2014
Gloeotrichia echinulata Monitoring Report

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Project Summary

A total of 24 lakes and ponds were monitored in the summer of 2014 for the blue-green algae known as *Gloeotrichia echinulata*, or "Gloeo". Eighteen were sampled once during peak growing season in late July or early August. The remaining six lakes were those with the highest 2013 levels of the algae and were sampled every 2 weeks throughout the summer. These lakes were Long Lake, Keoka Lake, McWain Pond, Moose Pond, Peabody Pond, and Crystal Lake. The first three of these lakes had Gloeo levels increase by 3 – 12 times between 2013 and 2014. The highest level was 72.4 colonies per liter in Keoka Lake, contrasting with a high of 16.6 colonies per liter in Moose Pond in 2013. The other three lakes had similar Gloeo levels in 2013 and 2014. The peak in Gloeo population in most lakes came in early August, just after water temperatures had peaked for the season.

Factors that Affect Gloeo Abundance

Light

Like many other species, Gloeo probably take biological cues from the intensity and duration of sunlight. Gloeo can only grow on sediments that are exposed to light. Lake bathymetry (bottom topography) will control the area of the lake that is shallow enough for light to reach (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, prefer higher temperatures than other algae types. Comparison of the Gloeo population peak and seasonal temperature peak suggest that high temperatures trigger Gloeo to rise into the water column. Climate change is causing temperatures to rise over time, which could help explain why more Gloeo is being seen now. It is also troubling because it means that Gloeo could be more prevalent, abundant, and harder to control in the future as temperatures keep rising.

Nutrients

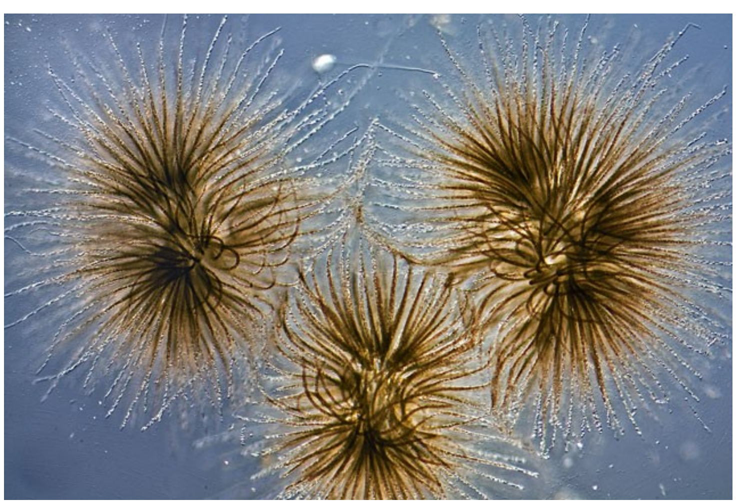
Because Gloeo grow on lake sediments, they are not as constrained by water column phosphorus levels. Most lake sediments do contain high levels of phosphorus. A lack of nutrient-rich sediment in areas with adequate light and temperature levels would be likely to limit Gloeo growth. Lakes may have rocky or sandy sediment with little phosphorus or may not have much "free" phosphorus available for Gloeo to use. Water column phosphorus levels will also affect the population to some extent.

Introduction and Background

Gloeotrichia echinulata ("Gloeo") is a colonial cyanobacterium. Each colony is made up of individual cells with long, hair-like filaments. Under a microscope they look like round, spiky balls. The tiny colonies, which are about 1-3 mm in diameter, tend to be free-floating in the water column, and only form surface scums at extremely high concentrations. The term "cyanobacterium" refers to the type or category of algae that Gloeo fits into. The cyanobacteria, also known as blue-green algae, are perhaps the worst type of algae for water quality. They are more persistent than other types of algae and can also produce toxins that are harmful to animals and humans. Gloeo in particular is able to take up phosphorus from sediments, which may be a key to why it is gaining a foothold in low-nutrient lakes in this region.

Algal blooms are a sign of water quality problems in lake systems. They tend to affect lakes in warmer climates or in areas of high urban development. The fact that Gloeo has appeared relatively recently in western Maine, and in other temperate, low-nutrient lakes in the northeast, is one of the reasons for this study. One possible explanation for this may be climate change. Cyanobacteria have specific light, temperature, and nutrient requirements. Higher water temperatures, caused by climate change, may be allowing Gloeo populations to expand.

Dormant Gloeo cells will survive in harsh conditions for long periods of time. Once favorable conditions are present, they will grow and divide on the sediment in shallow areas of the lake. While phosphorus levels may be low in the water column of this region's lakes, the sediment is a phosphorus sink and harbors large amounts of the nutrient. Gloeo take advantage of this and uptake the phosphorus from the sediment before becoming buoyant and floating into the water column. In this way they are not limited by the low nutrient levels within the water column. The Gloeo die after 2-4 weeks, releasing their stored phosphorus, which could potentially increase other algae growth in the water column and contribute to algal blooms.



Three Gloeo colonies magnified by a microscope

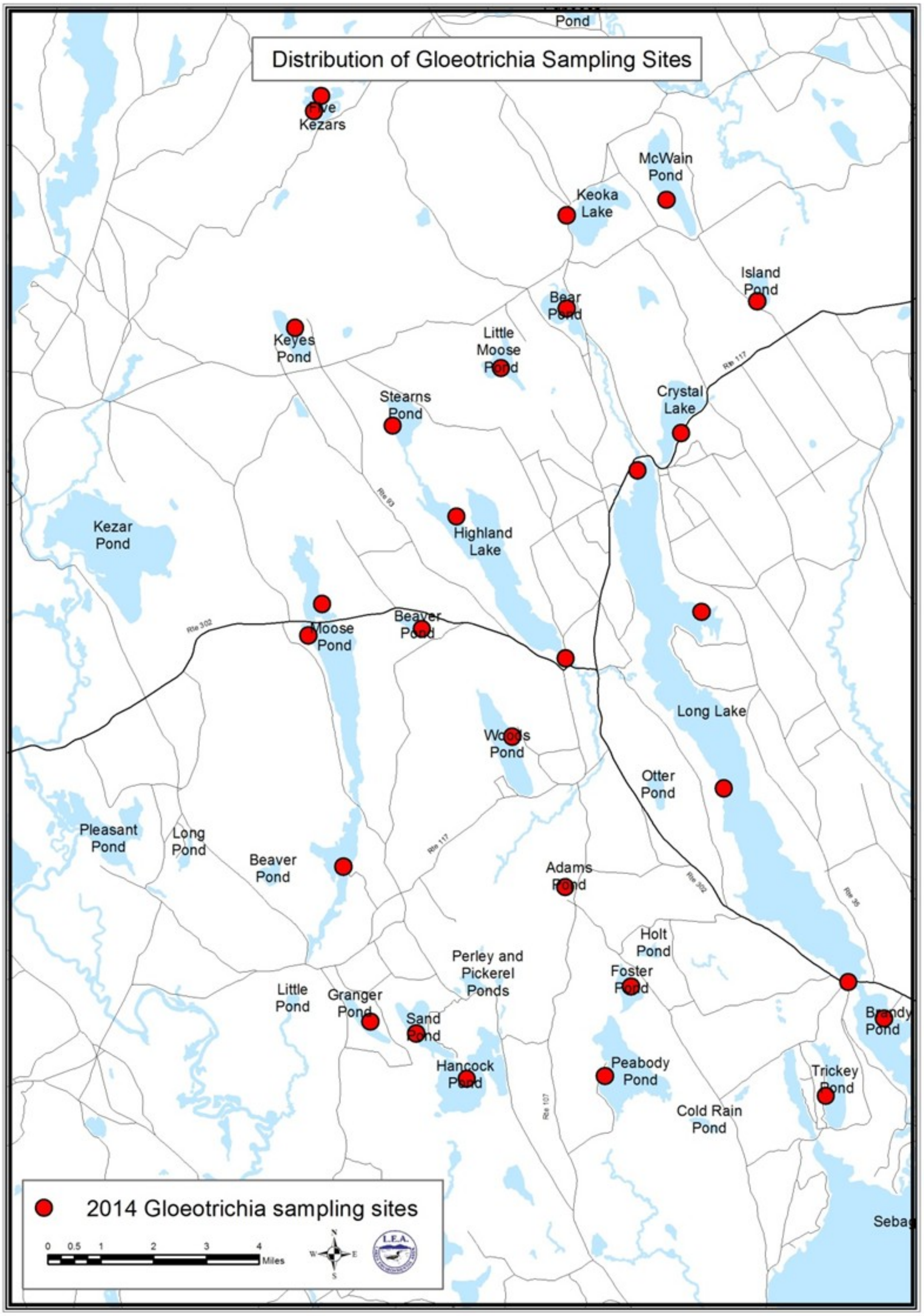


Figure 1. Map of 2014 *Gloeotrichia* sampling sites, located on lakes and ponds in the towns of Demark, Naples, Bridgton, Sweden, Waterford, and Harrison, Maine.

Sampling Methods

Six lakes in the western Maine Lakes Region were sampled roughly every two weeks (for a total of 7-8 samples at each site) throughout the summer of 2014. They included Long Lake (4 sites), Keoka Lake (1 site), McWain Pond (1 site), Moose Pond (3 sites), Peabody Pond (1 site), and Crystal Lake (1 site). These six lakes were chosen because they contained the highest levels of Gloeo out of the fifteen lakes originally sampled in 2013. Eighteen additional lakes in the region were sampled once during the anticipated peak in Gloeo abundance in late July/early August 2014. These included Adams Pond, Back Pond, Bear Pond, Beaver Pond (Bridgton), Brandy Pond, Foster Pond, Granger Pond, Hancock Pond, Highland Lake (2 sites), Island Pond, Keyes Pond, Little Moose Pond, Middle Pond, Papoose Pond, Sand Pond, Stearns Pond, Trickey Pond, and Woods Pond (figure 1). A total of 105 samples were counted.

Samples were collected using a plankton net with 80 µm mesh. The sites where samples were collected remained consistent throughout the season. 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.

Collecting a sample using a plankton net.

Table 1. Comparison of peak Gloeo concentrations in all lakes tested in 2013 and 2014, as well as the number of samples collected during the 2014 season.

Lake Name	Max. 2013 colonies/L	Max. 2014 colonies/L	Number of Samples taken in 2014
Adams Pond	Not tested	0	1
Back Pond	0.1	0	1
Bear Pond	Not tested	0.3	1
Beaver Pond (Bridgton)	Not tested	0	1
Brandy Pond	Not tested	2.1	1
Crystal Lake	2.3	3.3	8
Foster Pond	Not tested	0	1
Granger Pond	0	0	1
Hancock Pond	0	0	1
Highland Lake, Public Launch	0	0	1
Highland Lake, Highland Point	0	0	1
Island Pond	0	0	1
Keoka Lake	6.1	72.4	8
Keyes Pond	0	0	1
Long Lake (Harrison)	2.4	33.9	8
Long Lake (Cape Monday)	1.9	17.5	8
Long Lake (Bridgton)	8.0	20.6	8
Long Lake (Naples)	6.9	16.3	8
Little Moose Pond	Not tested	0	1
McWain Pond	9.4	26.3	8
Middle Pond	Not tested	0	1
Moose Pond (North Basin)	Not tested	0.9	8
Moose Pond (Middle Basin)	16.6	16.2	8
Moose Pond (South Basin)	Not tested	1.5	7
Papoose Pond	Not tested	0	1
Peabody Pond	1.9	2.4	7
Sand Pond	Not tested	0	1
Stearns Pond	0	0	1
Trickey Pond	0	0	1
Woods Pond	0	0	1

Results

The highest concentration of Gloeo found this summer was 72.4 colonies per liter on August 1st in Keoka Lake. At this level, the algae were clearly visible in the water column but did not form a surface scum. Comparisons of 2013 and 2014 Gloeo levels show that 3 lakes had higher levels this year than last year (Keoka Lake, McWain Pond, and Long Lake), while 3 others stayed about the same – Moose Pond, Peabody Pond, and Crystal Lake (see Table 1, previous page). Of the 18 additional lakes sampled, Brandy Pond was the only lake with greater than 1 colony per liter at 2.1 colonies per liter. The next highest level was on Bear Pond at 0.3. Brandy Pond was sampled on July 29th and Bear Pond on August 1st.

The date of the "peak" in concentration for most lakes was in early August, almost identical to the timing of the 2013 peak. Interestingly, in Long Lake, the peak occurred at 3 of the sites on August 5th, but remained low at the 4th site. At the next sampling on August 19th, levels were much lower at the first 3 sites, but peaked at the 4th and most southerly site in Naples (figure 2).

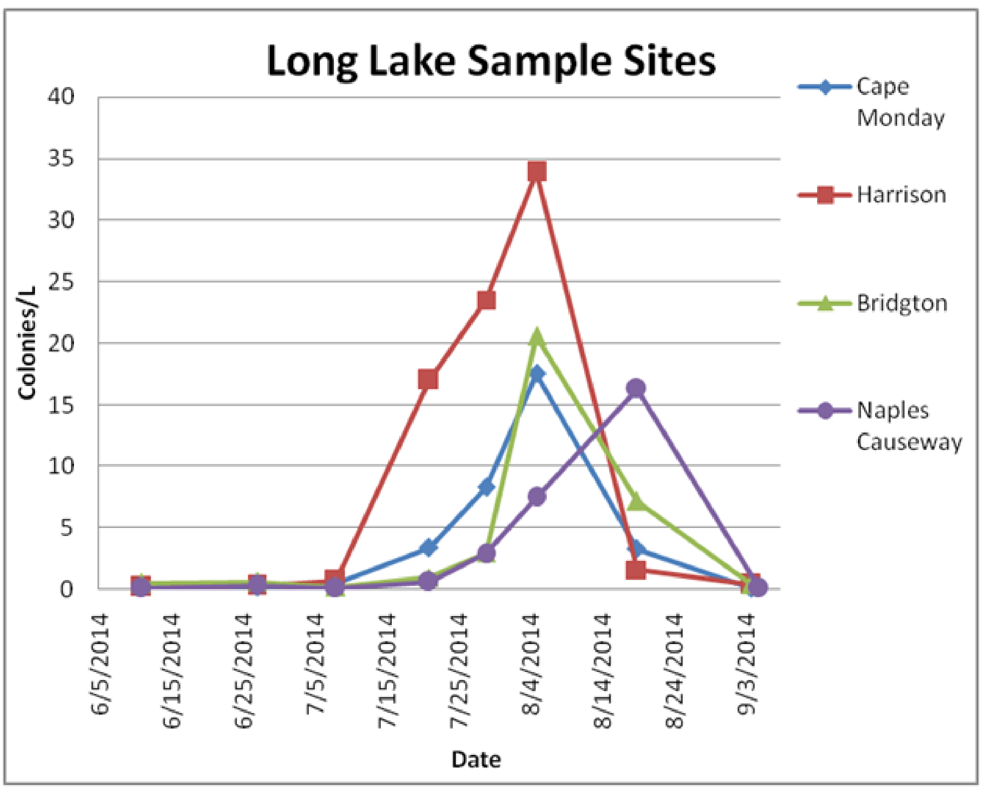
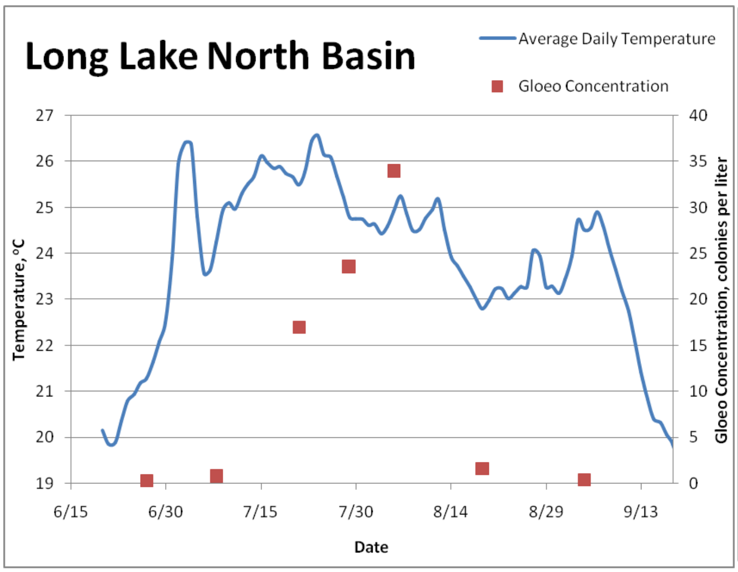


Figure 2. Results of 2014 Long Lake Gloeo sampling, showing concentrations of Gloeo from each sampling trip, as well as the difference in peak concentration between the first three sites and the Naples site.

Results

The peak in water temperature – that is, the highest recorded temperature – on most lakes was July 23rd or 24th, four to five days after the date of the 2013 peak. A period of sustained high temperature, defined as greater than 25 °C daily average surface water temperature, lasted from about July 14 to 27. This period of high temperature was followed one to two weeks later by the peak in Gloeo concentrations at most sites (figure 3).



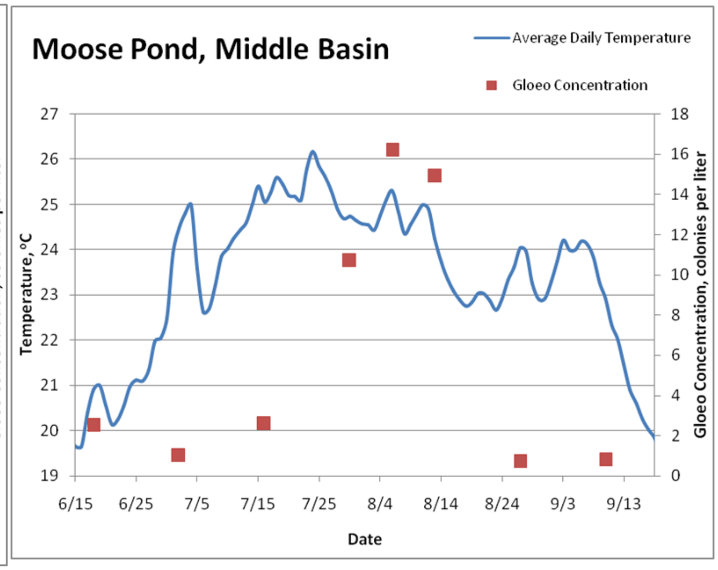
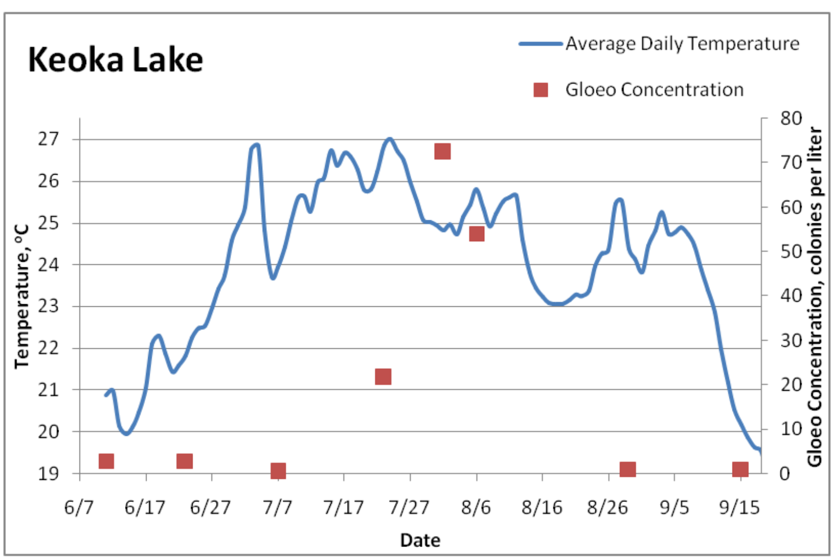


Figure 3. Comparison of 2014 summer daily average surface water temperatures and Gloeo concentrations at three different sites, each showing the peak in Gloeo concentration occurring shortly after the peak in temperature.



Results

Figure 4 shows individual sample results as well as season averages for the 11 sample sites that were tested multiple times in 2014. Averages remained below 10 colonies per liter at all sites except Keoka Lake, which had by far the highest concentrations of Gloeo. It also shows the low levels on the north and south basins of Moose Pond, Crystal Lake, and Peabody Pond.A different presentation of the data can be seen in Figure 5, which compares the concentrations at 7 sites over time. This graph only includes the 7 sites with the highest levels, excluding Moose Pond's north and south basin as well as Crystal Lake and Peabody Pond, all of which had peak levels under 3.5 colonies per liter.

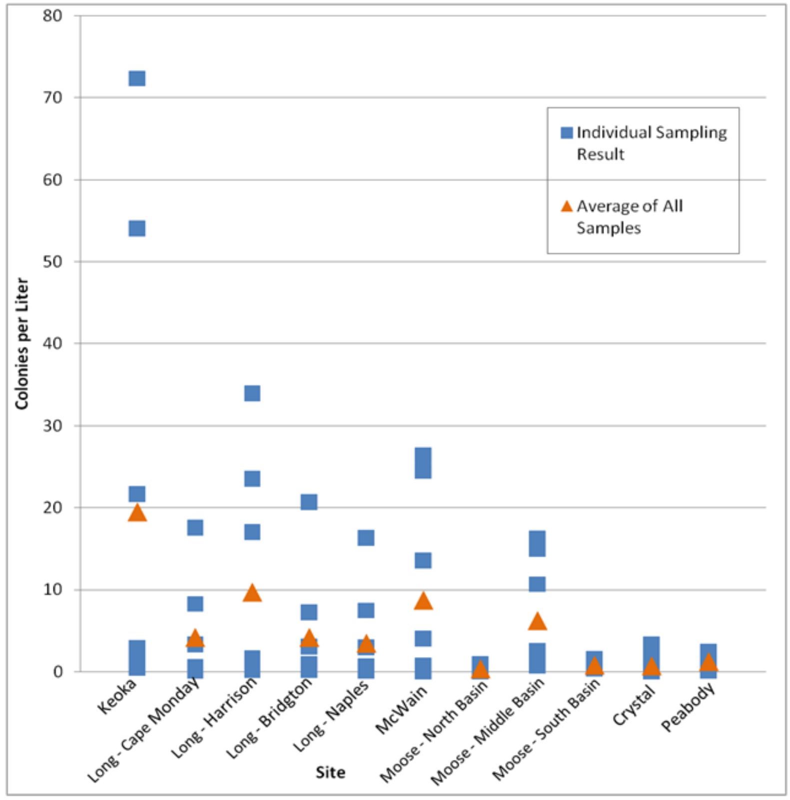


Figure 4. Gloeo concentrations at each sampling site over the season (each sample is marked by a blue square), as well as the average concentration at each site (orange triangles).

Anecdotal evidence suggests that Gloeo levels were highly variable later in the season. Gloeo could be seen in the water column of some lakes into September, though sampling suggests that levels were low. However, the "snapshot" method of sampling used in this study is not sensitive to day-to-day changes.

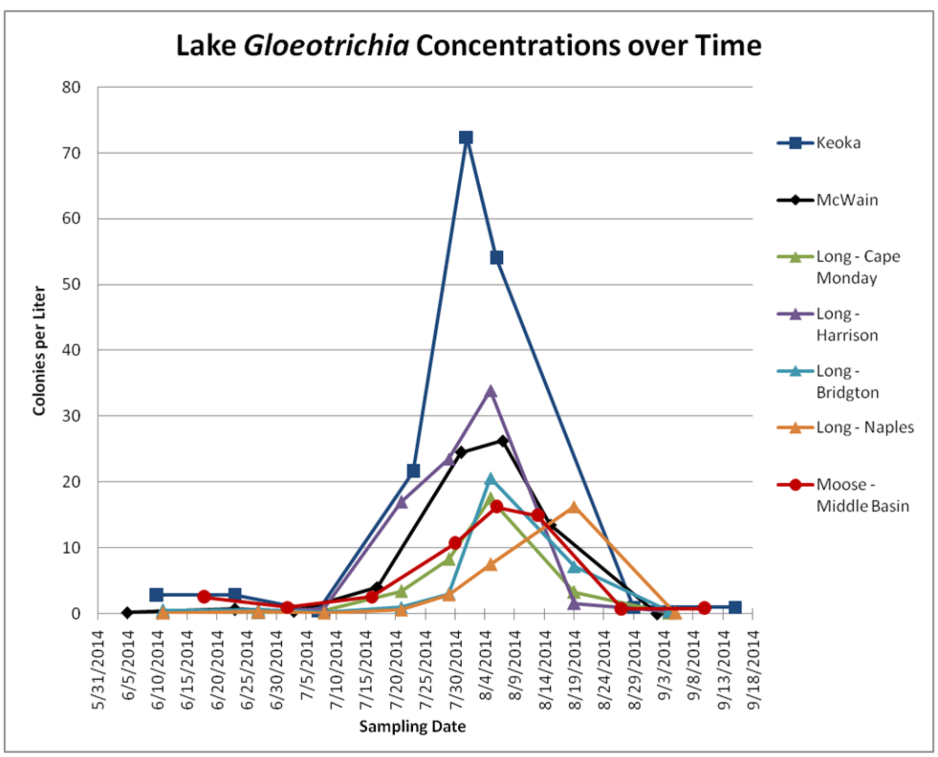
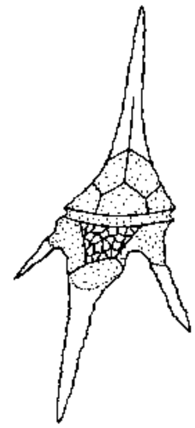


Figure 5. Concentrations of Gloeo throughout the summer at the 7 sites (across 4 lakes) with the highest Gloeo concentrations. This graph shows the population peak in early August at most sites.

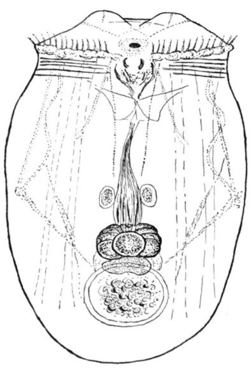
Results

Samples counted for Gloeo also contained a variety of other plankton species, which come in two types. Phytoplankton are the various types of algae that live in water and use photosynthesis to grow. They include green algae, metaphyton, cyanobacteria, dinoflagellates, and diatoms, among others. Zooplankton are small, insect-like organisms that swim in the water column and eat phytoplankton. They include copepods, daphnia, and rotifers, as well as a number of other species. There were a variety of plankton seen in the Gloeo samples, although most of the ones noted were fairly large. This is because samples were analyzed at a maximum of 30x magnification, which is not adequate for viewing very small algae species.



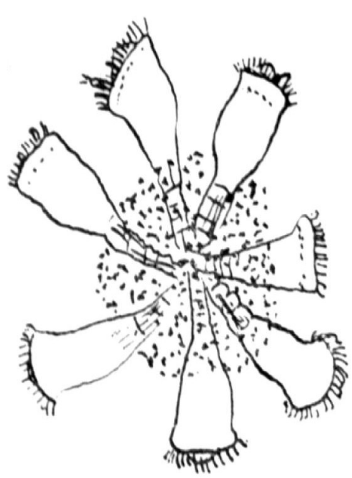
Ceratium, a type of phyto-plankton (algae)

Copepods were common in all of the samples. Rotifers were also very common, although relative concentrations of 3 common varieties varied between samples. Some samples had low levels of plankton and tended to have smaller sized copepods. These were usually the lakes that had little Gloeo – Peabody Pond, Crystal Lake, and the north and south basins of Moose Pond. Keoka Lake is a notable exception to this rule, with most of the samples containing few specimens other than Gloeo. Long Lake appeared to have the most plankton. Metaphyton algae clumps were seen in almost all the samples from Long Lake, and most of them contained large numbers of copepods as well. Most samples from Moose Pond contained a large number of conochilus, a type of colonial rotifer.



Ketatella, a type of rotifer

A Copepod



Conochilus, a colonial rotifer

Discussion

Putting the Results in Context

Keoka Lake had the highest Gloeo level recorded in the region with 72.4 colonies per liter. Most of the lakes sampled had little to no Gloeo whatsoever. Out of 24 lakes sampled, only 7 had levels over 1 colony per liter. Six of these lakes were the focal lakes which were tested every two weeks (the seventh was Brandy Pond, which is connected to high-Gloeo Long Lake). Three of the six focal lakes had levels similar to 2013, while the other three more than doubled in concentration compared to 2013 data. Gloeo populations can be variable between years due to a variety of influencing factors. Therefore, it will take long-term data over the next several years to determine the overall trend in Gloeo populations.

"While the high of 72 colonies per liter in Keoka Lake may not be an extreme level, it is still very visible in the water and is a real concern for human safety as well as the future of the Lakes Region."

Other lakes in Maine have experienced higher levels of Gloeo than were sampled in this study. The Belgrade Lakes area has seen levels as high as 250 colonies per liter. Lake Auburn and Panther Pond also have significant Gloeo populations. Levels well over 1000 colonies per liter have been reported in high nutrient systems in other areas of the world. While the high of 72 colonies per liter in Keoka Lake may not be an extreme level, it is still very visible in the water and is a real concern for human safety as well as the future of the Lakes Region.

Collecting a Gloeo sample on Keoka Lake, June 2014

Discussion

Some Observations from 2014 Sampling

Anecdotal evidence suggests that there was day-to-day variation in Gloeo levels on lakes with high populations. The data provides only a “snapshot” of what was happening at each site at the time it was sampled. Because only 7-8 samples were collected per site over the entire season, there are gaps in the data. For example, the recorded peak isn’t necessarily the “true” peak for a particular lake – it is only the highest level found at that site when it was sampled near the date of the population peak.

Daily fluctuation in concentration at a given site can be attributed to a number of causes, though wind and water currents are likely the main drivers. A strong easterly wind will “push” the water toward the western shore. These winds will cause lake currents to become stronger, which may result in the small, suspended Gloeo colonies accumulating downwind. To test the affect of wind and currents on Gloeo concentrations, sites on different sides of a lake could be sampled during various wind conditions and compared.

The need for multiple sample sites is particularly apparent when comparing the data from Long Lake, which had four test sites. Not only did concentrations increase dramatically between 2013 and 2014, but the sites with the highest Gloeo levels changed as well. In 2013, the two southern sites had the highest concentrations, whereas in 2014 the northernmost site had the most Gloeo. Also, the 2014 peak at the southernmost site in Naples was later than at the other Long Lake sites. This could be attributed to fluctuations due to wind, as discussed above, as Gloeo levels at the northerly sites dropped of greatly on the date of the Naples site peak. Having multiple sample sites per lake increases our knowledge of Gloeo dynamics greatly.

Another observation is that the Gloeo peak was, for the second year, preceded closely by the peak in water temperature. Gloeo colonies need about 12 days to mature on the lake bottom before becoming buoyant. (Karlsson, 2003). Our results from 2013 showed the lag time between high temperature and the peak in Gloeo concentrations to be about 11 days. A spike in temperature earlier in July, as well as about two weeks of sustained high temperatures, makes it difficult to pinpoint the exact length of this lag time in 2014, but it appears to be between 8 and 13 days. This is strong evidence which suggests a temperature cue causes rapid Gloeo growth.

Discussion

Possible Explanations for Results

Two of the biggest questions that remain unanswered after this study are, "Why are Gloeo seen in certain lakes and not in others?" and "Why was there a huge spike in Gloeo concentrations in 3 of the lakes, but the other 3 stayed similar to 2013 levels?"

The first question was addressed in the initial 2013 study by looking at differences in water quality and lake characteristics between lakes with and without Gloeo, but there were no clear correlations. It is known that Gloeo, being cyanobacteria, are most sensitive to light, temperature, and nutrients. They need abundant light and nutrients and warmer temperatures than other algae. Lakes with a good combination of light and nutrient availability would likely have more Gloeo than those without these attributes.

Light availability is affected by the lake's color and dissolved organic matter content. It is also affected by the bathymetry of the lake. Deep, steep-sided lakes will have less available area where light reaches the sediments than a shallow lake or one with a large littoral zone. Nutrient availability is affected by sediment quality. A sandy or rocky bottom will provide less phosphorus than a mucky bottom with large amounts of organic matter. Areas near high-nutrient sources (such as fertilized lawns, farms, or areas of erosion) will also be higher in phosphorus. Finally, lake temperature is being affected by climate change and is expected to increase over time.

The availability of light and nutrients may be playing a role in limiting Gloeo growth in the lakes with similar levels in 2013 and 2014. In Moose Pond, for example, there may be enough areas of adequate light and nutrients to produce about 16 colonies per liter of Gloeo. One thing the 3 lakes with higher Gloeo concentrations this year had in common was that they had a shallower maximum depth than the 3 lakes with consistent Gloeo levels (table 2). This might indicate that there is more area on the bottom of the lake available for Gloeo growth, however ecosystems are extremely complex and there are a number of factors affecting Gloeo population in a given lake.

Table 2. Maximum and average lake depth in lakes with elevated Gloeo populations.

	McWain Pond	LongLake	Keoka Lake	Peabody Pond	Crystal Lake	Moose Pond
Maximum Depth (ft)	42	59	42	64	65	70
Average Depth (ft)	23	34	25	45	33	20

Discussion

Scientific research suggests a number of other reasons why some lakes contain higher levels of Gloeo than others. Sediment mixing and strength of stratification both appear to affect Gloeo populations. More lake mixing and deeper epilimnion depth were associated with higher numbers of Gloeo colonies being released into the water column (Carey et al., 2014). Another study found that sediment disturbance, such as through wave action, increased the amount of Gloeo in a similar way (Karlsson-Elfgren et al., 2004).

Also, while Gloeo populations can fluctuate greatly from year to year, lakes that have already had high concentrations are the most vulnerable to future high concentrations. This is because over the course of the summer, some of the Gloeo colonies become dormant and settle out of the water column. These "resting cells" can persist until conditions are favorable for growth again, with each being able to produce multiple new colonies. The more Gloeo there are in the lake to begin with, the more dormant cells there will be, creating more potential for Gloeo growth the next summer.

Future Testing

Continued, regular monitoring is an essential part of understanding how Gloeo affects lakes. For this reason, LEA hopes to sustain and advance monitoring those lakes with the highest levels of the algae. Because concentrations are very low in the early summer, a future focus may be sampling more frequently in July and August.

Other possible studies could include investigating how Gloeo move in lakes by measuring the magnitude of the influence of wind speed and direction on Gloeo abundance at different sites on a lake. Another topic of interest is learning if there are sediment "hot spots" with ideal conditions for growth. This could be studied using sediment traps. Determining what percentage of each lake's bottom is viable for Gloeo production could indicate risk and help us to better understand why certain lakes have more Gloeo than others. The influence of color and organic matter on abundance and the monitoring of similar cyanobacterial species would also provide valuable insight.

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

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LEA Would Like to Thank...

Five Kezar Ponds Watershed Association
Hancock and Sand Ponds Association
Island Pond Association
Keoka Lake Association
McWain Pond Association
Moose Pond Association
Peabody Pond Association
Residents of Woods Pond
Trickey Pond Association

An anonymous family foundation

and all of our members

…for making this project possible with their generous support!

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