Keoka Lake Report

Lakes Environmental Association

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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	2019 Avg .Clarity	2019 Avg. phosphorus	2019 Avg. Chl-a	Clarity Trend .	Phos. Trend	Chl-a Trend
ADAMS POND	High	Moderate	Low	Increasing	Stable	Stable
BACK POND	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
BEAR POND	Moderate	Moderate	Low	Stable	Stable	Stable
BRANDY POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
CRYSTAL LAKE	Moderate	Moderate	Moderate	Decreasing	Decreasing	Increasing
FOSTER POND	Moderate	Moderate	Moderate	Increasing	Stable	Stable
GRANGER POND	High	Moderate	Moderate	Stable	Decreasing	Stable
HANCOCK POND	Moderate	Low	Moderate	Stable	Stable	Decreasing
HIGHLAND LAKE	Moderate	Moderate	Moderate	Increasing	Stable	Decreasing
ISLAND POND	Moderate	Moderate	Moderate	Decreasing	Stable	Stable
KEOKA LAKE	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
KEYES POND	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
LITTLE MOOSE	Moderate	Moderate	Low	Stable	Stable	Stable
LONG LAKE	Moderate	Moderate	Moderate	Stable	Stable	Stable
LONG LAKE	Moderate	Moderate	Moderate	Stable	Stable	Stable
LONG LAKE	Moderate	Moderate	Moderate	Increasing	Decreasing	Stable
McWAIN POND	Moderate	Moderate	Moderate	Stable	Decreasing	Decreasing
MIDDLE POND	Moderate	Moderate	Low	Increasing	Stable	Decreasing
MOOSE POND	Moderate	Moderate	Moderate	Stable	Decreasing	Stable
MOOSE POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
MOOSE POND	Moderate	Moderate	Moderate	Decreasing	Stable	Decreasing
PEABODY POND	High	Moderate	Moderate	Stable	Stable	Stable
SAND POND	Moderate	Moderate	Moderate	Stable	Stable	Stable
STEARNS POND	Moderate	Moderate	Moderate	Increasing	Stable	Decreasing
TRICKEY POND	High	Low	Low	Decreasing	Stable	Increasing
WOODS POND	Moderate	Moderate	Moderate	Increasing	Increasing	Stable

Key to Water Quality at a Glance Table

Chlorophyll-a and Phosphorus Trends : Available data from 1996-2019 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 or less chlorophyll-a in lake water samples over time.

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

Clarity Trends: Available data from 1996-2019 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.

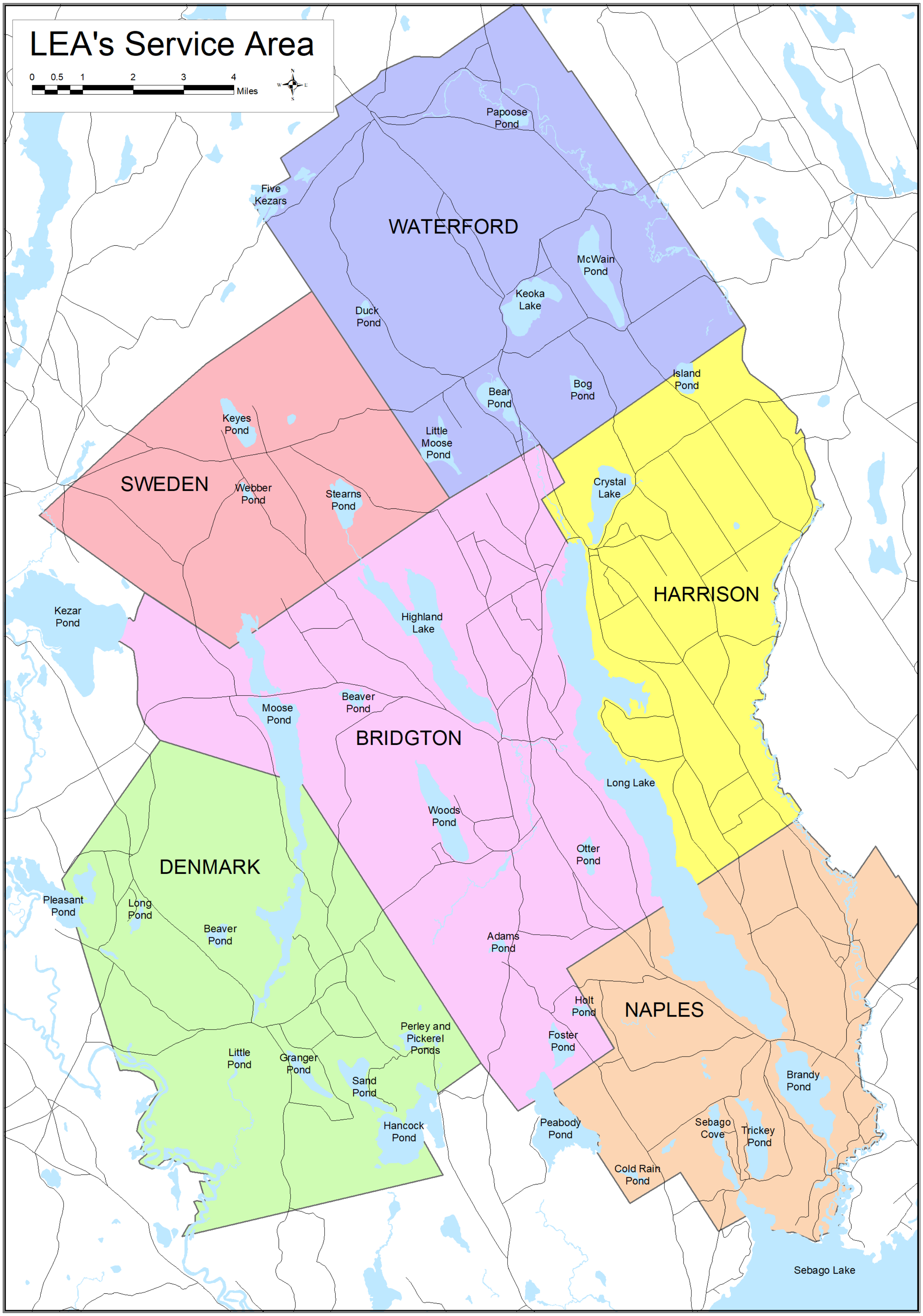
Increasing = deeper clarity readings over time

Stable = clarity readings are neither deeper nor shallower over time.

Decreasing = shallower clarity readings over time

2019 Average Chlorophyll-a concentrations, Phosphorus Concentrations, Color and clarity readings: Chlorophyll-a and phosphorus concentrations throughout the 2019 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
0
0.5
1
2
3
4
Miles
WATERFORD
SWEDEN
HARRISON
BRIDGTON
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
Beaver Pond
Moose Pond
Long Lake
Woods Pond
Otter Pond
Pleasant Pond
Long Pond
Beaver Pond
Adams Pond
Holt Pond
Perley and Pickerel Ponds
Foster Pond
Little Pond
Granger Pond
Sand Pond
Brandy Pond
Hancock Pond
Peabody Pond
Sebago Cove
Trickey Pond
Cold Rain Pond
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!**

2019 Volunteer Monitors and Lake Partners

Bill Ames and Paulina Knibbe	Jean Preis
Richard and Andy Buck	Jean Schilling
Steve Cavicchi	Amy March
Jeff and Susan Chormann	Julie and Dan McQueen
Janet Coulter	Tom Straub
Shelly Hall	Bob Mahanor
Joe and Carolee Garcia	McWain Shores Association
Jane Seeds	Bob Mercier
Carol Gestwicki	Papoose Pond Campbottom
Linda and Orrin Shane	Barry and Donna Patrie
Foster and Marcella Shibles	Nancy Pike
Bob Simmons	Don and Pat Sutherland

2019 Water Testing Crew

Hannah Sirois Olivia Mills Shannon Nelligan Addie Casali

Five Kezar Ponds Watershed Assoc.	Keyes Pond Env. Prot. Assoc.	Trickey Pond Env. Prot. Assoc.
Hancock and Sand Ponds Association	McWain Pond Association	Woods Pond Water Quality Comm.
Island Pond Association	Moose Pond Association	
Keoka Lake Association	Peabody Pond Protective Assoc.	

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

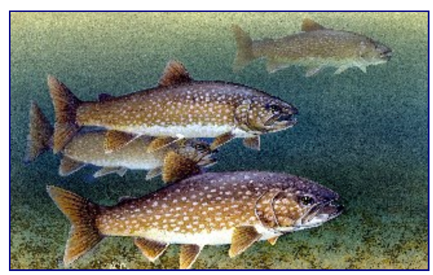
Epilimnion

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.

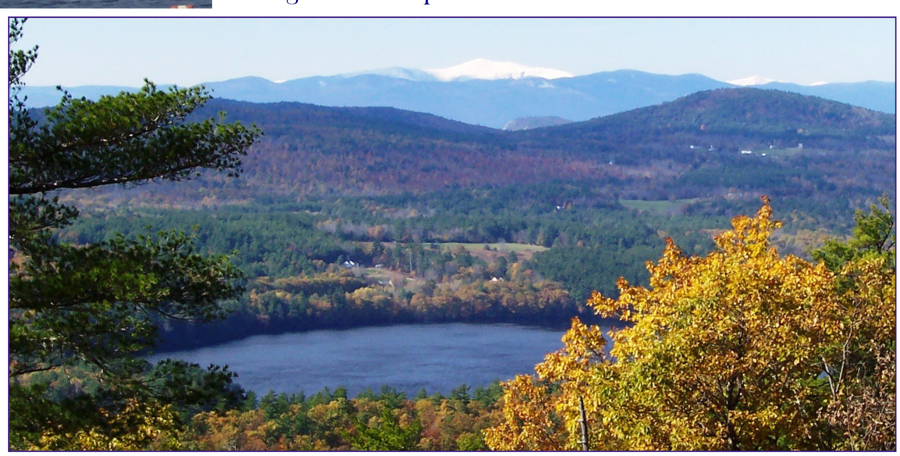
A year in the life of a lake

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. Phosphorus is measured in parts per billion (ppb). Surface-layer phosphorus samples are collected with a core tube, 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 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 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.

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 by-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.

The long-term average is determined for each lake that has been visited once annually for multiple years in a row. 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 2019 average values against long-term average values. This shows us if 2019 data is significantly different than historic data. If the p-value is above 0.05, there is no significant difference between 2019 averages and long-term averages. If the p-value is below 0.05, there is a significant difference between 2019 averages and long-term averages.

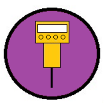
Coldwater Fish Habitat

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 2019 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 from that lake is available in chapters 2—5.

This symbol indicates that a series of temperature sensors was deployed in the lake in 2019. More information is available in chapter 3.



This symbol indicates that fluorometer profiles were taken from the lake in 2019. Fluorometer results are discussed in chapter 4.

This symbol indicates that LEA analyzed spatial differences in water quality over the surface of the lake in 2019. Spatial water quality results are discussed in chapter 5.

Lakes Environmental Association
2019 Water Testing Report

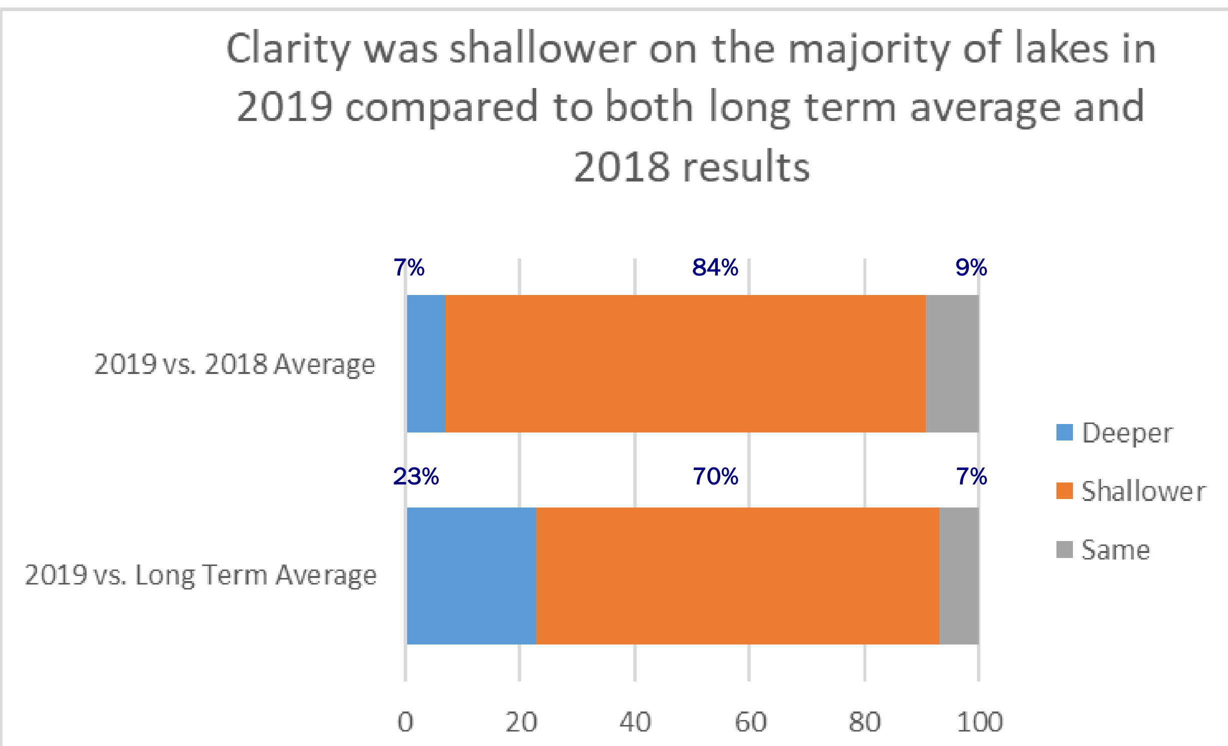
Chapter 1—Routine Monitoring Results

2019 as a Year

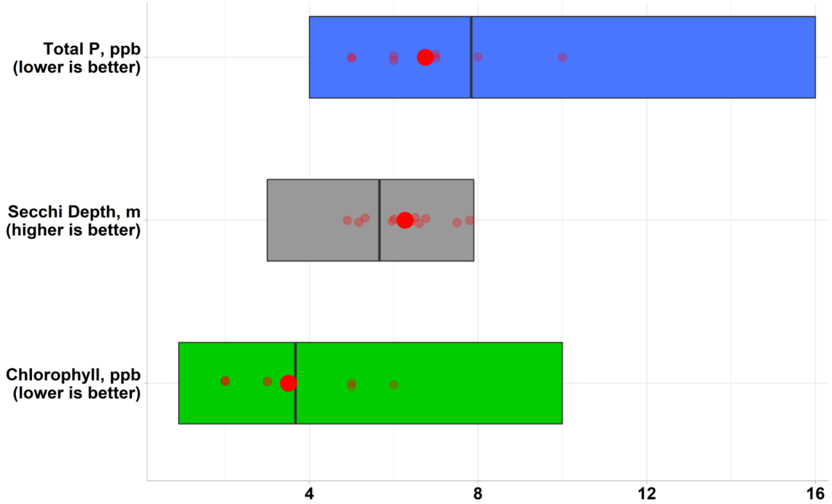
Clarity is an important measurement in lakes because it has a huge effect on ecology and water quality. At a basic level, clarity can be an indicator of algae growth. Low clarity readings may indicate high algae growth. Another measurement, chlorophyll, is a more direct measure of algae concentrations. Clarity and chlorophyll, together with phosphorus—a measure of the nutrients available for algae growth– are the key parameters used to determine lake water quality. LEA measures chlorophyll and phosphorus using a sample made up of water from the top layer of the lake. Phosphorus is also measured in the deeper waters of some lakes at individual depths.

On average in 2019, 30% of lakes had deeper (or similar) clarity, 76% of lakes had lower surface layer phosphorus, and 86% of lakes had lower or similar chlorophyll concentrations when compared to long-term averages. Because of this, many lakes and ponds went from having stable trends in clarity, phosphorus, or chlorophyll to having improving trends, or went from a negative trend to a stable one.

The winter snowpack was substantial for the third year, leading to erosion in the spring that resulted in poor clarity readings to begin the testing season. Ice-out was relatively late in 2019, which meant that the stratified period was shorter, but also contributed to the lower clarity seen at the beginning of the year. The overall low clarity readings are likely due to rain storms throughout the summer. Despite low clarity readings throughout the season, overall water quality in the Lakes Region was very good.



Keoka Lake



Surface Area:	460 acres
Maximum	42 feet
Mean Depth:	25 feet
Volume:	10,569 acre-feet
Watershed Ar-	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 2019's average value. The small red dots represent individual readings taken in 2019.

2019 Water Quality Highlights

The average Secchi disk reading for 2019 was 6.27 meters, fell into the moderately clear range, and was deeper than the long-term average of 5.95 meters. The average total phosphorus reading of 6.75 ppb fell into the moderate range and was less than the long-term average of 7.70 ppb. Deep water phosphorus values reached into the high range. The chlorophyll-a average of 3.50 ppb fell into the moderate range and was lower than the long-term average of 3.67 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 2019 was 23.25 SPU, indicating that water in Keoka Lake is moderately colored. Suitable fish habitat was present through June and July, however habitat became unsuitable from August through September. Low oxygen

Keoka Lake 2019 Quick Stats

	Deep Water Phosphorus (average in PPB)	Coldwater Fish Habitat	Water Color (SPU)	Clarity Trend	Phosphorus Trend	Chlorophyll-a Trend
Analysis Result	18	Unsuitable	23.25	Increasing	Decreasing	Stable
Interpretation	High deep water phosphorus	Less than 2m of fish habitat	Water was moderately colored	Deeper clarity readings over time	Less phosphorus in water over time	Neither more nor less chlorophyll over time

Lakes Environmental Association

2019 Water Testing Report

Chapter 3—High Resolution Temperature Monitoring

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.

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.

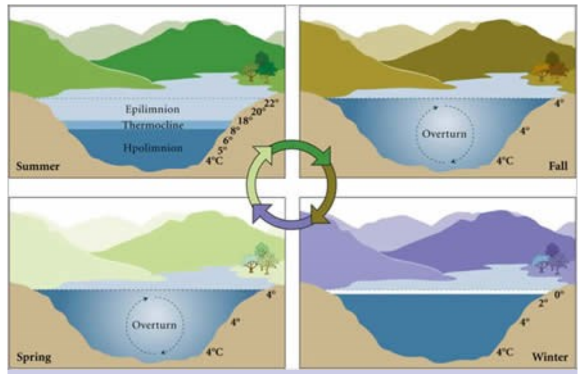
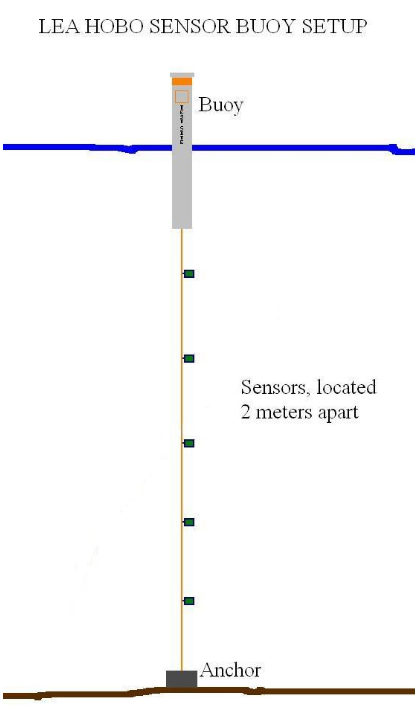


Diagram of Seasonal Stratification and Lake Mixing
Young, M. (2004). *Thermal Stratification in Lakes*. Baylor College of Medicine, Center For Educational Outreach.

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.

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.

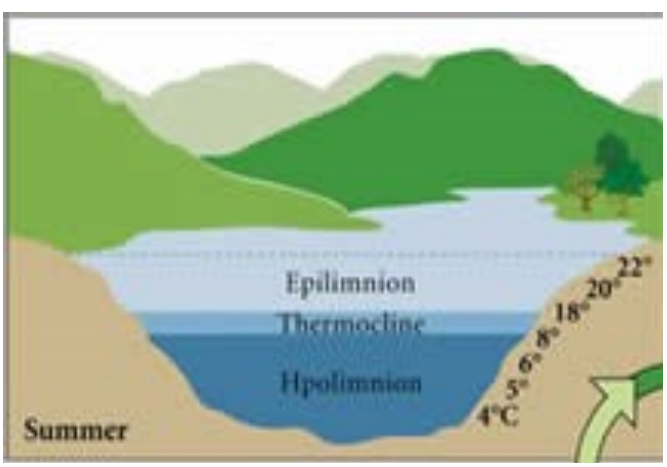
However, this method is time consuming, resulting in only 8 temperature profiles per year. While temperature sensors require an initial time investment, once deployed, the sensors record over 15,000 profiles before they are removed in the fall. This wealth of data provides much greater detail and clarity 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.

A HOBO temperature sensor

High-Resolution Temperature Monitoring: How to Read the Graph

The temperature monitoring summary includes a graph that displays all the data collected in the 2018 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.

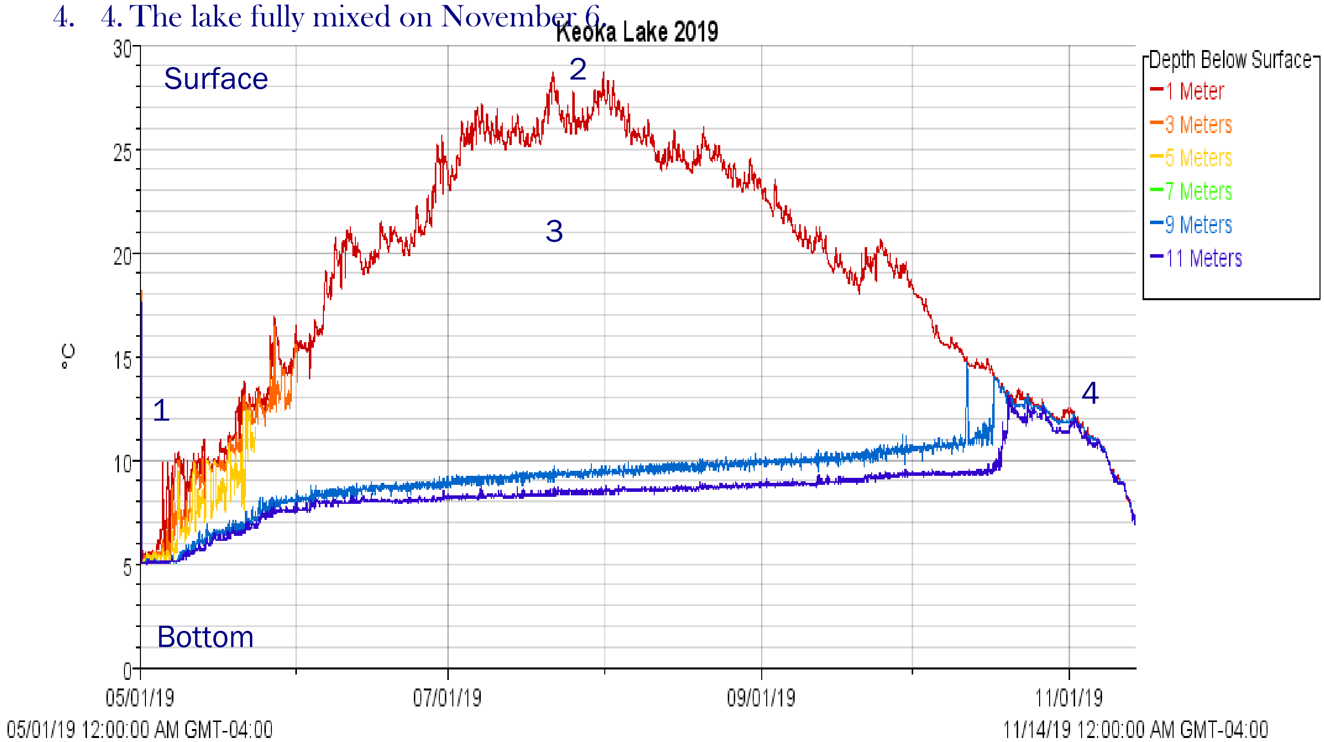
Keoka Lake

Summary

Although there is a large gap in the 2019 dataset, the remaining data from Keoka's season-long temperature profile looks similar to the 2018 profile. Based on available data, we can conclude the water column of Keoka Lake distinctly and strongly divided into layers based on temperature (stratified) in the warmer months. The temperature in the upper waters increased dramatically following air temperature increases but there was very little change in temperature over the season in the deepest waters (9—11 meters). Large temperature differentials like this result in surface waters that are unlikely to mix with deep waters during the summer months, thus reducing the chance that more nutrient-rich deep water could come to the surface and feed algae.

The following events can be seen in the graph below:

1. 1. Stratification began on May 5.
2. 2. Peak temperature (28.7 C/ 83.7 F) was seen on July 31.
3. 3. Due to equipment malfunction, data from the 3 meter, 5 meter, and 7 meter sensors are missing.
4. 4. The lake fully mixed on November 6.



Peak Temperature	Full Mixing
7/31	11/06

Lakes Environmental Association
2019 Water Testing Report

Chapter 4
Algae Monitoring via Fluorometer Profiles

LEA's Fluorometeric Chlorophyll Monitoring Programs

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

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 in the process of 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 1oC 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 results in Relative Fluorescence Units (RFUs). This measurement results 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 between 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 in the deeper layer of the lake.

Keoka Lake

Summary

Each month, 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. This phenomenon is common in many of the lakes we monitor and is 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 and September.

The following events can be seen in the graph below:

1. 1. Peak chlorophyll fluorescence occurred in September.
2. 2. Chlorophyll fluorescence peaked twice in August, once near surface waters and again below the thermocline.
3. 3. Unusual deep water fluorometric spike was seen in July.