2019 Report on the Health of the Norway Lakes

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May 18, 2020

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About the Report

The Lakes Association of Norway (LAON), with support from the Town of Norway and contributions from the membership, continued to monitor the health of the four Norway lakes:

- Lake Pennesseewassee (also called Norway Lake)
- Little Pennesseewassee Lake (also called Hobbs Pond)
- Sand Pond
- North Pond

The Courtesy Boat Inspection program for people bringing their boats into Lake Pennesseewassee continues, and has been successful at preventing invaders from getting into the lake. This year Scott Williams and staff from Lake and Watershed Resource Management Associates (LWRMA) conducted the level 3 invasive aquatic species screening of the four lakes in September and October. Their full reports are separate and may also be found on the LAON website in the water quality section (http://norwaylakes.org/water-quality/).

The water quality team sampled the four lakes monthly between May and September, with additional water clarity measurements on some lakes. Water quality measures include Secchi depth for clarity, as well as temperature and dissolved oxygen profiles at 1-meter increments from surface to bottom. Total Phosphorus, Chlorophyll, pH, Alkalinity, Conductivity and Color were measured at surface and near-bottom. Samples for phosphorus and chlorophyll were analyzed at the Maine State Health and Environmental Testing Laboratory (HETL), as were one-time samples for Alkalinity and Calcium (the ratio is an indicator of sediment release of phosphorus). The other measures were analyzed by the team on-site. More details about our methods are included at the end of this document.

Overview

The table below shows the average values at the surface and bottom (except Secchi depth) of the lakes for primary water quality parameters measured.

Table 1. Secchi depth and Phosphorus values for 2019 compared to the historical average for the four lakes.

Lake	Average 2019				Historical Avg			
	Secchi	Avg P	P Surf	P Bot	Secchi	Avg P	P Surf	P Bot
Sand Pond	7.34	7.9	3.8	13	7.4	8.0	6.2	14.2
Little Pennesseewassee	6.49	14.7	6	23.4	5.2	11.8	9.8	18.7
Pennesseewassee	5.41	10.0	6.6	13.4	5.8	9.9	9.0	11.5
North Pond	3.21	13.6	13.6	13.5	2.8	17.3	17.3	

(green)	Improved	Secchi - higher number is better
(red)	Worsened	P - lower number is better
(grey)	Too close to call	

The good news is that 2019 saw lower phosphorus levels in the surface waters of all the lakes tested. For 2019 we see that Little Pennesseewassee had higher phosphorus values in the bottom and combined surface and bottom water averages than the lake experienced historically. Lake Pennesseewassee had higher phosphorus levels in the bottom waters only, but also suffered from a decrease in water clarity as measured by the Secchi depth.

Historical Perspective

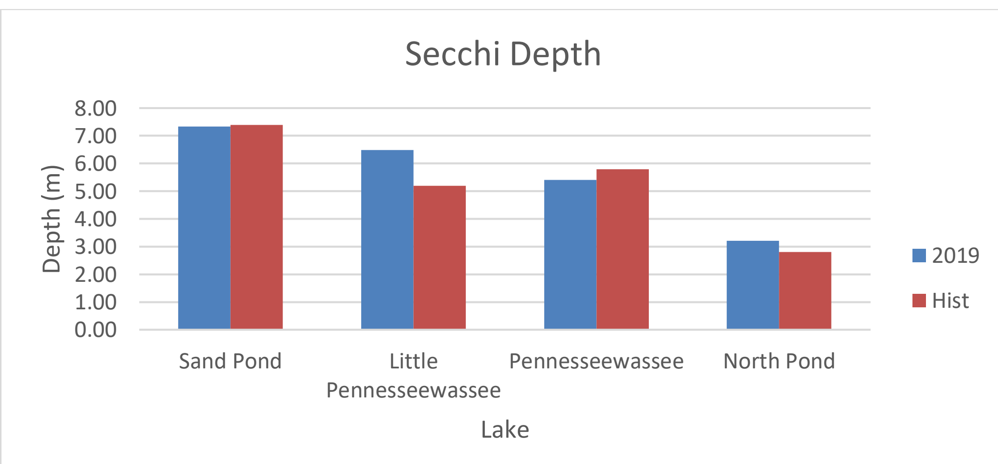


Figure 1. Average Secchi depth for 2019 and historical averages for the four lakes

The Secchi depth is a measure of water clarity. Little Pennesseewassee in 2019 had water clarity better than historical averages, while the other three lakes showed smaller differences (Figure 1). Lake

Pennesseewassee transparency, however, had decreased by almost 40 cm (about 15 inches). Water clarity in our lakes is mostly a function of the amount of microscopic algae (phytoplankton). High concentrations can lead to decreased light penetration, which can harm rooted vegetation on the bottom. Sand Pond has the clearest water followed by Hobbs and Pennesseewassee. North Pond always has visibility to the bottom at three meters.

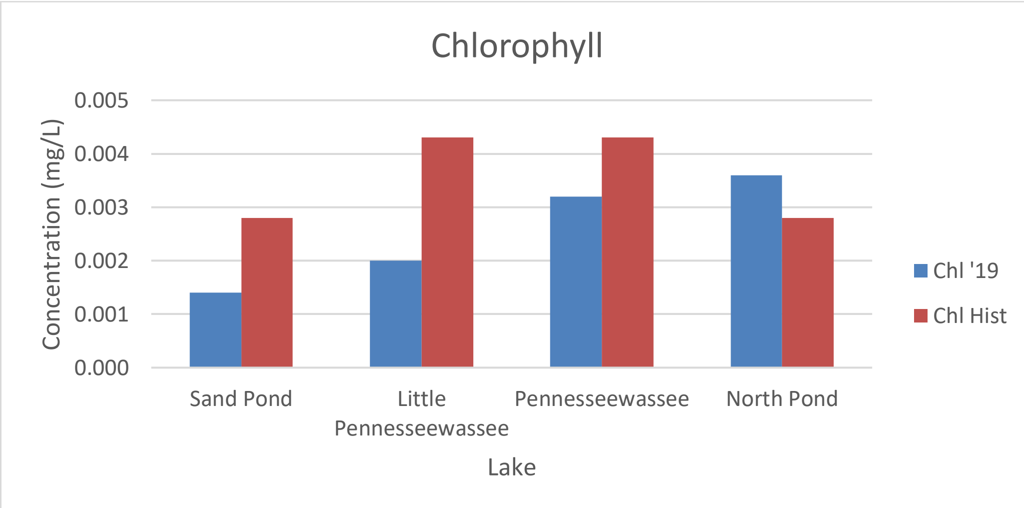


Figure 2. Average Chlorophyll concentrations for 2019 and the historical values for the four lakes.

Chlorophyll levels declined in all lakes except North Pond (Figure 2). Chlorophyll which is found in all photosynthetic organism, and in lakes, is used to quantify the amounts of microscopic algae (phytoplankton). Decreases in algae are good in this case, as an overabundance can lead to bad odors, foul smelling waters, and algal toxins which harm humans and animals. The figure shows a clear trend of the least amount of chlorophyll in Sand Pond, followed by Hobbs, Pennesseewassee and North, in a mirror image of the Secchi depth. In all of the lakes, the chlorophyll concentrations are not high enough to raise concerns yet.

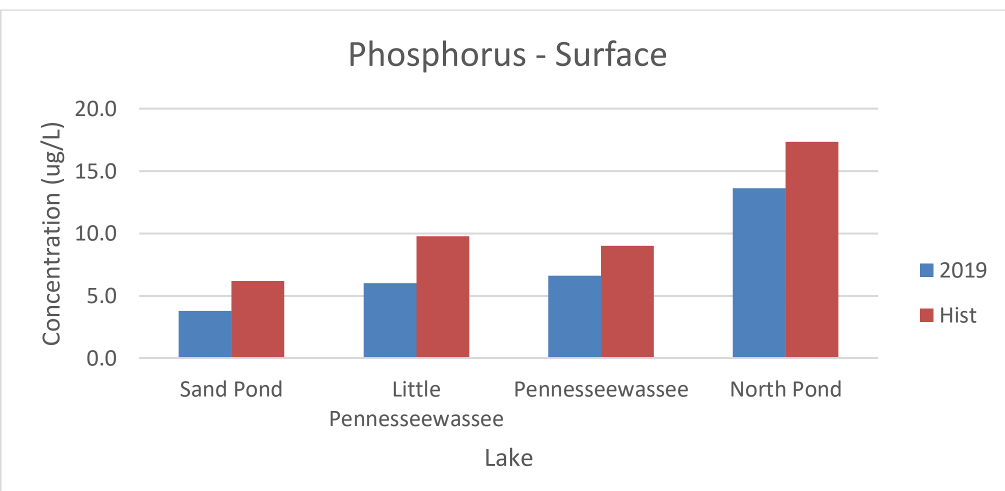


Figure 3. Average Surface Total Phosphorus concentrations for 2019 and historical values.

Surface phosphorus levels in the lakes showed a decline compared to historical data (Figure 3). Phosphorus is a plant nutrient, and in fresh waters is the primary cause for algal blooms. The decline therefore is a good sign for the lakes unless the concentrations are low because the nutrient has already been absorbed by algae for their growth. This seems unlikely since the chlorophyll levels shown above are below historic values. The figure also corroborates the Chlorophyll data, in that we expect lower chlorophyll concentrations when there are lower phosphorus levels. So here we also see a progression from Sand to Hobbs, to Pennesseewassee and North, much like the chlorophyll values in the previous figure.

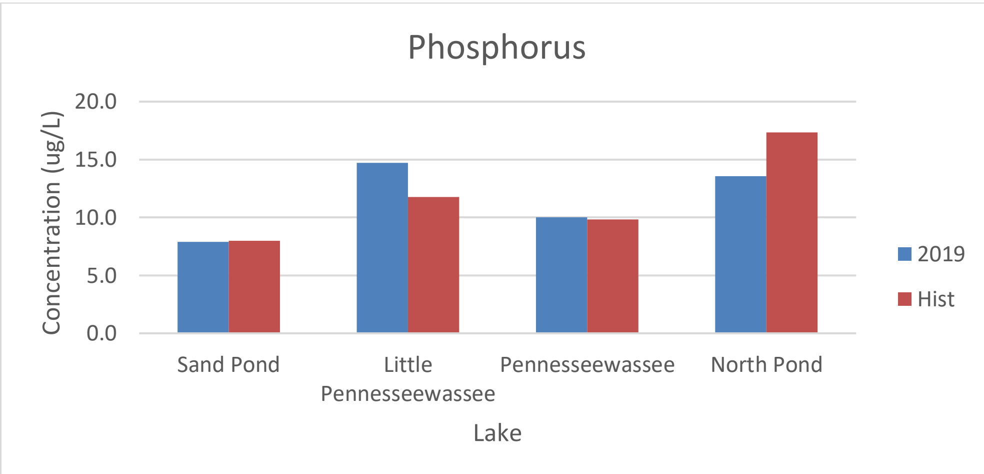


Figure 4. Average combined surface and deep-water Total Phosphorus concentrations for 2019 and historical values for the four lakes.

Combined surface and bottom Phosphorus concentrations were higher than historic values in Little Pennesseewassee during 2019 (Figure 4). They were stable in Sand Pond and Lake Pennesseewassee, and lower in North Pond. This may be an indication that work done by LAON and homeowners in the watershed restoration around North Pond may already be having a positive effect. Overall, the phosphorus levels in our lakes are in the middle of the good to bad range. If they rise much higher, there would be cause for concern.

More detail about lake ecology, what various water quality measures mean, and the historical trends of measurements from our lakes are provided in the 2015 report on the LAON website water quality section (http://norwaylakes.org/water-quality/).

Highlights of the 2019 sampling

The dissolved oxygen concentrations averaged over the depth of the surface layer (epilimnion) and the bottom layer (hypolimnion) are shown in Figure 5. These two water layers are separated at the thermocline, which is a rapid change in temperature of the water. The thermocline acts as a barrier to diffusion and inhibits substances, like phosphorus, from the lower layer getting into the surface layer. It is not as good at inhibiting the downward sinking of particles like dead algae, allowing the accumulation of organic matter in the bottom water. This organic matter is then subject to decomposition by bacteria. This process uses up oxygen and can release nutrients like phosphorus back into the water. The graph shows that surface oxygen remains fairly high, only declining slightly due to increasing temperatures during the summer. The bottom waters show a decline in oxygen concentration over time, due to the decomposition mentioned above. In fact, the oxygen concentrations near the bottom all go to zero (see the write-ups for individual lakes below) at the end of summer in all lakes except North Pond, which due to its shallowness is continuously mixed by the wind.

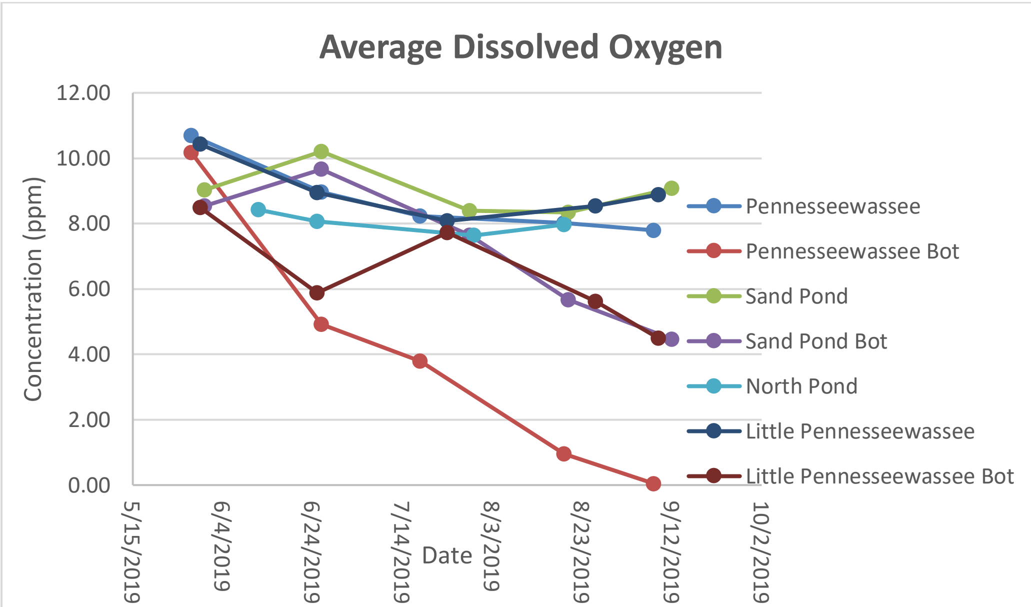


Figure 5. Average Dissolved Oxygen concentrations for surface and bottom waters in the four lakes through the 2019 season.

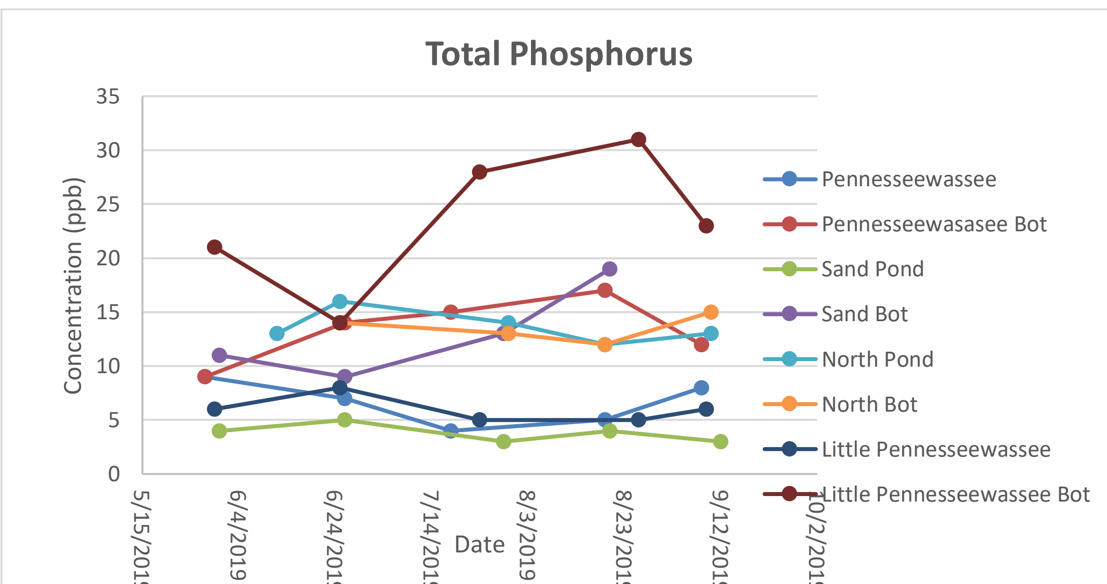


Figure 6. Total Phosphorus concentration in surface and bottom water of the lakes during the 2019 season.

Figure 6 shows the Total Phosphorus concentrations over the 2019 season. In the historical perspective as mentioned, above, increases in phosphorus are usually associated with algal blooms. It is clear that surface concentrations in our lakes remain relatively stable over the season. However, the concentrations in the bottom waters increase over time, indicating a transport of phosphorus as organic matter from the surface to the bottom waters by dead algae and other organic matter. This is also exacerbated by the declining oxygen content of the bottom waters also mentioned above, which aid in the release of phosphorus from the sediments.

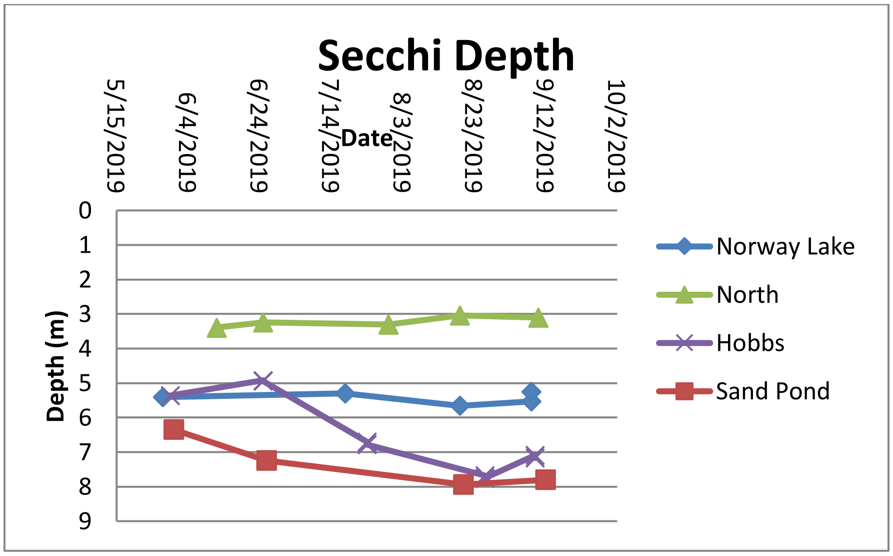


Figure 7. Secchi depth for the four lakes during the 2019 season.

Secchi depth, shown in Figure 7, is a measure of water clarity. Clarity is impacted by dissolved and particulate matter. In our lakes it is mostly a function of particulate matter, namely algae. Secchi depth is not a very good measure for North Pond, since it is shallow and we always see all the way to the bottom. In the other three lakes, the Secchi depth is a good measure of clarity. What we see is that transparency of the water in Lake Pennesseewassee remains relatively constant throughout the season. In Hobbs and Sand, the clarity improves (The Secchi disk can still be seen at deeper levels) over time. This change is partially due to succession of different algal species from spring to summer and fall, and the sinking out of larger species. A similar succession happens in Lake Pennesseewassee, but apparently does not have as much of an effect on clarity, perhaps due to the size of the lake and wind effects.

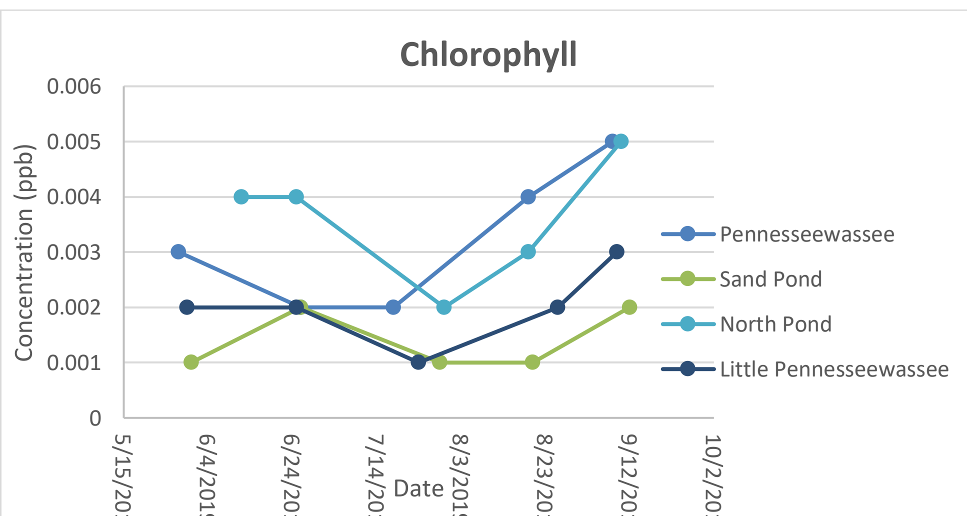
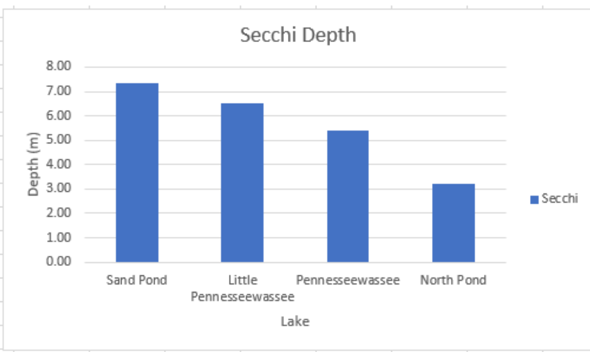
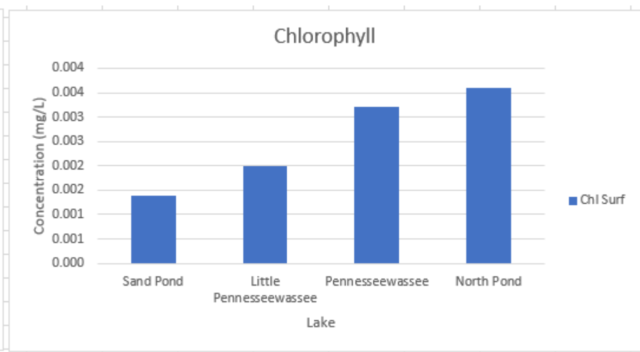


Figure 8. Chlorophyll values for the four lakes during the 2019 season.

Chlorophyll is an important parameter in that it measures the quantity of microscopic algae in the water. A small amount keeps our aquatic ecosystems healthy. But too much is a problem for the entire ecosystem, including humans. Figure 8 shows a classic pattern for lakes. In most instances the chlorophyll concentration is relatively high at the beginning of the season. This is typically when nutrient concentrations in the lakes are high due to the water mixing over the winter. It is also when grazers (small zooplankton) are not yet abundant. During the summer there is a dip in the chlorophyll because the algae have started to use up available nutrients, and the number of grazers that feed on them have increased. During early Fall there is a rebound in the numbers, and that is due to wind mixing the waters from below the thermocline into the upper layer, bringing nutrients along, thus allowing renewed growth.

As an illustration of the relationship between Secchi Depth and Chlorophyll, the figures below are from the 2019 sampling season. A regression analysis shows that Chlorophyll explains 87% of the variation in Secchi Depth.





Other parameters from the 2019 season

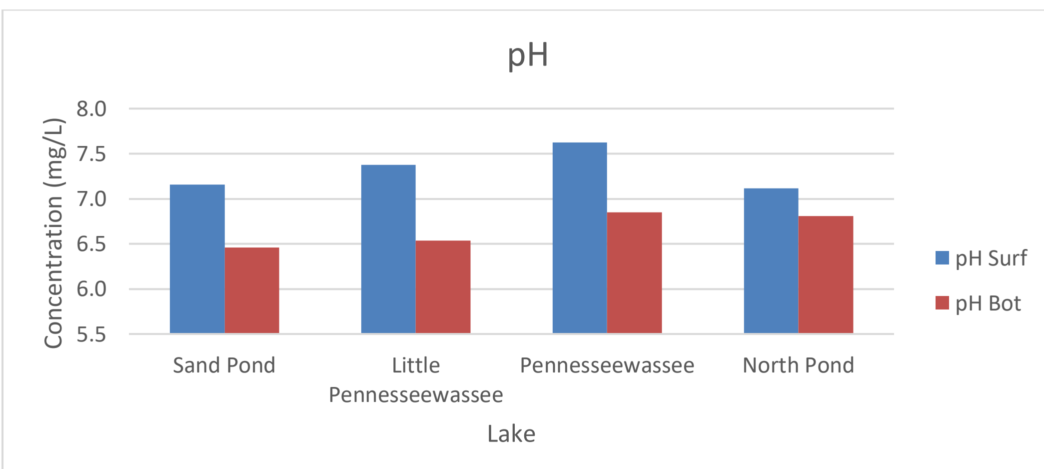


Figure 9. Average pH values in surface and bottom waters of the lakes during the 2019 season.

The pH of a water body is a measure of its hydrogen ion concentration, which we commonly refer to as acidity. A pH of 1 is very acidic, and 14 is very basic with neutrality at pH 7. Most surface waters tend to be in the 6-8 pH range, and our lakes are no exception. Figure 9 shows that average pH values range between about 6.4 and 7.6, well within the expected range. All of the surface values tend to be slightly alkaline (or basic), while the bottom waters are slightly acidic. The acidic nature of the bottom waters is not surprising in that our other data show that a lot of organic matter is decomposed in the deeper waters. The decomposition uses up oxygen as we have seen above, but also releases CO_2. Carbon dioxide (or CO_2) can combine with water molecules and in the process releases hydrogen ions, which increases the acidity.

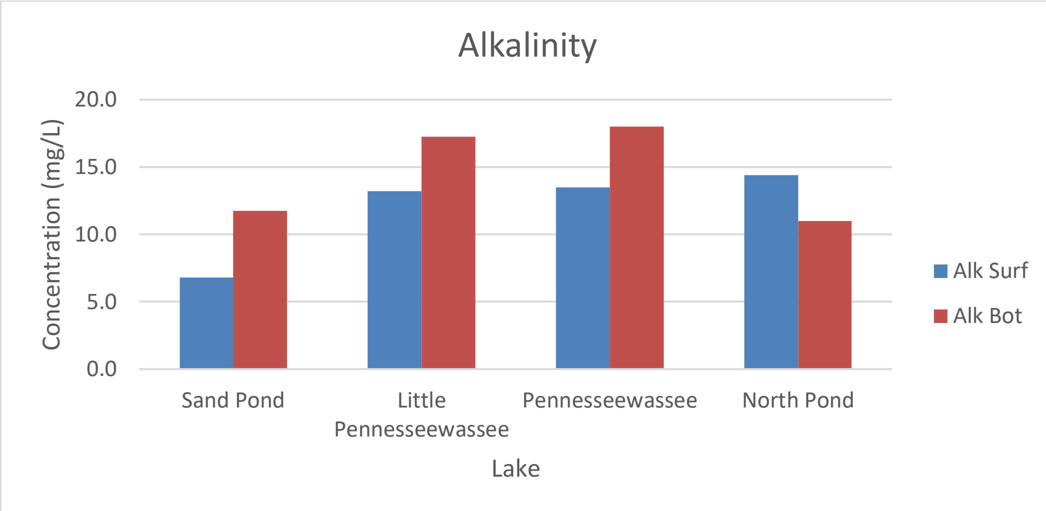


Figure 10. Average Alkalinity in the surface and bottom waters of the lakes during the 2019 season.

Alkalinity is not a measure how alkaline the water is, but rather of its acid neutralizing capacity. High alkalinity can buffer water against pH changes. Our lakes are on the lower side of the alkalinity measure and so are not as well buffered as other lakes (Figure 10). We had the State Environmental Health Testing Laboratory do a one-time analysis of alkalinity in the lakes. Their results came back with values of 6-14 for our surface waters, right in line with our on-site analyses.

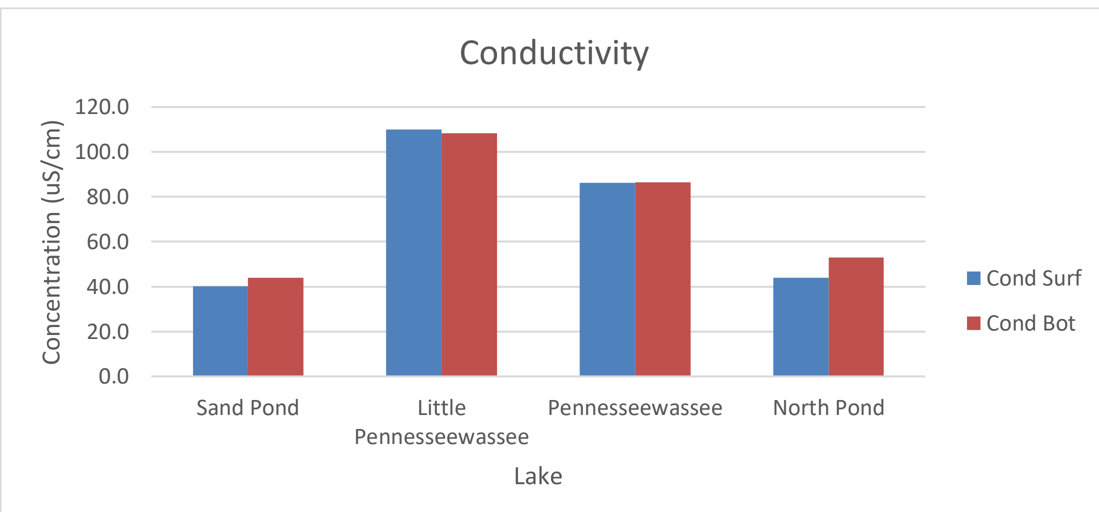


Figure 11. Average conductivity values in the surface and bottom waters for the 2019 season.

Conductivity is a measure of the amount of ions in the water, more ions means greater conductivity. This seemingly odd parameter is useful because it can indicate pollution. One ion is of particular interest to us, and that is chloride. Chloride is the negative ion that pairs with the positive sodium ion in road salt (sodium chloride). So high conductivity measurements indicate a potential influx of road salt to the lakes during winter road operations. Typical freshwater streams are in the range of 100-2000 µS/cm, so our lakes are on the low end (Figure 11). It is noteworthy that the highest values are found in Little Pennesseewassee and Lake Pennesseewassee, both adjacent to the highway, and more subject to road salt.

Individual Lake Analyses

Sand Pond:

Sand Pond is the best of the four lakes in terms of water quality. The surface phosphorus concentrations (Figure 3), and phytoplankton chlorophyll (Figure 2) were lower than in the other lakes (see Historical Perspective). As a result, water clarity was also greater (Figure 1). The lake does however exhibit oxygen depletion in the deep waters (Figure 13), and therefore, is an internal source of phosphorus due to release from the sediments. This is a warning that we need to be careful, or risk degradation of water quality that may result in unwanted phytoplankton blooms. Phosphorus levels in the surface waters were less than 4 parts per billion (ppb), which is on the low end of concentrations seen in lakes. In the bottom waters however, they average almost 15 ppb, indicating an internal storage of phosphorus in the lake sediments which was being released due to the low oxygen environment in the deeper waters.

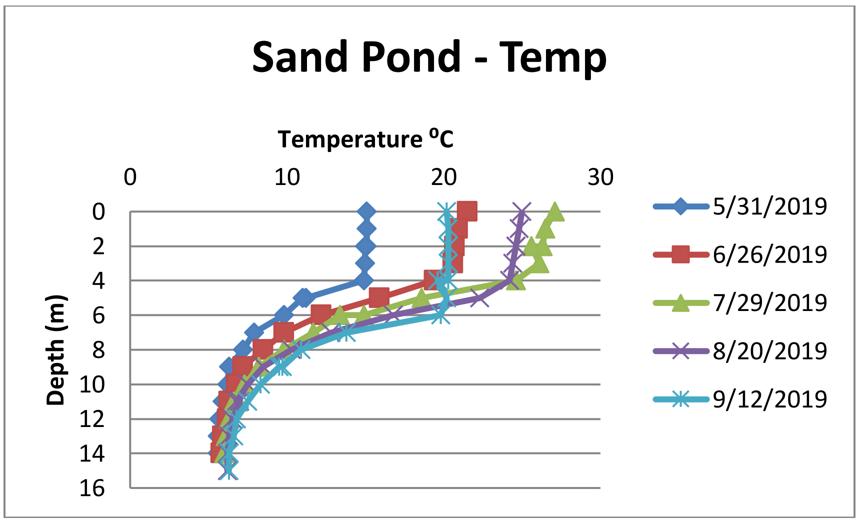


Figure 12. Sand Pond temperature profiles during the 2019 season.

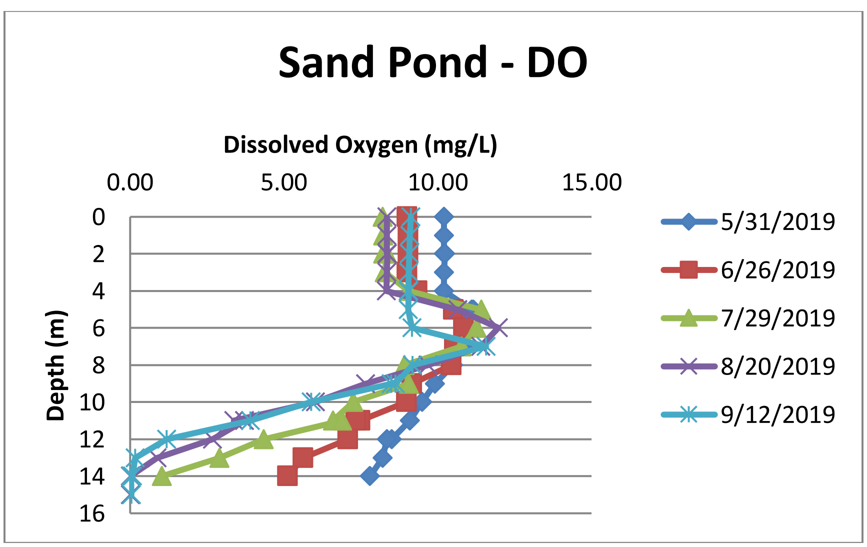


Figure 13. Sand Pond dissolved oxygen profiles during the 2019 season.

Figure 13 also shows a peak in oxygen concentrations just below 5 meters. This is due to phytoplankton finding a balance between high nutrients afforded by the deeper waters, and still being shallow enough to get enough sunlight for photosynthesis due to the clear water in the surface layer (Figure 7).

The Secchi depths averaged over 7 meters (Table 1), the clearest of any of the 4 lakes. During 2019, the Secchi depth increased from 6.3 m to almost 8 m. The lower value in May is indicative that the spring phytoplankton bloom was just ending. Typically, a spring bloom occurs due to abundant nutrients after winter mixing and abundant light as the sun rises higher in the sky as seasons change. The bloom ultimately reduces the available nutrients in the surface after stratification due to solar heating of the surface. The reduced nutrients lead to reduced phytoplankton growth in the surface, and to clearer waters later in the summer. The chlorophyll concentrations at less than 0.002 mg/L are indicative of a relatively clean lake and corroborate the Secchi disk readings.

Little Pennesseewassee (Hobbs Pond):

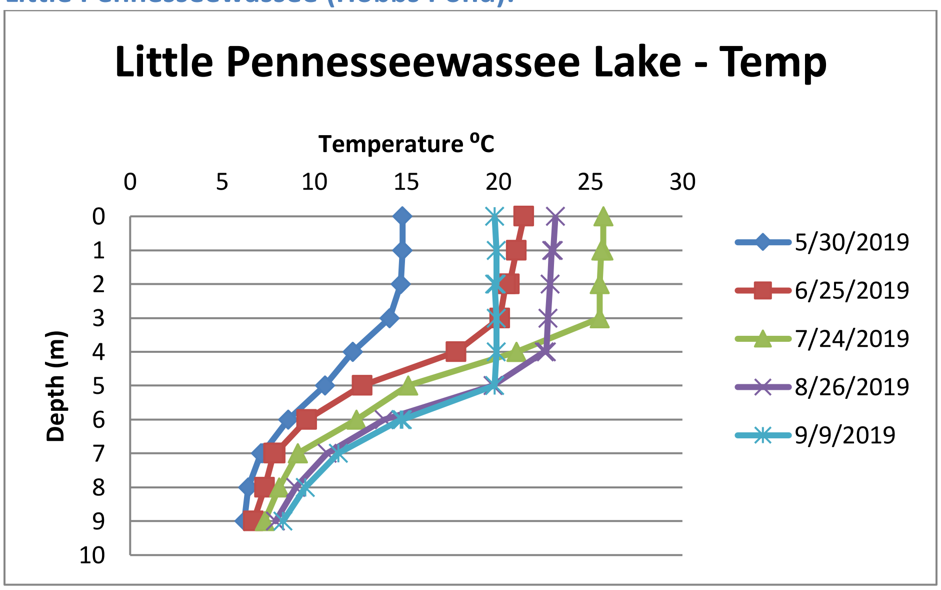


Figure 14. Temperature profiles for Little Pennesseewassee during the 2019 season.

Little Pennesseewassee, like the other lakes, is considered a medium productive (mesotrophic) lake. This is determined from the chlorophyll levels (between 1.5 and 6.5) and the phosphorus levels (between 5 and 10 parts per billion at the surface). The indicators have declined somewhat from the long-term average, indicating perhaps the lake status is improving.

The lakes were starting to stratify (become two-layered) by the time sampling began (Figure 14). The higher chlorophyll levels in May indicate that the Spring bloom was still ongoing, while in August the low values indicate depletion of nutrients from the surface waters. This is verified by the phosphorus concentrations which declined as well (Figure 6). The increase in phosphorus in September is due to the start of Autumnal mixing, which stirs the upper and lower water layers together, and as seen in Figure 6, the bottom waters have an abundance of phosphorus.

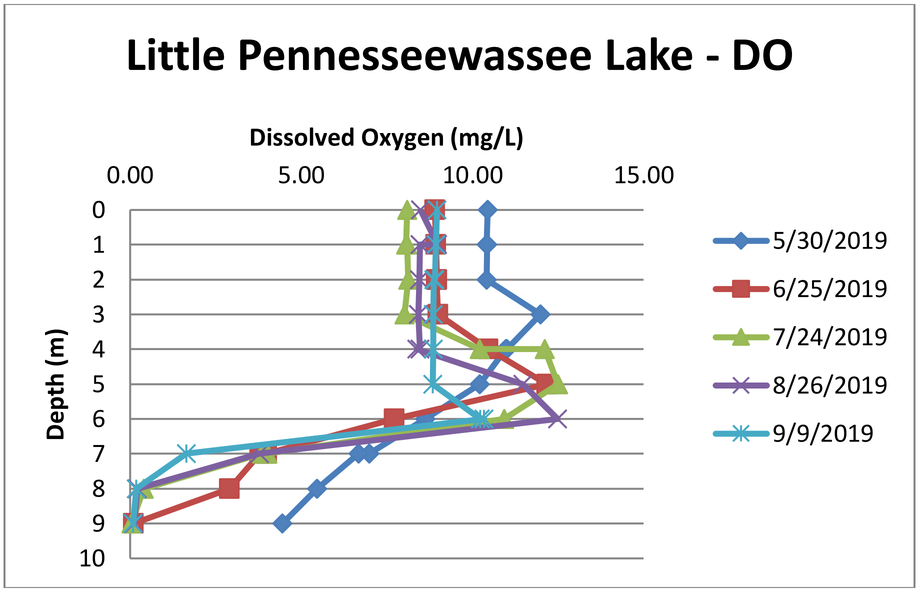


Figure 15. Dissolved oxygen profiles in Little Pennesseewassee for the 2019 season.

The dissolved oxygen concentrations in Little Pennesseewassee were similar to the other deep lakes. The surface layer was well oxygenated, but at the bottom, oxygen levels fell to zero due to decomposition of organic matter. Like Sand Pond, the water here also had a “deep chlorophyll maximum” as indicated by the peak of oxygen just below the surface mixed layer at about 5 meters. These phytoplankton are taking advantage of the higher nutrient levels in the deep layer, while still getting enough sunlight for photosynthesis, which causes the oxygen peak.

Water clarity, as indicated by Secchi depth (Figure 7), was lower in May and June, but then increased in July and August and declined slightly in September. This is due to phytoplankton growth, which was high initially, as indicated by the Chlorophyll concentration (Figure 8), and declined in August due to nutrient depletion in the surface water (Figure 6). In September the chlorophyll increases again due to Autumnal mixing which stirs deeper waters into the surface layer, and increasing the depth of the surface layer. The mixing also brings the phosphorus contained in the deeper water to the surface where phytoplankton use it to grow.

Lake Pennesseewassee:

Lake Pennesseewassee is also a medium productive lake (mesotrophic) having moderate amounts of phosphorus and phytoplankton in the surface waters. Water clarity is on the order of 5.5 meters (Table 1) during the summer, which is also indicative of a mesotrophic lake. Like the other lakes in our area, oxygen depletion occurs in the bottom waters (Figure 17), and there is elevated phosphorus in the bottom waters (Figure 6) due to release from the sediments during times of low oxygen. This is a warning sign that phosphorus needs to be managed, or the lake could suffer phytoplankton blooms as has happened in other areas.

The temperature profile in May shows that the lake was just beginning to stratify (Figure 16). The bottom water this early in the season is already above 10°C, unlike Sand Pond and Little Pennesseewassee which are roughly as deep, but have deep-water temperatures of only 5-6°C. We see this pattern in other years as well, and it may indicate a difference in circulation of the water mass in Pennesseewassee causes the bottom water to heat more rapidly than in the other lakes.

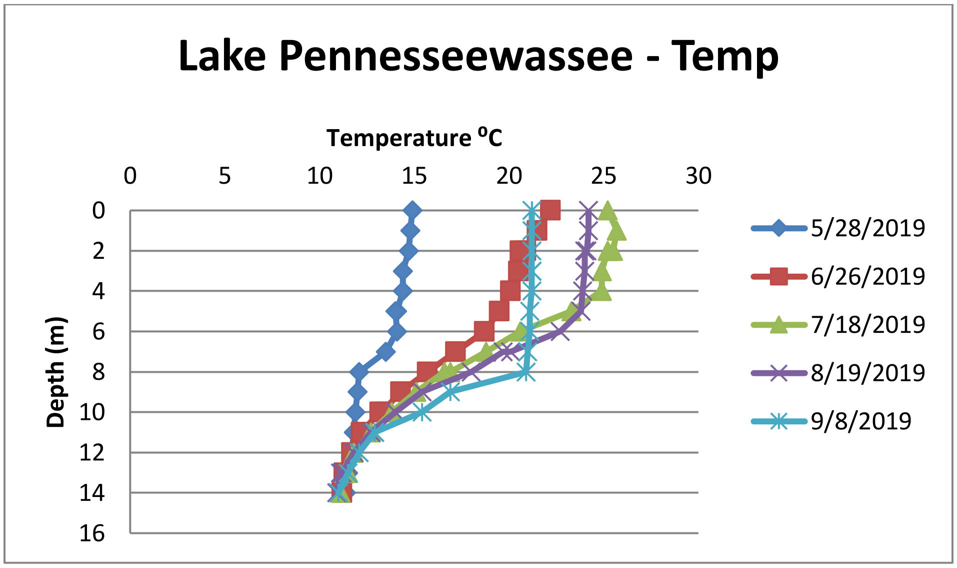


Figure 16. Temperature profiles in Lake Pennesseewassee (Norway Lake) during the 2019 season.

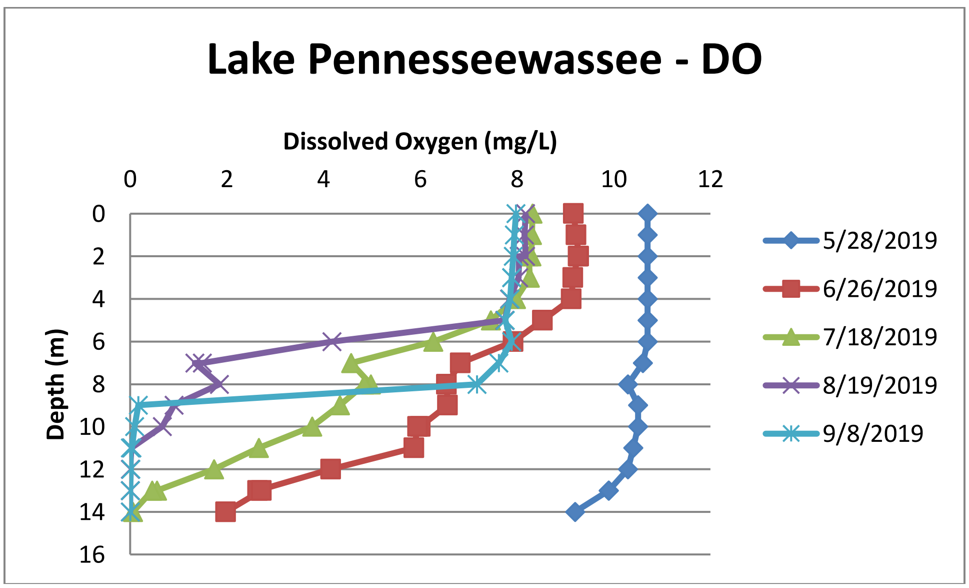


Figure 17. Dissolved oxygen profiles in Lake Penesseewassee (Norway Lake) during the 2019 season.

Penneseewassee, like the other lakes was starting to stratify (become two-layered) by June, due to solar heating. Surface total phosphorus was highest at the start of the season, and decreased slightly in August (Figure 6). This is consistent with the idea that the phytoplankton were using up the nutrients in the surface layer as seen in the chlorophyll values (Figure 8). Bottom water concentrations of phosphorus were 17 ppb by August (Figure 6), indicating a release of phosphorus stored in the lake sediments caused by the low oxygen environment in the deeper waters (Figure 17).

The dissolved oxygen in Lake Pennesseewassee showed interesting patterns this year. The July and August samples both show a decrease in oxygen at 6-7 meters. We saw the same phenomenon in 2017. This is most likely due to decomposition of microscopic phytoplankton and zooplankton that had been growing at the base of the surface layer. This decomposition releases phosphorus back into the water and contributes to the elevated phosphorus levels in the deep water.

North Pond:

North Pond is relatively shallow in comparison to the other lakes. For that reason, it mixes quite easily from top to bottom with any wind. This means that it does not really form two layers for any length of time. This is evident from both the temperature (Figure 18) and dissolved oxygen (Figure 19) profile graphs, which are pretty much straight up and down. Unlike the other lakes which suffer from oxygen depletion in the bottom waters, North Pond has plenty of oxygen throughout the water column as a result of the mixing.

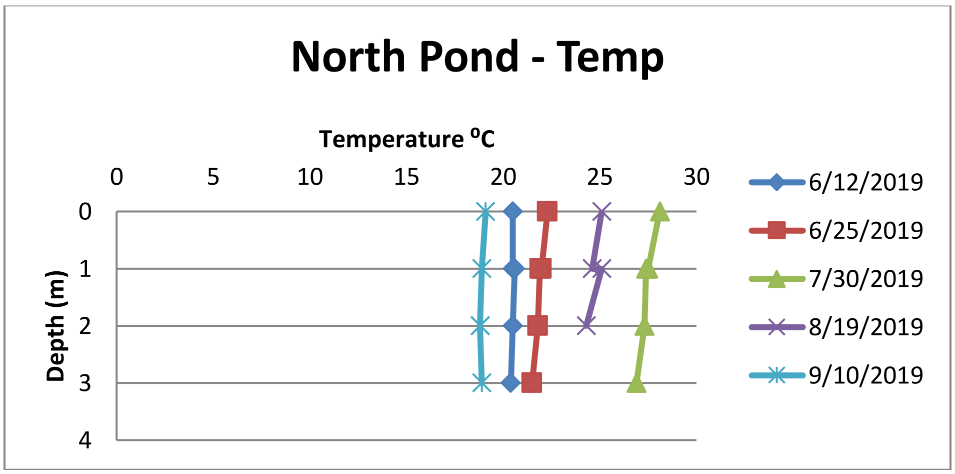


Figure 18. Temperature profiles for North Pond during the 2019 season.

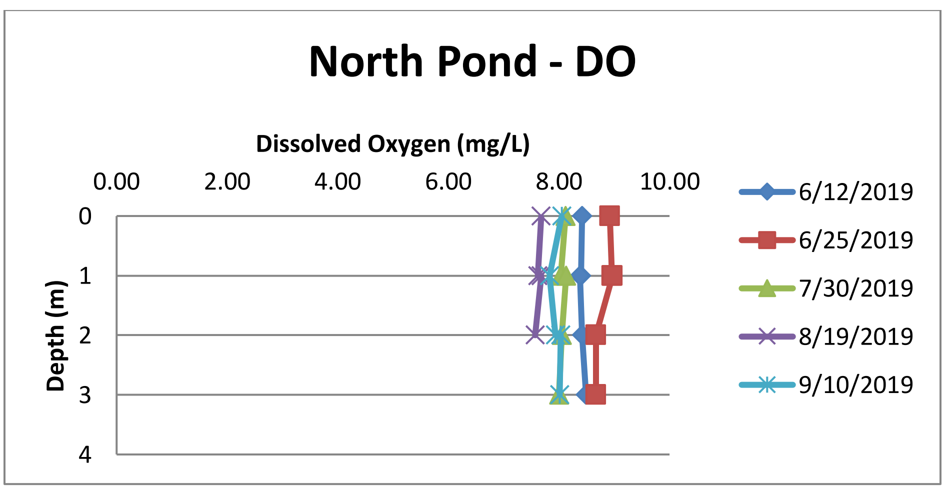


Figure 19. Dissolved oxygen profiles for North Pond during the 2019 season.

North Pond does have a high total phosphorus concentration, the highest of any of the lakes. This maybe from internal loading, as the bottom consists of very thick layers of peat. These high concentrations do not seem to cause nuisance phytoplankton blooms in the Pond itself. However, North Pond is a water source for Pennesseewassee, so could contribute to the phosphorus concentrations in that lake.

The chlorophyll levels are indicative that this lake is moderately productive (mesotrophic). As stated above, phytoplankton blooms do not seem to be a problem. However, the average chlorophyll concentrations are the highest of the four lakes (Figure 2). In addition, the current chlorophyll concentrations exceed historical values, while the values in the other lakes are lower than their respective historical values (Figure 2).

Methods

The methods described here are the ones currently employed. In the historical records discussed in this Report, other methods may have been used.

Water Clarity:
Water transparency was measured with a standard Secchi disk, 20 cm in diameter, with black and white quadrants. It was lowered on a measuring tape marked in meters. A measurement was made to the nearest centimeter, while looking through an Aquascope II©, at the point where the disk disappeared.

Water Samples:
Water samples were collected in 2-liter polycarbonate bottles. The first was immersed inverted at the surface and filled by turning it right-side up. A second was filled with from a van Dorn water bottle (marketed as a Beta bottle). The van Dorn bottle can be lowered to a specific depth with a marked line, and then closed at depth by sending a weight, called a messenger, down the line. The weight triggers the closing of the ends of the sampler. A second 2 liter polycarbonate bottle was filled from the van Dorn sampler. The 2-liter bottles were covered to seal out light with aluminum foil and duct tape. They were kept in a cooler on ice until return to shore for sample processing.

One exception to this was the collection of total phosphorus samples. For surface samples, a conical tube was inverted and passed through the surface in an arc so that the tube emerged right-side up. The deep samples for total phosphorus were collected in a conical tube directly from the van Dorn sampler prior to any other sample being taken.

Total Phosphorus:
Total phosphorus samples were collected as described in Water Samples. Both samples were collected in 50 ml tubes to measure out the volume, and then transferred into Erlenmeyer flasks and sealed with a screw top. These samples were kept refrigerated and sent to the Maine State Health and Environmental Testing Laboratory (HETL) in Augusta to be analyzed.

Chlorophyll:
Chlorophyll was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The water was then vacuum filtered with a hand pump (Mightyvac™) through a 0.45 micrometer pore-size filter. The volume filtered was recorded, and typically was between 300-600 mL. After filtration was complete, the filters were frozen and sent to the Maine State Health and Environmental Testing Laboratory (HETL) in Augusta to be analyzed spectrophotometrically.

Dissolved Oxygen:

DO was measured at 1-meter intervals from surface to the bottom with a YSI ProODO meter. The meter was calibrated daily with air-saturated water. This was done by filling a container with tap water and bubbling air through it with the use of an aquarium pump and air stone. Barometric pressure was obtained for the calibration from the National Weather Service, using the Lewiston-Auburn station. The meter has a stated accuracy ± 0.1 mg/L for DO and ± 0.2°C for temperature.

Temperature:
Temperature was measured at 1-meter intervals from surface to the bottom with a YSI ProODO meter. The meter has a stated accuracy of ± 0.2°C for temperature.

Conductivity:
Conductivity was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The conductivity was then measured on a subsample of about 100 ml, with an Orion VersaStar meter and an Orion 013005MD conductivity cell. The probe was calibrated with a 84 microSiemens standard solution. The stated accuracy of the instrument is ± 0.5% of reading, ±1 digit.

pH:
pH was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The pH was then measured with an Orion VersaStar meter and an Orion 8302BNUMD Ross Ultra pH/ATC triode. The probe was calibrated each sampling day with a pH 7.0 and pH 4.0 buffer solutions. The meter has a stated accuracy of ± 0.002 pH units.

Alkalinity
Alkalinity was measured with a Hannah HI775 Freshwater Alkalinity Checker. It is a photometric instrument that uses an LED and silicon photocell. The stated accuracy is ±5 mg/L.
In August we also collected samples for alkalinity measurements that were conducted at the HETL laboratory. They were done with EPA approved methods. Our results are comparable to the HETL results.

Color:
Water color was measured with a Hannah HI727 Color Checker. It is a photometric instrument that uses an LED and silicon photocell. The stated accuracy is ±10 Platinum Color Units.