Report of Results for Pleasant Lake, Island Falls, ME

Avery Lamb, Jasmine Saros

Climate Change Institute, University of Maine

A sediment core was collected in winter 2023 by students in the Saros lab and members of the Island Falls Lakes Association. Researchers drilled a hole through the ice and collected lake sediment using a gravity coring device. When sediment is collected in this manner, it preserves the chronological deposition of the sediment that was accumulated at the bottom of the lake over time. The sediment core collected was 22.5 cm long and spans from 2023 at the top to approximately 1800 at the bottom. By sectioning the sediment core from top to bottom, we can reconstruct how conditions of the lake have changed over time.

What we measured: Island Falls Lakes Association members were interested in the recent prevalence of algal blooms during the summer seasons. To reconstruct what types of algae are present in the algal community and how the algal community has changed over time in Pleasant Lake, we extracted and measured photosynthetic pigments and DNA from the sediment. Photosynthetic pigments are the chemical compounds used by primary producers (on land, plants; in the lake, algae) to photosynthesize. Different pigments can indicate different types of algae. We identified and measured nine photosynthetic pigments in the Pleasant Lake sediment core—alloxanthin, canthaxanthin, lutein, zeaxanthin, fucoxanthin, diadinoxanthin, chlorophyll-c_2, chlorophyll-a, and pheophytin-a. Table 1 describes the kinds of algae that each pigment represents. Pigments like chlorophyll-a, and pheophytin-a represent the overall primary productivity of the lake (i.e. how much total algae there is in the lake). Pigments like canthaxanthin and zeaxanthin specifically represent cyanobacteria.

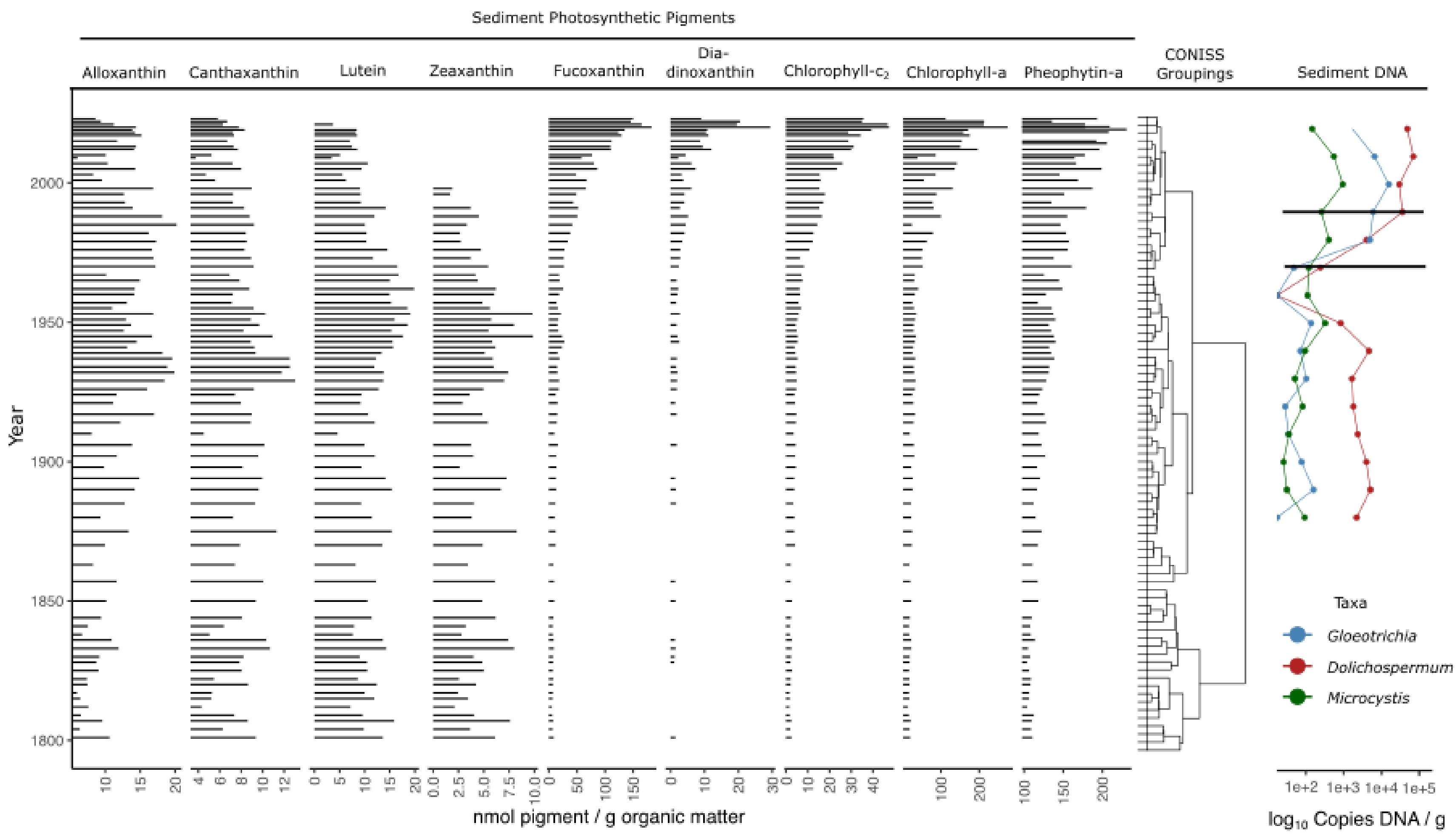
Additionally, DNA of three specific taxa of potentially harmful cyanobacteria (*Gloeotrichia*, *Dolichospermum*, and *Microcystis*) were extracted and measured from sediment samples representative of 10-year periods from 1880 - 2023. We chose to measure these three cyanobacteria taxa because they are frequently identified in Maine algal blooms and each has a specific set of environmental conditions that it prefers (e.g., *Gloeotrichia* prefers low nutrient conditions, while *Dolichospermum* and *Microcystis* prefer medium to high nutrient conditions.)

Table 1. Different photosynthetic pigments and the types of algae that produce them.

Photosynthetic Pigment	**Type of Algae**
Alloxanthin	Cryptophytes
Canthaxanthin	Cyanobacteria
Lutein	Green algae, plants
Zeaxanthin	Cyanobacteria
Fucoxanthin	Diatoms, chrysophytes
Diadinoxanthin	Diatoms, dinoflagellates, chrysophytes
Chlorophyll-c_2	Dinoflagellates, diatoms, chrysophytes
Chlorophyll-a	All algae
Pheophytin-a	All algae

How we analyzed the data: This report contains two data-driven figures and a conceptual diagram, described in more detail below. In summary, Figure 1 is a visual representation of photosynthetic pigments and sediment DNA profiles of the Pleasant Lake core, with natural clusters and breakpoints in the data indicated. Breakpoints and clusters were analyzed in the pigment data using CONISS and broken stick analyses and in the sediment DNA data using break point analysis. Figure 2 shows a plot of a Principal Component Analysis (PCA) that allows us to identify patterns of similarity and dissimilarity in the data. Illustration 1 demonstrates the differences between absolute and relative changes.

Figure 1. Sediment profiles of photosynthetic pigments and sediment DNA from most recent (top, 2023) to oldest (bottom, 1800).



How to interpret Figure 1: Figure 1 shows sediment profiles of the photosynthetic pigments and sediment DNA measured in the Pleasant Lake core. The vertical axis shows the date/age of the sediment at that interval. At the top is 2023, and as you move down the profile, you move back in time to approximately 1800. The first nine columns (moving horizontally) represent different photosynthetic pigments, with the name of the pigment labeled at the top. The amount (concentration) of pigment in each sediment interval is indicated with horizontal bars. The right-most column shows the concentrations of cyanobacterial DNA in each of our 10-year interval sediment samples. The number of copies of DNA of each taxa (*Gloeotrichia*, *Dolichospermum*, and *Microcystis*) are shown in blue, red, and green, respectively. The CONISS Groupings column indicates the results of a CONISS analysis of the pigments, showing which samples are clustered together and if/where big changes in the data occur in a tree-like diagram. Using a similar breakpoint analysis, two breakpoints were identified in the sediment DNA profiles, at 1970 and 1990. These breakpoints are shown as horizontal black lines in the sediment DNA column.

Key Take-Aways from Figure 1: Nine pigments were identified in the Pleasant Lake core, including two pigments that are indicators of total algae (chlorophyll-a and pheophytin-a) and seven pigments that are indicators of specific types of algae, including cryptophytes, cyanobacteria, green algae, diatoms, chrysophytes, and dinoflagellates. Pigments follow one of two general trends from 1800-2023: 1. Increases in pigment concentrations since ~1950 (fucoxanthin, diadinoxanthin, chlorophyll-c2, chlorophyll-a, pheophytin-a), or 2. Relatively variable pigment concentrations from with noticeable peaks and valleys until ~1950 followed by a steady decrease until present day (alloxanthin, canthaxanthin, lutein, zeaxanthin). The increases in chlorophyll-a and pheophytin-a could indicate an increase in overall algae in Pleasant Lake. We are often conservative in interpreting the extent of this increase because the breakdown of total-algae pigments in older sediment is common and can be somewhat misleading. However, we have more confidence that this is an authentic increase because we see similar trends in other pigments that are not as prone to degradation, like chlorophyll-c2.

Through the tree-like diagram, the CONISS analysis describes how samples cluster together and if/when any abrupt changes in the data occur. The tree “branches” indicate that there are indeed natural groupings within the data. However, although there are natural groupings, when analyzed further, there are no statistical breakpoints, or points of abrupt change in the pigment data. This indicates that the changes we see over time in the algal community happened relatively gradually, not abruptly, and that there seems to be no single deterministic point of change.

Measurements of sediment DNA concentrations show that all three taxa (*Gloeotrichia*, *Dolichospermum*, and *Microcystis*) are present in variable proportions over time. At most points, *Dolichospermum*—a taxa that prefers mid-range nutrient concentrations—is the cyanobacteria with the highest concentration of gene copy numbers. From 1880-1950, gene copy numbers were relatively steady, followed by a period of variability between 1950-1990, and a return to relatively constant (although noticeably higher) gene copies numbers from 1990-present. The breakpoint analysis of the DNA data indicates two statistical breakpoints, highlighting the period of time that corresponds to an overall increase in total algae.

Noticeably, the increases in cyanobacterial sediment DNA do not correspond to an increase in cyanobacterial photosynthetic pigments. This can be explained by considering that the sediment DNA is showing discrete increases in gene copy numbers, while the photosynthetic pigments are showing relative changes in the algal community proportions. From chlorophyll-a and pheophytin-a, we see an increase in total algae since ~1950, but the algal type-specific pigments, we see a relative decrease in cryptophytes, green algae, and cyanobacteria and a relative increase in diatoms, dinoflagellates, and chrysophytes. So while we see an absolute increase in cyanobacteria gene copy numbers since 1950, cyanobacteria are not the relatively predominant type of algae. Illustration 1 demonstrates the absolute vs. relative changes that the combined pigment and sediment DNA data suggest cyanobacteria experienced in Pleasant Lake.

Illustration 1. Conceptual diagram of past and current algal communities. Though the absolute amount of cyanobacteria (specifically, *Gloeotrichia*, *Dolichospermum*, and *Microcystis*) has increased, the proportion of cyanobacteria within the algal community has decreased.

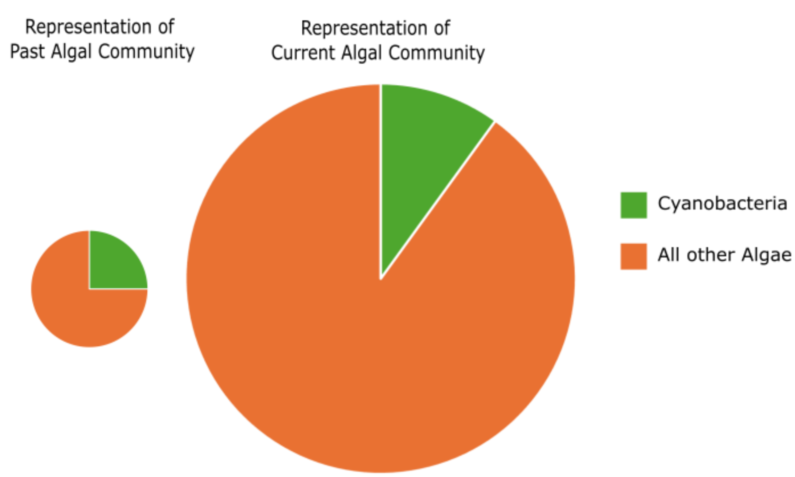
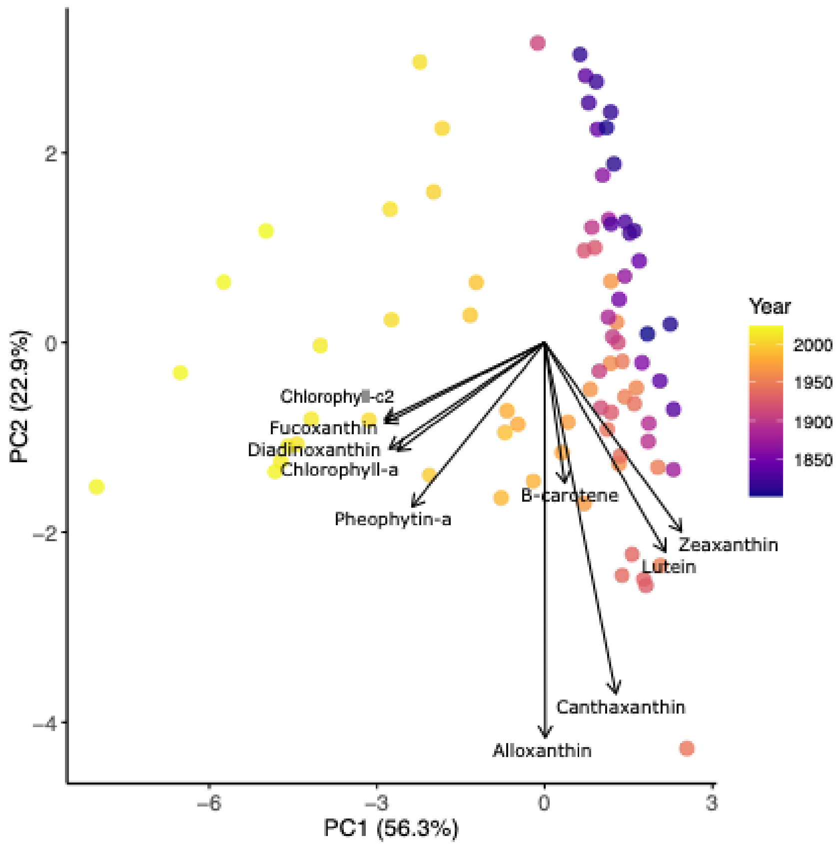


Figure 2. Principal Component Analysis (PCA) biplot of all photosynthetic pigments in the Pleasant Lake sediment core.



How to interpret Figure 2: Figure 2 shows a plot of the Principal Component Analysis (PCA) performed on the photosynthetic data. Each point on the plot is representative of one sediment slice. Points on the plot are colored on a gradient that represents time. Moving from yellow through pink to indigo, samples in the gradient represent newer to older sediment (2023 to 1800). Points plotted closer together in space are more similar and points further apart, more different. Black arrows originating from the middle of the plot represent each individual photosynthetic pigment and indicate which pigments are the most responsible for differences between points.

Key Take-Aways from Figure 2: In the PCA, points shift from right to left over time, with the oldest points on the right and the more recent points on the left. A shift in this direction corresponds with total algae (chlorophyll-a, pheophytin-a) and diatom, chrysophyte, and dinoflagellate pigments (fucoxanthin, diadinoxanthin, and chlorophyll-c_2). This PCA is additional statistical evidence that diatoms, chrysophytes, and dinoflagellates (not cyanobacteria) are the primary types of algae that correspond with increases in Pleasant Lake algae since ~1950.

Conclusions: The variety of pigments present in the sediment core indicate a diversity of different algae in Pleasant Lake. Having a diverse set of algae, including green algae, diatoms, cryptophytes, chrysophytes, and cyanobacteria, is generally a positive sign of a healthy lake with a complex and balanced ecosystem. **Overall, the Pleasant Lake sediment profiles indicate a current lake with a diverse algal community not necessarily dominated by cyanobacteria.** However, it is important to note that sediment cores represent averages over long time periods (years, decades). There can still be seasonal variation of different algae within Pleasant Lake, including brief times dominated by cyanobacteria (cyanobacterial blooms), that are not apparent in this data.