ESTIMATE OF LONG-TERM PHYTOPLANKTON BIOMASS IN LAKE BEMIDJI

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***Abstract*—Phytoplankton are photosynthetic organisms that are the base of aquatic food webs. In a dimictic temperate lake such as Lake Bemidji, the environment adjusts with the changing water temperatures and sunlight levels. The phytoplankton in a dimictic lake are adapted to subsist in long term seasonal changes but the exact change to the number of phytoplankton in unknown. The focus of this study was to estimate the biomass of phytoplankton in a long term period including winter stratification and summer peak. From a period between March 2023 and October 2023 water samples were collected from the lake in the south basin, filtered, and analyzed with spectrophotometry to find the chlorophyll a content. The data was graphed and analyzed with regression statistics to track the changing biomass of phytoplankton in the study period. The phytoplankton persisted in lower amounts under the ice, but significantly increased during the summer months, peaking in the fall and decreasing again along with decreasing temperatures.**

I. Introduction

Phytoplankton are organisms that make up the base of many aquatic ecosystems. Phytoplankton convert solar energy into food by photosynthesis, while also passing the energy on when getting consumed by other organisms. They can be found in the open water areas of water bodies and closer to shore. Phytoplankton can be found in bodies of water with high amounts of nutrients and primary productivity called eutrophic waters to those with a limited number of resources called oligotrophic waters.

In a stratified body of water, the majority of phytoplankton stay in a vertical layer called the deep chlorophyll maxima, influenced by mixing patterns, light availability, and nutrients (Klausmeier and Litchman 2001). Phytoplankton vertical distribution in a stratified water column is affected by an inverse relationship between light availability near the top and higher nutrient levels near the bottom (Mellard et al. 2011). There are qualities of phytoplankton that affect how they survive under the full year in a freshwater lake. Freshwater phytoplankton have a growth rate that is limited to water below 40 °C (Eppley 1972), meaning they can grow and reproduce under both winter and summer conditions of standard water temperatures. Some species of phytoplankton can regulate the intensity of light they receive by adjusting their depth in the water column, some even preferring lower intensity light (Richardson et al. 1983). The productive importance of phytoplankton species depends on the conditions of the lake. Depending on the season the dominant species of phytoplankton changes. In a simulation based on Lake Constance, the dominant species in late winter are diatoms or Cryptophycae. As the edible plankton get eaten by increasing herbivore populations, inedible plankton grow, and the herbivores decrease. The Cryptophycyeae and inedible algae dominate until diatoms become prominent, then diatoms are replaced by dinoflagellates (Sommer et al. 1986). Diatoms are more suited to colder water scenarios and in more temperate lakes than other phytoplankton (Lürling et al. 2013).

Phytoplankton exist in areas that can be covered in ice for a significant period of time. Lake Baikal, the largest freshwater lake by volume, has communities of microbes under the ice, mainly formed by groups of diatoms or dinoflagellates (Bashenkhaeva et al. 2015). In the arctic ocean, marine phytoplankton were found to bloom while still under ice cover with the right amount of sunlight (Hill et al. 2018). If not mobile, phytoplankton can survive under icy conditions through hibernation or reduced functionality, including the production of specialized cells (Bertilsson et al. 2013). In a seasonally freezing temperate lake, water temperatures decrease significantly when forming ice. Snowfall on top of the ice scatters some light away from the water, blocking out sunlight and decreasing photosynthesis. Wind is unable to mix the surface waters of the lake, with stratification of water levels occurring. Nutrients are not as distributed equally due to the stratification as well. Despite the negative changes phytoplankton have adaptations necessary to survive in the winter.

Lake Bemidji is a highly productive lake that freezes yearly. The organic compound chlorophyll a can be used to estimate the biomass of phytoplankton within the water. For example, a January 1981 study on four reservoirs in the Czech Republic found that as concentration of chlorophyll a in the reservoirs increased, the biomass of algae also increased (Desortová 1981). A study on five lakes of different trophic status in eastern Germany used four different methods of estimating phytoplankton biomass, including microscopic counts, constant chlorophyll a in proportion to wet weight, variable chlorophyll a ratio to wet weight in relation to biomass, and variable chlorophyll ratios to wet weight in relation to chlorophyll concentration. The three chlorophyll a based estimations all had strong statistical correlations to phytoplankton biomass (Kazprzac et al. 2008). It is important to know how phytoplankton species make an impact on a shallow eutrophic ecosystem during the winter months, first by measuring the concentrations of the chlorophyll.

Therefore, the objective of this study is to measure levels of chlorophyll a of Lake Bemidji in Minnesota from a time with ice covering the lake, until the fall turnover. This chlorophyll a data can be used to estimate how the biomass of phytoplankton changes over the seasons.

II. Methods

Lake Bemidji, located in Bemidji, MN is a shallow eutrophic lake in the temperate region. Lake Bemidji is split into two basins and is connected to the Mississippi River for both the inflow and outflow of water. The sampling location was the south basin of Lake Bemidji (47.47930, -94.86962). Water sampling occurred every two weeks from March 1, 2023, to March 31, 2023, with a break during ice out, then from June 21, 2023, to August 9, 2023, and lastly a fall session from September 16, 2023 until turnover (Table 1).

Table 1: Dates of days water samples were collected from Lake Bemidji south basin

Spring sessions	Summer sessions	Fall sessions
3/1/23	6/21/23	9/16/23
3/19/23	7/5/23	10/5/23
3/31/23	7/18/23	10/12/23
	8/9/23	10/19/23

During winter sampling, an ice auger was used to drill a hole into the ice and remove ice from the water. The HYDROLAB HL7 multiparameter sonde operating probe (OTT Hydromet, 2017) or YSI multiparameter meter were lowered into the water to measure water temperature and dissolved oxygen levels. Data was collected at the surface, one meter down, and if possible two meters down. With a two meter composite water sampler (a PVC pipe with two rubber stoppers), water was collected from the surface to two meters down. The pipe was lowered until close to submerged, and the top stopper was placed. The pipe was then removed from the hole as horizontally as possible, and the other stopper was placed on the other hole. The 1 L brown bottles were filled with water and placed into a cooler. The bottles were labeled with date and time. The process was repeated three times at close to 15 minute intervals. During warmer months, the sampling was conducted by boat. A boat was anchored around 30.5 m or less near the coordinates. From the boat the HYDROLAB or YSI were lowered into the water and operated per the procedure, and water collected into the brown bottles.

Each interval produced two brown bottles of sample water. The samples were filtered through 0.5 um 45 mm glass filters and placed into 15 mL plastic vials, with the water volume being recorded. The vials were kept cold in a refrigerator until needed, covered in aluminum foil. To prepare for spectrophotometry, 10 mL of acetone were placed in each vial for at least 10 hours before processing. The spectrophotometer machine was calibrated using 10 mL of acetone in a cuvette placed in the machine then the acetone disposed in a labeled container. The vials with the filters were placed in a centrifuge for five minutes with a speed of 2.8. When ready, the vial liquid was placed into the cuvette and placed into the machine for chlorophyll reading with a wavelength of 664. After reading, the liquid was disposed of in the waste bottle. Between every reading and calibration the cuvette was rinsed with deionized water. After every six vials, the spectrophotometer machine was recalibrated using acetone. Cuvette length, volume of acetone, volume of water sample, and the wavelength value were recorded.

Using a wavelength to concentration conversion, the chlorophyll content was produced.

$$\text{Chlorophyll (mg/m3)} = 12.31 * \lambda 664 * \text{Vol\_ext\_L}) / ((\text{Vol\_fil\_L}/1000) * \text{Cuvette\_length\_cm})$$

λ664 is the wavelength of light used for the spectrophotometer. (Vol_ext_L) is the volume of acetone added to each sample. (Vol_fil_L) is the volume of water filtered for each sample. (Cuvette_length_cm) is the length of the cuvette used for the spectrophotometry. The resulting concentrations were graphed in relation to the span of time of the study. To test for significant trends in chlorophyll, temperature, and dissolved oxygen over each individual season, regression was used.

III. RESULTS

Over the course of the study, water samples and probe data were collected from eleven separate days, divided into spring, summer, and fall sessions (Table 1). The number of chlorophyll samples totaled ninety-eight, and sixty-five data points for the water temperature and oxygen levels were collected.

In the spring session, the chlorophyll concentrations were below 5 mg/L (P=0.16). The chlorophyll increased significantly going into the summer session (P=0.01) until, where the chlorophyll

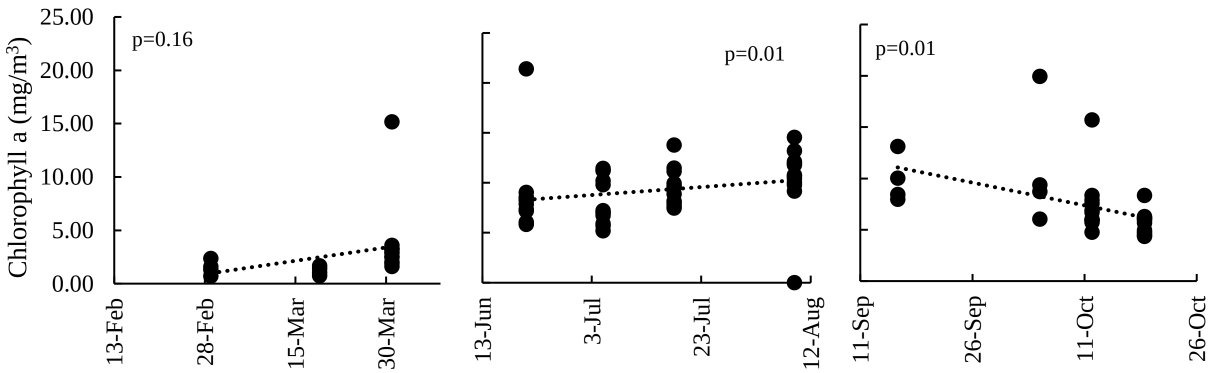

Fig. 1. Chlorophyll a measurements collected from Lake Bemidji water samples and processed using spectrophotometry. (Left to right: Spring session, Summer session, Fall Session; 2023)

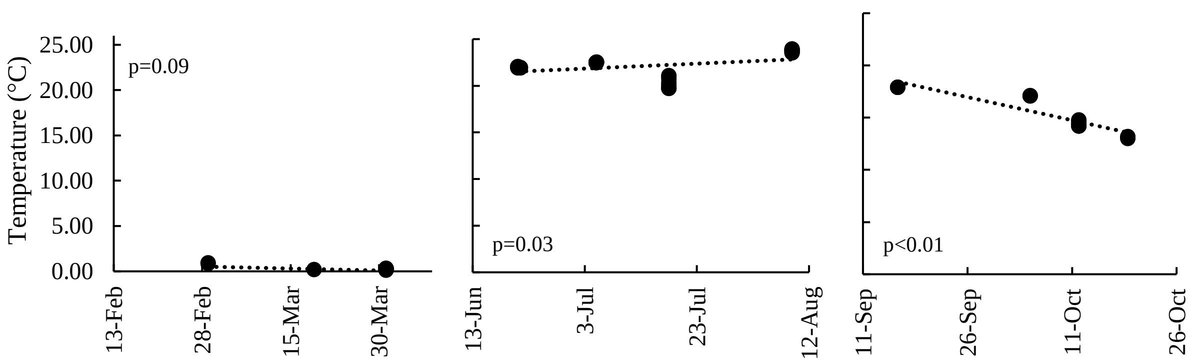

Fig. 2. Measured water temperatres (0-2 m) from Lake Bemidji Using HYDROLAB or YSI meters. (Left to right: Spring session, Summer session, Fall Session; 2023)

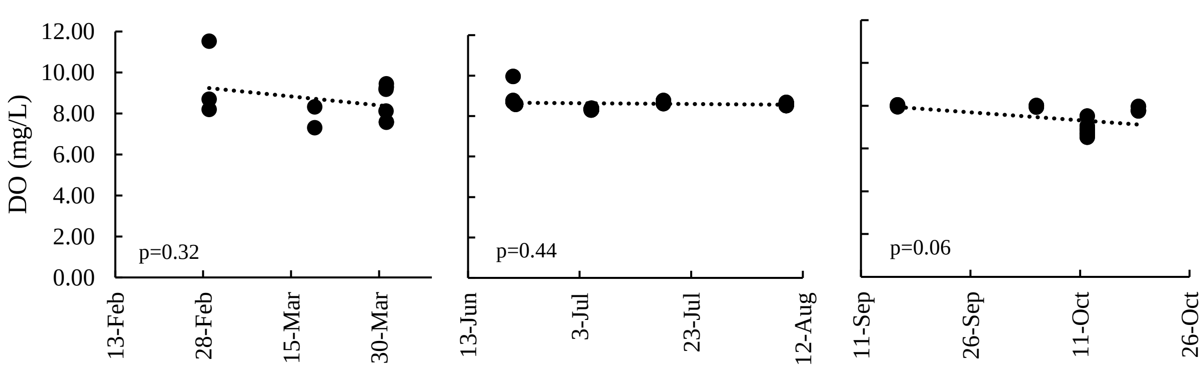

Figure 3: Dissolved oxygen concentrations measured from Lake Bemidji using HYDROLAB or YSI meters. (Left to right: Spring session, Summer session, Fall Session; 2023)

significantly decreases at (P=0.01). The water temperature data started in the spring between -0.13-0.93 °C (P=0.09), in relation to icy conditions of the lake (Figure 2). In the summer the water temperature increased substantially to levels between 19.30-23.95 °C (P=0.03). Temperatures decreased in the fall session between 17.93-13 °C (P<0.01).

The dissolved oxygen concentrations varied from a top value of 11.54 mg/L during the spring session (P=0.32), stable concentrations during the summer (P=0.44) and a lowest value of 6.53 mg/L in the fall (P=0.06) without statistically significant trends between the seasons.

IV. Discussion

The chlorophyll concentrations were at their highest in late summer and fall. The chlorophyll concentrations of Lake Bemidji peaked in the months of August and September. In a study of chlorophyll concentrations in 56 north temperate lakes, the first peak of the eutrophic lakes occurred during spring months of March and April, while a second peak appeared during August and September (Marshall and Peters 1989). The specific trends of chlorophyll concentrations can vary significantly between water bodies. Six lakes on Beaver Island on Lake Michigan and Lake Michigan proper were sampled for phytoplankton biomass using both plankton counts and fluorometry for ten of twelve months (Butts and Carrick 2017). All seven lakes had unique biomass profiles, while four of the sites in particular had unimodal peaks similar to the trend seen in Lake Bemidji.

The dissolved oxygen did not make any statistically significant changes during the three separate sessions as well as the overall study span. Normally during months with ice cover, the lack of primary production and high demand for oxygen depletes it to lower levels (Zdorovennova et al. 2021). The dissolved oxygen levels did not increase from ice to open water transition. Dissolved oxygen has its highest concentrations near the top waters and decreases with depth. However, only the upper two meters of the lake were tested for the study, meaning the entire water column is not considered. The temperature of the water inversely effects the oxygen content, with higher temperatures carrying less oxygen (Harvey et al. 2011). From June to August the water temperatures were at their greatest, but the dissolved oxygen observed did not greatly decrease.

In conclusion, the concentrations of chlorophyll collected in Lake Bemidji existed in small but noticeable concentrations during the month of March under ice cover, grew steadily throughout the spring when the ice was removed, peaked in late summer and early fall, then decreased along with the water temperatures. Therefore, the biomass of phytoplankton can be estimated to be at its highest point of the season in the turn from summer to fall.

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