THE EFFECTS OF FISH PRESENCE AND MIXING PATTERNS ON WATER CLARITY IN LAKES: ARCO, DEMING, AND ITASCA

Steven Harren, Jacob Kartak, Jonathan Knight, Justin Lehman
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Abstract

In the summer of 2009, in Itasca State Park, MN, samples of zooplankton, chlorophyll a concentrations, and Secchi disk readings were studied in three lakes with differing characteristics. Our study sites were Deming Lake (fish, meromictic), Arco Lake (fishless, meromictic), and Lake Itasca (fish, dimictic). Our variables of interest were the presence or absence of fish, and whether the lake was dimictic or meromictic. Our study showed that Arco Lake, a small meromictic fishless lake, had the highest Secchi disk reading. Along with a high level of water clarity there was an abundance of large zooplankton. We contributed this high level of clarity with the absence of fish, and its meromictic stratification. Lake Itasca showed its true dimictic characteristics in our data, showing relatively low fluctuations in temperature and dissolved oxygen levels.

Introduction

Our study was part of a class project for Biology 3807: Field Ecology. This course was offered by the University of Minnesota: Twin Cities and was located in Itasca State Park, Minnesota.

We were interested in the effects of fish on the clarity of water of some local lakes. There are two main factors to water clarity of lakes, phytoplankton biomass and suspended sediments (Schrage and Downing, 2004). We were only concerned with phytoplankton concentrations for our study because we didn't have the equipment to test suspended sediments.

As found in other studies, fish have a top-down effect on lentic water clarity. Zooplanktivorous fish often decrease the population of zooplankton in a lake (Reissig et al., 2006). With lower levels of grazing zooplankton, algae and other phytoplankton increases. As previously stated, this generally decreases water quality.

In our study we tested the different zooplankton levels and chlorophyll a concentrations (a strong indicator of phytoplankton) of three local lakes. We tested the effects of the presence of fish and differences of stratification on lentic plankton concentration and water quality. We sampled lakes Itasca, Deming, and Arco located in Itasca State Park, MN.

The effects of holomictic mixing versus meromictic mixing is poorly documented so we tested the effects of different levels of stratification on water clarity as well as effects of fish. Holomictic mixing is total mixing of lake water, generally once in spring and once in the fall. Meromictic mixing is mixing of only a portion of the water. This generally results in a saltier solution in this area called the monolimnion. Meromictic lakes are caused by saltwater intrusion, generally by runoff, or by sheltering from wind, which inhibits mixing (Kalff, 342-345).

Lake Itasca was our control as it is holomictic and contains fish. Deming Lake contains fish but is meromictic. Arco Lake contains no fish and is also meromictic.

We predicted that Arco would be the clearest lake of our study lakes. Arco lake has no fish and therefore zooplankton is one of the top predators of the food web and will have relatively high numbers. As mentioned, the next tier in the trophic levels is phytoplankton. A higher amount of zooplankton will decrease phytoplankton and overall clarity. Since Deming and Itasca have fish, we predict that they will both have lower zooplankton levels and clarity.

We also predict the distribution of zooplankton will be lower in the lakes with fish due to predation. Zooplankton have less of a chance of being predated the deeper they are. Therefore, a fishless lake like Arco should see a higher proportion of zooplankton in the shallower depths, where more phytoplankton tend to live.

Methods

Study Site

For our group project we decided to sample three different lakes with different characteristics to compare and contrast these major differences. Our study involved the lakes of Arco, Deming and Itasca. Arco Lake is a meromictic and fishless lake located off of Main Park Drive approximately 5 miles south from the Itasca Biological Station. It has an area of 5.68 acres and its deepest point is 10.5 meters (Reese III and Brient, 1990). Arco had a Secchi disk reading of 7.125 meters on June 17th, 2009.

Deming Lake is also a meromictic lake but it does have fish in it. It is located off Main Park Drive approximately 4.5 miles south from the Itasca Biology Station. It has an area of 8.4 acres and its deepest point is 15 meters (Condon et al., 1996). Deming had a Secchi disk reading of 1.8 meters on June 17th, 2009.

Itasca Lake is a dimictic lake that also has fish in it and is located at IBS. It has an area of 1,077.0 acres and its deepest point is 13.5 meters (MDNR, 2009). Itasca had a Secchi disk reading of 3.575 meters on June 17th, 2009.

Using a depth finder (Eagle, Ultra Classic), we located the deepest part of each lake. Once at the deepest part we used a handheld oxygen conductivity, salinity, and temperature gauge (YSI incorporated, Model 85, 1998) to measure the dissolved oxygen, temperature, conductivity, and salinity levels every .5 m section from the water's surface to the lake floor. These measurements were all documented and used to locate the approximate locations of the epilimnion, metalimnion and hypolimnion layers of the three lakes. The monimolimnion layer was also located and recorded for both Arco and Deming Lakes.

A Secchi disk was used to measure the clarity of the water in all three lakes. This tool is a simple but effective way to measure how clear a lake is by lowering a black and white flat disk attached to a rope down into the lake until the disk disappears. At the depth where the disk is no longer seen is measured with the rope and documented as the clarity in meters of the lake.

A closing zooplankton net was used to collect two samples at each of the limnotic levels at each lake. This tool is a net that funnels down to a clear removable jar at the bottom in which zooplankton can be captured and poured into a separate collection container. Ethanol was added to each sample to kill the living zooplankton to simplify the task of counting the species present at each limnotic level.

A water sample was collected at each limnotic level to be brought back to the lab for filtration. Once back at the lab, we filtered each water sample using a vacuum flask. The filters were then folded and covered by aluminum foil to keep light from reacting with the chlorophyll sample readings. After the filtration process, we added 5 mL of 95% ethanol solution into a 15 mL centrifuge test tubes and added one filter to each tube. The filters were ripped up and pushed completely into the solution at the bottom of the tube. We then subjected these tubes to darkness for an hour to let the ethanol draw out the chlorophyll in each sample.

The samples were then put into a centrifuge for 5 minutes each to separate the filter remnants from the ethanol containing the chlorophyll. A pipette was used to extract the liquid from the test tubes and transferred into 3 mL cuvettes. A spectrophotometer (Beckman Coulter, Du 520 General Purpose UV/Vis) was first calibrated with the 95% ethanol solution as a blank sample, and then was set to the wavelength of 665 nanometers. The absorbance by chlorophyll *a* was then recorded for each sample. The number given by the spectrophotometer was then plugged into the formula:

$c = \frac{c_e \cdot V_e \cdot F}{V}$ which gave the amount of chlorophyll in milligrams per liter of the water.

The samples of zooplankton that were collected from each lake at each limnotic level were used to estimate the concentrations at each location. The sample was mixed to evenly distribute the organisms in solution. Using a pipette 1 mL of the water was transferred to an examination slide. Once under the microscope (Olympus Optical Company, CH-2), the different zooplankton were counted and tallied by species. This method was used to visually see and compare the concentrations and sizes of the zooplankton in the different lakes as well as the different limnotic levels in each lake.

Results

Limnotic levels

For Deming Lake, the layers are at the following levels: the epilimnion is from the surface or 0 to 1.5 m, the metalimnion is from 2 to 6 m, the hypolimnion is from 6.5 to 11 m and the monimolimnion is from 11.5 to 15 m. For Arco Lake, the layers are at the following levels: the epilimnion is from 0 to 2 m, the metalimnion is from 2.5 to 6 m, the hypolimnion is from 6.5 to 8.5 m and the monimolimnion is from 9 to 10.5 m. For Itasca Lake, the layers are at the following locations: the epilimnion is from 0 to 4 meters, the metalimnion is from 4.5 to 10.5 m, and the hypolimnion is from 11 to 13.5 m. Itasca Lake mixes completely, so there is no monimolimnion level.

Deming Lake

Zooplankton specimens were collected in Deming Lake; two from each limnion. The average count of zooplankton in the epilimnion level was 32.895 zooplankton/L. The metalimnion was determined to be 69.01 zooplankton/L (Figure 1). The hypolimnion and monimolimnion were observed to be 6.46 and 281.46 zooplankton/liter respectively.

Chlorophyll *a* samples in Deming Lake in each of the four limnotic levels gave us an idea of what to expect for water quality (Figure 2). In the epilimnion chlorophyll *a* concentration was 16.492 μg/L. The metalimnion had a concentration of 26.718 μg/L.

The hypolimnion was calculated to be 26.489 μg/L. Finally the chlorophyll *a* concentration in the monimolimnion was 38.938 μg/L.

Since Deming reaches approximately 15 meters of water we were effectively able to obtain temperature, dissolved oxygen, specific conductivity, and salinity for each half meter. Temperature falls pretty steadily from 19 degrees Celsius on the surface down to the bottom which was measured at 4.7 degrees Celsius (Figure 3). Dissolved oxygen fluctuates slightly around 7.5-8 mg/L until we got down to 4.5 meters. From 4.5 meters on we experienced a notable drop-off until 7.5 meters, at this point no more dissolved oxygen is measured (Figure 4). Specific conductivity shows a pretty consistent climb in Deming Lake (Figure 5). Near the surface of the lake it was measured to be 126.4 μS, it rose consistently while we got deeper. Our final reading at the bottom of Deming Lake was 437 μS.

Arco Lake

In the epilimnion layer of Arco Lake we found a density of 195.982 zooplankton/L (Figure 6). In the metalimnion our zooplankton/L was 177.99. As we moved deeper into the hypolimnion we found a density of 184.17 zooplankton/L. The monimolimnion was recorded as our lowest zooplankton/L measurement at 132.685.

The chlorophyll a concentration in the epilimnion was noted as 6.251 μg/L (Figure 2). As we moved down to the metalimnion our chlorophyll a concentration remained pretty constant, at 6.616 μg/L. It was at the hypolimnion we saw a significant jump up to 30.995 μg/L. This jump was followed by an even larger jump in chlorophyll a concentration in the monimolimnion layer, measuring 139.76 μg/L.

Temperature was measured at the surface, 18.6 degrees Celsius, and to no surprise dropped consistently down to 4.8 degrees Celsius (Figure 3). Oxygen concentration was 7.92 mg/L at .5 meters. Dissolved oxygen remained somewhat constant until a depth of about 3 meters, from 3 meters to 4.5 meters deep the dissolved oxygen rose to as high as 12.6 mg/L (Figure 4). Dissolved oxygen steadily declined and zeroed out at a depth of 9 meters. Specific conductivity was measured at 100.4 μS near the surface of the water, it slowly rose up to 250.7 μS at the bottom of Arco Lake.

Lake Itasca

Lake Itasca was measured at a temperature of 17.7 degrees Celsius, it didn't fall nearly as low as the previously discussed lakes near the bottom; 10.6 degrees Celsius (Figure 3). Dissolved oxygen was 7.97 mg/L at the surface of Lake Itasca, falling steadily until 11 meters deep, where it was recorded as zero (Figure 4). Specific conductivity was recorded as 330.9 μS and stayed constant until a depth of 5 meters (Figure 5). From 5 meters on down to the bottom, the conductivity rose to a reading of 406.9 μS at Itasca's deepest point of 13.5 meters.

Lake Itasca's chlorophyll *a* concentration levels stayed relatively constant at the different limnotic zones (Figure 2). The concentrations in the epilimnion, metalimnion, and hypolimnion were 5.253 μg/L, 4.887 μg/L, and 7.98 μg/L respectively.

Zooplankton was found very abundantly in the epilimnion, with a recording of 678.155 zooplankton/L (Figure 7). In the metalimnion the zooplankton/L dropped down considerably to 26.25. There was a slight rise in the hypolimnion level up to 216.26 zooplankton/L.

Secchi disk measurements were taken at each lake they are illustrated in (Figure 8). Arco Lake had a reading of 7.125 meters. Itasca had the second highest with 3.575 m, followed by Deming Lake with 1.8 m.

Discussion

Phytoplankton

In this study we were interested in the top-down effect fish have on water clarity. We hypothesized that of the three lakes in our study, Arco would be the clearest because it does not have fish to eat zooplankton, which results in higher numbers of zooplankton and lower numbers of phytoplankton.

As we predicted, Arco was the clearest of the three lakes, followed by Itasca and Deming respectively. Since Arco was the clearest, we expected it to have the lowest levels of phytoplankton. We analyzed water samples for chlorophyll *a* taken from the epilimion, metalimnion, hypolimnioin, and monimolimnion and graphed the concentrations (Figure 2). Only the concentrations in the epi- and hypoliminions of each lake were considered because we suspect that the lower levels of the lakes contain residual amounts of chlorophyll *a* in dead phytoplankton that produce concentration readings much higher than what is representative of chlorophyll *a* contained in living phytoplankton (Moss, 1968).

Comparative analysis of the chlorophyll concentrations from each of the lakes produced unexpected results. Itasca and Arco had similar levels of chlorophyll *a* in their respective epi- and hypolimnions but considerably different secchi depths (Figure 8). Because water clarity is dependent on phytoplankton and suspended sediment (Scharage and Downing 2004), it is probable that the lower water clarity in Itasca is a result of more suspended sediments than Arco since they both have similar concentrations of chlorophyll *a* in their upper two layers. The difference in clarity while maintaining similar phytoplankton levels may also be affected by the different mixing properties of the two lakes. The results from Deming were as expected, i.e. higher levels of chlorophyll *a* correlated to lower water clarity.

Zooplankton

Zooplankton results followed closely what we predicted. Arco had the highest number of large zooplankton, which have the greatest effect on phytoplankton levels. Both Itasca and Deming had lower levels of the larger zooplankton.

Daphnia were the largest zooplankton sampled (other than 1 *Leptodora* in Itasca), and therefore most likely had the biggest effect on phytoplankton levels. Arco had at least double the levels of *Daphnia* in each layer as any other lake. Other large phytoplankton-grazing organisms like *Chaoborus* and *Bosmina* also followed patterns of higher levels in Arco. Again, we didn't test size but Arco's *Daphnia* appeared to be significantly larger than *Daphnia* from other lakes. The high levels of *Daphnia* in Arco help explain why it has less phytoplankton levels than Deming.

Itasca had the highest total number of zooplankton but a majority of it was Rotifera, specifically *Asplanchna*. We didn't test the size of zooplankton but Rotifera and the Dinoflagellates were the smallest zooplankton, which made up most of Itasca's zooplankton.

Results for our predictions of zooplankton migration in the different stratification levels were different than expected. Arco Lake had the highest number of *Daphnia* and other large phytoplanktivorous organisms in the Epilimnion. This supports our hypothesis that zooplankton will take advantage of the warmer water in the absence of predators. However, Deming and Itasca follow this trend as well. We couldn't find any supporting documentation on why this may be.

Dimictic versus Meromictic Lakes

Lake Itasca's characteristics closely follow our expectations as far as range of temperature and dissolved oxygen. It is very apparent in Figures 3 and 4 that Itasca is relatively constant when compared to Deming and Arco Lakes. Temperature in Itasca is fluctuates much less showing its true dimictic qualities. Arco and Deming's data regarding temperature and dissolved oxygen show that they are indeed meromictic lakes and do not mix completely. Along with not mixing completely they have distinct limnotic levels. Oxygen follows a similar trend in the three lakes. Dissolved oxygen readings are further evidence that the structure in Lake Itasca differs from that of Arco and Deming. Dissolved oxygen fluctuates much less in Itasca.

In Lake Itasca Chlorophyll a concentrations are relatively constant throughout the limnotic levels. We contribute this pattern to its holomictic composition.

Bias / Error

We had limited resources and time so our results may contain slight errors. We studied the lakes with the help of 16 other students from our class. We also only had about a week to put our project together, one day to use the help of our class, and about 3 weeks to do any research.

All members of our class learned zooplankton identification on the spot, including us. This may create some bias towards larger and potentially easier to identify zooplankton. Our sample size may have created a little bias as well. We were only able to collect data in one spot off each lake. We would have gotten more reliable results if we were able to collect data from multiple spots or days. We also would have gotten more reliable data if we were able to collect samples from 1m increments. We also may have had a slight error due to the fact that we collected data on the stratification levels the day before we actually collected zooplankton and phytoplankton levels. These potential errors may have skewed our data slightly but not enough to falsify our evidence.

Conclusion

Almost all of our evidence supports our prediction that fish greatly affect water clarity. Fish are top-down predators and therefore affect all other trophic levels. Arco Lake doesn't have fish and therefore has higher levels of zooplankton. Deming and Itasca have fish and consequently have lower levels of larger zooplankton. Phytoplankton levels also followed zooplankton levels in all three lakes. Water clarity followed these trends as well. Arco was the clearest because it didn't contain fish.

Lake	Area (acres)	Deepest Point (m)	Secchi Disk (m)	Mixing Characteristics	Fish Present
Itasca	1,077	13.5	3.575	Dimictic	Yes
Deming	8.4	15	1.8	Meromictic	Yes
Arco	5.68	10.5	7.125	Meromictic	No

Table 1.

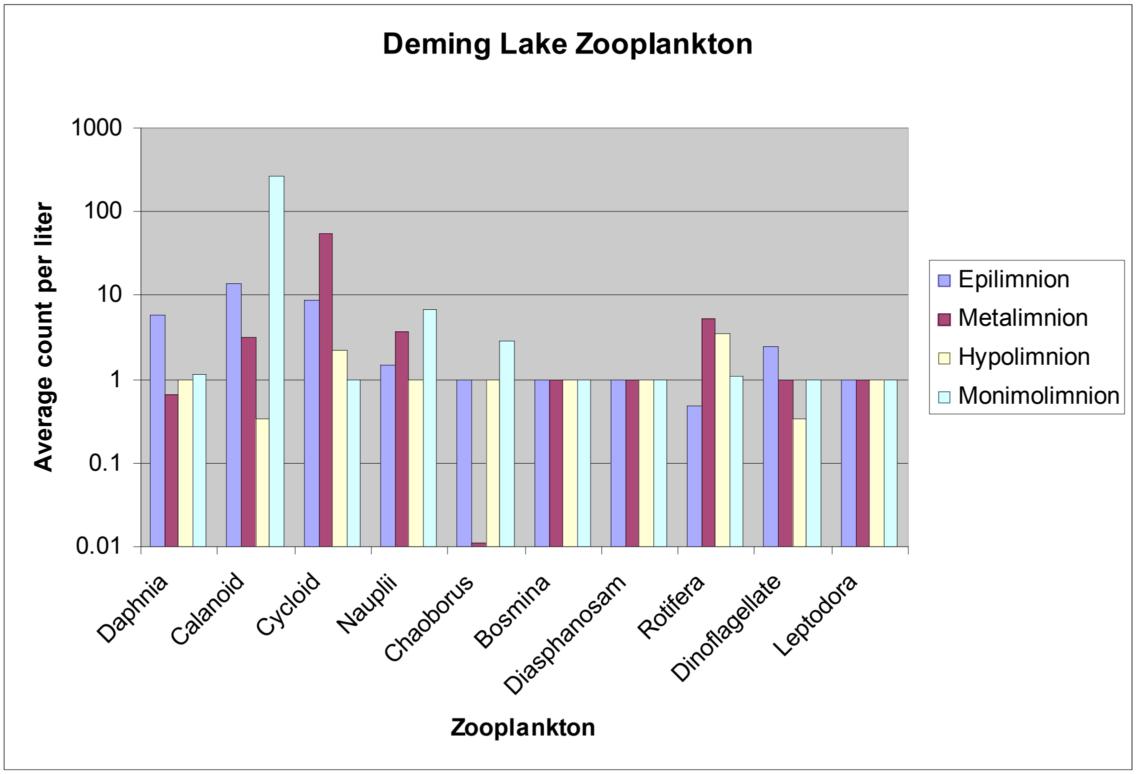
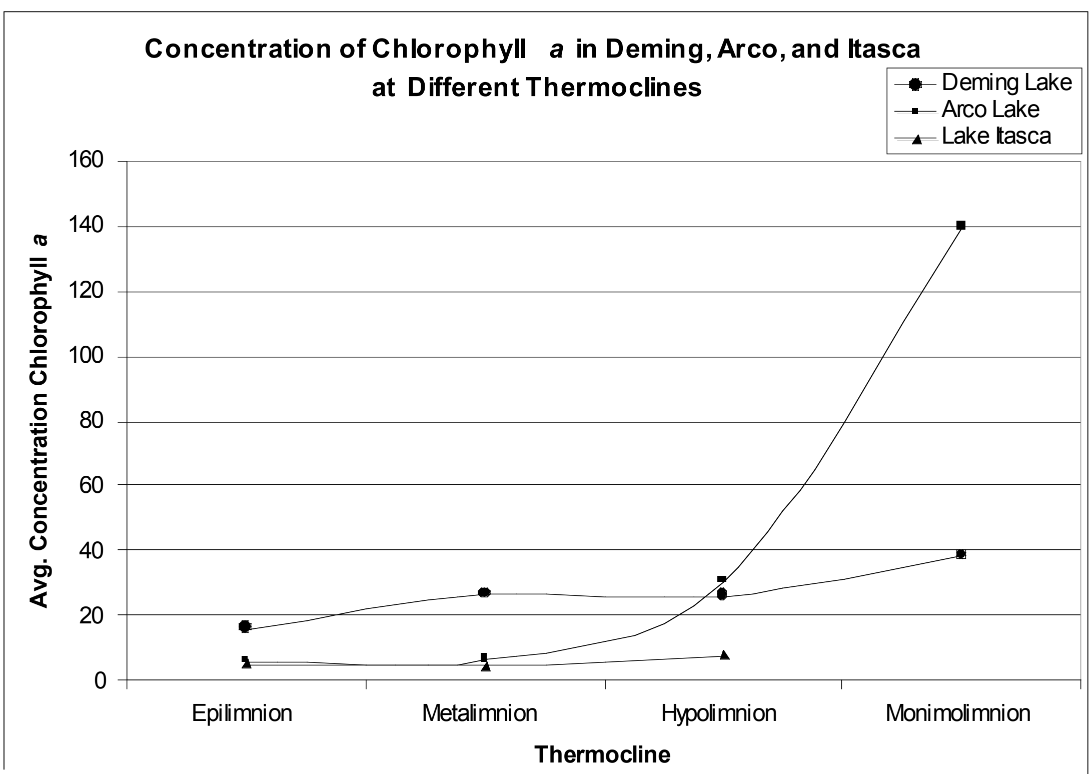


Figure 1



Figure

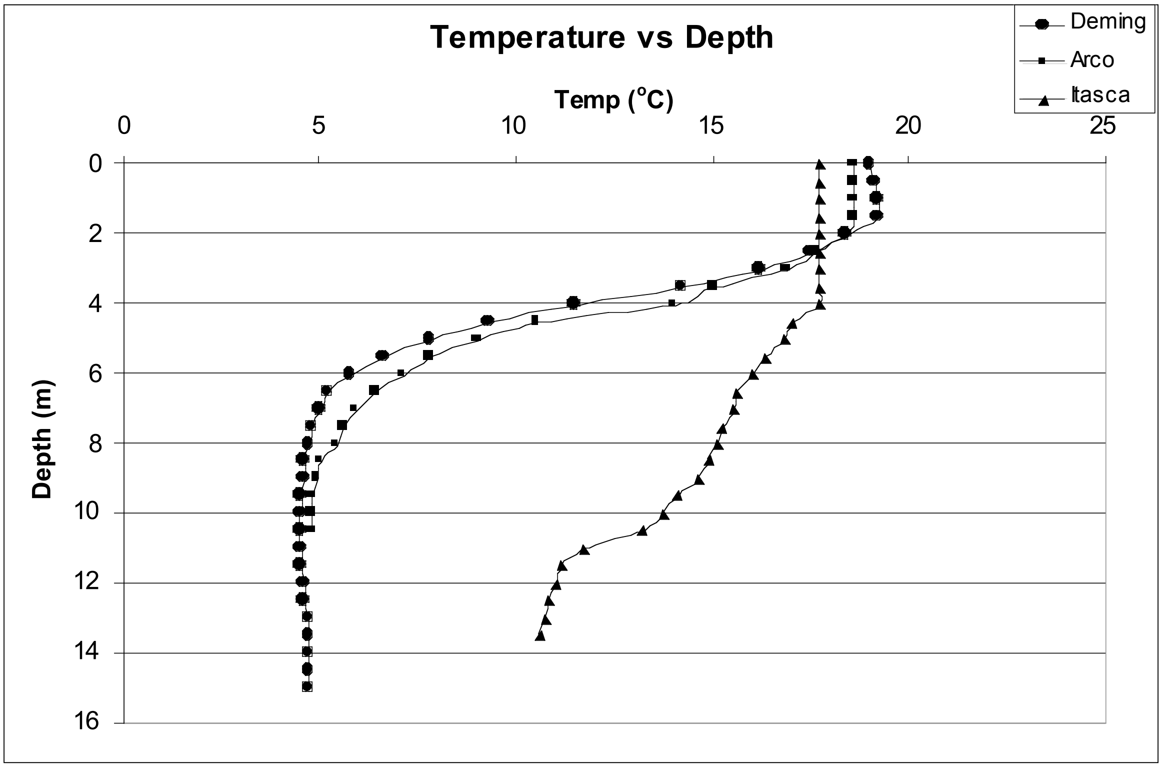
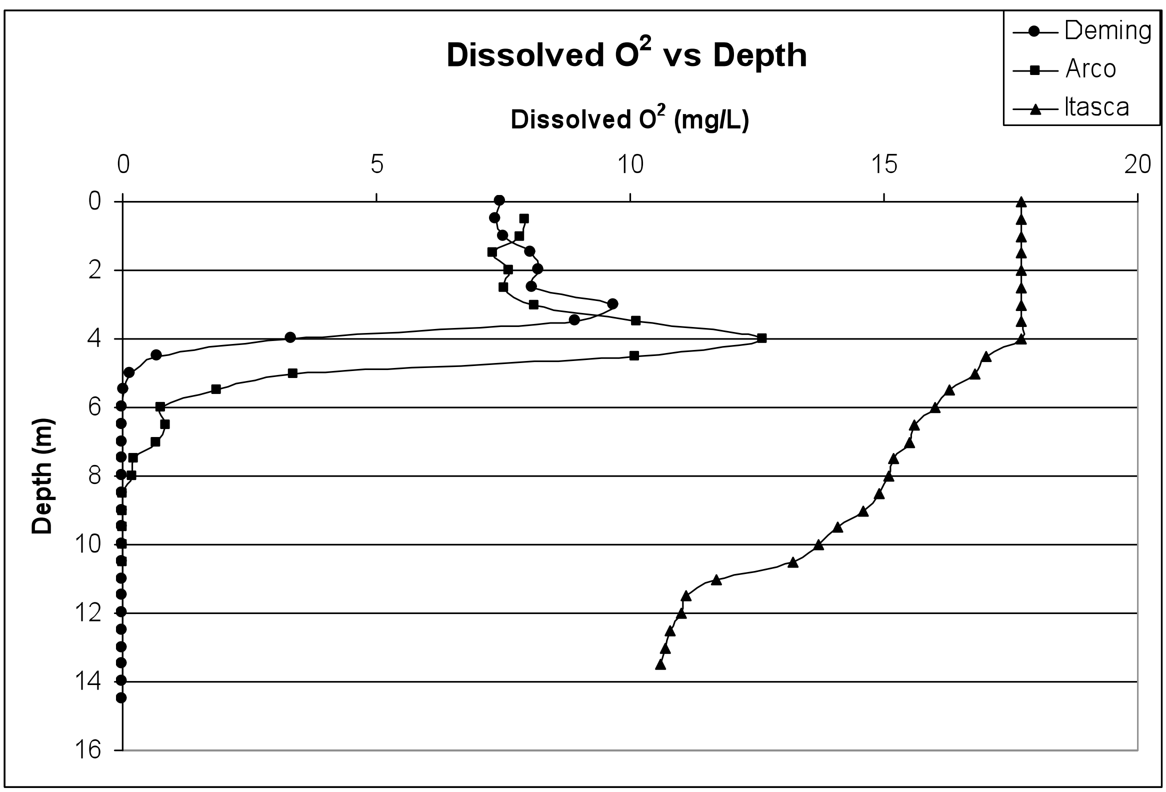


Figure 3



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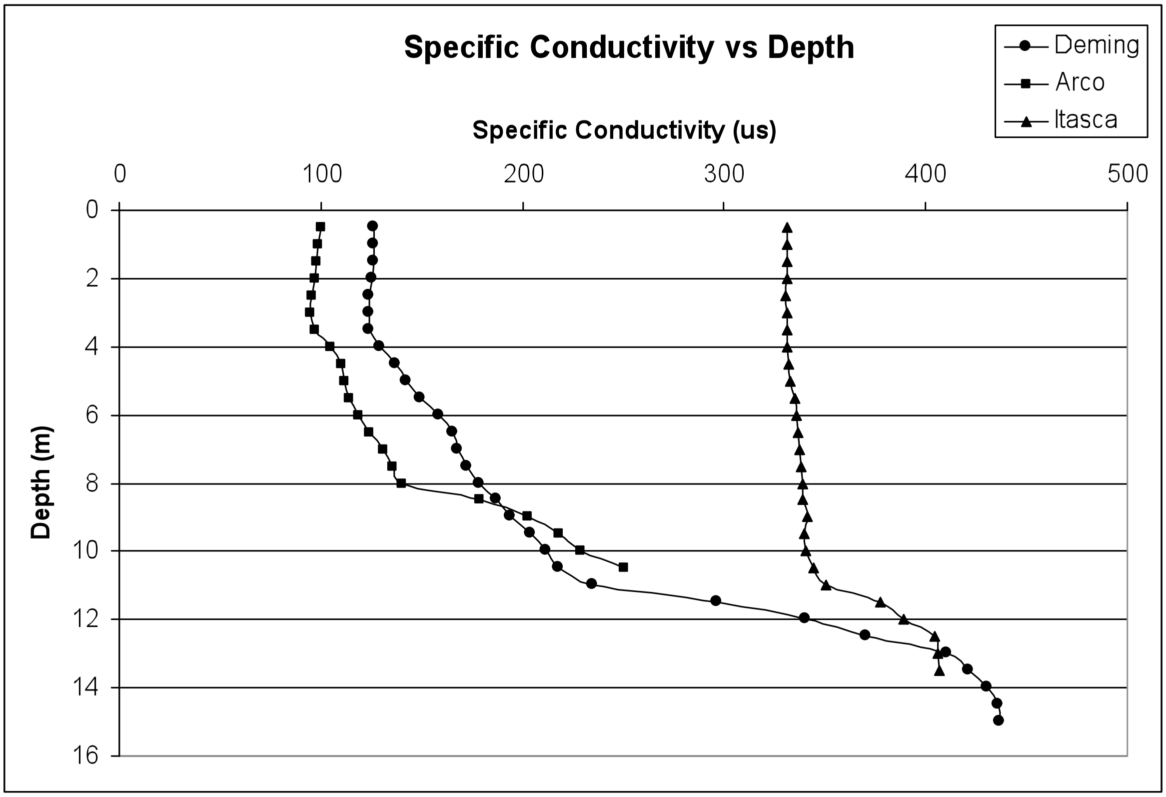

Figure 5

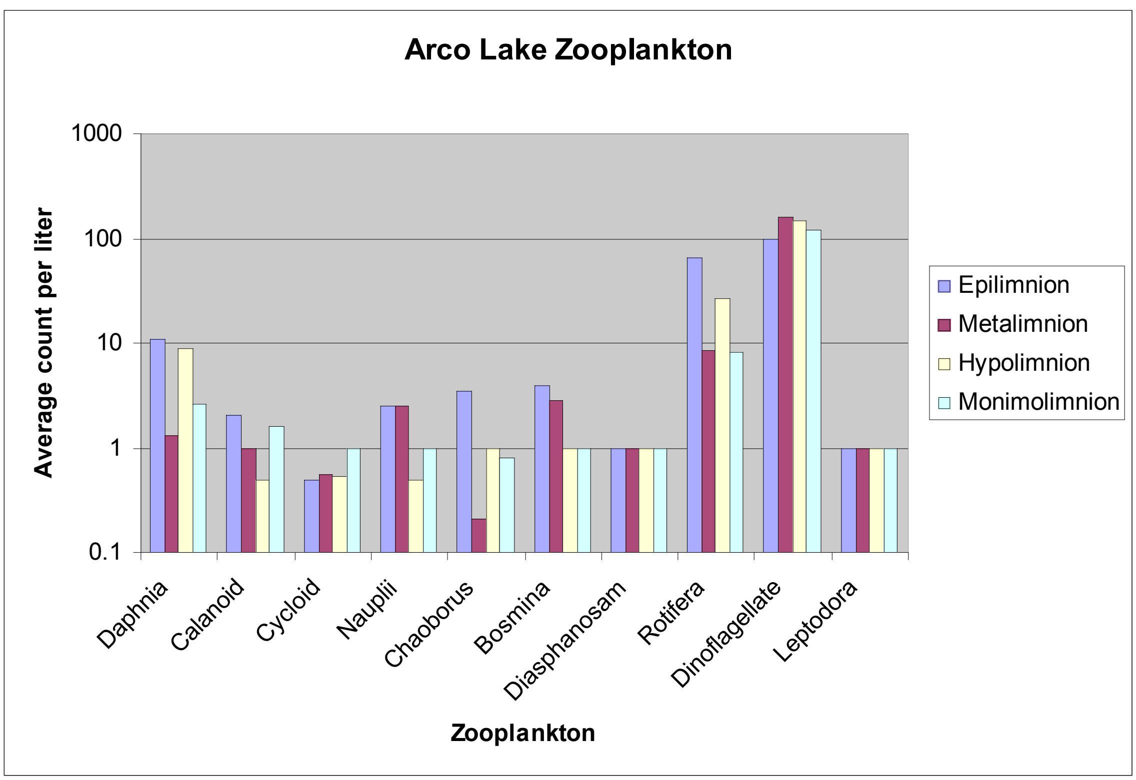

Figure 6

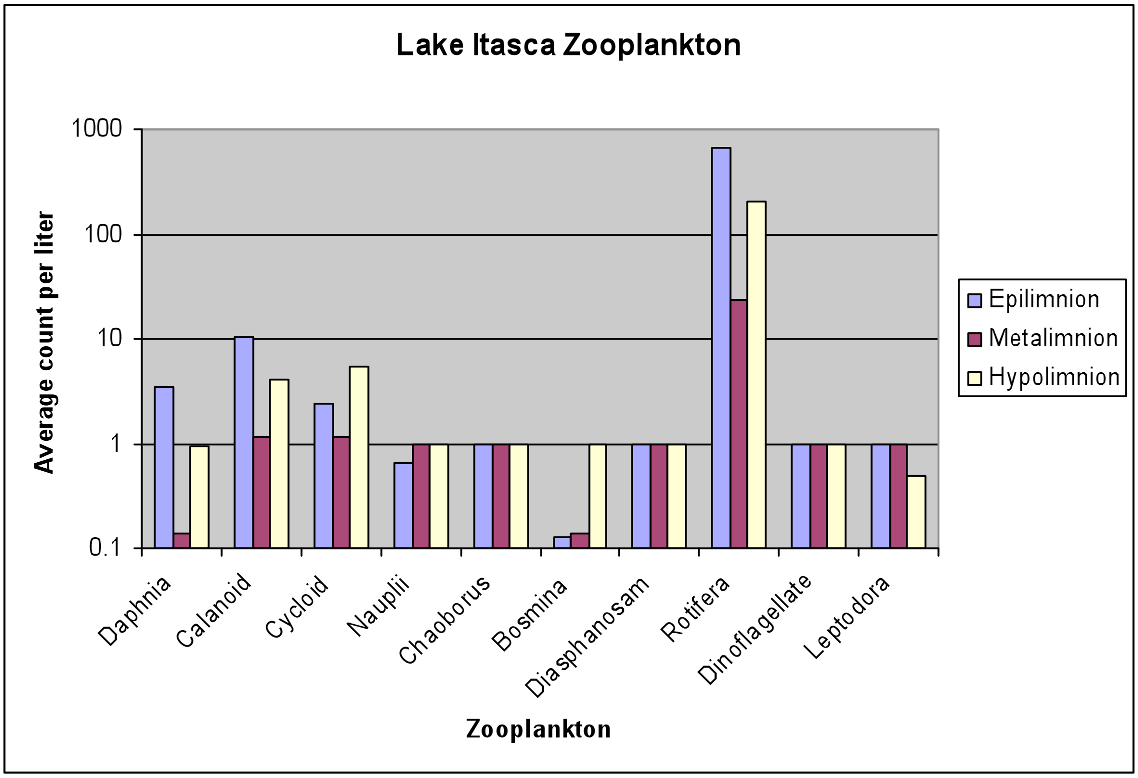

Figure 7

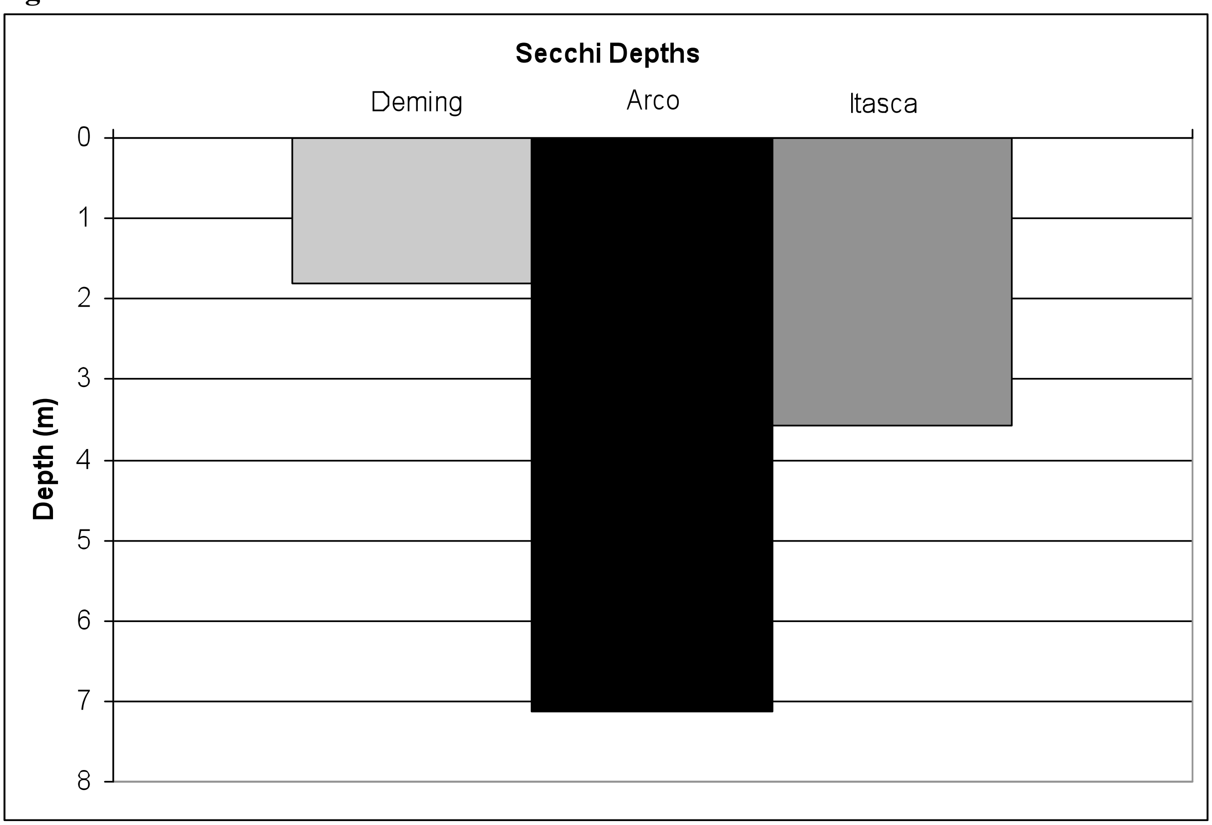

Figure 8

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