2023 Report on the Health of the Norway Lakes

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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 2023 and also for 2022 to show the annual difference. This year was the third year in a row for a cyanobacterial bloom in late summer in Hobbs Pond (Little Pennesseewassee). These organisms used to be called blue green algae because they are photosynthetic, but their structure is bacterial and have since been reclassified as such. Cyanobacteria may produce toxins that are harmful to people, dogs and livestock, however, no microcystin toxins have been found in Hobbs Pond.

Table 1. Secchi depth, Total Phosphorus and Chlorophyll concentrations for 2023 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 2023 (2022)					Historical Avg (1976-2023)*					
	Secchi	Avg P	P Surf	P Bot	Chl-0m	Secchi	Avg P	P Surf	P Bot	Chl-0m	Chl Cores**
Sand Pond	7.12 (7.21)	8.9 (14.5)	3.8 (4)	14.0 (25)	2.6 (1.4)	7.37	8.41	5.41	15.83	1.66	2.58
Little Pennesseewassee	4.88 (5.29)	14.12 (21.1)	7.5 (7)	20.5 (43.6)	3.0 (2.4)	5.45	13.29	8.93	22	2.48	4.31
Pennesseewassee	4.27 (5.18)	15.4 (14.5)	8.4 (7)	22.4 (22)	4.6 (3.2)	5.72	10.24	8.37	16.3	3.32	4.45
North Pond	3.1 (3.22)	13.17 (19.3)	13.17 (16.5)	NA (23.5)	4.0 (3.8)	2.93	17.62	16.94	29.82	5.18	6.06

Secchi - higher number is better
P - lower number is better

2023 Average vs Historical	
(green)	Improved
(red)	Worsened
(grey)	Too close to call

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

** Prior to 2018 samples were often collected with a" core" (a hose) that extended from the surface to the thermocline (rapid change in temperature) in order to obtain a surface layer average.

Cyanobacterial blooms are caused by increased nutrient levels. Although the Hobbs Pond nutrient concentrations appear to be declining to former levels, the values in Norway lake seem to be increasing. The high average P is mostly due to the high bottom concentrations. These bottom nutrients may be driven to the surface by various stirring events such as wind mixing. The other lakes, except North Pond, also showed increased P concentrations but to a lesser degree. Interestingly, the chlorophyll (algae) concentrations are lower than historical values. Secchi depths (water clarity) were not much different from those in the past. See page 12 for what is and can be done to address nutrient levels.

On the bright side, 2023 saw lower phosphorus levels in the waters relative to historic values in all the lakes except Pennesseewassee. Chlorophyll concentrations, indicating the number of algae, were around or lower than historical values in all the lakes except Pennesseewassee.

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/).

The Phosphorus story.

During the past three years. We have seen an unusual cyanobacterial bloom in Little Pennesseewassee (Hobbs Pond). Cyanobacteria (formerly known as blue green algae) can produce toxins harmful to animals and humans. Algal blooms are often associated with high nutrient levels needed by the organisms, and phosphorus is one that is often limiting to their growth in freshwaters. As soon as the blooms started, LAON began investigating their cause. We looked for nutrient sources and identified possible pathways for their entry into Hobbs Pond. Early on, through DNA testing, we identified runoff from fields as a possible pathway for phosphorus to enter Hobbs. We looked at the historical total phosphorus trends in all the lakes (Fig. 1). While surface phosphorus concentrations have declined slightly, bottom phosphorus concentrations have increased in Hobbs Pond and Sand Pond. Pennesseewassee shows no trend, while there are too few bottom data for North Pond.

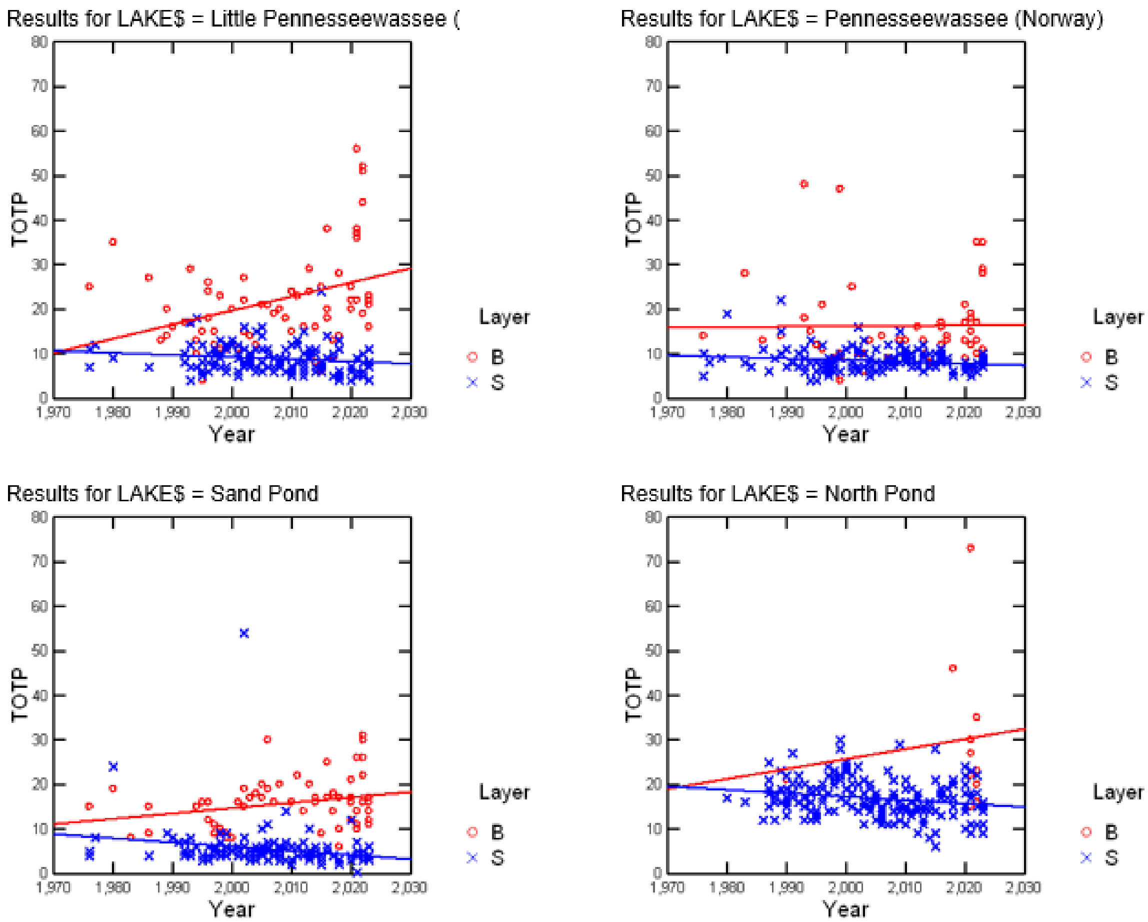


Figure 1. Total phosphorus over time in all four lakes. Least squares regression lines show the trends of the data.

Significantly, high concentrations of phosphorus were not confined to Hobbs (Figure 1), although it had the highest amounts and suffered cyanobacterial blooms. Beginning in 2021 we see greater concentrations of phosphorus in all the lakes (Fig. 2), with Lake Pennesseewassee (Norway) only developing high Phosphorus levels in 2022. It is not clear at this time why Norway Lake was

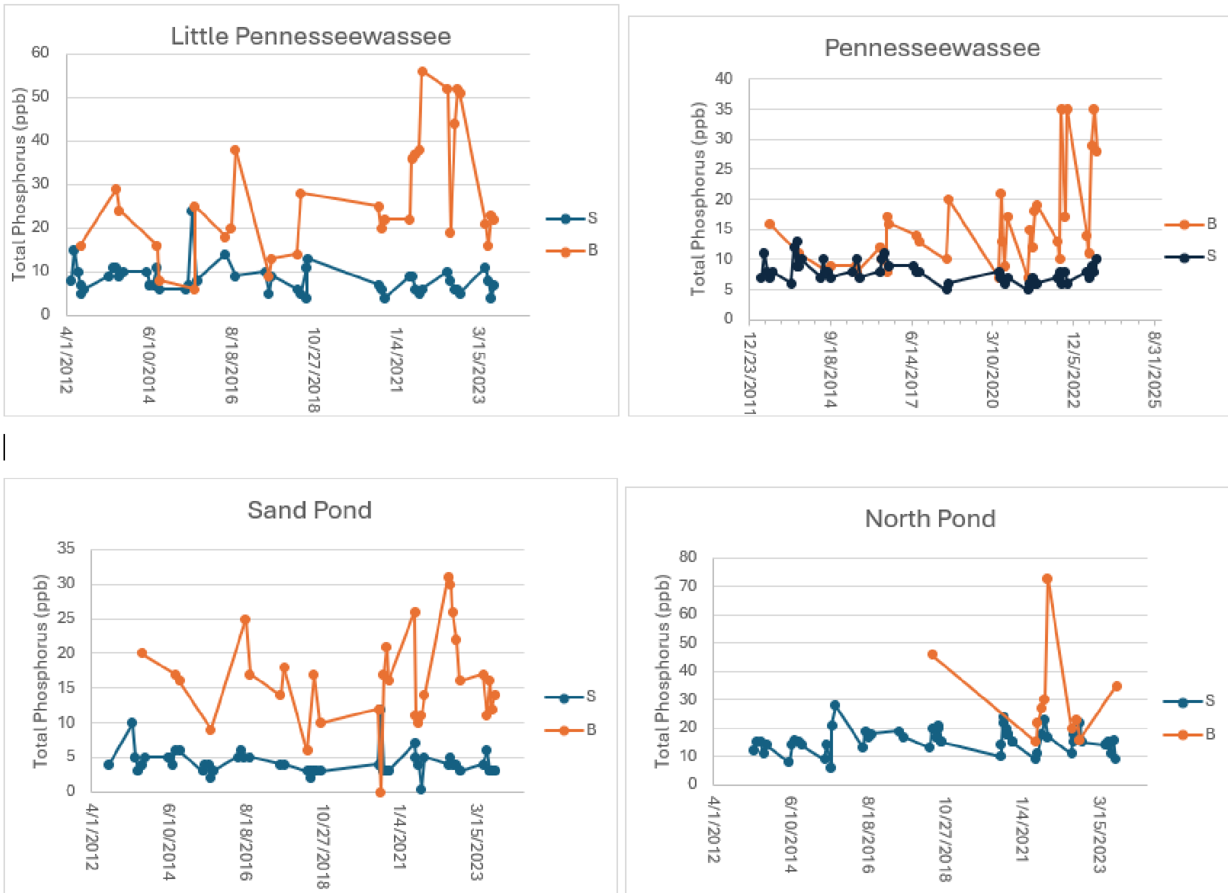


Figure 2. Phosphorus concentrations for surface (S) and bottom (B) water 2013-2023 in the four lakes.

delayed a year. The high phosphorus declined to more normal levels in 2023 except in Norway Lake. North Pond is different from the others in that it does not regularly form two layers, which is why there are so few results for the bottom. The regional impact of phosphorus on the three deeper lakes may point to meteorological/climatic factors playing a role in the Hobbs Pond blooms as warmer temperatures and high phosphorus favor cyanobacteria.

Climate Change

Evidence of climate change is shown in the data. Our lakes have been warming since the time LAON started collecting data (Figure 3). The atmospheric temperature mirrors that of the water temperatures (Fig 4). This warming trend is apparent in the upper layer of water, while the bottom layer remained at a relatively constant temperature over this time. Because North Pond is shallow and tends to be well mixed, surface and bottom temperature are very similar.

Temperature had other effects. The dissolved oxygen concentration also decreased in the surface layer over time as seen in Figure 4. This decline is predicted by physics as warm water can hold less dissolved oxygen than colder water can (Figure 5).

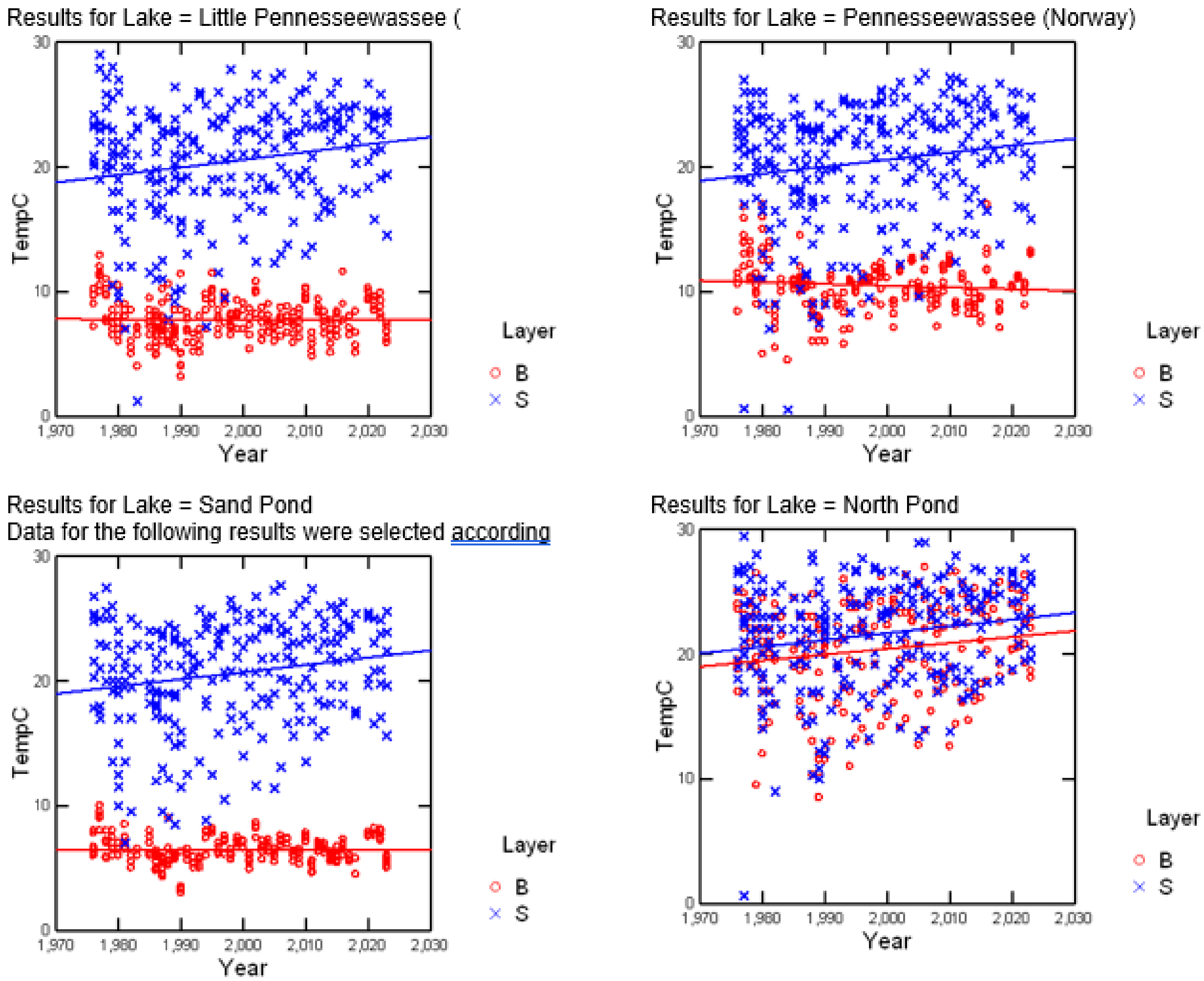


Figure 3. Water temperature in the surface (S) and bottom (B) layer of water in each of the four lakes since 1976. Least squares regression lines show the trends of the data.

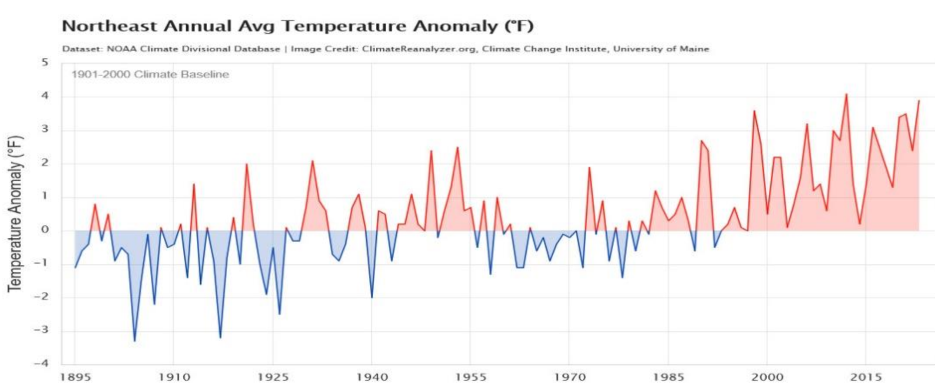


Figure 4 Air temperature anomaly (difference from average) in the Northeast (Source: https://climatereanalyzer.org/clim/noaa-us-monthly/).

Effects on Dissolved Oxygen

Temperature, however, is not responsible for the decrease in oxygen content of the bottom layer. Rather, this decline is due to the decomposition of organic matter, mostly dead algae from the water column and plant matter from the shore. When algae in the water dies, it sinks to deeper depths where bacterial activity breaks down the organic matter. Two important things happen during this process. First is that oxygen is consumed by the action of the bacteria. Second is that the lower oxygen content at the bottom changes the chemistry of the sediments, allowing phosphorus to be released back into the water. As time goes on more and more organic matter accumulates at the bottom of the lake. The lake bottom then becomes a reservoir for phosphorus. This phosphorus can be tied up in the sediments if oxygen is present but is released from the sediment when oxygen gets depleted.

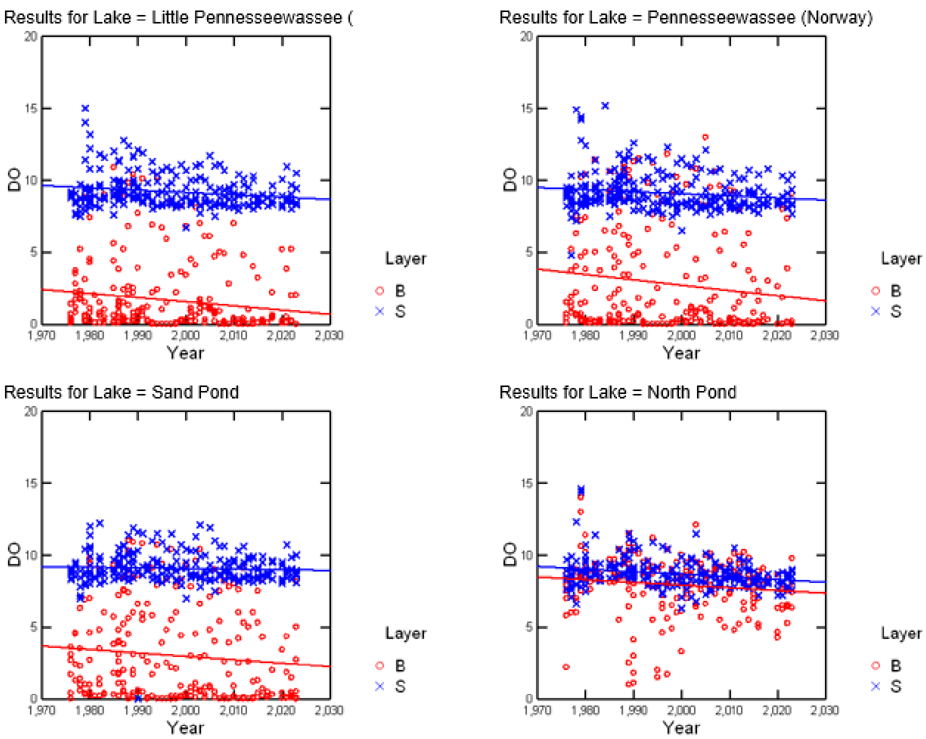


Figure 5. Dissolved oxygen in the four lakes in the surface (S) and bottom (B) layers since 1976. Least squares regression lines show the trends of the data.

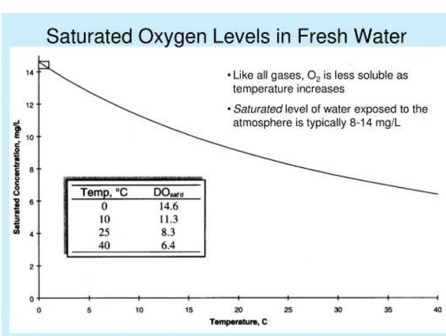


Figure 6. Dissolved oxygen in water at different temperatures.

Effects on Algal Chlorophyll

The process of releasing phosphorus from the sediment is called internal cycling. The effect of this internal cycling can be detrimental by increasing available phosphorus, thus increasing algal growth (figure 6). Phosphorus is a limiting nutrient (in least supply) in freshwaters and increases in phosphorus lead to greater algae as seen by chlorophyll concentrations. Note the similarity of the regression lines for three of the lakes (Fig 6) between chlorophyll and total phosphorus. Sand Pond is skewed by the two outliers on the right side of the graph and would be similar to the others if these two points were excluded. This accumulation of Phosphorus in the deep and release from the sediments is a proverbial vicious cycle.

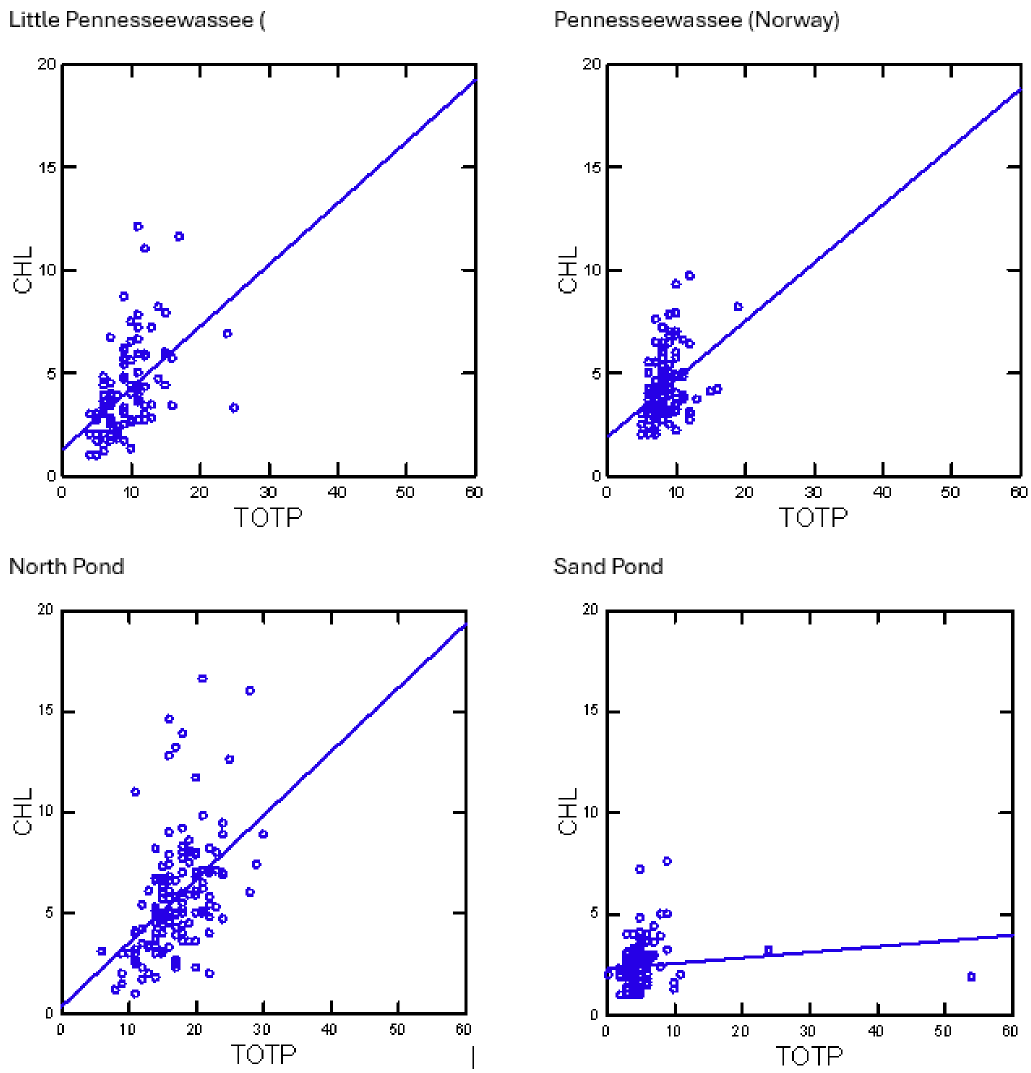


Figure 7. Relationship between algal chlorophyll concentrations and total phosphorus concentrations in the four lakes. Least squares regression lines show the trends of the data.

Water Clarity

As algal concentrations increase, water clarity, measured as Secchi depth, decreases (Figure 7). North Pond is the anomaly since the Secchi disk almost always hits the bottom, capping the Secchi Depth to around 3 meters. Water clarity is obviously a characteristic of our lakes which we value. There are studies that show that as water clarity decreases, property values decrease. This should provide an incentive for us to reduce inputs of phosphorus into our lakes and keep water clarity high by reducing algal populations.

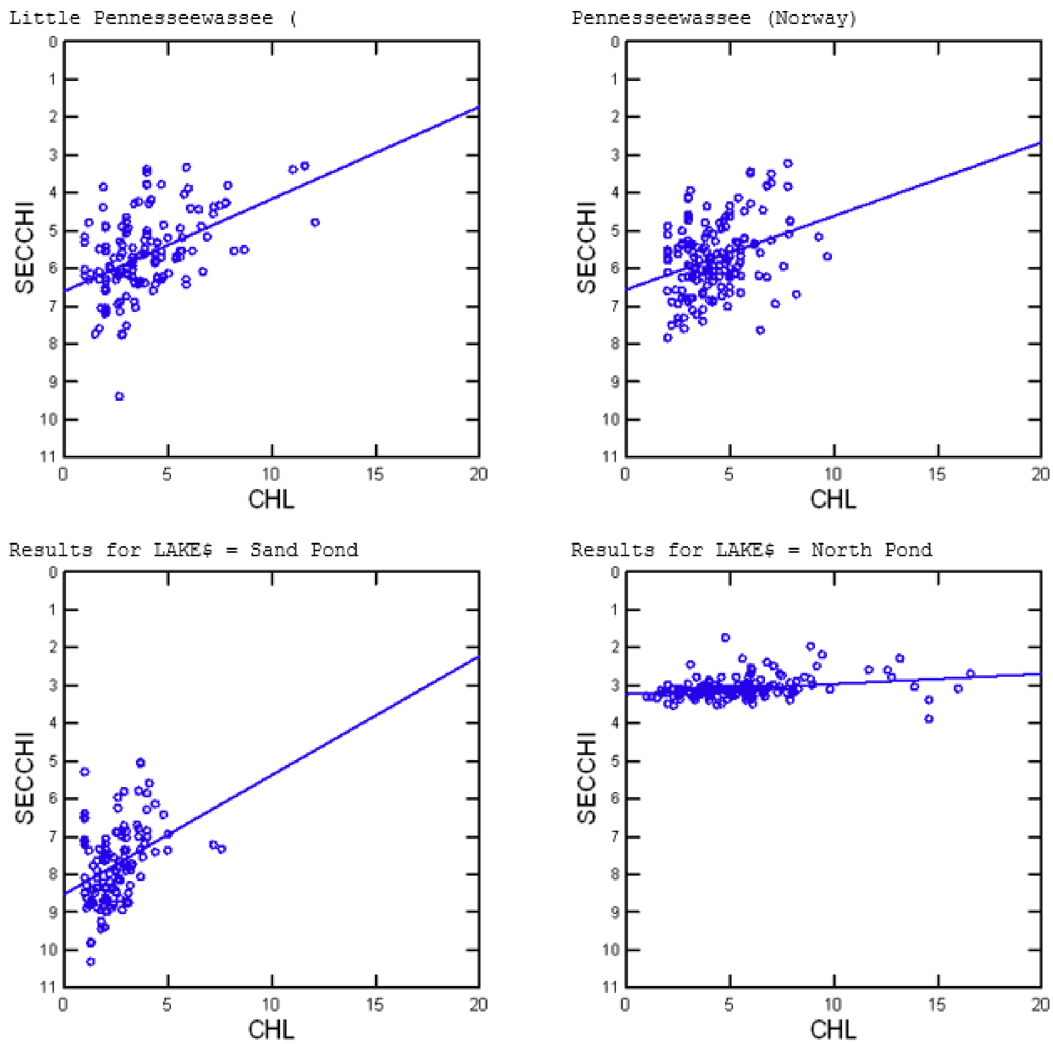


Figure 8. Relationship between Chlorophyll (algal concentration) and Secchi Depth (water clarity). Note that Secchi depth increases from top to bottom of the graphs to indicate deeper visibility. Least squares regression lines show the trends of the data.

The trends in chlorophyll (algal abundance) seem to be declining (Figure 8), but this needs to be taken with a grain of salt due to the wide scatter of data. While the decline in chlorophyll is encouraging, the picture for phosphorus is not as good (Figure 1) which shows declining phosphorus trends in the surface waters but increasing trends in the bottom. The decline in the surface could be due to increased uptake by plants and algae near the surface, and accumulation of detrital (dead organic matter) phosphorus near the bottom. The encouraging news here is that, so far, there is no evidence for increased algal abundance due to bottom phosphorus based on chlorophyll data (Figure 8)

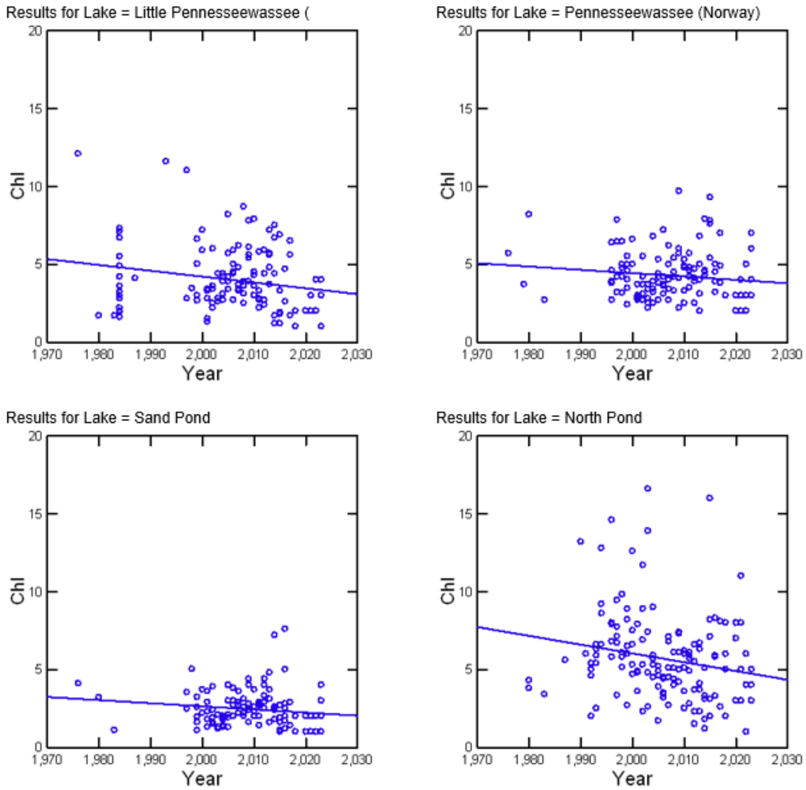


Figure 9. Chlorophyll concentrations in the four lakes since 1976. Least squares regression lines show the trends of the data.

There are, however, relationships among the phosphorus levels and chlorophyll at times (Figure 9). Phosphorus fluctuations at the surface and bottom mostly follow each other, indicating exchange between the two layers, probably from surface to the bottom. This is not always the case as can be seen in 2017 by the decline in the bottom phosphorus, with an increase at the surface. In this instance there might be an upward flow of phosphorus due to a mixing event. On occasion there is also symmetry between phosphorus chlorophyll concentrations as seen in the 2000 to 2001 transition with high values in the Fall and subsequent low values the following year.

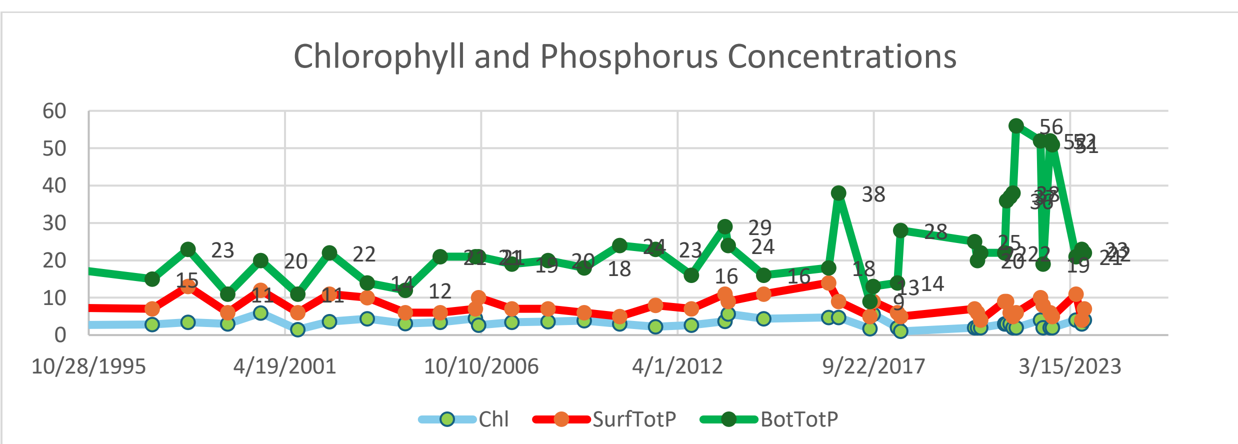


Figure 10. Chlorophyll and Phosphorus concentrations over time showing the relationship among them.

Weather Effects

We explored the possible impacts of weather related to the bloom. The data comes from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NOAA NCEI). Specifically, we looked for precipitation (rainfall) and wind speed data. The closest station to our lakes for precipitation data was in Poland, Maine while the closest windspeed data were from the Portland Jetport.

Rainfall is important as it is a driver for external inputs of nutrients, like phosphorus, through runoff from land surfaces. Rainfall data showed an interesting occurrence of heavy rain during July 2021 (Figure 10) which coincided with the start of the cyanobacterial bloom in Hobbs Pond and the increased phosphorus levels seen in the lakes. This was recorded as an average of over 1/3 of an inch per day during July 2021, and over 11 inches total for the month. The high value for average daily precipitation was exceeded only once during the ten-year period we looked at, in 2018. However, the total of 11.42 inches in July 2021 was at least 2 inches greater than any other monthly precipitation over the ten-year period.

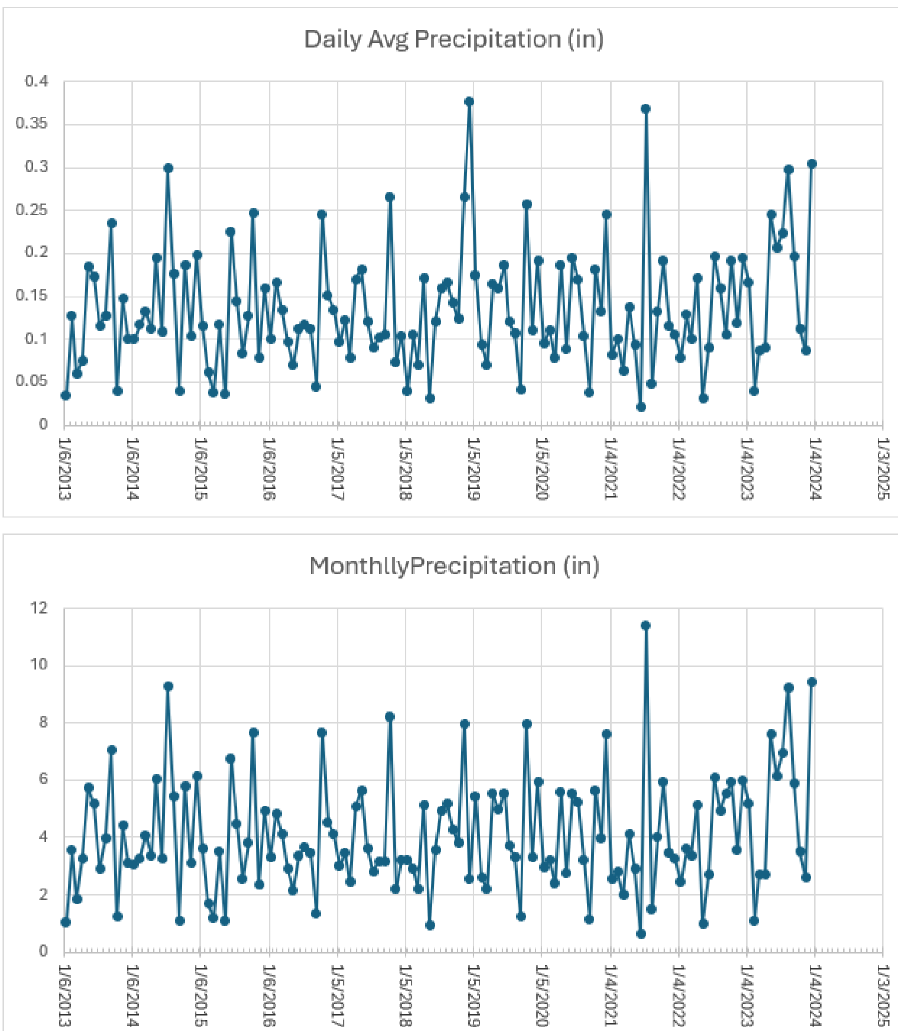
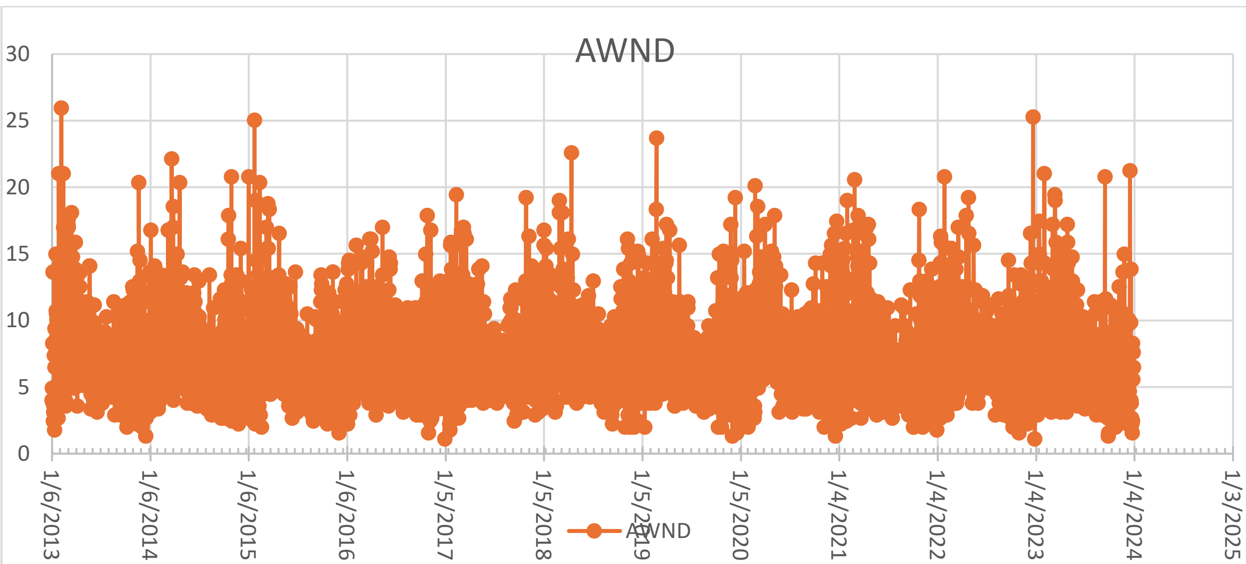


Figure 11. Average daily precipitation and total monthly precipitation recorded at the Poland, Maine weather station.

We looked at wind speed because it causes turbulence in the water and can lead to mixing of surface and bottom water. Wind speed data was not conclusive as no patterns, either in average wind speed or fastest wind speed, were found that could be coincident to the bloom (Figure 11). Average wind speeds in 2021 were less than 20 mph with one exception. These speeds were typical of the ten-year time period and were less than the maximum values of several other years. The same can be said for the maximum 2-minute winds. The maximum remained below 40 mph with one exception. There were four other years that had peak winds greater than that.

An alternative suggests that low wind speed and strong stratification by warm water leads to vertical differences in distribution of cyanobacteria (Wilkinson, et al., 2019). Stronger winds tend to disperse them randomly in the surface layer, while weaker winds allow them to choose their preferred depth according to light intensity. This is because these cyanobacteria can regulate their buoyancy, and hence their depth, through gas vesicles.



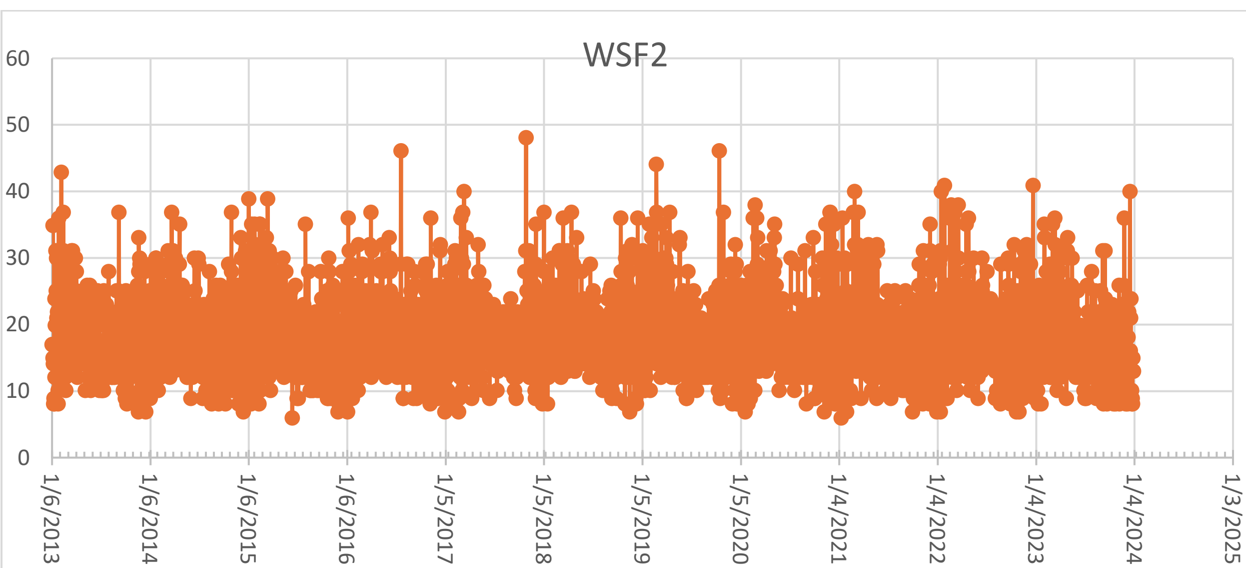


Figure 12. Average wind speed (mph) and Fastest 2-minute wind speed at the Portland Jetport.

Keeping Phosphorus out of our lakes

What is being done through LAON:

Lake Pennesseewassee: In recent years, extreme rainfall events have caused three significant erosion sites to develop along Lake Pennesseewassee that were not present before 2022. Erosion at these sites caused hundreds of tons of phosphorus ladened sediment to flow into the lake, and undoubtedly was a major contributor to increased phosphorus levels. LAON has worked with property owners to address one site this year, is working with other property owners to address a second site this year and is working with the Town of Norway to address the third site, possibly next year. We anticipate that each of these remediation projects will have significant long term beneficial effects. In addition, LAON is working on a 10 year watershed plan to address many other erosion sites identified during its last watershed survey.

Hobbs Pond: LAON is supporting Hobbs Pond in two ways. It began conducting special water quality tests in 2022 in order to better understand possible sources of phosphorus. That information will guide remediation efforts In addition. in 2024, LAON worked with the Maine Department of Environmental Protection (DEP) to conduct a survey of the Hobbs Pond watershed, identifying 54 erosion sites with varying degrees of impact. We will develop a watershed protection plan for Hobbs Pond and apply for a grant that will support remediation efforts for those sites, looking to address them in 2025.

What you can do:

Property owners near the lakes can do a number of things to make sure they are not contributing to the problem:

See the LAON website Homeowner Toolkit: http://norwaylakes.org/conservation-and-building-codes/

- Plantings and buffer zones
- Control erosion
- Adhere to shoreland zoning regulations

Consider making your property Lakesmart: https://8478f1.p3cdn1.secureserver.net/wp-content/uploads/2016/07/LakeSmart-Brochure.pdf

Abide by the new wake zone regulations to prevent shoreline erosion. See wake zone depth maps:

- Sand Pond https://8478f1.p3cdn1.secureserver.net/wp-content/uploads/2023/05/Sand-Pond-wake-zone-and-depth-map.pdf
- Hobbs Pond
- North Pond https://8478f1.p3cdn1.secureserver.net/wp-content/uploads/2023/05/North-Pond-Wake-and-Depth-Map-email.pdf
- Pennesseewassee https://8478f1.p3cdn1.secureserver.net/wp-content/uploads/2023/05/Lake-Pennesseewassee-wake-zone-and-depth-map.pdf

Summary

The Hobbs Pond cyanobacterial blooms were likely the result of weather conditions that allowed phosphorus-rich bottom water to mix closer to the surface, that is, above the Secchi depth allowing rapid growth of cyanobacteria. Alternatively, the phosphorus rich water may have come in from outside the Pond. Feeder streams are one such source, overland flow another, a third possibility has been raised and that was breeching of a beaver dam adjacent to Hobbs Pond. Furthermore, the increasing temperatures of the surface waters may aid the growth of algae and cyanobacterial organisms. In the other lakes, similar phosphorus increases were observed, but not cyanobacterial blooms. This could possibly be because of competition with other algae or some other factor. On a positive note, recent phosphorus concentrations in the bottom waters seem to be dropping (except in Pennesseewassee) to more normal levels (Figure 1), lending hope that the cyanobacterial blooms may disappear. Indeed, the Hobbs Pond bloom in 2023 was the smallest seen.

References

Wilkinson, A. A., Hondzo, M., & Guala, M. (2019). Investigating abiotic drivers for vertical and temporal heterogeneities of cyanobacteria concentrations in lakes using a seasonal in situ monitoring station. Water Resources Research, 55, 954–972. https://doi.org/10.1029/2018WR024228

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.