2022 Report on the Health of the Norway Lakes

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What matters

Before reading this report, it is important to realize why we measure and test our waters. It is *to assess lake health and to understand the factors that affect that health*. From a very simplistic perspective, we focus on what we can influence - preventing the growth of excess algae while others focus on preventing introductions and eliminating invasive species from the lakes.

High concentrations of algae have undesirable consequences like reducing water clarity and removing oxygen from lakes. The decreased light penetration can harm rooted vegetation on the bottom and decreases the aesthetic quality of the lakes. An overabundance of some species can also lead to foul smelling waters, bad taste in drinking water and algal toxins which harm humans and animals. The biggest single item that promotes algae growth is phosphorus. While phosphorus occurs naturally in lakes, excess amounts can enter lakes via erosion, both from storm water runoff, and from shoreline erosion. Therefore, our primary measurements are water clarity and items related to phosphorus levels. We property owners can have a significant influence on phosphorus levels, which is why LAON devotes a great deal of effort on preventing erosion through our watershed surveys which can provide homeowners with remediation grants.

About the Report

The Lakes Association of Norway (LAON), with support from the Town of Norway and contributions from the membership, continues 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. Due to covid-19 concerns, this year the Lake and Watershed Resource Management Associates (LWRMA) was not able to conduct an invasive aquatic species screening of our lakes. Fortunately, LAON's volunteer Invasive Plant Patrols were able to survey most of all four lakes and did not find any new invasives. They have been working to reduce the invasive yellow iris.

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). The other measures were analyzed by the team on-site. More details about our methods are included at the end of this document

Overview

Table 1 below shows the average values at the surface and bottom (except Secchi depth) of the lakes for primary water quality parameters measured for 2022 and also for 2021 to show the annual difference. The year 2022 saw another cyanobacterial bloom develop in late summer in Hobbs Pond (Little Pennesseewassee). These organisms used to be called blue green algae and are photosynthetic. However, they may produce toxins that are harmful to people, dogs and livestock. The bloom was probably caused by increased nutrient levels. The high average P is

Table 1. Secchi depth, Total Phosphorus and Chlorophyll concentrations for 2020 compared to the historical average for the four lakes. Data presented as average, surface, and bottom water concentrations. Phosphorus and chlorophyll are in parts per billion (ppb)..

Lake	Average 2022 (2021)					Historical Avg *				
	Secchi	Avg P	P Surf	P Bot	Chl	Secchi	Avg P	P Surf	P Bot	Chl
Sand Pond	7.44 (7.32)	14.5 (9.33)	4 (4.26)	25 (14.4)	1 (2)	7.4	9	3	15	2.5
Little Pennesseewassee	5.59 (5.82)	21.1 (22.4)	7 (7)	43.6 (37)	2 (3)	5.6	14.5	10	19	4.5
Pennesseewassee	5.18 (5.73)	14.5 (10.1)	7 (6)	22(14.2)	3 (3)	5.2	10.5	8	13	4.6
North Pond	3.22 (3.17)	19.3 (24.5)	16.5 (15.6)	21.8 (33.4)	4 (6)	3	25.5	17	34	6.9

** Historical data through 2018 can be found through :* https://www.lakesofmaine.org/index.html?r=1681319726

Secchi - higher number is better

P - lower number is better

2022 Average vs Historical	
(green)	Improved
(red)	Worsened
(grey)	Too close to call

mostly due to the bottom concentration being significantly higher than average. The bloom probably occurred due to this water being stirred into the surface after strong winds caused mixing. The other lakes, except North Pond, also showed increased P concentrations but to a lesser degree. Interestingly, the chlorophyll concentrations are lower than historical values. Secchi depths were not much different from those in the past.

On the bright side, 2022 saw lower phosphorus levels in the surface waters of Little Pennesseewassee, Pennesseewassee relative to historic values. Chlorophyll concentrations, indicating the amount of algae, were lower in all the lakes compared t historical values.

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 2021 sampling

Oxygen is critical for the life of most organisms like fish, plants, and invertebrates. Figure 1 shows the oxygen requirements for fish. The dissolved oxygen (DO) concentrations at the top and the bottom of each lake during the season is shown in Figure 2. It is noteworthy that the deep lakes all are depleted of oxygen at the bottom during the summer. The surface on the other hand gets oxygen from the atmosphere as well as algal and plant photosynthesis. For Hobbs Pond, the bottom oxygen was already at 5 ppm in May and the no-oxygen level again occurred by June. The bottom layer of the deep lakes like Hobbs Pond typically do not have enough light to allow photosynthesis and has no other sources of oxygen. As a result, the level of oxygen near the bottom declines due to decomposition of dead algae by bacteria. A side effect of the low oxygen is the release of phosphorus from the sediments, contributing to the high levels of this nutrient in the bottom water. Lake Pennesseewassee was also at zero ppm by June, even though it started near 8 ppm in May. The scale for oxygen in North Pond only goes between 5 and 9 ppm, so no oxygen depletion of concern there. Sand Pond had anomalous data this year in that oxygen at the bottom was near zero all season.

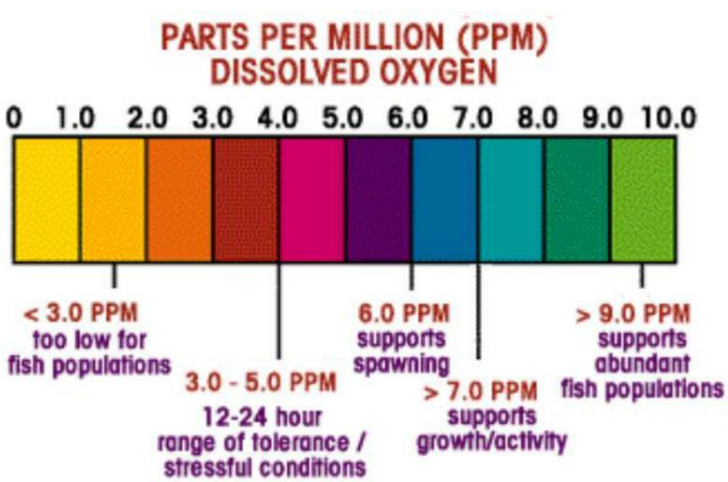

Figure 1. Oxygen requirements for fish.

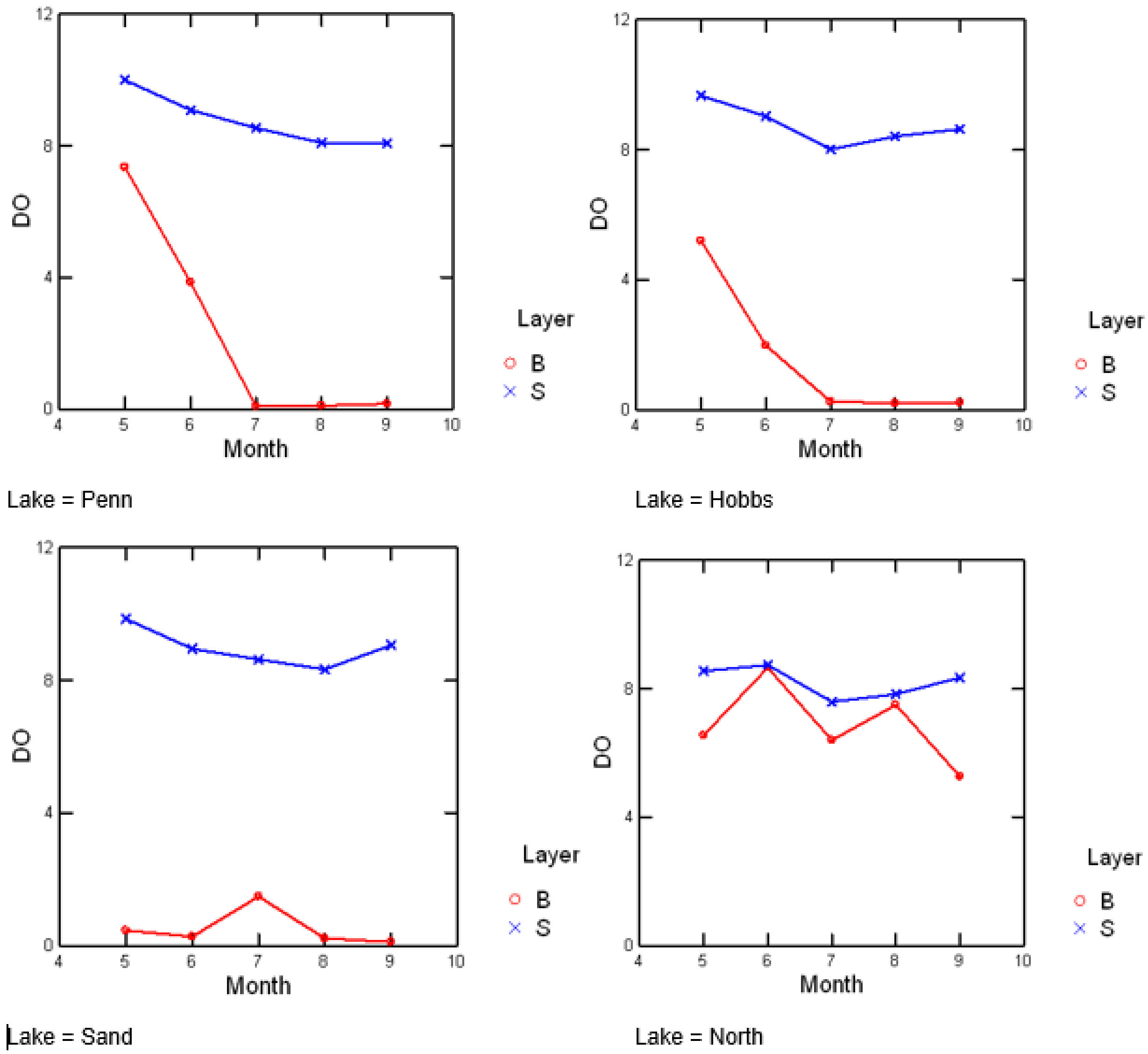

Figure 2. Dissolved Oxygen concentrations (ppm) for surface and bottom waters in Little Pennesseewassee (Hobbs) and North Pond, and Pennesseewassee and Sand Pond through the 2022 season.

Figure 3 shows the Total Phosphorus concentrations at the surface and bottom of each lake over the 2022 season, except for Hobbs Pond, where additional samples were taken to try and determine why the cyanobacterial bloom was occurring. The concentrations in the bottom waters generally increase over the summer, indicating a transport of phosphorus contained in organic matter from the surface to the bottom waters by decaying algae and other organic matter. It may also be introduced through runoff and groundwater discharge into a lake. As mentioned earlier, the concentrations may also increase near the bottom due to low oxygen levels, which aids in the release of phosphorus from the sediments, called internal loading. Sand Pond seems to be an exception here since the bottom concentrations drop during the season. This decrease also happened last year. Note that the concentrations for Hobbs Pond are much higher than in the other lakes.

Scientists have developed a rough idea of what levels of phosphorus in lakes can lead to problems (Table2). The phosphorus content of the surface water of our lakes, except North Pond, fall into the oligotrophic category, which is very good. Chlorophyll values are also below 4, again indicating oligotrophic waters. North Pond ranks as mesotrophic. The bottom waters of all the lakes at times are in the eutrophic category for phosphorus. Eutrophic means over-enriched with nutrients, and susceptible to algal blooms and other problems.

Table 2 Table of threshold values used to classify lakes. Note µg/L = ppb. (Source: https://www.encyclopedie-environnement.org/en/water/phosphorus-and-eutrophication/)

Statut trophique	Phosphore total (µg/L)	Chlorophylle *a* (µg/L)	Transparence (m)
Ultra-oligotrophe	< 5	< 2,5	> 6
Oligotrophe	5-10	< 8	> 3
Mésotrophe	10-30	8-25	3-1,5
Eutrophe	30-100	25-75	1,5-0,7
Hypereutrophe	> 100	> 75	< 0,7

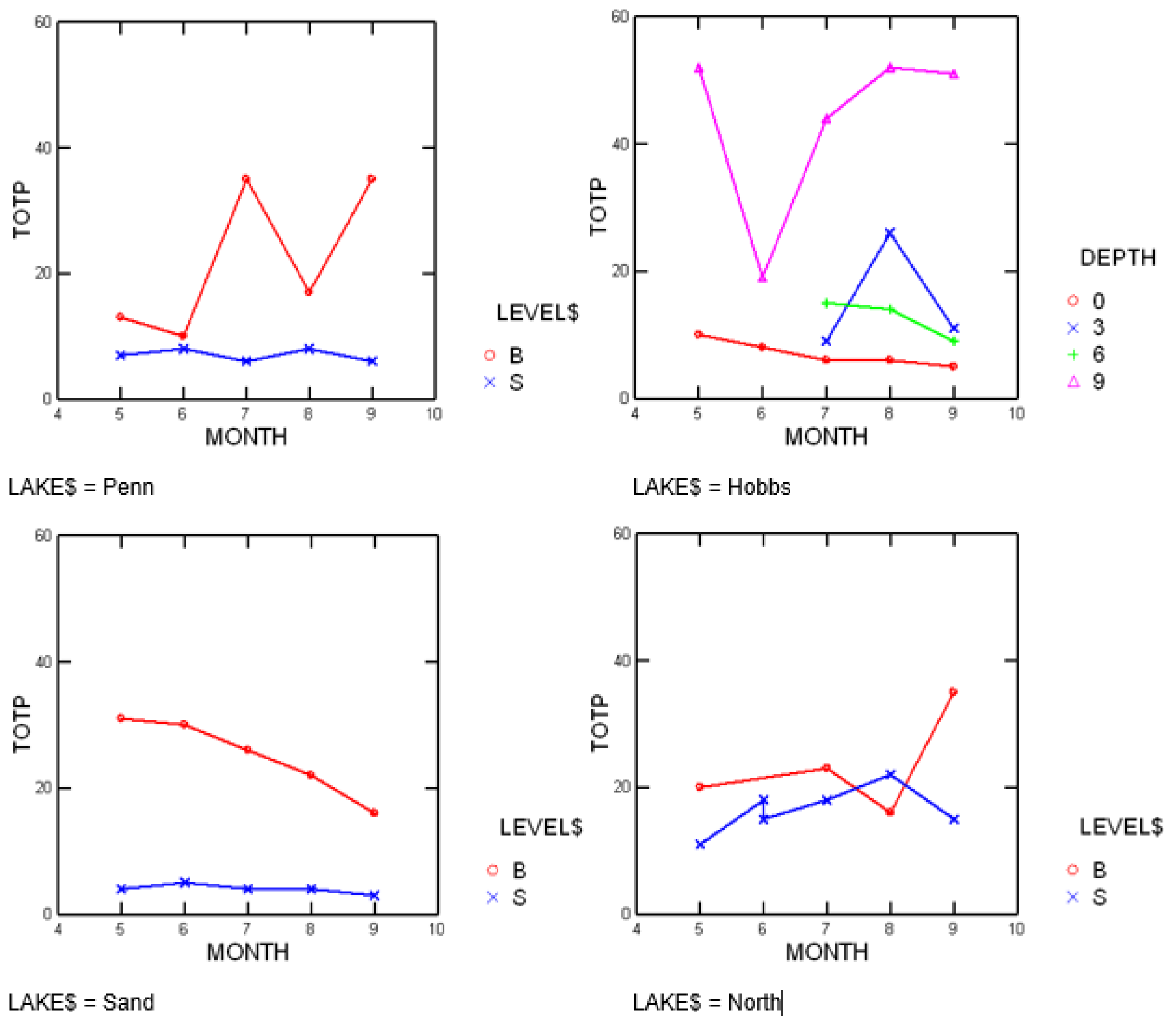

Figure 3. Total phosphorus concentration (ppb) in the surface (S) and bottom (B) water for the four lakes during the 2022 season.

Secchi depth, shown in Figure 4, 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. The Secchi depth is also a good indicator for how deep light for photosynthesis can reach. As a rule of thumb, the euphotic zone (where there is sufficient light for photosynthesis) is 2-3 times the Secchi depth. 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 starts low and tends to increase as the summer progresses. This change is partially due to a spring "bloom" when phytoplankton become abundant followed by heating of the surface due to increased sunlight. The heating causes a layering of the water and allows the depletion of nutrients from the surface. A succession of different algal species from spring to summer and fall occurs due to their different abilities to compete for the remaining nutrients in the surface, and the sinking out of larger species. The Secchi depths shown here are what are called "transparence" in Table 2. According to the table, this measure shows our lakes may be considered oligotrophic.

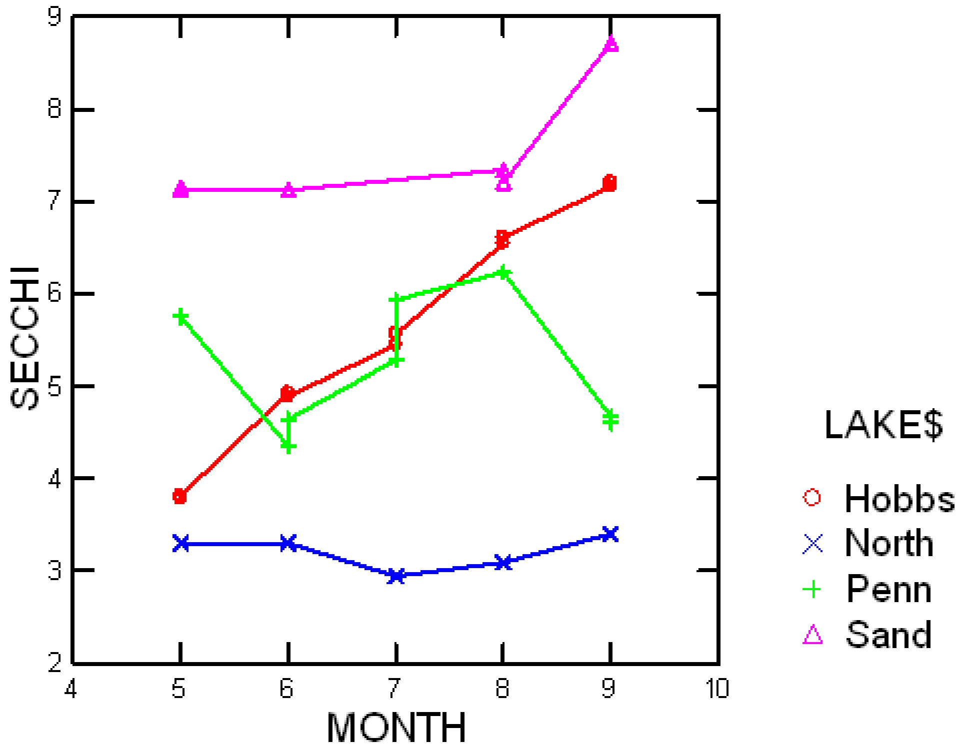

Figure 4. Secchi depths through the 2022 season for the four lakes.

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. In Maine waters the average chlorophyll concentration is .0054 mg/L (https://www.mainevlmp.org/distribution-of-water-quality-data/). Our lakes are lower, with the exception of the September value in North Pond (Figure 5). The data in Figure 5 shows that Sand Pond and North Pond had lower values near the start of the season and increased thereafter, while Lake Pennesseewassee and Hobbs Pond had higher levels early and decreasing values later in the season

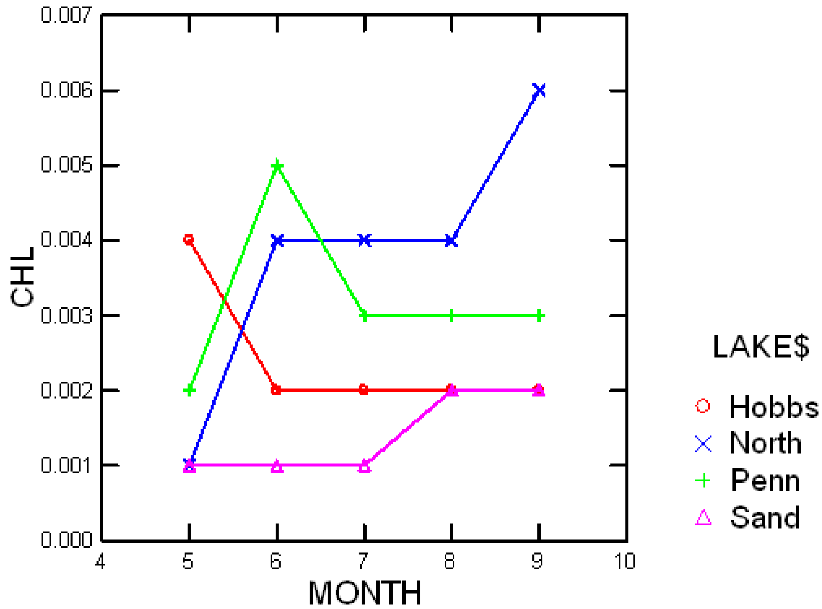

Figure 5. Chlorophyll values for the four lakes during the 2022 season.

Other parameters from the 2022 season

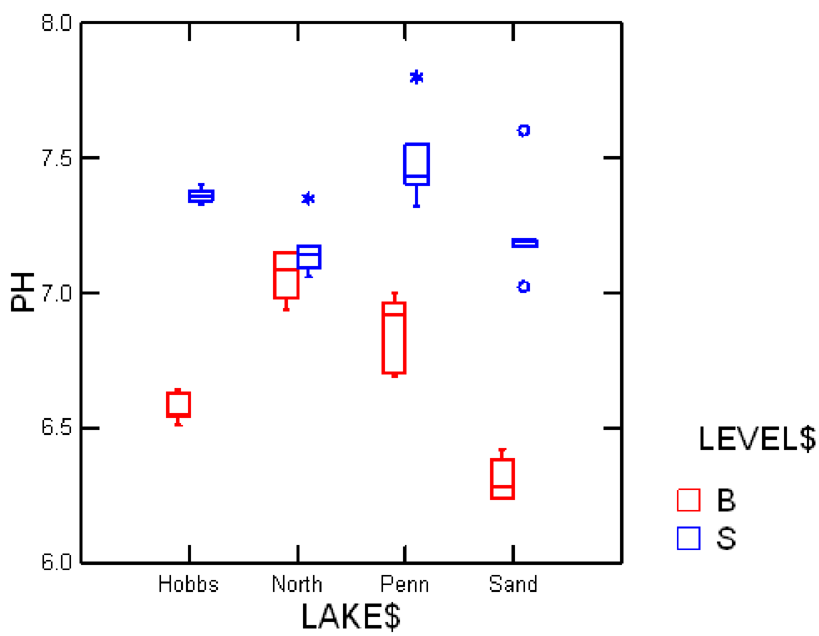

Figure 6. Box plot of pH values in surface and bottom waters of the lakes during the 2022 season. The horizontal line in the box is median, whiskers are the range, circles and asterisks are outliers.

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 6 shows that average pH values this year ranged between 6.2 and 7.8. The surface values tend to be slightly alkaline or basic (above 7.0), while the bottom waters are slightly acidic (below 7.0). This is related to the phytoplankton algae. As they photosynthesize, they take in carbon dioxide, which in turn causes a reduction of hydrogen ions through associated chemistry. When they die and sink, they decompose in the bottom waters which releases carbon dioxide, and that in turn results in the release of hydrogen ions. Carbon dioxide (or CO_2) can combine with water molecules and in the process releases hydrogen ions, which increases the acidity.

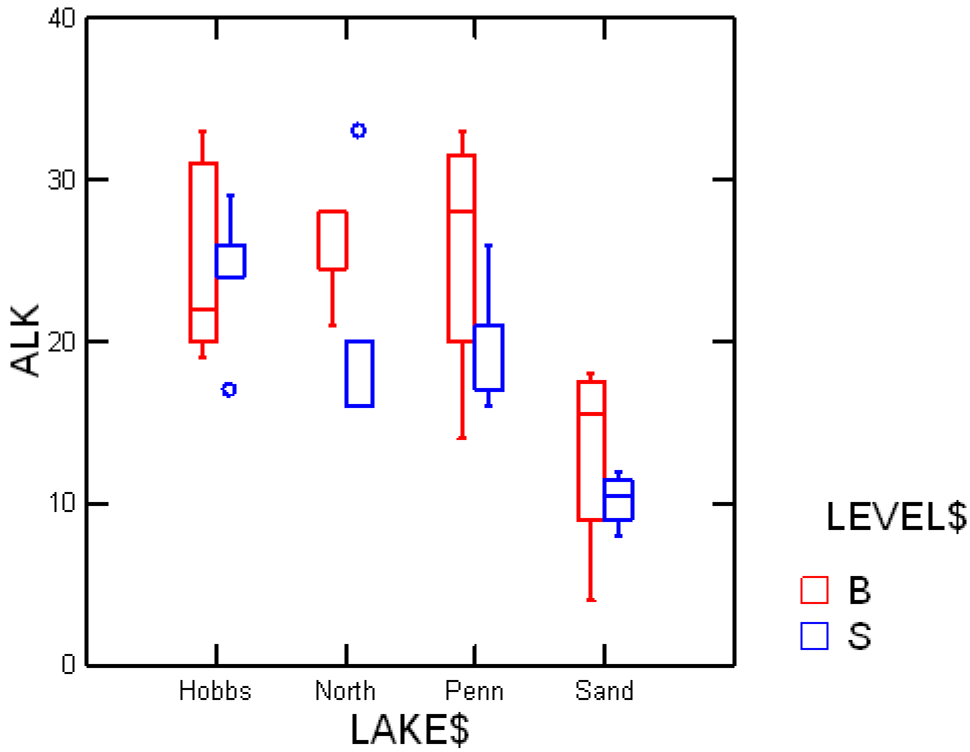

Figure 7. Box plot of Alkalinity (mg/L as $CaCO_3$) in the surface and bottom waters of the lakes during the 2022 season. The horizontal line in the box is median, whiskers are the range, circles and asterisks are outliers.

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 such as might happen when acid rain falls. According to the Lake Stewards of Maine website the alkalinity in Maine waters is 11.9 mg/L as $CaCO_3$ on average, with a maximum of 156 (https://www.mainevlmp.org/distribution-of-water-quality-data/). Our lakes are higher than the mean of other lakes in the region (Figure 7) except for Sand Pond which is close to the mean. The University of Massachusetts published the table below (Table 3) showing a lake's sensitivity to acid rain. Those with lower alkalinities are more sensitive to acid rain than those with higher alkalinities. You can see that our lakes are mostly in the non-sensitive range with Sand Pond being in the sensitive range.

Table 3. Alkalinity values associated with various levels of sensitivity to acidification by acid rain.

0* mg/l: Acidified	5-10 mg/l: Highly Sensitive
0-2 mg/l: Critical	10-20 mg/l: Sensitive
2-5 mg/l: Endangered	20 mg/l: Not Sensitive

https://www.umass.edu/mwwp/protocols/lakes/ph_alkalinity_lake.html
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, but most Maine lakes fall below 100, with an average near 35. The data for 2021 were very similar to last year's values. The range averaged from 42.1 in Sand Pond to 108 in Hobbs (Figure 8). This is within the range of Maine lakes (https://www.mainevlmp.org/distribution-of-water-quality-data/). The highest values were seen in Hobbs Pond and Pennesseewassee and both are adjacent to the highway, and thus, more subject to road salt, which is a major contributor to conductivity in the Northeastern states. These values are also at the high end of the values found in Maine (https://www.mainevlmp.org/distribution-of-water-quality-data/). While not alarming, these data indicate that the roads may be a source of pollution to Hobbs and Pennesseewassee.

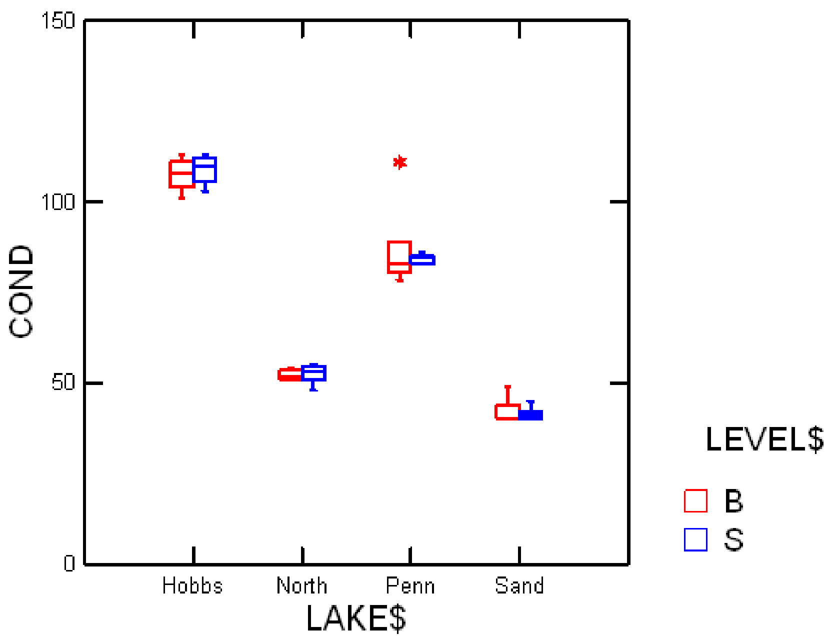

Figure 8. Box plot of conductivity values in the surface and bottom waters for the 2022 season. The horizontal line in the box is median, whiskers are the range, circles and asterisks are outliers.

The color of water can vary for several reasons like the amount and type suspended particles, dissolved chemicals, certain species of phytoplankton or pollutants. In typical lakes and streams, color is due to decomposing vegetation which releases organic compounds like a tea bag in a cup of water. The decomposition forms chemical compounds collectively known as tannins or humic substances which have a coloration like tea. Since light is important for the growth of aquatic plants and phytoplankton, highly colored water may hamper their growth at deeper depths. Like last year, Hobbs Pond had the highest and most varied color in the bottom water (Figure 9). The other lakes, while lower, also showed the same trend of higher values in the bottom. This is most likely due to the decomposition of organic matter such as algae and leaves. The color values observed in Maine waters are mostly in the 10-20 SPU range but can be over 60. Our surface waters are in the Maine average but the bottom water tends to the high end.

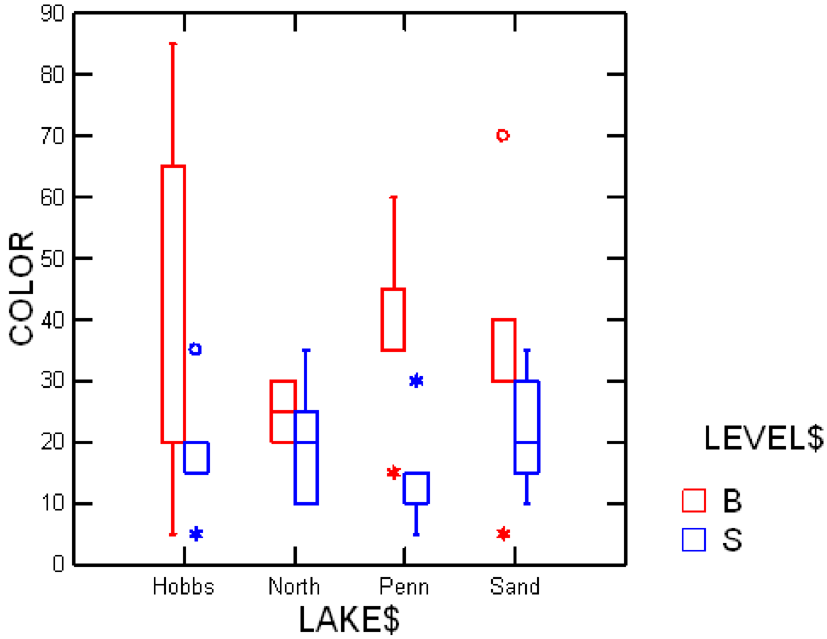

Figure 9. Box plot of Color of water (Platinum Units) for the lakes throughout the summer season. The horizontal line in the box is median, whiskers are the range, circles and asterisks are outliers.

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 5) were lower than in the other lakes for the surface samples. However, the average and bottom concentrations have risen above historical values (Table 1). This is clearly a sign that conditions are changing. Water clarity was also greater than in the other lakes but not much different from historical values (Figure 4, Table 1). During 2022, San Pond already showed temperature stratification (layering) in the May sampling (Figure 10). The surface layer continued to warm through August and then started to cool by September. The thermocline (the region where temperature changes from warm surface to cooler bottom water) during this period became deeper as the surface layer warmed and became thicker.

The lake exhibits oxygen depletion in the deep waters (Figure 11) but has an oxygen bump below the thermocline. The bump in dissolved oxygen was more pronounced and developed earlier than last year. The peak in oxygen concentrations just below 5 meters, is a recurring feature of the lake caused by phytoplankton growing at depth. Plankton grows there because the thermocline is a barrier to diffusion of substances like phosphorus and other nutrients moving from the bottom to the surface, thus the concentration of nutrients is higher there since phytoplankton use up the nutrients in the surface layer. Light at this depth is still adequate for photosynthesis to occur. The Secchi depth shown in Figure 4 ranges between 7 and 9 meters. This transparency is the clearest of all four lakes. Some phytoplankton can regulate their buoyancy and have found a way to maintain a depth where nutrients (phosphorus) are high in the deeper waters while still being shallow enough to get enough sunlight for photosynthesis due to the water clarity of the surface layer and are responsible for the increased dissolved oxygen.

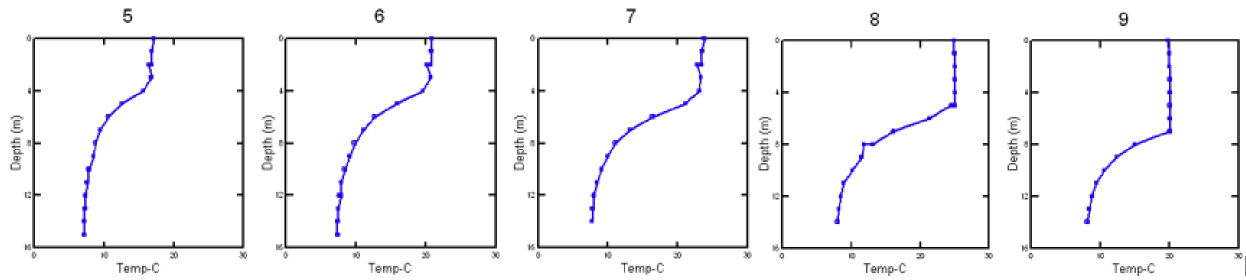

Figure 10. Sand Pond temperature profiles by month during the 2022 season.

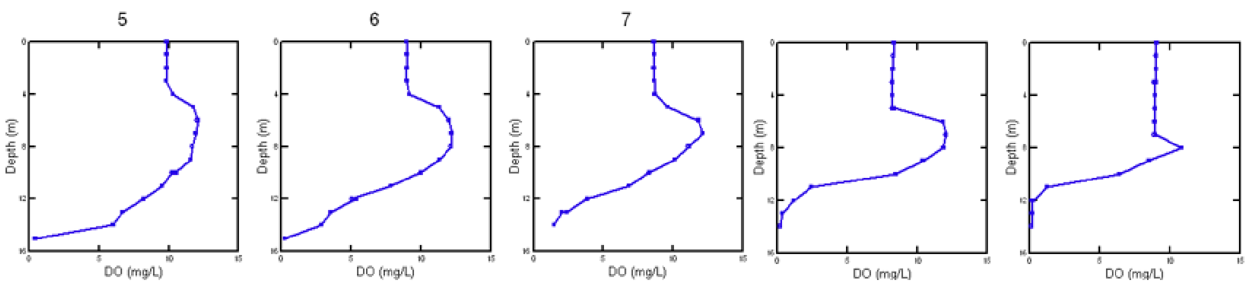

Figure 11. Sand Pond dissolved oxygen profiles by month during the 2022 season.

Plankton and other organic matter sinking from the surface cause the oxygen depletion in the deep-water. As the organic matter decays in the lower layer, oxygen is used up in the decay process and phosphorus is released. In addition, low oxygen near the bottom causes phosphorus to be released from the sediments by unbinding it from minerals. Phosphorus levels in the surface (4 parts per billion, ppb) waters increased a small amount over historical values (3 ppb), while the deep concentrations (25 ppb) increased significantly from historic values (15 ppb). We need to manage phosphorus in the watersheds of all these lakes. While Sand Pond remains good, these changes are troubling.

The pH and alkalinity are linked since alkalinity is a measure of the buffering capacity of water. The Sand Pond pH values are not unusual (Fig 6), but the alkalinity was lower than the other lakes (Fig 7), indicating a potential for acidification. Conductivity is a measure of dissolved substances in water and the values for Sand Pond were the lowest of the four lakes (Figure 8). While low for our lakes they still fall above the middle in comparison to Maine lakes (https://www.mainevlmp.org/resources/maine-lake-data/maines-water-quality-data/). These low values indicate that runoff of road salt is not a problem, not surprising given the remoteness from the highways in the area. While some color was found in the water indicating decomposing leaves, the values were low (Figure 9) and not of concern.

Little Pennesseewassee (Hobbs Pond):

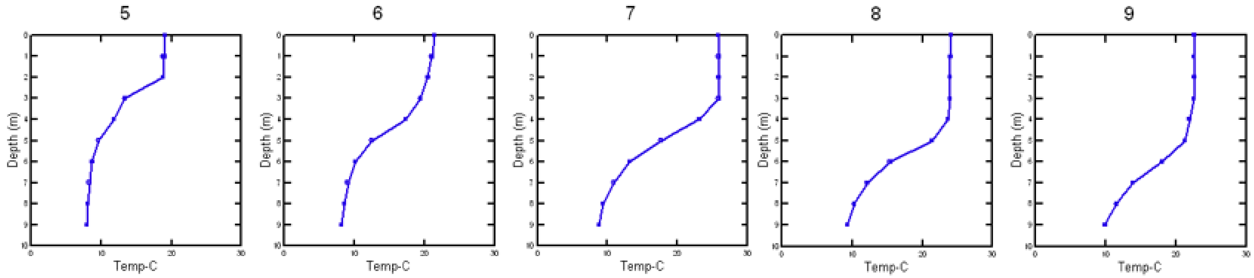

Figure 12. Temperature profiles by month for Little Pennesseewassee during the 2022 season.

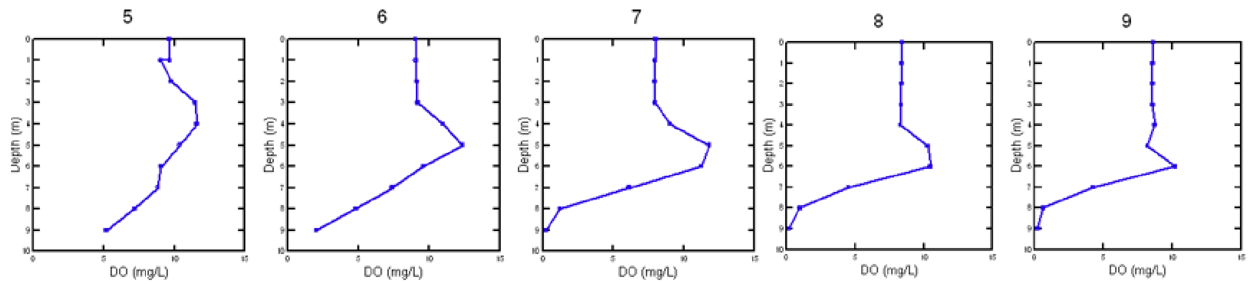

Figure 13. Dissolved oxygen profiles by month in Little Pennesseewassee for the 2022 season.

Little Pennesseewassee (Hobbs Pond), was again affected by a cyanobacterial bloom (bluegreen algae) in 2022. The genus was identified as *Planktothrix* by the Maine Department of Environmental Protection. Temperature profiles showed a distinct thermocline (the transition between warmer surface and colder deep waters) in May, which deepened further in July and August than it did last year (Fig 12). This could have been due to wind mixing or purely through surface heating. As result phosphorus could have been brought to the surface and subsequently stimulated the cyanobacterial bloom. The high phosphorus levels also could have been a residual from the previous year possibly due to the removal of a beaver dam or input from streams due to landuse practices.

Hobbs Pond started the year with an extremely high bottom phosphorus concentration (52 ppb) in May which dipped in June, but then went up again to alarmingly high levels 44-51 ppb through (Figure 3). This scenario has not been observed previously in Hobbs Pond. We can look at the historical data and see that in recent years there has been a significant and rapid rise in bottom total phosphorus concentrations (Figure below). The surface concentrations are more in line with the historical data. As you can see from the figure, there have been some changes in the way samples were collected over time. Nevertheless, the data are compelling in their story. For some reason, concentrations have recently increased. We are trying to assess the cause(s) by conducting additional sampling. This sampling involves doing source tracking of DNA, that is identifying the organisms responsible for DNA in streams and the lake. Specifically, we have tested for human and cow DNA since there is some concern about manure spreading in fields surrounding the lake, and the potential for septic system failures in the houses and camps on the shore. Both of these are potential sources of phosphorus for the lake. At the same time we collect the DNA samples, we are also collecting samples to be analyzed for phosphorus content. This work is ongoing at least through the Fall of this year.

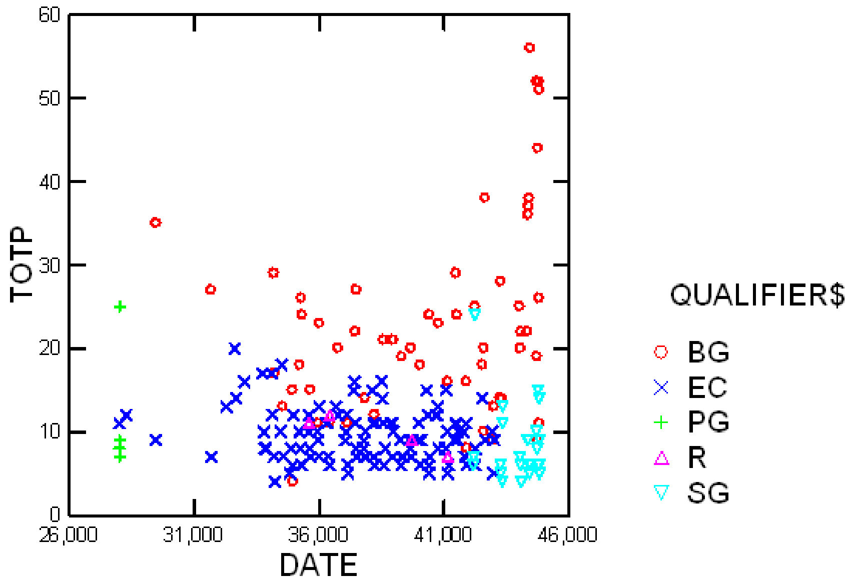

Figure . Total phosphorus concentrations in Little Pennesseewassee form 1976-2022. BG = bottom grab, EC = epilimnetic core (a tube sample from surface to the thermocline), PG = profile grab, R = repeat, SG = surface grab.

The dissolved oxygen concentrations in Little Pennesseewassee (Figure 13) 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 as early as June. 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. This oxygen peak slowly became deeper as the surface layer became thicker during the season, and the peak also became less pronounced possibly due to decreasing light intensities at depth.

Water clarity, as indicated by Secchi depth (Figure 4), was lowest in May, but then increased for the rest of the season. This is due to phytoplankton growth, which was high initially, as indicated by the Chlorophyll concentration (Figure 5), and then declined to lower values due to nutrient depletion in the surface water (Figure 6). Some of these may have settled to the thermocline where they contributed to the dissolved oxygen bump in concentration.

The pH values were normal (Fig 6) although the bottom water had a pH much lower than the surface, indication the decomposition of organic matter driving down the pH in the deep water. The alkalinity was similar to Hobbs and North Ponds roughly between 20 and 30 (Fig 7). The alkalinity values of the lake were above the state average, which gives it some protection from acidification. Conductivity was the highest of any of the lakes and exceeded the higher end normal for Maine lakes (Figure 8). This is likely due to runoff of winter salt from the highway. Color values for the surface were like the other lakes, but the bottom water had levels 2-3 times those of other lakes (Figure 9). The color of water in the region is mostly due to decomposing leaves.

Lake Pennesseewassee:

Lake Pennesseewassee is at the surface and has characteristics of an oligotrophic lake (low productivity lake having low amounts of phosphorus and phytoplankton in the surface waters (Table 2, Fig. 3 and 5). However, the deeper water has much higher phosphorus, more characteristic of a mesotrophic (medium productivity) lake. Water clarity is on the ranges between 5 and 7 meters (Figure 4), which is also indicative of a oligotrophic lake. Like the other deep lakes in our area, oxygen depletion occurs in the bottom waters (Figure 2 and 15), and there is elevated phosphorus in the bottom waters (Figure 3) due to release from the sediments during times of low oxygen. Thus, while the lake is apparently in good shape, there are warning signs that phosphorus needs to be managed, or the lake could suffer phytoplankton blooms as has happened in other areas. To this end, we recently conducted a shoreline survey, which has helped to mitigate phosphorus runoff from the drainage basin by fixing erosion problems.

The temperature profile in May is just starting to show signs of stratification as the surface is being warmed by the sun (Figure 14). The stratification becomes stronger (larger difference between surface and deep-water temperatures) through the season, and the surface layer becomes thicker, deepening the thermocline.

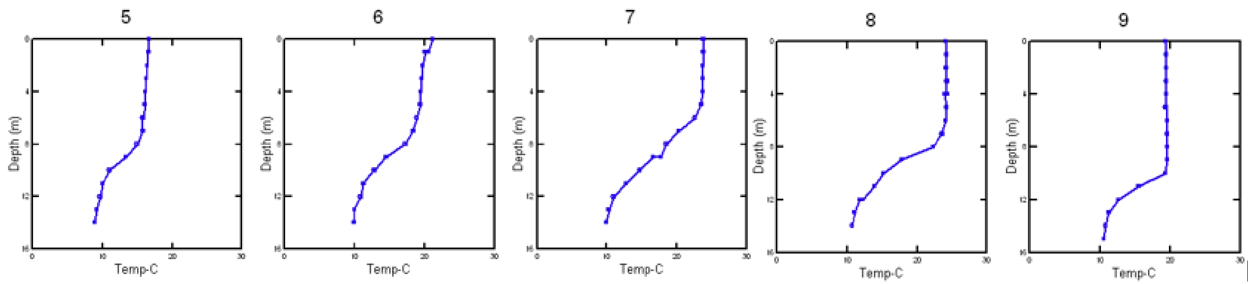

Figure 14. Temperature profiles by month in Lake Pennesseewassee (Norway Lake) during the 2022 season.

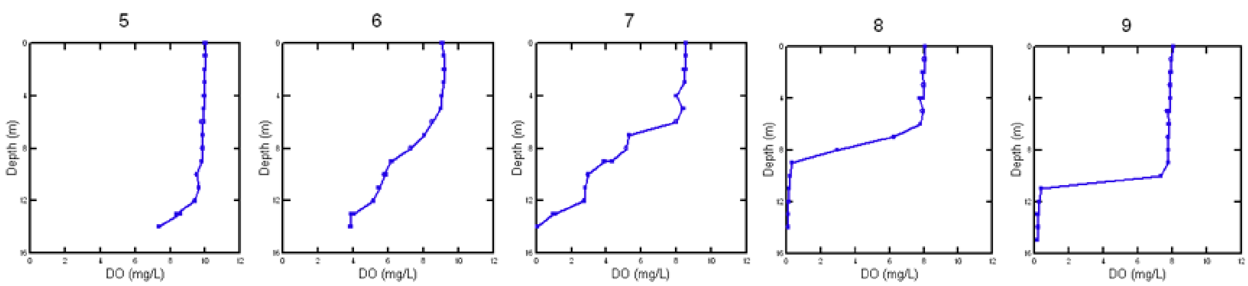

Figure 15. Dissolved oxygen profiles by month in Lake Penesseewassee (Norway Lake) during the 2022 season. May data was not taken.

As early as May, we see slightly lower oxygen concentrations near the bottom (Figure 15). The oxygen concentration in the bottom waters continues to decrease throughout the summer due to decomposition of organic matter and no mechanism to replenish oxygen in the deep water. By July the deep water is devoid of oxygen from the bottom to almost 6 meters from the surface, and the difference in oxygen between surface and deep water becomes very sharp in August and September. On a more positive note, the oxygen content did not decrease as rapidly as last year. In June bottom oxygen was at about 4 mg/L while last year it was already down to 2 mg/L.

The Secchi depth fluctuated starting at near 6 m in May, then dropping in June to about 4.5 m before rising through August to over 6 m and then dropping again in September (Figure 4).. The drop in June can be attributed to an increase in phytoplankton algae as seen by the chlorophyll values (Figure 5). Phosphorus concentrations in the surface remain relatively constant but are seen to increase in the bottom water from 13 ppb in May to 35 ppb in September (Figure 3). This trend indicates a release of phosphorus stored in the lake sediments caused by the low oxygen environment in the deeper waters (Figure 15).

The pH values were in the normal range for surface waters, around pH 7.4 in the surface and just below pH 7 in the deep water (Figure 6). Alkalinity values were also normal for our area, but higher than the state average, indicating the system is buffered against pH changes (Figure 7). Conductivity values (Figure 8) were second only to Little Pennesseewassee (Hobbs Pond). While both lakes are located next to State Route 118, Pennesseewassee probabbly has a lower conductivity because there is more volume to dilute the road salt than in Hobbs Pond. The conductivity levels, while relatively high, are below the maximum levels found in Maine. Water color was higher in the bottom water than in the surface indicating more organic matter decomposition, mostly leaves and algae, affecting the deeper water.

North Pond:

North Pond is relatively shallow (3 m) in comparison to the other lakes. For that reason, it mixes quite easily from top to bottom with any wind. This means that it usually does not form two layers for any length of time. During 2022 the temperature range observed was also very narrow compared to other lakes. We did not observe any temperature stratification (Figure 16). Unlike the other lakes which suffer from oxygen depletion in the bottom waters, North Pond typically has plenty of oxygen throughout the water column as a result of wind mixing. However, in 2022 there were several instances of weak dissolved oxygen stratification near bottom indicating oxygen uptake in the sediments due to decomposition of organic matter there. The observed oxygen levels never became less than 5 mg/L (Figure 17), which is the level at which fish may become stressed (Figure 1).

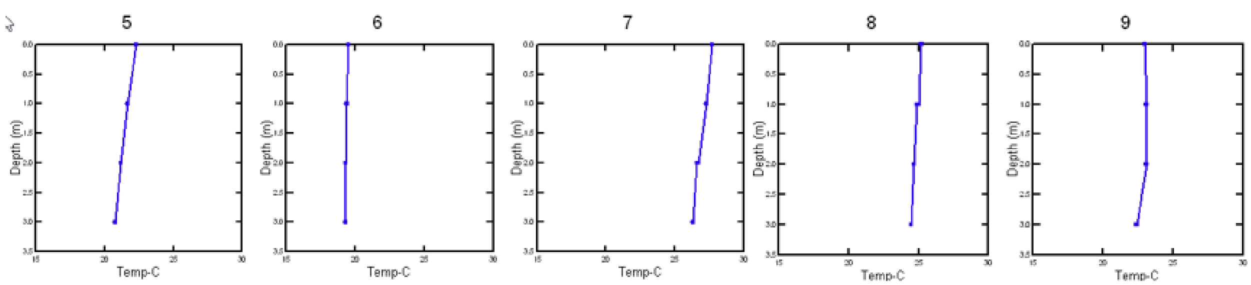

Figure 16. Temperature profiles by month for North Pond during the 2022 season. Note the scale is only from 15-30 °C whereas for the other lakes the scale was 0-30 °C.

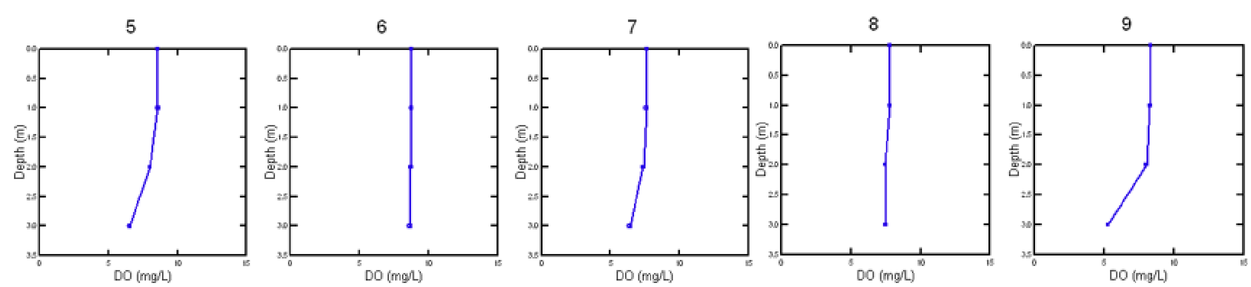

Figure 17. Dissolved oxygen profiles by month for North Pond during the 2022 season.

Phosphorus concentrations fluctuated somewhat in both the surface and bottom waters but remained relatively stable through the summer around 10-20 ppb (Figure 3), with the exception of a rise in the bottom concentrations in September. This is a similar pattern to last year where the bottom water also spiked in September to 74 ppb. This may be due to internal loading, as the bottom consists of very thick layers of peat, which can release phosphorus. 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 a low productivity (oligotrophic) but the phosporus concentrations would classify it as moderately productive (mesotrophic). As stated above, phytoplankton blooms do not seem to be a problem. However, the chlorophyll concentrations are generally the highest of the four lakes (Figure 5). A good sign is that the current chlorophyll concentrations have not risen above average historical values (Tale 1).

North Pond pH values are just above 7, which is normal for lakes, and due to it being well mixed, surface and bottom have similar pH values. Alkalinity values were just above average values for Maine. Conductivity is on the low side for our lakes and just about at the State average, reflecting normal geologic conditions and low input of road salt. The color of the water is similar to that of the other lakes.

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 2 liter polycarbonate bottle was filled from a van Dorn sampler. 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. 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 an electric pump at < 8 in Hg vacuum, 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:

The 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 10.0, 7.0 and 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.

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.