters do not easily mix with the deeper waters. 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 de-stratification.



Hancock Pond

The water column of Hancock Pond was weakly stratified when sensors were deployed on May 16. By mid-June, Hancock Pond had stratified into distinct layers. Surface water temperatures increased in late May, cooled in early June, increased dramatically in late June, cooled slightly in July, and increased again in August. During the summer months, little temperature change was seen in Hancock Pond's deep waters, creating large temperature differences between shallow and deep waters. This large temperature difference limits cooler, nutrient-rich deep waters from mixing with warmer surface waters. When these two layers mix, it provides algae with an additional food source. Please note that the watershed can still contribute phosphorus to the lake, regardless of stratification. Hancock Pond's shallower waters began to cool in September through November. Full mixing had not yet occurred when sensors were retrieved on November 8.

The following events can be seen in the graph below:

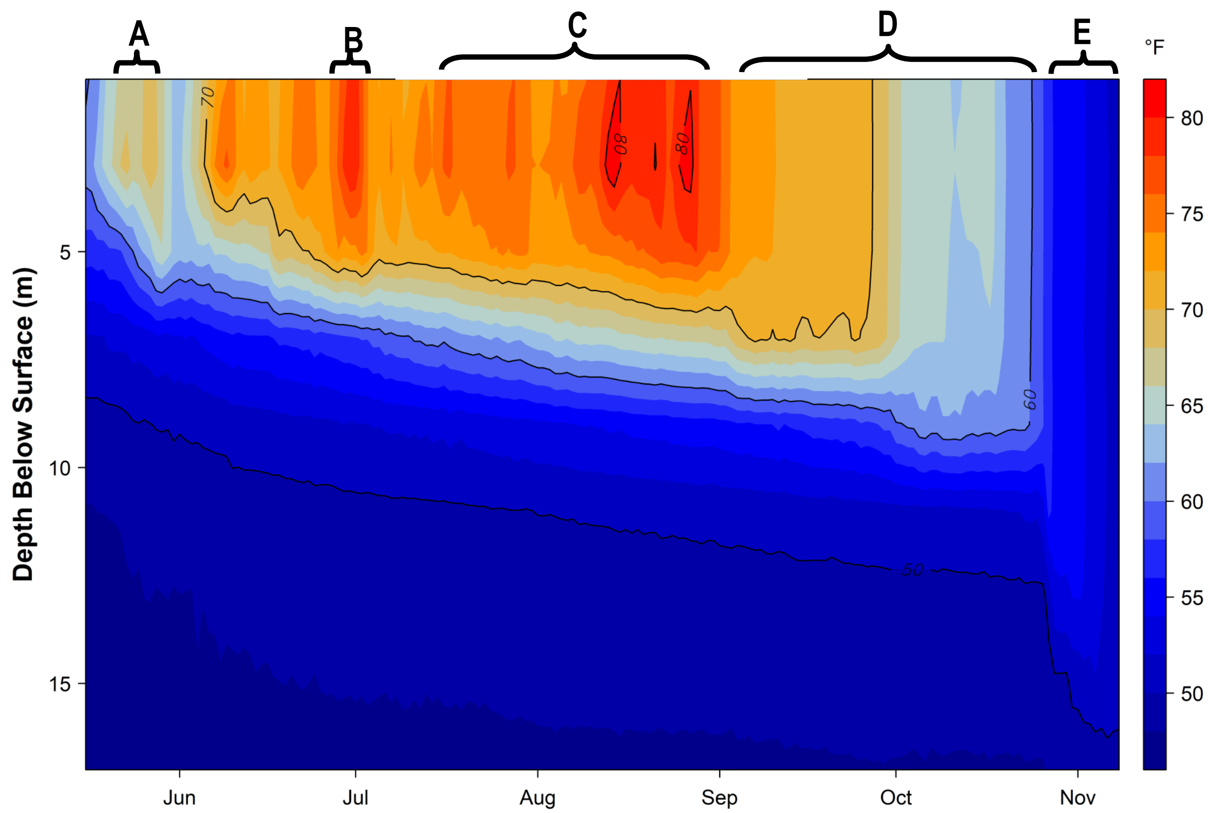
A. May data show an early season warm period followed by a cool period.

B. Late June data show surface water temperature increases dramatically, followed by a second cooling period.

C. Surface water temperature increases in mid-July, peaks on August 14 (28.1°C/ 82.5°F) and stays warm through early September.

D. Shallow waters mix with waters from the middle depths, pushing the thermocline deeper into the water column.

E. Temperatures throughout the water column are becoming more uniform but temperature differences in the deep waters indicate that full mixing has not yet occurred.



Deployment Date	Peak Temperature (°F)	Full Mixing	Retrieval Date
5/16/2021	82.5	After Retrieval	11/8/2021

Sand Pond

The water column of Sand Pond was stratified when sensors were deployed on May 18. Surface water temperatures increased in late May, decreased in early June, increased dramatically in late June, cooled slightly in July, and increased again in August. During the summer months, little temperature change was seen in Sand Pond's deep waters, creating large temperature differences between shallow and deep waters. This large temperature difference limits cooler, nutrient-rich deep waters from mixing with warmer surface waters. When these two layers mix, it provides algae with an additional food source. Please note that the watershed can still contribute phosphorus to the lake, regardless of stratification. Sand Pond's shallower waters began to cool in September through November. Full mixing had not yet occurred when sensors were retrieved on November 8.

The following events can be seen in the graph below:

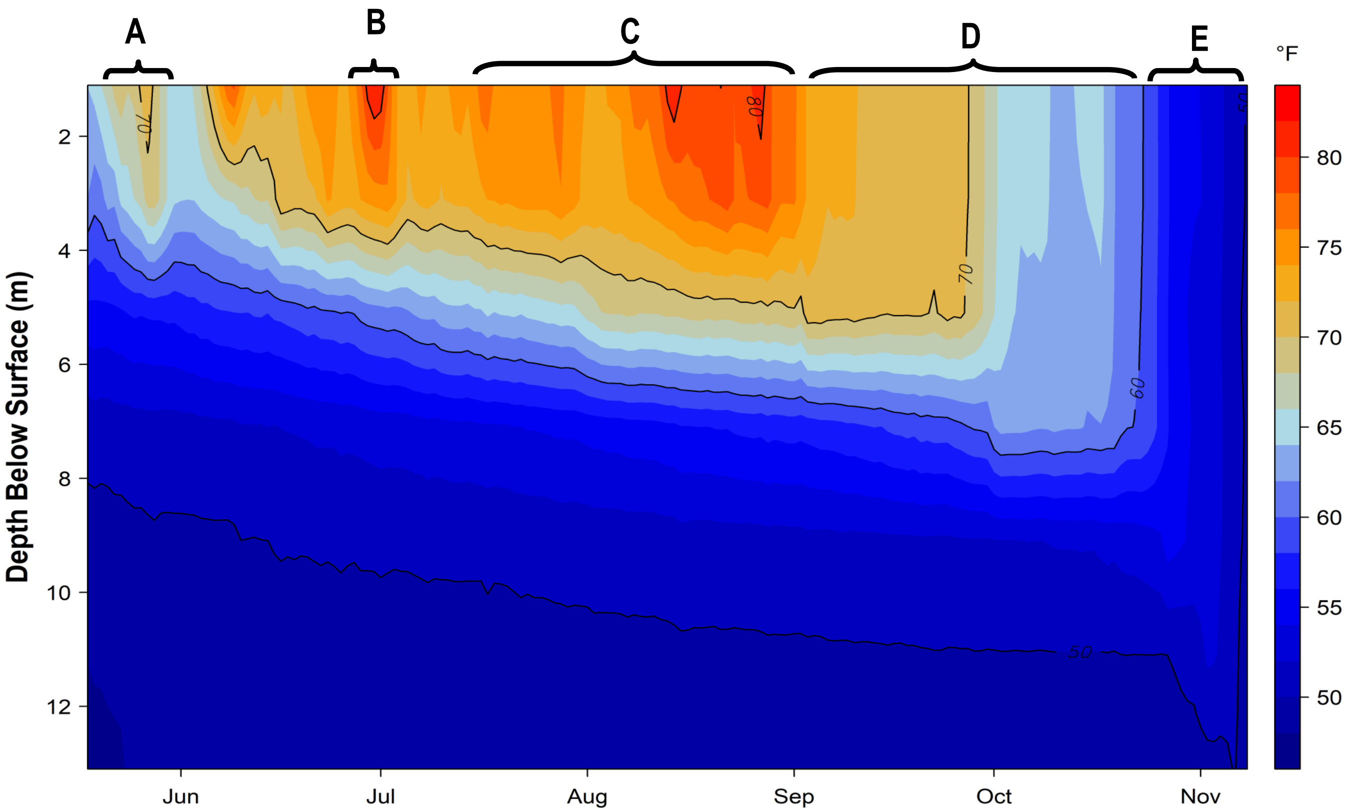
A. May data show an early season warm period, followed by a cool period.

B. Late June data show Sand Pond's temperature peak (28.3°C/ 83.0°F) on June 30, followed by a second cooling period.

C. Surface water temperature increases in mid-July, reaches a second peak on August 14 (28.3°C/ 83.0°F), and stays warm through early September.

D. Shallow waters mix with waters from the middle depths, pushing the thermocline deeper into the water column.

E. Temperatures throughout the water column are becoming more uniform but temperature differences in the deep waters indicate that full mixing has not yet occurred.



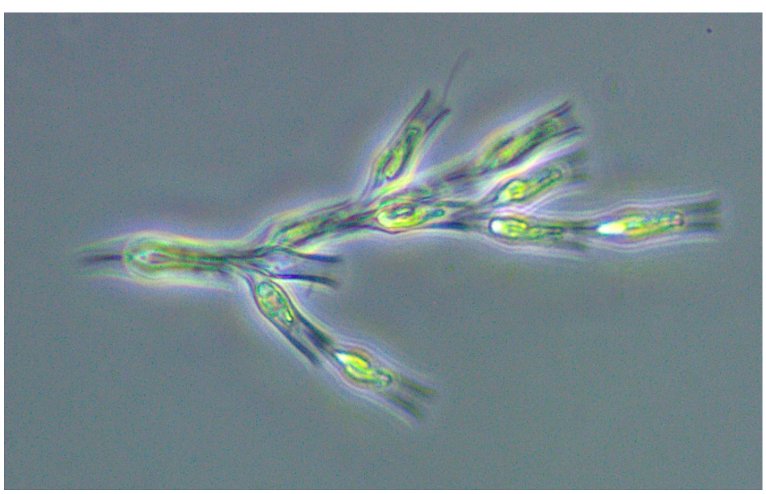
Deployment Date	Peak Temperature (°F)	Full Mixing	Retrieval Date
5/18/2021	83.0	After Retrieval	11/8/2021

Lakes Environmental Association

2021 Water Testing Report

Chapter 3

Algae Monitoring via Fluorometer Profiles



LEA's Algae & Fluorometric Chlorophyll Monitoring Programs

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.

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

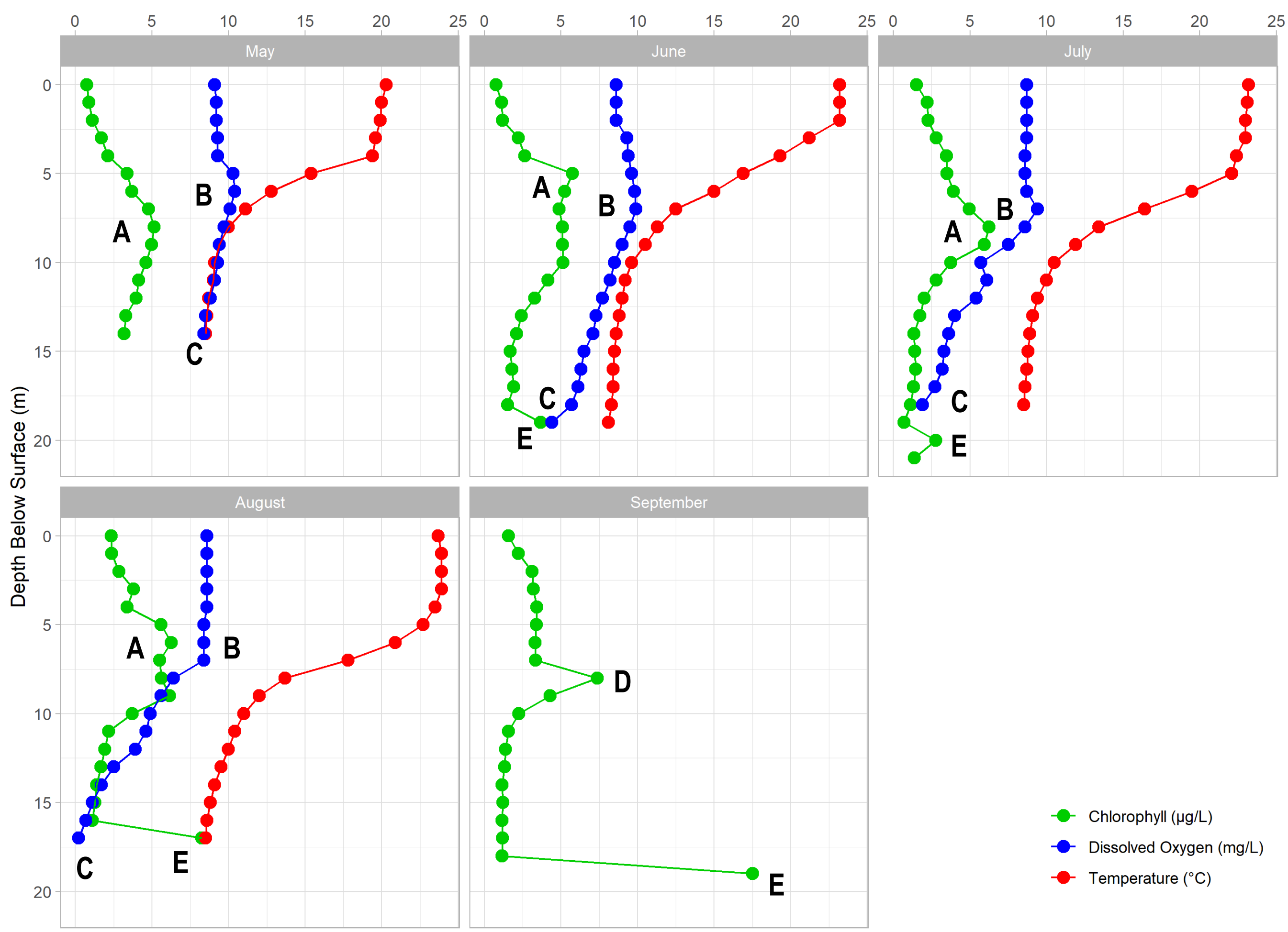
The fluorometer, which is calibrated to measure chlorophyll-a, works by emitting blue light at a specific wavelength designed to cause the chlorophyll-a molecules to enter a high-energy ("excited") state. When the molecules return to their normal state, they give off light (fluoresce) at a different 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 the lakes and ponds listed on the right 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 prefer 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 nutrients.

Hancock Pond

Monthly increases in fluorescence often occur near a rapid decrease in water temperature. This fluorescence increase is likely a result of algae "sitting" on top of denser cold water and photosynthesizing (**A**). An increase in oxygen concentration is typically noted either at or just below the fluorescence peak because algae produce oxygen as a by-product of photosynthesis (**B**). Over the course of the season, oxygen is biologically consumed by bacteria in the deep waters and the difference in water density between warm and cold waters prevent oxygen rich warm water from mixing with cold waters. This can be seen from month to month as decreasing oxygen concentrations in deep, cold waters as the season progresses (**C**). September's fluorometer profile was collected after the regular water testing season had concluded. This means that temperature and oxygen data are not available for September. However, September's florescence peak was about as deep into the water column as it was in other months. This is likely because Hancock Pond was still distinctly stratified in September, providing algae a place to 'sit' (**D**). Increased fluorescence values seen near the bottom of the pond in June, July, August, and September are likely caused by interference from bottom sediments (**E**).



Sand Pond

Monthly increases in fluorescence often occur near a rapid decrease in water temperature. This fluorescence increase is likely a result of algae "sitting" on top of denser cold water and photosynthesizing (**A**). Over the course of the season, oxygen is biologically consumed by bacteria in the deep waters and the difference in water density between warm and cold waters prevent oxygen rich warm water from mixing with cold waters. This can be seen from month to month as decreasing oxygen concentrations in deep, cold waters as the season progresses (**B**). September's fluorometer profile was collected after the regular water testing season had concluded. This means that temperature and oxygen data are not available for September. However, September's fluorescence peak was deeper in the water column than it was in other months. This is likely because surface waters had begun to mix in September which pushes the thermocline down, however, there is still a difference in water temperature between upper and bottom waters which provides algae a place to 'sit' (**C**). Increased fluorescence values seen near the bottom of the pond in August and September are likely caused by interference from bottom sediments (**D**).