



LAKE & WATERSHED ASSOCIATES

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2022 Ellis (Roxbury) Pond Water Quality Monitoring and Assessment Report

Executive Summary:

Indicators of water quality for Ellis Pond (aka: Roxbury Pond and Silver Lake) were close to historical averages in 2022. The lake was slightly clearer than average, the concentration of phosphorus, the key nutrient that limits algal growth was the same as the historical average*, and chlorophyll-a, which directly measures algal density, was slightly lower (better than) the historical average for the lake. Late summer dissolved oxygen levels in the deepest area of the lake were very low (depleted) from late July through late August, similar to conditions documented in recent years.

Shorter periods of ice cover (from late fall formation to early spring), 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 the future health of Maine lakes. Ongoing efforts to protect the lake through aggressive watershed conservation initiatives will continue to be essential to the long term health of Ellis (Roxbury) Pond.

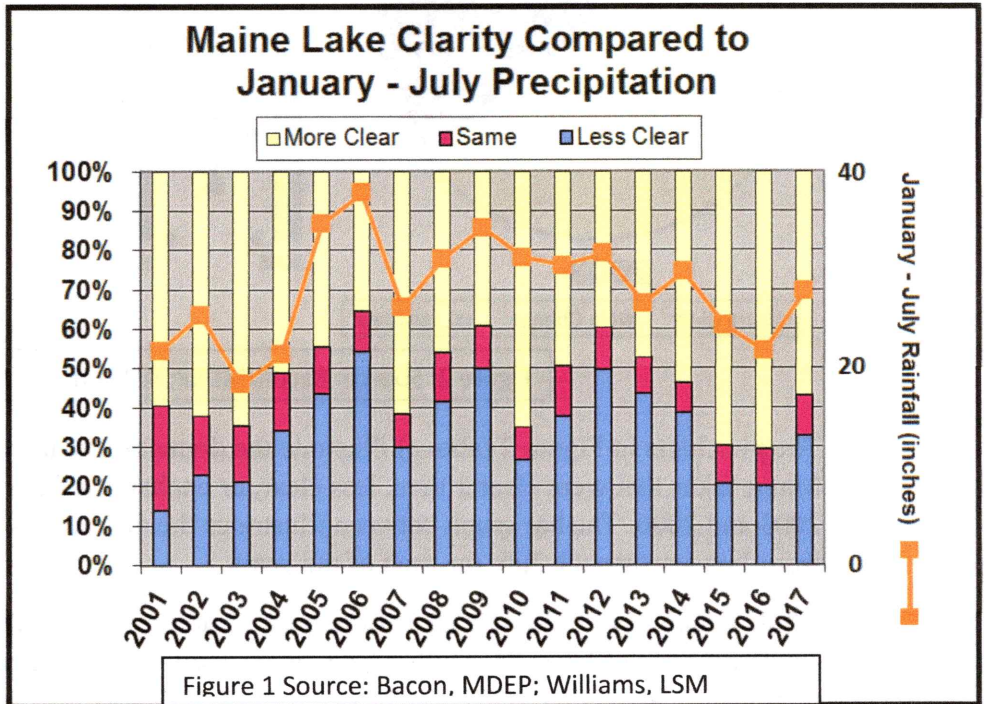
**Based on the historical method (integrated epilimnetic core) that has been used to measure the concentration of phosphorus. Additional surface grab samples were gathered by Ross Swain, the results of which were similar to, and of value, but are not directly comparable to the core method average.*

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.

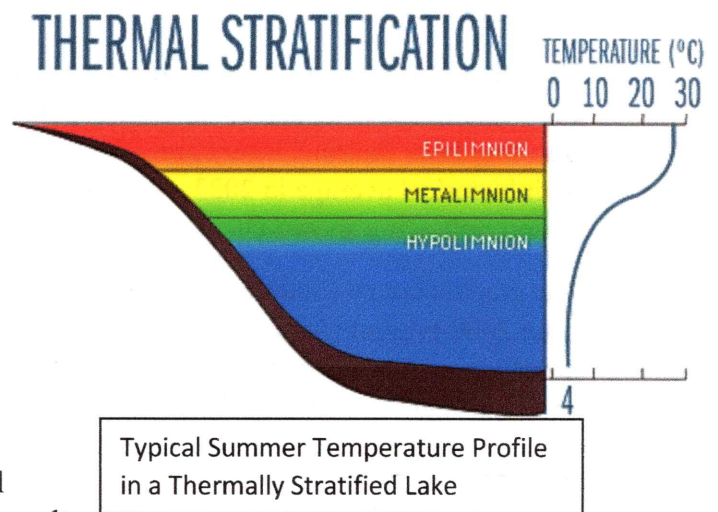
Historically, it has generally been accepted that clearer lake water is an indication of healthy lake ecosystems. This may not always be the case in the era of climate change. Many Maine lakes tend to be clearer during drier years, ostensibly due to reduced stormwater runoff from their watersheds during such periods, resulting in less algal growth. Algae are essential to the overall health and biological diversity of lake ecosystems. A significant decline in algae, combined with warming lake temperatures, may result in

the disruption of lake food webs, and along with rising water temperature, may contribute to stress to fisheries from the loss of critical habitat to greater susceptibility to parasitic infections.

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 greater 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.



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 a substantial increase in planktonic algal growth, and reduced water clarity, especially during the late summer and early fall period.



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

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. Ellis Pond 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 do 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, including the exact times that sampling events occur.

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 Ellis Pond (Figure 3). The lake was slightly clearer than average, based on Secchi transparency data covering 5 months. The concentration of epilimnetic core total phosphorus, the key nutrient that has a bearing on algae growth, was the same as the historical average, and chlorophyll-a, which is a direct measure of planktonic algal density, was slightly lower (better than) the historical average for the lake.

Note that the historical water quality indicator averages for Maine lakes have not been updated by the Maine DEP since 2018.

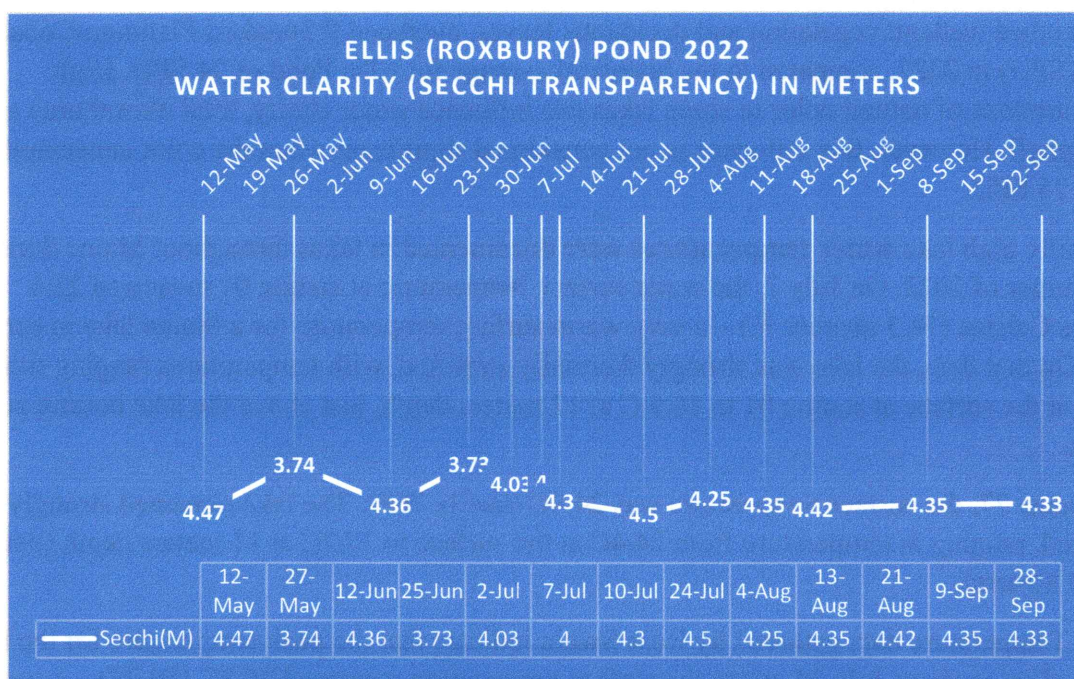


Figure 4

Core **total phosphorus** samples measured 11 ppb on both July 7 and August 13, averaging 11 ppb for 2022, which is also the historical average for the lake.

“Surface grab” phosphorus samples, taken by Ross Swain, measured 10 ppb in June, 9ppb in July and 12 ppb in August. Surface grab samples represent a simple, inexpensive way to estimate the concentration of phosphorus in a lake. However, they are not directly comparable with samples gathered using the epilimnetic core process, which is considered to be a more precise measurement of the available phosphorus in the region of the lake water column where most planktonic algal metabolism takes place. Moreover, nearly all of the historical phosphorus data for the lake have been obtained using the core method. Nonetheless, the three grab samples taken in 2022 average very close to the average for the two core samples.

A total phosphorus sample taken near the bottom of the deepest point in the lake on August 13, when dissolved oxygen was essentially depleted in the deepest two meters of the water column, measured 12 ppb – only 1 ppb higher than in the overlying hypolimnion. This suggests that the lake may have recently mixed (“turned over”), a phenomenon that is common to Ellis Pond as a result of the relatively shallow lake bathymetry (depth profiles), and frequent moderate wind in the area. Mixing can obscure data used to measure the release of phosphorus from anoxic bottom sediments, typically having a diluting effect.

Core **Chlorophyll-a** samples – a direct measurement of the concentration of planktonic algae in the lake, measured 4 ppb on July 7, and 3 ppb on August 13, averaging 3.5 ppb, compared to the historical average of 4.2 ppb.

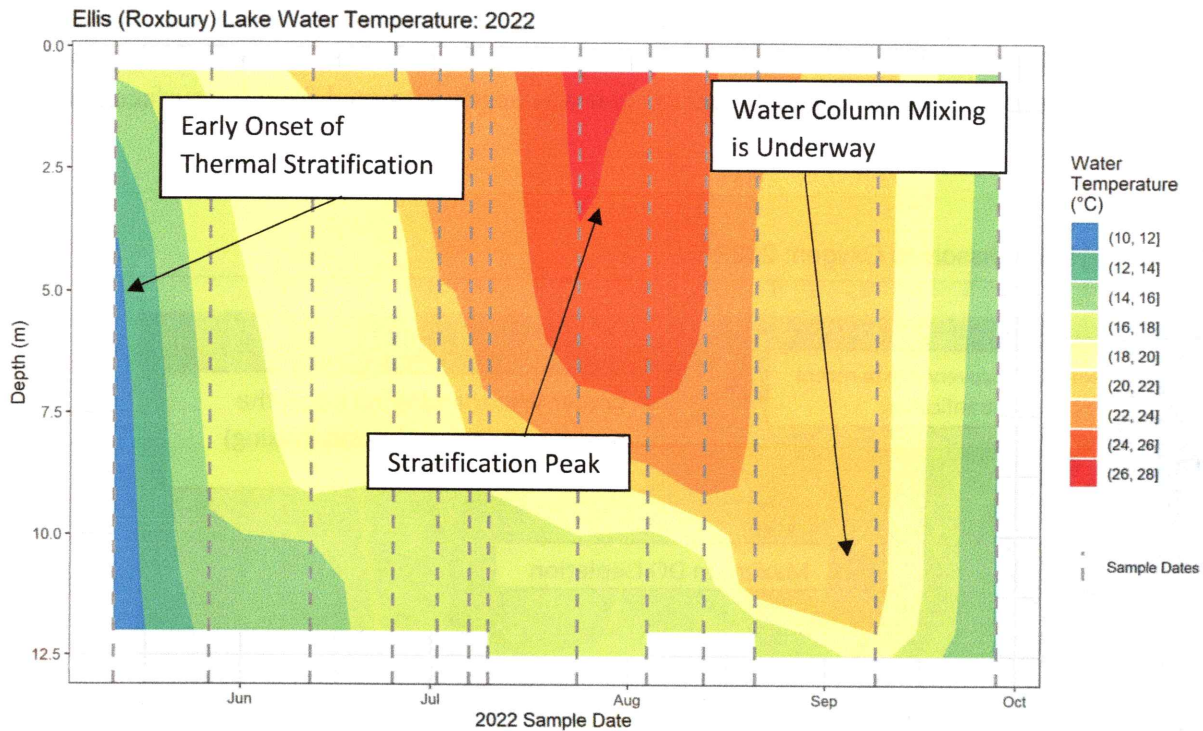


Figure 5: Heat Map of Water Temperature at Station 01 from May through September, 2022

Figure 6 is a contour map that illustrates the variability of **dissolved oxygen (DO)** in the water column at the deep station monitoring site from May through September. The graphic shows the relatively high DO throughout the water column in May.

The solubility of oxygen in water is inversely related to water temperature. If all other factors were held constant, the coldest water in the lake would always have the highest concentration of DO. However, other factors, including microbial decomposition of organic matter, also have a bearing on DO concentration in lakes, and partial or complete mixing of the water column can result in a diluting effect on DO, and anoxic water from the deepest region mixes with the high DO overlying water.

By June 12, the concentration of DO in the deepest 3 meters of the water column had dropped substantially, relative to the temperature. However, by June 25, the temperature at 12 meters depth had increased by nearly 3 degrees C, and DO had increased, as well, indicating that the lake had recently mixed. During the month of July, the bottom (12M) temperature cooled slowly, and oxygen decreased to 0.0 ppm in the deepest 3 meters by July 24. There was some additional evidence of partial mixing of the water column during the month of August. DO reached the greatest level of depletion on August 4, when the deepest 4 meters of the water column were

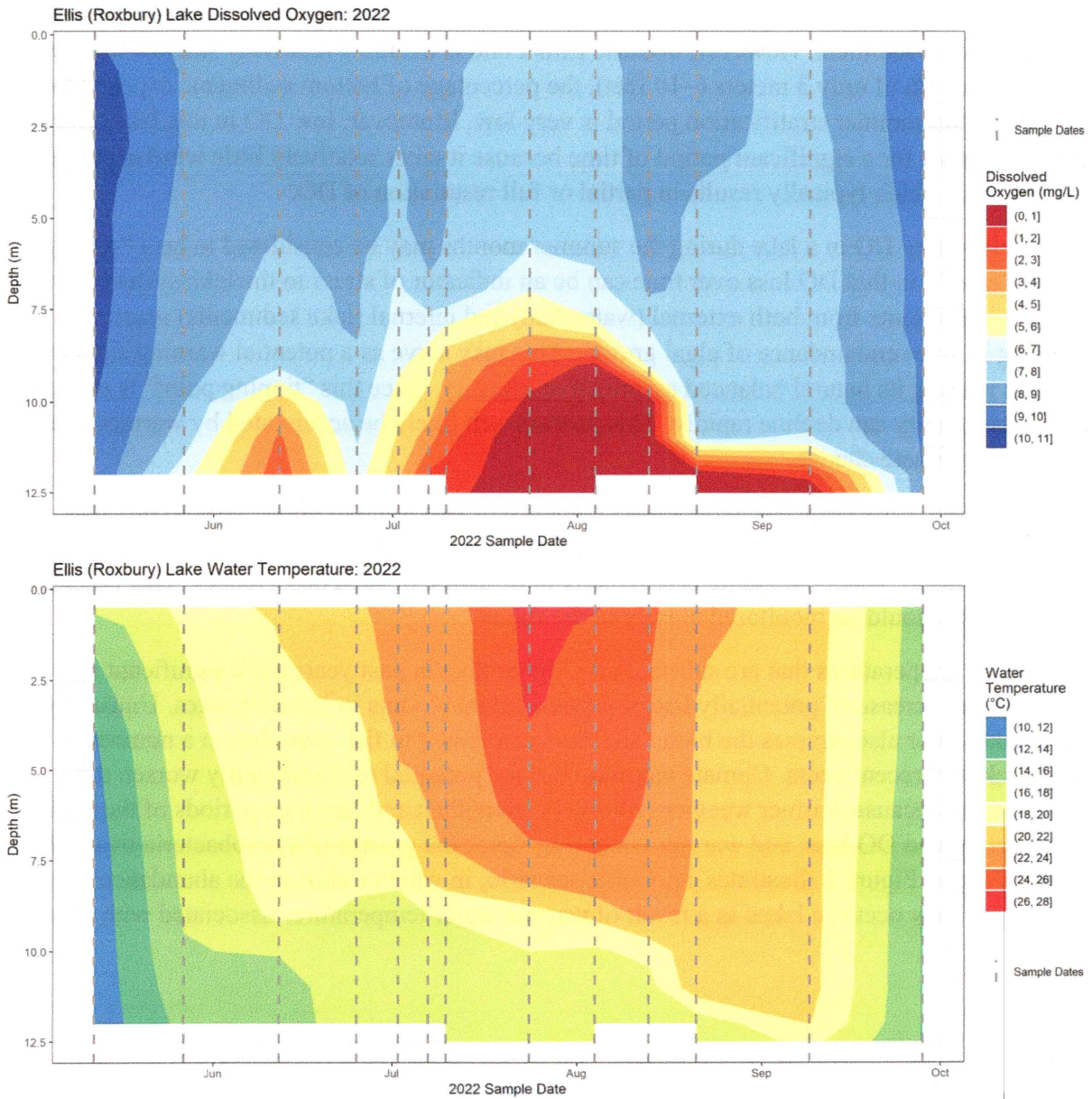
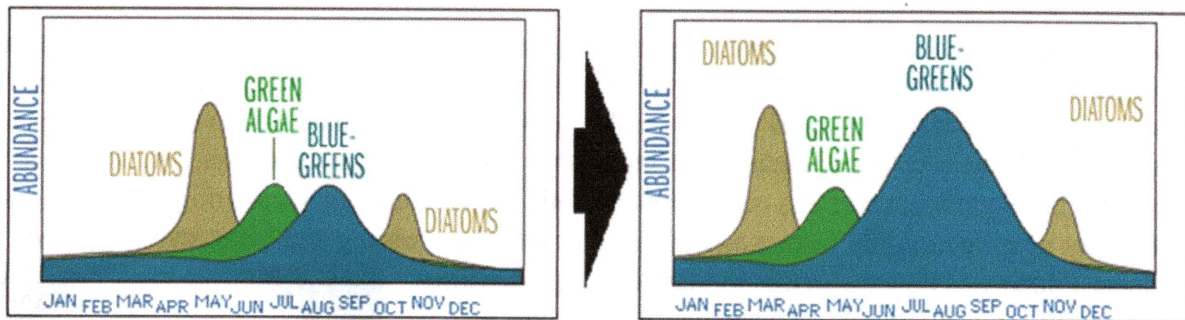


Figure 7: synchronized (timing) maps showing changes in DO associated with water column temperature

Many thanks to Jeremy Deeds (MDEP) for his assistance in generating the heat maps, and to Ross Swain for gathering the May through Sept. Data

Dissolved oxygen is a key indicator of the overall health of lakes. However, the interpretation of oxygen changes in a lake water column is a nuanced process that involves multiple variables. The periods of very low DO that occur in Ellis Pond during the summer month indicate that the lake is moderately biologically productive, which is consistent with water clarity and phosphorus

SEASONAL SUCCESSION OF PHYTOPLANKTON POPULATIONS



Possible increase in duration and abundance of Cyanophytes under climate change scenario of increased lake water temperatures.

Figure 8

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 4 mg/l, compared to the historical average of 5.4 mg/l for Ellis Pond. 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.

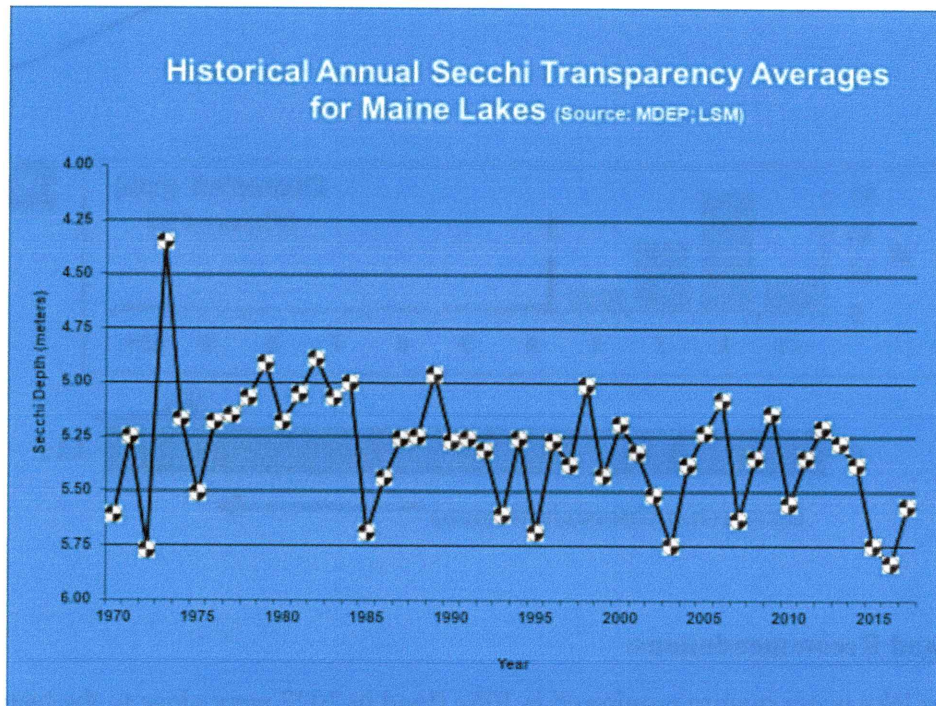
“Metaphyton” is a broad term for a number of species of filamentous algae that form cotton candy-like green/yellow “clouds” in shallow areas of lakes, and streams. Metaphyton occurs naturally, and provides a number of ecological benefits to lake ecosystems. The algae that constitute metaphyton are common 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.



Metaphyton abundance is difficult to quantify in individual lakes because this alga is not uniformly distributed throughout the body of water. In recent years substantial pockets of metaphyton have been reported and documented by observers in the Ellis Pond community –

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 (better) 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.

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 – often in the late summer and early fall. 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 further accelerate the growth of cyanobacteria (aka: bluegreen algae)

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 Ellis Pond and its watershed will be essential to maintaining the 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 the erosive intensity of stormwater runoff associated with extreme precipitation increases.

Prepared by Lake & Watershed Associates Senior Limnologist, Scott Williams