Lakes Environmental Association
2022 Water Testing Report

Chapter 2 — Automated Monitoring Buoys

LEA's Automated Buoys

Highland Lake buoy

Each year, LEA deploys two fully automated monitoring buoys – one on Highland Lake and one on Long Lake in the north basin (see map next page). 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 monitoring 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 was first deployed in 2014 and has seven temperature and oxygen sensors mounted at 2-meter (6.6-ft) intervals from the surface of the lake to near the bottom. Also mounted on the buoy are two solar radiation sensors and a single 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 has oxygen and temperature sensors at 2-meter intervals (total of eight) and a single chlorophyll sensor. Both buoys use three 10-watt solar panels and a rechargeable battery as their power supply (see schematic next page).

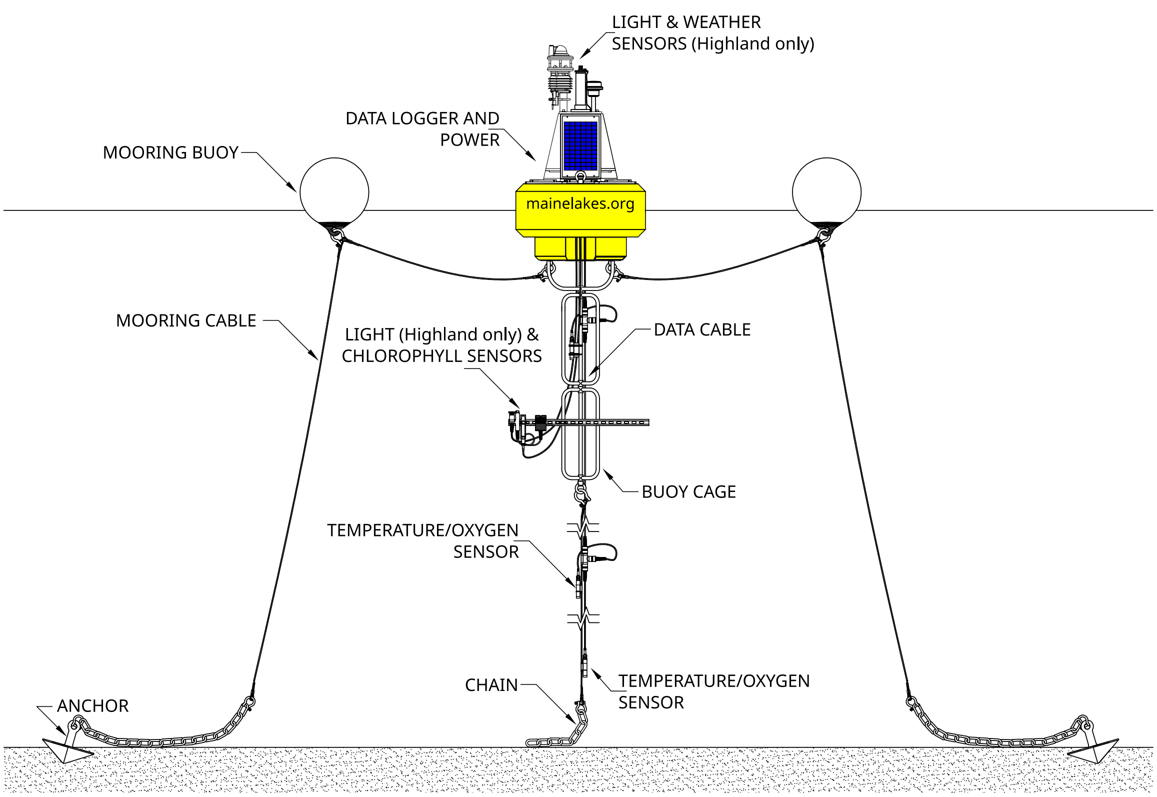
The advantages of these buoys are that they automate and enhance the water quality monitoring process. Our traditional (boat-based) water testing program collects data once every two weeks from each lake, usually around the same time of day. In contrast, the buoys automatically record readings from each sensor every 15 minutes, or 96 times per day and can be left in the water longer than the traditional monitoring season. Even though the buoys measure fewer water quality parameters than the testing program does (for instance phosphorus is not measured), the wealth of additional data gives us an incredibly detailed picture of what is happening in the lake at any given time throughout the open-water growing season. The simultaneous measurements of water temperature, dissolved oxygen, algae (chlorophyll), water clarity, and weather conditions lets us see the effects of air temperature, wind, and precipitation events in real time, thus allowing us to better interpret how these factors affect lake conditions.

Long Lake buoy

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 acquired 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.

Map of buoy locations



Automated Buoy Schematic

2022 Buoy Deployment

We present the latest buoy findings in three sections beginning with a general summary of the deployment and data followed by a summary of weather conditions that helped drive the patterns of temperature, oxygen, and algae in each lake in 2022. Those patterns are then presented for each lake in the remaining two sections.

Deployment and Results Summary

We upgraded the buoys with new equipment that included new data loggers for both sites and new sensors on the Highland Lake buoy. The equipment was ordered at the end of 2021, but did not reach LEA until July 2022 (because of supply chain issues). That delay meant we did not deploy the buoys until July 8 for Highland and July 11 for Long Lake. The buoys were in place recording data until October 28, when they were both removed from the lakes.

Despite the late season start, we had an array of HOBO temperature loggers (see Water Testing Report Chapter 3) in place at each buoy site during the six months prior to buoy deployment. This meant that those sensors filled in the gap in temperature between the onset of stratification at the beginning of May and the start of the automated buoy deployment in July. Combined, the buoys collected 20,891 sets of sensor readings during their time (108 to 111 days) on the water. Much of this data was available in real time on our website.

During deployment, we did one to two onsite visits to clean and replace sensors and provide calibration checks using our multiparameter sonde. One oxygen sensor on the Long Lake buoy failed and caused a power drain that shut down the buoy for about five days. That sensor was replaced, and then the replacement had to be replaced along with the chlorophyll sensor due to faulty readings. An error programming the new data logger for the weather sensors led to the loss of rain data. Also, several weather sensors started to fail towards the end of the deployment.

The water temperature patterns in both lakes showed the same basic response to the warmer and drier-than-average conditions of 2022. Stratification and mixing events occurred about the same time; wind events in July, August, and September led both lakes to mix the surface with deeper water followed by restratification during the warm periods in August and September that followed. Still, the water temperature patterns did vary between the two lakes due in large part to contrasting size and shape. For example, the thermocline depth (location in the water column where temperature changes most rapidly) was generally deeper and the temperatures were slightly warmer at the deeper Long Lake site. Also, complete mixing (lake turnover) occurred in Long Lake 20 days later than in Highland Lake.

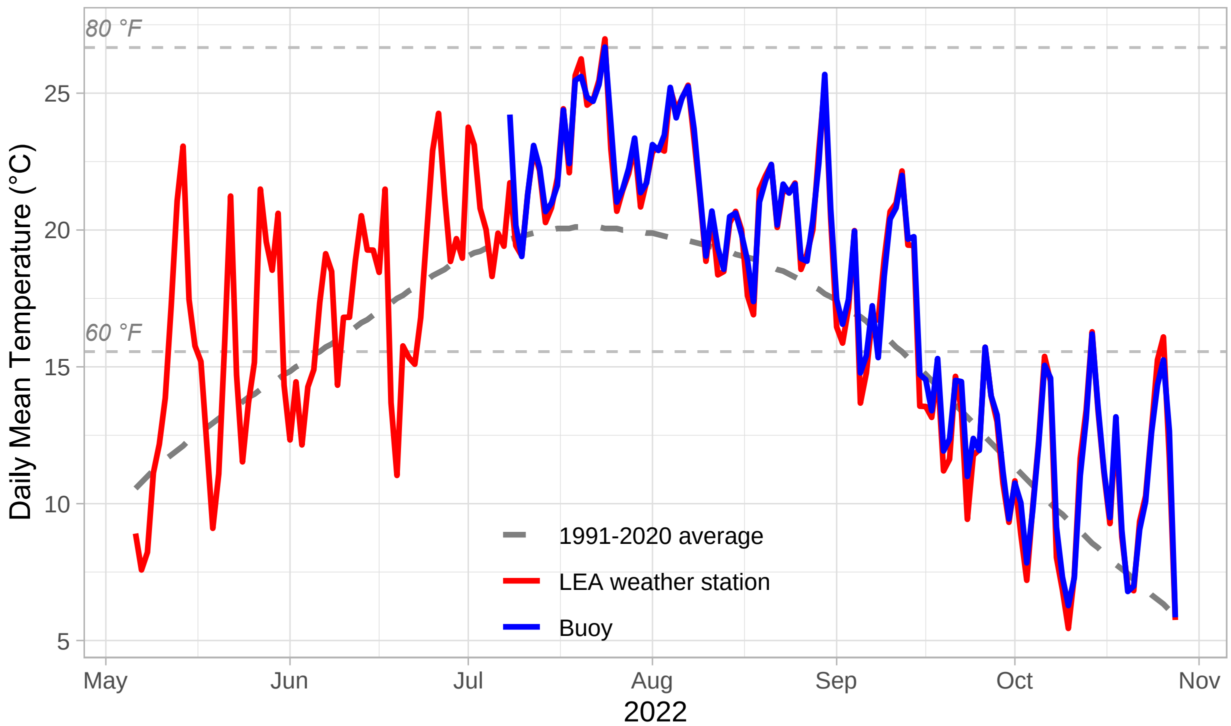
In both lakes, dissolved oxygen declined as temperature increased and as stratification strengthened. Anoxia (absence of dissolved oxygen) occurred in each system in 2022, but as in previous years, Highland Lake's greater oxygen consumption rate meant that it developed anoxia sooner (early July as opposed to late August) and lasted longer than Long Lake.

Chlorophyll fluorescence, which is an estimate of algae concentration, was very similar between Highland Lake and Long Lake, even though the Long Lake sensor was twice as deep. Fluorescence on the Highland buoy increased by a factor of about four in September, but fluorescence seemed fairly consistent with time on Long Lake.

Overall, the 2022 season had some challenges with the equipment delays, programming errors, and sensor failures. Nevertheless, we were able to successfully monitor both lakes for much of the summer season using these automated buoys. Staff members Ben Peierls, Maggie Welch, Shannon Nelligan, and Michael Flannery, and intern Hanna Holden provided technical support in the field; we thank all who were involved and have supported the buoys in the past.

Weather Conditions (Highland Lake)

Air Temperature

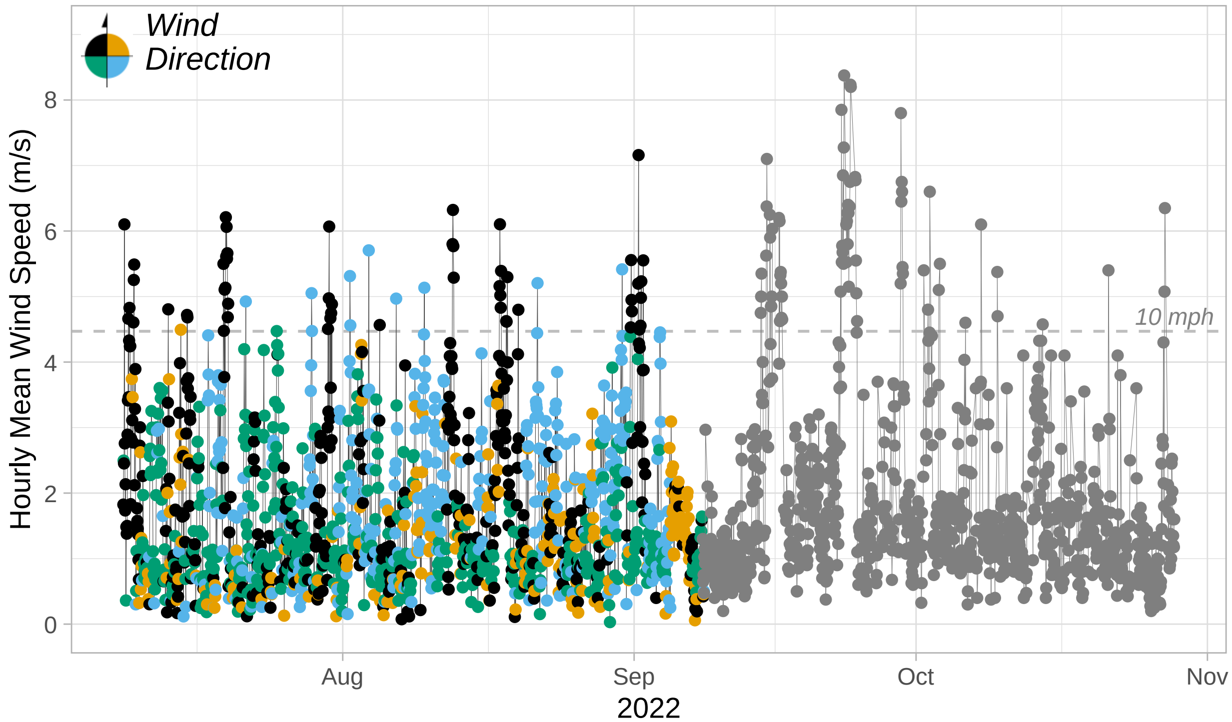


Local weather conditions (air temperature, wind, rain) play a major role in controlling lake water quality. Sensors on the Highland Lake buoy collect weather and water data simultaneously, and the weather data results are summarized in this and the following two sections. We used data from our land-based weather station (near the east shore of Highland Lake and 1.4 km from the buoy) to fill in temperature and rain data before the buoy was deployed. Because the two lakes are geographically close together, the Highland Lake weather data are applicable to Long Lake as well, though the surrounding topography does affect local conditions at each site.

Air temperature is important for understanding the heating, cooling, stability, and evaporation of lakes because it plays a strong role in the heat balance of surface water. Warm weather favors stable, stratified lake conditions, while cooler temperatures reduce the energy needed to mix water layers. Air temperature measured on the buoy ranged from 1.5 to 33 °C (34.7 to 91.4 °F). The daily mean values (blue line, above) followed a typical seasonal pattern albeit generally warmer than normal for this area throughout much of the deployment (1991-2020 average, gray dashed line, above; source: Global Historical Climatology Network, Station USC00170844 Bridgton). Average air temperature was above normal for May, July, August, and October, while June and September were close to normal on average. Our nearby weather station (red line) recorded almost identical readings to the buoy sensor, differing only in the extreme values (temperature range -0.62 to 34.3 °C (30.9 to 93.7 °F), which shows how lake water can have a moderating influence on the overlying air temperature.

Weather Conditions (Highland Lake)

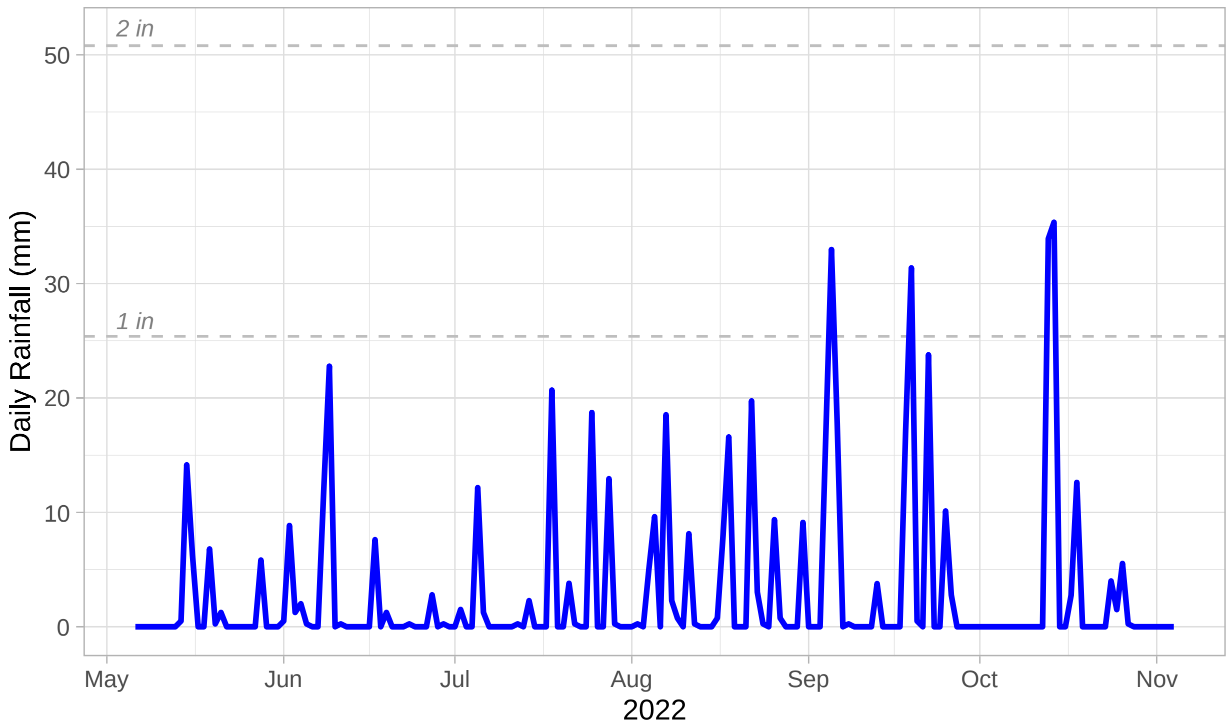
Wind



Wind also has a significant impact on conditions within a lake. Together with temperature, wind controls the physical structure of a lake, like the change from being stratified to being fully mixed. Wind-driven waves can cause erosion in certain cases. Wind speed and direction measurements recorded by the buoy were quite variable at the 15-minute scale, so broader scale patterns were examined using hourly mean values; the land-based measurement did not correlate well with the buoy, so the record starts in July. In the figure above, the height of the point denotes the mean wind speed and the color indicates the direction from which the wind is blowing (like a weather vane); for example, black means the wind was blowing from anywhere in the north to west (N-W) quadrant. Grey symbols indicate when the direction data was lost. Hourly mean wind speed ranged from 0.030 to 7.2 m/s (0.067 to 16 mph), and the buoy recorded a maximum wind speed of 14.8 m/s (33.1 mph) on September 24; this was around the time Post-Tropical Cyclone Fiona passed by the area as it headed for landfall on Nova Scotia. Other notable strong winds occurred at the start of the record in July, mid-August, and early and mid-September. Wind direction was highly variable, though stronger winds tended to come out of the N-W and S-E quadrants, the prevailing winds for this area. Since the longest lake axis is aligned in those directions, wind measurements at the buoy may be stronger for prevailing winds than other directions because they are unimpeded by local topography.

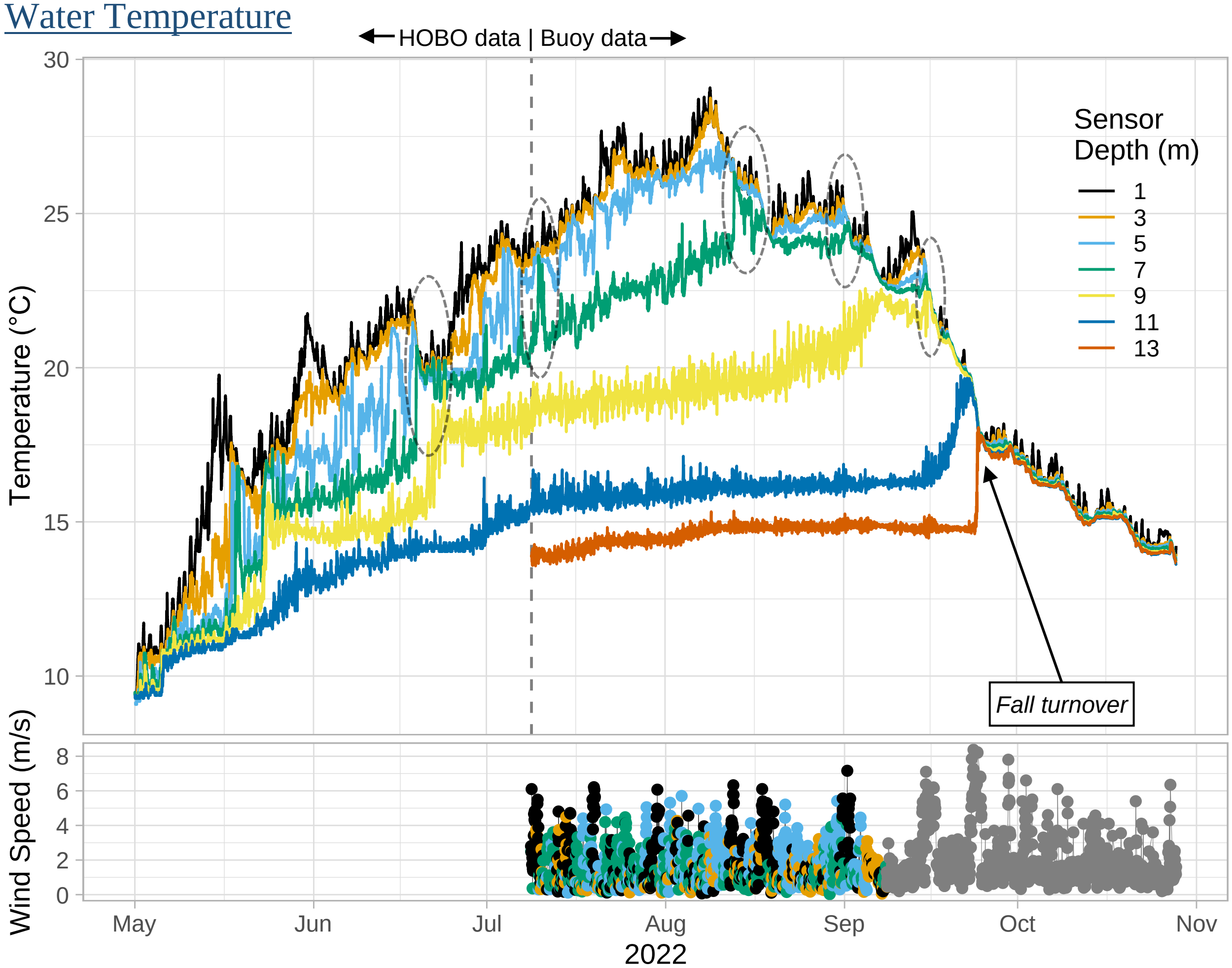
Weather Conditions (Highland Lake)

Rain



Rain adds water directly to a lake and also indirectly through watershed runoff. Rain is important in maintaining lake levels, but sediment and nutrients can be delivered along with it, depending on rain amount and intensity. Total rain recorded at the LEA weather station from May through October was about 535 mm (21.1 in), which was more than 2021, but less than the 30-year (1991-2010) normal rainfall of 668 mm (26.3 in) for the same months. This came following another lower-than-normal winter snowfall. The weather station recorded less rainfall than normal during May, June, and July. Total rainfall in August was close to normal for the area, and September proved to be much wetter than normal. The most rain to fall in one day (35.4 mm or 1.39 in) happened on October 14. High intensity storm events have the most impact on water quality because of the erosion and pollution potential. Most of the time when rain fell, rain intensity was about 1.8 mm per hour (0.069 in/hr), but a maximum of 14 mm per hour (0.55 in/hr) on August 7. Climate change models predict that along with warming air and water temperature, Maine will experience more precipitation and more periods of high intensity rainfall; this could lead to increases in phosphorus loading to lakes.

Water Temperature

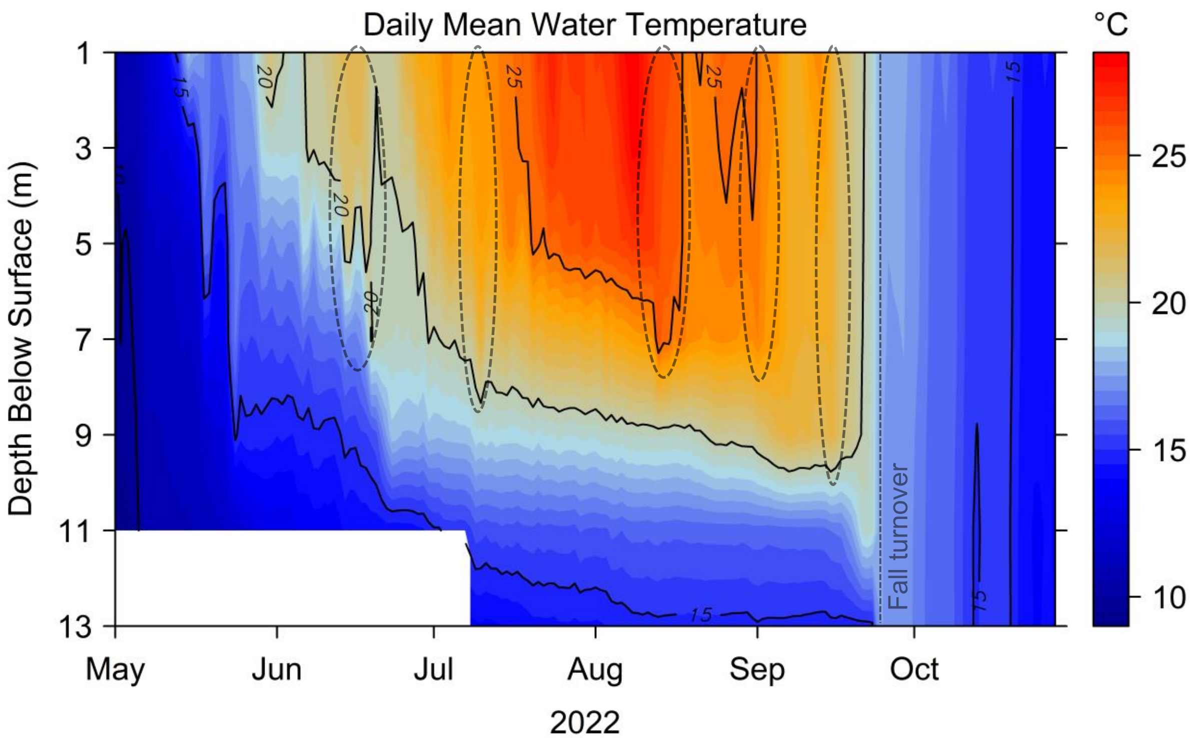


Water temperature data forms the foundation for most water quality measures and is essential for understanding lake physical dynamics, nutrient cycling, metabolic rates, and habitat availability for fish and other aquatic organisms. Data from individual temperature sensors, along with hourly mean winds, are shown in the above figure; values prior to July 8 came from HOBO temperature loggers (the logger at 13 m did not record data). Each colored line represents water temperature at a specific depth below the surface recorded at 15-minute intervals. The minimum temperature after ice-out was about 4 °C (39 °F; not shown), and the maximum recorded temperature on Highland Lake was 29.1 °C (84.4 °F) on August 8 at 1 m.

Lake water temperature varies in response to heat fluxes and winds. Daily heating and cooling of the surface water can be seen in the saw-tooth pattern of the 1-m sensor data (black line). In deeper waters, the temperature variation gradually gets more rapid and irregular from the wind-driven “sloshing” of internal waves (or seiches). During warm periods, lakes in our area tend to stratify (seen where colored lines separate) into a warm, upper layer (epilimnion) and a cooler, deep layer (hypolimnion). On Highland Lake, stratification began in early May and continued throughout the summer, except for bouts of partial water column mixing (seen where the upper four or five sensor lines briefly come together; see circled areas). This happened throughout the season, especially at times of rapid cooling and high winds. Calm, warm periods caused the lake to re-stratify after these short mixing events. Surface waters began cooling in August, which gradually reduced water column stability and deepened the epilimnion. Complete mixing (turnover) occurred on September 24 following significant wind around that time. This is the earliest fall turnover date recorded by the automated buoy or HOBO temperature loggers (see table below) and a month earlier than last year. By comparison, Long Lake mixed 20 days later on October 14.

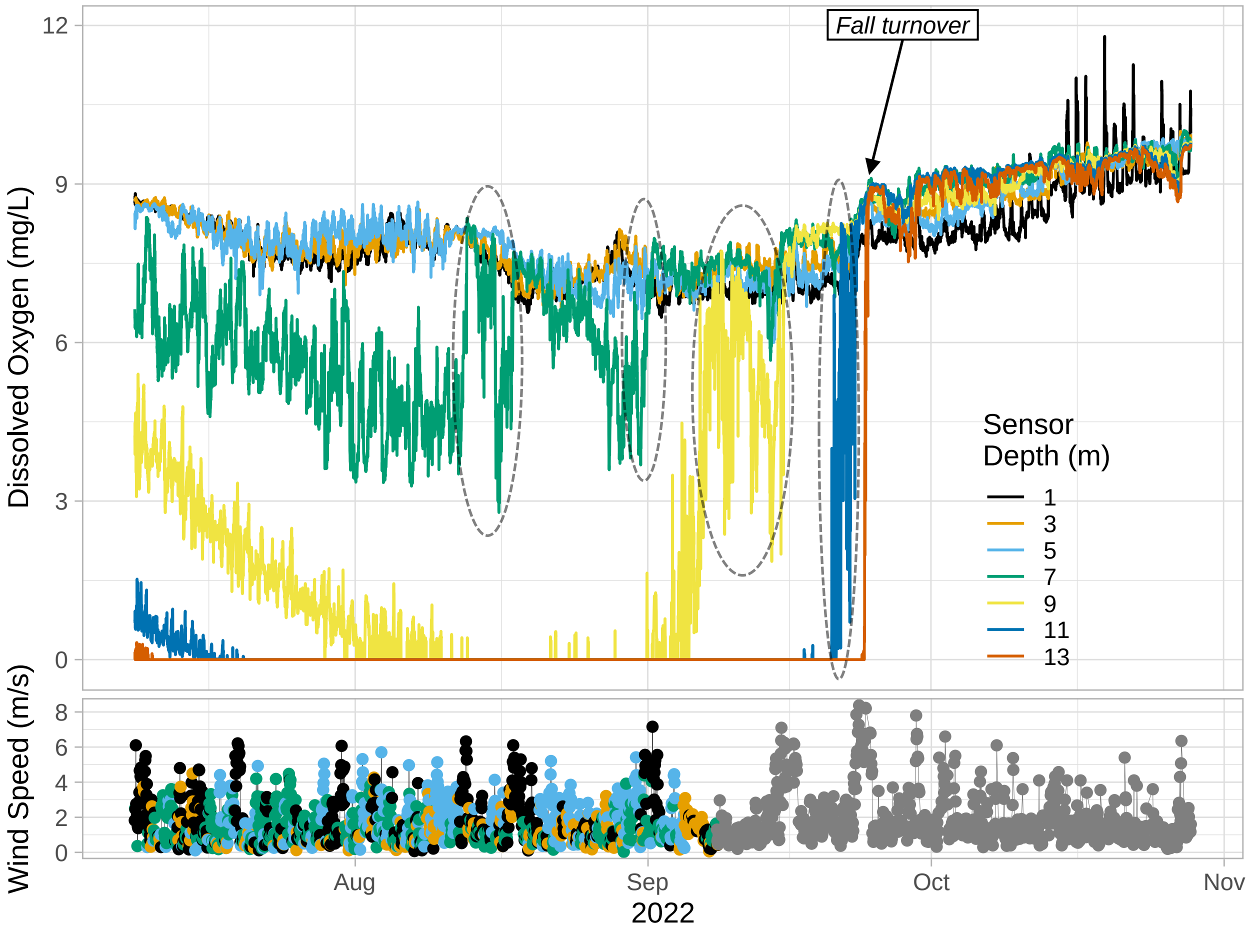
Date of Fall Turnover (Complete Mixing) by Year

YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Turnover Date	after 10/11	10/12	10/11	10/10	11/4?	10/16	10/9	10/8	10/24	9/24



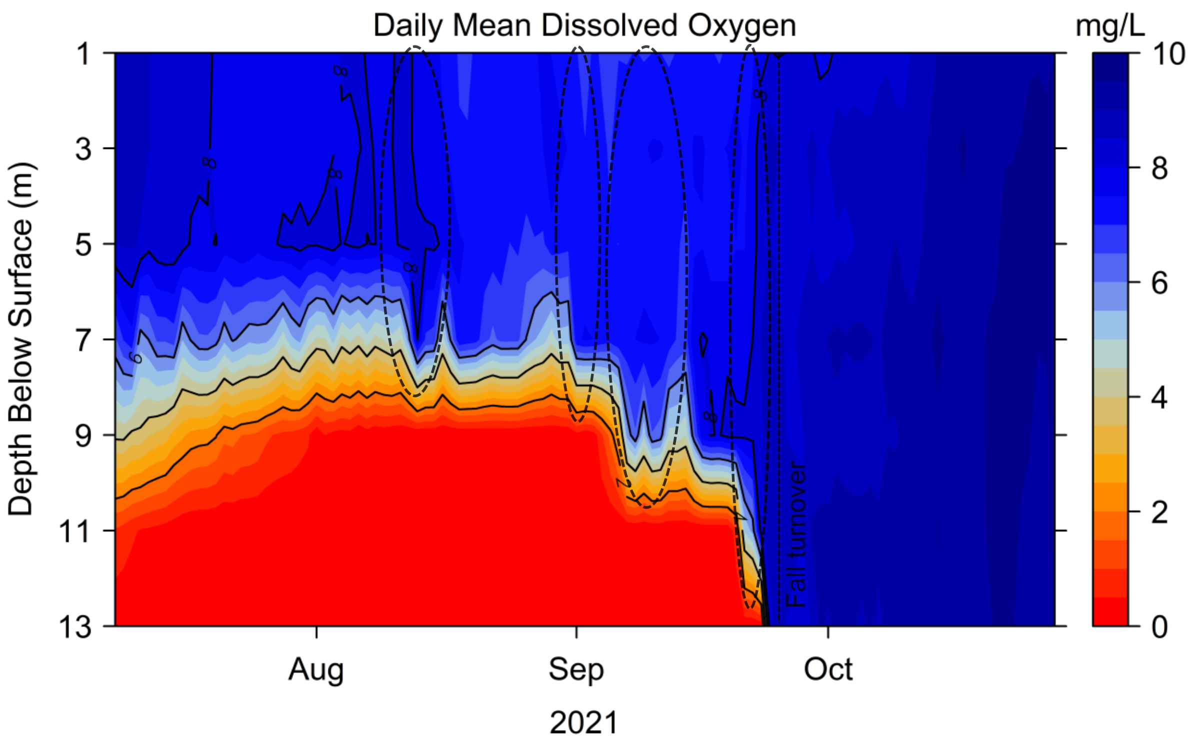
Another, perhaps easier, way to visualize the temperature data is with contour plots (or heat maps) shown in the figure above, which uses daily mean values for smoother lines. Temperature variation across depth and time is represented by colored contours, where the blue to red color range corresponds to a low to high temperature range. The blank area from May to July is due to missing data. Temperature stratification shows up as areas where colors change in the vertical direction and contour lines are tilted more towards horizontal (from May through September). The area where contours come closest together (i.e., temperature changes most rapidly with depth) is called the thermocline. The partial mixing events previously discussed, can be seen as sharp dips in the contour lines (circled areas), and when contour lines are vertical from top to bottom (such as late-September into October), the lake is completely mixed. Warm, stratified conditions stand out as darker red and orange areas during July through August. The downward sloping contours show that the upper layer (epilimnion) and thermocline generally deepened throughout the summer; thermocline depths ranged from about 2 m in May to 12 m before fall turnover.

Dissolved Oxygen



The same types of plots used for temperature can be used to examine the dissolved oxygen (DO) concentration time series collected at each buoy. The data shown above has been corrected for sensor drift and biofouling using independent, discrete DO measurements at the same location; note that the start of the time series is different than that for the temperature data.

The data show generally decreasing DO from beginning of deployment through the end of August, particularly for deep waters. Some of that is simply due to warming, since cold water can contain more DO than warm water, all else being equal. Oxygen in the deeper waters, however, decreased more rapidly; DO concentration at 13 m reached 0 mg/L (anoxia) right after the buoy was deployed. DO loss is caused by biological consumption (animals and bacteria using oxygen) and lack of aeration during stratified conditions. With cooler temperatures and strong enough winds, however, deep waters were able to be mixed and aerated as evidenced by the rapid and large DO concentration swings throughout August and September (circled areas). The daily warming-cooling cycle of the air, the daily cycle of photosynthesis and respiration, and the back and forth rocking of internal waves are responsible for the smaller variations in DO concentration seen in the figure. By late September, the water column was completely saturated with oxygen after temperatures decreased and winds fully mixed the lake (turnover).



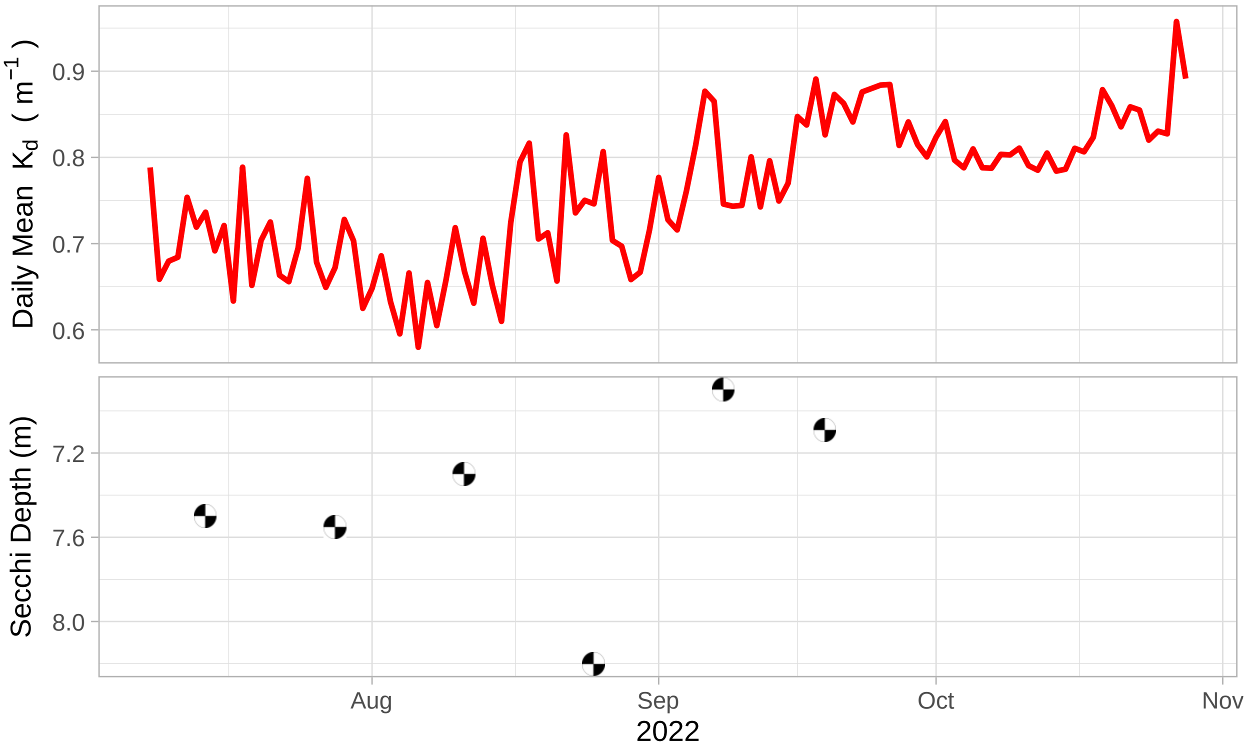
We can also illustrate the buoy dissolved oxygen (DO) data using depth-date contour plots as was done for temperature, though here we have reversed the color scheme so that red and blue signify low and high DO, respectively. The contour plot clearly highlights the pattern of lower DO concentrations in summertime deep waters and provides a quick visual gauge of where and when hypoxic (DO < ~2–4 mg/L) conditions occur. As was seen in the previous line plot, Highland Lake bottom water became anoxic (DO = 0 mg/L) starting right after deployment in July and remained so until late September, when the water column mixed completely. Anoxia reached into waters as shallow as 9 m (~30 ft) during the summer. Prior to lake turnover, partial wind mixing events can be seen in the downward dips in the DO contours, such as during mid-August and the first half of September (circled areas).

Besides wind and water temperature, the major control of lake water DO concentrations is biological activity (i.e., respiration and photosynthesis). Oxygen is a byproduct of photosynthesis, so actively growing algae can be an additional source of oxygen in shallow, aerated, well-lit waters. In contrast, deep water DO is reduced when microbes, fish, and plants respire or "breathe" and oxygen cannot be replenished due to thermal stratification. This oxygen consumption eventually leads to **hypoxia** and **anoxia**. Fish tend to avoid and are stressed when moving through areas that have DO concentrations below about 4 mg/L, while anoxic bottom waters can allow phosphorus trapped in sediments to be released into the water column for use by algae. These phenomena highlight the importance of collecting oxygen data.

Hypoxia: low dissolved oxygen concentration detrimental to aquatic organisms

Anoxia: complete absence of dissolved oxygen

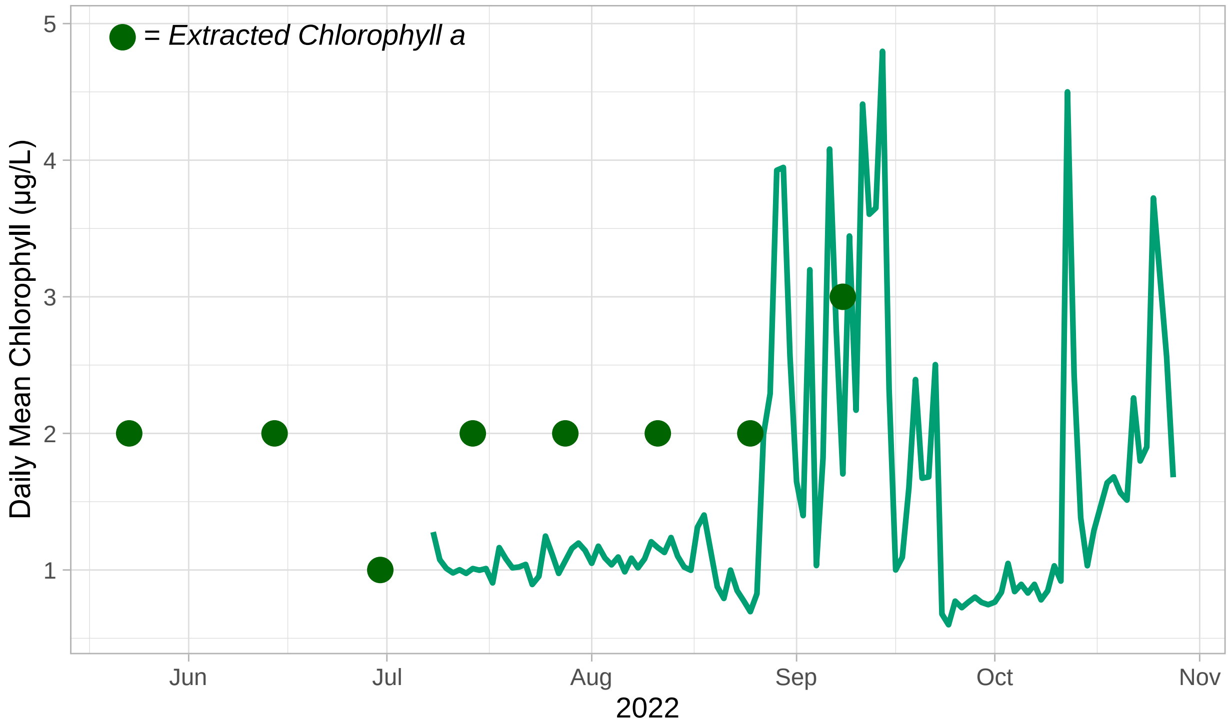
Light Attenuation (Water Clarity)



The Highland buoy has two light sensors, one mounted on top of the buoy and one mounted at 1.5 m depth below the water surface. Both sensors measure the amount of light at visible wavelengths (400-700 nm) reaching them, but the underwater sensor receives less light because the water and the matter it contains reduces or attenuates the solar energy. This decrease in light with depth is quantified using the diffuse light attenuation coefficient (or K_d), which is calculated using the above- and below-water sensor readings. K_d is a measure of water transparency or clarity like Secchi depth, except lower K_d values indicate clearer water. When K_d equals 1 m^{-1}, the photic zone (i.e., where there is enough light for algae to grow) is about 4.6 m (15 ft) deep and a K_d of 0.6 m^{-1} means the photic zone is about 7.8 m (26 ft) deep. At the buoy, daily mean K_d varied from 0.58 to 0.96 m^{-1} with an overall mean of 0.76 m^{-1}. While this is a small range in K_d, it means the photic zone varied in depth by about 3 m. K_d values decreased (increased clarity) from July into August, and then increased (clarity decreased) throughout the rest of the deployment.

Light attenuation is a function of material that absorbs or reflects light like humic and tannic acids, soils and sediments, algae, and even water itself. These same factors influence Secchi depth measurements, so we would expect these two water clarity indicators to be correlated. The lower panel shows Secchi depths measured near the buoy during regular monitoring trips; note reversed depth scale. While the two parameters were not correlated in 2022 because of so few data points, both measures showed a general tendency for higher water clarity in July and August as compared to September. We know that a combination of the factors mentioned above control water clarity, and having comprehensive light data is very helpful in understanding and monitoring changes in this important water quality index.

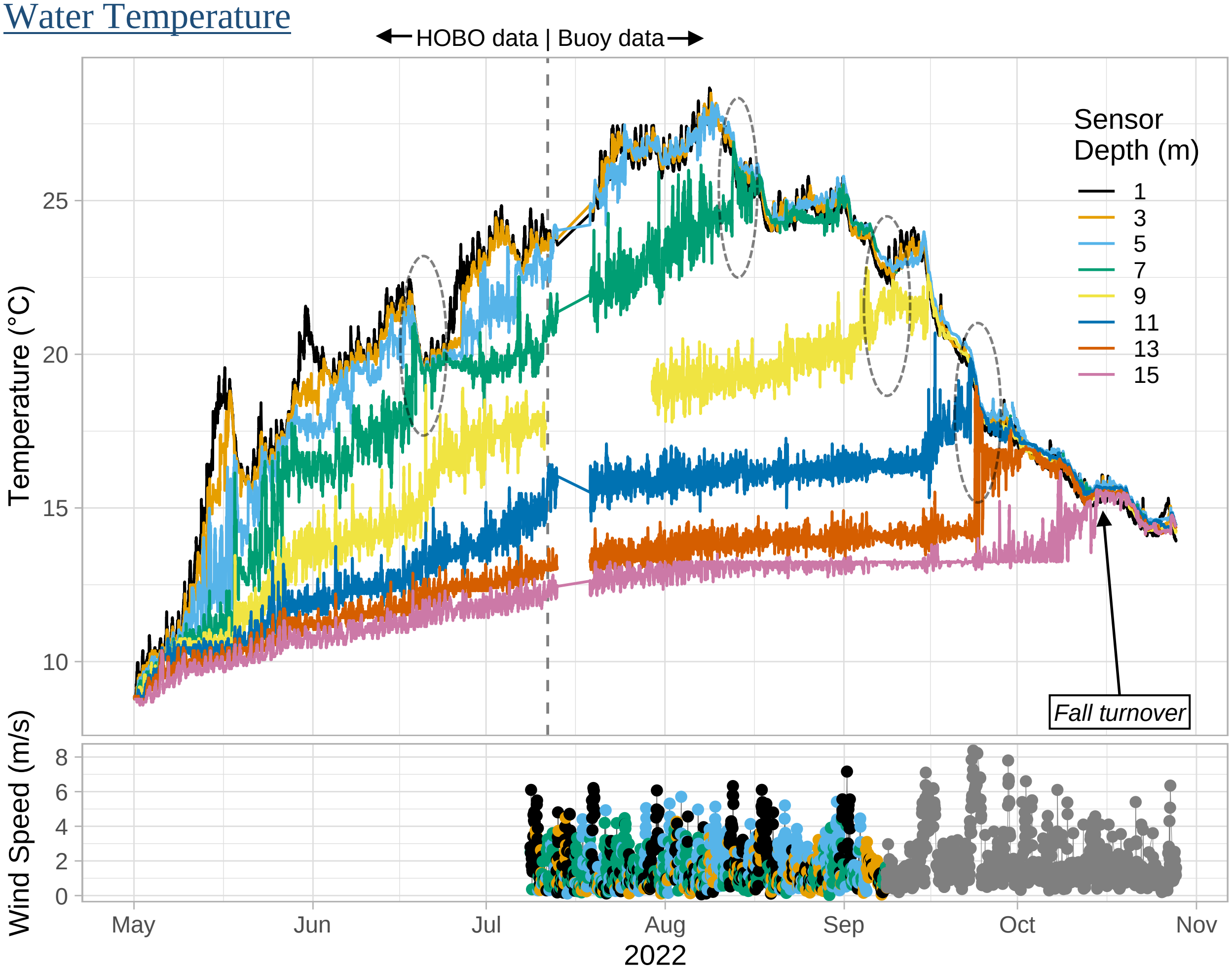
Chlorophyll or Algae Biomass



The Highland buoy has one sensor mounted 1.5 m below the lake surface that measures chlorophyll concentrations using fluorescence (same as the field fluorometer used on regular testing trips and discussed in Chapter 4 of the Water Testing Report). The amount of this pigment (found in all plants and algae and used for photosynthesis) can be used as a proxy for algae biomass and as a measure of lake productivity. It is important to note that field fluorescence is a relative measure and is not as accurate as lab-based chlorophyll *a* measurements. Also, chlorophyll fluorescence often shows variation with depth and the buoy data is from a single discrete depth. Still, buoy chlorophyll and extracted chlorophyll *a* concentrations in the epilimnion (upper mixed layer) from our regular testing trips (points in the figure above) were within one µg/L (or parts per billion) of each other during the period.

Daily mean chlorophyll based on fluorescence, after filtering out extreme outliers, ranged from about 0.6 to 4.8 µg/L, with a mean of 1.5 µg/L (or parts per billion). Overall, these values represent low to moderate chlorophyll levels. There was little variation in chlorophyll at the beginning of the record, but levels increased and became more variable at the end of August through September. We think it unlikely that biofouling near the sensor caused the increase, since we cleaned the sensors and mounting arm in the first half of August. Chlorophyll will often increase (i.e., algae can grow) if enough nutrients (phosphorus) and light are available. Since rainfall increased in August and September, the increase in chlorophyll seen then could have been a function of nutrients introduced by runoff. The drop in chlorophyll in late September coincided with the lake turnover, suggesting that some of the variability could be due to mixing near-surface algae down deeper. Phosphorus brought up from bottom waters during turnover may have fueled the increase in algae seen October. There are, of course, other factors that control algae populations, like competition between different species and zooplankton grazing, but those are beyond the monitoring capabilities of the buoy.

Water Temperature

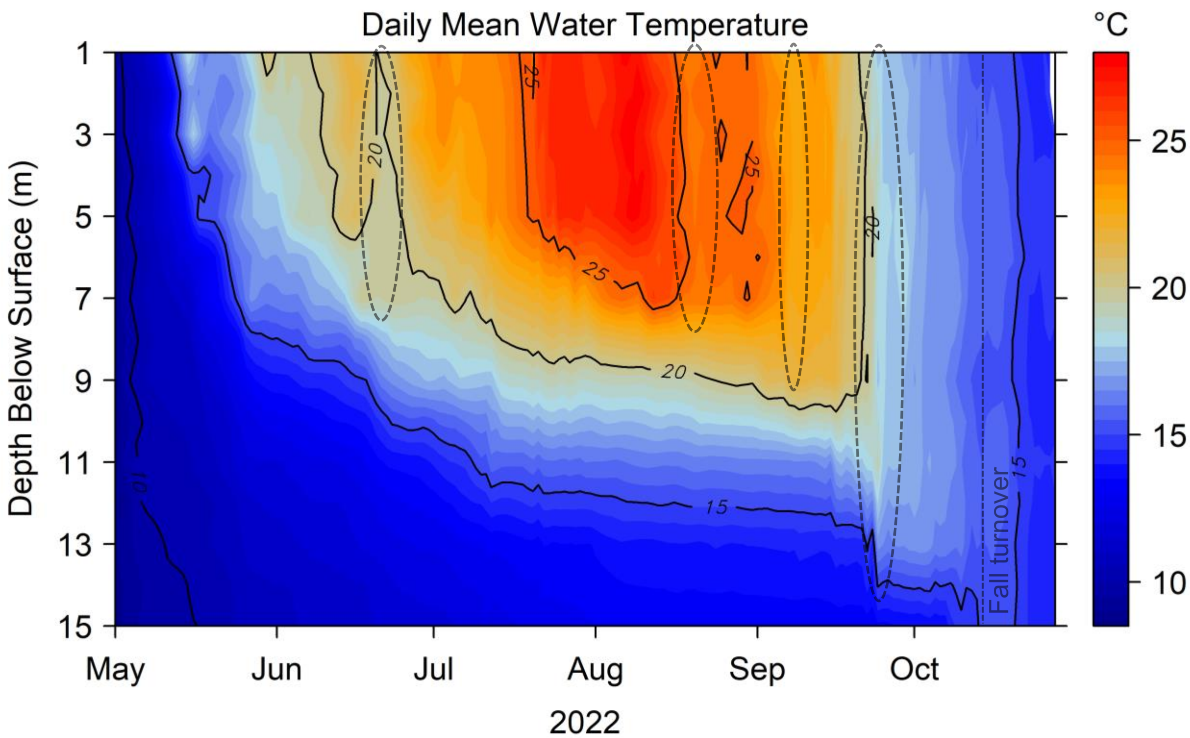


Water temperature data forms the foundation for most water quality measures and is essential for understanding lake physical dynamics, nutrient cycling, metabolic rates, and habitat availability for fish and other aquatic organisms. Data from the individual temperature sensors, along with hourly mean winds, are shown in the above figure; values prior to July 11 came from HOBO temperature loggers. Each colored line represents water temperature at a specific depth below the surface recorded at 15-minute intervals. The gaps in the lines are when the buoy lost power. The minimum temperature after ice-out was about 4 °C (39 °F; not shown), and the maximum recorded temperature on Long Lake was 28.7 °C (83.7°F) on August 8.

Lake water temperature varies in response to heat fluxes and winds. Daily heating and cooling of the surface water can be seen in the saw-tooth pattern of the 1-m sensor data (black line). In deeper waters, the temperature variation gradually gets more rapid and irregular from the wind-driven “sloshing” of internal waves (or seiches). During warm periods, lakes in our area tend to stratify (seen where colored lines separate) into a warm, upper layer (epilimnion) and a cooler, deep layer (hypolimnion). On Long Lake, stratification began in early May and continued throughout the summer, except for bouts of partial water column mixing (seen where the upper four or five sensor lines briefly come together; see circled areas). This happened throughout the season, especially at times of rapid cooling and high winds. Calm, warm periods caused the lake to re-stratify after these short mixing events. Surface waters began cooling in August, which gradually reduced water column stability and deepened the epilimnion. Brief deep water mixing occurred on October 8 and 13, but it wasn't until October 14 following about 24 hours of moderate winds that the water column was completely mixed. This turnover date is one of the earliest yet recorded by the automated buoy or previous temperature sensor arrays (see table below). By comparison, Highland Lake mixed 20 days earlier on September 24.

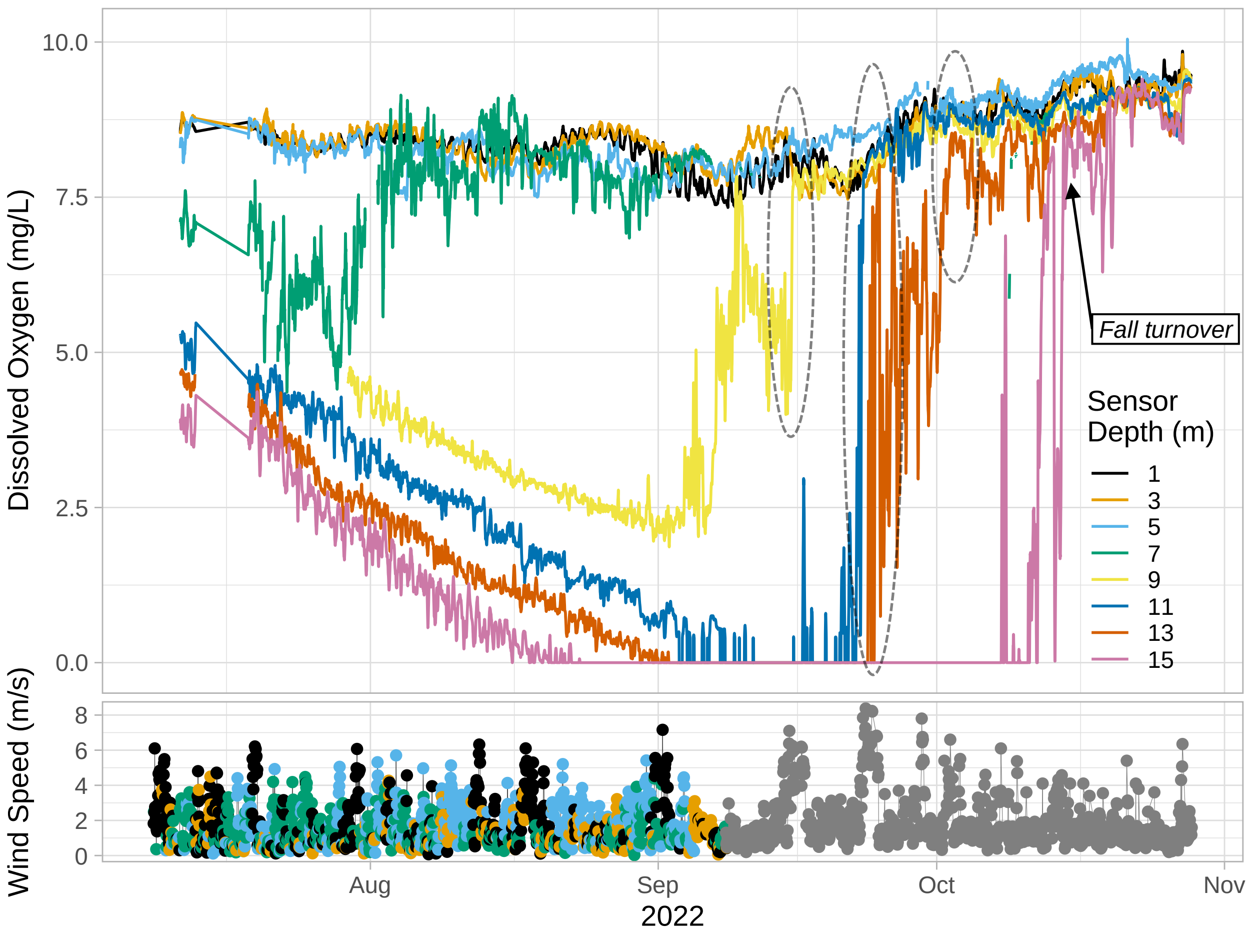
Date of Fall Turnover (Complete Mixing) by Year

YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Turnover Date	10/25	10/23	N/A	N/A	11/4	10/18	10/18	10/8	10/27	10/14



Another, perhaps easier, way to visualize the temperature data is with contour plots (or heat maps) shown in the figure above, which uses daily mean values for smoother lines. Temperature variation across depth and time is represented by colored contours, where the blue to red color range corresponds to a low to high temperature range. Temperature stratification shows up as areas where colors change in the vertical direction and contour lines are tilted more towards horizontal (from May through September). The area where contours come closest together (i.e., temperature changes most rapidly with depth) is called the thermocline. The partial mixing events previously discussed, can be seen as sharp dips in the contour lines (circled areas), and when contour lines are vertical from top to bottom (such as from mid-October on), the lake is completely mixed. Warm, stratified conditions stand out as darker red and orange areas during July through August. The downward sloping contours show that the upper layer (epilimnion) and thermocline generally deepened throughout the summer; thermocline depths ranged from about 2 m in May to 14 m before fall turnover.

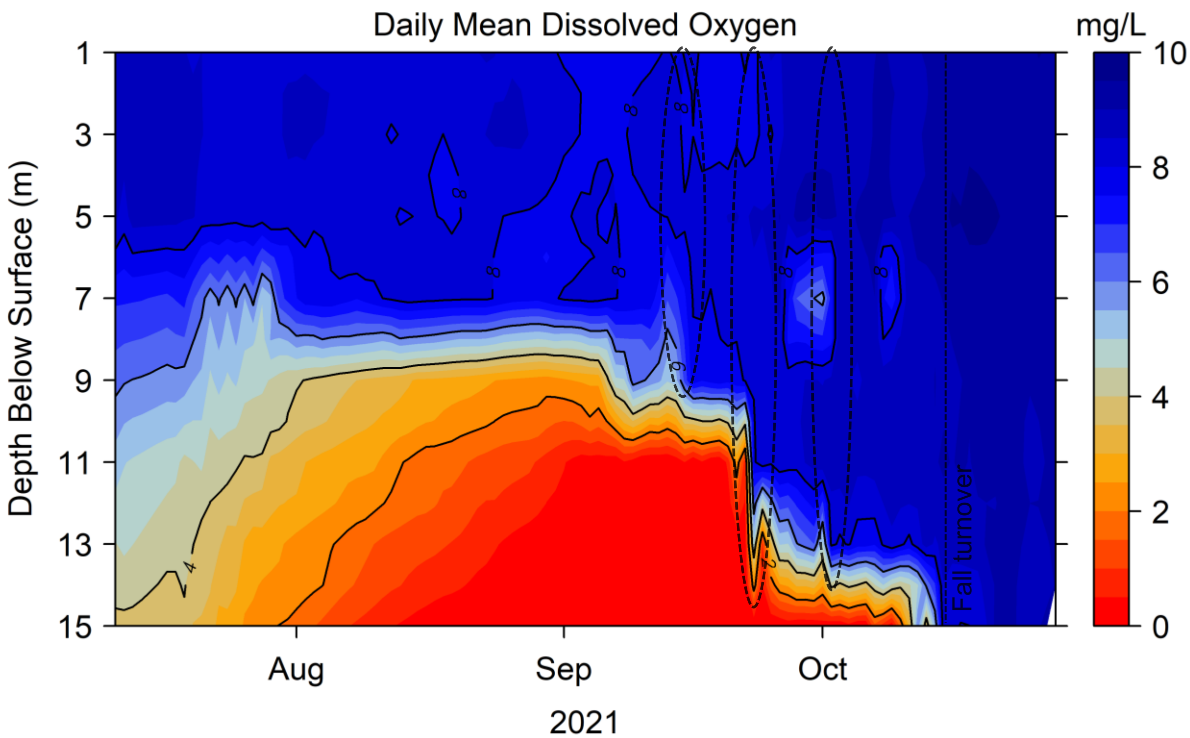
Dissolved Oxygen



The same types of plots used for temperature can be used to examine the dissolved oxygen (DO) time series collected at each buoy. The data shown above has been corrected for sensor drift and biofouling using independent, discrete DO measurements at the same location; note that the start of the time series is different than that for the temperature data. Gaps in the record were caused by a power failure and sensor problems. The sensor at 9 m had to be replaced twice, and the sensor at 7 m had periods of bad readings that needed filtering before it failed altogether.

The data exhibit a pattern of generally decreasing DO from beginning of deployment through the end of August, particularly for deep waters. Some of that is simply due to warming water, since cold water can contain more DO than warm water, all else being equal. Oxygen in the deeper waters, however, decreased more rapidly; deep DO readings reached 0 mg/L (anoxia) by late August to early September. DO loss is caused by biological consumption (animals and bacteria using oxygen) and lack of aeration during stratified conditions. With cooler temperatures and strong enough winds, however, deep waters were able to be mixed and aerated as evidenced by the rapid and large DO concentration swings during September through October (circled areas). The daily warming-cooling cycle of the air, the daily cycle of photosynthesis and respiration, and the back and forth rocking of internal waves are responsible for the smaller variations in DO concentration seen in the figure. By mid-October, the water column was completely saturated with oxygen after temperatures dropped and winds fully mixed the lake (turnover).

Long Lake Conditions 2022



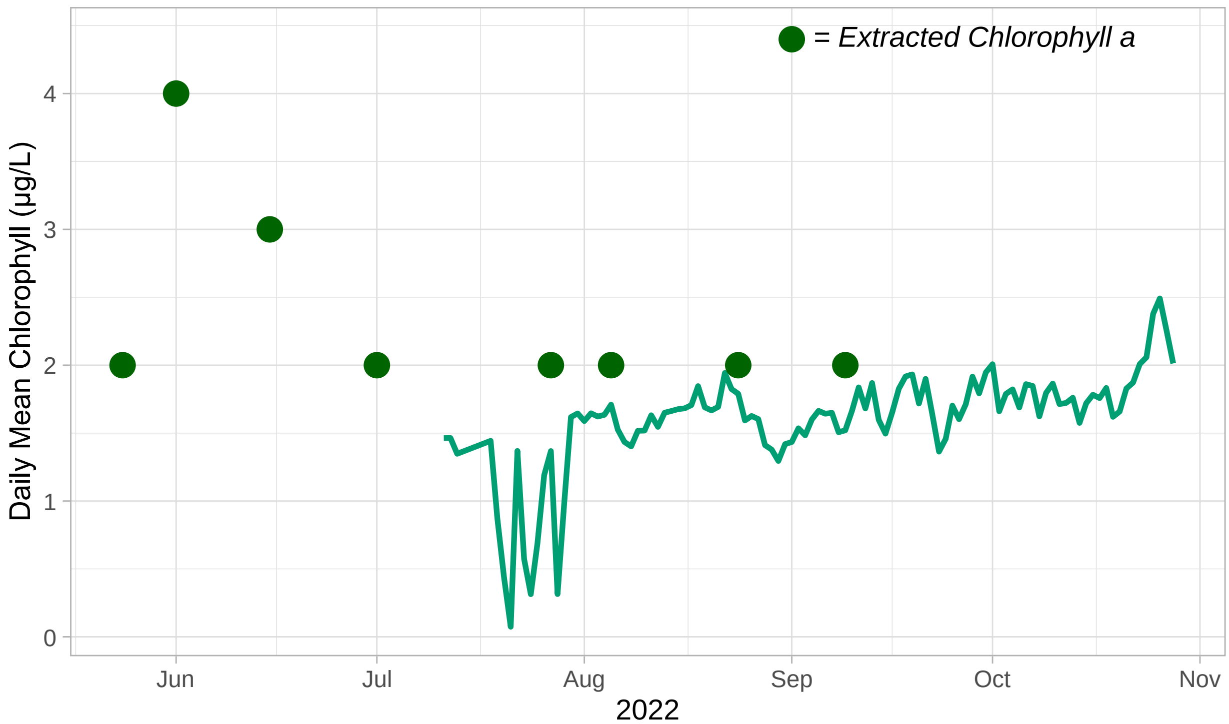
We can also illustrate the buoy dissolved oxygen (DO) data using depth-date contour plots as was done for temperature, though here we have reversed the color scheme so that red and blue signify low and high DO, respectively. The data has been interpolated to fill in the gaps caused by missing sensor readings. The contour plot clearly highlights the pattern of lower DO concentrations in summertime deep waters and provides a quick visual gauge of where and when hypoxic (< ~2–4 mg/L) conditions occur. As was seen in the previous line plot, Long Lake bottom water became anoxic (DO = 0 mg/L) by the latter half of August and remained so for the deepest water until mid-October, when the water column mixed completely. Anoxia reached into waters as shallow as 11 m (~36 ft) during the summer. Prior to lake turnover, partial wind mixing events can be seen in the downward dips in the DO contours (circled areas). Compared to Highland Lake, Long Lake had low DO conditions for less time (see plot on page 11).

Besides wind and water temperature, the major control of lake water DO concentrations is biological activity (i.e., respiration and photosynthesis). Oxygen is a byproduct of photosynthesis, so actively growing algae can be an additional source of oxygen in shallow, well-lit, aerated waters. In contrast, deep water DO is reduced when microbes, fish, and plants respire or "breathe" and oxygen cannot be replenished due to thermal stratification. This oxygen consumption eventually leads to **hypoxia** and **anoxia**. Fish tend to avoid and are stressed when moving through areas that have DO concentrations below about 4 mg/L, while anoxic bottom waters can allow phosphorus trapped in sediments to be released for use by algae. These phenomena highlight the importance of collecting oxygen data.

Hypoxia: low dissolved oxygen concentration detrimental to aquatic organisms

Anoxia: complete absence of dissolved oxygen

Chlorophyll or Algae Biomass



The Long Lake buoy has a single sensor mounted 3 m below the lake surface that measures chlorophyll concentrations using fluorescence (same as the field fluorometer used on regular testing trips and discussed in chapter 4). The sensor was moved from last year's position at 5 m. In late July, the sensor was replaced due to increased noise and signal loss. The amount of this pigment (found in all plants and algae and used for photosynthesis) can be used as a proxy for algae biomass and as a measure of lake productivity. It is important to note that field fluorescence is a relative measure and is not as accurate as lab-based chlorophyll *a* measurements. Also, chlorophyll fluorescence often shows variation with depth and the buoy data is from a single discrete depth. Still, buoy chlorophyll and extracted chlorophyll *a* concentrations in the epilimnion (upper mixed layer) from our regular testing trips (points in the figure) were within one µg/L (or parts per billion) of each other during the period.

Daily mean chlorophyll based on fluorescence, ranged from near 0.1 to 2.5 µg/L, with a mean of 1.6 µg/L. Overall, these are low chlorophyll values. There was little variation in chlorophyll variation over time other than rapid drops in concentration in the latter half of July. These concentration drops were probably not real as the sensor was experiencing signal loss and failure before it was replaced. Chlorophyll will often increase (i.e., algae can grow) if enough nutrients (phosphorus) and light are available. Runoff from rain events or wind-driven mixing can add nutrients that fuel algae production and increase chlorophyll. The limited range and variation of the buoy chlorophyll data suggest that rain and wind were not strong drivers of the observed patterns. There are, of course, other factors that control algae populations, like competition between different species and zooplankton grazing, but those are beyond the monitoring capabilities of the buoy.