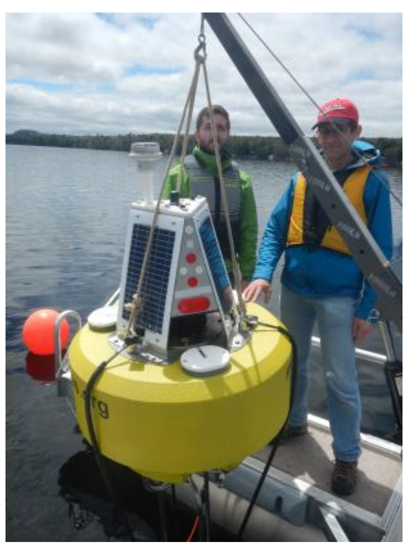
Lakes Environmental Association
2017 Water Testing Report

Chapter 2—High Resolution Automated Monitoring Buoys



LEA's Automated Testing Buoys

Each year, LEA deploys two fully automated monitoring buoys – one on Highland Lake and one on Long Lake. These buoys collect water quality information at 15-minute intervals throughout the spring, summer, and fall. This data is transmitted to us in real time, so we can see conditions change on the lake as they happen. The goals of LEA's testing buoy program are to better understand the condition of our lakes, to raise awareness of water quality issues locally, and to contribute to worldwide research and knowledge on lakes.

The Highland Lake Buoy

The Highland Lake buoy was first deployed in 2014 and contains temperature and oxygen sensors at 2-meter intervals from the surface of the lake to near the bottom. It also contains two solar radiation sensors and a chlorophyll sensor, as well as a small weather station for measuring precipitation, barometric pressure, relative humidity, wind speed and direction, and air temperature. The Long Lake buoy was first deployed in August, 2016. Like the Highland Lake buoy, it contains oxygen and temperature sensors at 2 meter intervals. It also has chlorophyll sensors located at three depths. Both buoys contain three 10-watt solar panels and a rechargeable battery as their power supply.

The advantages of these buoys are that they automate and enhance the water quality monitoring process. Using traditional (manual) water testing techniques, we are only able to collect data once every two weeks from each lake, usually around the same time of day. In contrast, the buoy automatically collects readings from each sensor at 15-minute intervals, resulting in 96 readings for each parameter every day. We are also able to leave the buoy in the water over a longer period of time than the traditional monitoring season. The wealth of additional data provided gives us a much more detailed picture of what is happening in the lake at any given time.

The information collected by the buoys allows us to better understand lake dynamics throughout the growing season. The combined and simultaneous measurements of algae growth, temperature, oxygen, and weather conditions lets us see the effects of wind and precipitation events in real time, thus allowing us to better interpret how these factors affect lake conditions.

Another aspect of the buoy program is our ability to collaborate with researchers on a larger scale by sharing ideas and methods and contributing to research. Buoys similar to LEA's can be seen in lakes throughout New England and the world. An international organization called GLEON (Global Lake Ecological Observatory Network) helps to connect researchers that collect and use lake data, particularly from automated monitoring buoys, for a variety of projects. GLEON's mission is "to understand, predict, and communicate the impact of natural and anthropogenic influences on lake and reservoir ecosystems."

LEA could not have purchased either buoy without a great deal of support from several sources. The Highland buoy was funded by a grant from an anonymous foundation and contributions from landowners around Highland Lake. The Long Lake buoy was funded by a very generous donation from a resident of Long Lake, foundation funding, and contributions from lakefront landowners. LEA worked closely with Colby College professor Dr. Whitney King and Fondriest Environmental to design and set up the buoys.

During the months when the buoys are deployed, real-time data can be viewed on LEA's website: http://www.mainelakes.org/water-testing-program/highland-lake/.

Deployment

The 2017 buoy deployments started with the Long Lake buoy on 12 May, followed by the Highland Lake buoy, which was installed on 17 May (a month later than in 2016). Both buoys were in place recording data until early November, when they were removed from the lakes (6 Nov. for Highland, 7 Nov. for Long). The sensors were cleaned and calibrated several times throughout the deployment period. Unfortunately, several sensors on the Highland Lake buoy and one sensor on the Long Lake buoy stopped working for part or all of the period. Some sensors were unable to be replaced or fixed, resulting in some missing data.

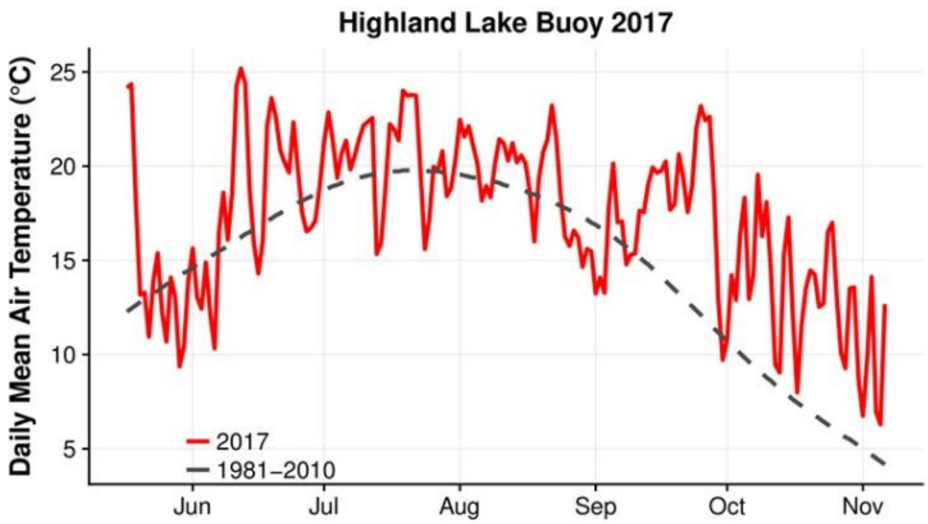
The Long Lake Buoy

2017 Results

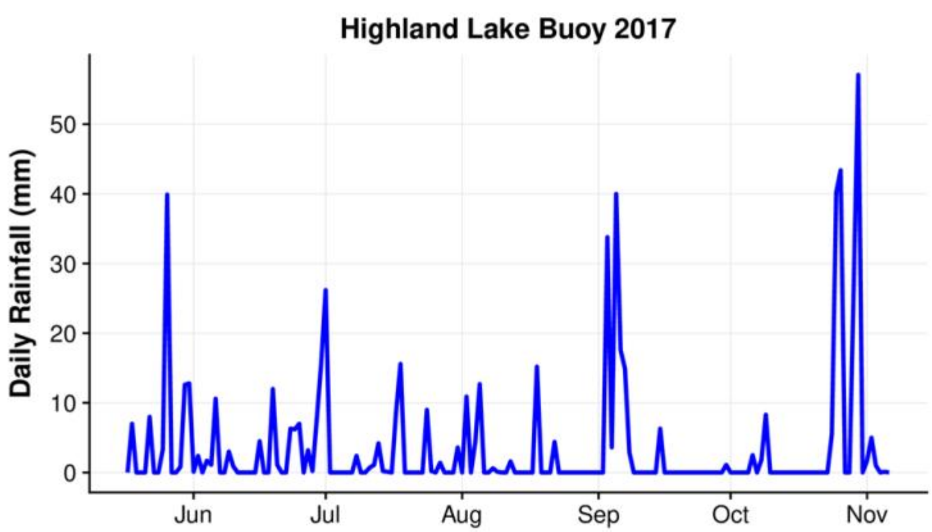
The following two pages summarize weather conditions that contributed to the temperature, oxygen, and chlorophyll patterns seen on each lake in 2017. Individual summaries of each buoy's data start on page 6.

Both lakes showed remarkably similar temperature patterns, despite differences in overall size and shape between the two lakes. Anoxia (absence of dissolved oxygen) affected both lakes in 2017, but Highland Lake developed anoxia sooner than Long Lake (late July as opposed to September). Chlorophyll fluorescence in Highland Lake was relatively low throughout the deployment until mid and late September, when values peaked. In contrast, the Long Lake chlorophyll record showed higher and more variable readings. A similar September peak in chlorophyll was seen in Long Lake, but it was not as high as the Highland peak relative to the other readings from throughout the season.

Meteorological Conditions over the 2017 Season

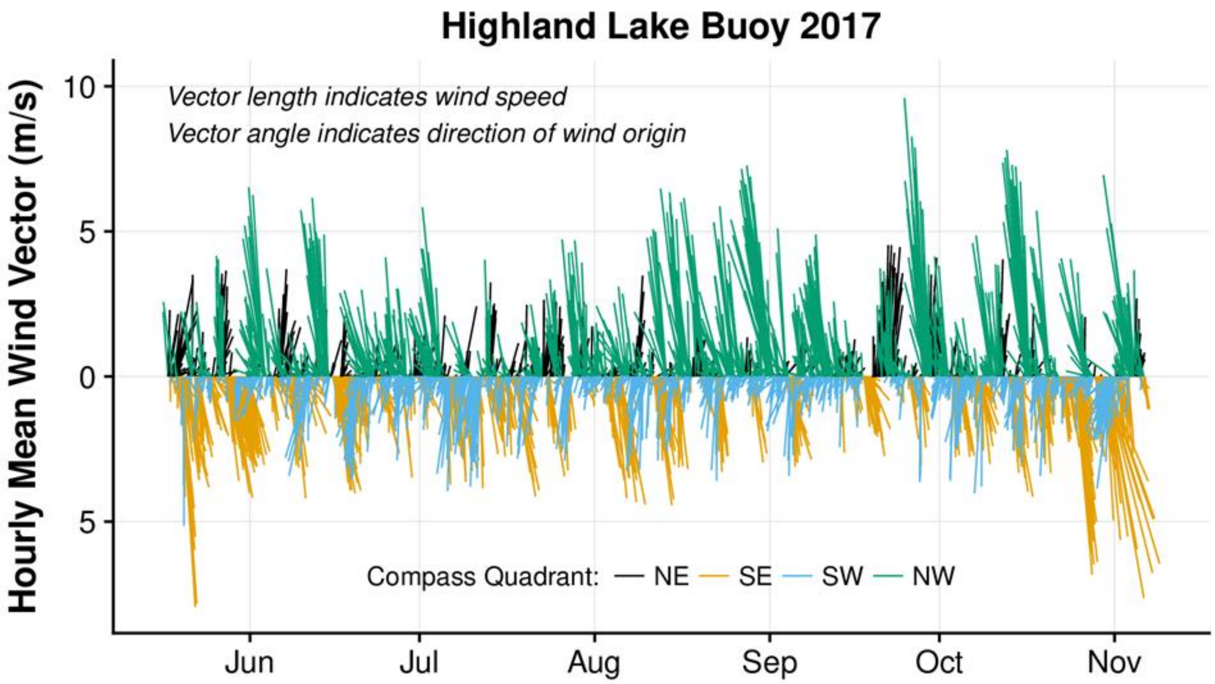


The driving forces of local weather play a major role in lake water quality conditions. The meteorological sensors on the Highland Lake buoy collect weather data at the same time as water data. Because the two lakes are geographically close together, these data are applicable to Long Lake as well. Air temperature followed a typical seasonal pattern, but with several periods of above-normal (1981-2010) values, especially at the beginning of the deployment and in the fall. Instantaneous temperature readings ranged from 2.1 to 32.9 °C (35.8 to 91.2 °F).



Total rain recorded by the buoy during the deployment was almost 61 cm, or just slightly less than the 30-year normal rainfall for May through October. This was a change from the very dry conditions in the previous year. Significant rainfall events occurred in late May, early July, early September, and late October.

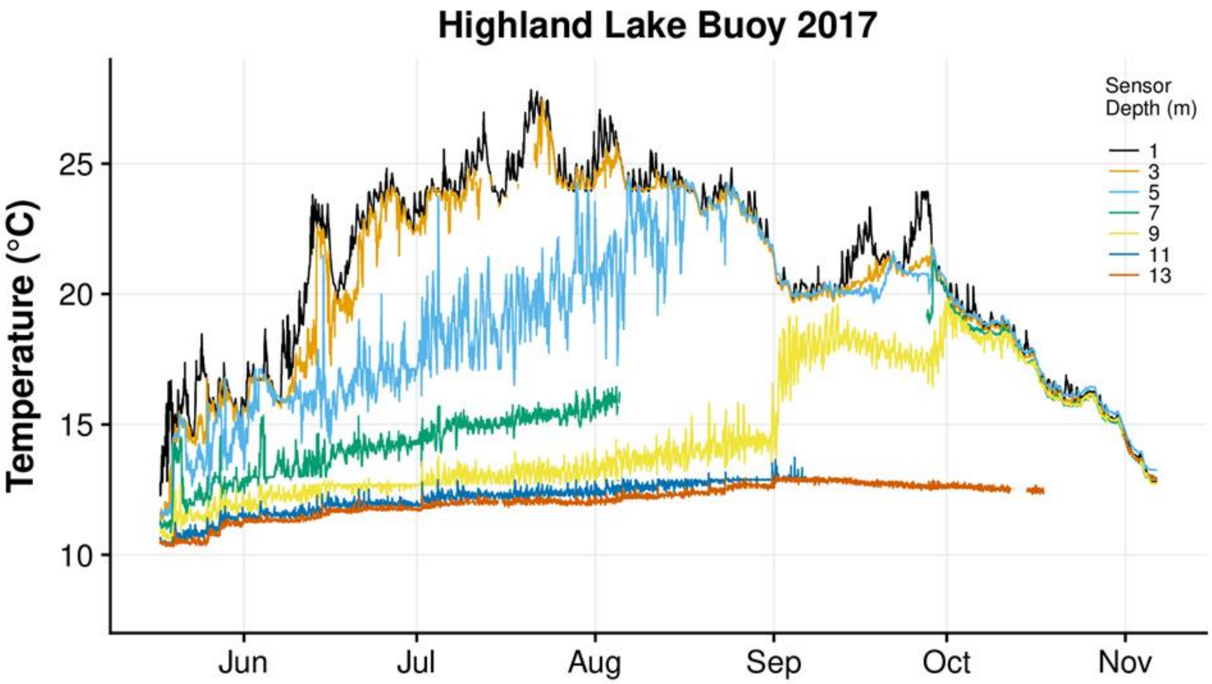
Meteorological Conditions over the 2017 Season, Continued



Wind speed and direction measurements recorded by the buoy were quite variable, but some basic patterns and events are evident. In the figure above, the vector lines indicate wind speed by length and wind direction (from where it is coming) by the angle, where north is straight up. Wind varies with time, but the clumping of similar colors in the figure shows the wind coming from the same direction for up to several days. Also, the strongest winds (> 5 m/s) tend to originate from the northwest or the southeast direction. Those more extreme events tended to occur in the late spring/early summer and fall, though there were some exceptions. In particular, the region experienced a powerful storm on 1 July that spawned five tornadoes in or close to LEA's service area and the buoys. The short-lived events are not evident in the plot because of the hourly averaging. Also, during one 15-minute period around the time of the storm, the sensor recorded an error, so it is possible the winds overwhelmed the sensor.

Highland Lake

Water Temperature

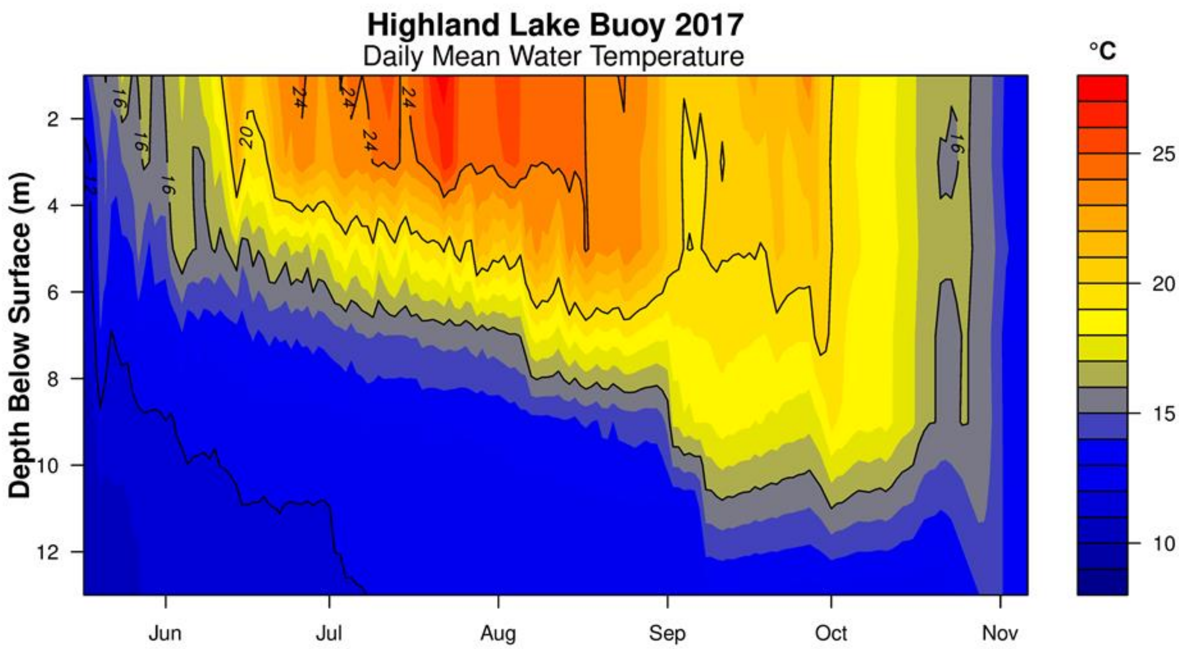


Data from the individual temperature sensors are shown in the above figure. Each colored line represents water temperature at a specific depth below the surface at a 15-minute interval. Some data is missing due to problems with sensors. The maximum recorded temperature on Highland Lake was 27.8 °C (82.0 °F) in mid-July, and the minimum temperature was 10.3 °C, or 50.5 °F, at the start of the record. Temperature varied much more in the middle of the water column due to the "sloshing" of the internal waves (or seiches) near the thermocline, a region of rapidly changing temperature and density. Stratification (indicated by wide spaces between lines) was already starting to set up at the beginning of the deployment and partial mixing (lines getting closer together) occurred throughout the season, especially at times of high winds. Complete mixing is estimated to have occurred on about 4 November following significant wind events between the end of October and early November. The deepest sensor on the Highland Lake buoy malfunctioned, so this date is approximate. This timing is quite a bit later than previous years, as shown in the table below.

Date of Fall Turnover (Complete Mixing) by Year					
LAKE	2013	2014	2015	2016	2017
Highland Lake	after 10/11	10/12	10/11	10/10	11/4?

Highland Lake

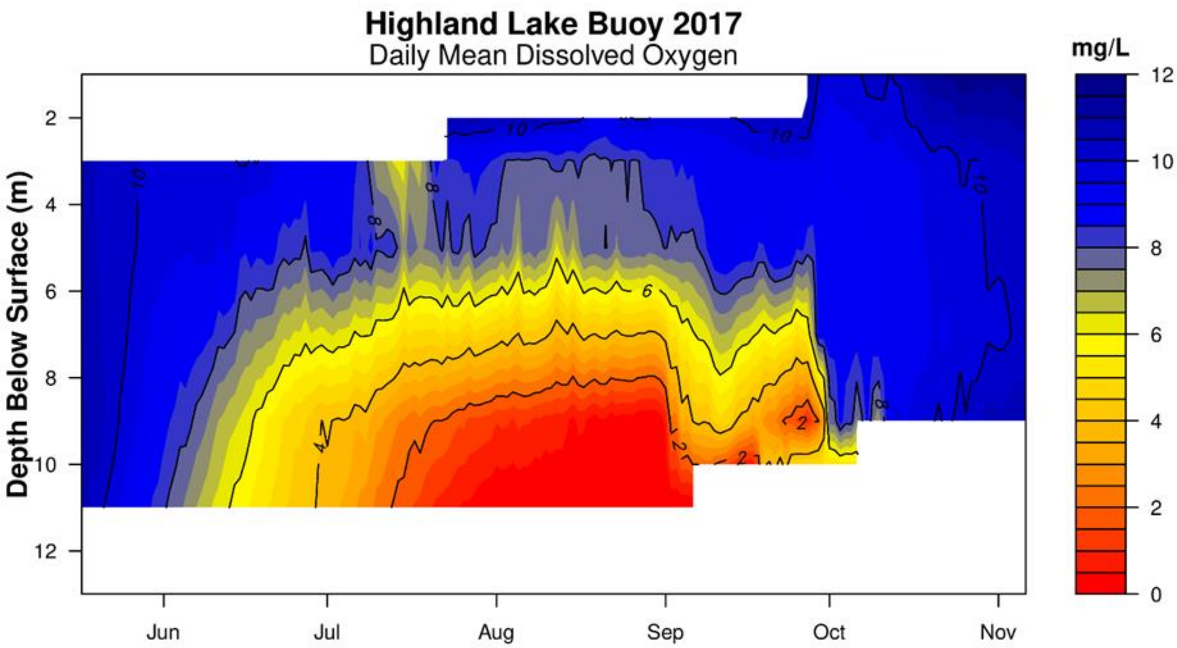
Water Temperature Heat Map



Another, perhaps easier way to visualize the data is with contour plots (or heat maps). In the above figure, temperature across depth and time is represented by colored contours, where reds and blues correspond to highest and lowest values, respectively. Peaks in surface water temperatures are associated with warmer ambient air temperatures, while storm events cause mixing that contributes to the cooling of the surface waters. Temperature stratification shows up in areas of the plot where colors change from the lake surface to the bottom and contour lines are roughly horizontal (such as between mid-June and September). Vertical contour lines indicate mixing, and areas of a single color from top to bottom (such as at the far right) indicate completely mixed conditions. In this graphic, the warm, stratified summer conditions stand out, as do mixing events in June, September, and November. The graph shows a gradual warming within the deeper waters over time until the lake mixes.

Highland Lake

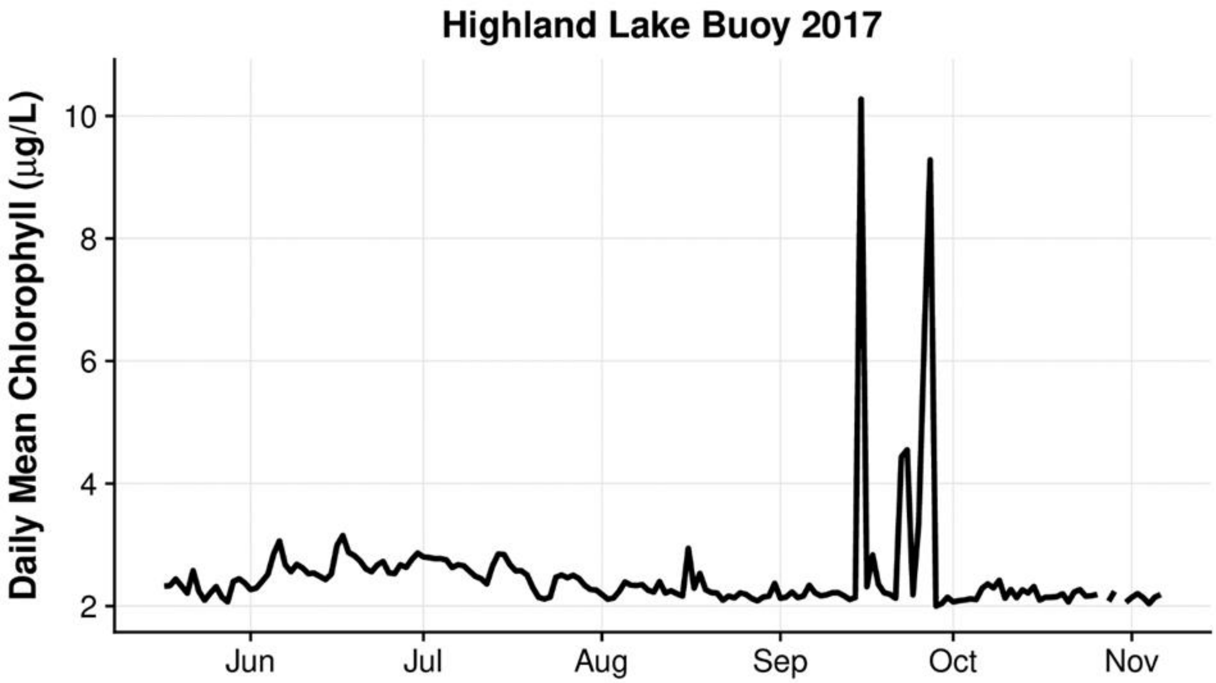
Dissolved Oxygen



The same type of contour plot is used to show the dissolved oxygen (DO) data from the buoy in the above figure, though the color scheme is reversed so that reds and blues indicate low and high DO, respectively. Lake water oxygen concentrations are affected by a combination of water temperature, wind, and biological activity. Cold water contains more DO than warm water, all else being equal. Winds blowing across the lake surface will blend in atmospheric oxygen, but only as deep as the stratified upper layer of the lake. Oxygen is a byproduct of photosynthesis, so actively growing algae can increase DO concentrations. Respiration can be seen as the opposite of photosynthesis, because it is a process that decreases oxygen levels. DO within the lake is reduced when microbes, fish, and plants respire. When the lake is stratified, DO in the bottom layer is not replenished by wind mixing or photosynthesis, causing the DO to gradually get depleted over the summer. Fish tend to avoid areas that have concentrations below 4 mg/L and waters with near-zero DO enhance phosphorus release from the sediments. The Highland Lake plot has large blocks without colors because of malfunctioning sensors. The buoy data shows a typical summer pattern of lower DO concentrations in the deeper waters. Highland Lake developed anoxia (absence of DO) in late July. The severity of anoxia appears to have been reduced beginning in September, but because of missing data, the exact pattern is unclear. It is assumed that Highland Lake mixed at about the same time as Long Lake, on November 4th, at which time the entire lake would be re-oxygenated.

Highland Lake

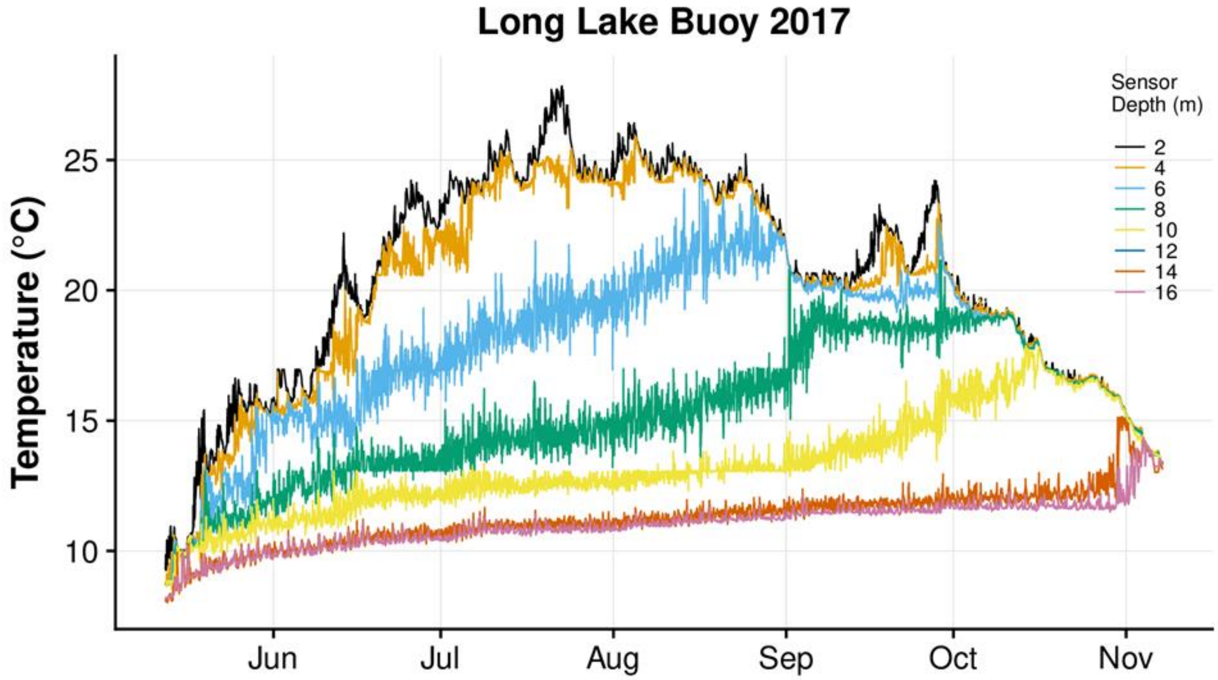
Chlorophyll or Algae Biomass



The buoy contains one sensor near the lake surface that detects chlorophyll pigment using fluorescence. The amount of this pigment (found in all plants and algae) can be used as a proxy for algae biomass and a measure for how productive a lake is. However, it is important to note that fluorescence is a relative measure, and is not as accurate as lab-based chlorophyll measurements. For Highland Lake, chlorophyll was relatively low throughout the deployment until mid and late September, when values peaked. This followed a period of heavy rains earlier in the month as well as some wind-driven mixing that might have brought phosphorus and other nutrients into the upper water layers, stimulating algal growth.

Long Lake (North Basin)

Water Temperature

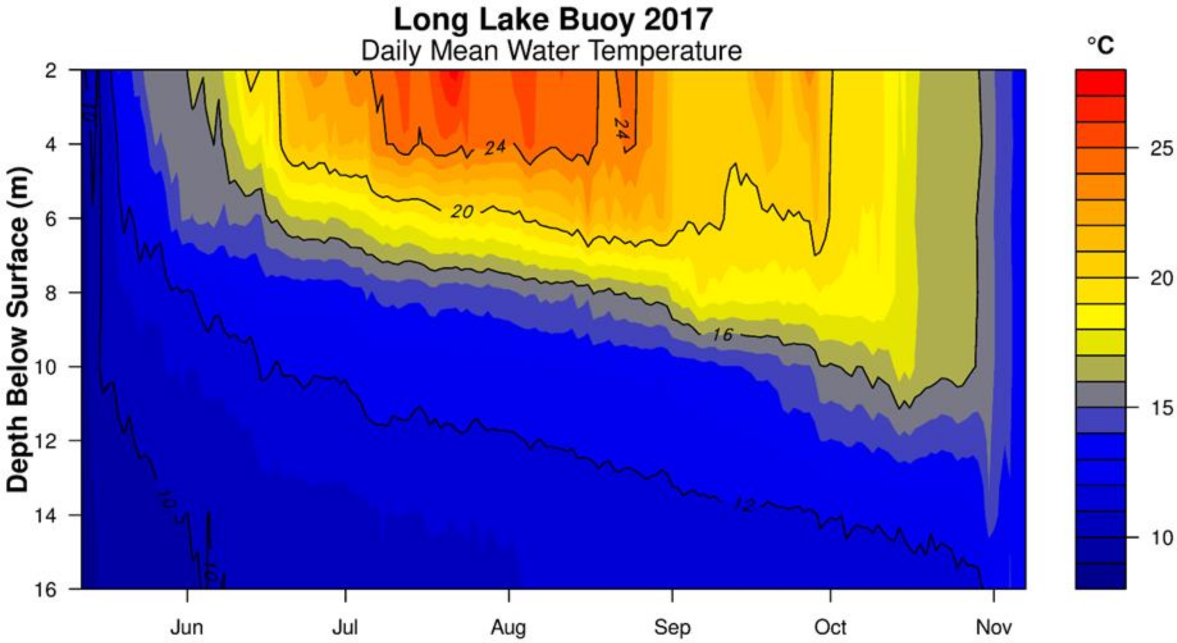


Data from the individual temperature sensors on the Long Lake buoy are shown in the above graph. Each colored line represents water temperature at a specific depth below the surface at 15-minute intervals. Maximum recorded temperature was 27.8 °C (82.0 °F) in mid-July, while the minimum temperature was 8.0 °C, or 50.5 °F, at the start of the record. Temperature varied much more in the middle of the water column due to the "sloshing" of the internal waves (or seiches) near the thermocline, a zone of rapidly changing temperature and density. Stratification (indicated by wide spaces between lines) was just beginning to set up when the buoy was deployed and partial mixing (lines getting closer together) occurred throughout the season, especially at times of high winds. Complete mixing occurred on about 4 November following significant wind events between the end of October and early November. This timing is about a week and a half later than previous years as shown in the table below.

Date of Fall Turnover (Complete Mixing) by Year					
LAKE	2013	2014	2015	2016	2017
Long Lake North	10/25	10/23	No Data	No Data	11/4

Long Lake (North Basin)

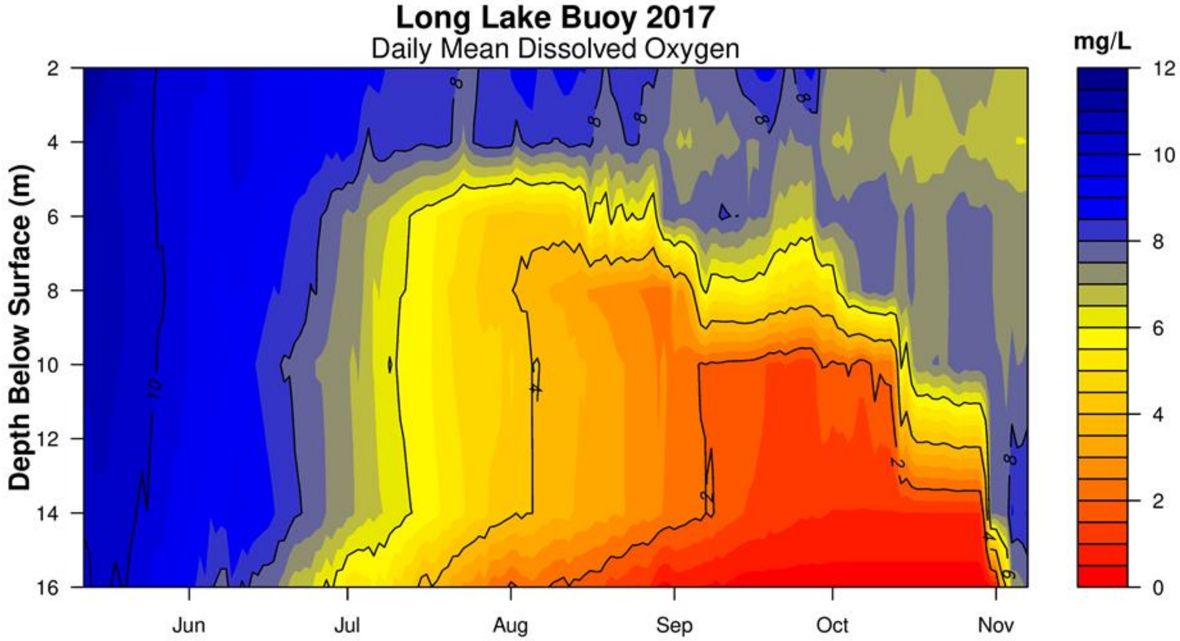
Water Temperature Heat Map



Another, perhaps easier way to visualize the data is with contour plots (or heat maps). In these figures, temperature across depth and time is represented by colored contours, where reds and blues correspond to highest and lowest values, respectively. Peaks in surface water temperatures are associated with warmer ambient air temperatures, while storm events cause mixing that contributes to the cooling of the surface waters. Temperature stratification is evident in areas of the plot where colors change from the lake surface to the bottom and contour lines are roughly horizontal (such as between mid-June and September). Vertical contour lines indicate that mixing is occurring, and areas of a single color (such as at the extreme right of the graph) indicate well-mixed water conditions. In this graphic, the warm, stratified summer conditions stand out, as do mixing events in June, September, and November. The graph shows a gradual warming within the deeper waters over time until the lake mixes.

Long Lake (North Basin)

Dissolved Oxygen



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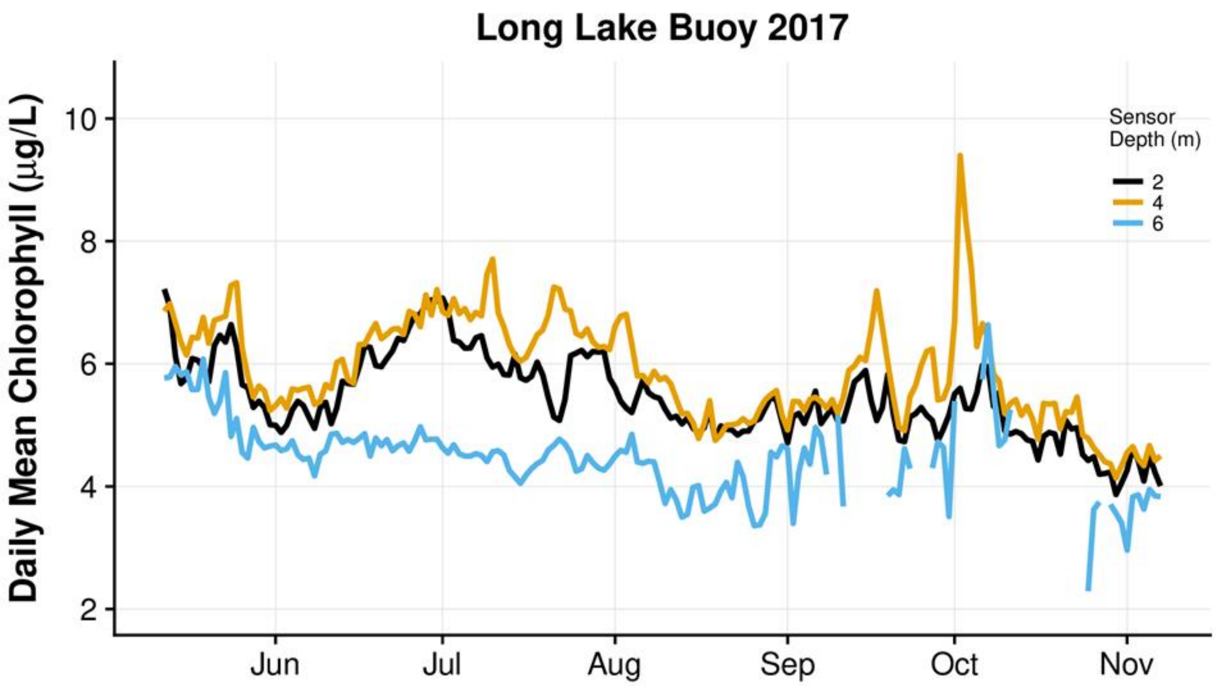
Long Lake (North Basin)

Chlorophyll or Algae Biomass



The buoy incorporates sensors that detect chlorophyll pigment by fluorescence. The amount of this pigment (found in all plants and algae) can be used as a proxy for algae biomass and a measure for how productive a lake is. However, it is important to note that fluorescence is a relative measure, and is not as accurate as lab-based chlorophyll measurements. The Long Lake buoy uses sensors at three different depths to assess if and where algae might be concentrated. In Long Lake, algae concentrations were higher around 2 m and 4 m than at 6 m for the majority of the deployment. The highest chlorophyll values were seen at 4 meters at the beginning of October. This peak followed a period of heavy rains in September as well as some wind-driven mixing that might have brought phosphorus and other nutrients into the upper water layers, stimulating algal growth. Some late-season chlorophyll data from the 6 meter sensor was removed due to sensor error.