2015 Report on the Health of the Norway Lakes

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About the Report

The Lakes Association of Norway (LAON), with support from the Town of Norway, continued to monitor the health of the four Norway lakes: Pennesseewassee, Little Pennesseewassee (Hobbs Pond), Sand, and North Ponds in 2015. This year we were also able to add a new program to have voluntary boat inspections for people bringing their boats into Lake Pennesseewassee. Water quality monitoring was a combined effort of volunteers and professional lake scientists. This year volunteer monitors collected all of the water quality samples, while professional lake scientists conducted a full level 3 screening survey for invasive aquatic species on the four lakes. Monitoring of the lakes' water chemistry took place from early May through September, during the time of the year when lakes and ponds are the most biologically productive and water quality problems are most likely to occur. The invasive aquatic species screening of the four lakes occurred from 9/22/15 to 10/6/15, and was conducted by Lake and Watershed Resource Management Associates for the Lakes Association of Norway. They again found no invasive plants in any of the lakes. Their full report is separate and may also be found on the LAON website http://norwaylakes.org/water-quality/.

Acknowledgements

We wish to thank all who have shown stewardship to the lakes and those who have contributed to the monitoring efforts, especially Jeanne Silverman, Eric Grondin, Ray Snedeker and our Intern from OHCHS, Izabel Earle

Executive Summary

The water quality analysis indicates mostly good news. The table below shows average values for the 2015 season, in comparison to 40+ years of data. Concentrations of total phosphorus were lower (and lower is better) in three lakes, and the same in the third lake (Hobbs Pond) if we ignore one high value, possibly caused by sample contamination. Algal abundance is measured by chlorophyll concentrations. Declines in chlorophyll (lower is better) were measured in Sand and Hobbs Ponds, and with one exceptional value would be lower in Pennesseewassee as well. Chlorophyll remained the same as the historical value in North Pond. Secchi depth is a measure of water clarity (larger is better) and only Sand Pond exceeded the historical averages in 2015. Dissolved oxygen (DO), reported here as mg/liter, remained near saturation in the surface layer, but in three lakes declined to levels unhealthy for aquatic life. The exception was North Pond which repeatedly is stirred by winds due to its shallow depth. It is unclear at this time, why water clarity would decline in the other lakes despite improvements in total phosphorus and chlorophyll. It is important note that other Lake observers may have taken Secchi disk measurements that were not available to us at the time this report was written. These results will be incorporated into future reports as part of the long term data averages.

	Phos (ug/L)		**Chl (mg/L)**		**Secchi (m)**	**DO Surf**	**DO Bot**
Sand	3.2 (5.9)		1.1 (2.8)		8.7 (7.4)	8.63	2.9
Norway	7.4 (9)		15.4 (4.3)	2.6*	4.6 (5.8)	8.56	1.67
North	15.6 (17)		2.8 (2.8)		2.4 (2.8)	8.32	7.21
Hobbs	10.2 (6.7)	6.7*	2.0 (4.3)		4.9 (5.2)	8.5	0.73

numbers in parentheses are the long term average

* the average value without an outlier

Background Lake Ecology

2015 Weather Influences on Maine Lakes:

Annual weather, especially the period from January through mid-summer, can have a strong bearing on lake water quality, and often accounts for a significant percentage of the natural variability that occurs in lakes from one year to the next. Spring and early summer runoff often carries a significant percentage of the annual nutrient loads into lakes. The winter of 2014 saw very heavy snowfall, which can be expected to be reflected in the conditions found during the lake monitoring period. The weather during the spring and early summer of 2015 was warm with rain events in every month, although May was fairly dry. This dry spell lasted 28 days without rain between April 29 and May 26. Rain events in April and June dropped over 1 inch, and September saw an almost 5 inch rain event. The month with the most precipitation was September, with 6.713", compared to a median value of 3.173". This may have allowed more runoff into the lakes just as they were beginning to destratify due to cooling air temperatures.

Warm summer temperatures lead to stronger lake stratification which may cause increased oxygen depletion in deeper parts of the lakes. The *hottest day* of 2015 was August 16, with a high temperature of 91°F, while the average for that day is only 77°F. The *hottest month* of 2015 was August with an average daily high temperature of 80°F.

Stratification:

Stratification is a term used by lake ecologists to refer to the layering of water in a lake due to warming of the surface by the sun. The lake becomes layered because warmer water is less dense and floats on top of colder denser water. The upper layer is referred to as the *epilimnion*, while the lower layer is called the *hypolimnion*.

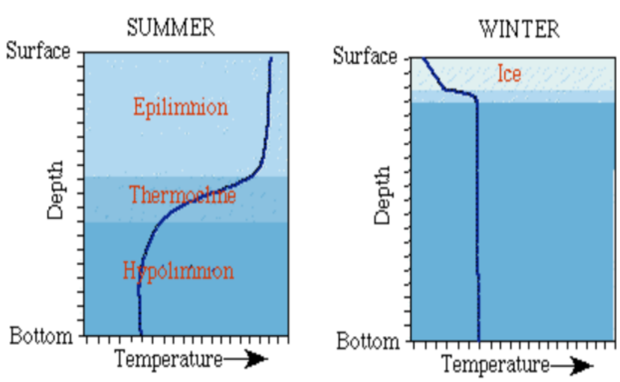


Figure1. Source http://www.sgreen.us/pmaslin/limno/strat.html

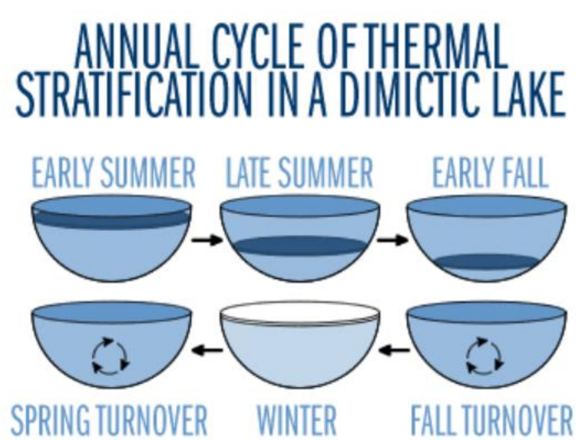


Figure 2. Source http://www.waterontheweb.org/under/lakeecology/05_stratification.html

This layering is important for the ecology because the zone of rapid change in temperature between the two layers (called the *thermocline*) inhibits exchange of materials like gases and nutrients. For example, oxygen from the atmosphere or photosynthesis by plants and algae cannot penetrate into the deep layer. This becomes important as the summer proceeds because organic matter decomposes in the deep layer using up oxygen. The organic matter is mostly composed of dead organisms that sink from the surface layer. The result is that the deep layer contains less and less oxygen as the summer goes on. The stratification is eventually broken down in autumn and winter as the atmosphere cools, cooling the surface water and allowing mixing of the entire lake.

The low oxygen concentration makes the deep layer unsuitable for most fish and other oxygen-requiring organisms.

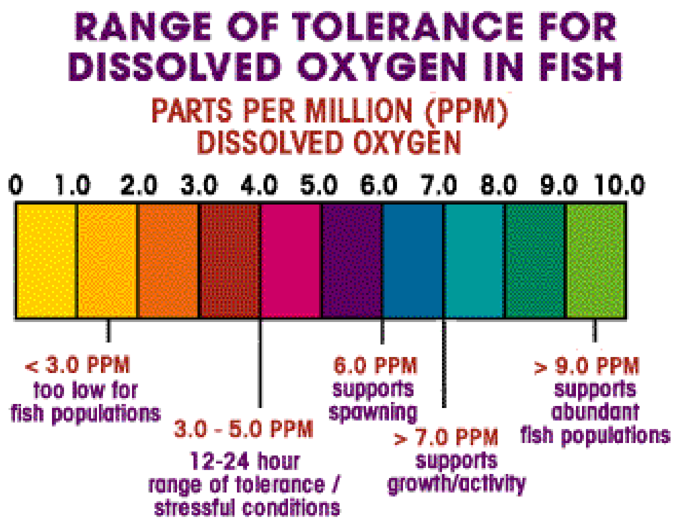


Figure 3. Source http://www.water-research.net/index.php/dissovled-oxygen-in-water

Stratification not only affects oxygen levels, but a side effect is that sediments in anoxic (no oxygen) water release nitrogen and phosphorus that were chemically locked in the sediment while oxygen was present. These nutrients typically would not go up to the surface layer until mixing began in autumn. The exception might be if a strong storm caused a mixing event.

Additional issues in anoxic waters are other chemicals, like hydrogen sulfide (rotten egg smell) that is poisonous to oxygen-requiring organisms. Also released from sediments are iron and manganese which can cause taste and odor problems in the water.

Phosphorus

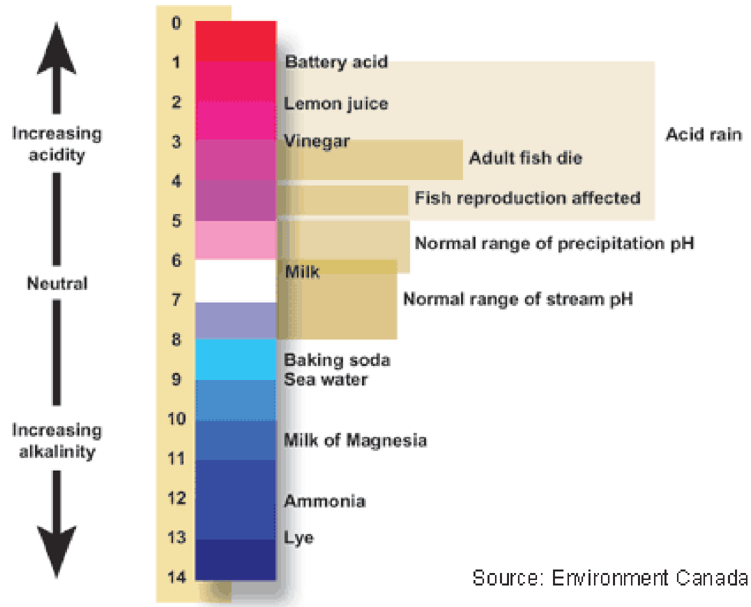
Phosphorus is a nutrient, which is defined as a necessary substance for organisms to live. More specifically nutrients in the context of lakes refer to substances required for algal growth. Limiting nutrients are those nutrients that are available to algae in the least amount, relative to other nutrients, and thus can prevent them from growing. Most freshwater ecosystems are phosphorus limited. This means that additional phosphorus added to a system is likely to cause rapid growth of algae. Such blooms can lead to oxygen depletion as these blooms die off. Algal blooms may in some cases cause other problems such as taste and odor issues in drinking water, toxins, displacement of other organism, and more. This is why so much attention is being focused on keeping phosphorus from entering lakes and streams.

Chlorophyll

Chlorophyll is a substance in plants and algae that allows them to photosynthesize, that is convert carbon dioxide to organic compounds using the sun as energy. Because all algae have chlorophyll, and it is relatively easy to measure, it is often used as a substitute for measuring algal biomass.

pH

pH is a measure of how acidic a solution is, and the acidity of water determines, in part, what species can live there, and what kinds of chemical reactions can take place. Most normal surface waters fall in the range of 6-8 on the pH scale.



Conductivity

Water is a good insulator, until substances are dissolved in it. So measuring conductivity gives an idea of the total amount of dissolved material. Most waters on earth have dissolved substances in them, most are good for you in small amounts. If you have ever tasted distilled water, you may have thought it lacked taste or was flat. That is because we have come to appreciate the dissolved matter in our drinking water. Increases in conductivity may occur as road salt use increases.

Color

We often think of water as being colorless, but water may have color due to dissolved or particulate material in the water. You may have seen streams that are muddy colored due to suspended sediment, Lakes and streams may also be colored like tea, due to the decomposition of vegetation. These dissolved materials are called tannins or humic substances. Highly colored water will limit the penetration of sunlight, reducing plant growth.

Alkalinity

Alkalinity is the ability of water t resist changes in pH – a buffering capacity if you will. More correctly, it is the acid neutralizing capacity of water. The alkalinity derives from the rock and soil through which the water has flowed. Limestone rock typically makes waters that are more alkaline while flowing through granite makes them have less alkalinity. Alkalinity is important for aquatic life in that it can buffer them against pH changes.

Summer 2015 Overview Graphs

Total Phosphorus

Phosphorus concentrations remained steady during the 2015 season for Sand Pond and Norway Lake, as did Hobbs Pond with one high exception (Figure 4). North Pond showed a steady increase in phosphorus levels. This trend could have implications for Norway Lake which is partially fed by a stream flowing ou of North Pond.

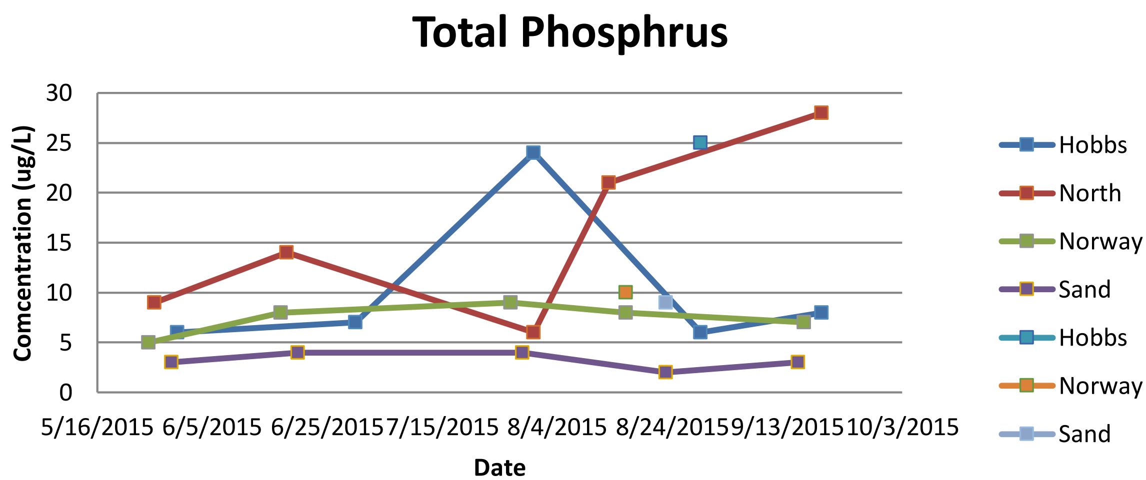


Figure 4. Total Phosphorus concentrations during 2015 Season. Single points indicate deep layer concentrations.

Secchi Depth

Water clarity as measured by Secchi depth increased during the season at all four lakes (Figure 5). This is most likely due to a spring bloom of algae, which then use up the nutrients in the surface layer of the lakes causing a decline in algae over the season.

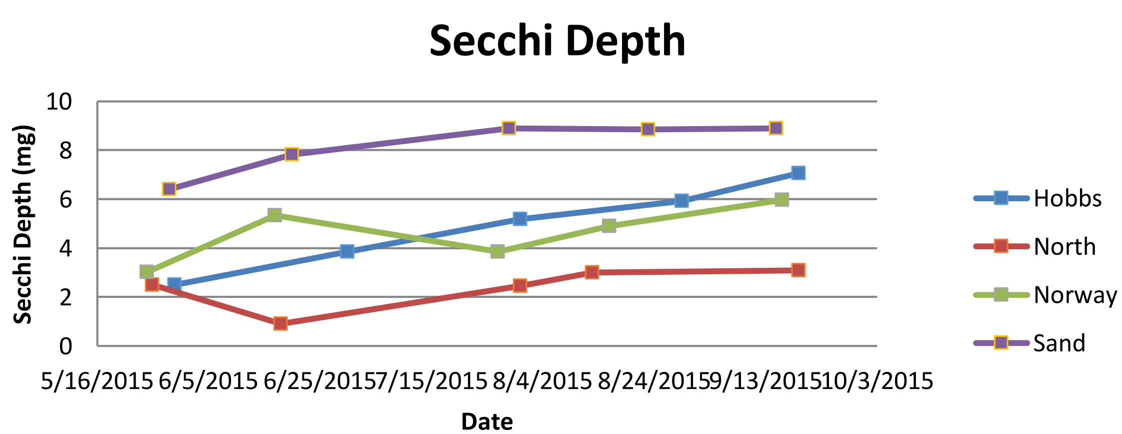


Figure 5. Secchi depth measurements during the 2015 season.

Dissolved Oxygen

Dissolved oxygen declined in the surface water of all four lakes by about 1 milligram per liter. This decline is mostly due to the temperature increase, which decreases the amount of oxygen soluble in water. The bottom layer oxygen content declined drastically in three of the lakes due to the decomposition of decaying organisms in the deep layer, mostly they algae bloom from the spring. The one exception to this is North Pond which is too shallow to stratify permanently, allowing atmospheric oxygen to be mixed into the water column throughout the summer.

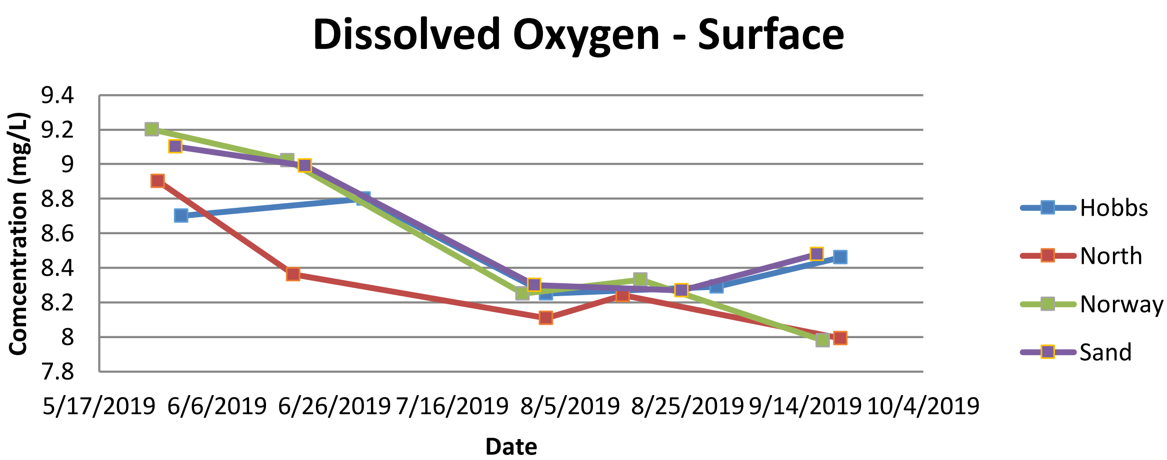


Figure 6. Surface dissolved oxygen measurements during the 2015 season.

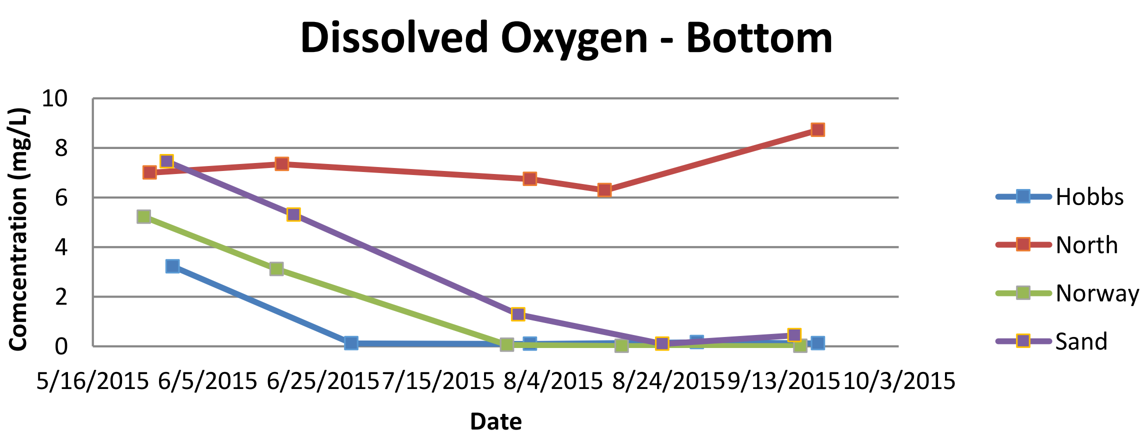


Figure 7. Bottom layer dissolved oxygen measurements during the 2015 season.

Temperature

Surface temperatures in all four lakes rose and peaked at around 25 degrees C (77°F), ten cooled down somewhat for the remainder of the summer. Bottom water temperatures remained between 5-10 °C (41-50 °F) with the exception of North Pond, which was well mixed, and so bottome and surface temperatures were very close.

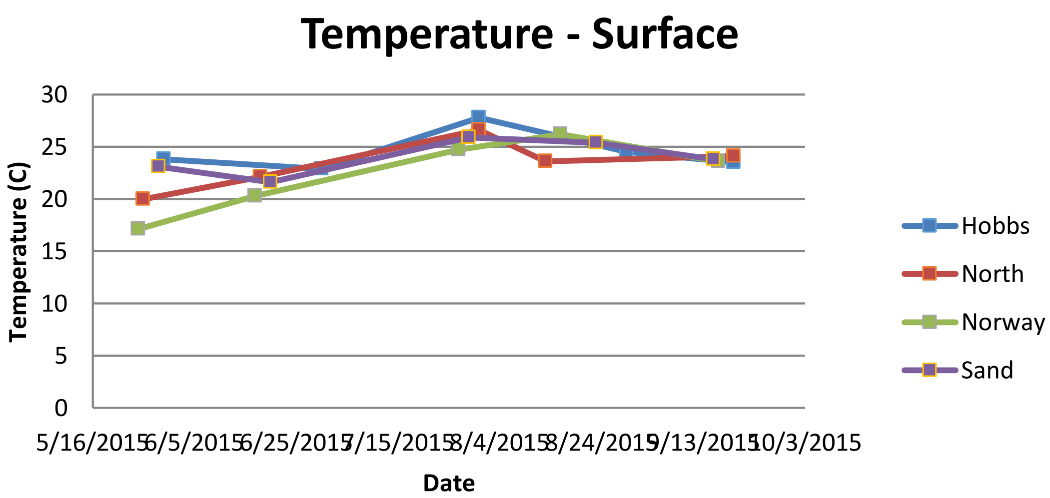


Figure 8. Surface temperature during 2015 season.

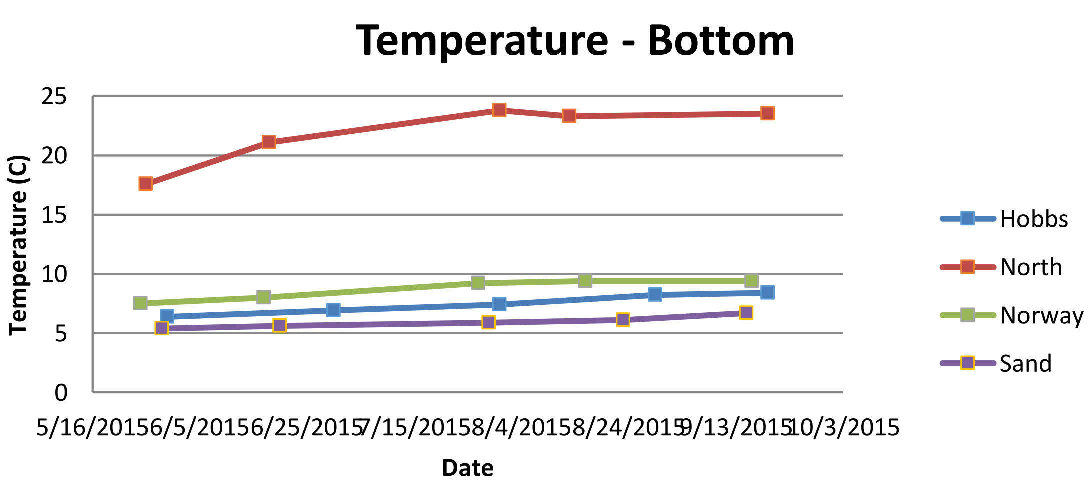


Figure9. Bottom layer temperature during the 2015 season.

Chlorophyll

Chlorophyll is a compound found in all plants and algae that performs photosynthesis, the conversion of sunlight and carbon dioxide into organic matter. Therefore, it is often used as a measure of the biomass of algae in lakes and oceans. Chlorophyll concentrations in the four remained relatively constant over the season with two exceptions. There was an initial very high value in Norway Lake and an increase in the concentrations in North Pond towards the end of the summer.

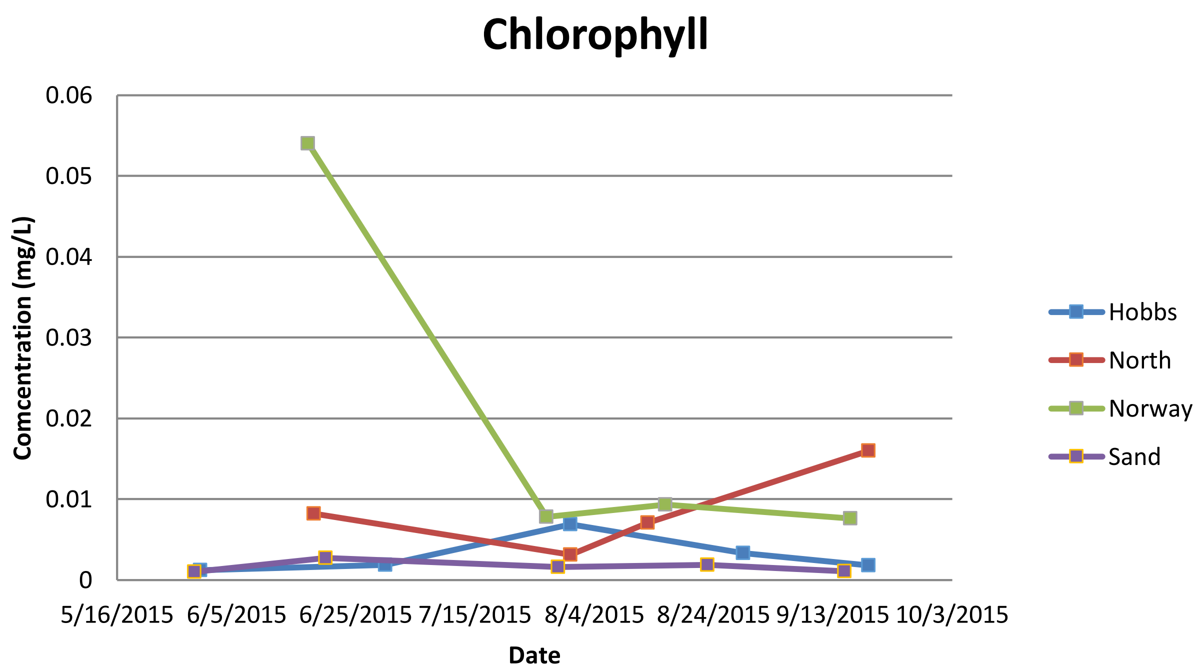


Figure 10. Chlorophyll during the 2015 season.

Individual Lake Analyses

Pennesseewassee Lake:

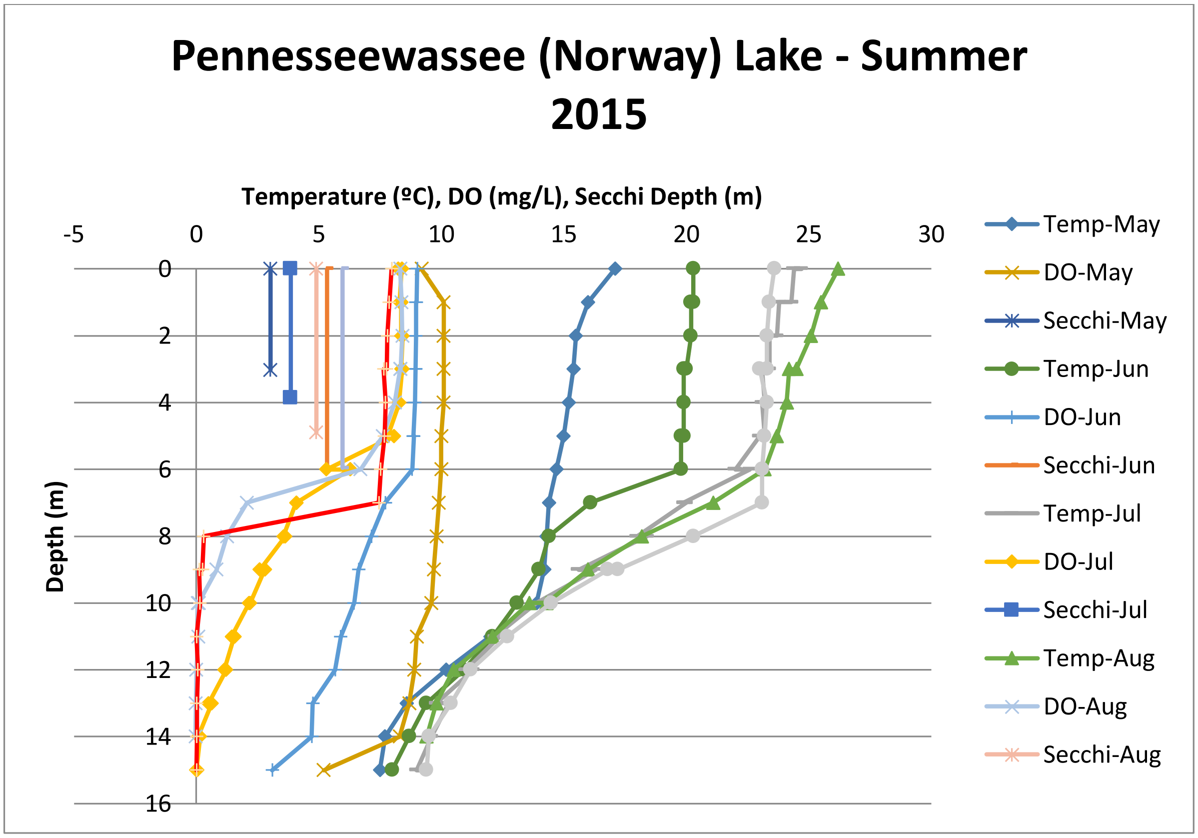


Figure 11. Norway Lake temperature, dissolved oxygen, and Secchi depth during 2015.

Water Clarity: The water in Lake Pennesseewassee was less clear in 2015, average 4.6 meters (15 feet), when compared to the historical 40+ year average for the lake of 5.8 meters (~19 feet). This is not a good indication of how the lake should be headed. The decrease in clarity means particles in the water are more abundant than previously. Such particles may be plankton, sediment, or other substances that can absorb light. Clarity did increase through the summer period from 3 to 6 meters (9.8 – 19.7 feet), most likely due to the decline of algae as the surface water layer becomes depleted of nutrients. The historical data indicates that Lake Pennesseewassee is holding steady or maybe improving slightly as shown by the trend line in the data shown in Figure 12.

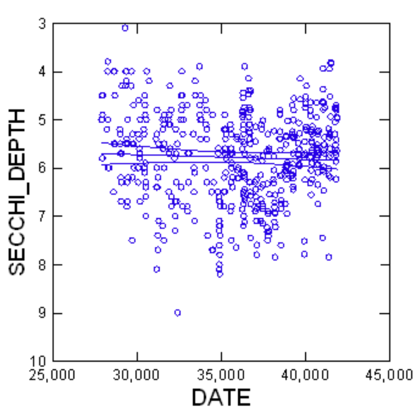


Figure 12. Secchi depths and trend line with 95% confidence interval for Lake Pennesseewassee over 40+ years.

Phosphorus: The 5 month average concentration of phosphorus was less than the historical average (7.4 parts per billion (ppb) vs. the average of 9 ppb). Reduced phosphorus is a positive result, since it is the nutrient responsible for the growth of algae in lakes. The long-term trend (40+ years) of phosphorus in the surface layer of the lake (epilimnion) is shown in the Figure 13. The figures show DATE as a number between 25,000 and 45,000. This is an artifact of changing date format between the spreadsheet (Excel) and the statistical software (SYSTAT). The dates of the samples fall between 1974 and the present. The red line in the figure is the statistical trend of the data. The dark blue lines are the upper and lower 95% Confidence intervals. The light blue lines are the upper and lower Prediction Intervals. While it may appear that the red line is on a downward slope, it is not significantly different from a flat line according to statistical methods (Analysis of Variance p=0.408) likely due to the amount of scatter in the data.

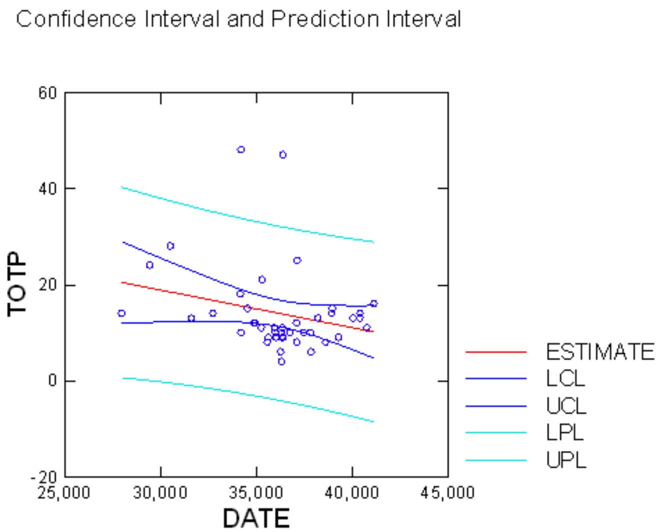


Figure 13. Total P results for LAKE = Pennesseewassee Lake LAYER = SURFACE

Similar results for the long term data are found in the lower layer of the lake (hypolimnion) as shown in Figure 14. There is an apparent downward trend of the long-term data, but it is not statistically different from a flat line.

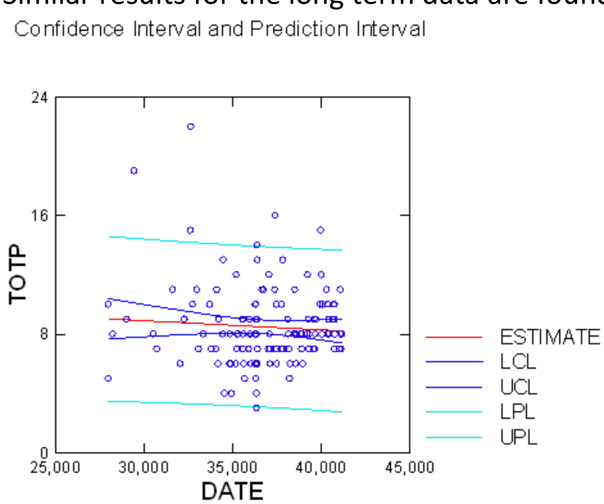


Figure 14. Total P results for LAKE = Pennesseewassee Lake LAYER = BOTTOM

Chlorophyll: Algae as measured by Chlorophyll concentrations was high with an average of 15.45 micrograms per liter (µg/L). This was due to one measurement (possibly erroneous, or possibly during the "spring phytoplankton bloom") in June of 54 µg/L. Ignoring that one value reduces the average to 2.61 µg/L, which lower than the long-term average of 4.3 (1976-2012). Figure 15 shows all of the data collected by LAON. It shows that chlorophyll levels have been fairly steady during the period of observation, with a possibly a slight decline.

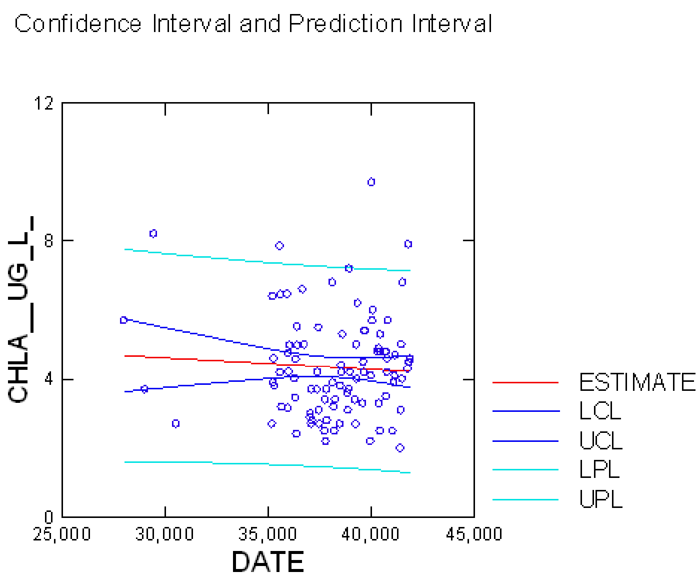


Figure 15. Chlorophyll concentrations for the 40+ years of observations on Lake Pennesseewassee.

Dissolved Oxygen: The dissolved oxygen is reported here as milligrams per liter (mg/L). In May the lake was well oxygenated (Figure 11). However, as stratification became stronger in June through September mixing of the surface and deep water is prevented, as is diffusion across the thermocline (see the section on Background Lake Ecology). This caused a rapid decline of DO levels in the lower layer, which ultimately resulted in the bottom water becoming almost completely anoxic (without oxygen). This means that the bottom waters become uninhabitable by fish and other organisms. This phenomenon, while not good, has been occurring in the lake for many decades. The graph below (Figure 16) shows all of the DO data collected by LAON over the past 40+ years plotted as dissolved oxygen vs. depth. The line is LOWESS smoothing function showing the trend of the data. One can readily see that below 5 meters (~16.4 feet) oxygen levels have a tendency to decline. While this may give the impression that everything is normal, there are two other ways to look at the data that raise some concern. The first is a contour plot of all the data over time (Figure 17) which clearly shows oxygen depleted water becoming more common in recent years (more blues than yellows). This is also shown by the average DO levels of the entire water column on each sampling date during the same 40+ year time period (Figure 18). This again shows a decline in average DO levels over time.

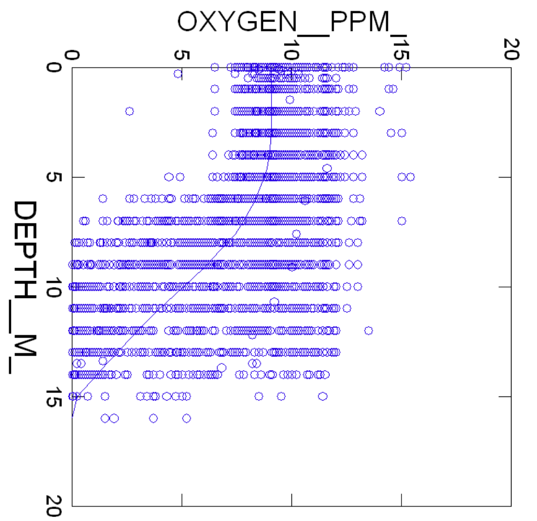


Figure 16. Dissolved oxygen versus depth in Pennesseewassee Lake for all data collected over the past 40+ years.

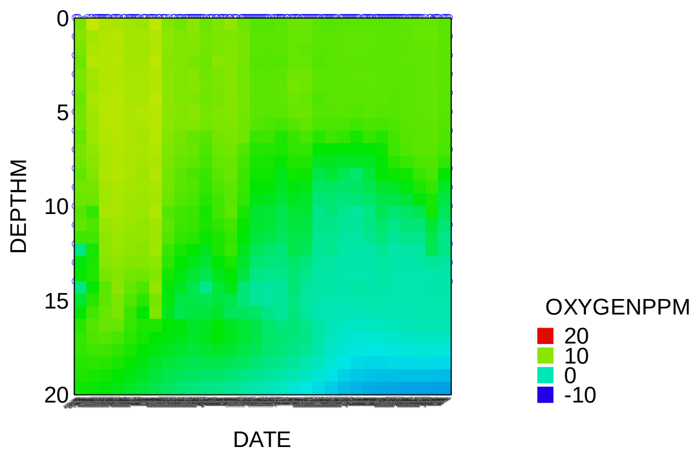


Figure 17. Contour plot of DO in Norway Lake during summer, over the 40+ year time span.

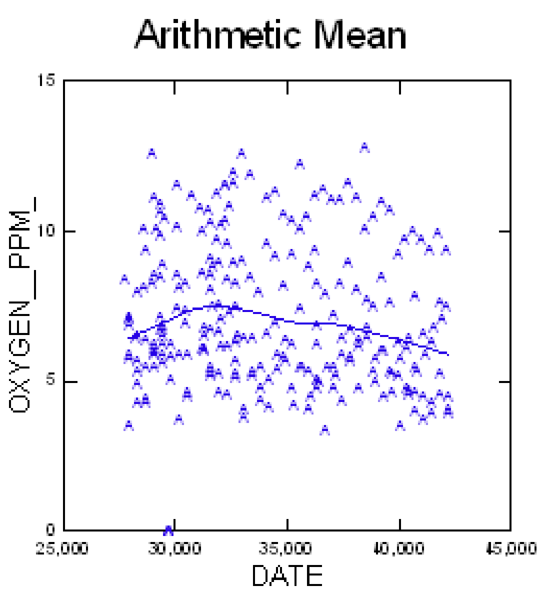


Figure 18. Average DO concentrations in Norway Lake on each sampling date, over the 40+ year time span.

pH: pH in Norway Lake shows an apparent increase and then leveling off over the past 40 years. These values fall within the norm for most lake ecosystems.

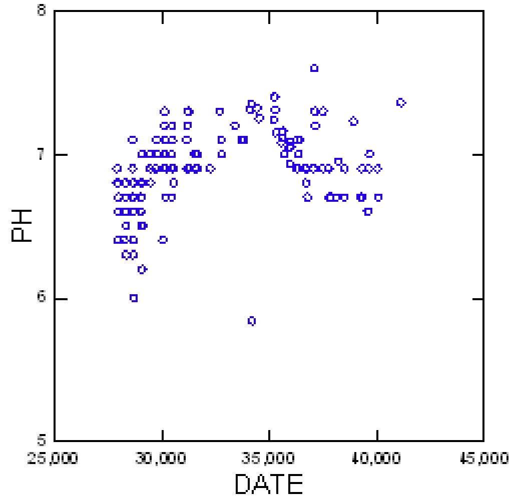


Figure 19. pH over the 40+ years of data collection in Norway Lake.

Alkalinity: Alkalinity is not very high in the Norway Lakes, and has a fair amount of variability. The three initial high values skew the trendline in Figure 20, so the trend is probably flat.

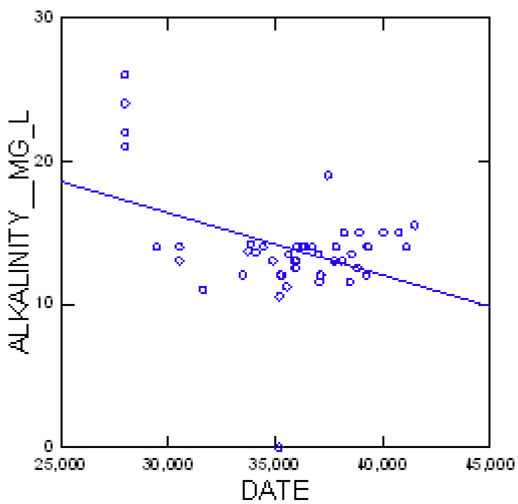


Figure 20. Alkalinity in Norway Lake over the 40+ years of data collection.

Conductivity: The conductivity in the Norway lakes appears to be rising (Figure 21), but there are too few data points to make an accurate assessment.

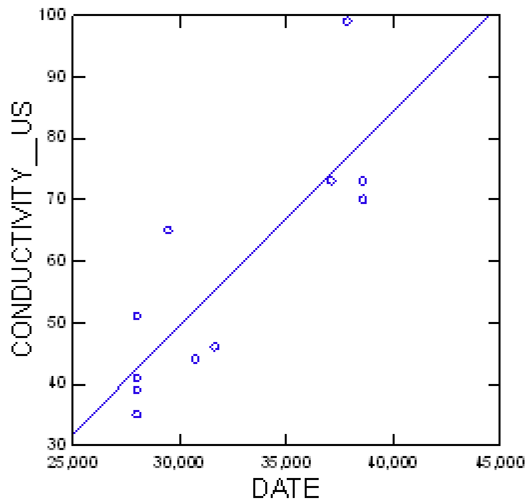


Figure 21. Conductivity in Norway Lake over the past 40+ years of data collection.

Color: Color in Norway Lake was remained in the range of 5-30 Standard Platinum Color Units (SPU) over the past 40 years. There is a hint of decline in the trend shown in Figure 22, but it is not significant.

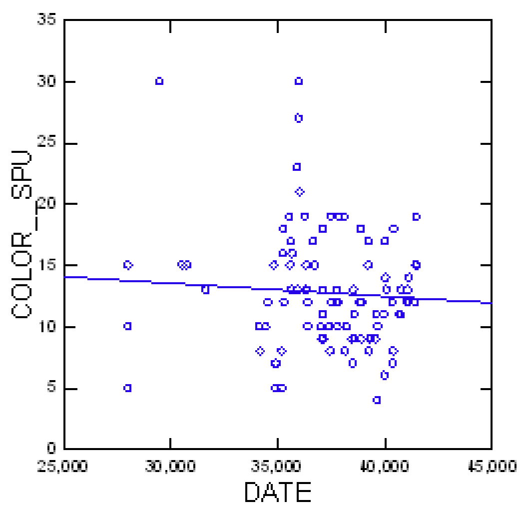


Figure 22. Color, in Standard Platinum Units, for Norway Lake over the past 40+ years of data collection.

Invasive Aquatic Species: The Invasive Aquatic Plant Screening Surveys conducted for LAON by Lake & Watershed Resource Management Associates found no invasive aquatic plants in any of the four Norway lakes during the 2015 screening. They did find yellow iris (*Iris pseudocorus*) in Pennesseewassee at three locations. This plant is considered invasive in other parts of the country. The threat to Maine lakes remains undetermined, but we should view this arrival with suspicion. Over the past years, the Chinese Mystery Snail has been found in all four of our lakes.

Hobbs Pond (Little Penn):

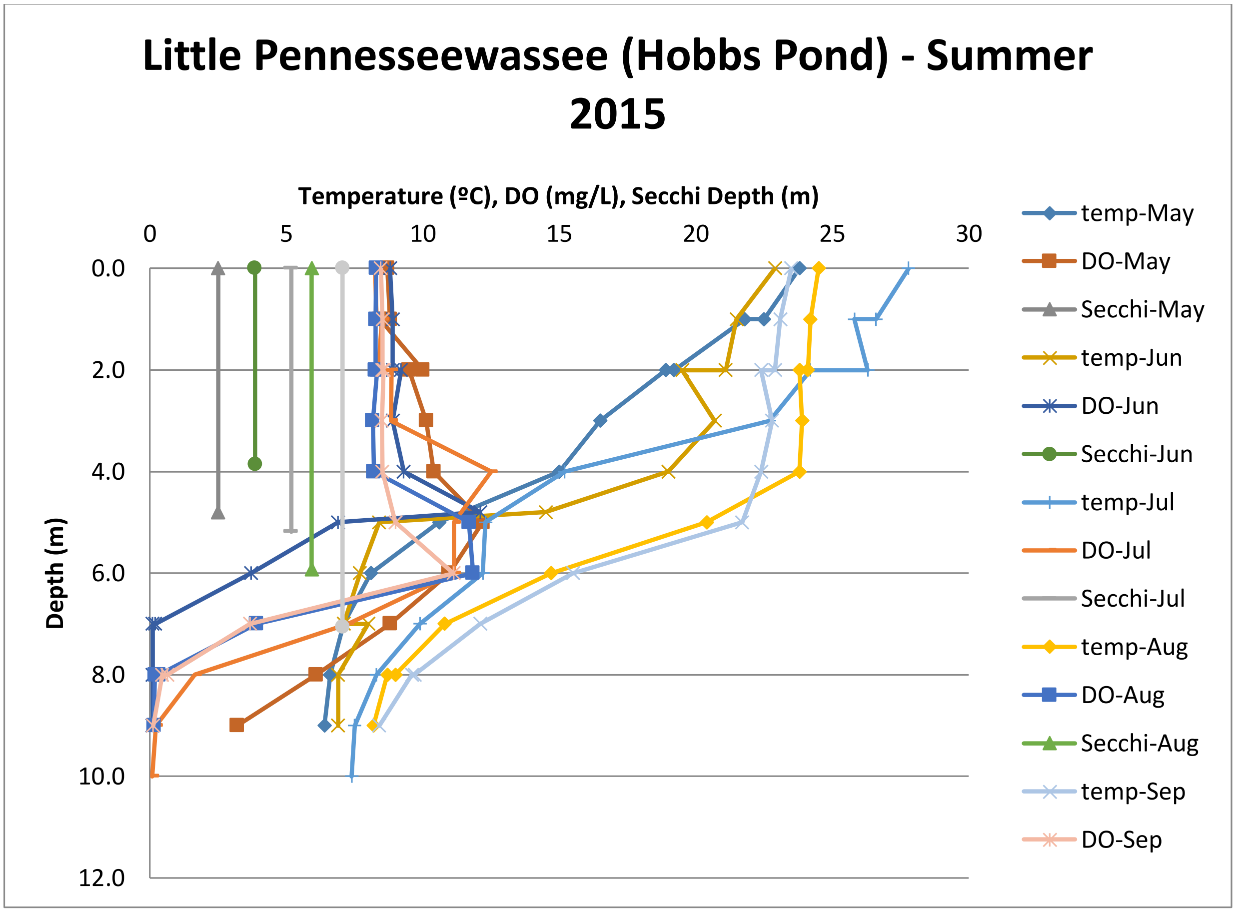


Figure 23. Hobbs Pond temperature, dissolved oxygen, and Secchi depth during 2015

Water Clarity: Hobbs Pond water clarity in 2015 averaged 4.9 meters (~16 feet), compared to the 5.2 meter historical average for the pond. The clarity improved, as was true for all the lakes, throughout the summer from 2.5 to 7.06 meters (8.2 - 23.2 feet) as shown in Figure 23. Over the 40+ years of measurements on Hobbs Pond, the Secchi readings have improved steadily as shown in Figure 24 from a little over 4 meters to almost 6 meters. The fact that water clarity is improving is a positive sign for the lake.

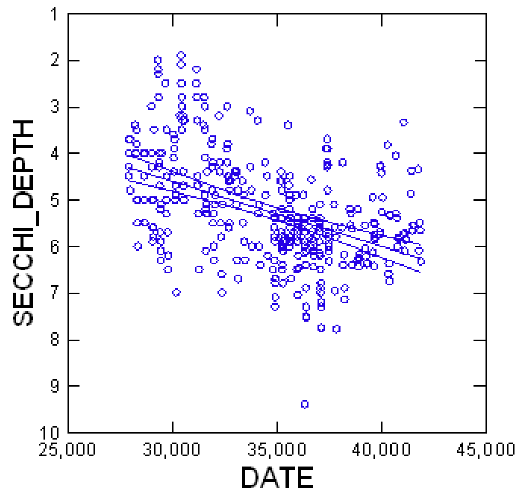


Figure 24. Secchi depth and trend line with 95% confidence interval for Hobbs Pond over 40+ years of sampling.

Phosphorus: Phosphorus levels were 10.2 ppb, compared to the historical average of ~10 ppb. This mainly due to one measurement of 24 ppb in July. Without that value the average Total Phosphorus concentration would be 6.75 ppb. The long-term trend (40+ years) of phosphorus in the surface layer of the lake (epilimnion) is shown in Figure 25. The figures show DATE as a number between 25,000 and 45,000. This is an artifact of changing date format between the spreadsheet (Excel) and the statistical software (SYSTAT). The dates of the samples fall between 1974 and the present. The red line in the figure is the statistical trend of the data. The dark blue lines are the upper and lower 95% Confidence intervals. The light blue lines are the upper and lower Prediction Intervals. While it may appear that the red line is on a downward slope, it is not significantly different from a flat line according to statistical methods (Analysis of Variance p=0.180) due to the amount of variability in the data.

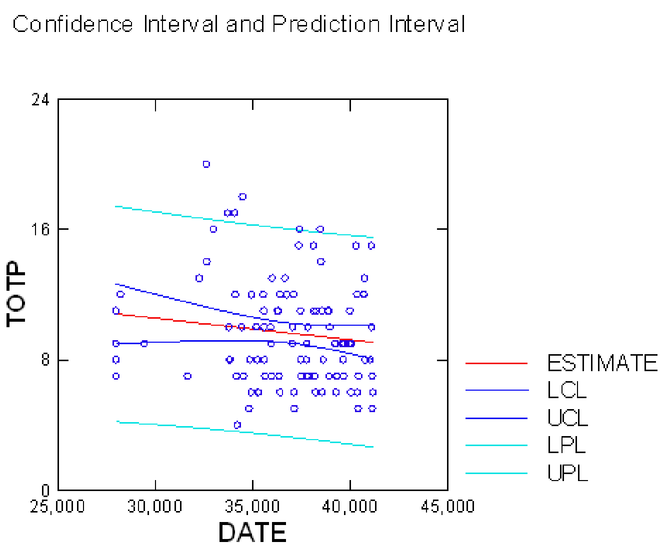


Figure 25. Total P results for LAKE = Little Pennesseewassee LAYER = SURFACE

Long-term data for the lower layer (Figure 26) again showed a downward trend that was not significantly different from a flat line.

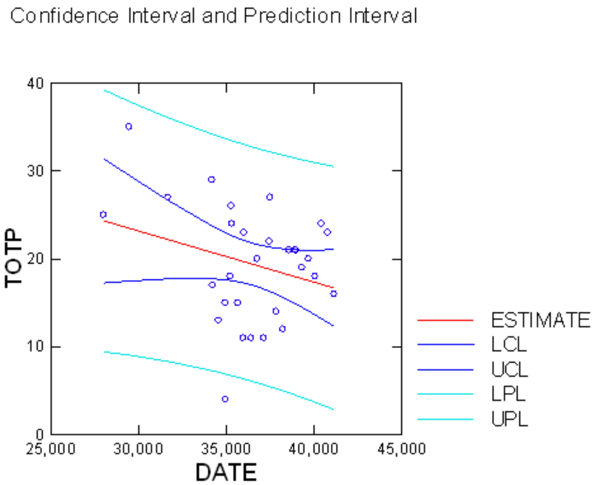


Figure 26. Total P results for LAKE = Little Pennesseewassee LAYER = BOTTOM

Chlorophyll: Algae as measured by Chlorophyll concentrations was low with an average of 2.0 µg/L. The long term average is ~4.29 µg/L, so this year was a good year. This would also be consistent with a lower Total Phosphorus level. Figure 27 shows all of the data collected by LAON. It shows that chlorophyll levels have been increasing during the period of observation, which is not a good indicator.

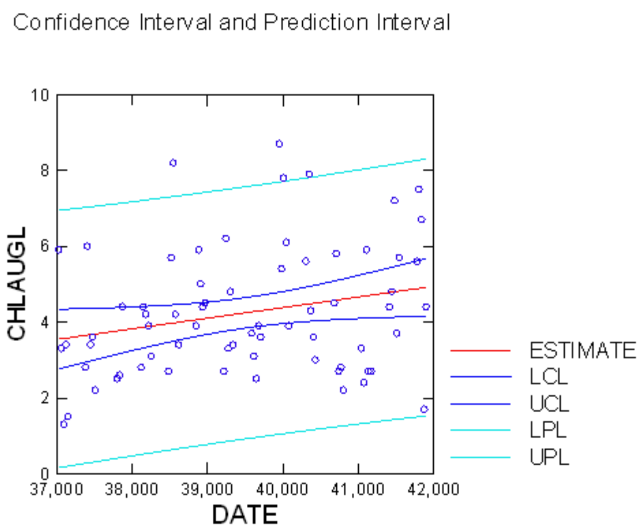


Figure 27. Chlorophyll concentrations for the 40+ years of observations on Little Pennesseewassee Lake (Hobbs Pond).

Dissolved Oxygen: The dissolved oxygen is reported here as milligrams per liter (mg/L). In May the lake was well oxygenated at the surface, but was already showing a decline in DO near the bottom (Figure 23). As stratification became stronger in June through September mixing of the surface and deep water is prevented, as is diffusion across the thermocline (see the section on Background Lake Ecology). This caused a rapid decline of DO levels in the lower layer, which ultimately resulted in the near-bottom water becoming almost completely anoxic (without oxygen). This means that the bottom waters become uninhabitable by fish and other oxygen-requiring organisms. However, there is a noticeable increase in the DO levels just below the thermocline, which helps to introduce some oxygen to the deep layer. This increase is caused by photosynthetic algae and/or cyanobacteria that thrive just below the thermocline. The surface layer by this time has become depleted of nutrients, but there is an abundance of nutrients below the thermocline. Light penetration is sufficient to reach this depth, allowing these photosynthetic organisms to grow. This general scenario has been occurring in the lake for many years. The graph below (Figure 28) shows all of the DO data collected by LAON over the past 40+ years. The line is LOWESS smoothing function showing the trend of the data. One can readily see that below 5 meters (~16.4 feet) oxygen levels have a tendency to decline, but there is a slight increase just before that happens. While this may give the impression that everything is normal, there are two other ways to look at the data that raise some concern. The first is a contour plot of all the data over time (Figure 29) which clearly shows oxygen depleted water becoming more common in recent years (more blues than greens). This is also shown by the average DO levels of the water column from top to bottom, on each sampling date during the same 40+ year time period (Figure 30). These data, like those for Sand Pond, show an initial rise followed by a decline in average DO levels over time.

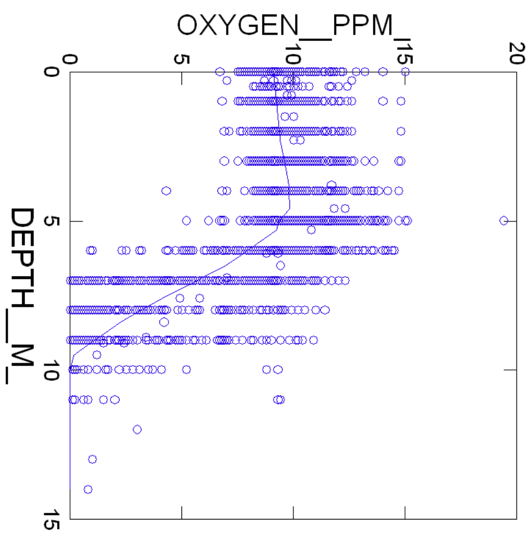


Figure 28. Dissolved oxygen versus depth in Little Pennesseewassee Lake (Hobbs Pond) for all data collected over the past 40+ years.

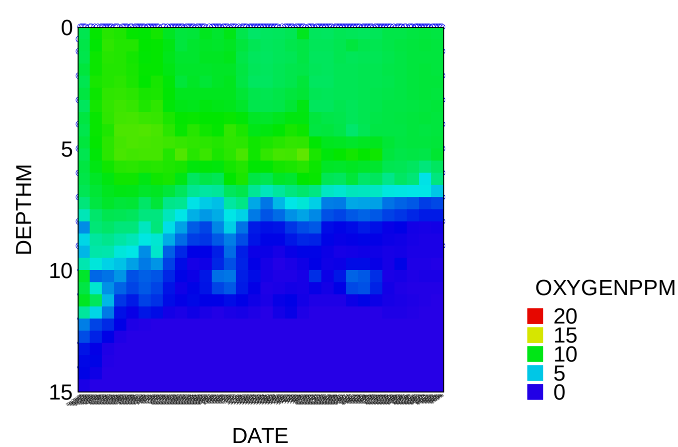


Figure 29. Contour plot of DO in Hobbs Pond during the summer, over the 40+ year time span.

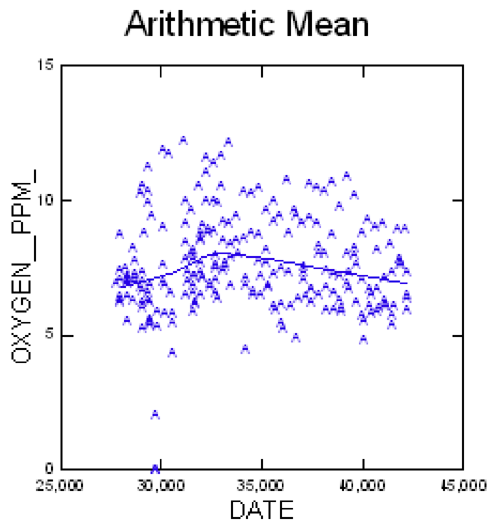


Figure 30. Average DO concentrations in Hobbs Pond on each sampling date, over the 40+ year time span.

pH: pH in Hobbs Pond shows an apparent increase and then leveling off over the past 40 years (Figure 31). These values fall within the norm for most lake ecosystems. In the earlier years of data collection, different methods were used which might account for some of the lower values.

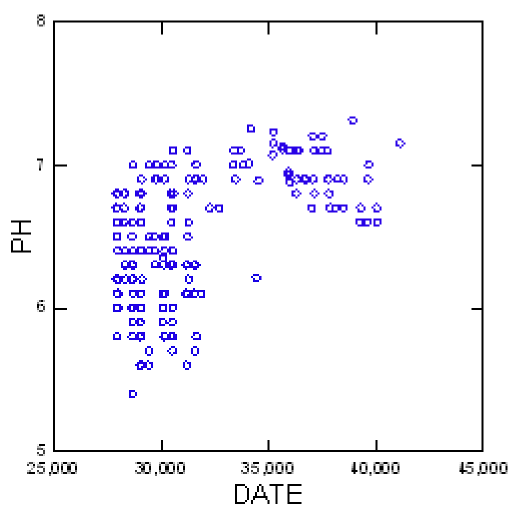


Figure 31. pH over the 40+ years of data collection in Hobbs Pond.

Alkalinity: Alkalinity is not very high in the Norway Lakes, and has a fair amount of variability. The two high values skew the trendline in Figure 32, and this may not be an accurate reflection of the trend.

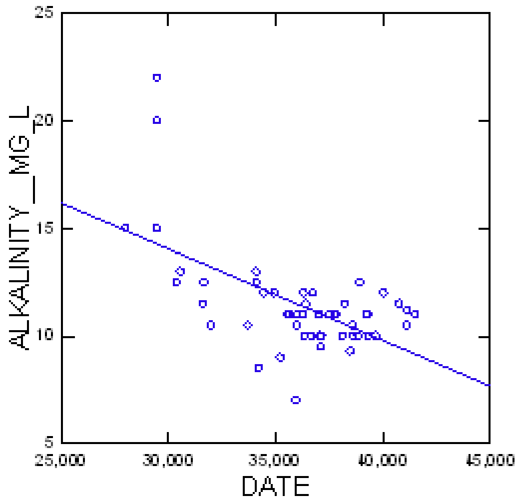


Figure 32. Alkalinity in Hobbs Pond over the 40+ years of data collection.

Conductivity: The conductivity in the Norway lakes appears to be rising (Figure 33), but there are too few data points to make an accurate assessment.

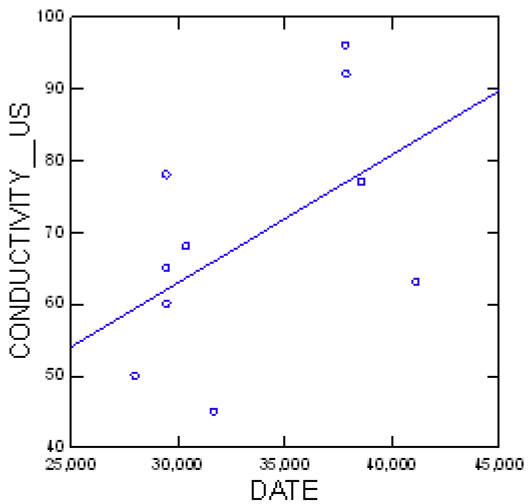


Figure 33. Conductivity in Hobbs Pond over the past 40+ years of data collection.

Color: Color in Hobbs Pond was remained mostly in the range of 5-30 Standard Platinum Color Units (SPU) with one exception of near 60 over the past 40 years (Figure 34). The trend shown in Figure 34 is not significant.

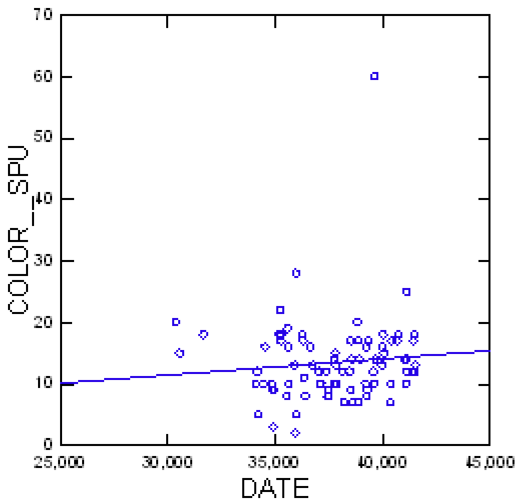


Figure 34. Color, in Standard Platinum Units, for Hobbs Pond over the past 40+ years of data collection.

Invasive Aquatic Species: The Invasive Aquatic Plant Screening Surveys conducted for LAON by Lake & Watershed Resource Management Associates found no invasive aquatic plants in any of the four Norway lakes during the 2015 screening. Over the past years, the Chinese Mystery Snail has been found in all four of our lakes.

Sand Pond:

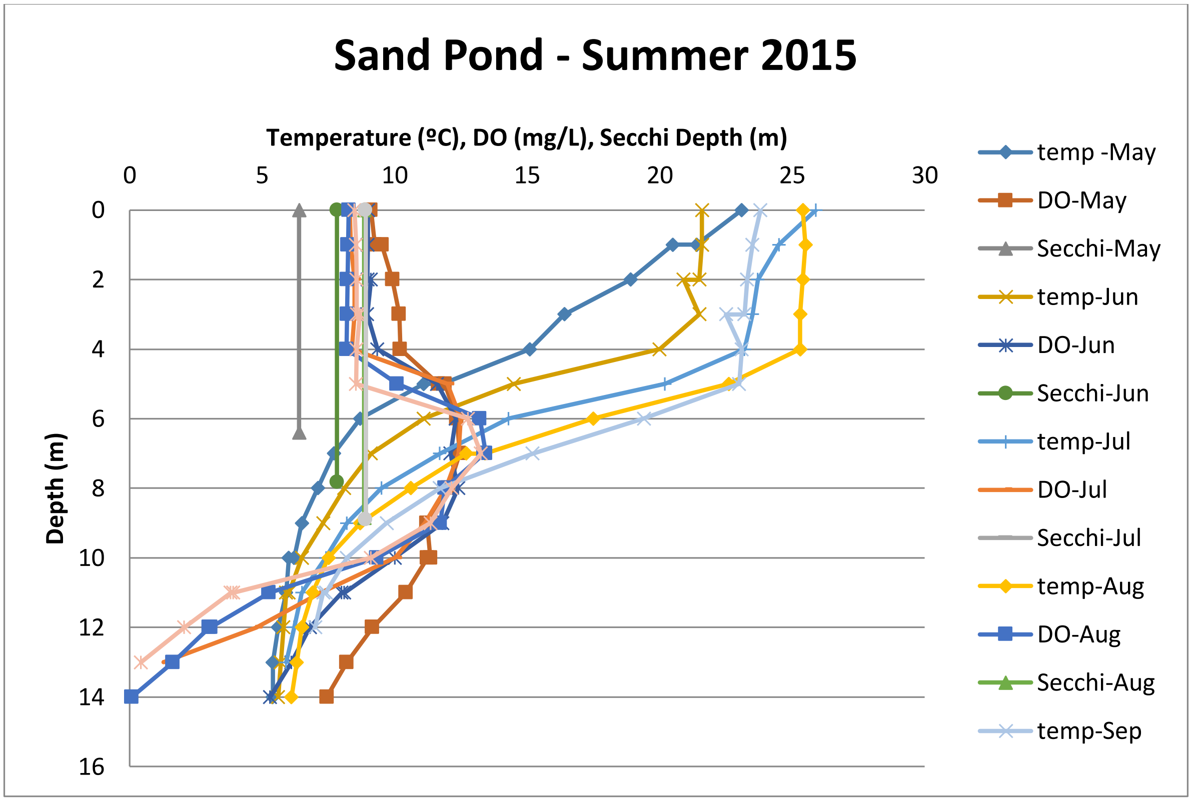


Figure 35. Sand Pond temperature, dissolved oxygen, and Secchi depth during 2015

Water Clarity: Sand Pond experienced another good year in 2015. Water clarity averaged over 8.1 meters (26.8 feet), compared to the historical average of 7.4 meters. As in the other lakes, the clarity increased over the summer from 6.4 m to a maximum of 8.9 m (Figure 35). The historical data shows that Sand Pond has improved water clarity over the observational time period (Figure 36).

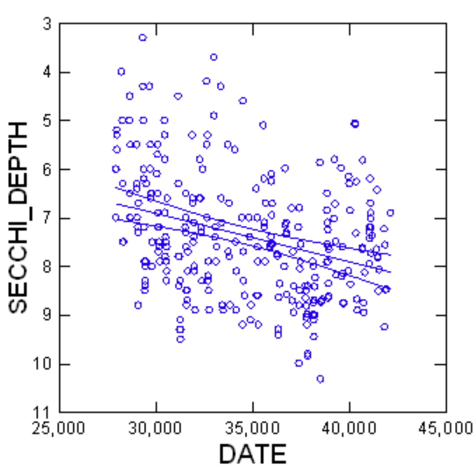


Figure 36. Secchi depth and trendline with 95% confidence interval for Sand Pond over the past 40+ years.

Phosphorus: The average total Phosphorous concentrations was lower than the other Norway lakes at 3.2 ppb. The historical average of Total Phosphorus in the surface layer is 5.97 ppb.

Again, this is a very good sign for the lake. Sand Pond is not hydrologically connected to the other three Norway lakes, which *are* connected via tributary streams. The long-term trend (40+ years) of phosphorus in the surface layer of the lake (epilimnion) is shown in Figure 37. The figures show DATE as a number between 25,000 and 45,000. This is an artifact of changing date format between the spreadsheet (Excel) and the statistical software (SYSTAT). The dates of the samples fall between 1974 and the present. The red line in the figure is the statistical trend of the data. The dark blue lines are the upper and lower 95% Confidence intervals. The light blue lines are the upper and lower Prediction Intervals. In Sand Pond, the red trend line is fairly flat, and this is borne out by statistical methods (Analysis of Variance p=0.305).

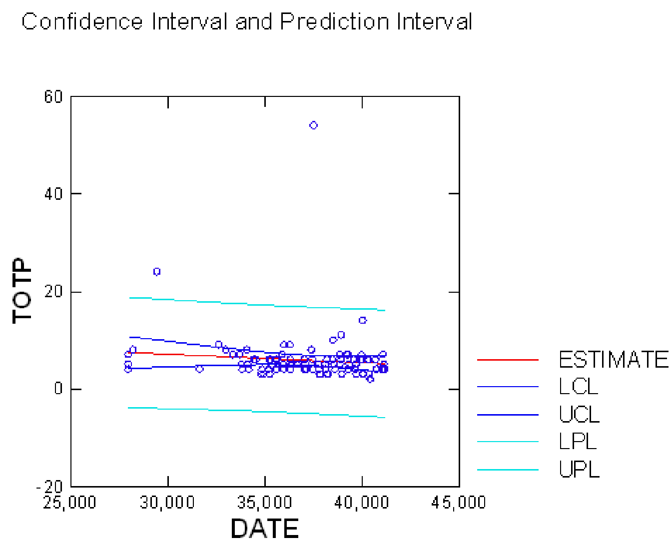


Figure 37. Total P results for LAKE = Sand Pond LAYER = SURFACE

The long-term trend in the bottom waters of Sand Pond (Figure 38) however shows an increase in phosphorus concentration, which is statistically different from a flat line (Analysis of Variance p=0.043). However, we should not read too much into this because there is some scatter in the data and in the early years there were not many samples taken at depth in the lake.

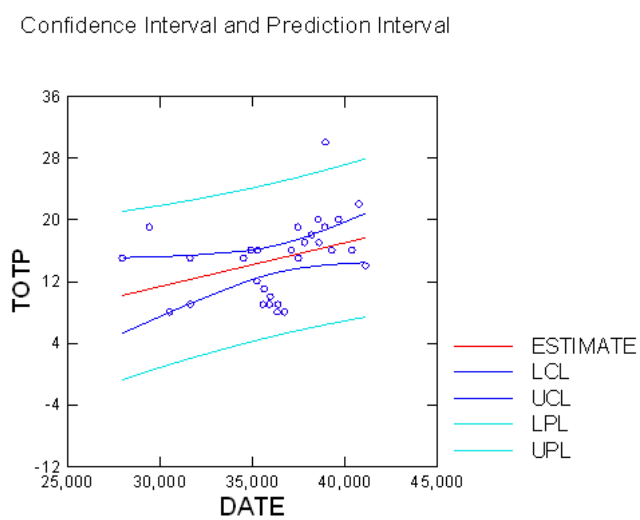


Figure 38. Total P results for LAKE = Sand Pond LAYER = BOTTOM

Chlorophyll: Algae as measured by Chlorophyll concentrations was low with an average of 1 µg/L. The long term average is ~2.5 µg/L, so this is also consistent with the lower Total P values. Figure 39 shows all of the data collected by LAON. It shows that chlorophyll levels have slight increased during the period of observation, which is a possible warning sign.

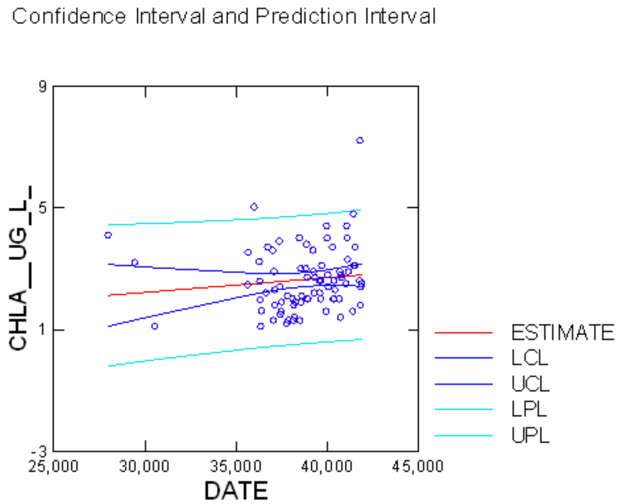


Figure 39. Chlorophyll concentrations for the 40+ years of observations on Sand Pond.

Dissolved Oxygen: The dissolved oxygen is reported here as milligrams per liter (mg/L). In May the lake was well oxygenated with a noticeable increase at about 6 meters (~19.7 feet). There was only a slight decline in DO near the bottom (Figure 35). Stratification became stronger in June through September, with a thermocline becoming established below 4 meters (~13 feet), preventing mixing of the surface and deep water, as well as diffusion across the thermocline (see the section on Background Lake Ecology). This caused a decline of DO levels especially near the bottom, but a bump in the DO levels persisted throughout the season just below the thermocline. This bump helps to introduce some oxygen to the deep layer, and is caused by photosynthetic algae and/or cyanobacteria that thrive just below the thermocline. The surface layer by this time has become depleted of nutrients, but there is an abundance of nutrients below the thermocline. Light penetration is sufficient to reach this depth, allowing these photosynthetic organisms to grow. This means that the bottom waters become uninhabitable by fish and other organisms only in the deepest part of the lake (the bottom 3 meters). This general scenario has been occurring in the lake for many years. The graph below (Figure 40) shows all of the DO data collected by LAON over the past 40+ years. The line is a LOWESS smoothing function showing the trend of the data. One can readily see the bump in DO at about 7 meters (~23 feet), and that below that, oxygen levels decline. While this may give the impression that everything is normal, there are two other ways to look at the data that do raise some concern. The first is a contour plot of all the data over time (Figure 41) which clearly shows oxygen depleted water becoming more common in recent years (more blue than green). This is also shown by the average DO level in the lake, on each sampling date during the same 40+ year time period (Figure 42). After an initial rise,this again shows a decline in average DO levels over time.

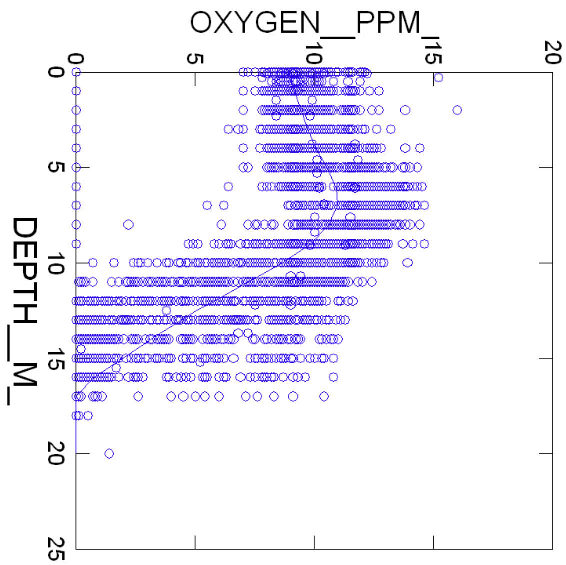


Figure 40. Dissolved oxygen versus depth in Sand Pond for all data collected over the past 40+ years.

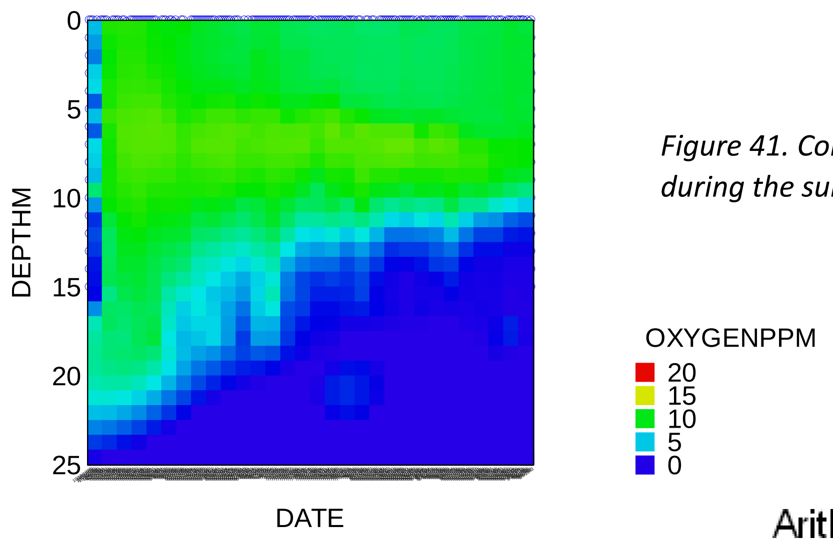


Figure 41. Contour plot of DO in Sand Pond during the summers, over the 40+ year time span.

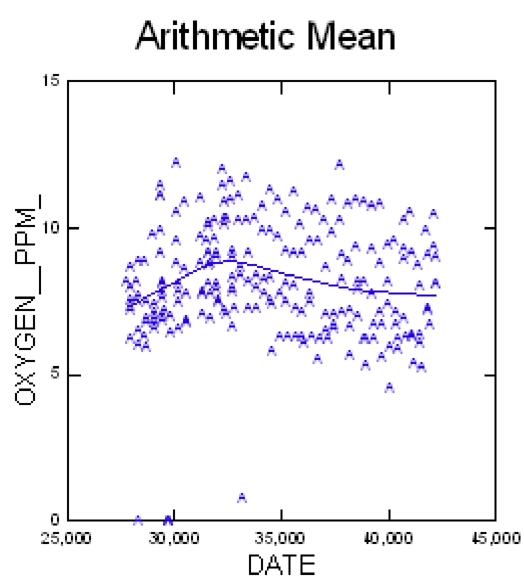


Figure 42. Average DO concentrations in Sand Pond on each sampling date, over the 40+ year time span.

pH: pH in Sand Pond shows an apparent increase and then leveling off over the past 40 years. These values fall within the norm for most lake ecosystems.

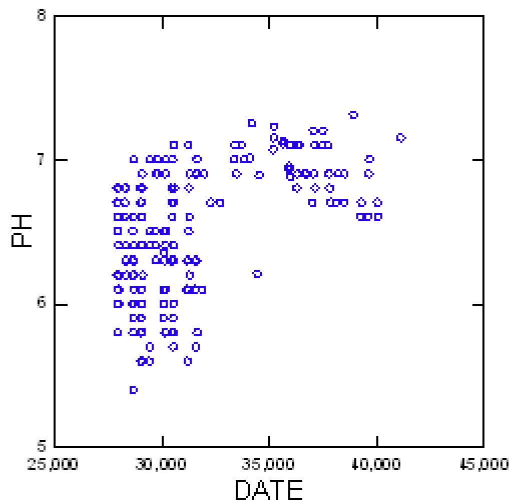


Figure 43. pH over the 40+ years of data collection in Sand Pond.

Alkalinity: Alkalinity is not very high in the Norway Lakes, and has a fair amount of variability. There is a apparently decreasing trend in the data but the scatter in the data is largely responsible for this (Figure 44).

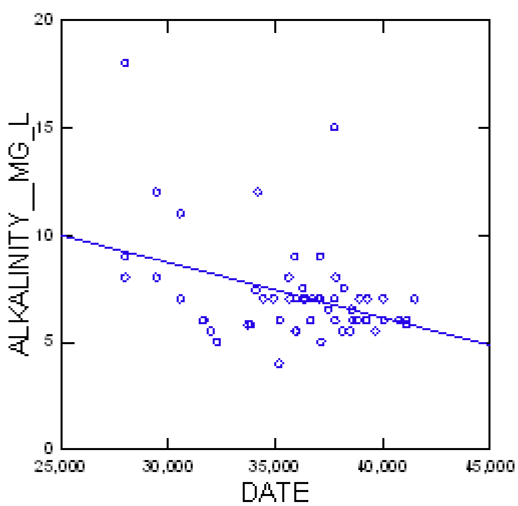


Figure 44. Alkalinity in Sand Pond over the 40+ years of data collection.

Conductivity: The conductivity in the Norway lakes appears to be rising (Figure 45), but there are too few data points to make an accurate assessment.

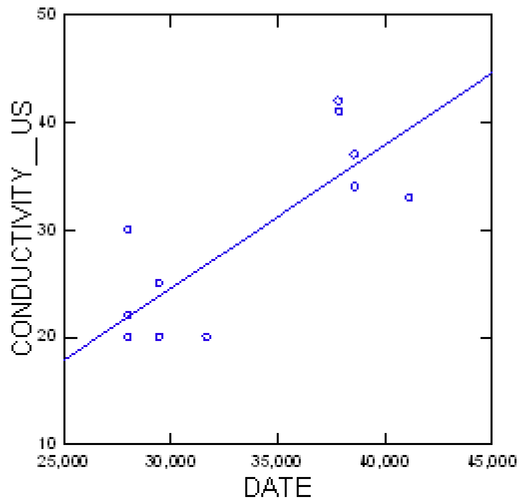


Figure 45. Conductivity in Sand Pond over the past 40+ years of data collection.

Color: Color in Sand Pond has remained in the range of 2-30 Standard Platinum Color Units (SPU) over the past 40 years (Figure 46). There is an apparent decline in the trend shown, but this is highly influenced by the first three measurements, and is not reliable.

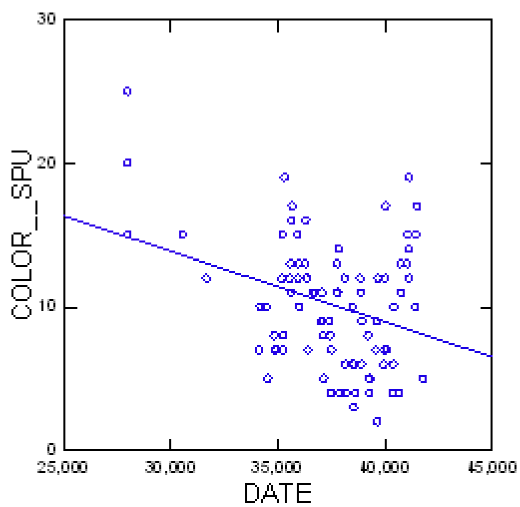


Figure 46. Color, in Standard Platinum Units, for Sand Pond over the past 40+ years of data collection.

Invasive Aquatic Species: The Invasive Aquatic Plant Screening Surveys conducted for LAON by Lake & Watershed Resource Management Associates found no invasive aquatic plants in any of the four Norway lakes during the 2015 screening. Over the past years, the Chinese Mystery Snail has been found in all four of our lakes. Although, none were observed in Sand Pond since 2008. The ecological significance of this invader has not been determined.

North Pond:

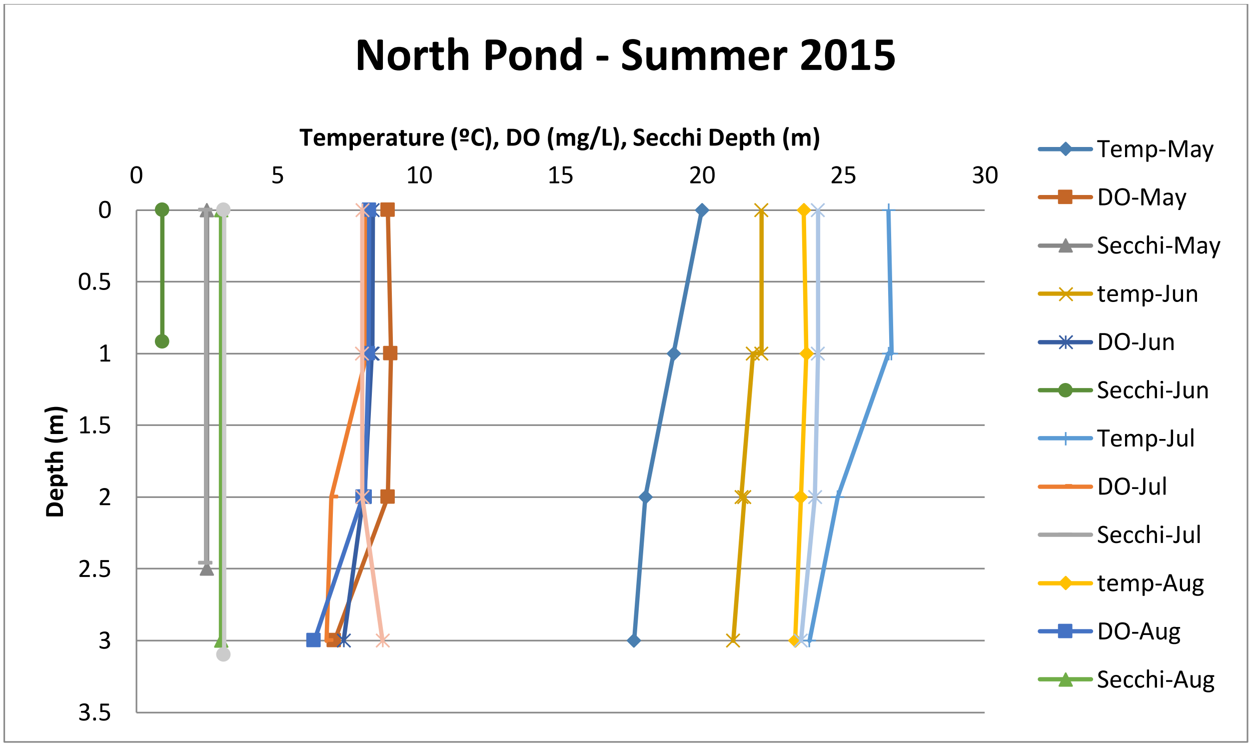


Figure 47. North Pond temperature, dissolved oxygen, and Secchi depth during 2015

Water Clarity: North Pond is relatively shallow, having a maximum depth of less than 15 feet. Water clarity measurements are limited because the Secchi disk usually reaches the bottom prior to disappearing from view. One exception this past year probably occurred because wind had stirred up particles (Figure 47). Prior to the late 1980's, visibility nearly always extended to the bottom. In the 80's, the pond experienced algae blooms, and visibility was often limited to 12 -13 feet. In 2015 the clarity was only 2.4 m while the historical average is 2.8 m. The low average of 2.4 m was influenced by one reading of very low measurement of 0.9 m in June. The Secchi disk measurements over the past 40+ years are shown in Figure 48. This shows that transparency of the water almost always reached the bottom of the lake (about 3 meters). The trendline shows an increase in clarity over time, but there is much variability in the data.

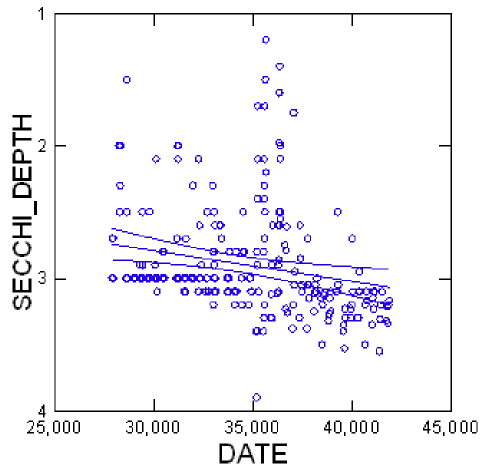


Figure 48. Secchi depths and trendline with 95% confidence interval for North Pond over the past 40+ years.

Phosphorus: North Pond is different from the rest of the lakes LAON observes in that it is relatively shallow throughout (max 15 feet). The shallowness impacts many measurements of the lake, and one is that, unlike the other lakes which typically stratify in the summer, North Pond may stratify and destratify repeatedly whenever periods of calm weather are followed by strong wind events. Lake ecologists call this a polymictic lake, that is one which repeatedly mixes. Therefore, North Pond does not exhibit a two layered system like the other lakes as seen in the temperature profiles in Figure 47. The average phosphorus concentration for the year was 15.6 ppb, slightly less when compared to the historical average of 17ppb. This is the highest of any of the four lakes. The long-term trend (40+ years) of phosphorus in the lake, in this case without layers, is shown in Figure 49. The figures show DATE as a number between 25,000 and 45,000. This is an artifact of changing date format between the spreadsheet (Excel) and the statistical software (SYSTAT). The dates of the samples fall between 1974 and the present. The red line in the figure is the statistical trend of the data. The dark blue lines are the upper and lower 95% Confidence intervals. The light blue lines are the upper and lower Prediction Intervals. While it may appear that the red line is on a downward slope, it is not significantly different from a flat line according to statistical methods (Analysis of Variance p=0.065).

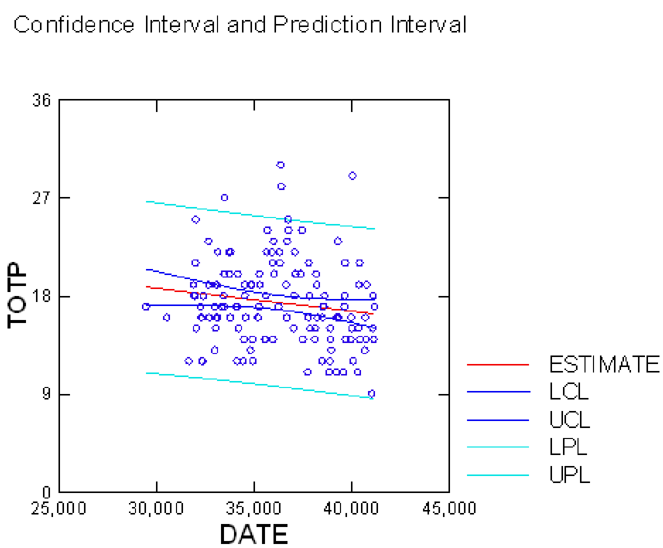


Figure 49. Total P results for LAKE = North Pond

Chlorophyll: Algae as measured by Chlorophyll concentrations was low with an average of 2.4 µg/L. The long term average is ~2.8 µg/L, so the current readings are consistent with the long term average. The historical data show that there has been a decline in the chlorophyll concentrations over the 40+ years of measurements (Figure 50).

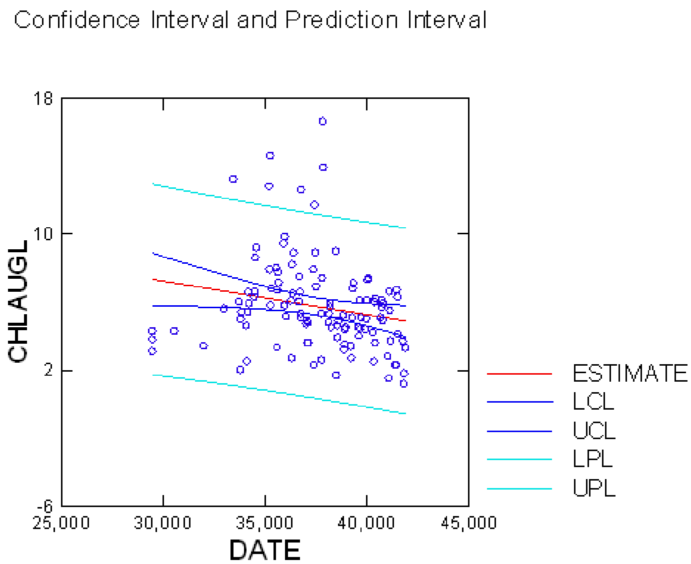


Figure 50. Chlorophyll concentrations for the 40+ years of observations on North Pond.

Dissolved Oxygen: The dissolved oxygen is reported here as milligrams per liter (mg/L). North Pond is a relatively shallow lake (~3 meters, not quite 10 feet) compared to the others surveyed by LAON. Due to this shallow depth, the lake never really gets seasonally stratified because the wind can easily mix the water from surface to bottom. This means that North Pond never suffers from any persistent oxygen depletions. Our data from summer of 2015 show only small variations in DO with depth, and also that there is almost constant temperature (no stratification) with depth (Figure 47). This means the habitat is favorable for oxygen-requiring aquatic life. The graph below (Figure 51) shows all of the DO data collected by LAON over the past 40+ years. The line is a LOWESS smoothing function showing the trend of the data. One can readily see the DO is nearly constant throughout the water column. Oxygen levels do decline on occasion but probably do not persist for any length of time, depending on the weather conditions. The relatively good DO levels in North Pond can also be seen to hold over time in two other figures. The first is a contour plot of all the data over time (Figure 52) which clearly shows oxygen becoming slightly depleted in recent years (more greens than yellows). This is also shown by average DO levels throughout the water column, on each sampling date during the same 40+ year time period (Figure 53). While the changes are not as pronounced, these data show a decline of DO since the earlier years of the surveys.

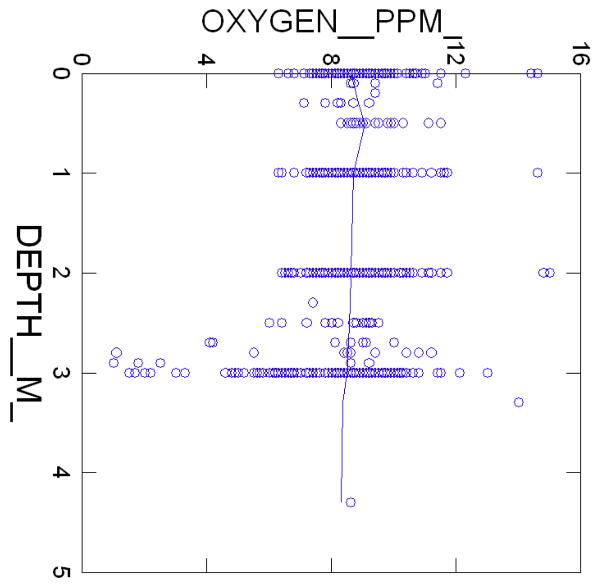


Figure 51. Dissolved oxygen versus depth in North Pond for all data collected over the past 40+ years.

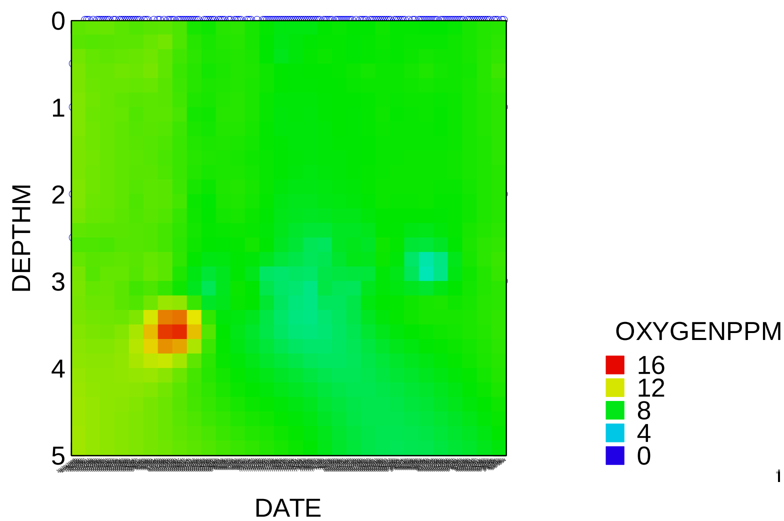


Figure 52. Contour plot of DO in North Pond during the summers, over the 40+ year time span

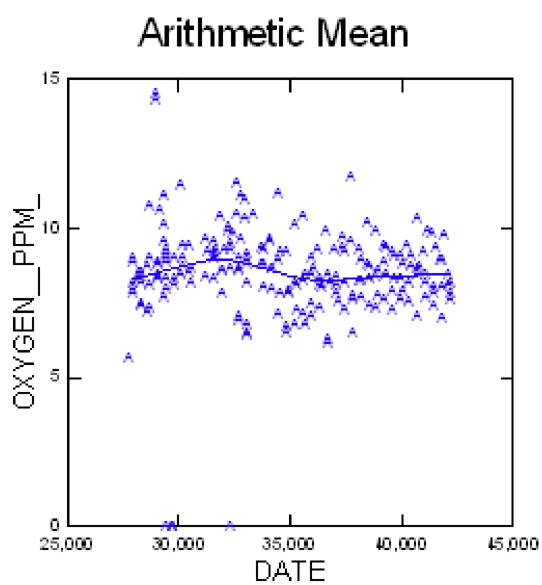


Figure 53. Average DO concentrations in North Pond on each sampling date, over the 40+ year time span.

pH: pH in North Pond shows an apparent increase and then leveling off over the past 40 years (Figure 54). These values fall within the norm for most lake ecosystems.

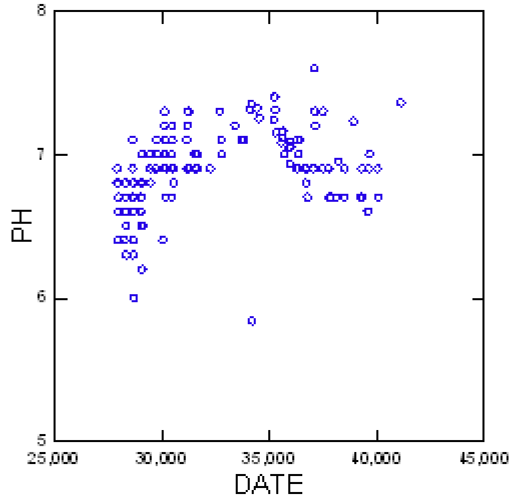


Figure 54. pH over the 40+ years of data collection in North Pond.

Alkalinity: Alkalinity is not very high in the Norway Lakes, and has a fair amount of variability. There is too much variability in the data to suspect that the trendline in Figure 55 is real.

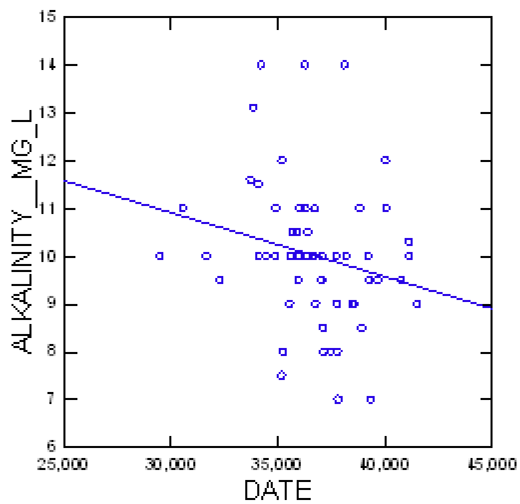


Figure 55. Alkalinity in North Pond over the 40+ years of data collection.

Conductivity: The conductivity in the Norway lakes appears to be rising (Figure 56), but there are too few data points to make an accurate assessment.

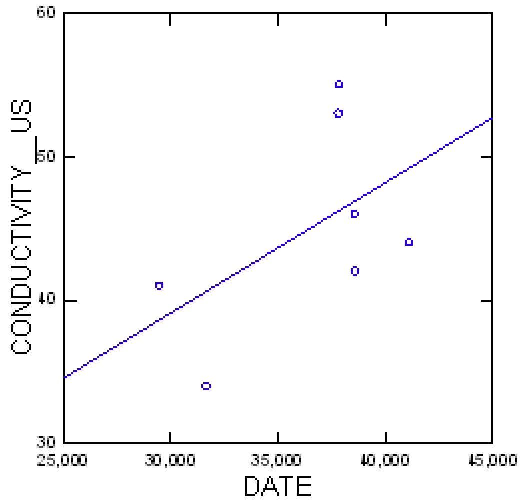


Figure 56. Conductivity in North Pond over the past 40+ years of data collection.

Color: Color in North Pond was remained in the range of 5-30 Standard Platinum Color Units (SPU) over the past 40 years. There is a hint of decline in the trend shown in Figure 57, but it is not significant.

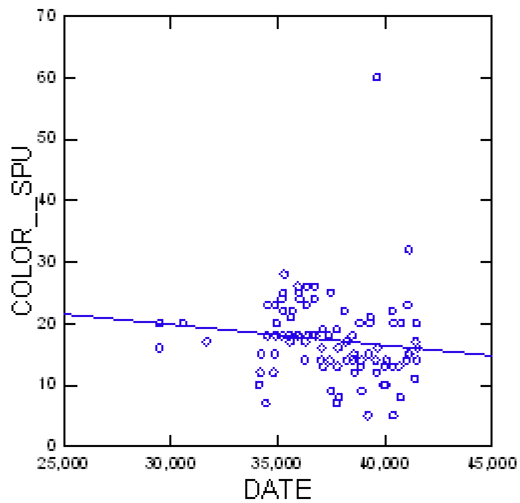


Figure 57. Color, in Standard Platinum Units, for North Pond over the past 40+ years of data collection.

Invasive Aquatic Plants: The Invasive Aquatic Plant Screening Surveys conducted for LAON by Lake & Watershed Resource Management Associates found no invasive aquatic plants in any of the four Norway lakes during the 2015 screening. Over the past years, the Chinese Mystery Snail has been found in all four of our lakes. The ecological significance of this invader has not been determined.

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.

Phosphorus

Total phosphorus was collected using a weighted flexible-plastic tube (epilimnetic core) lowered to the top of the thermocline to obtain and integrated water sample for the surface layer. The contents of the tube were poured into a 2 liter plastic bottle and mixed. The bottom layer was sampled with a van Dorn water bottle (Beta sampler). Both samples were placed into 50 ml tubes to measure out the volume and then put 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 in the same way as phosphorus, that is using a core tube for the surface layer and a van Dorn bottle for the deep layer. The samples were stored in 2 liter bottles wrapped and kept dark and refrigerated until they were brought back to shore. The water was then vacuum filtered with a hand pump (Mightyvac™) through a 0.45 micrometer pore filter. The volume filtered was recorded, and the filter frozen. The frozen filter was then 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 water-saturated air in the storage sleeve. At the beginning of the season and periodically throughout the summer the probe was calibrated with air-saturated water. Barometric pressure was obtained for the calibration from the National Weather Service, and used 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 samples were collected at the same time that phosphorus and chlorophyll samples were taken with the epilimnetic core, and the van Dorn sampler. Samples were then kept in the dark and refrigerated until return to shore. The conductivity was then measured with an Extech EC600 meter and an EC605 conductivity probe. The probe was calibrated with a 1413 microSiemens standard solution. The stated accuracy of the instrument is ± 1% full scale.

pH

pH samples were collected at the same time that phosphorus and chlorophyll samples were taken with the epilimnetic core, and the van Dorn sampler. Samples were then kept in the dark and refrigerated until return to shore. The conductivity was then measured with an Extech EC600 meter and an PH305 pH/Temperature electrode. The probe was calibrated each sampling day with a pH 7.0 buffer. At the start of the season and periodically during the season, a three-point calibration was used with pH 4.0, 7.0 and 10.01 buffers. The meter has a stated accuracy of ±0.02 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.