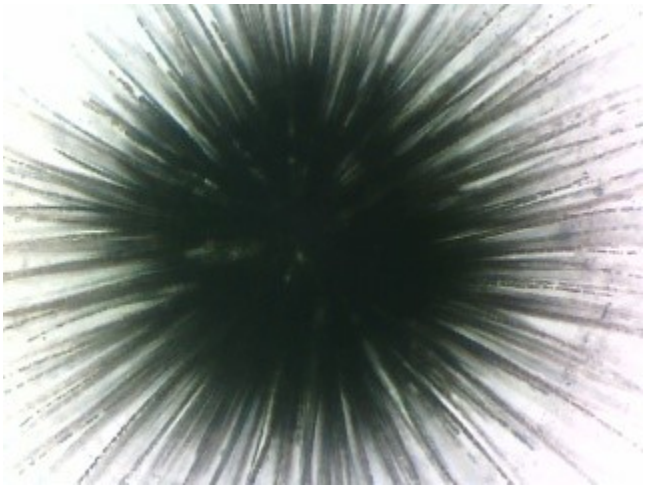
2016
Gloeotrichia echinulata
Monitoring Report

January 17, 2017



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Project Summary

A total of 32 sites on 26 lakes and ponds were monitored for the cyanobacteria (blue-green algae) known as *Gloeotrichia echinulata*, or "Gloeo" in the summer of 2016. This monitoring is part of LEA's advanced testing program which began in 2013. Twenty-four sites were sampled once in late July or early August. The remaining eight sites were sampled between 2 and 5 times approximately once per week between July 18th and August 25th. The sites sampled more than once were on Long Lake (4 sites), Keoka Lake, McWain Pond, Moose Pond, and Peabody Pond. The highest level of Gloeo recorded in 2016 was 58.0 colonies per liter (col/L) in Keoka Lake. The highest level in 2015 was 192.4 col/L in Moose Pond; in 2014 it was 72.4 col/L in Keoka Lake and in 2013 it was 16.6 col/L in Moose Pond. Only two sites, Keoka Lake and the Harrison site on Long Lake, had concentrations above 10 col/L in 2016. Concentrations across the region were similar or even less than in previous years. Variability between years can be explained by weather patterns as well as the "snapshot" nature of sampling, which cannot capture the complexity and rapidly changing nature of Gloeo populations throughout a lake.

Factors that Affect Gloeo Abundance

Light

Like many other species, Gloeo take biological cues from the intensity and duration of sunlight. They can only grow on sediments that are exposed to light. Lake bathymetry (the shape and contours of the lake bed) will control the area of the lake that is shallow enough for light to reach the bottom (known as the littoral zone). Lake clarity and color also impact how deep light can penetrate. Low clarity and/or high color mean that less of the lake bottom is exposed to light.

Temperature

Cyanobacteria, including Gloeo, have higher optimum temperatures than other algae types. Comparison of the population peak and seasonal temperature peak suggest that high temperatures influence the timing of Gloeo blooms. Climate change is causing temperatures to rise over time, which could explain why Gloeo may be becoming more prevalent in the Northeastern US.

Nutrients

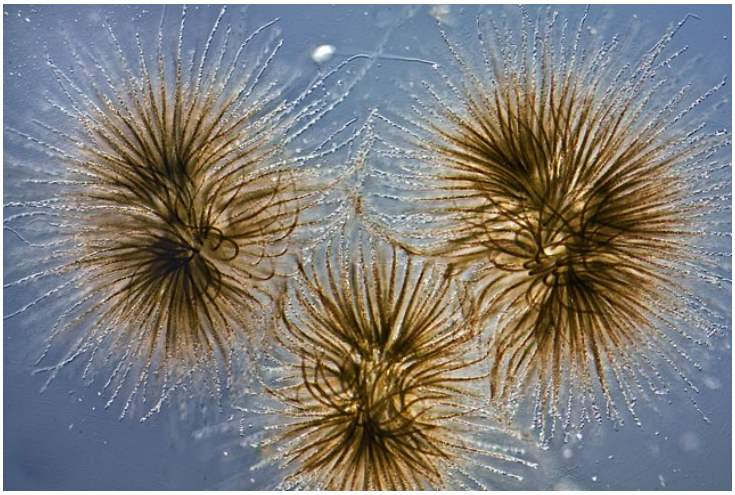
The quality and availability of nutrients within the sediment strongly influences Gloeo growth. Most cyanobacteria do not thrive in low-nutrient lakes because they rely on high phosphorus levels within the water. Unlike most algae, Gloeo cells divide primarily on lake sediments rather than in the water itself. Sediments contain relatively large amounts of phosphorus, which Gloeo use to grow before floating from the sediment into the water column when they mature. The algae cells can also store excess phosphorus which is used to reproduce once they are buoyant.

Introduction and Background

Gloeotrichia echinulata ("Gloeo") is a colonial cyanobacteria species. Each colony is made up of numerous hair-like filaments that radiate outward, creating the characteristic "fuzzy ball" appearance of this species. The colonies are approximately 1-3 mm in diameter and tend to be free-floating in the water column, only forming surface scums at extremely high concentrations. Cyanobacteria, also known as blue-green algae, can cause harmful algal blooms in freshwater. Several cyanobacterial species, including Gloeo, are capable of producing toxins that are harmful to animals and humans. They are more persistent than other types of algae and outcompete other species when nutrient levels are high. While they are often referred to as a type of algae (including in this report), cyanobacteria are actually photosynthetic bacteria.

Algal blooms are often a sign of water quality problems in lake systems. They tend to affect lakes in warmer climates or in heavily developed or agricultural areas with high nutrient levels. However, Gloeo blooms are different. Unlike most other cyanobacteria, they are able to grow successfully in temperate, low-nutrient lakes such as those in the Lakes Region. This is because they have a different life history strategy than most other algae—they reproduce and grow mainly on the sediment before becoming buoyant and floating into the water column. Sediment is a phosphorus sink and harbors larger amounts of the nutrient than the water column, meaning that Gloeo can grow in otherwise nutrient-poor lakes. They also take advantage of the high clarity that exists in many of our lakes. The clearer the water, the greater the area of sediment exposed to light and the more area this species has to grow.

Researchers are concerned that Gloeo may be increasing nutrient levels and algae growth within lakes by moving phosphorus from the bottom of the lake up into the water column, where it can be used by other algae. Gloeo blooms are generally short-lived, lasting only about 2 weeks in late July and early August. Smaller amounts of the algae can be seen in early July and persist into September. Anecdotal reports indicate an increase in Gloeo abundance within New England over the last decade or two. While it has always been a part of the algae community in many lakes, increasing temperatures due to climate change may be exacerbating growth.



Three Gloeo colonies magnified by a microscope

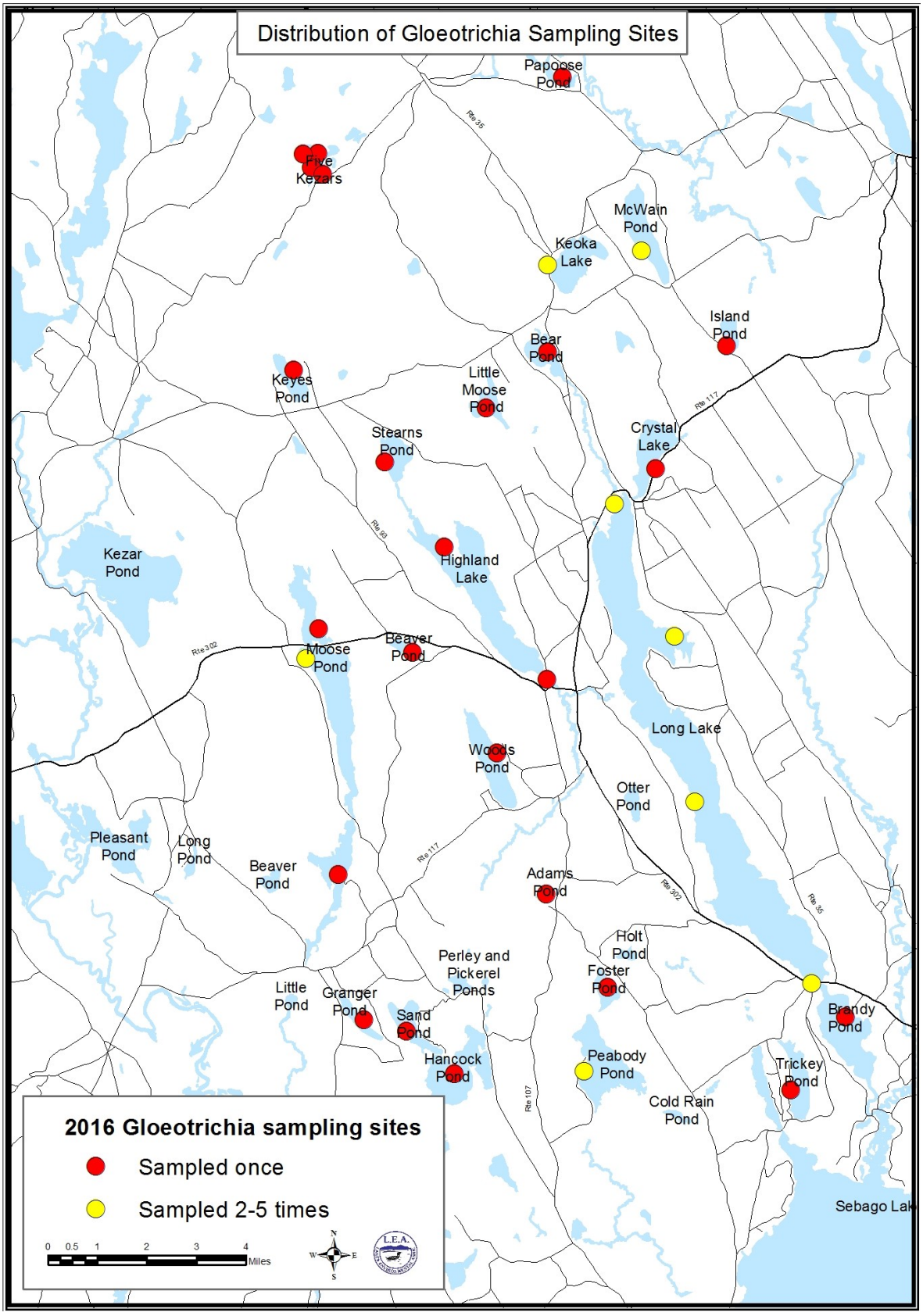


Figure 1. Map of 2016 *Gloeotrichia* sampling sites, located on lakes and ponds in the towns of Demark, Naples, Bridgton, Sweden, Waterford, and Harrison, Maine. Map shows sites sampled once per year in red and more than once per year in yellow.

Sampling Methods

Eight sites on five lakes and ponds in the western Maine Lakes Region were sampled between 2 and 5 times in July and August of 2016. Sample scheduling was intended to coincide with the peak in Gloeo population, which was determined based on data from the 2013—2015 sampling seasons and previous studies. The sites sampled multiple times were Long Lake (4 sites), Keoka Lake, McWain Pond, Moose Pond (main basin), and Peabody Pond. These lakes have consistently had the highest Gloeo concentrations in the region.

Twenty-four additional sites were sampled once during the anticipated peak in Gloeo abundance in late July/early August. These included Adams Pond, Back Pond, Bear Pond, Beaver Pond (Bridgton), Brandy Pond, Crystal Lake, Foster Pond, Granger Pond, Hancock Pond, Highland Lake (2 sites), Island Pond, Jewett Pond, Keyes Pond, Little Moose Pond, Middle Pond, Moose Pond (north and south basins), Mud Pond, Papoose Pond, Sand Pond, Stearns Pond, Trickey Pond, and Woods Pond (see Figure 1 on previous page). These sites had little to no Gloeo (defined as <5 col/L) when sampled in previous years.

Samples were collected using a plankton net with 80 µm mesh. The sites where samples were collected remained consistent throughout the season and between years. All sites were located in shallow areas between 2 – 3.5 meters in depth. Two 1-meter deep tows were collected for each sample and rinsed into a 125 mL opaque bottle, then preserved with approximately 2 ml of Lugol's solution. Samples were counted using a stereomicroscope at 10 – 30x magnification. A total of 56 samples were counted in 2016.

Collecting a sample using a plankton net.

Table 1. Comparison of peak Gloeo concentrations in all lakes tested from 2013—2016.

Lake Name	Max. 2013 colonies/L	Max. 2014 colonies/L	Max. 2015 colonies/L	Max. 2016 colonies/L
Adams Pond	Not tested	0	0	0
Back Pond	0.1	0	0	0
Bear Pond	Not tested	0.3	0.2	3.9
Beaver Pond (Bridgton)	Not tested	0	0	0
Brandy Pond	Not tested	2.1	4.1	0.8
Crystal Lake	2.3	3.3	1.2	1.7
Foster Pond	Not tested	0	0	0
Granger Pond	0	0	0	0
Hancock Pond	0	0	0	0
Highland Lake, Public Launch	0	0	0.1	0
Highland Lake, Highland Point	0	0	0	0
Island Pond	0	0	0	0
Jewett Pond	Not tested	Not tested	Not tested	0
Keoka Lake	6.1	72.4	5.5	58
Keyes Pond	0	0	0	0
Long Lake (Harrison)	2.4	33.9	42.2	15.2
Long Lake (Cape Monday)	1.9	17.5	6.1	4.2
Long Lake (Bridgton)	8.0	20.6	5.3	9.6
Long Lake (Naples)	6.9	16.3	4.1	6.7
Little Moose Pond	Not tested	0	0	0
McWain Pond	9.4	26.3	12.8	4.1
Middle Pond	Not tested	0	0	0
Moose Pond (North Basin)	Not tested	0.9	1.4	0.4
Moose Pond (Middle Basin)	16.6	16.2	192.4	5.8
Moose Pond (South Basin)	Not tested	1.5	1.7	0.1
Mud Pond	Not tested	Not tested	Not tested	0
Papoose Pond	Not tested	0	0	0
Peabody Pond	1.9	2.4	2.2	1.7
Sand Pond	Not tested	0	0	0
Stearns Pond	0	0	0	0
Trickey Pond	0	0	0	0
Woods Pond	0	0	0	0

Results

The highest concentration of Gloeo recorded in 2016 was 58.0 colonies per liter (col/L) on July 27th in Keoka Lake. The Harrison site on Long Lake was the second highest at 15.2 col/L, which was much lower than its 2014 and 2015 peak concentrations. These were the only two sites to have maximum values over 10 col/L. Gloeo concentrations at McWain Pond, Moose Pond, the three remaining Long Lake sites, and Peabody Pond either fell or were similar to 2013-2015 levels (see Table 1 on the previous page and Figure 4 on Page 9).

Of the 24 sites sampled once during the summer, Bear Pond and Crystal Lake were the only sites with greater than 1 col/L of Gloeo present. Levels were still low at 3.9 and 1.7 col/L respectively. Brandy Pond and the north and south basins of Moose Pond both had levels lower than 1 col/L, while the rest of the sites contained 0 col/L.

The timing of the maximum concentration for most sites appears to be similar or slightly earlier than in past years, occurring around the end of July and beginning of August. The first samples collected from Keoka Lake and McWain Pond, both on July 27th, contained their highest levels of Gloeo for the season, so it is possible that the peak in concentration occurred prior to the start of sample collection. If this is the case, then peak concentrations would have occurred earlier than in past years. Moose Pond's peak date was also relatively early, on July 25th. However, all four Long Lake sites reached their highest concentrations on August 3rd, which is right around the usual peak date for lakes in the region (Figure 2).

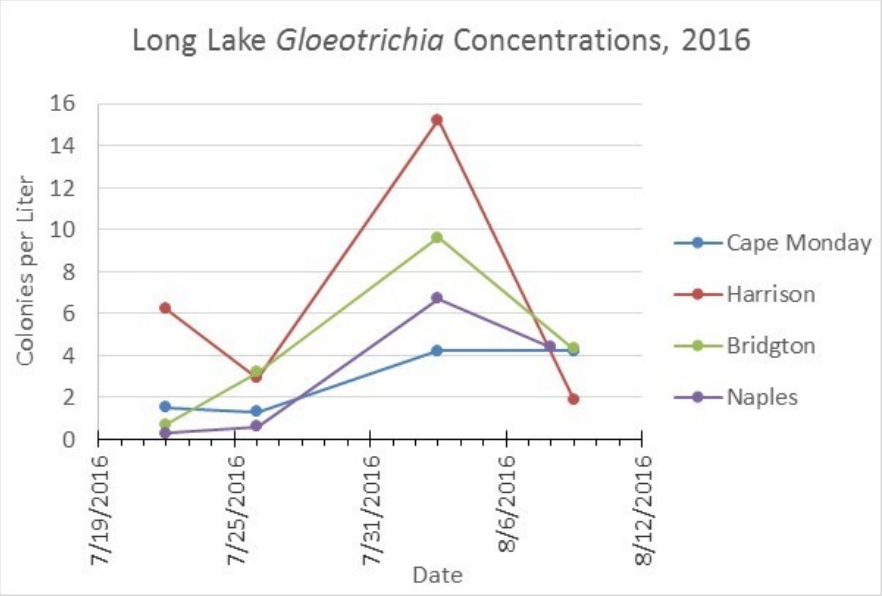


Figure 2. Results of 2016 Long Lake Gloeo sampling. The Cape Monday, Bridgton, and Naples sites remained consistently low in Gloeo (below 10 colonies/liter). The Harrison site had the highest peak concentration at 15.2 col/L.

Results

Figure 3 shows individual sample results as well as season averages for the 8 sites that were tested multiple times in 2016. Keoka Lake and Long Lake in Harrison had the highest maximum and average Gloeo concentrations. Only three samples contained levels over 10 col/L.

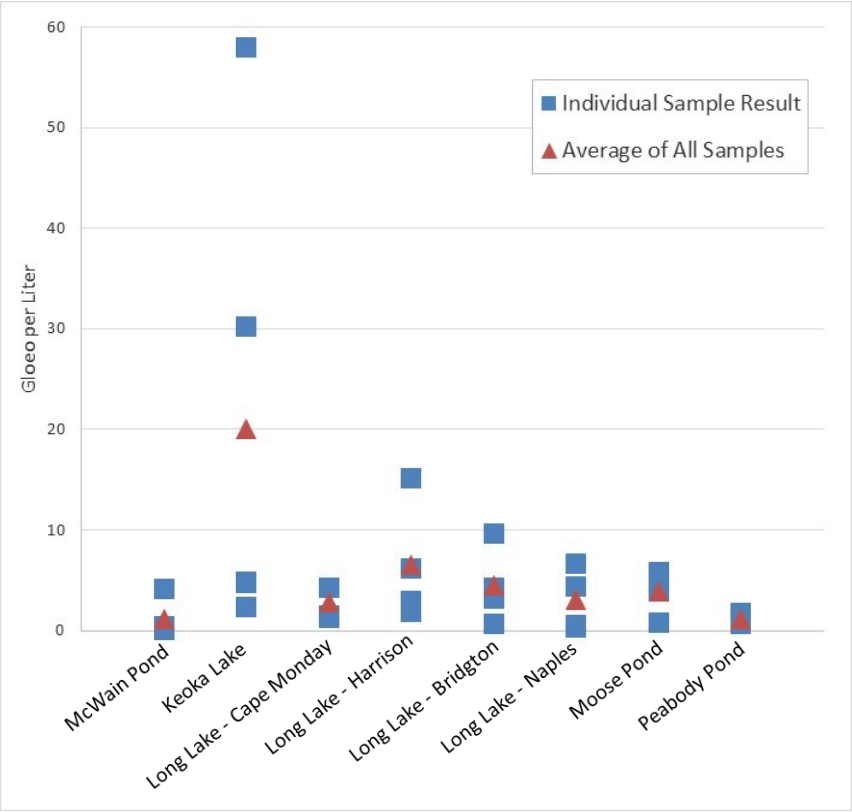
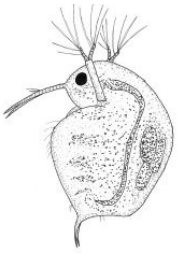
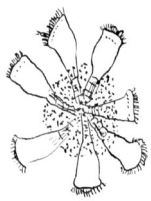


Figure 3. Gloeo concentrations at sampling sites with 2 or more samples taken over the season (each sample is marked by a blue square), as well as the average concentration at each site (red triangles).

Samples counted for Gloeo also contained a variety of other types of plankton, of which there are two kinds. *Phytoplankton* are the algae that live in the water column and use photosynthesis to grow. Examples include green algae, cyanobacteria, dinoflagellates and diatoms. *Zooplankton* are small, insect-like crustaceans that swim in the water column and eat phytoplankton. They include copepods, bosminids, and rotifers, among others. There were a variety of plankton seen in the Gloeo samples, although most of the ones noted were fairly large due to the low magnification used to count samples.



Copepods (bottom left) were common in all of the samples and were almost always the dominant zooplankton. Holopedium, a zooplankton that is causing increasing concern in Canadian lakes due to its competition with Daphnia species, was noted at 12 sites, sometimes being the dominant zooplankton. Conochilus rotifers (bottom right) were common in Moose Pond, which is a trend that has been noted in previous years' samples. Bosminids (top right) were common in Peabody Pond, McWain Pond, and Long Lake.



Results

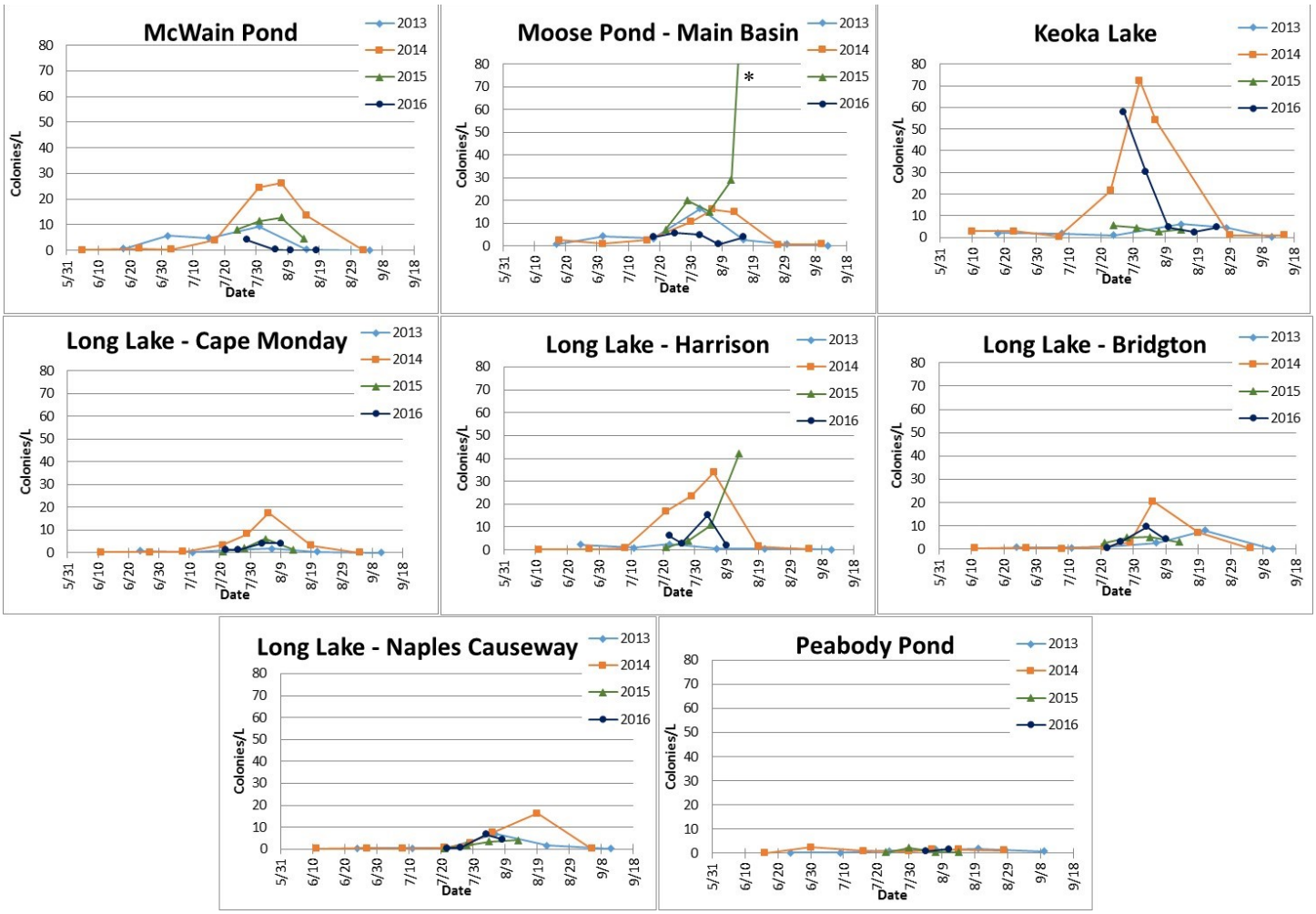


Figure 4. All data from 2013-2016 Gloeo monitoring at sites where samples were taken more than once per season. The graphs have the same scales on both the X and Y axis so the magnitude of Gloeo concentrations can be visualized. *Note: the peak concentration on Moose Pond in 2015 was 192 col/L (not shown on graph).

The graphs in Figure 4 (above) display all of the data collected between 2013—2016 at each site that was sampled for Gloeo more than once per year. Both axes have the same scale, allowing for easy comparison between graphs. The Moose Pond curve for 2015 is cut off due to a high reading of 192 col/L, which was over twice as much as the next highest concentration and would have thrown off the scale if it were included.

Peak levels in 2016 were all lower than historical highs. However, the lakes with and without Gloeo appear to remain the same from year to year. The same four lakes (Long, McWain Pond, Keoka Lake, and Moose Pond) generally have the highest levels every year, although the relative amounts change. A few other sites (Peabody Pond, Crystal Lake, Bear Pond, Brandy Pond) have had consistently low concentrations each year, while the rest have had virtually no Gloeo since sampling began.

Results

Temperature is an important factor which may partially explain the timing of peak Gloeo concentrations. Figure 5 shows 2016 average daily water temperature and Gloeo concentrations from Moose Pond. The peak in temperature occurred on July 29th and the measured Gloeo peak was on July 25th. Note that the "actual" Gloeo peak may have occurred on a date and time that was not sampled. Other lakes had peak concentrations on July 27th and August 3rd; however, no samples were collected between July 28th and 31st.

Moose Pond's relatively low peak concentration of 5.8 col/L on July 25th is in contrast with the 2015 peak of 192 col/L on August 19th, both in terms of concentration and date of occurrence. The peak in temperature in 2015 was delayed significantly by a cold spring, occurring around August 19th. Interestingly, Gloeo peak concentration in Moose Pond in 2015 lined up with the temperature peak, even though it was much later than normal. Gloeo concentrations from all sites in July and early August 2015 were relatively low, except for two samples from later in the season (Moose Pond and Long Lake in Harrison). Unfortunately, sampling was finished by mid-August so it is unknown if more sites had population surges as a result of the warmer temperatures.

Moose Pond was not sampled later than August 16th in 2016, so it unknown if the population increased after this date. However, the concentration on August 16th was less than 4 col/L and it is unlikely that concentrations rose much higher after that date due to the consistently low values throughout the summer and the steady decline in temperature throughout August and September.

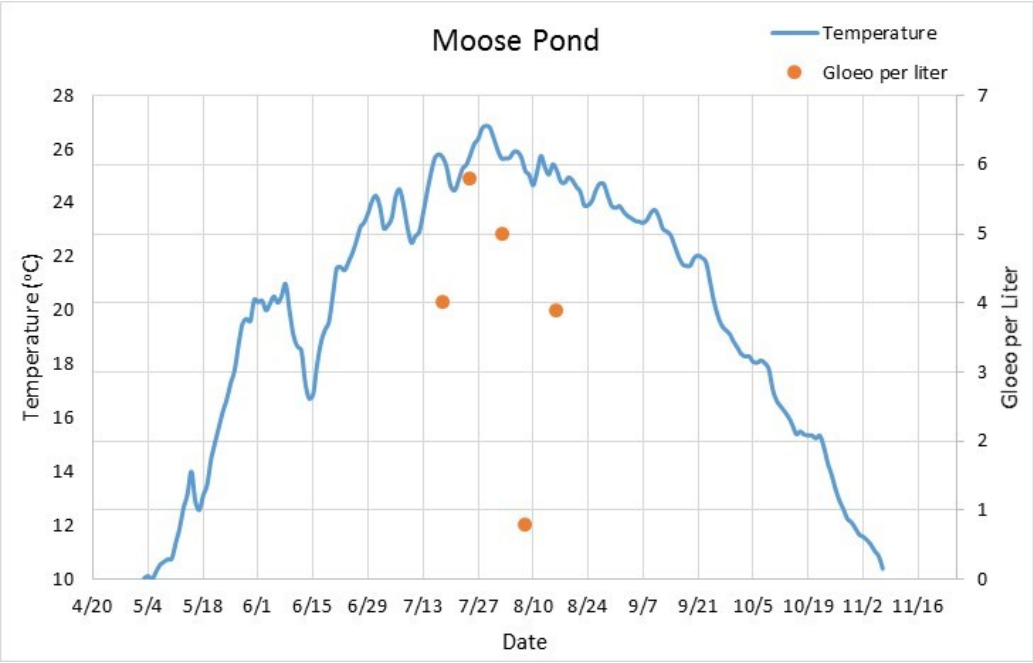


Figure 5. Comparison of 2016 summer daily average surface water temperatures and Gloeo concentrations in Moose Pond.

Discussion

Putting the Results in Context

About 60% of the sites sampled had little to no Gloeo in 2016 and in the previous 3 years of sampling. Ten sites on 7 lakes have had levels above 1 col/L. The good news is that most of these sites have stable, relatively low populations. Only Keoka Lake, Long Lake, Moose Pond, and McWain Pond have had Gloeo levels above 10 col/L in the four years LEA has been monitoring this algae.

Levels of Gloeo under 10 col/ L are generally considered to be low and not a serious concern. However, Gloeo is large compared to most algae that live in the water column. Therefore, very low concentrations—even around 1 col/L—are very visible. This can be an aesthetic concern, but it is not an immediate water quality or human health problem.

Due to the algae's size, concentrations of Gloeo as low as 1 col/L can be seen easily in the water column.

It is also important to put the higher concentrations that have been found into context. Many lakes, even within Maine, have had higher Gloeo concentrations than the lakes studied by LEA. Great Pond and Long Pond, both within the Belgrade Lakes system, contain Gloeo, and levels in excess of 250 colonies per liter have been seen there. Lake Auburn and Panther Pond also have significant populations in most years. Levels well over 1000 colonies per liter have been reported in high nutrient systems in other areas of the world. While sampling, LEA has not encountered green surface scums that form during high concentration Gloeo blooms.

It is thought that Gloeo populations may be increasing in lower-nutrient systems due to climate change. These algae are not "invasive" or "exotic" species, as they have long been present in lakes to varying degrees (Ewing et al., 2009). Sediment cores on several Maine lakes done by researchers at Bates College show that not only has Gloeo been found in low-nutrient Maine lakes since before European settlement, but also that a wide variety of patterns in historical concentrations exist. These patterns are not consistent between lakes over time, which raises further questions about the drivers of Gloeo population dynamics. These differences suggest that smaller-scale interactions and individual lake characteristics play an important role in the ability of this species to proliferate.

Discussion

Observations from 2016 Sampling

2016 was a very dry year with better than average water quality, as measured by surface water phosphorus, chlorophyll, and clarity. Ice out occurred much earlier than average, but a cool and windy spring delayed the set up of stratification and the lack of rain reduced nutrient inputs to the lakes. Gloeo concentrations overall were not as high as in previous years, particularly in McWain Pond and Moose Pond, which both had their lowest maximum concentrations since sampling began in 2013.

Gloeo recruitment (movement from the sediments into the water column) appeared to occur earlier in 2016 than in 2015, which may be related to lake temperature patterns. The relatively late date of maximum water temperature in 2015 was correlated with a later peak in concentration, whereas in 2016 the temperature and Gloeo peaks were also correlated but both occurred almost a month earlier than in 2015.

An important consideration when designing a sampling plan is that Gloeo populations are hugely variable both over time and spatially across lakes. The differing results from the four sites of Long Lake make this clear. This makes it very difficult to accurately assess concentrations for a lake as a whole, especially when collecting only one sample per lake. Because of the tremendous variability within a lake, LEA's sampling is only able to provide a "snapshot" of how much Gloeo is in a certain place at a certain time. The data presented by LEA in this report should be viewed with this in mind.

Patterns in concentration across a lake depend on a number of factors, wind and water currents being two of the most important. Colonies can easily accumulate downwind in coves or near shorelines and just as easily shift to another area when the wind direction changes. Prevailing wind patterns and weather conditions are noted when samples are collected.

Shallow sediment area and substrate quality are also important controls on recruitment. Gloeo can only grow successfully on shallow sediments that receive adequate light inputs and are rich in phosphorus. Lakes with sand and gravel substrate will likely have little of the algae. Lakes that have a high proportion of shallow area (a large littoral zone) are more likely to have Gloeo because of the large area available for their growth. A comparison of the morphological characteristics of Lake Region lakes shows Gloeo appears more commonly in large, deep lakes than in smaller, shallower ones. The reason for this pattern, and why some larger, deep lakes (such as Highland Lake) do not have Gloeo is unknown.

Discussion

Possible Explanations for Results

After 4 years of sampling on multiple lakes in the Lakes Region, it is clear that some basins are not currently able to sustain Gloeo populations. Most of the lakes with noticeable levels of Gloeo are in the same chain of lakes: Keoka Lake, Bear Pond, Crystal Lake, Long Lake, and Brandy Pond are all connected to one another. Moose Pond, Peabody Pond and McWain Pond are the only other ponds with elevated levels in the area. However, we are still not able to definitively answer the question of why Gloeo thrives in some lakes but not others.

Most of the lakes in the area have very similar water quality—moderate to low levels of nutrients and chlorophyll-a and good clarity. Abundance may be related to lake depth or area, and the extent of shallow water areas and sediment quality are factors. In-lake biology and chemistry are also important controls on growth. Aquatic plants, micronutrients, food web interactions, underlying soils and geology, damming and historical land uses are a few of the many factors that could influence where and to what degree Gloeo are present.

As far as year to year variation, just like with other water quality parameters, weather appears to be very important in controlling Gloeo growth. In 2016, dry weather conditions appeared to reduce abundance in most lakes. Most phosphorus enters lakes in the form of runoff during rainstorms. The lack of rain reduced the amount of phosphorus entering the system, meaning there was less for Gloeo colonies on the sediment to uptake.

The overall temperature pattern also appears to affect the timing of recruitment. Peak temperatures correlated with peak Gloeo concentrations in 2015 and 2016, despite the timing of these events differing by almost a month from one year to the next. In 2013 and 2014, Gloeo peak concentrations were slightly later than the peak in temperature. Peak temperature in both years occurred between July 20th and 24th and the peak in Gloeo concentration was between July 29th and August 6th.

Another weather phenomenon that occurred in 2016 which may have affected abundance was a period of very heavy winds for about a week in mid-June. These conditions stirred up sediment and caused large waves, potentially burying Gloeo resting cells (the over-wintering cells that settle onto the sediment and form the next year's bloom) or washing them into deeper water, where the lack of light would prevent their growth.

Discussion

Future Testing

Gloeo monitoring provides an estimate of the impact this algae has in the Lakes Region. Sampling was condensed in 2015 and 2016, which caused us to miss some early and late season activity. In 2017, sampling will be expanded to at least 5 weeks on the four lakes that have historically had the most Gloeo. Due to the time consuming nature of counting each individual sample, there is a limit to the number of samples that can be processed each year. A pilot project involving observations from land owners may be undertaken in 2017 in conjunction with lake associations on Moose Pond, McWain Pond, and Keoka Lake. This will allow us to collect more data about Gloeo blooms and get better spatial coverage of these lakes.

However, monitoring in itself does not answer many deeper questions about why this species of algae appears in certain lakes or how it can be controlled. Future expansion of the scope of Gloeo research at LEA may include looking at sediment quality and area, the effects of aquatic plants and food webs, and a multivariate analysis of the impact of various water quality and hydrological features of lakes. LEA will also continue to work with various groups in the state who study Gloeo.

For more information about our Gloeo program, please visit our website, www.mainelakes.org.

References

Ewing, H, Cottingham, K., Leavitt, P., Carey, C., Rydin, E., & Weathers, K. 2009. Evidence for the early stages of eutrophication in association with Gloeotrichia echinulata in a Maine, USA, lake. *94th ESA Annual Meeting*.

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Keoka Lake Association
McWain Pond Association
Moose Pond Association
Peabody Pond Association
Trickey Pond Environmental Protection Association
Friends of Woods Pond

An anonymous foundation

and all of our members

…for making this project possible with their generous support!

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