Effects of Zooplankton Density and Diversity on Water Clarity in Five Lakes within Itasca State Park, Minnesota

Bobby Stephenson, Chet Forsberg, and Brian Mavencamp

Undergraduate students, Itasca Biological Station of the University of Minnesota, Itasca State Park, Minnesota, U.S.A.

Abstract

The effects of zooplankton density and diversity on water clarity were studied on five different lakes within Itasca State Park (northwest Minnesota). Water turbidity is affected by suspended organic material and dissolved organic material, and zooplankton graze on this suspended organic material and thus clarity of the water increases. It has been shown that with increased density of zooplankton, especially herbivorous zooplankton, that there is a correlated increase in water clarity. In our study, zooplankton diversity also increased with greater zooplankton densities. It is not clear, however, that diversity has any effect on the clarity of the water itself since some zooplankton feed on other zooplankton and not phytoplankton. The lake with the lowest secchi reading showed the lowest diversity of zooplankton, although it did have the third highest density of zooplankton. The lake with the highest secchi reading, however, showed the highest density and highest diversity of zooplankton. All of the lakes tested followed a trend of increasing water clarity with increasing density and diversity of zooplankton, with the exception of Deming. Average absorbance of chlorophyll-a showed no statistical correlation between zooplankton density or zooplankton diversity. This suggests that there is a correlation between zooplankton density and diversity towards water clarity.

Introduction

Lake trophic states range from oligotrophic to eutrophic (and even hypereutrophic) states, and they exhibit a wide range of water clarities depending upon the state of the lake. Oligotrophic lakes tend to be very clear with low plant productivity levels. (Tranvik 1988) This may be because their lake beds are composed of hard rock or because of relatively low lake nutrient levels. Research has also shown that nutrient watersheds can have a bottom-up impact on phytoplankton and zooplankton, thus affecting water clarity. Nutrients such as phosphorus and nitrogen supply the food resource for phytoplankton, which is the food source for zooplankton. (Kalff 2002) Understanding of this trophic cascade is important in understanding the significance of watershed nutrients on lake clarity, although we did not gather this data to analyze in our study. Eutrophic lakes tend to have less clear water with high plant productivity levels. Their high plant productivity levels are a result of high nutrient concentrations. Eutrophic lakes will show higher concentrations of suspended organic material, especially algae, and will also exhibit higher densities of lake vegetation and fish. (Christoffersen, Klysner, Riemann, Søndergaard 1993).

It has also been found in multiple studies that zooplankton will feed on algae causing an increase in water clarity (Hembre and Megard, 2005). Zooplankton, depending on whether they are positively or negatively phototactic, will exhibit a diel vertical migration (DVM) each day for reproduction and abundance of algae (De Meester, 1993). The ultimate factor for this DVM is predator avoidance, but the proximate factors are light and predatory kairomones (Zaret and Suffern, 1976). In meromictic, partially meromictic and oligomictic lakes, predatory fish are sometimes not present. As in the case of lakes Josephine, Arco, and Deming, zooplankton will exhibit positive phototaxis and remain in the epilimnion both day and night. Arco Lake is meromictic and has a surface area of 1.4 hectares and a maximum depth of 10.2 meters. Deming Lake is oligomictic and has a surface area of 5.2 hectares and a maximum depth of 17.4 meters. Lake Josephine, which is partially meromictic, has a surface area of 8.0 hectares and a maximum depth of 13.0 meters. Lakes Itasca and Mary are both holomictic, mixing completely in the spring and the fall. Mary's maximum depth reaches 12.5 meters and it has a surface area of 22.6 hectares. Itasca's maximum depth reaches 14 meters and it has a surface area of 436 hectares (Gage and Gorham 1985).

In this study we investigated water clarity versus zooplankton density and diversity within 5 different lakes in the Itasca State Park. We predicted that with an increased density and diversity of zooplankton there will be an increase in water clarity.

Methods

Three sampling locations were chosen for each lake. Due to Itasca's larger size, a sampling location was chosen randomly from the north, west, and east end of the lake. Three locations on each lake were sampled to establish more precise, mean values for secci depths, water column zooplankton levels, and surface-water algae concentrations.

Each water column sample was taken at a depth between 6.3 and 11 meters. To obtain our zooplankton samples, a full water column sample was done at each location using a zooplankton net that was lowered completely down to the bottom and then raised, in the open position, to the lake's surface. The water column samples were then contained in a small labeled cup. After each water column sample was taken, the water column filter was rinsed with bottled tap water to clean it for further testing.

At each sample location, water clarity was determined by the use of a Secchi Disk. To assess surface-water algae levels, surface water was gathered with a labled 1 Liter bottle. During testing the boats were anchored to establish a stable sampling environment.

Students in the Field Ecology class took part in the lake sampling and in the lab work procedures. First, the zooplankton samples were preserved with 70% ethanol. Each sample was then placed in a beaker, and a Hensen-Stempel pipette was used to gather 1 mL of zooplankton. The 1 mL samples were then placed on Sedgwick-rafter cells, and each cell was counted under a microscope. Another lab test was done to analyze each lake's algae density. The surface lake samples were first filtered using a vacuum filtration kit; two micron mesh-glass filters were used to collect the algae. After each 300 mL sample was filtrated, the mesh glass filter was then placed in a test-tube, which was also filled with ethanol. The collected filters were mashed up insided the test-tubes and then placed in a centrafuge. The samples were spun the in a centrafuge, which were then analyzed by a spectrophotometer calibrated at 665 nanometers.

Results

The data collected was organized using Microsoft Excel and made into four graphs from the five lake locations. The graphs include total zooplankton density per liter versus secchi depth, herbivorous zooplankton density per liter versus secchi depth, average zooplankton diversity per sample versus secchi depth, and algae concentration versus secchi depth.

The secchi depth results of the five lakes sampled ranged from a mean value of 1.8 meters to 3.4 meters. Arco Lake's mean secchi depth was 3.2 meters, Deming Lake's mean secchi depth was 1.8 meters, Lake Itasca's mean secchi depth was 3.2 meters, Josephine Lake's mean secchi depth was 3.3 meters, and Mary Lake's mean secchi depth was 3.4 meters.

A spectrophotometer was used to analyze our algae samples. From the samples obtained, the chlorophyll-a concentrations ranged from a mean value of 6.4 µg/L to 14.3 µg/L. Arco Lake's mean chlorophyll-a concentration was 7.8 µg/L, Deming's was 8.9 µg/L, Itasca's was 14.3 µg/L, Josephine's was 6.4 µg/L, and Mary's was 8.7 µg/L.

A total of nine different zooplankton species were classified and tallied, and of the nine classified species four of them are herbivorous. Three categories of analysis were taken into account from the data collection of zooplankton: total zooplankton density per liter, herbivorous zooplankton density per liter, and average zooplankton diversity per sample.

Arco Lake's mean total zooplankton density was 21 x 10^{-3} per liter. Arco's mean herbivorous zooplankton density was 2 x 10^{-3} per liter, and its average zooplankton diversity was 4.33 per sample. Deming Lake's mean total zooplankton density was 16 x 10^{-3} per liter. Deming's mean herbivorous zooplankton density was 1.55 x 10^{-3} per liter, and its average zooplankton diversity was 3.33 per sample. Josephine Lake's mean total zooplankton density was 32 x 10^{-3} per liter. Josephine's mean herbivorous zooplankton density was 9.6 x 10^{-3} per liter, and its average zooplankton diversity was 4.56 per sample. Lake Itasca's mean total zooplankton density was 33 x 10^{-3} per liter. Itasca's mean herbivorous zooplankton density was 14 x 10^{-3} per liter, and its average zooplankton diversity was 4.33 per sample. Mary Lake's mean total zooplankton density was 96 x 10^{-3} per liter. Mary's mean herbivorous zooplankton density was 12 x 10^{-3} per liter, and its average zooplankton diversity was 4.89 per sample.

Our total zooplankton density per liter versus secchi depth graph (see graph ?) showed minimal correlation with an r^2 value of 0.13. Our herbivorous zooplankton density per liter versus secchi depth graph (see graph ?) showed a slightly higher correlation with an r^2 value of

0.33. Also, our average zooplankton diversity per sample versus secchi depth graph (see graph ?) showed a small correlation with an r2 value of 0.31. Our algae concentration versus secchi depth graph (see graph ?) showed no correlation with an r^2 value of 0.

Discussion

The presence of algae in a lake is a major cause of turbid water. Zooplankton primarily feed on algae, resulting in clearer water. The results of our experiment provide evidence to support the hypothesis that a higher density and diversity of zooplankton will result in an increase in water clarity. We observed that the lakes with more species diversity and herbivorous zooplankton density correlate to a higher secchi depth reading, or water clarity. For example, Mary Lake had by far the density with an average of 95.56 zooplankton per liter, and it also had the highest average secchi depth of 3.40 meters.

Along with taking the secchi depth and observing zooplankton, we also recorded the light irradiance of each lake. We can observe that Demming Lake, which has the lowest average of herbivorous zooplankton per sample (201.67), has the lowest irradiance for each depth, while Mary Lake, which has the highest average of herbivorous zooplankton per sample (1900.56), has the highest irradiance for each depth. The secchi depth readings helped support these findings since they followed the same pattern.

The purpose of this experiment was to observe how zooplankton density and diversity affect water clarity. We found that both variables affect water clarity but diversity has more of a definite pattern relating it to water clarity. We found that there was no statistical correlation between chlorophyll a and the secchi disk readings.

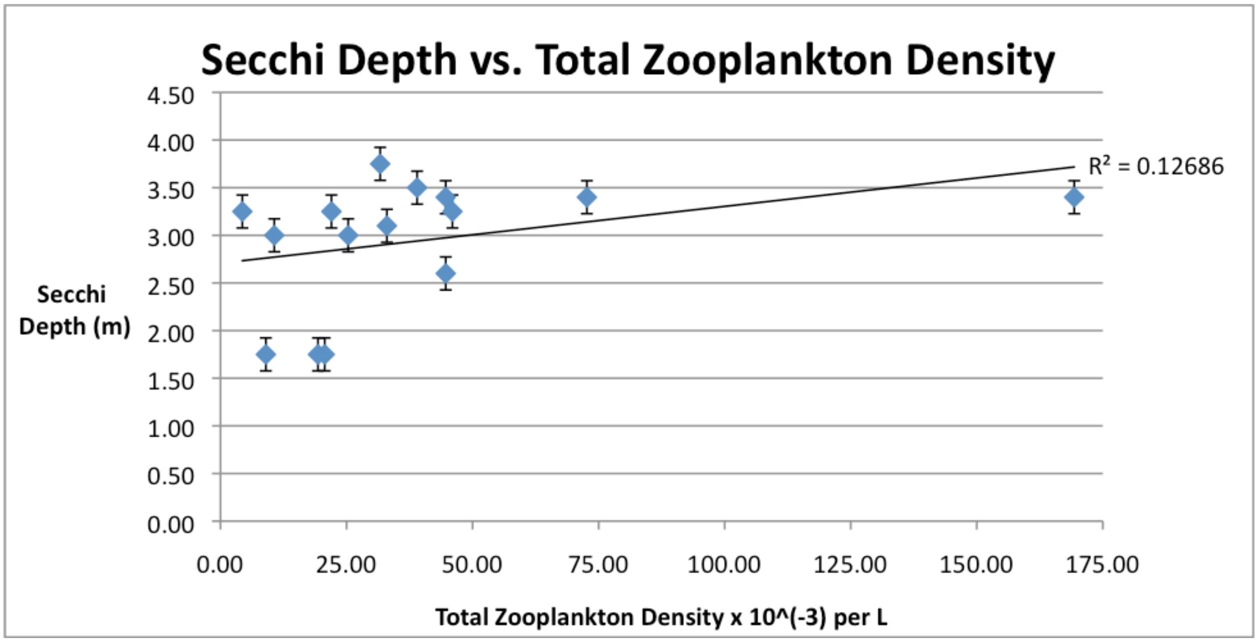
We have observed the effects of zooplankton density and diversity on water quality at 5 different lakes. The results of this experiment help support our hypothesis that clearer lakes tend to have a higher density and diversity of zooplankton present.

Acknowledgments

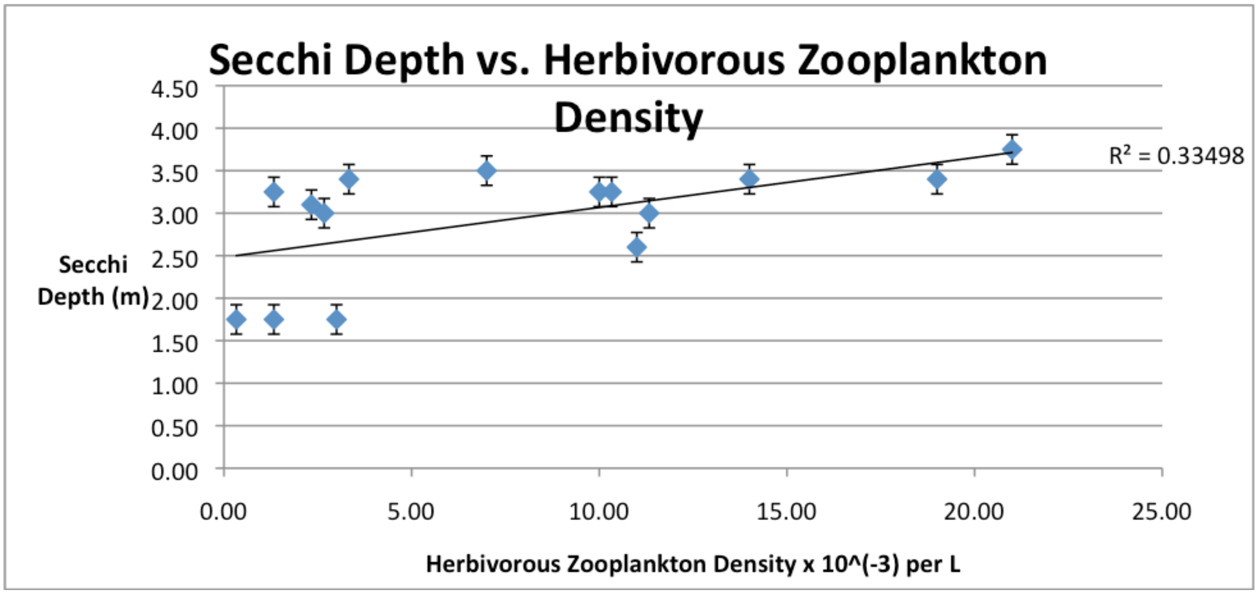
We want to thank the students of the Field Ecology class for their help in sampling, counting, and recording the data used in this study. Professor Leif Hembre was also instrumental in the preparation and directing of us towards the proper topic and scope of this study. We wish to also thank the Itasca Biological Station of the University of Minnesota for providing us with the proper equipment used in sampling and analyzing our data.

Charts and Graphs

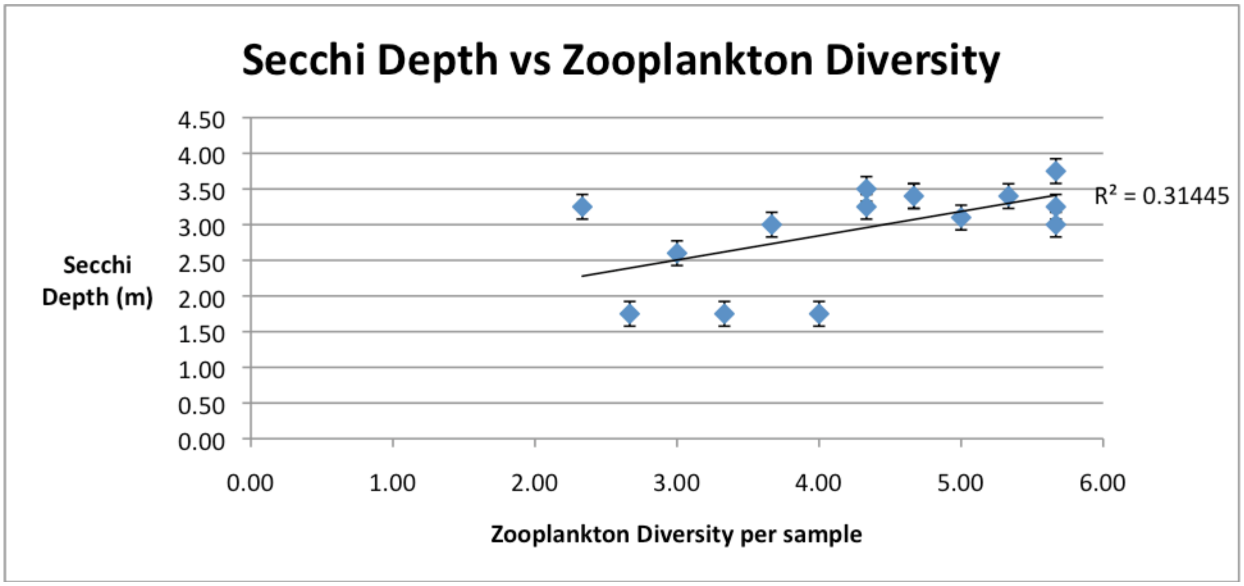
Lake Sampled	Zooplankton/ L x 10^{-3}	Secchi Reading (m)
Demming 1	9.00	1.75
Demming 2	20.67	1.75
Demming 3	19.33	1.75
Arco 1	4.33	3.25
Arco 2	25.33	3.00
Arco 3	33.00	3.10
Josephine 1	39.00	3.50
Josephine 2	10.67	3.00
Josephine 3	46.00	3.25
Mary 1	72.67	3.40
Mary 2	169.33	3.40
Mary 3	44.67	3.40
Itasca 1	44.67	2.60
Itasca 2	22.00	3.25
Itasca 3	31.67	3.75



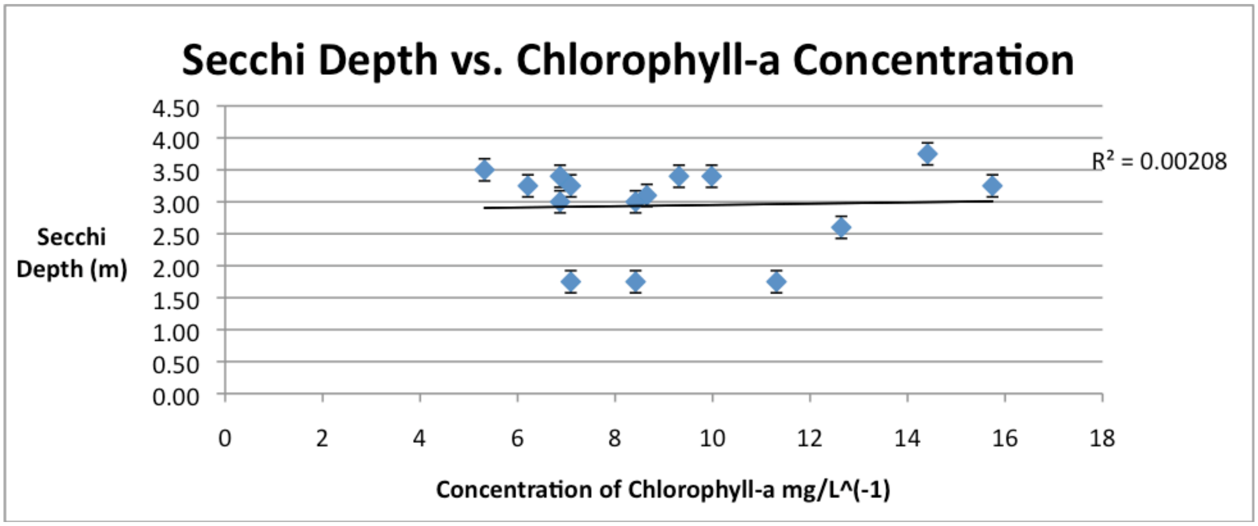
Lake Sampled	Large Herbivores x 10^{-3} per L	Secchi Reading (m)
Demming 1	3.00	1.75
Demming 2	1.33	1.75
Demming 3	0.33	1.75
Arco 1	1.33	3.25
Arco 2	2.67	3.00
Arco 3	2.33	3.10
Josephine 1	7.00	3.50
Josephine 2	11.33	3.00
Josephine 3	10.33	3.25
Mary 1	3.33	3.40
Mary 2	19.00	3.40
Mary 3	14.00	3.40
Itasca 1	11.00	2.60
Itasca 2	10.00	3.25
Itasca 3	21.00	3.75



Lake Sampled	Avg Diversity	Secchi Reading (m)
Demming 1	2.67	1.75
Demming 2	4.00	1.75
Demming 3	3.33	1.75
Arco 1	2.33	3.25
Arco 2	5.67	3.00
Arco 3	5.00	3.10
Josephine 1	4.33	3.50
Josephine 2	3.67	3.00
Josephine 3	5.67	3.25
Mary 1	5.33	3.40
Mary 2	4.67	3.40
Mary 3	4.67	3.40
Itasca 1	3.00	2.60
Itasca 2	4.33	3.25
Itasca 3	5.67	3.75



Lake Sampled	concentration	Secchi Reading (m)
Demming 1	8.42	1.75
Demming 2	11.31	1.75
Demming 3	7.09	1.75
Arco 1	6.21	3.25
Arco 2	8.42	3.00
Arco 3	8.65	3.10
Josephine 1	5.32	3.50
Josephine 2	6.87	3.00
Josephine 3	7.09	3.25
Mary 1	6.87	3.40
Mary 2	9.98	3.40
Mary 3	9.31	3.40
Itasca 1	12.64	2.60
Itasca 2	15.74	3.25
Itasca 3	14.41	3.75



References

Christoffersen, K., Klysner, A., Riemann, B., Søndergaard, M. (1993) Potential role of fish predation and natural populations of zooplankton in structuring a plankton community in eutrophic lake water. *Limnology and Oceanography*, Vol. 38, No. 3, pp. 561-573

De Meester, L. (1993) Genotype, fish-mediated chemicals, and phototactic behavior in Daphnia magna. *Ecology,* 1467-1474.

Gage, M.A. & Gorham, E. (1985) Alkaline phosphatase activity and cellular phosphorus as an index of the phosphorus status of phytoplankton in Minnesota lakes. *Freshwater Biology*, **15**, 227-233.

Hembre, L.K. & Megard, R.O. (2005) Timing of predation by rainbow trout controls Daphnia demography and the trophic status of a Minnesota lake. *Freshwater Biology,* 1064-1080.

Kalff, J. (2002) Limnology*: inland water ecosystems*, Prentice-Hall, Inc. Upper Saddle River, NJ

Suffern, S. & Zaret, T. (1976) Vertical Migration of Zooplankton as a Predator Avoidance Mechanism. *Limnology and Oceanography,* 804-813.

Tranvik, L.J. (1988) Availability of dissolved organic carbon for planktonic bacteria in oligotrophic lakes of differing humic content. *Microbial ecology*, 16:311-322