Report on the Health of Thompson Lake 2016

This report is a summary and analysis of findings of water quality monitoring of Thompson Lake from May through September, 2016. Most of the readings, samples and observations were gathered at the deepest point in the lake, situated to the west of Hayes Point in Oxford. The majority of historical water quality information for Thompson Lake is also based on sampling at the Hayes Point deep station.

In addition to the sampling that we conducted, Maine VLMP-certified volunteer lake monitor Ron Armontrout, provided Secchi transparency (lake water clarity) readings. This additional information has been very helpful in developing an overview of conditions in the lake during the 2016 monitoring season.

All sampling was conducted in accordance with protocol and quality assurance standards established by the Maine DEP and the Maine Volunteer Lake Monitoring Program.

Overview: *Overall, Thompson Lake experienced substantially above average water quality in 2016 (compared to historical averages for this waterbody), based on the clarity of the water, and the concentrations of phosphorus and algae (chloropyll-a) measured at the deepest point in the lake during the five month period.*

Weather Influences:
Weather conditions can have a strong influence on indicators of lake water quality. Much of the natural variability that is common in lakes from year to year can often be attributed, in part, to overall weather patterns, and sometimes to individual storm events.

Extreme weather events, including heavy rain, strong wind, and abnormally high temperatures associated with climate change may be increasingly frequent in the future. Such events are likely to have a measurable effect on lake systems, including a reduction in the period of ice cover, lower dissolved oxygen concentrations in deep areas during late summer, an increase in nutrient and sediment levels in stormwater runoff from soil erosion in lake watersheds, and more.

*Weather and climate can have a significant bearing on both short and long-term indicators of lake water quality. Over time, the up and down nature of weather will have varying effects on individual lakes, and can be a confounding factor in identifying trends in lake water quality. Extreme weather associated with climate change isn't making the process of trend analysis any easier! But all indications are that, over time, climate change is likely to have an overall negative effect on Maine's lakes.

The weather throughout much of 2016 was very dry. We often think of extreme weather in terms of intense precipitation and temperature swings. *However, both precipitation and drought can certainly be characterized as extreme weather, and climatologists are in general agreement that both extreme drought and precipitation are increasing in frequency and severity in many regions of the world as a result of climate change.*

According to the National Weather Service, the U.S. Geological Survey, and Maine's Drought Task Force, as of early October, 2016, drought conditions ranged from moderate to severe throughout the State of Maine. Factors influencing this condition accelerated during the past several months. Precipitation was below average in May, June, July, August and September, which, according to the National Weather Service, was the driest September since 1978, and the 12th driest month on record for the southern part of the state. "The drought is expected to continue and expand," said Tom Hawley, of the National Weather Service in Gray. "September rainfall was well below average for the entire state. Many locations in southern Maine received less than one inch for the month."

According to Nicholas Stasulis, Data Section Chief, U.S.G.S., *groundwater levels in some areas of southern and southwestern Maine were the lowest on record for July and August, going back 15-35 years.* Many streams that normally flow throughout the year have been completely dry for months, and *as of mid-October, three of Maine's largest rivers were at the lowest flow conditions on record*.

National Weather Service records indicate that much of southern and central Maine experienced a relatively warm winter with below normal snowfall. This was followed by warm late winter-early spring conditions that led to the *earliest ice-out conditions on record for many lakes in southern and central Maine.* Ambient temperatures throughout much of Maine were above normal from July through September, which combined with below normal precipitation, led to very dry conditions.

A number of more isolated instances of extreme weather also occurred during the summer months, including highly localized heavy rain events, such as the thunderstorm on June 28 that produced 8 inches of rain over a period of 4-6 hours in Parlin Pond Township, according to Certified Lake Monitor, Dave Drouin. Such events can cause severe soil erosion and flooding, and dramatic swings in indicators of water quality. Dave indicated that Parlin Pond turned "brown" for several days, which caused Secchi disk readings to drop substantially.

The ways in which drought and other climate-related influences affect lakes can be divided into short and long-term effects, as well as recreational and ecological impacts. The specific attributes of individual lakes (bathymetry, natural flushing rate, watershed development, existing water quality conditions, and more) have a strong bearing on the nature and extent of the ways in which each responds to weather and climate.

One of the most profound ways in which a warming climate is likely to influence lakes is through a shortening of the period of ice cover. Reliable historical "ice-out" data for lakes throughout New England document that lakes are free of ice earlier in the spring than they were a century ago. The image below from a study of New England Lakes by Glenn Hodgins et al looked at *ice-out* dates (because of abundant historical data), and does not take into account the fact that unusually warm weather during the fall/winter period has likely resulted in later formation of ice cover on lakes throughout New England, which, combined with the early ice-out data, would likely show a very dramatic shortening of the overall period of ice cover for lakes throughout the region. But the ice-out data alone show a clear shortening of the period of ice cover over a period of two centuries.

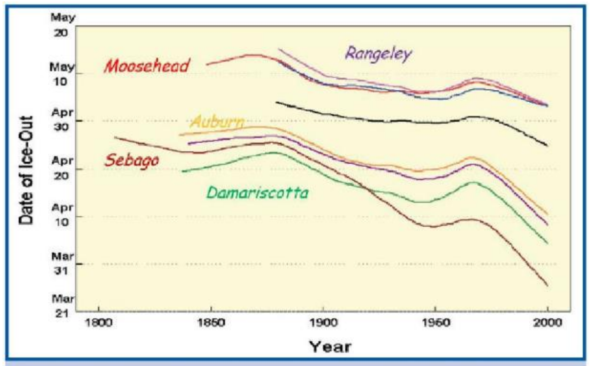


Figure 1: Smoothed lines of ice-out dates over time for the eight lakes in New England with the longest periods of record. The top four lines represent lakes in northern and western Maine and the bottom four lines represent lakes in southern Maine. Source: Hodgkins, G.A., James, I.C., and Huntington, T.G., 2002, Historical changes in lake ice-out dates as indicators of climate change in New England, 1850-2000: International Journal of Climatology, v. 22, p. 1819-1827.

Maine weather was unusually warm from September through the end of 2016. The combined effect was a dramatic reduction in the period of ice cover for many Maine lakes, especially in southern Maine. And as many who enjoy skating and fishing on ice will recall, the thickness of the ice was only marginally safe for recreation last winter!

By the middle of March, VLMP lake monitors (and others) started reporting ice-out conditions in southern Maine – up to one month earlier than the historical average for many lakes. These observations can be viewed at: www.mainevlmp.org/near-real-time-lake-data/#iceout.

By early summer, lake monitors in southern Maine reported unusually low water levels for many lakes, ostensibly due to the lack of winter snow melt and spring rain, followed by early ice-out. The effects of lower-than-average lake water level vary, depending on the slope of the lake bottom along shoreline areas. The photo below, taken by Bill Baxter on Swan Lake in July clearly illustrates the effect of low water level in lakeshore areas where the bottom is relatively shallow. The impact of drought upon recreation is evident in this photo.

During the course of the summer, lake monitors and lake shoreline communities reported concerns over what many referred to as "more green cotton-candy algae (metaphyton) than they had observed in the past." Public awareness, and concern over metaphyton during the past decade suggests that there *has* been an overall increase in the abundance of this type of littoral algae in Maine lakes. Nearly all of the information on metaphyton abundance in Maine lakes is anecdotal/observational. However, when many individuals representing numerous bodies of water report similar observations, it is not unreasonable to assume that they accurately reflect the occurrence of a phenomenon such as this one.

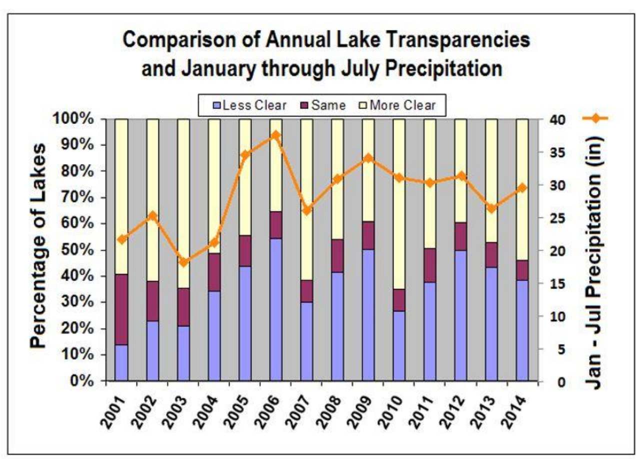
The ecology of metaphyton in lakes is not well understood. *Based once again on qualitative observation, there appears to be a relationship between the annual/seasonal abundance of metaphyton in lakes, and early ice-out, which generally results in earlier sunlight and warming of littoral (shallow) areas.* If that relationship does exist, the early melting of lake ice in March could be related to widespread greater abundance in metaphyton last summer. An increase in metaphyton may be linked to changing conditions associated with climate change.

Drought, and associated prolonged low lake water level can result in the exposure of large littoral areas that support native aquatic plants (aka: macrophytes) to drying and freezing conditions, threatening the health of many beneficial ecosystem functions supported by native lake plants. Rooted lake plants physically stabilize lake-bottom sediments, reducing turbidity from wind and wave action. They also tie-up nutrients that could otherwise be available to less desirable cyanobacteria (aka blue-green algae). Lake plants also protect shoreline areas from the erosive effects of wind and wave action, and they provide structural habitat and food for fish and aquatic insects. Extended periods of low lake water level can cause negative short and long-term effects for beneficial lake plants.

Low lake levels caused by drought can also "de-water" wetlands adjacent to lakes, impacting the many benefits that they provide to healthy lake ecosystems.

The effects of drought on lake water quality vary over time, and from one lake to the next. *In the short-term, many lakes may become clearer, because lack of precipitation means less stormwater runoff, and runoff is the "vehicle" that transports pollutants, such as the nutrient phosphorus, eroded soil particles (and much more) to lakes from their watersheds.*

The adjacent graphic illustrates the relationship between annual precipitation from January through July, and lake water clarity (Secchi transparency) for several hundred Maine lakes from 2001-2014. The chart suggests that many (but not all) lakes tend to be clearer during dry years, and less clear during years of greater precipitation during the period from January through July.



Last summer, many certified lake monitors reported unusually deep Secchi readings for their lakes. Volunteer lake data are still coming in, and it will be several weeks before we know how the 2016 data compare to previous years. However, given the intensity of the drought prior to and throughout the summer, it is likely that a relatively high percentage of Maine lakes will be shown to have been clearer than their historical average during the past several months. Algal growth in this group of lakes is most strongly influenced by external (watershed) sources of phosphorus. They are typically lakes that have relatively low concentrations of phosphorus, and are therefore easily influenced by incoming sources from the watershed.

However, the image above also shows that while a majority of lakes are generally clearer during dry years, some are not. Lack of precipitation is often associated with warm air and water temperatures. And early ice-loss, higher lake water temperatures, and lower water levels can result in an increase in the duration of the period of thermal stratification. This can result in lower summer dissolved oxygen levels in the deepest thermal layer of lakes, which in turn can trigger the release of phosphorus from bottom sediments in some lakes, leading to a phenomenon known as "internal phosphorus recycling." *Lakes that have existing moderate concentrations of phosphorus, and resulting low Secchi readings, due to the internal release of phosphorus may be less clear during dry years, because even though stormwater runoff from the watersheds of this group of lakes contains phosphorus, the concentration is lower than what already exists in the lake, and flushing from stormwater runoff tends to lower the in-lake concentration through dilution.*

Another negative influence of the lack of precipitation is reduced natural flushing, resulting in an increase water residence time and greater evaporation which can concentrate any existing pollutants in all lakes.

Moderate phosphorus levels and warmer water temperatures associated with drought can also facilitate a shift in the balance of algae in lake water toward cyanobacteria (aka bluegreen algae), which may be associated with the release of toxins. "Harmful algal blooms" (HAB's) are more likely to occur from warming in general, and may or may not be associated with drought or excess runoff.

Drought offers us a vision of possible clearer lakes, if we are able to effectively protect them from watershed pollutants– especially phosphorus and sediment. But the effects of prolonged drought on wetlands and beneficial native plant communities is less certain, and remains to be seen.

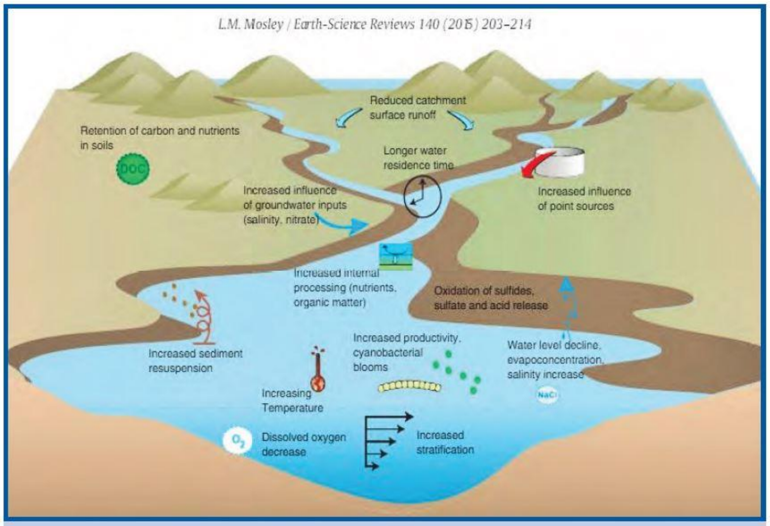


Illustration Source: Drought impacts on the water quality of freshwater systems; review and integration; 2015; Luke M. Mosley; Water Quality Science, PO Box 310, Belair, SA 5052, Australia.

The image above is a conceptual representation that summarizes common processes that influence water quality during drought.

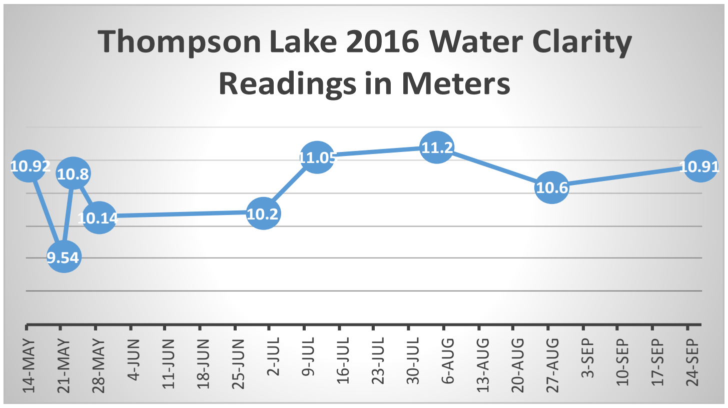
**Excerpted from a recent article authored by Scott Williams for the Maine Volunteer Lake Monitoring Program*

Another critical factor that influences the sensitivity and vulnerability of individual lakes is the amount of time that it takes for a lake to completely "flush" or replace the water in the lake basin. Lake flushing rate is based on the volume of the lake basin, the area of the watershed and the average annual precipitation. The lower the flushing rate, the longer water is retained in the lake. Lakes that flush slowly, like Thompson (which takes more than 3 years to replace all of the water in the basin) are more sensitive to phosphorus, because of the amount of time that it takes to replace the water.

2016 Water Quality Monitoring Summary:
A key indicator of biological productivity in lake systems is water clarity (aka Secchi transparency) Lake clarity is primarily influenced by the concentration of algae in the water. However, suspended sediment particles from eroded soil in the watershed can at times also influence clarity. *The clarity of the water in Thompson Lake was consistently above average for the lake throughout the 5 month monitoring season in 2016.*

Water Clarity: During the course of the monitoring season, the distance that one could see down into the water from the lake surface (aka: Secchi transparency) varied from a very high (good) reading of 11.2 (more than 36 feet!) meters on August 4, to the lowest reading of the season – 9.54 (~31 feet) meters, taken by Ron Armontrout, on May 21, which, although the lowest reading of the season, was a very good reading by any lake standard.

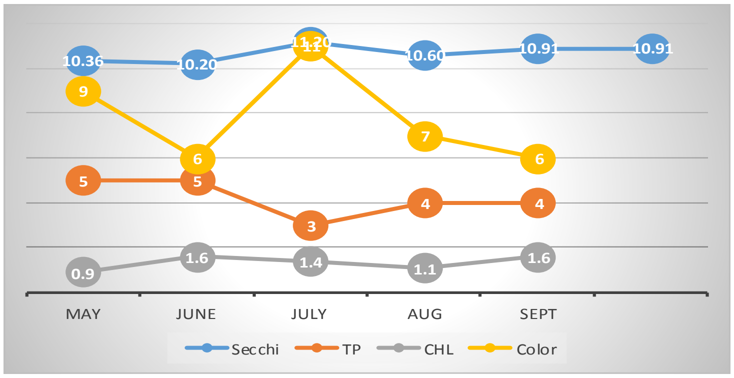
Historical water clarity data for Thompson have shown on many occasions that the lake is very sensitive to heavy rain events and stormwater runoff, often resulting in rapid measurable negative changes in water clarity, and that, conversely, the lake tends to be clearer during periods of low precipitation and runoff. *The average for the May through September period was 10.7 meters (about 35 feet!), which is nearly two meters higher/better/clearer than the Thompson Lake historical average of 9.0 meters! 2016 is tied with 2003 for the two clearest years on record for the lake.* The previous five years had shown a short-term decline in Thompson's water clarity. *The remarkable increase in lake clarity during the past two years is almost certainly influenced by drought conditions, and to reduced stormwater runoff from the watershed during that period.*



<u>Total Phosphorus:</u> The concentration of the nutrient phosphorus in lake water largely determines the growth of algae in the water, which in turn influences water clarity and oxygen levels. The average concentration of total phosphorus (TP = combined organic and inorganic forms) in the lake in 2016 was 4 parts per billion (ppb). The historical average for the lake is 5 ppb. During the course of the 5 month monitoring period, TP varied from a very low concentration of 3 ppb in July, to a high of 5 ppb in May and June. Annual phosphorus concentrations in Thompson Lake since 1980 have ranged from a low of 3 ppb in 2009 to a high of 11 ppb in 1994.

<u>Chlorophyll-a:</u> *The average concentration of chlorophyll-a, (CHL) a direct measurement of algae growth in the water was 1.3ppb, which is the lowest annual concentration on record for Thompson Lake!* The lowest reading for the season was 0.9 ppb in May, and the highest was 1.6 ppb in both June and September. This very low indication of planktonic algae growth in the lake in 2016 was consistent with the exceptionally clear water and relatively low phosphorus.

It is worth noting that while over time there is generally good correlation between water clarity and the concentration of total phosphorus and chlorophyll-a in lake water, the inter-related physical, chemical and biological processes that are represented through the water quality data do not necessarily correlate well when viewed as single monthly readings/samples. During a typical lake monitoring season, the sampling represents an instantaneous "snapshot" of conditions in the lake when the samples and readings were taken. But lake ecosystems are highly variable and dynamic, resulting in what may appear to be (and very likely are) temporal phase discontinuity between the indicators.

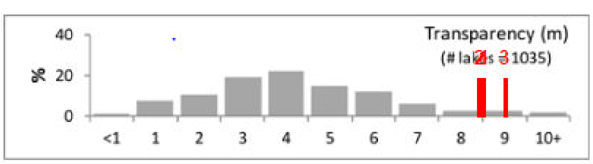


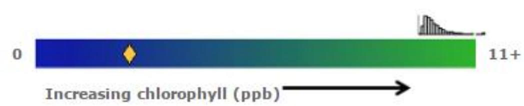
Monthly results for key indicators of lake water quality in 2016:
Secchi Transparency in Meters; Total Phosphorus (TP), and Chlorophyll-a in ppb; Color in SPU

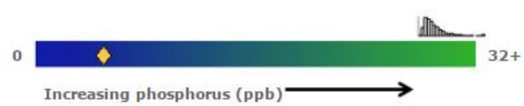
The chart above illustrates the three trophic state indicators that were measured throughout the 2016 lake monitoring (measurements of lake biological productivity): Secchi transparency (water clarity), total phosphorus, and chlorophyll-a. Also shown is the concentration of natural color in the water during the period – an indication of the concentration of humic acids in the water, influenced primarily by the leaching of organic compounds from wetland vegetation in the watershed. High concentrations of lake color can have a complex influence on the trophic indicators. But the color concentration in Thompson is relatively averaging about 9SPU’s over the history of data collection from 1980- present. Some lake scientists have hypothesized that climate change is likely to cause an increase in humic acid in lakes over time, resulting in the “browning” of lakes, as well as dysfunction for physical, chemical and biological processes in lake systems.

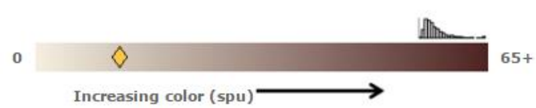
The series of bar graphics to the right show the Thompson Lake historical average (yellow diamond) for each of the four water quality indicators. Each bar represents a range, or continuum of values for the indicator shown, increasing from left to right. The historical averages may vary substantially from averages for individual years, as was the case in 2016.

Histograms, illustrating the frequency distribution for each indicator, can be viewed at www.lakesofmaine.org The transparency histogram for Thompson Lake is illustrated below. The red bars indicate the sampling station. This graphic illustrates that the exceptional water clarity for Thompson Lake occurs only in a small percentage of Maine lakes.

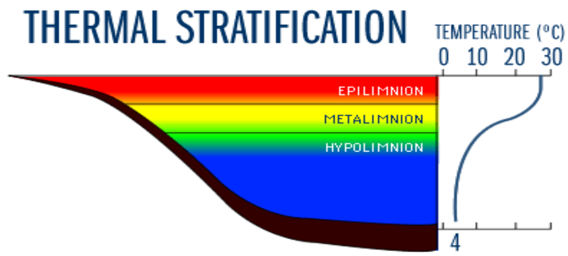








Dissolved Oxygen:
The amount of oxygen that is dissolved in the water in the deepest area of a lake during the late summer and early fall, until the lake mixes or "turns over" is a critical indicator of overall lake health. Thompson Lake has maintained high levels of dissolved oxygen through the summer/fall period for as long as data have been collected for the lake – even in the deepest, and most critical location of the "deep station" near Hayes Point. This characteristic of exceptional water quality is the primary factor that allows coldwater fish to thrive in this lake.



One climate-related factor that may negatively influence this process is the lengthening of the period of time during the year when the lake is free of ice cover. Warm ambient temperatures in the fall may cause deep lakes like Thompson to "turn over", or mix, in the fall, resulting in a longer period of time when the hypolimnion (deep, cold layer) is isolated from the atmosphere. Late mixing of the water in the fall could, and likely, will, result in lower dissolved oxygen levels prior to mixing. Earlier "ice-out" in the spring will likely result in the earlier onset of stratification. When combined with late mixing (destratification) in the fall, oxygen levels in the deepest area of the lake will likely be lower at a critical time of the year for the coldwater fishery. Dissolved oxygen levels in Thompson Lake are currently high throughout the year, due primarily to low biological productivity, thereby providing the fishery and water quality with somewhat of a "buffer" against change.

"Ice-out" occurred relatively early in 2016, which could have resulted in a significant lengthening of the period of thermal stratification, which, in turn, could have caused late summer dissolved oxygen concentrations to be reduced in the deepest area of the lake. However, following the melting of the ice in the spring, several weeks of relatively cool, windy weather was likely to have slowed the warming of the lake, and delayed what might otherwise have been an extended period of stratification.

Conductivity is a measure of the ability of lake water to pass an electrical current. It is a measure of the concentration of ions in the water. As lake watersheds become more developed, and indicators of water quality show evidence of a negative change, conductivity concentration generally increases. The historical conductivity concentration in Thompson Lake is 38 ms/cm, based on eight samples taken since the 1970's. A sample taken in August, 2016 measured 50 ms/cm. This increase over the historical average may be the result of the concentration of ions in the lake as evaporation occurred, resulting from the severe drought. The lake level in late summer and early fall appeared to be unusually low in 2016.

Gloeotrichia:
We continued to monitor the presence of Gloeotrichia in Thompson Lake in 2016. This blue-green algae has often appeared in Thompson historically at low densities during mid to late summer. "Gloeo" colonies are typically observed relatively close to the water surface, having the appearance of tiny, fuzzy, green-white dots. Gloeotrichia is sometimes described as having the appearance of "tapioca in lake water". It is found in many lake algal communities throughout Maine. However, Gloeo may be increasing in some lakes, and it has been associated with water quality concerns in a small number Maine lakes in recent years. Gloeo is the subject of current research, in an attempt to determine why it may be more prevalent in Maine lakes in recent years, and possible implications for lake ecosystems.

Monthly observation/measurement of Gloeo density in Thompson documented 0 colonies until August 4 when colonies were reported at low density, consistent with both the timing and density of what has been observed historically in Thompson Lake. Such late summer, low density observations of Gloeo in Thompson Lake have been documented for several decades.

***UPDATE:* TLEA Participates in Pilot Lake Vulnerability Study:** A sustainability grant from the George Mitchell Center at the University of Maine has enabled staff from the Maine Volunteer Lake Monitoring Program, the Maine DEP, the University of Southern Maine, and scientists from the Mitchell Center and VLMP Advisory Board to conduct a critically important pilot study of a small group of Maine lakes (including Thompson) to determine ways in which the chemistry of lake sediments influences lake vulnerability. An equally important factor that is being considered in this process is lake community capacity for effecting stewardship over time.

Representatives of TLEA, and VLMP Certified Lake Monitor, Ron Armontrout, participated in this study in 2015. Also included was the participation by TLEA members in surveys designed to assess community capacity for lake protection. The project is investigating important inter-relationships between physical and social science in the long-term stewardship of Maine lakes. This study will ultimately lead to a significant refinement of Maine's Lake Vulnerability Index. TLEA's role in the pilot study has been, and will continue to be very helpful, benefitting all of Maine's lakes. A second group of lakes were sampled in 2016, and a third is planned for 2017 or 2018, pending the availability of funding. A final report will be published within the next two years, the findings of which will be presented to TLEA.

Summary:
Overall, the water in Thompson Lake was substantially clearer than the historical average for the lake in 2016, and was tied with 2003 as the clearest years on record for the lake. The concentration of phosphorus in the lake was lower (better) than the historical average, and the concentration of algae in the lake was very low –also the lowest (least algae) year on record for Thompson
Thompson Lake continues to exhibit water quality that is significantly above the average for Maine lakes. The number, and complexity of threats to Maine lakes will very likely continue to grow as climate change exacerbates the effects of everything from watershed development to the breadth of invasive species infestations.

It is important to make note of the fact that the drought conditions experienced in 2015 and 2016 represent extreme events that may occur more frequently in the future. The Northeastern area of the U.S. is projected to be "wetter than average" as a result of the influence of climate change. The exceptional conditions in the lake in 2016 could quickly change following extended periods of extreme wet weather. Efforts to identify and mitigate land use problems associated with stormwater runoff from the watershed to the lake will continue to be the most effective way to protect Thompson Lake from the uncertain influences of a changing climate.

TLEA has played a critically important role in protecting the lake for more than four decades. The protection of our lakes is ultimately a local issue, and TLEA has the proven experience and capacity to assume the role of leadership in the Thompson Lake watershed community.

Prepared by Scott Willliams
Senior Limnologist, LWRMA