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2022 Thompson Lake Water Quality Monitoring and Assessment Report

Executive Summary:

Indicators of water quality for Thompson Lake were close to historical averages in 2022. The lake was slightly less clear, but phosphorus, the key nutrient that limits algal growth, and chlorophyll-a, which directly measures algal density, were slightly lower (better than) the historical averages for the lake. Late summer dissolved oxygen levels in the deepest area of the lake – long considered to be the "canary in the coal mine" for deep clear lakes, remained well within healthy limits to support Thompson's vibrant coldwater fishery.

Even though Thompson remains one of Maine's cleanest and clearest lakes, a warming climate has the potential to negatively affect lakes in a number of ways over time. Shorter periods of ice cover, record high summer water temperatures a longer growing season for algae and other lake plants, and an increase in severe weather, ranging from soil-eroding storm events to extended periods of drought will not benefit lake ecosystems. Ongoing efforts to protect the lake through aggressive watershed conservation initiatives will be essential to the long term health of the lake.

Lake Water Quality in the Era of a Warming Climate:

Lake water quality may be influenced at any point in time by a wide range of both natural and anthropogenic factors. The combined effect of these has a bearing on the extent to which monthly, seasonal and annual "natural variability" occurs in many of the indicators that are used to assess lake ecosystems.

Annual weather fluctuations and trends in temperature, wind, and precipitation typically influence both short and long-term conditions that occur in individual lakes. The degree to which they affect individual lakes depends on the natural characteristics of the lake, and the extent to which the lake and watershed have been altered through development. Natural characteristics include, but are not limited to the bathymetry (depth profile) and shape of the lake basin and its orientation to prevailing winds, and the geographic area, soil chemistry, and hydrologic characteristics of the watershed. Natural features such as wetlands within the watershed may also be factors. The combined effect of these variables plays a role in the sensitivity and response of individual lakes to watershed development.

Foremost among the influences of weather on our lakes are precipitation and temperature, both of which are increasing in intensity through the process of climate warming. In recent years, unusually warm ambient temperatures throughout the year have resulted in historic high summer lake water surface temperatures (mid 80's F in southern and central Maine), later formation of ice cover in the fall/winter, and earlier "ice out" in the spring. The overall reduced period of ice cover on lakes is a clear indicator of the potential changes that climate warming will likely have, and almost certainly is now having, on Maine's lakes, relative to their historical state.

Precipitation events are becoming more extreme, and multiple years of moderate to severe drought have occurred throughout much of Maine during the past two decades. Intense rain events can significantly increase the erosive force of watershed stormwater runoff, transporting more sediment and phosphorus into lakes. Drought reduces the inflow of water to lake basins from their watersheds and increases evaporation of lake water, resulting in low water levels, which can cause the desiccation of sensitive, beneficial aquatic plant communities, reduce fishery habitat, and it may contribute to shoreline erosion. Drought is often associated with warmer ambient temperatures and an increase in lake water temperature.

Drought is often punctuated by localized extreme precipitation events, during which high-velocity, erosive stormwater runoff from the watershed reaches lakes, carrying with it elevated concentrations of soil particles, nutrients and other pollutants. In recent years, unusual algal blooms that have been observed and documented in a number of Maine lakes are likely to have been triggered by the combined effects of extreme weather.

Historically, it has generally been accepted that clearer lake water is an indication of healthy lake ecosystems. This may not always be the case in the era of climate change. Many Maine lakes tend to be clearer during drier years, ostensibly due to reduced stormwater runoff from their watersheds during such periods, resulting in less algal growth. Algae are essential to the overall health and biological diversity of lake ecosystems. Dramatic declines in algae, combined with warming lake temperatures, can result in the disruption of a lake's food web, and along with rising water temperature, may contribute to fish mortality and the loss of critical habitat for some species.

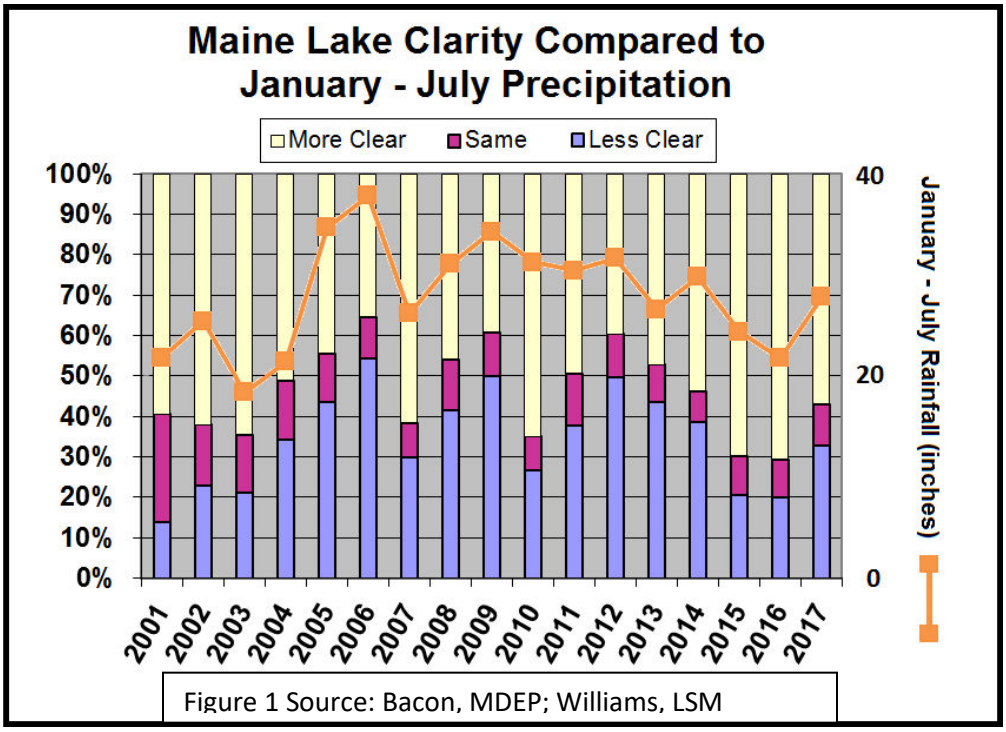


Figure 1 Source: Bacon, MDEP; Williams, LSM

An observational analysis of the Secchi transparency (water clarity) of Maine lakes from 2001 through 2017 (Linda Bacon/MEP; and Scott Williams/LSM) showed that during that period of time, a significant number of Maine lakes tended to be clearer during drier years (Figure 1). Stormwater runoff is the vehicle by which phosphorus and other pollutants are transported from watersheds to lakes. Lakes tended to be less clear during years when there was more precipitation and runoff during the period from January through mid- summer. Periods of drought may be deceptively causing apparent improving trends (based on water clarity) in water quality for some lakes in Maine, based on deeper Secchi disk readings, and lower concentrations of phosphorus and planktonic algae. This observational study suggests that stormwater runoff from lake watersheds contributes to reduced lake clarity, but it also raises questions about whether an increase in lake clarity should always be considered beneficial to lakes. In the future, it will be increasingly important to take into account the influence of extreme weather associated with a warming climate when assessing lake water quality.

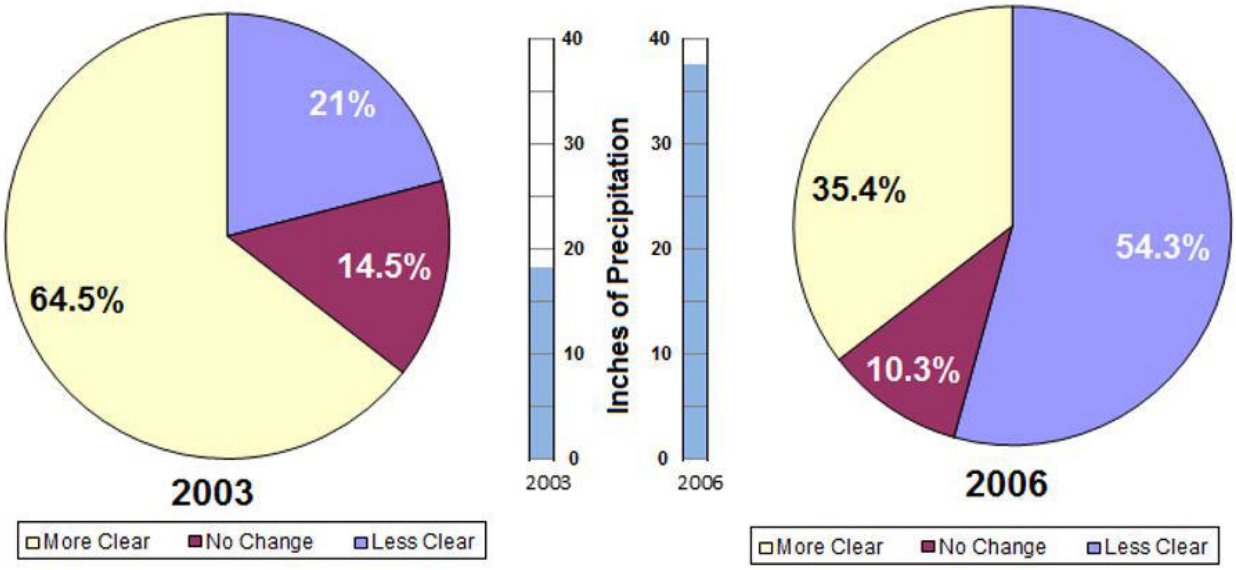
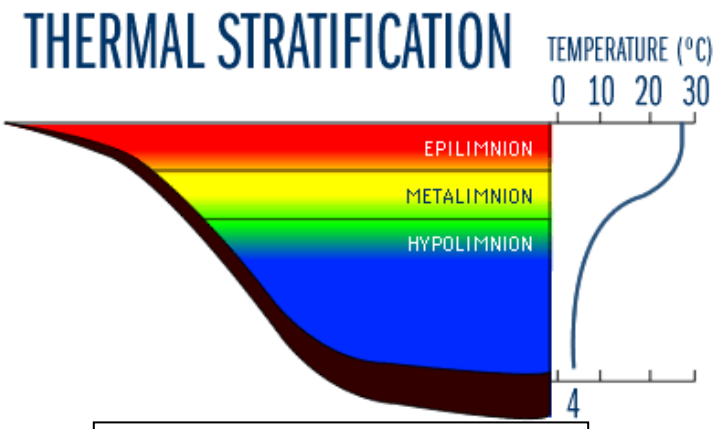


Figure 2: Source: Bacon/MDEP; Williams/VLMP

The pie charts in Figure 2 (above) illustrate the dramatic change that occurred in the number of lakes that were clearer than, less clear, or unchanged from their historical averages in 2003 and 2006. The bar graph between illustrates the differences in precipitation for the period from January through July for each of the years.

While a majority of Maine's lakes have been clearer to varying degrees during drier years, smaller groups of lakes have either been unchanged, or in some cases, have been less clear than their historical average. This may be due to several factors, including current water quality conditions in individual lakes, the degree to which individual lake watersheds are developed, whether or not a lake is experiencing internal phosphorus loading and recycling (in additional to external/watershed sources) - and more recently, the possibility that warming lake water temperatures are causing longer periods of thermal stratification. Relatively shallow lakes that have undergone little or no stratification in the past are now experiencing this phenomenon – which may, in some cases, exacerbate dissolved oxygen loss and the release of phosphorus from lake sediments to the overlying water, resulting in greater planktonic algae growth and reduced water clarity.

An extended period of thermal stratification typically results in greater loss of dissolved oxygen in the lake water column during the period because warmer water is able to contain less dissolved oxygen, and water in the deepest area of stratified lakes is isolated from atmospheric sources of oxygen for longer periods. Depending on the biological productivity of individual lakes, oxygen concentrations may drop to critically low levels, triggering the release of phosphorus in the lake sediments to the overlying water. The "pulse" of phosphorus associated with this internal release process may, under certain circumstances, result in an increase in planktonic algal growth, and reduced water clarity, especially during the warm summer and early fall period.



Typical Summer Temperature Profile in a Thermally Stratified Lake

Another small group of lakes that may actually be clearer during wet years are those that are highly productive, and which experience persistent severe algae blooms. These lakes may actually benefit from the diluting effects of precipitation, because phosphorus concentrations in the body of water are higher than incoming levels in stormwater runoff.

Climate warming, and associated extreme weather events may compound (and confound) the complexity of tracking, predicting and characterizing lake water quality. In recent years, an increasing number of lakes that have historically experienced relatively "good" water quality, and which have otherwise been considered to be stable, have experienced significant changes, very likely due to the de-stabilizing influence of a warming climate. Although in some cases it may be possible to predict the manner in which individual lakes will respond to climate change, the process through which warming effects complex biogeochemical reactions in lake ecosystems may not always be clear in advance of the changes.

Potential Weather Influences in 2022:

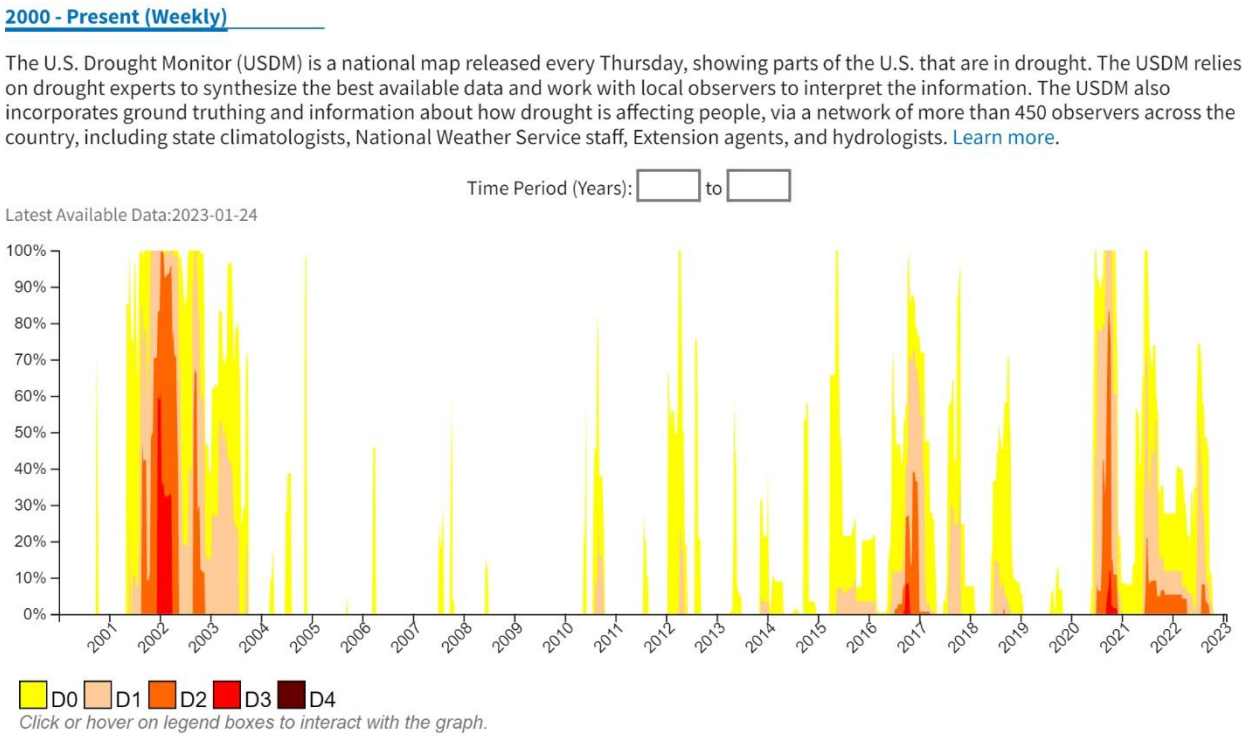
Maine once again experienced a relatively dry summer in 2022. While the extent of the drought varied, most of the state experienced below average precipitation for the first several months of the year. For the past few years, Maine has experienced drought ranging from "abnormally dry conditions" to "moderate and severe drought" (source: Drought.gov).

The effects of drought on lakes may be cumulative, depending on the amount of time that it takes (on average) for the volume of water in a lake to be replaced, or "flushed" (not to be confused with "turning over", or mixing). Because this natural process is relatively slow, a dry year may continue to influence water quality and ecological effects for a year or more following the period

of drought. Drought-related effects may be cumulative, depending on the duration and severity of drought conditions.

Drought conditions in Maine changed dramatically during the last months of 2022, which has been characterized as one of the wettest periods in more than a century. The abrupt reversal, resulting from multiple heavy precipitation events, may result in many lakes being less clear than their historical average in 2023 – depending, in part on conditions during the spring runoff period, following snowmelt.

The graphic below (Source: Drought.gov) illustrates the significant drought conditions in Maine from 2000-present (January, 2023). The color box in the lower left begins with "abnormally dry" in yellow, to more extreme conditions in the far right boxes. Note that many years since the severe drought period of 2001-2003, show significant drought conditions.



2022 Overview and Summary of Findings for Thompson Lake:

The following summary information is the product of "baseline" sampling and assessment that was conducted at Thompson Lake, situated in the towns of Oxford, Otisfield, Poland and Casco , ME (MIDAS # 3444) from May through October, 2022 by LWRMA staff. Additional Secchi Transparency (water clarity) data were gathered from May through October by Certified Volunteer Lake Monitors, Paul Cain and John Powers. Their data have been included in this

report. The value of the work of trained volunteer lake monitors in assessing the health of Maine's lakes cannot be overstated.

Water quality monitoring/sampling was conducted at the "deep hole" station, which is the deepest known location in the lake, and it is the area where the greatest volume of historical data has been obtained for several decades. Despite its large geographic area, Thompson is classified as a single basin lake. The lake basin is open, without significant restrictions to circulation and mixing. The deep hole monitoring station (#01) is generally representative of overall conditions in single basin lakes. Historical sampling of conditions in the lake have shown this to be the case. While some variability may occur within the lake, this is typically due to the influences of tributaries and "near shore effects" from wind and wave action. Data gathered in other locations certainly has value, but is not necessarily representative of overall water quality of the lake, which is the purpose of this assessment.

For most Maine lakes, August and early September sampling is generally considered to be the most critical period of the year because potentially stressful conditions in the lake associated with several months of warm weather are typically most evident. Ideally, in order to confidently detect both short-term changes (such as an impending algal bloom), as well as long-term trends, a minimum of monthly sampling frequency is required for at least five continuous months during the open water period from May through September or October. Historical data sources referenced are from the Maine Department of Environmental Protection, Lake Stewards of Maine (www.lakesofmaine.org), and LWRMA field records and reports.

The characterization of changes that take place in a lake from one year to the next is a nuanced process. While terms such as "above and below average" may be relevant for one or more critical indicators of water quality, they may not take into consideration the fact that lakes are highly dynamic systems that are in a constant state of flux, with significant fluctuations occurring throughout any given year.

Water Quality Indicators and Related Phenomena

In 2022, the three primary "trophic state: water quality indicators (Secchi transparency, total phosphorus and chlorophyll-a) were relatively close to the long-term (historical) averages for Thompson lake (Figure 3). The lake was somewhat less clear, based on Secchi transparency data covering nearly 6 months (See note below). However, the concentration of total phosphorus, the key nutrient that has a bearing on algae growth, was very slightly below the historical average, as was chlorophyll-a, which is a direct measure of planktonic algal density.

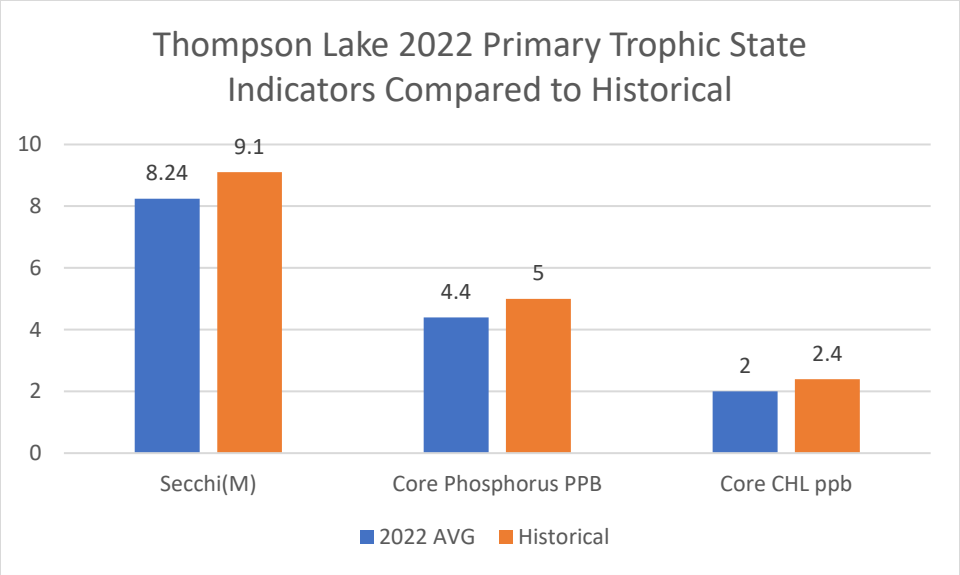


Figure 3

Figures 4 & 5 illustrate the variability in **Secchi transparency (water clarity**) readings at monitoring stations 01 and 02 in 2022.

At Station 01, the highest (clearest) reading of 9.73 meters was recorded on July 29, and the lowest reading of 7.17 meters was recorded on June 25. The average for the 6 month period (14 readings) was 8.24 M, compared to the historical average of 9.1 meters. Note: The lower average in 2022 is based, in part on the relatively low inclusion of the late October reading (7.2M) in the calculation of the seasonal average. Most of the historical averages for Thompson Lake do not include October data.

Station 02 readings ranged from a low (least clear) reading of 6.66 meters on June 15 to the unusually high (very clear) reading of 12.1 meters on July 13. The average for the three month period (5 readings over 3 months) was 9.2 meters.

Overall, the changes in water clarity throughout the period were somewhat typical for the lake, being influenced by successional shifts in plankton populations and metabolism, as well as weather factors. However, the very unusual increase in water clarity recorded at station 02 on July 15, followed by an equally sharp decline on July 31 is difficult to explain, and lacking likely causative factors, should be considered an anomaly. It will be interesting to observe whether or not similar changes occur in this area of the lake in the future.

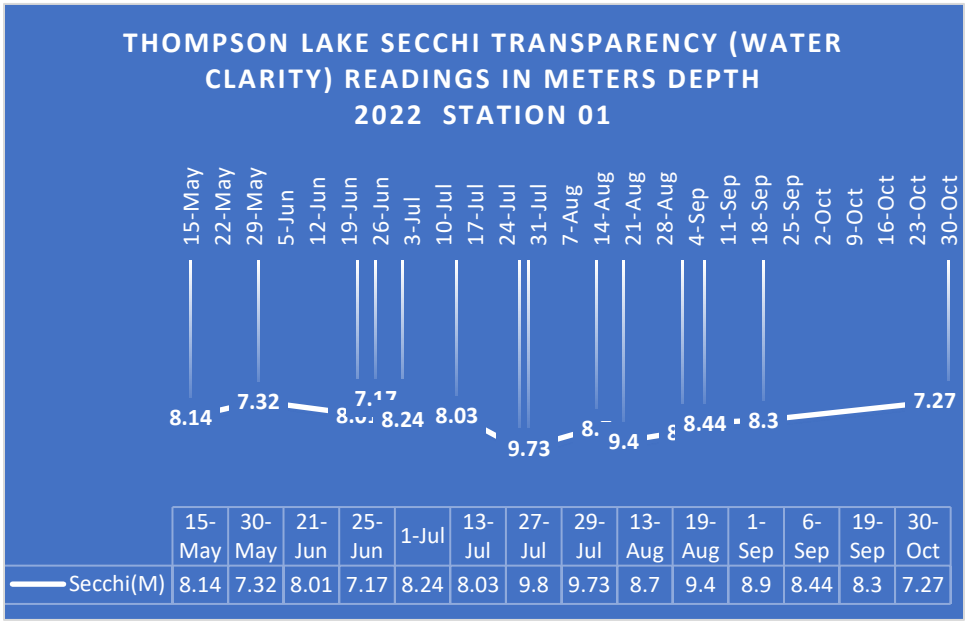


Figure 4:

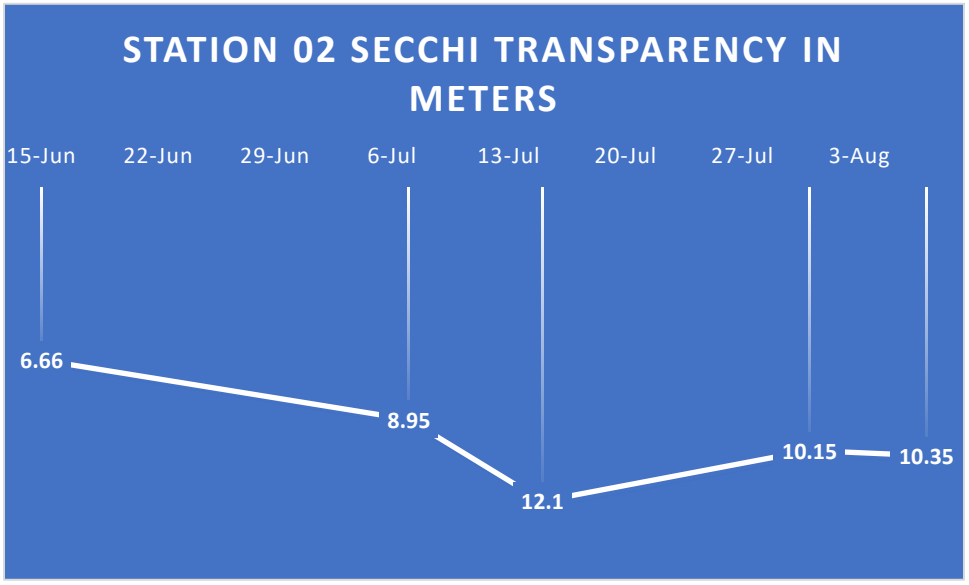


Figure 5

The image on the following page (Figure 6) is a listing of Maine's 50 clearest lakes (as of 2017). Thompson Lake is circled. Source: Maine DEP/Lake Stewards of Maine/www.lakesofmaine.org

Figure 6

Maine's 50 Clearest Lakes (2017)

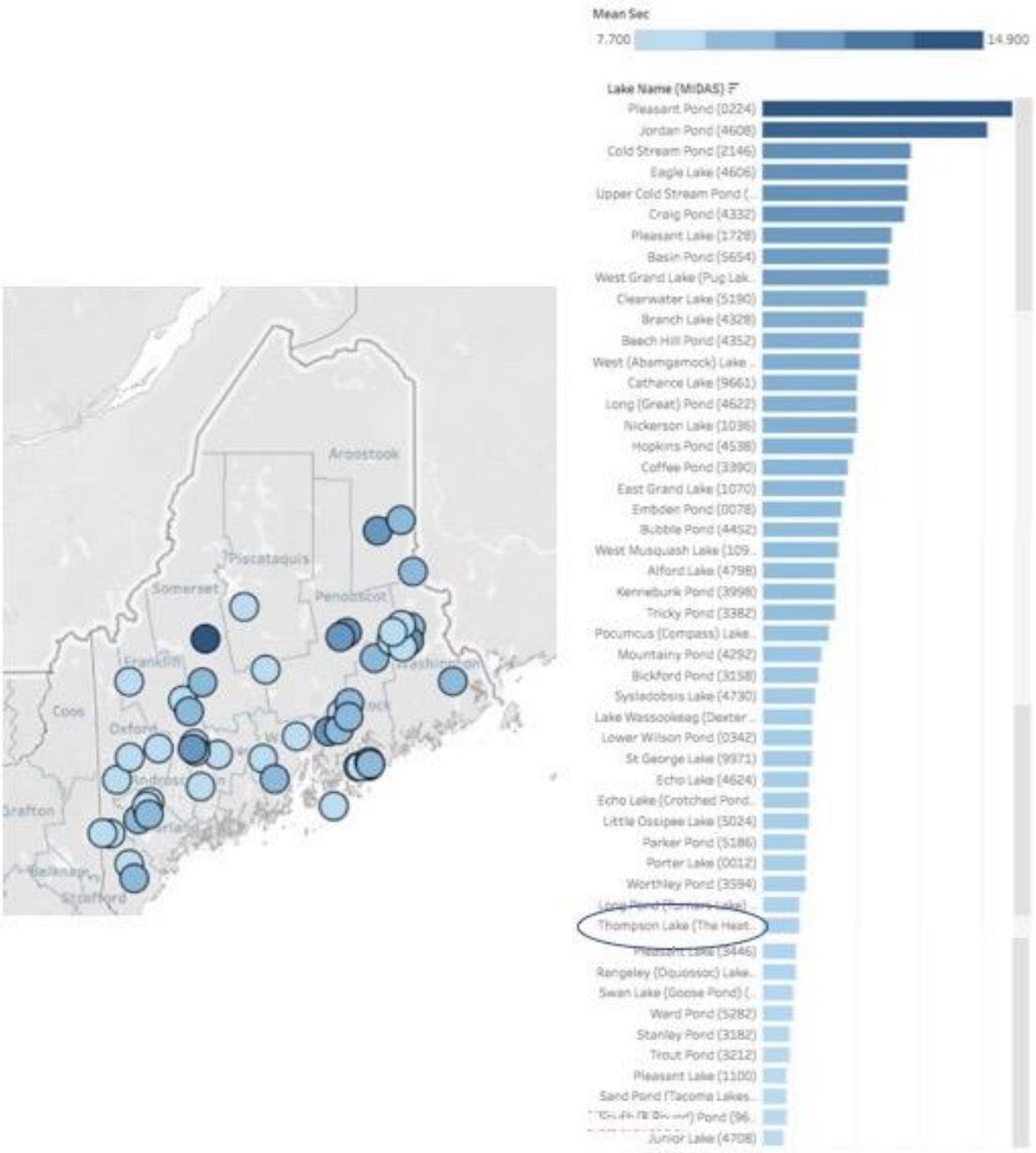


Figure 7 illustrates the individual values/readings for Secchi Transparency, and epilimnetic core (mixed upper water column sample) total phosphorus, chlorophyll-a, and natural water color during the 2022 monitoring period.

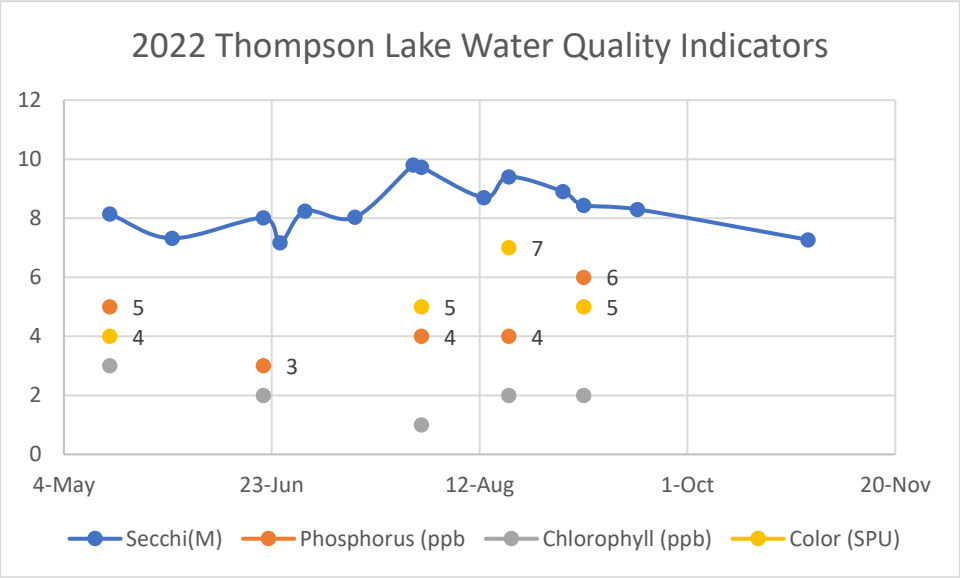


Figure 7

Core **total phosphorus** samples varied from a low reading of 3 parts per billion (ppb) on June 21, and a high reading of 6 ppb on September 6. The average for the five month period was 4.4 ppb, very close to the historical average of 4 ppb.

Core **Chlorophyll-a** samples ranged from a very low reading of 1 ppb on July 29, to a high of 3 ppb on May 11. The five month average was 2 ppb, very close to the historical average of 2.4 ppb.

Water color, a natural phenomenon that is primarily influenced by humic compounds contained in watershed wetland vegetation and deciduous leaves, averaged 10.1 Standard Platinum/Cobalt Units (SPU), compared to the historical average for Thompson Lake of 9.6 SPU. High concentrations of natural color in some lakes can influence water clarity, total phosphorus and chlorophyll. However, this influence is not considered significant below 25 SPU.

Unusually high lake **water temperatures** were documented in lakes throughout Maine during the summer of 2022. On July 29, the water surface temperature at station 01 measured 26.8 degrees Celsius (80.2 degrees F.), possibly the highest surface temperature on record at this sampling station.. On that date, the lake was strongly thermally stratified, with temperatures ranging from 26.8C at the surface at station 01 to 8.8 C at 30 meters depth, just above the lake bottom at 108 feet.

The lake was stratified throughout the monitoring period from May 11 through September 6, although on September 6, the surface temperature had dropped to 16.5 C, and the thermal gradient to 30 meters depth was just over 6 degrees C.

Historically, Thompson Lake has not experienced significant **dissolved oxygen (DO)** loss during the summer stratification period . Dissolved oxygen is a key indicator of the overall low biological productivity of the lake. Moderately high levels of DO throughout the year is essential to the existence of the healthy coldwater fishery supported in Thompson Lake. Some natural DO loss occurs in all lakes that experience extended periods of thermal stratification because the cold, dense water in the deepest area of the lake is isolated from sources of oxygen (algal photosynthesis and atmospheric). During the period, bacterial decomposition of organic matter in the lake causes some "consumption" of DO. The relatively low loss of DO in Thompson is consistent with very clear water and low algal productivity and metabolism. Climate warming has the potential to cause an increase in DO loss in the lake over time, as algal productivity/metabolism and water temperatures increase.

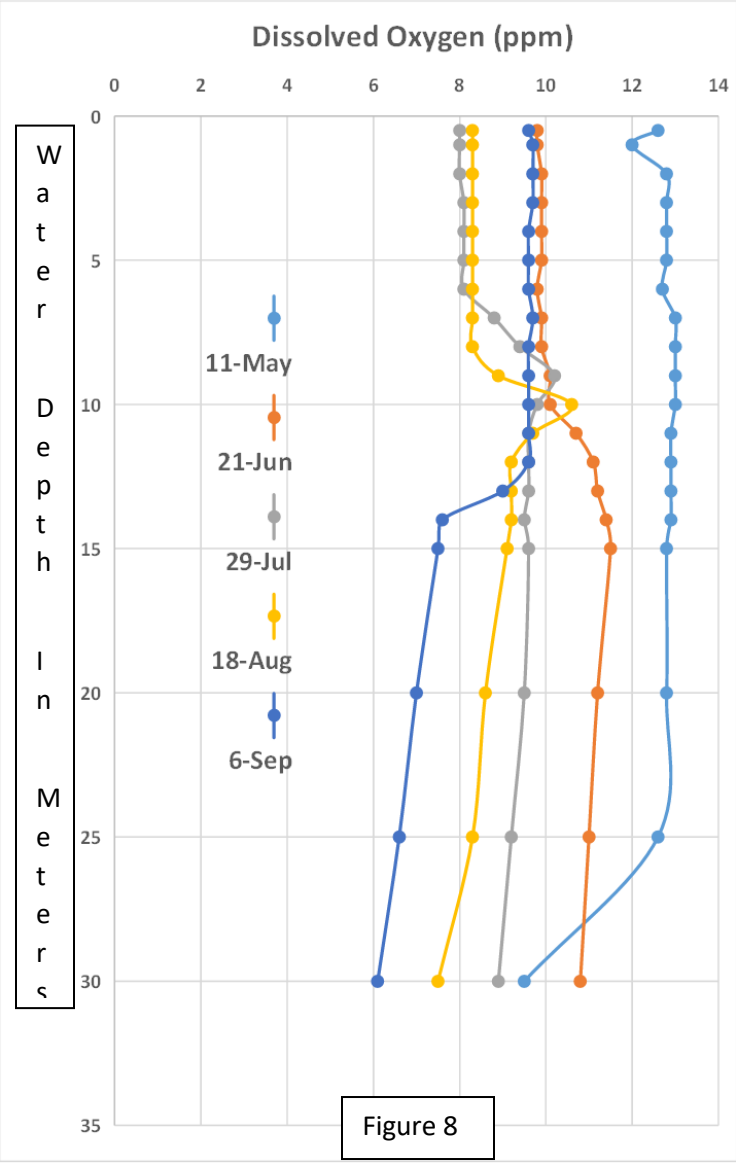


Figure 8

Figure 8 illustrates the monthly dissolved oxygen profiles that were obtained from May through September at Station 01. The loss of DO in the deepest area of the lake during the period while evident in Figure 8, was close to late summer historical levels for this critical indicator of lake health. Because climate warming will almost certainly influence this phenomenon over time, ideally, temperature and dissolved oxygen profiles should continue to be gathered in October (and possibly November) to determine the duration of the period of thermal stratification, and the extent of oxygen loss that takes place prior to the destratification and mixing of the lake in the Fall.

Lake water temperatures that are substantially higher than in past years are a significant risk factor for an increase of potentially harmful (toxic) algal blooms in Maine's lakes. Unusually

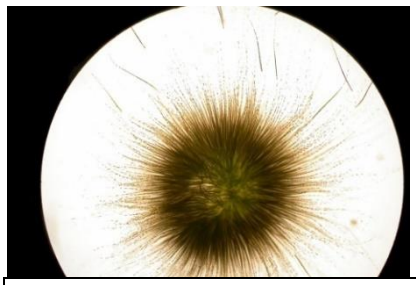
warm lake water also stresses the biota, and has been linked to fish mortality in a number of Maine lakes in recent years.

Total Alkalinity is a measure of the capacity of lake water to buffer acidified precipitation and water entering the lake from its watershed. Alkalinity, measured in August and September averaged 5.7 mg/l , compared to the historical average of 7.4 mg/l for Thompson Lake. Some annual variability of total alkalinity is common, and likely influenced by weather factors that influence watershed hydrologic input concentration (or lack thereof during periods of drought) from tributaries and runoff.

"Metaphyton" is a broad term for a number of species of filamentous algae that form cotton candy-like green/yellow "clouds" in shallow areas of lakes, and streams. Metaphyton occurs naturally, and provides a number of ecological benefits to lake ecosystems. The algae that constitute metaphyton are common in lakes throughout Maine. They provide food and beneficial habitat for a wide range of lake Fauna. However, many lake communities, volunteer lake monitors, and lake scientists have reported a substantial increase in metaphyton abundance in recent years (observational data). The significance of this increase is not fully known, but may be the result of some influence(s) of weather events associated with climate warming. Continued monitoring and reporting unusual changes in the abundance and location of this algae will hopefully lead to a better understanding of its ecological significance.

Our monitoring of metaphyton in Thompson Lake in 2022 was limited to observational monitoring of the shallow boat launch cove in Oxford, and spot checks of similar shallow areas on the easterly shoreline. While metaphyton was observed, occurred at low densities, typical of historical conditions for the lake.

Gloeotrichia echinulata is a bluegreen algae (cyanobacteria) that has been observed/documented historically in a number of relatively clear Maine lakes. However, historical concentrations of this species, which forms colonies that are visible to the naked eye, have been very low. In recent years, "Gloeo" has been documented in an increasing number of less clear lakes, and at higher densities. The significance of this increase is not fully understood, but some information suggests that it may be influenced by factors associated with climate warming and historical watershed land use. Gloeo was documented in moderate to high densities in the severe algal bloom that occurred in Lake Auburn in 2012. Gloeo has been consistently present and observable in Thompson Lake for several decades, typically during late August and throughout September. Densities have always been very low. Gloeo was observed in Thompson Lake in both July and August, 2022 at relatively low density (~1.0 on the density



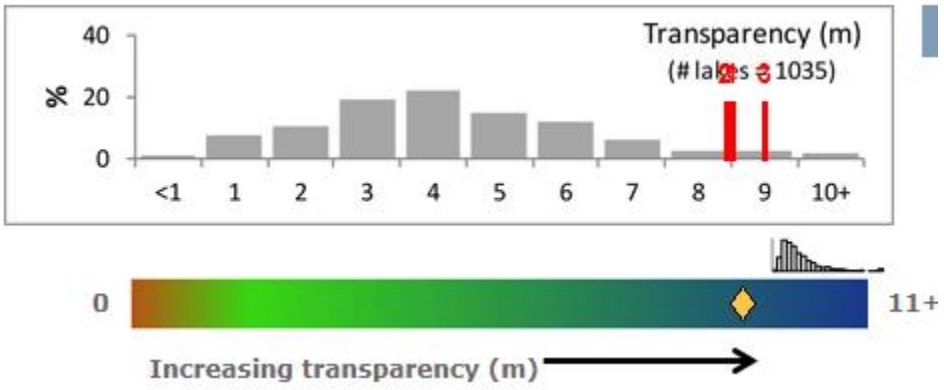
Magnified Image of *Gloeotrichia Colony*

scale of 1-6). The Gloeo "bloom" occurred somewhat earlier than has been observed historically.

Additional Water Quality Visualization Graphics

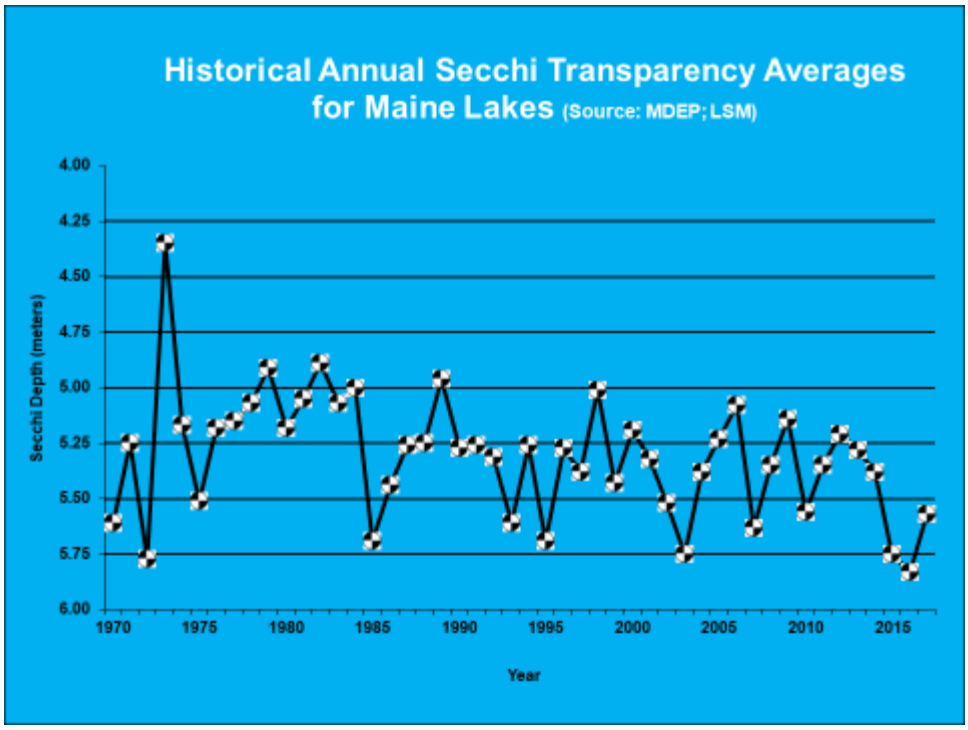
The "color ramps" below, produced on the www.lakesofmaine.org website, illustrate the range of data for several indicators of water quality for several hundred Maine lakes. The yellow diamond on each ramp indicates the historical average value for Thompson Lake. The bar charts shown above each color ramp is a histogram that illustrates the distribution frequency for Maine lakes for each indicator. The red line in each indicates the historical average for this lake. The histogram shows where the lake is situated, relative to the total number of Maine lakes assessed/represented (indicated by "# of lakes").

The first ramp shows water clarity, ranging from least clear on the left, to clearest on the right. The yellow diamond depicts the historical average, relative to more than 1,000 Maine lakes. The bar graph (histogram) situated illustrates the position of the lake relative to others in the group.

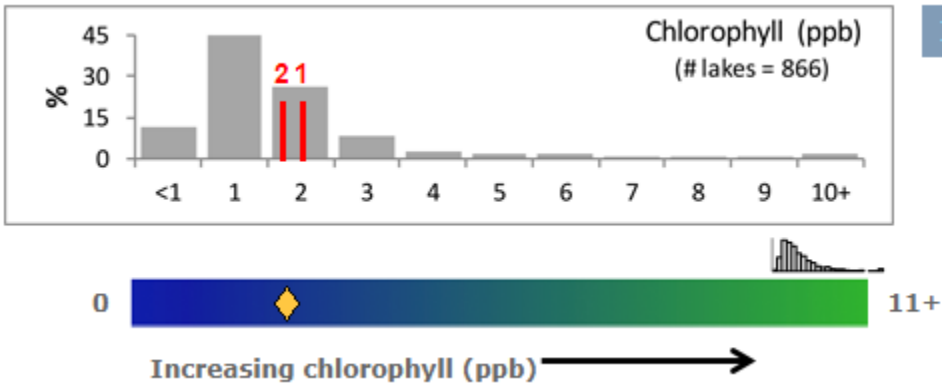


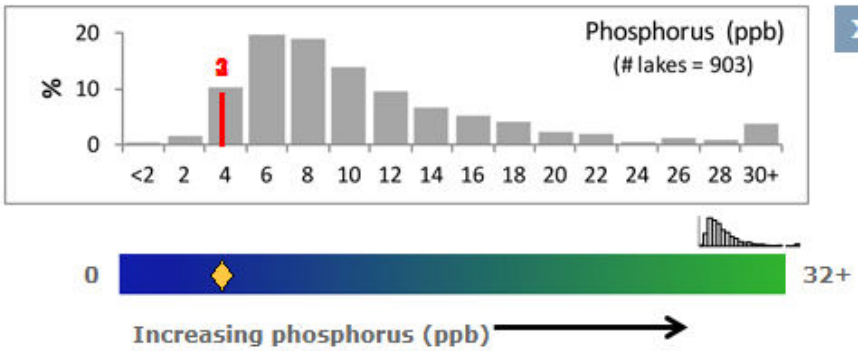
The historical water clarity annual averages for Maine lakes (based on data from numerous sources for more than 1,000 lakes) has varied in the 4.75-5.75 meter range for the past few decades.

The following graphic illustrates the annual average Secchi value for Maine lakes, based on the number of lakes for which data were available for the individual years.



Note that the color ramp scales for total phosphorus and chlorophyll below illustrate higher water clarity on the lower left side of the ramp, whereas the Secchi transparency ramp above shows higher water clarity/quality on the right end of the scale.





Summary and Recommendations:

Thompson Lake water quality indicators monitored in 2022 were close to the historical averages for the lake, although water clarity (Secchi Transparency) was slightly less clear – possibly due to the addition of a late October water clarity reading in the calculation of the seasonal average. "Natural variability", influenced by weather, normal cyclical transitions of aquatic flora and fauna, and other factors, accounts in varying degrees for variability in water quality indicators throughout the year. Continued gathering of data from the lake and its watershed over time is very helpful in the interpretation of variability, and is especially helpful in distinguishing changes due to natural phenomena from anthropogenic influences.

Climate warming is a very real threat to the ecological health of Maine's lakes. Mid- summer lake water temperatures in the mid 80's(F), combined with other weather extremes that have been documented in recent years, including intense, localized precipitation and runoff events, drought, reduced periods of ice cover, and other unusual meteorological phenomena pose a significant threat to relatively stable historical conditions in the lake.

During recent years, a number of lakes throughout Maine that have previously been considered to be stable, and have had average to above average water quality, have experienced measurable negative changes, characterized by declining water clarity, caused by a proliferation of cyanobacteria/bluegreen algae. The combination of the hydrologic sensitivity to phosphorus of individual lakes, watershed development pressures, and weather extremes, in some cases has appeared to trigger the internal release of phosphorus from lake bottom sediments, which can result in an acceleration of algal growth.

Once a lake exceeds its natural assimilative capacity, restoration may be difficult, uncertain, and very costly.

Given the rapid manner in which such changes can take place at this point in time, continued vigilance in monitoring and protecting Thompson Lake and its watershed will be essential to maintaining the exceptional clarity and overall health of the lake ecosystem. Preventing, documenting and resolving disturbances in the watershed is critically important. Ensuring that new residential development, agriculture and timber harvesting incorporate "best water quality

protection practices", as well as revisiting and evaluating the effectiveness of existing water quality protective measures (properly sized culverts, runoff diversion practices and vegetated buffers) will be necessary, as the potential for erosive intensity of stormwater runoff associated with extreme precipitation increases.

Prepared by Lake & Watershed Associates Senior Limnologist, Scott Williams