Spring 5-2017

A Survey of Lake Thoreau's Benthic Invertebrate Community

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by

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A Thesis
Submitted to the Honors College of
The University of Southern Mississippi
In Partial Fulfillment
Of the Requirements for the Degree of
Bachelor of Science
In the Department of Biological Sciences

May 2017

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ABSTRACT

A SURVEY OF LAKE THOREAU'S BENTHIC INVERTEBRATE COMMUNITY

This survey was conducted at the Lake Thoreau Environmental Center in Hattiesburg, MS. It began with four benthic samples taken in the deep area of the lake as well as four taken in the lake's shallow area. Samples were taken with a 6"x6" Ekman Grab Sampler and filtered through a U.S. standard 30 mesh sieve (openings = 0.6 mm). The samples were initially stored in formaldehyde for 24 hours, and then transferred into ethanol. In the laboratory, macroinvertebrates were picked out of the samples while viewing the samples through a dissecting microscope. High densities of the phantom midge *Chaoborus* larvae were found in all four of the deep water samples, along with mites, a few copepods, and an amphipod. Within the shallow water samples there were high densities of oligochaetes (Phylum Annelida). Also present were Heleidae representatives, chironomid larvae, mites, and copepods. Only a few *Chaoborus* larvae were present in the shallow water samples. The changes in fauna found between the shallow water areas (ca. depth = 1.5 m) and the deep water areas (ca. depth = 4.5 m) are likely the result of anoxic conditions that occur near the bottom of the lake in deep areas during the summer and early fall, and perhaps at other times of the year. In contrast the bottom of the lake in the shallow area always possesses relatively high amounts of oxygen. By distinguishing the fauna in the Lake Thoreau environment one can see how biodiversity and density fluctuate across the lake during at least the fall portion of the year.

ACKNOWLEDGMENTS

I thank Dr. David Beckett for his help through this process and sharing his knowledge and supplies with me. I also thank Jamaal Bankhead for sharing his work spaces and encouraging me to stick with it. Thanks also goes out to my parents for always pushing me to achieve my goals and Justin Whigham for being my rock over the past years.

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INTRODUCTION

Within the deep water areas of many lakes and reservoirs the abiotic factors of oxygen and temperature are often found to be more greatly stratified than in the shallow water areas. The propensity of the water to thermally stratify is due to the layering of the water caused by the warming of surface waters. Consequently warmer (less dense, lighter) waters sit on top of deeper, colder (denser) waters, especially during the summer. Often accompanying this thermal stratification is an unequal distribution of dissolved oxygen, generally with higher levels at the surface and lower levels in the deep portion of the lake or reservoir. The lack of oxygen near the bottom of the lake is due to oxygen uptake by the organisms living on or in the bottom, and the fact that little photosynthesis takes place in deep (dark) waters. Also, there is no exchange of air with the atmosphere (the bottom layer of the water is covered by the lighter surface layer of water). Opposing these stratifications are episodes of mixing of the waters (from top to bottom) which usually occur in the fall and spring. During mixing the lake's surface waters decrease in temperature during the cooler months and that layer of cooling water sinks down and begin to mix with the deeper waters. As the upper layers continue to cool the whole lake will mix, causing an equal distribution of temperature and oxygen throughout the various depths of the lake. This phenomenon is termed lake overturn. The various episodes of mixing and stratification influence the different types of invertebrates found in the lake bottom (the "benthic fauna"). During and after the mixing more oxygen-dependent invertebrates should be found in the lake bottom, and during the months of stratification bottom invertebrates dependent on oxygen may be eliminated.

Lake Thoreau is an artificial lake (i.e. it is a reservoir) located within the Eubanks Preserve which is part of the Lake Thoreau Environmental Center. The Environmental Center is composed of the Eubanks Preserve as well as the Longleaf Preserve, 131 acres and 160 acres respectively (Lake Thoreau Environmental Center 2014). Lake Thoreau itself is approximately 11 acres in area, and contains a dock, a dam, a wetland area, a watershed, a beaver dam, and both a shallow water area marked with a buoy and a deep water area, also marked with a buoy. Each buoy is secured to the bottom of the lake at depths of 1.4 - 1.7 m (shallow area) and 4.5 - 4.7 m (deep area), respectively. These areas are affected by significantly different abiotic factors. The shallow end of this system, as recorded over an entire year, had varying temperatures as a function of season, but on each date it generally exhibited virtually the same temperature throughout the whole water column, that is, the surface and bottom waters were thoroughly mixed (Coughlin 2012). The deep end of the lake was found to be more stratified, and mixing occurred only seasonally, thus creating hypoxic conditions on the bottom of the deep zones of the lake (Coughlin 2012). All in all, Lake Thoreau is a typical reservoir system with both lacustrine and riverine properties, and consequently there is a physical transition stretching from the shallow areas to the deep water areas (Thornton *et al.* 1990; Wetzel 2001; Coughlin 2012). The invertebrate biota within the lake had not been explored prior to this thesis.

Typically reservoirs contain mainly organisms that require oxygen to survive, and once these areas become hypoxic the organisms either relocate or die off (Wetzel 2001). Lake Thoreau has been categorized as a eutrophic lake that does undergo hypoxic conditions (Coughlin 2012). In other reservoirs benthic invertebrate samples are generally taken when conditions are oxygen rich, and continuously sampled until no invertebrates are found. Within a constantly fluctuating reservoir in Wisconsin with an average depth of 7.5 m, the benthic community was composed of about 98% Oligochaeta and Chironomidae (Kaster and Jacobi 1978). Similarly within a reservoir in Brazil the benthic community was found to contain 46% Chaoboridae, 24% Oligochaeta, 17% Chironomidae, and 13% Gastropoda (Moreno and Callisto 2006). I theorized that in Lake Thoreau the benthic invertebrate community might vary as a function of anoxic conditions which were present during a portion of the year in the deep end of the lake.

To obtain samples of benthic invertebrates I used an Ekman Grab Sampler with a sampling area of 232 cm^2. Other researchers recommend using Ponar grabs due to their easy deployment and high performance rate (Greeson *et al*. 1989); however the sediments of Lake Thoreau are soft and the Ekman Grab Sampler worked well in sampling the lake's benthic fauna.

Figure 1. Lake Thoreau aerial view (Google Maps).

CHAPTER 2

MATERIALS AND METHODS

During the months of October and November 2016 abiotic measurements were taken at Lake Thoreau's deep water and shallow water areas. These included water temperature (^{o}C), air temperature (^{o}C), and cloud cover. On the second to last day of determining these abiotic factors samples of the benthic invertebrate fauna were taken using the Ekman Grab Sampler.

On all three dates water temperatures were determined from the surface of the water and at every half meter until the bottom of the lake was reached. These data were determined with an aquatic thermometer. In order to measure water temperature, the boat was tied to the deep water buoy; the thermometer was lowered down to the bottom of the lake in half meter increments. Water temperatures in the shallow portion of the lake were measured in the same manner.

For sampling the benthic fauna the Ekman Grab Sampler was lowered to the bottom of the lake, while the boat was tied to the deep water buoy and a "grab" (sample) was taken. The sample was then pulled onto the boat, emptied into a plastic tub, then rinsed through a U.S. Standard 30 sieve (openings = 0.6 mm) bucket, and then stored in lake water in plastic containers. This process was repeated while tied to the shallow water buoy, and a total of four deep water samples and four shallow water samples were obtained.

Once back in the lab 10% formalin was added to the containers and they were left to sit for 24 hours. After 24 hours the formalin was rinsed from the samples with water into a standard 30 size sieve (openings = 0.6 mm). The samples were then placed back into their plastic containers and preserved with 70% ethanol. A dissecting scope was employed in the process of picking all the macroinvertebrates from the sediment and detritus in the samples. Invertebrates were then identified using dichotomous keys and separated into various vials based on sample number and species. The population densities were calculated by taking the number of individuals in a single grab (number per Ekman grab; Ekman grab area = 232 cm^2) and multiplying that number by 43.056, which converted the density per grab sample to density per m^2 (Greeson *et al.*1989).

CHAPTER 3

RESULTS

On the 14th of October, 2016 the first round of abiotic factors were determined. The air temperature was 30.0°C and skies were partly cloudy. In the shallow water sample site the temperature of the surface water was 25.8°C, the mid-depth water was around 24.0°C, and the benthic area was 24.1°C (Figure 2). The top of the epilimnion (surface layer) at the deep water site had a temperature of 26.5°C and the temperature at the bottom of the hypolimnion (bottom water layer) was 20.2°C (Figure 3).

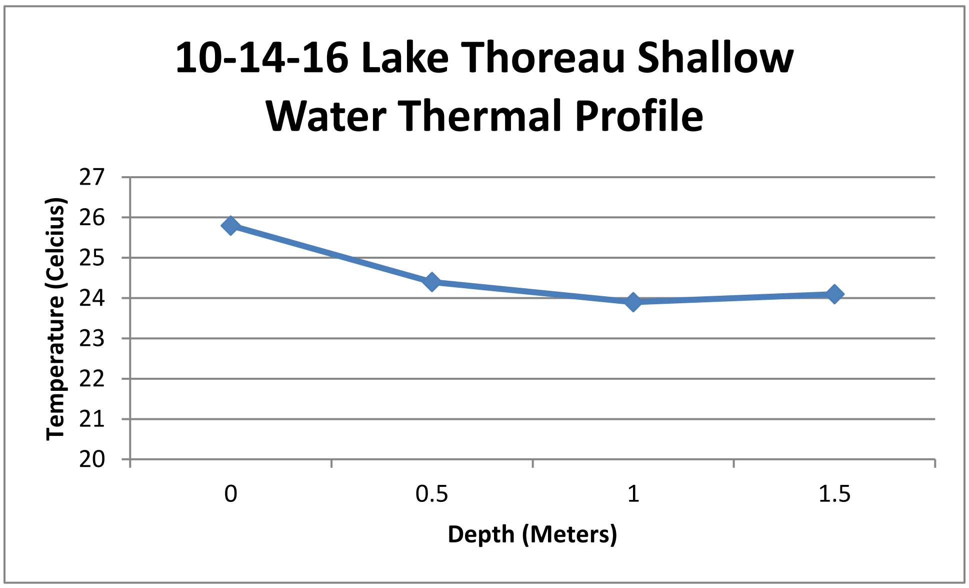

Figure 2. Thermal profile of the shallow water sample site of Lake Thoreau, taken on October 14, 2016. Showing a temperature range of 1.9°C with a maximum temperature of 25.8°C and a minimum temperature of 23.9°C.

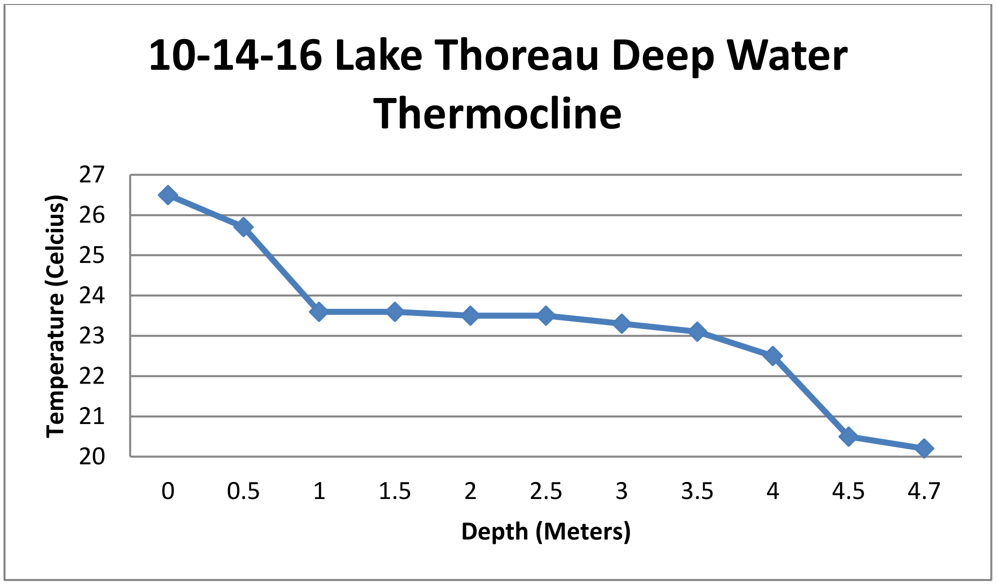

Figure 3. Thermal profile of the deep water sample site of Lake Thoreau, taken on October 14, 2016. Showing a temperature range of 6.3ºC with a maximum temperature of 26.5ºC and a minimum temperature of 20.2ºC.

On the 28th of October, 2016, the second rounds of abiotic factors were measured and the benthic grab samples were collected. The air temperature was 30.5ºC, and it was partly cloudy. The temperature of the surface water at the shallow site was 25.6ºC, the mid-depth waters had a temperature of approximately 23.0ºC, and the water at the bottom was at 21.7ºC (Figure 4). At the deep water site the epilimnion had a temperature of 23.6ºC, and the bottom of the hypolimnion had a temperature of 20.4ºC (Figure 5).

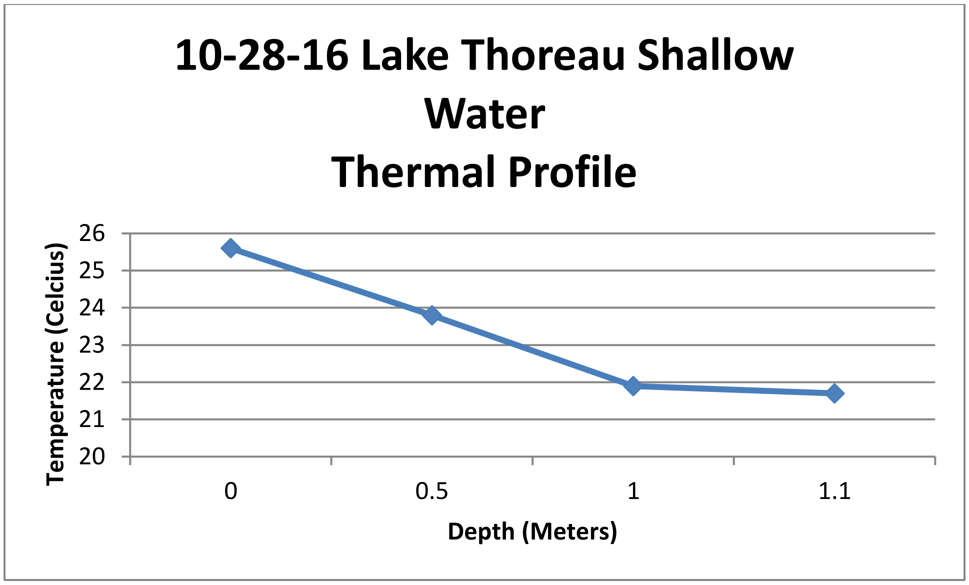

Figure 4. Thermal profile of the shallow water sample site of Lake Thoreau, taken on October 28, 2016. Showing a temperature range of 3.9ºC with a maximum temperature of 25.6ºC and a minimum temperature of 21.7ºC.

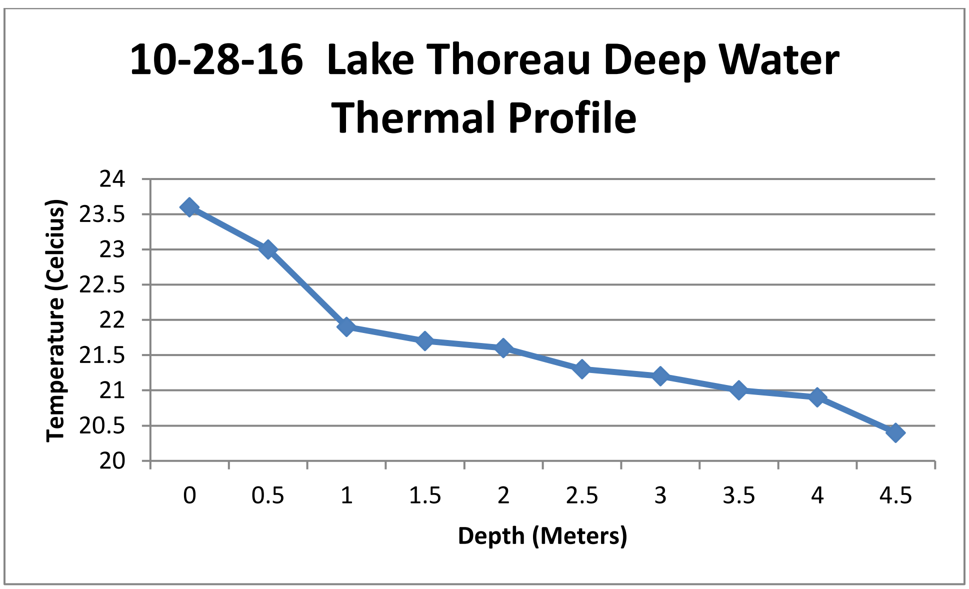

Figure 5. Thermal profile of the deep water sample site of Lake Thoreau, taken on October 28, 2016. Showing a temperature range of 3.2ºC with a maximum temperature of 23.6ºC and a minimum temperature of 20.4ºC.

On the 4th of November, 2016 the third and final rounds of the abiotic parameters were measured. The air temperature was 30.5ºC and skies were clear. The thermal profiles taken on this day showed little difference between the top of the water column and the bottom at the shallow water sampling site (Figure 6). The temperature of the surface water was 22.7ºC, the temperature at mid-depth was 22.6ºC, and the bottom water was measured as 22.3ºC. The deep water site showed that the epilimnion had a maximum temperature of 22.8ºC whereas the temperature at the bottom of the hypolimnion was 20.4ºC (Figure 7).

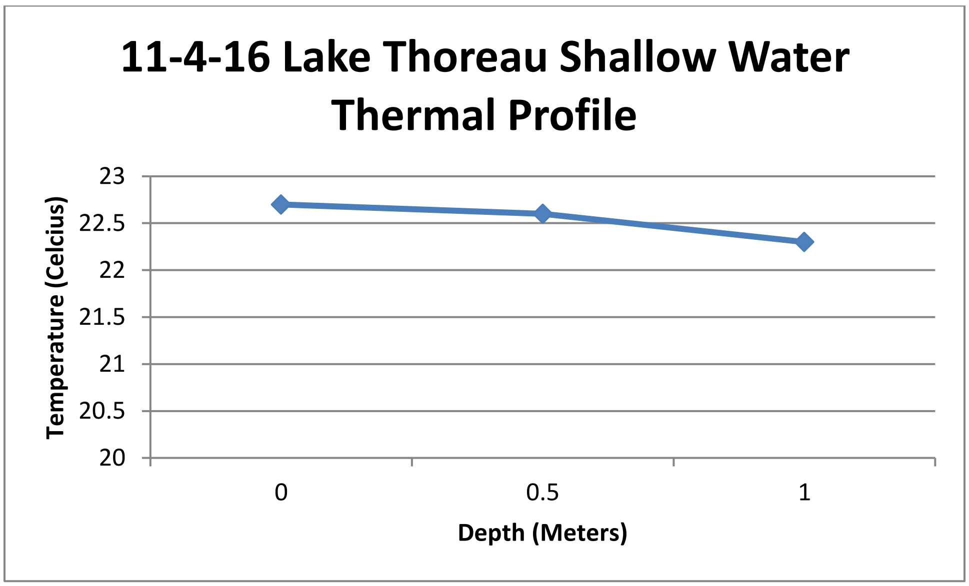

Figure 6. Thermal profile of the shallow water sample site of Lake Thoreau, taken on November 4, 2016. Showing a temperature range of 0.4ºC with a maximum temperature of 22.7ºC and a minimum temperature of 22.3ºC.

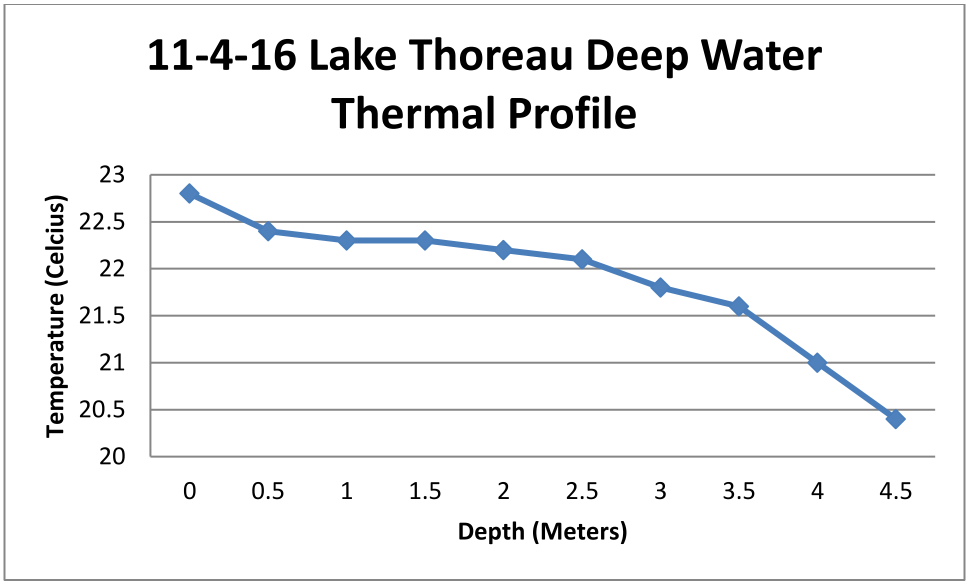

Figure 7. Thermal profile of the deep water sample site of Lake Thoreau, taken on November 4, 2016. Showing a temperature range of 2.4ºC with a maximum temperature of 22.8ºC and a minimum temperature of 20.4ºC.

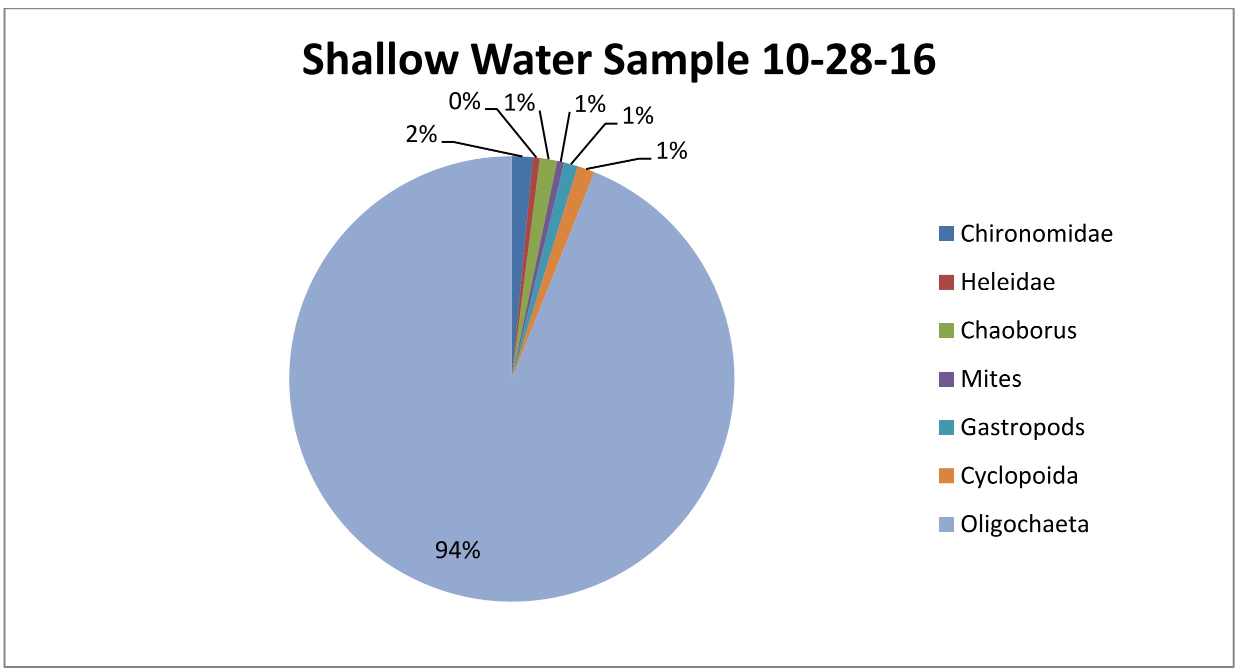

Figure 8. Percentages of organisms collected in the shallow water site on October 28, 2016. There were 397 organisms collected at this site.

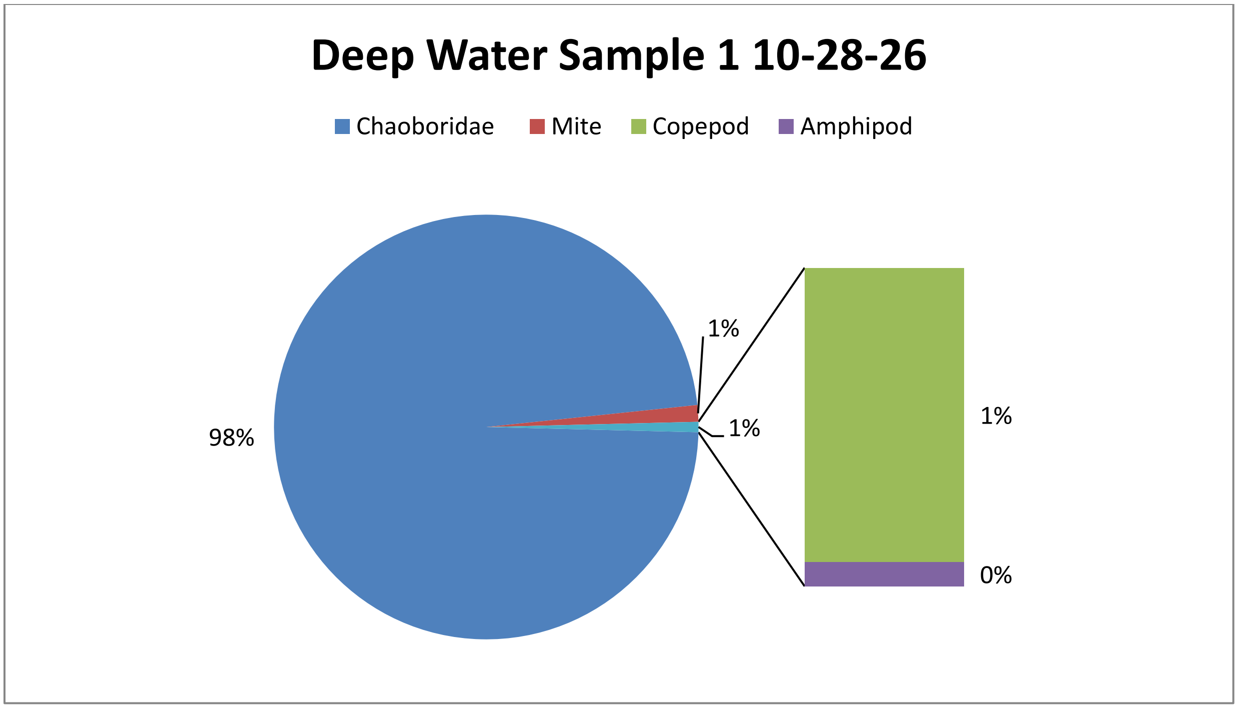

Figure 9. Percentages of organisms collected in the first sample taken at the deep water site on October 28, 2016. There were 1,660 organisms collected in this sample.

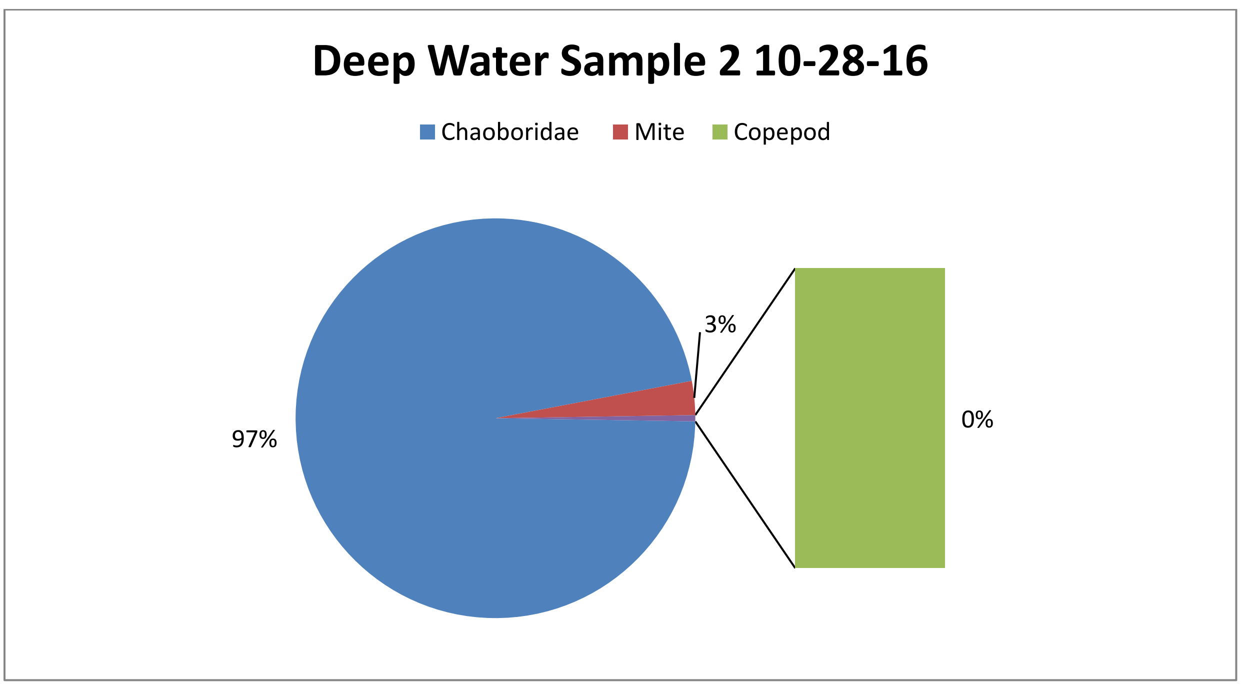

Figure 10. Percentages of organisms collected in the second sample taken at the deep water site on October 28, 2016. There were 1,603 organisms collected in this sample.

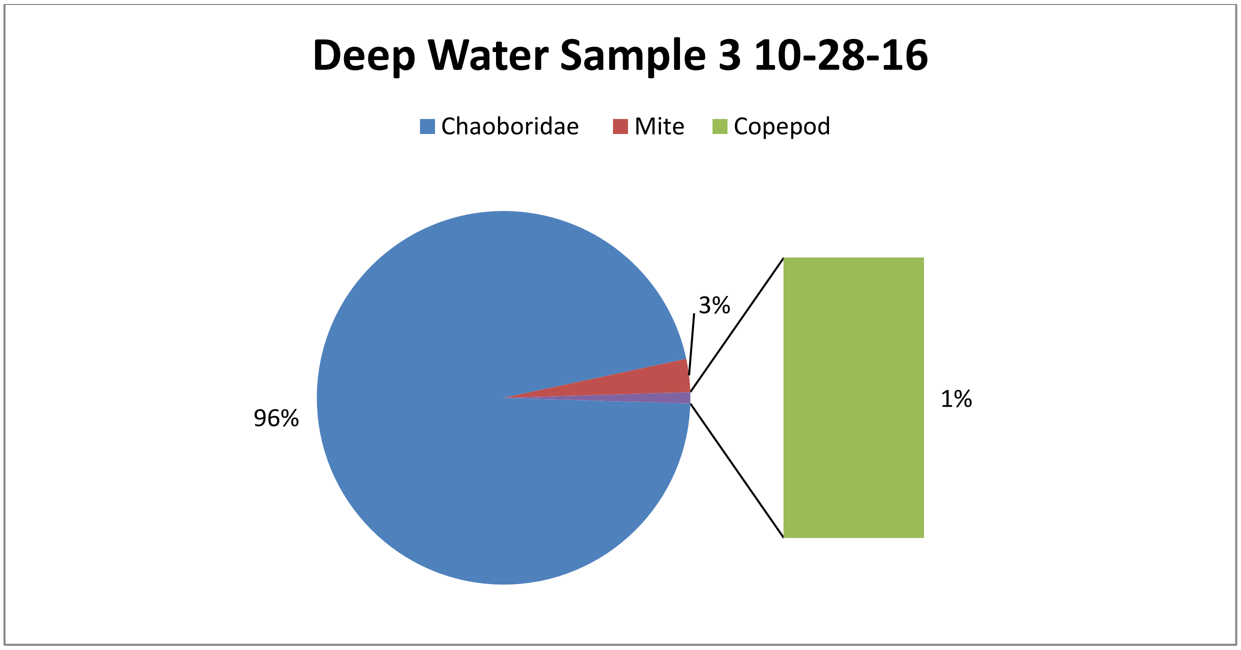

Figure 11. Percentage of organisms collected in the third sample taken at the deep water site on October 28, 2016. There were 1,976 organisms collected in this sample.

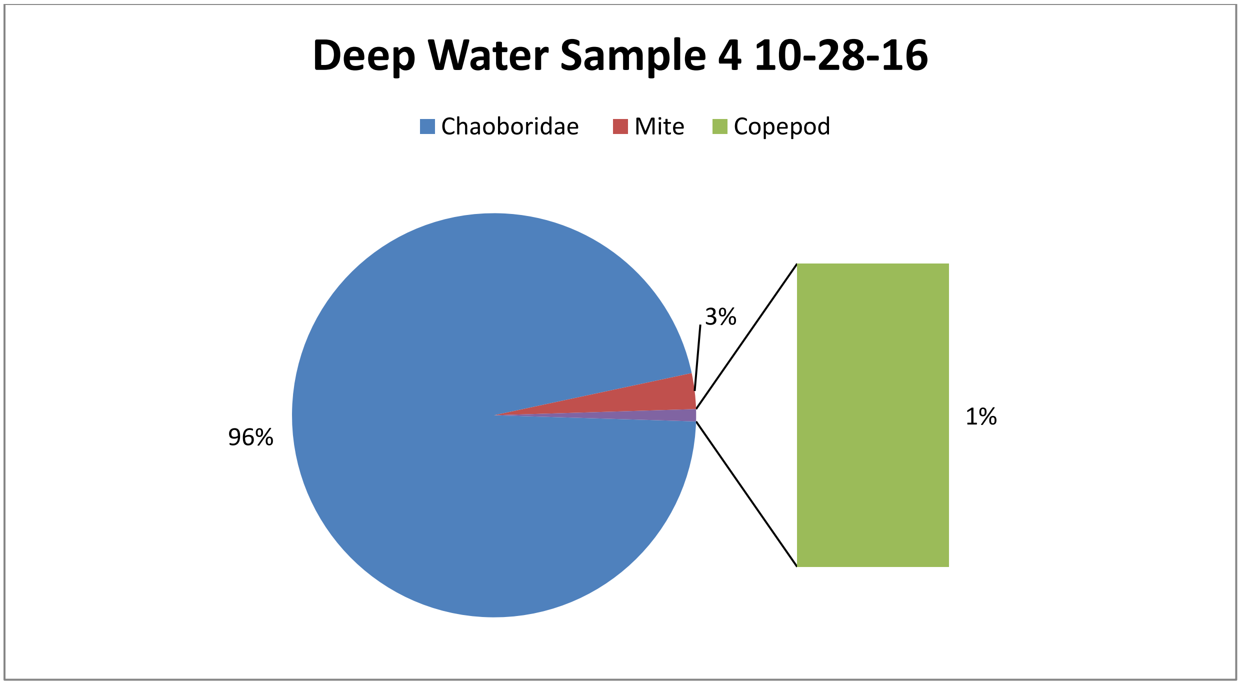

Figure 12. Percentage of organisms collected in the fourth sample taken in the deep water site on October 28, 2016. There were 1,644 organisms collected in this sample.

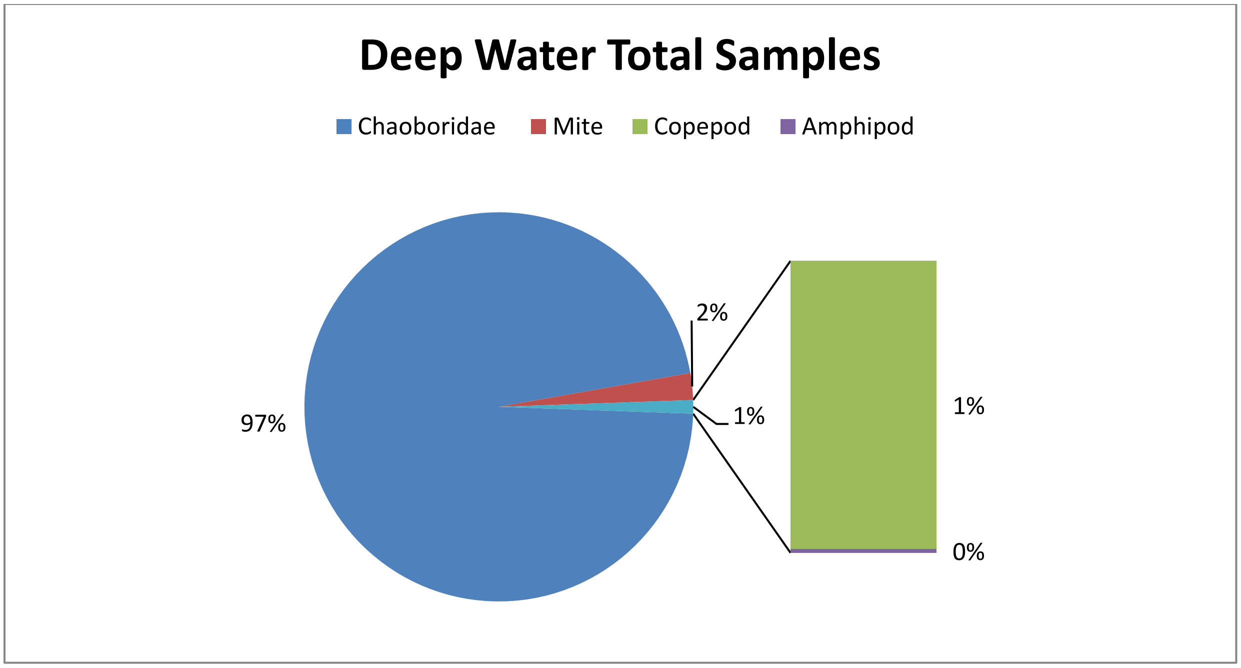

Figure 13. Percentage of organisms collected over all four samples of the deep water site on October 28, 2016. In total, 6,883 organisms were collected at the deep water site.

A total of 397 invertebrates were collected within the shallow water sample. Of the 397 specimens six (1.5%) were identified as dipteran larvae, two (0.5%) were within the family Heleidae, five (1.3%) were *Chaoborus* sp. larvae, two (0.5%) were mites, four (1.0%) were gastropods, five (1.3%) were cyclopoid copepods, and 373 (94.0%) were oligochaetes (Figure 8).

Within the four deep water samples a total of 6,883 specimens were collected; of those 6,653 (96.7%) were *Chaoborus* sp. larvae, 153 (2.2%) were mites, 76 (1.1%) were cyclopoid copepods, and 1 (0.01%) was an amphipod (Figure 13). Broken down further the first deep water sample had a total of 1,660 invertebrates; of those 1,626 (98.0%) were *Chaoborus* sp. larvae, 21 (1.3%) were mites, 12 (0.7%) were cyclopoid copepods, and 1 (0.06%) was an amphipod (Figure 9). The second deep water sample had a total of 1,603 specimens; of those 1,551(96.8%) were *Chaoborus* sp. larvae, 44 (2.7%) were mites, and 8 (0.5%) were cyclopoid copepods (Figure 10). The third deep water sample had a total of 1,976 individuals; of those

1,895 (95.9%) were *Chaoborus* sp. larvae, 41 (2.1%) were mites, and 40 (2.0%) were cyclopoid copepods (Figure 11). The fourth deep water sample had a total of 1,644 specimens; of those 1,581 (96.2%) were *Chaoborus* sp. larvae, 47 (2.9%) were mites, and 16 (0.9%) were cyclopoid copepods (Figure 12). The four deep water samples were therefore all quite similar to each other in terms of the density and composition of their collected benthic faunas (Figures 9 -12).

Clearly the deep water samples were dominated by *Chaoborus* sp. larvae while the shallow water sample was dominated by oligochaetes. Extrapolating the mean number of individuals in the deep water samples to a mean density per m^2 showed the estimated number of organisms residing on the lake bottom. For the deep water area it was found that there were an amazing 71,613 *Chaoborus sp.* larvae per m^2 of the lake bottom. In comparison the shallow water site were found to contain 16,060 oligochaetes, 344 Chironomidae, 215 cyclopoid copepods, 215 *Chaoborus* larvae, 172 gastropods, and 86 mites per m^2 of lake bottom.

CHAPTER 4

DISCUSSION

The measurements of temperatures in the shallow area on November 4th showed a very small difference (0.4˚C) between the temperature at the surface and at the bottom of the lake (at a depth of 1.0 m) (Figure 6). In contrast, the shallow area site had an appreciable temperature difference (3.9˚C) between the temperature of the surface water and the bottom on October 28th (Figure 4). Although this difference was somewhat unexpected, heating on warm sunny days can create such temperature differences which generally are then disrupted overnight with cooling night-time temperatures (Beckett, personal communication).

It is likely that thermal stratification still existed at deep water site during sampling. On October 14th a temperature difference of 5.6˚C existed between the surface waters and the bottom waters of the hypolimnion. However, it is also clear that the vertical stratification was weakening over the sampling period as the calendar days progressed from mid-October to early November. This was exhibited by the lessening of the temperature differences between the surface waters and the bottom of the hypolimnion on the successive sampling dates (differences were 5.6˚C on October 14, 3.2˚C on October 28, and 2.4˚C on November 4).

The stratification of the water column in the deep water areas probably created a hypolimnion devoid of oxygen in or around the sediment. This created an environment drastically different from that found in the shallow water area. *Chaoborus* sp. larvae, which were found at high densities in the bottom of Lake Thoreau, are able to exist in anoxic conditions (Maddell 1998). Consequently they are able to escape predation from visual predators (fish) by staying, during the daylight hours, in or near the bottom sediments in anoxic waters. Since fish require oxygen, the anoxic waters serve as a refuge for phantom midge larvae during the daylight hours. *Chaoborus* larvae exhibit a daily vertical migration in which they move from the bottom sediments up toward the surface at night (Wetzel 1983). As they move into the surface waters of the lake they feed on zooplankton (copepods and cladocerans), and at sunrise they begin to descend.

The densities of *Chaoborus* larvae found in the bottom of Lake Thoreau are very high. For example Wetzel (1983) reported a density of approximately 1800 *Chaoborus* larvae per m^2 in the sediments of Lake Vechten (located in the Netherlands). The density of *Chaoborus* larvae in Lake Thoreau is about 40 times that of Lake Vechten. Interestingly, huge swarms of *Chaoborus* adults occur in the African Great Lakes of Malawi and Victoria where they are collected by local people to make *kungu* cakes, biscuits or burgers.

Mites are found in freshwater systems as crustacean predators, insect larvae predators, or generalists (Proctor & Pritchard 1989). Due to the high number of *Chaoborus* larvae found in the deep water samples, the mites found within those samples were probably insect larvae specialists. The cyclopoid copepods found within the deep-water sample are known to be able to survive in areas with as little as 25% oxygen for up to four days (Tinson and Laybourn-Parry 1985).

In contrast to *Chaoborus* sp., oligochaetes require at least some oxygen in or immediately above the sediments in which they are found (Thorp and Rogers 2014). In Lake Thoreau densities of oligochaetes were high in the shallow area of the lake (16, 060 individuals per m^2 of lake bottom). However, no oligochaetes were present in the sediments of the deep water area of Lake Thoreau. This is a clear indication of the effect of oxygen on the distribution of the dominant benthic organisms of this lake. *Chaoborus* larvae thrive in the deep anoxic portion of the lake. Oligochaetes could potentially be found within deeper lentic waters, but as oxygen concentrations remain low over extended times the density of oligochaetes tends to decrease (Rieradevall and Real 1994). However, oligochaetes thrive in the shallow depths of the lake where sufficient oxygen occurs in and above the lake sediments.

Lake Thoreau was also found to possess a large quantity of a plant identified by Dr. Mac Alford as *Eleocharis parvula*. This is a small spike-rush that fruits in late winter and fall, and is found commonly in North America's ponds, ditches, brackish water, coastal tidal marshes, as well as swamps, and mud flats (Nees & Schauer 1836). The abundance of this species has increased this year (from past years) according to the Lake Thoreau Environmental Center Outreach Coordinator Dr. Mike Davis. This abrupt increase of *E. parvula* within the lake caused a large amount of sunlight to be prevented from reaching as deeply into the water as it had in the past. Therefore, it caused the benthic water to not receive as much heat and light. The sudden increase in abundance of this plant could be due to pollutional runoff from construction sites around the lake, as there are many residential homes in the surrounding area. Other species of plants could have been eliminated due to the pollutional impact and *E. parvula* could have proliferated as it is not affected by pollution as much as other species (Willis et al. 2010).

All in all, the shallow water area showed a greater biodiversity of organisms than the deeper areas. Comparatively, the deep water area had a lower amount of biodiversity of macroinvertebrates. Dissolved oxygen was probably the driving force producing these differences. Population densities and location of species could change drastically after mixing has occurred in the lake, but another survey would be needed to determine this.

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