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The Effects of Wind Exposure on Microorganism Stratification and Distribution in Lake Itasca and Deming Lake.

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Abstract

The surface area of a lake has a significant influence on the amount of mixing the lake will receive from wind exposure. This influences the thermal stratification the water column in that lake which will have a direct effect on the biotic stratification. In turn, the biotic stratification of a lake will affect the overall environmental conditions of that lake, such as pH and chlorophyll content. Lakes with small surface areas sometimes become meromictic with a hypolimnion that never mixes with the rest of the lake. This results in a dead zone at the bottom of the lake in which organismal diversity is very low. In this experiment we compared the thermal and biotic stratification between meromictic Deming lake and a holomictic Lake Itasca within Itasca state park, MN. Deming Lake had a surface area that was much smaller than that of lake Itasca with much less exposure to the wind; therefore, we hypothesized that Deming lake would have a greater degree of thermal and biotic stratification than Lake Itasca which was much more exposed to the wind. We used light meters, pH samples, and conductivity measurements to compare the thermal stratification of these two lakes. We also took water samples to determine the chlorophyll content, and the biotic diversity at different depths to compare the biotic stratification of these two lakes. Our results were consistent with our hypothesis, and showed us that Deming Lake, which was less exposed to the wind, had a fixed thermal and biotic stratification, while the thermal and biotic stratification of Lake Itasca had a higher degree of mixture.

Introduction

Lake stratification can be described as the separation of lakes into three distinct layers Epilimnion, Metalimnion, and Hypolimnion. The cause of this separation is the relative temperature of the water, hence the name thermal stratification. This is the least dense layer and it has the highest oxygen content due to dissolved oxygen from the atmosphere. It has a photosynthesis-respiration ratio that is greater than one and receives the most sunlight. The middle layer is called Metalimnion. This layer is characterized by rapid a decrease in temperature as depth increases. The lowest layer is called Hypolimnion. This layer has the lowest oxygen content due to higher levels of respiration than photosynthesis, and receives almost no light from the sun.

Apart from the thermal stratification of lakes, lentic waters such as lakes and ponds are different from lotic waters such as streams, springs and rivers in that they have define zones. Pelagic zone describes the vertical zonation of lakes and other lentic waters. The pelagic zone is divided into two zones, the photic and aphotic zones. The photic zone is where the ratio of photosynthesis to respiration is greater than one, and it is found near the surface of lentic waters. The aphotic zone has photosynthesis to respiration ratio of less than one and it is found below the photic zone. In the photic zone there is good penetration of light and high numbers of photosynthetic organisms such as phytoplankton live in this zone, as a result it has high oxygen content. In the aphotic zone the number of respiratory organisms outnumbers the photosynthetic organism depleting the zone oxygen content to a very low level (Reynolds, 1980).

Lakes are classified into separate categories according to the level of mixing that they undergo in a year. Lakes that mix completely at least once a year are called holomictic, and lakes that only mix partially once a year are called meromictic. Lakes that mix completely twice a year are called dimictic. Factors that influence the amount of mixing a lake will undergo are depth, surface area, the inflow and outflow of water, and exposure to wind.

In this experiment, we will be comparing the stratification of Lake Itasca, and Deming Lake in Itasca state park, Minnesota. Also, the effects of the lakes stratification on the concentration of biological organisms found at different depths within the lakes will be tested. The surface area of these two lakes is significantly different, but they both reach a similar maximum depth. This means that the primary factor contributing to any differences in stratification we may find will be wind exposure. Lake Itasca has a much greater surface area and it is more exposed to wind than Deming Lake, which is located in a valley. Therefore, we hypothesize the water in Lake Itasca will be more mixed with a deeper Epilimnion layer than Deming Lake. Because the vertical distribution of the biota in a lakes water column is directly dependent upon the level of stratification (Schindler et al. 1996), we hypothesis that distribution of organisms in Lake Itasca will be more homogeneously spread throughout the water column, while in Deming Lake organisms will be more heterogeneously distributed with respect to depth.

Methods:

Overview

We tested the wind effect on Deming Lake and Lake Itasca stratification on June 13th, 2011. Data were collected by Bio 3807 Ecology class, from the deepest point in each lake. The Light Meter was used to measure the light attenuation, closing Zooplankten Net was used to collect biotic organisms; YSI model used to collect temperature (°C), water conductivity (µmhos cm^{-1}) and dissolved oxygen (mg/L). A Van Dorn water Sampler was used to collect water samples that later were assayed with a Spectrophotometer to measure absorbance at 665nm which was ultimately used to determine chlorophyll a content.

Study Site

Deming Lake and Itasca Lake are located in Northwestern Minnesota. Lake Itasca, the official headwaters of the Mississippi River, is a dimictic lake that mixes seasonally. It is 1065 acres in surface area. Deming Lake is a meromictic lake that does not mix thoroughly, and is 12.4 acres in surface area. Samples were taken from the deepest point of both lakes, 40+ feet for Lake Itasca and 30+ feet for Deming Lake

Field Work:

Temperature, Conductivity & Dissolved Oxygen

Temperature (°C), water conductivity (µmhos cm^{-1}) and dissolved oxygen (mg/L) were taken with YSI Model 85 probe. Data for every half-meter down to 10m were recorded. This data were collected in order to examine the lake stratification layers.

Water Clarity

In order to measure the light levels in the water, a Light meter was used for data collection at every half meter down to 10m. Moreover, a Secchi disk was used to measure the water clarity for each lake.

Water samples

Ten jars of one-liter water samples for every meter down to 10 meters depth were collected using Van Dorn nets. Also, using Zooplankton nets 20 samples were obtained for each lake (every half meter down to 10m).

Lab work:

Chlorophyll concentrations & pH

Using accumet Portable Laboratory &Accumet AP Series Handheld ph/mV/Ion meter the pH for each meter of water samples in both lakes were measured. After filtering 300 ml of water for one liter water samples, the filter papers were frozen for approximately three days for Lake Itasca and one day for Deming Lake due to time limitation. In order to determine chlorophyll level for each lake, filter papers were dissolved in 5 ml alcohol and centrifuged for ten minutes. Then, 1ml of supernatant was transferred into cuvette, and measured the absorbance at a wavelength of 665 nm by using DU 520 Spectrophotometer.

Zooplankton Counts

Using the water samples that have been taken by Zooplankton net, the zooplankton; *Chaoborus, Diaphanosoma, Rotifera, Nauplii, Cyclopoid, Calanoid*, and *Daphnia pulicaria, mendotae*, or *mendotae* (helmet) were counted for each sample. Using Sedgwick-Rafter counting chambers and Hensen-Stemple pipettes; 3 sub samples of each sample collected is used to gather the Zooplankton density for each lakes. was tested. After that using the equation below, the zooplankton for each depth measured.

C= (# of zooplankton observed * Dilution volume V_d) / V_f

***Results*:**

Temperature & Dissolved Oxygen

The data collected for water temperature and dissolved oxygen were used to estimate the lake stratification for Lake Itasca and Deming Lake, also to test chlorophyll level data. Temperature and dissolved oxygen in both lakes were proportional to each other; oxygen dissolved decreased as the temperature decreased (fig.1a&1b). Figure 1b shows that Deming lake at depth of 4-5m supersaturated oxygen.

Chlorophyll concentrations

Chlorophyll concentration is tightly affected by water temperature, oxygen dissolved and light level; therefore, the chlorophyll concentrations data shows exclusively the effect of those three factors in changing chlorophyll concentration level within Lake Itasca and Deming

Lake. According to figure 2a&b chlorophyll concentrations for Lake Itasca and Deming Lake gradually decreases proportional to light level (Fig. 3a&3b).

Water Clarity

In both lakes, declines in water clarity were observed. According to Figure 3.0a&b the light levels at the surface are at its maximum; Deming Lake has higher light attenuation than Lake Itasca at water surface(fig.3a&3b) However, in both lakes, the light level of the water decreases, as it gets deeper.

Secchi disk

The water clarity for both lakes shows the significant differences. Lake Itasca has a secchi depth of 2.3m; whereas, Deming lake has a secchi depth of 1.5m

Conductivity

Water conductivity for both lakes increases with depth (fig.4.a&4b). However, Lake Itasca starts with higher water conductivity (300 µmhos cm^{-1}) compared to Deming lakes; conductivity at the surface (150 µmhos cm^{-1}).

pH

pH for Lake Itasca is more basic at the surface than Deming Lake. However, in both lakes, the PH decreases with depth(figs 5.a&5b). Furthermore, in both lakes PH gets to neutral around 4-5 meters depth.

Figures:

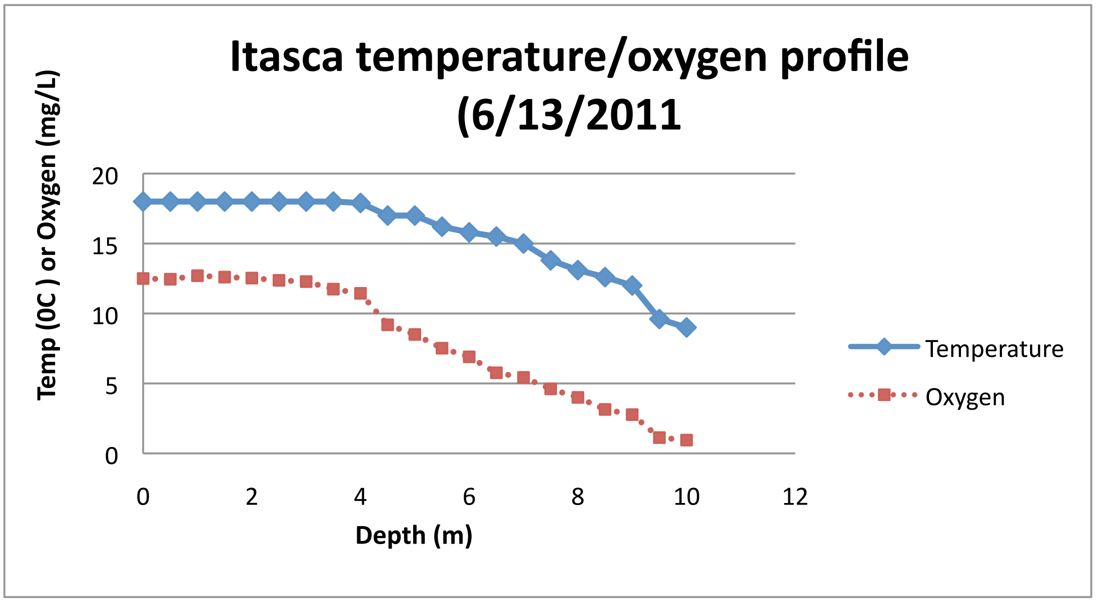

Figure 1a: Water Temperature in °C and dissolved water in mg per liter for Lake Itasca.

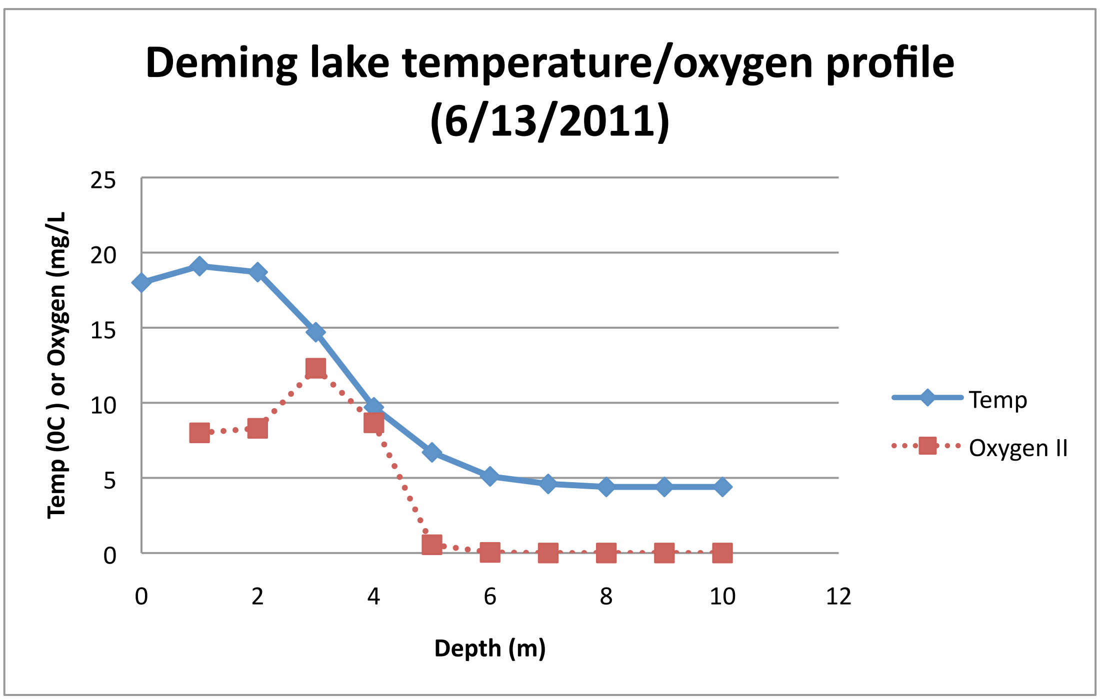

Figure 1b: Water Temperature in °C and dissolved water in mg per liter for Lake Itasca.

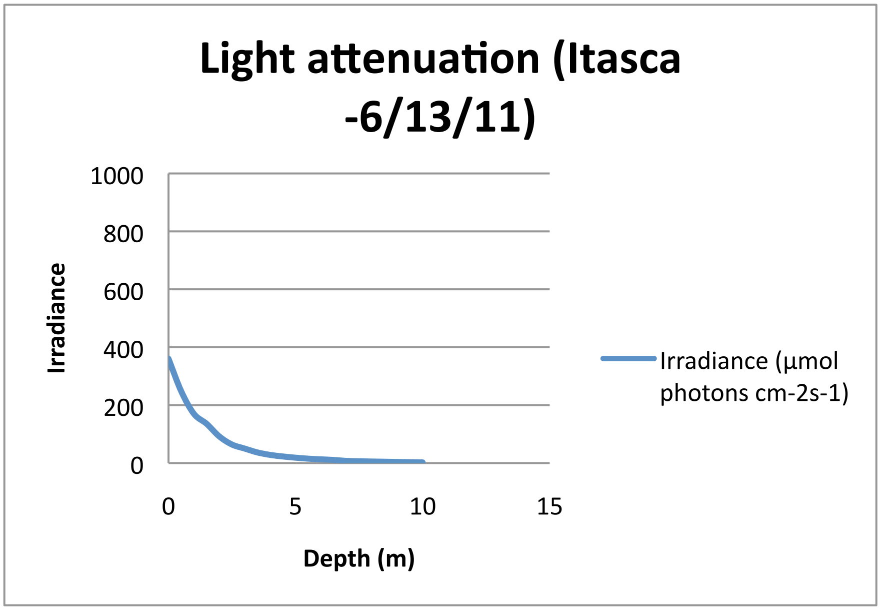

Figure 3a: The light level (µmol photons cm-2s-1) in Lake Itasca within 10 meters deep. The light level is proportional to the depth. Irradiance of light decrease as the Lake gets deeper.

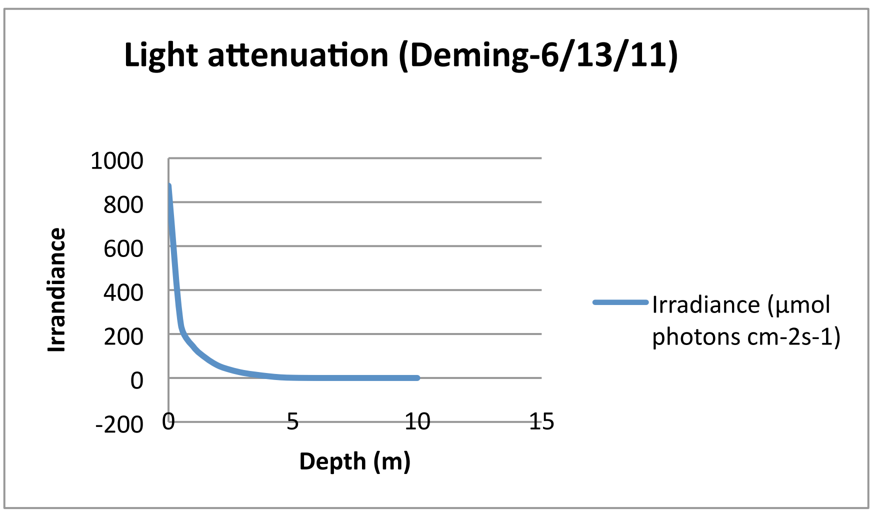

Figure 3b: The light level (µmol photons cm-2s-1) in Deming Lake within 10 meters deep. The light level is proportional to the depth. Irradiance of light decrease as the Lake gets deeper. Note, attenuationof light was equal zero after 4 meters.

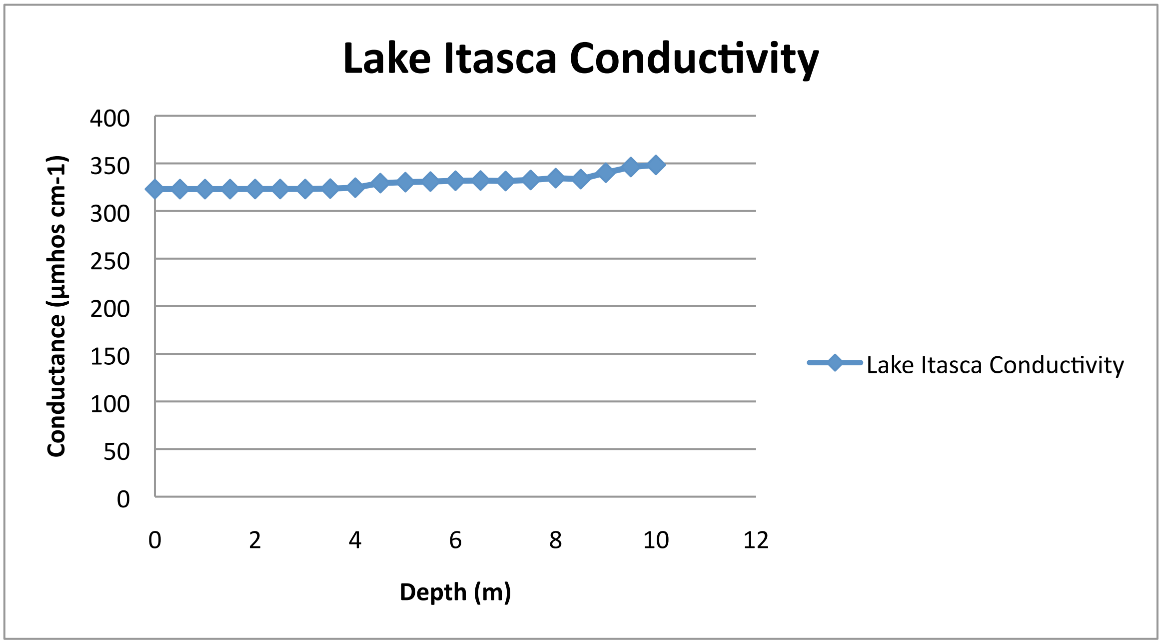

Figure 4a: Water conductivity (µmhos cm-1) for Lake Itasca within 10 meters depth.

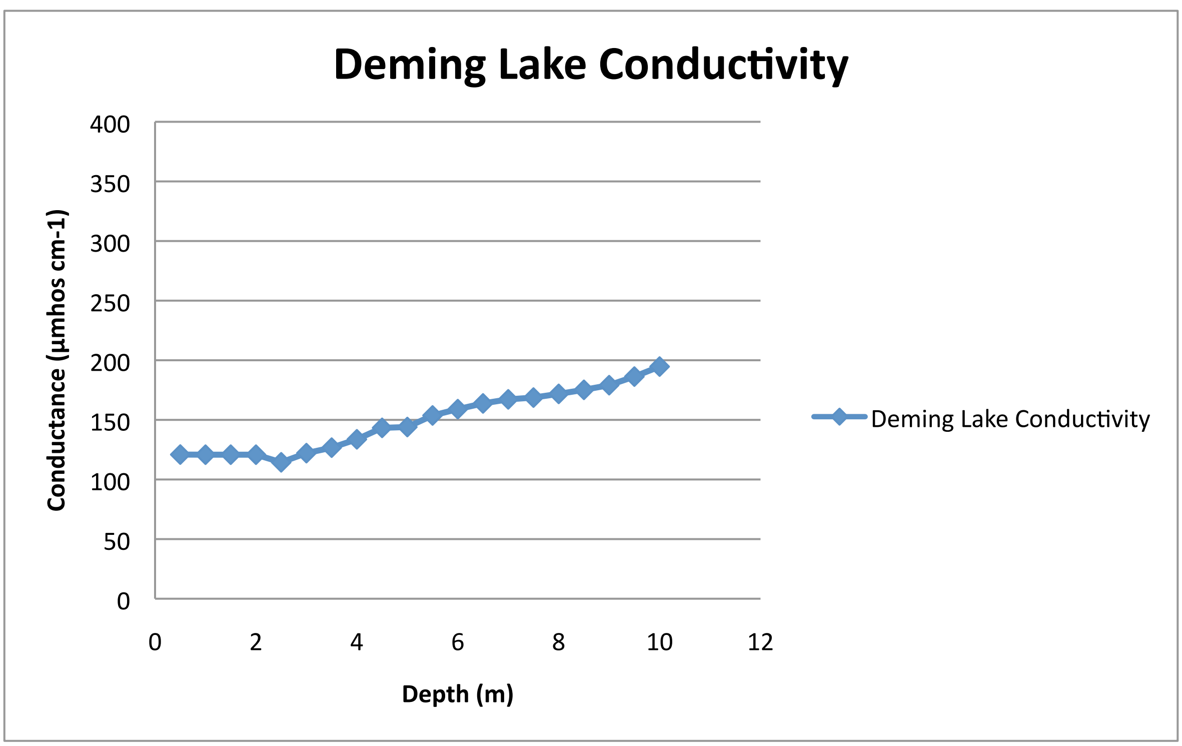

Figure 4b: Water conductivity (µmhos cm-1) for Deming Lake within 10 meters depth.

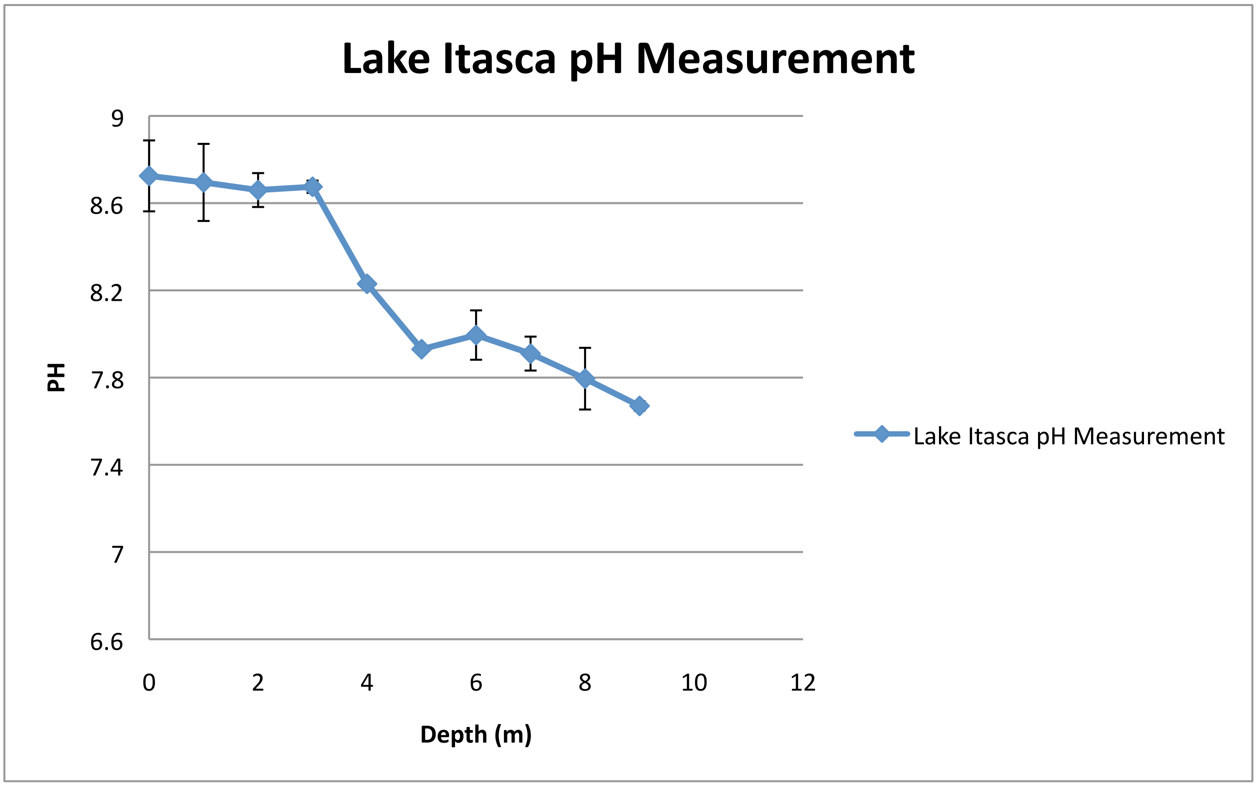

Figure 5a: PH level in Lake Itasca within 10 meters depth. Error bars cannot be seen on some of the data points because they have zero standard deviation, and others have standard deviations that are too small to be detected.

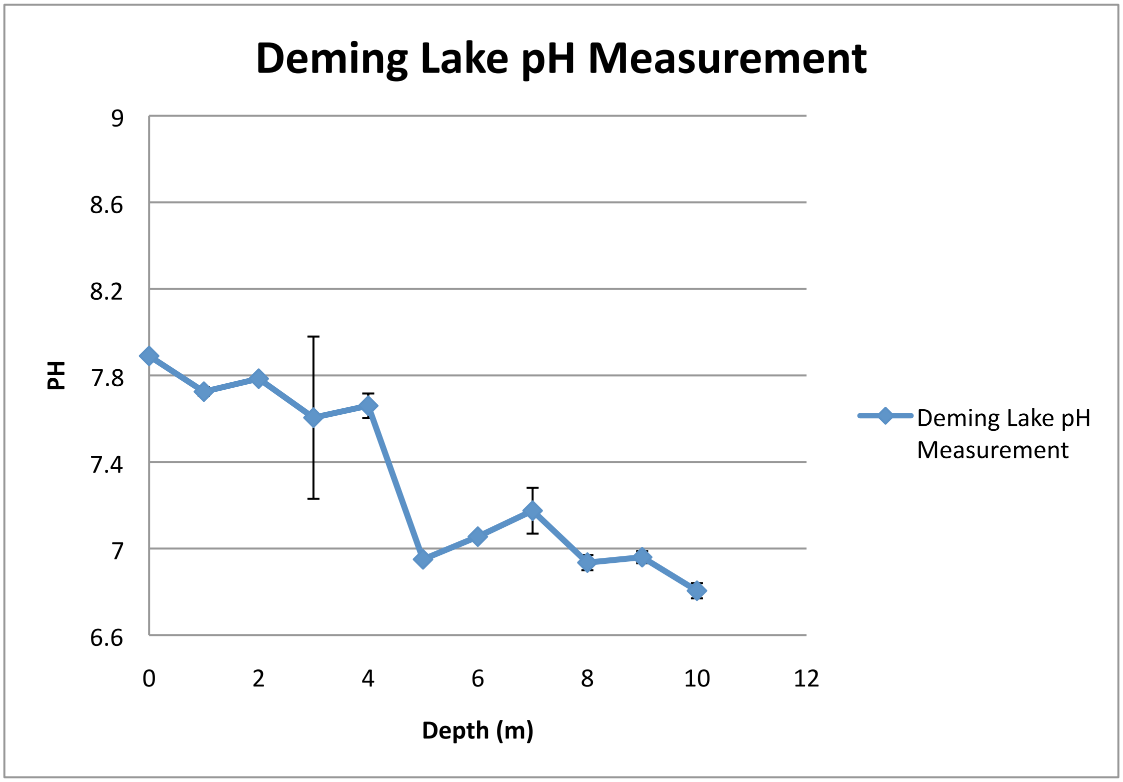

Figure 5b: PH level in Deming Lake within 10 meters depth. Error bars cannot be seen on some of the data points because they have zero standard deviation, and others have standard deviations that are too small to be detected.

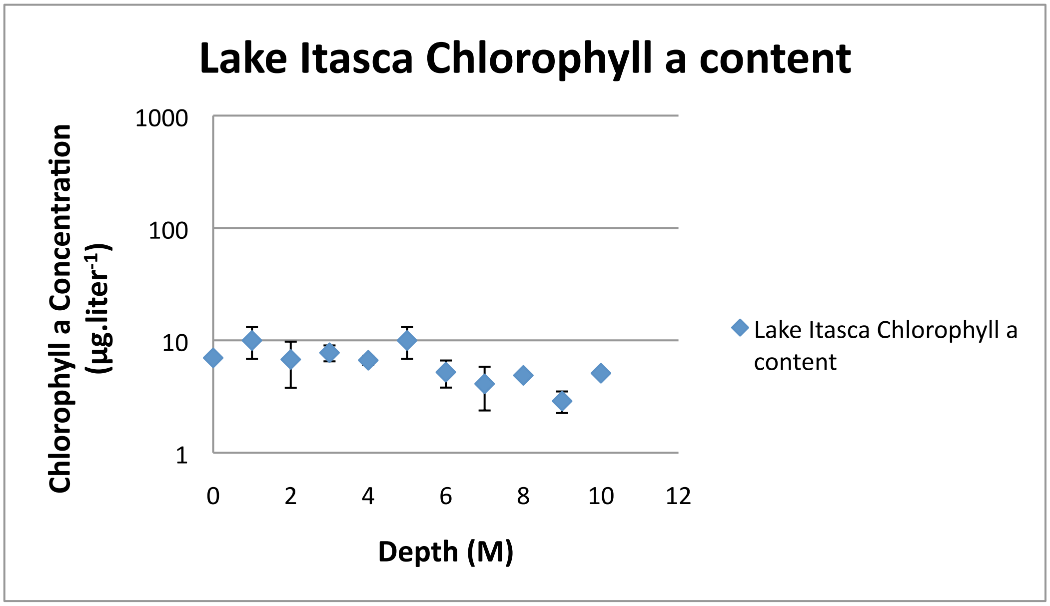

Figure 2a: The Variability of chlorophyll concentration (µg.liter^{-1}) in Lake Itasca within 10 meter deep. The chlorophyll concentration decrease as the lake gets deeper. Error bars cannot be seen on some of the data points because they have zero standard deviation, and others have standard deviations that are too small to be detected.

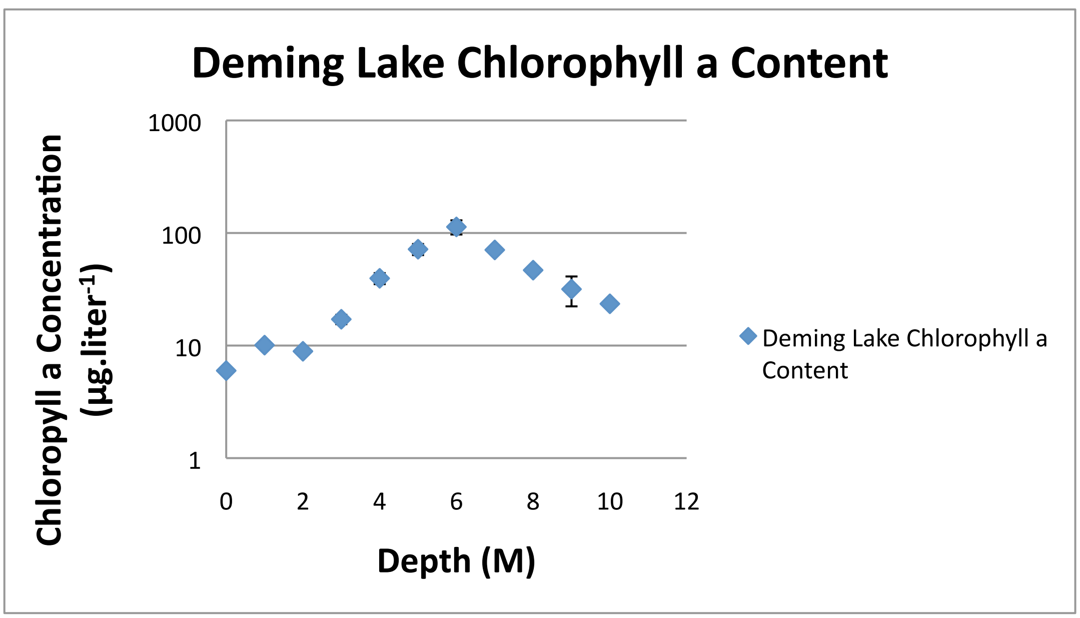

Figure 2b: The Variability of chlorophyll concentration (µg.liter^{-1}) in Deming Lake within 10 meters deep. The chlorophyll concentration decrease as the lake gets deeper. Error bars cannot be seen on some of the data points because they have zero standard deviation, and others have standard deviations that are too small to be detected.

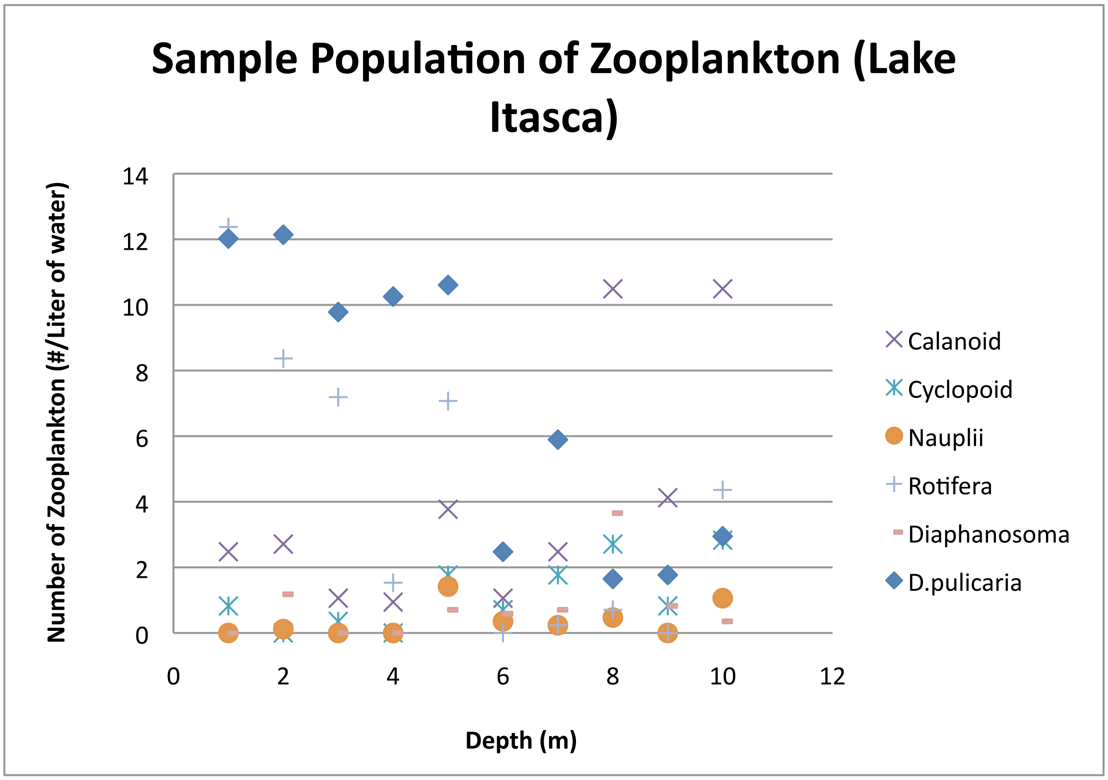

Figure 6a: frequency of zooplankton species in Lake Itasca up to 10m depth

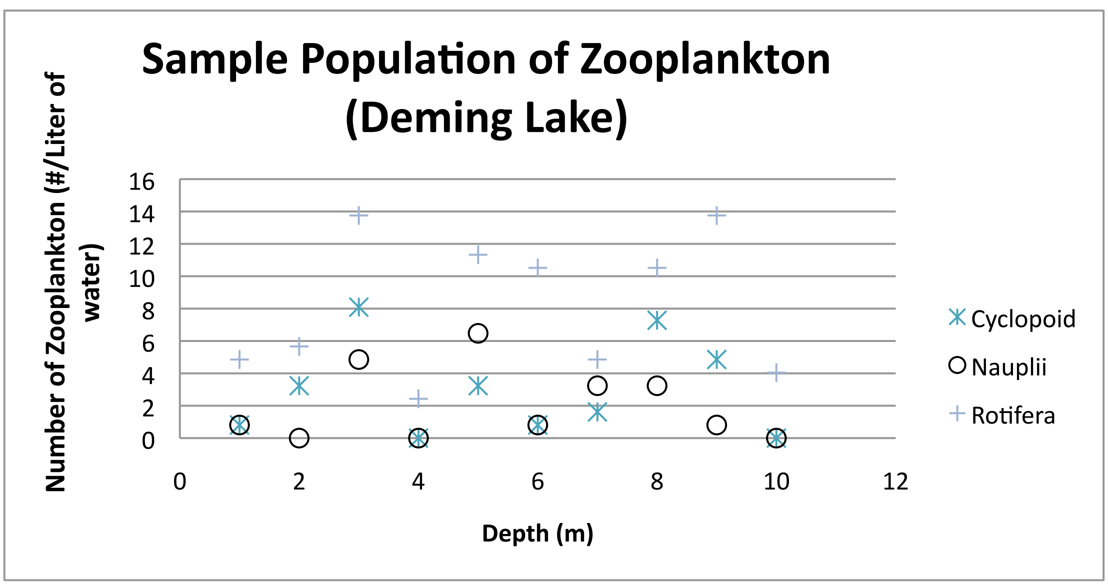

Figure 6b: frequency of zooplankton species in Deming Lake up to 10m depth

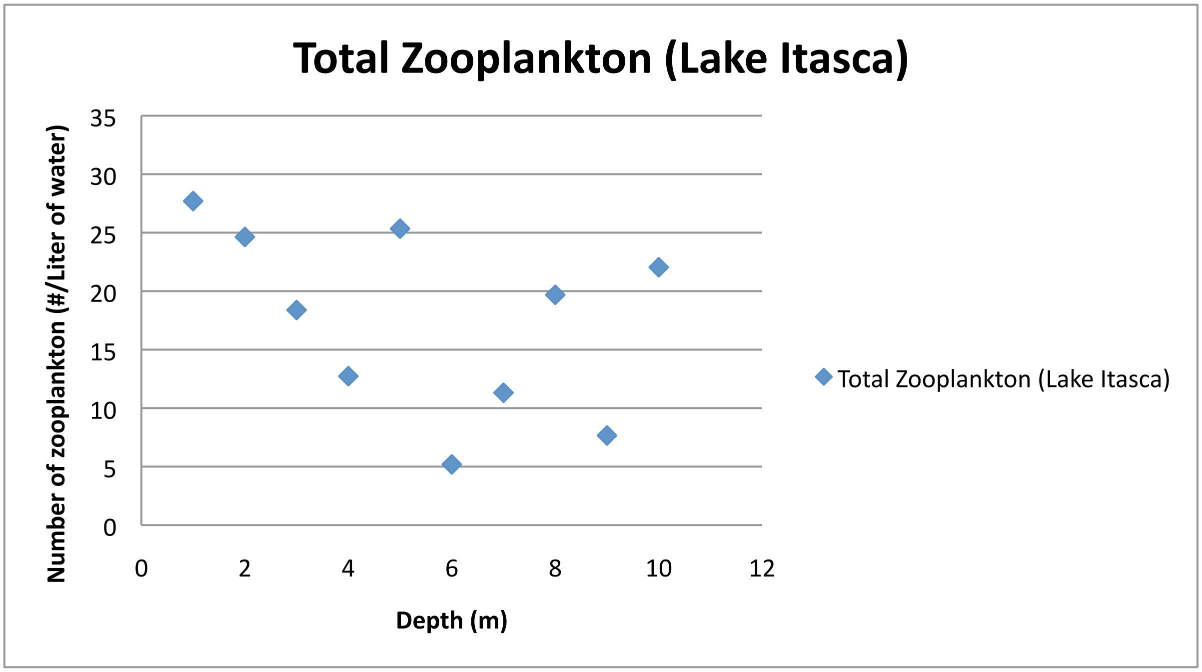

Figure 7a: Total frequency of zooplankton in Lake Itasca

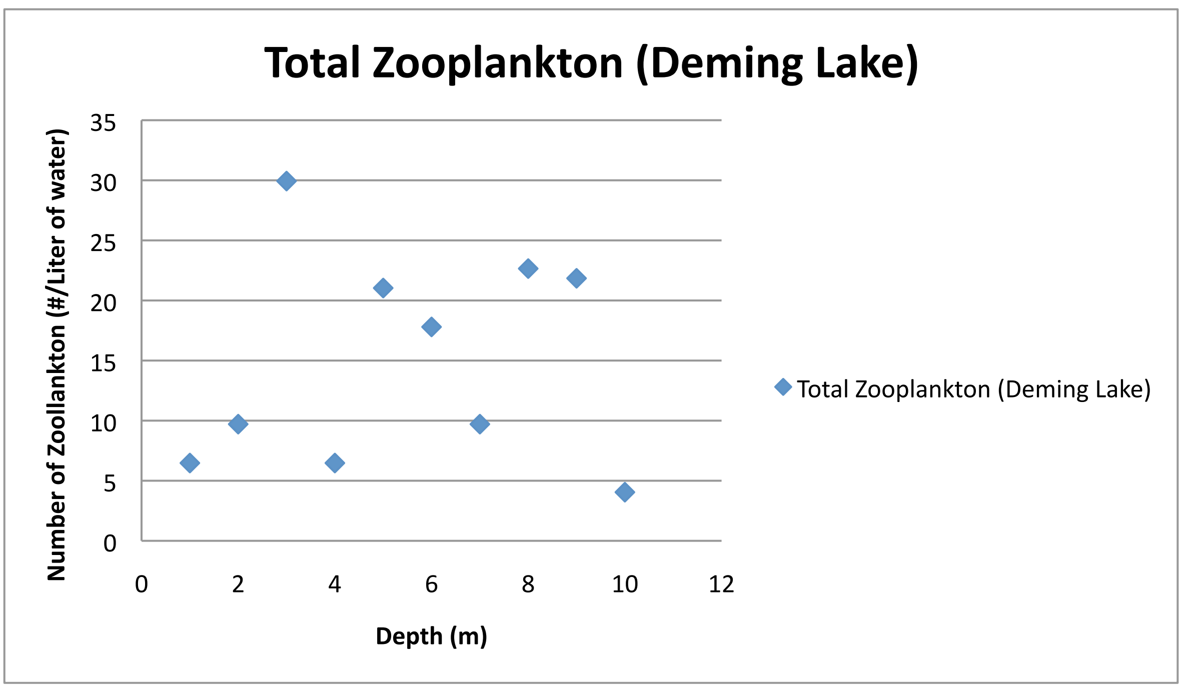

Figure 7b: Total frequency of zooplankton in Deming Lake

Discussion

The purpose of this study was to compare the effect of wind exposure on the biotic, oxygen, and thermal stratification on Lake Itasca and Deming Lake. Lake Itasca has a surface area of 1065.13 acres compared to the surface area of Deming Lake which has a surface area of 12.36 acres. As a result of this difference in surface area, Lake Itasca is more exposed to the effects of the wind. Apart from the differences in surface area that account for the effects of wind on thermal stratification, Deming Lake is found in a valley surrounded by trees which also contributes to minimal exposure to the wind, and results in stronger thermal stratification with clearly defined layers. The results of this study illustrated that the thermal stratification of Lake Itasca was found to be more mixed than the thermal stratification of Lake Deming (figure 1A, and 1B). These results are consistent with our hypothesis that the thermal stratification of Lake Itasca would be more mixed than the thermal stratification of Deming Lake.

The epilimnion of Lake Itasca was found to be 5.0m deep, and the epiliminon of Deming Lake was found to be 3.0 m deep. Due to the lack of mixing from wind exposure there is a gradual increase in temperature from 17 to 19 ^{0}C within 0.0 to 3.0 m depth in Deming Lake, while Lake Itasca shows a constant temperature of 18 ^{0}C from 0.0 to 5.0 m depth due to the mixing effect of wind exposure. The metalinion of Lake Itasca was found at a range of five m to ten meters depth, with a gradual decline in temperature ranging from 17 to 8 ^{0}C, while the metelimnion of Deming Lake was found at a range of 3 to 5 m depth, and had a steep decline in temperature ranging from 19 to 5 ^{0}C. This difference is due to the larger amount of mixing in Lake Itasca from wind exposure. We were unable to detect the presence of the hypolimnion in

Lake Itasca, meaning that it must be located at a depth below 10.0 m. The hypolimnion of Deming Lake was found to begin at a depth of 5.0 m with constant temperature of 5^{0}C. (Figure 1a& 1b)

The oxygen content of Lake Itasca was also found to be more mixed (fig. 1A) than oxygen content of Deming Lake(fig 1B), this is also due to the increased exposure to wind in Lake Itasca. The epilimnion of Lake Itasca had a constant oxygen content of 12.2 mg/L, whereas the epilimnion of Deming Lake had a surface oxygen content of 8 mg/L with a steep increase to 12.5 mg/L at 3 m depth. The explanation for this sharp increase in oxygen content in the epilimnion is caused by the supersaturation of this layer by the presence of phytoplankton which releases oxygen as a byproduct of photosynthesis. In the metelimnion of Lake Itasca there is a gradual decrease in oxygen content ranging from 11.9 to 1 mg/L. this is a gradual decline in oxygen content 5 to 10m and can be explained by Lake Itasca's increased wind exposure. The metalimnion of Deming Lake had a sharp decrease in oxygen content ranging from 12.2 mg/L to 0.5 mg/L, the range of this decline was found to be from 3m to 5m. This sharp decline in oxygen content of Deming Lake is due to the lack of exposure to mixing by the wind. The hypolimnion of Lake Itasca was not detected by our measurements, but our last oxygen content reading at a depth of 10m was found to be 0.5 mg/L. The oxygen content of the hypolimnion of Deming Lake was found to equal 0 mg/L at a depth of 5m. This is due to the relatively higher presence of respirators found in the hypolimnion of Deming Lake compared to the amount of oxygen being released by photosynthesizing organisms (fig.1b). the sharp spike in oxygen content at 3m depth in Deming Lake (fig.1b) is due to the strong thermal stratification of lake Deming which has trapped the oxygen being produced by the phytoplankton in this layer.

The light level in Lake Itasca shows gradual exponential decrease from 350 to 0 µmol photons cm^{-2} s^{-1} down to 7.0m (fig. 3A). Whereas Deming Lake shows steep exponential decline from 890 to 200 µmol photons cm^{-2} s^{-1} within depth 0 to 0.5m and then, gradual decrease from 200 to 0 within .5m to 4.0m. In addition, the secchi disk shows significant differences in water clarity in both lakes, Lake Itasca secchi depth of 2.3m, and Deming Lake has secchi depth of 1.5m (fig 3B). This difference in light attenuation between Itasca and Deming lake can be explained by the difference in abundance of *Daphnia mendotae* between the two lakes. Increased abundance of *Daphnia medotae* correlates directly with water clarity because *Daphnia medotae* consume the phytoplankton that reduce water clarity when they produce chlorophyll though photosynthesis (Hembre, Megard, 2005). Lake Itasca was found to have a much higher abundance of *Daphnia mendotae* than Deming Lake in which no presence of *Daphnia mendotae* where found (figures 6A, 6B).

The water conductivity for Lake Itasca slightly consisted within 350 to 320 conductance, but Deming Lake it has a gradually increases in water conductivity from 0 to 0.5 m and then it stays consistent within 175 and 150 conductance (fig 4a&4b). Conductivity is dependent upon the amount of dissolved ions in the water (Walse, 1998). The larger amount of conductivity in Lake Itasca is due largely due to the high amount of water sheds that deposit ions into the water. The difference in the change in conductivity with depth between the two lakes can be explained by the difference in stratification between the two lakes. Lake Itasca is less stratified than Deming Lake; therefore, the concentration of ions in the water is also less stratified. The thermal stratification of Deming Lake has resulted in a steady stream of dead organic material sinking to the bottom and accumulating in the sediment. When the bacteria in the sediment decompose the dead organic material they release CO_2 which gets absorbed into the water and is ionized into carbonic acid carbonic acid (H_2CO_3), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^-) which all contribute to increased conductivity. The reason the concentration of these ions is much higher in the hypolimnion of Deming Lake is because it is meromictic, and the water in the hypolimnion never mixes with the rest of the lake, unlike Lake Itasca which is holomictic.

The pH in Lake Itasca in the epilimnion 0 to 3.0m depth was 8.7, in the metalimnion between 3m and 5m depth the pH shows a significant decrease from 8.7 to 7.9. The hypolimnion showed another slight decrease from 7.9 to 7.7. The epilimnion of Deming Lake 0 to 3m depth had an average pH of 7.7. The metalimnion 3m to 5m depth showed and steep decline in pH from 7.7 to 6.9. The hypolimnion had an average pH of 6.9. (Figures 5A, 5B) Deming Lake had an overall lower pH than Lake Itasca, but both lakes showed the same trend with the pH showing a sharp decline in the metalimnions, and remaining consistent in the epilimnions, and hypolimnions. The lower pH in Deming Lake can be explained by the higher concentration of carbonic acid (H_2CO_3), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^-) that are produced by the decomposition of dead organic material by bacteria (Schink, Zekus, 1981). These chemicals become trapped in the hypolimnion and do not mix with the rest of the lake, resulting in a buildup of acidic compounds that do not get neutralized by phytoplankton through photosynthesis. The living organisms in the hypolimnion of Deming Lake are also contributing to the lower pH by absorbing oxygen and releasing CO_2 through respiration. The CO_2 released in the hypolimnion gets converted to carbonic acid (H_2CO_3), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^-), which accumulate in this layer because there is very little light for photosynthesis which would convert the CO_2 back to oxygen and raise the pH. The higher pH in Lake Itasca can be explained by the increased amount of mixing between the layers, which moves the CO_2 absorbed by the water into depths where enough light penetrates for the phytoplankton to convert the CO_2 into oxygen; effectively reducing the amount of carbonic acid (H_2CO_3), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^-) in the water.

The chlorophyll content of Lake Itasca was found to be more mixed (fig.2a) than chlorophyll content of Deming Lake (fig 2b). However, the chlorophyll contents in Deming Lake gradually increases from depth of 4.0m to 6 .0m, and reaches a maximum within depth of 6.0 m due to the accumulation of decayed algae. Even though the accumulative algae that found in taken water samples are dead, they still retain their chlorophyll contents, thus photosynthesis is still occurring.

The overall results of our experiment where consistent with our original hypothesis. We found that Lake Itasca had a higher amount of mixing between the epilimnion, metalimnion, and hypolimnion than Lake Deming, which had a higher amount of stratification between the three layers. This difference in stratification was mainly due to the difference in surface area of the two lakes which contributed to a significant difference in wind exposure and turbidity. This information is important to biologists who are studying lake ecosystems, as well as conservation programs that are interested in preserving a lakes natural biota.

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