Study of Water Quality, Zooplankton Species Composition and Macrophyte Diversity in Loon Lake, Steuben County, NY (September 2014)

Submitted to

The Loon Lake Association and the Loon Lake Watershed Alliance

by

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and

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EXECUTIVE SUMMARY

- In the fall, 2014, SUNY Geneseo students along with Biology Professor Isidro Bosch studied the water quality, zooplankton species composition and submerged macrophyte diversity of Loon Lake. The more productive Conesus Lake was sampled to provide a basis for comparisons of water quality.

- Water quality analysis showed that for Loon Lake:
  - chemical indicators of nutrient enrichment such as conductivity and redox potential were at moderate levels typical for a mesotrophic lake and consistent with the CSLAP data
  - a bloom of phytoplankton was evident on both sampling dates; all indicators of phytoplankton biomass were high and within a range typical of eutrophic lakes
  - the late season bloom continues a pattern that emerged in recent years (~2006), as indicated by analysis of CSLAP data, and included significant amounts of cyanobacteria, such as *Microcystis* and *Anabaena,* as well as diatoms and dinoflagellates

- Rotifers and crustaceans that are characteristic of the region dominate the zooplankton community. The most common crustacean is the relatively large herbivore, *Daphnia galeata.* Due to its size and abundance, *D.galeata* was the principal contributor to a potential herbivore filtration rate that was 38% higher than that of Conesus Lake, where the introduced alewife continues to prey on and suppress the large zooplankton species.

- Macrophytes were sparse in Loon Lake, in part because sampling was conducted late in the growing season and after mechanical harvesting had been completed:
  - twelve macrophyte species were identified, ten of which are native to the region and widely distributed in lakes
  - the most abundant species were wild celery and two pondweeds, white-stem and clasping-leaf, which reportedly favor low phosphorus lakes
  - the exotic and opportunistic Eurasian watermilfoil was only 1.5% of the biomass and is probably kept in check by low nutrient levels in Loon Lake

- Our results provide insights for Loon Lake management:
  - efforts to prevent colonization of invasive species must be intensified; invasive plants pose a serious threat to the balance of the native macrophytes and introduction of a zooplankton predator (e.g. alewife) could deplete the important herbivore populations
  - nutrient management must remain a priority if there is any hope of minimizing the risk of late season, cyanobacteria-dominated blooms
  - because mechanical harvesting suspends sediments and nutrients and removes macrophytes that compete for light and nutrients with phytoplankton, a harvesting plan should consider the balance of the lake ecosystem in addition to the priorities of lake residents

SCOPE OF RESEARCH

In the fall, 2014, students in SUNY Geneseo's Aquatic Community Ecology course and their professor, Dr. Isidro Bosch, conducted surveys of water quality, zooplankton species composition and macrophyte diversity in Loon Lake. Data for Conesus Lake, located ~30 km to the NNW, served as a reference of a more productive trophic state. The Loon Lake Association and the Loon Lake Watershed Alliance are presently working on a lake characterization report. We hoped that our research could provide useful knowledge on the state of the lake and generate insights that could help stakeholders identify priorities for watershed management.

To study water quality, depth profiles of water temperature, oxygen, conductivity, pH, redox potential, *in vivo* chlorophyll and visible light were taken with a Hydrolab multiparameter sonde over the deepest part of the lake. We also measured the turbidity of the water using a Hach 2100 Handheld Turbidity Meter, a Secchi disc, and chlorophyll *a* concentrations.

To study the zooplankton we collected vertical net samples in the upper 5-6 m of the water column, and sampled at discrete depths with a Van Dorn bottle to obtain quantitative estimates of abundance. The zooplankton samples were preserved in 50% ethanol and analyzed in the laboratory. We compared our results to data collected in Conesus Lake by professor Joe Makarewicz and co-workers from SUNY Brockport.

The submerged macrophytes of Loon Lake were sampled using a standard rake method. Collections were made at various depths and locations to achieve representative sampling. Macrophytes were sorted by species, blotted dry and weighed to determine % wet weight composition, species diversity and distribution. The conclusions of the macrophyte study are limited by the fact that samples were collected late in the growing season and after weeks of mechanical harvesting had taken place in Loon Lake.

ACKNOWLEDGEMENTS

This project was made possible by the collaboration of a group of lake residents who are devoted to the conservation of Loon Lake. We are thankful for the hospitality and good will that was extended to our large group by, among others, Alice Publow, Art Rothfuss, Bob Reynolds, Rod Lindsey and Ed Sick. The work was supported by SUNY Geneseo and the Department of Biology.

Section I. Water Quality Assessment of Loon Lake

RESEARCH FINDINGS

On September 4th and 18th, 2014, we surveyed the water quality of Loon Lake to better understand the driving forces behind recent increases in the magnitude of phytoplankton blooms, which happened even as phosphorus levels in the water remained low. Conesus Lake, a productive lake in nearby Livingston County, NY with historical total phosphorus values averaging 22 µg/L was sampled on Sep 25, and served as a reference lake. Water column profiles that were taken during a phytoplankton bloom showed that some chemical indicators of trophic state such as redox potential (ORP) and conductivity were well within the range expected for a mesotrophic lake. In contrast, the average turbidity of >3 NTU, Secchi depths of 1.7 m and chlorophyll concentration of 10.8 µg/L were more typical of a eutrophic lake. Net samples contained large numbers of colonial cyanobacteria, including *Microcystis aeruginosa* and species of *Anabaena,* along with diatoms and dinoflagellates. Cyanobacteria utilize nutrients efficiently due to their small cell size and produce toxins that deter herbivory. These unique charactersitics could lead to an accumulation of cyanobacterial biomass that might explain Loon Lake's high phytoplankton standing c rop and turbidity despite its mesotrophic nutrient conditions.

CONCLUSIONS

- Chemical indicators of productivity such as conductivity and redox potential were found to be at moderate levels that are typical for a mesotrophic lake

- A significant bloom of phytoplankton was evident on both sampling dates; all indicators of plant biomass were high and within a range typical of eutrophic lakes, as they were in Conesus Lake

- The bloom included significant amounts of cyanobacteria such as *Microcystis* and *Anabaena* which are potentially toxic, as well as diatoms and dinoflagellates

- Intensive blooms of phytoplankton seem to be a relatively new phenomenon to Loon Lake; they were first prominent in 2006, according to the CSLAP database, and seem to recur annually late in the growing season (Aug-Sep)

INTRODUCTION

Loon Lake is characterized as mesotrophic (moderately productive) based on long-term averages of total phosphorus (TP) near 14 µg/L, Secchi depths in excess of 5 m, and chlorophyll *a* values below 4 µg/L. By contrast, in the more productive neighboring Conesus Lake, TP averages have been higher than 20 µg/L (21.9 in 2014), Secchi depths ranged between 2-4 m and the average chl *a* value was 7.8 µg/L (Makarewicz and Lewis 2012, 2014). Ecological events such as changes in nutrient loading, the invasion by alewife in the late 1970's and by zebra mussels in the early 1990's, have changed the trophic state of Conesus between mesotrophic to borderline eutrophic and back over the last 50 years. The trophic state of Loon Lake remained stable for nearly a decade after 1994, when CSLAP sampling begun. In recent years, however, phytoplankton blooms have produced levels of chl *a* and turbidity that are more characteristic of a eutrophic lake, despite the fact that nutrients supplies for plants remain at historically moderate concentrations (CSLAP 2013). Bloom conditions persisted in 2013, with chl *a* biomass soaring to 48.6 µg/L and Secchi depths at a low of 1.85 m in September. Data showing that more than half (and as high as 2/3) of the chlorophyll in these blooms is of blue green algal (cyanobacteria) origin (CSLAP data) have raised the specter that these potentially toxic cyanobacterial species may be increasing in dominance.

In September 2014 we studied the water quality of Loon Lake to examine what conditions were associated with the late season phytoplankton blooms and determine what species were dominant during these outbreaks. Loon Lake conditions were compared to data for Conesus Lake that was also collected in September. Conesus Lake should demonstrate conditions in a more productive ecosystem and serve as a reference for the Loon Lake study.

METHODS

On two dates (9/4 and 9/18), water quality samples were taken in Loon Lake, NY. The same measurements were taken on 9/25 in Conesus Lake, which is located ~30 km NNW of Loon Lake. A Hydrolab 5A Multiparameter Sonde (Hach corp.) was deployed in the morning and afternoon on each date, with on board sensors measuring temperature, pH, redox potential, *in vivo* chlorophyll, conductivity, dissolved oxygen, visible light (PAR 400-800 nm) throughout the water column. The sensors were calibrated prior to each use following recommended procedures. From light readings we calculated the light absorptive/scattering characteristics of the water column as an attenuation coefficient (k) using the formula:

$$k = \frac{\ln(PAR\ at\ upper\ depth) - \ln(\ PAR\ at\ lower\ depth)}{(lower\ depth - upper\ depth)}$$

Higher values of k are characteristic of more turbid water.

A Van Dorn bottle was used to collect 2.2 L samples from depths of 1, 3, 6, 9 meters. Each of these discrete depth samples was analyzed for pH, conductivity, and turbidity independently. The turbidity in units of NTU (nephelometer turbidity units) was measured using a HACH 2100Q turbidity meter. Conductivity (in microsiemens, µS) and pH were measured using a HACH HQ40d multimeter. From each of the Van Dorn collections, 1 liter of sample water was stored in dark Nalgene bottles and a known volume was filtered the same day through a Whatman glass fiber filter in a dark room and frozen for later chlorophyll *a* (chl *a*) analysis. The filters were then extracted for 4.5 hours in 90% alkaline acetone, centrifuged, and placed into Trilogy Fluorometer with standard model 043 module to determine the chl *a* concentration using the acidification method. Secchi depth was determined on each sampling trip using a standard Secchi disc.

RESULTS

Water Column Structure

Based on temperature and dissolved oxygen profiles, both Loon Lake and Conesus Lake experienced thermal stratification during the summer and early fall, a pattern that is typical of temperate lakes (**Figure 1**). The first sampling date for Loon Lake (9/4) showed a strongly established thermocline from 3-8 meters, with temperatures at 24 and 12 º C, respectively. The second and third profiling dates, 9/18 and 9/27, showed a gradual decrease in the integrity of the thermocline as Loon Lake was becoming more mixed. By 11/4, Loon Lake was completely mixed and the temperature throughout the water column was 12ºC. The dissolved oxygen profile was measured on 9/4 and 9/18 for Loon Lake and 9/25 for Conesus Lake (**Figure 2**). The lakes showed similar oxygen distributions; the concentration of oxygen is a constant 10 mg/L from 1-5 m depth and then sharply decreased to almost 0 mg/L by 8 m in Loon Lake and 10 m in Conesus Lake.

Chemistry

Conesus Lake conductivity readings exceeded >400 µS/cm from 1-13 m while the conductivity in Loon Lake was about 120 µS/cm from 1-8 m for both sampling dates (**Figure 3**). Thus, the concentrations of dissolved solids in Loon Lake were less than a third that of Conesus Lake. In all profiles there was a slight increase of conductivity in the hypolimnion, beginning at 8 m for Loon Lake and 13 m for Conesus Lake.

The Oxidation Redox Potential profiles were similar in the upper water column (**Figure 4**); surface values ranged from 180-230 mV and decrease gradually until a depth of 8 m, where both lakes experience a steep drop in ORP. The decrease in ORP is consistent with a decline in oxygen and an increase in carbon dioxide in the hypolimnion. Loon Lake had higher ORP levels than Conesus at comparable depths. Conesus Lake had the lowest ORP near the bottom; this is indicative of very reducing conditions and the presence of anaerobic conditions.

Turbidity

Loon Lake was more turbid than Conesus Lake. This observation is supported by various metrics. At a depth of 1m Loon Lake had a turbidity of 3.37 NTU and Conesus Lake had a turbidity of 2.12 NTU (**Table 1**). Attenuation coefficients for each lake were calculated at depths of 2 to 4 meters; Conesus Lake had lower attenuation coefficients than Loon (~ 0.47 and ~ 0.75, respectively) (**Table 2**). The Secchi depths were 1.8 m for Loon Lake and 1.7 m for Conesus Lake (**Table 3**). These values are essentially the same. Secchi Secchi depth measurements are not precise because they are easily affected by environmental conditions such as cloud cover, wave action, sun angle.

Water samples were collected and filtered on 9/4 at Loon Lake to assess chl *a* concentrations. Using the acetone extraction method, the concentrations (in µg/L) at depths of 1, 3, and 6 meters was determined to be 11.78, 13.37, and 7.38 µg/L (**Table 4**). As shown by the in vivo chl *a* profiles in **Figure 5** and by the analytical determinations in **Table 4**, the peak pigment concentration in Loon Lake was at 3-5 m, a depth where water density was sufficient to keep phytoplankton from sinking below the thermocline. The dominant phytoplankton in the Sep 4 Loon Lake bloom were diatoms, including *Tabelleria*, *Asterionella*, and *Diatoma*, cyanobacteria, including several species of *Anabaena* and various sized colonies of the potentially toxic *Microcystis*, and the dinoflagellate *Ceratium*.

DISCUSSION

This study was a compilation of water quality data collected from Loon Lake and Conesus Lake in September 2014, when both lakes were thermally stratified. It assessed the general state of the water column in Loon Lake and any potential risks to water quality.

Loon Lake's status as a recreational lake for fishing and swimming is currently classified as *threatened* by increasing turbidity, as mentioned in the CSLAP 2013 report. Conductivity profiles serve as general indicator of anions and cations and thus, to some extent, also track patterns of available nutrients. As shown in **Table 5**, conductivity for Loon Lake was much lower than that of Conesus Lake throughout the water column. This was expected, given the historically higher nutrient concentrations in Conesus Lake. The redox potential, or ORP, is a measure of the tendency of chemicals in the water to acquire or lose electrons. ORP is an indicator of anaerobic activity; a lower ORP indicates increased anaerobic activity. Loss of oxygen and buildup of CO_2 in the water is due primarily to microbial metabolism and ultimately is a function of the amount of organic fallout from the surface. Thus, the more productive Conesus Lake predictably showed a lower or more negative Redox potential.

In temperate lakes, such as the classically high mesotrophic Conesus Lake, elevated nutrient levels are associated with high turbidity due to the increased biomass of phytoplankton (Makarewicz et al. 2012). As shown in **Figure 5**, *in vivo* levels of chl *a* in Loon Lake and Conesus Lake were comparable. Chl *a* measured analytically by Makarewicz and Lewis (2014) for Conesus Lake was in the range of 6-8 μg/L in Sept. 2014, compared to the 7.8-13.8 μg/L we measured for Loon Lake. Therefore, despite having lower phosphorus levels and lower conductivity values, Loon Lake was shown to have disproportionately high levels of chl *a* and turbidity. A comparison of the Carlson's Trophic indexes for the two lakes substantiates this point. Carlson's Index for Loon Lake using chl *a* and Secchi depth were indicative of a eutrophic lake (54.0 and 51.7, respectively). However, the Carlson's Index for total phosphorous (42.2) categorizes Loon Lake as mesotrophic. This discrepancy in trophic status between parameters is unusual. For example, Carlson's Index for Conesus Lake, based on total phosphorous (45.1), chl*a* (49.2), and Secchi depth (46.0), are all very similar and reliably indicate a high mesotrophic/eutrophic status.

We propose that the rise in Loon Lake chl *a* and turbidity is due in large part to a growing influence by cyanobacteria. Support of this view comes from several lines of evidence. First, cyanobacteria species of *Anabaena* and *Microcystis* were prominent in the phytoplankton bloom sampled by our group on 9/4. Second, cyanobacterial chl *a* made up more than half of the total chl *a* in bloom samples, according to 2012-13 CSLAP data. Lastly, In examining historical data on chl *a* and Secchi depth we found two important trends that are relevant to this discussion. First, the intensity of blooms has increased over the last 8-9 years, as shown by declining Secchi depth readings (**Figure 4**). Second, the densest blooms have occurred in August and September **(Figure 4, 5**), a time when cyanobacteria are abundant in the phytoplankton community of temperate lakes.

Cyanobacterial cells utilize nutrients more efficiently than larger algal cells and can thrive in low nutrient environments (Jensen *et al*., 1994, Downing *et. al.,* 2001). Moreover, some species are capable of producing toxins such as anatoxin and microcystin (Råbergh *et. al*, 1991). Because they are not readily ingested by herbivorous zooplankton, the cyanobacterial biomass tends to accumulate in the water column rather than be consumed and transferred to higher trophic levels. Thus, it is possible to have an increase in the standing crop of phytoplankton even as the nutrient concentrations remain stable because less biomass is transferred to the herbivore trophic level.

Section I – Tables

Table 1: Water turbidity as NTUs (Nephelometer turbidity units) for Loon Lake (Sep 4 and 18) and Conesus Lake (Sep 25) at different depths. Each turbidity value is an average of 4 samples.

Collection	Depth	Turbidity
Loon Lake 9-4	3 m	3.6
	6 m	2.2
	9 m	4.3
Loon Lake 9-18	3 m	3.2
	6 m	3.4
	9 m	5.4
Conesus Lake 9-25	1 m	2.1
	3 m	2.6
	6 m	2.5
	9 m	2.1

Table 2: Attenuation coefficients for Loon Lake and Conesus Lake. The Loon Lake values are noticeably higher, indicating that light is being absorbed more rapidly.

Location and Sampling Date	Attenuation Coefficient Mean $\pm$ S.D.
Loon Lake 9-4	0.752, 0.740
Loon Lake 9-18	0.753
Conesus Lake 9-25	0.474

Table 3: Secchi depths measured over the deepest part of each lake.

Secchi Depth (m)	
Conesus Lake	1.7 ± 0.1
Loon Lake 9/4	1.8, 1.8
9/18	2.1 ± 0.2

Table 4: Concentration of chl *a* in micrograms per L shown for different depths in Loon Lake on 9/4. Two samples were analyzed for each depth.

Depth (m)	Chlorophyll (µg/L)
1	11.78 ± 0.51
3	13.37 ± 0.20
6	7.38 ± 2.98

Table 5: Table showing a comparison of water chemistry parameters between Loon Lake (9/4) and Conesus Lake 9/25. The drop in Loon Lake ORP at 9 m is an indication that the reading was taken close to the lake bottom.

	Loon Lake			Conesus Lake		
Depth (m)	Conductivity (µS/cm)	pH	ORP (mV)	Conductivity (µS/cm)	pH	ORP (mV)
1	123.2	7.23	301.57	-	-	175.56
3	139.9	7.25	305.31	353	7.39	175.93
6	148.35	7.08	310.53	363	7.49	180.92
9	148	7.1	85	362	7.49	182.71

Appendix I: Tables showing long-term averages for Secchi depths in meters (m) used to create Figure 6A. The raw data was taken from the 2013 CSLAP report for Loon Lake.

Year	Avg. Secchi Depth June-July (m)	Avg. Secchi Depth Aug-Sep (m)	Ratio Jun-Jul/ Aug-Sep
1994	4.59	3.5	1.31
1995	4.38	2.8	1.56
1996	5.54	3.9	1.42
1997	4.75	4.3	1.10
1998	3.96	3.1	1.28
1999	4.79	2.6	1.84
2000	4.43	5.2	0.85
2001	6.33	6.2	1.02
2002	6.85	5.5	1.25
2003	6.00	4.2	1.43
2004	7.85	7.2	1.09
2005	7.38	7	1.05
2006	3.90	2.5	1.56
2007	5.15	2.5	2.06
2008	4.11	3.4	1.21
2009	3.60	2.2	1.64
2010	4.54	2.3	1.97
2011	4.10	3	1.37
2012	3.89	2.9	1.34
2013	3.74	2.1	1.78
1994-2005 avg	5.57	4.63	1.27
2006-2013 avg	4.13	2.61	1.58

Appendix II: Tables showing long-term averages ratio of Total Nitrogen to Total Phosphorus , and chlrophyll a used to create Figure 6B. The raw data was taken from the 2013 CSLAP report for Loon Lake. There were no nutrient data collected for 1997-2001.

Year	TN/TP mg/L Jun-Sep	Chla µg/L Jun-Sep	Chla µg/L Jun-July	Chla µg/L Aug-. Oct	Chla late/early Ratio
1997	-	4.7	1.9	7.4	3.89
1998	-	6.9	6.8	5.6	0.82
1999	-	7.5	8.7	7.4	0.85
2000	-	4.0	4.3	2.8	0.66
2001	-	1.7	1.6	1.7	1.04
2002	116.6	0.4	0.4	0.1	0.20
2003	45.5	2.0	0.5	3.2	6.35
2004	68.4	5.0	1.9	6.5	3.51
2005	36.9	4.6	0.6	7.6	11.92
2006	121.2	4.4	2.8	7.2	2.59
2007	106.4	13.8	3.4	20.0	5.89
2008	80.2	3.5	1.7	5.2	3.07
2009	87.5	15.2	4.3	22.3	5.25
2010	69.1	7.1	6.0	8.2	1.36
2011	63.1	10.9	4.2	17.6	4.19
2012	60.3	7.7	2.4	9.7	4.11
2013	72.8	11.8	3.0	18.5	6.15

Section I - Figures

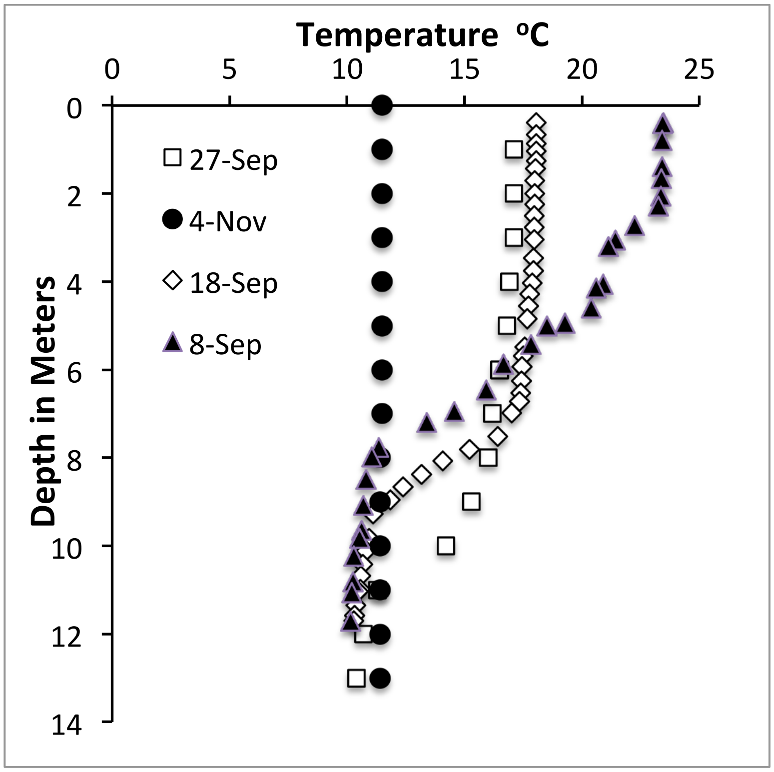

Figure 1: Temperature profiles in Loon Lake for four dates in late summer and autumn as the lake lost its temperature stratification and became isothermal by Nov 4 (Autumn data provided by Alice Publow).

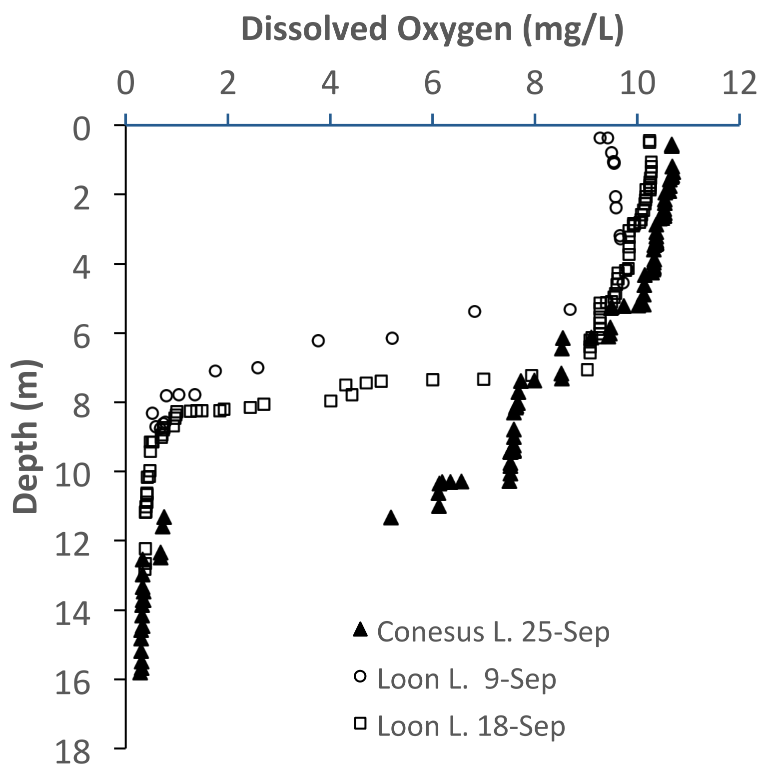

Figure 2: Dissolved oxygen profiles for Conesus Lake and Loon Lake; the lakes have comparable water column stratification with a well-defined thermocline. The slight differences in the profiles are due to the greater depth of Conesus Lake.

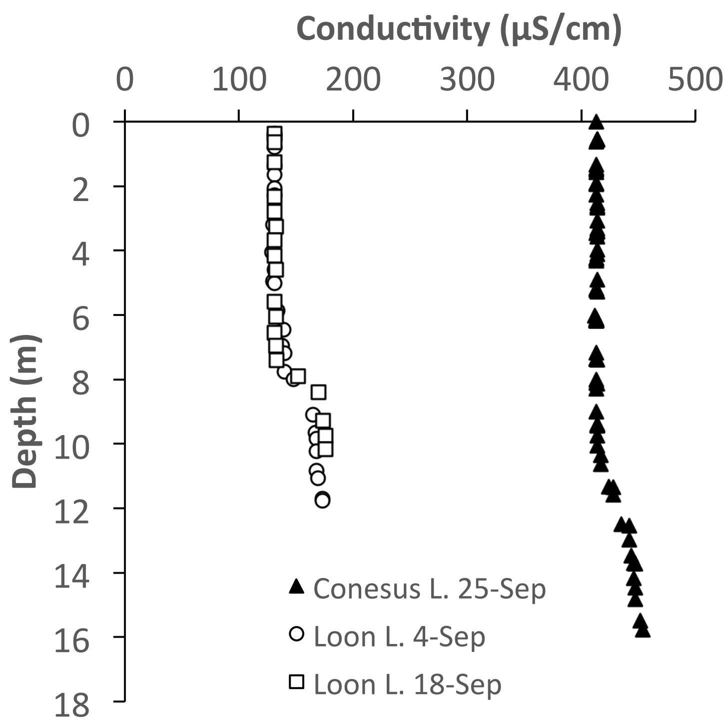

Figure 3: Conductivity profiles for Loon Lake and Conesus Lake. Conductivity is an indicator of dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conesus Lake had a higher conductivity, as expected in a more eutrophic lake.

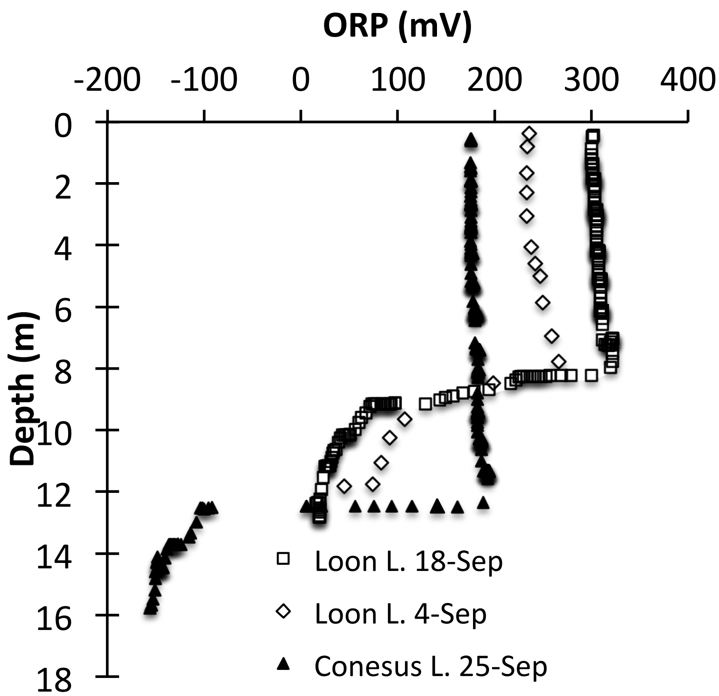

Figure 4. This graph shows changes in the Oxidation-reduction potential (ORP) with depth. The more negative values (-100 mv) are associated with anoxic waters in the hypolimnion of Conesus Lake. Higher values are due to a higher concentration of dissolved oxygen and a low CO_2 content. The change in ORP from 9/4 (circles) to 9/18 (squares) in Loon Lake may be due to lower surface temperatures.

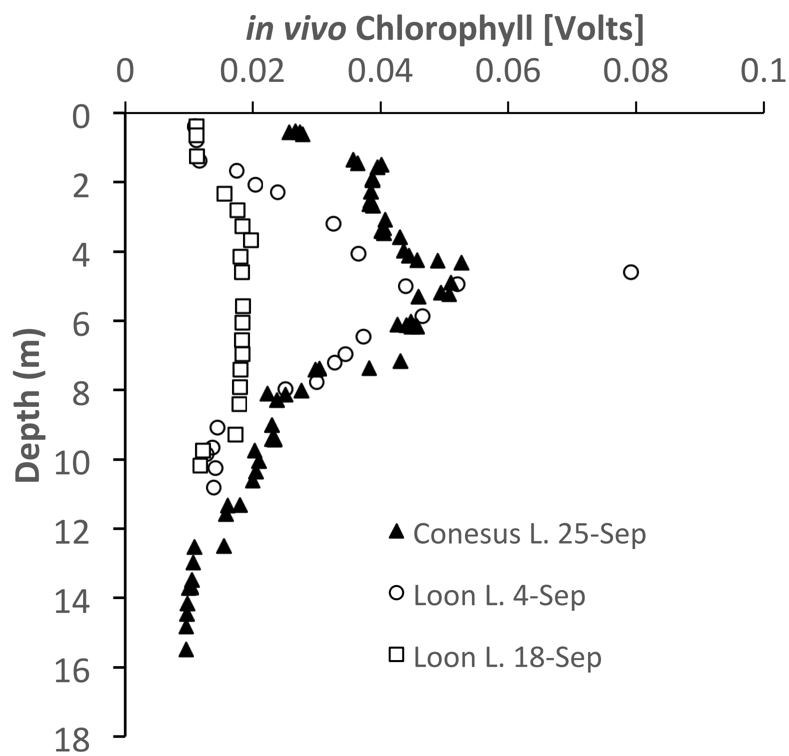

Figure 5: Profiles of *in vivo* chlorophyll for Loon Lake and Conesus Lake showing strong similarities between 4-Sep and 25-Sep. The spikes in chlorophyll near a depth of 5 m are likely due to the settlement of algae along a temperature-density barrier at the top the thermocline.

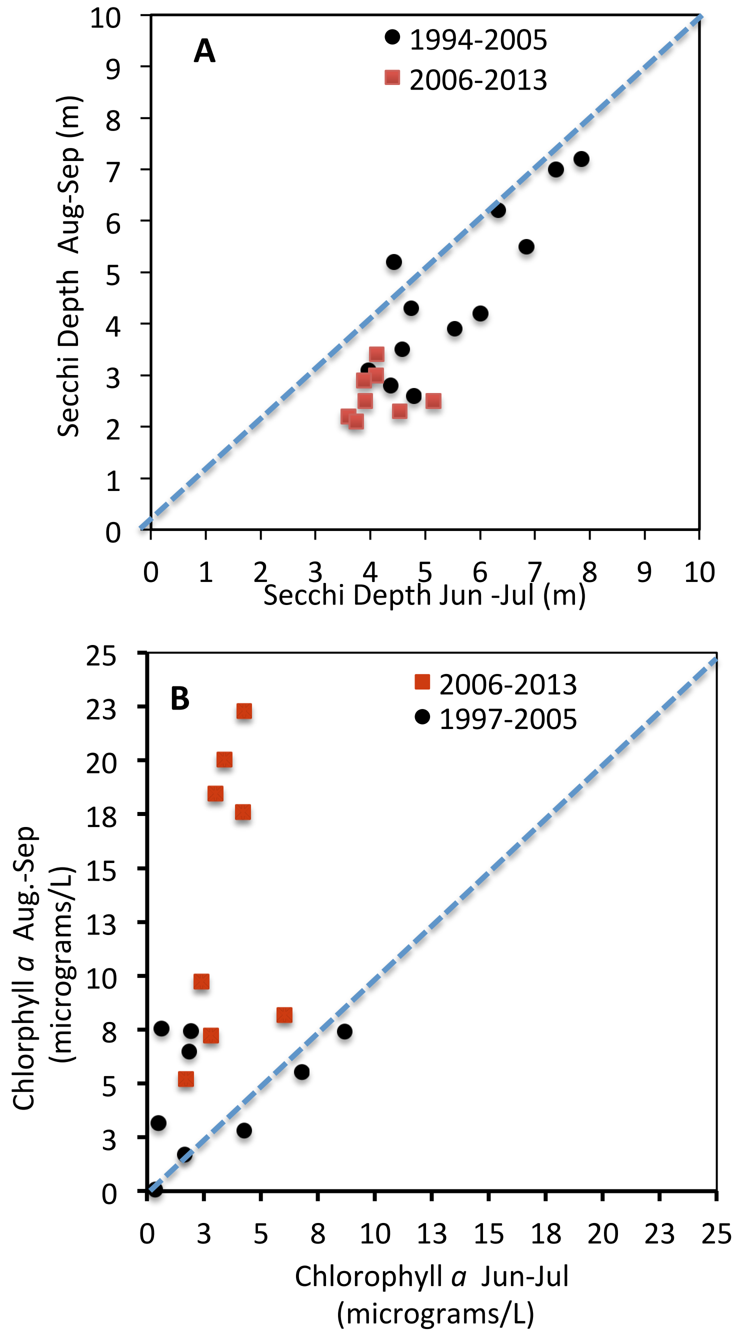

Figure 6. Historical averages of Secchi depths (A) and chl *a* (B) for Loon Lake separated into early growing season (Jun-Jul) and late growing season (Aug – Sep). The line that traverses each graph delineates where early and late season values would be equal. Phytoplankton biomass (chl *a*) in Aug-Sep shows a general increase since 2006 while Secchi depths have decreased over the same time frame.

Section II. Assessment of the Loon Lake Zooplankton Community : Species composition, Size, and Filter Feeding Capacity

RESEARCH FINDINGS

Rotifers were the most abundant zooplankters in Loon Lake with a maximum density of 259, 545 individuals per m^3, followed by cladocerans (water fleas – average ind. per $m^{3,}$ 30,465 and maximum 62,727) and cyclopoid copepods (average 18,182 individuals per m^3 and maximum 33,636), not including nauplius larvae (32,698 per m^3). The dominant rotifers were *Keratella, (mostly K. cochliaris), Kellicottia longispina, and Polyarthra (mostly P. vulgaris).* The most abundant crustaceans were the herbivorous cladocerans, *Daphnia galeata* and *Bosmina longirostris* and the predatory copepod *Acanthocyclops* sp., with average densities of 12, 955, 11,818, and 9,659 per m^3, respectively. The average crustacean length in Loon Lake (0.828 mm) was larger than that of Hemlock Lake (average = 0.340 mm) and Conesus Lake (average = 0.268 mm). Given their abundance, large size, and calculated filtration rates, Loon Lake herbivorous zooplankters have the potential to filter nearly a quarter of the lake volume in a day.

CONCLUSIONS

- Loon Lake has a diverse and abundant zooplankton community that is comprised of species characteristic of the region
- The dominant species in terms of biomass is the herbivorous cladoceran *Daphnia galeata;* rotifers are more abundant but their small size and low feeding rates makes them less important to the trophic dynamics of the lake
- The potential feeding rate of the herbivorous zooplankters in Loon Lake is 38% higher than feeding rates in Conesus Lake, where the introduced alewife continues to prey on and suppress the large species of *Daphnia*
- One important management goal should be to protect the large zooplankters in Loon Lake by keeping the populations of predatory baitfish in check and by preventing the introduction of new baitfish species

INTRODUCTION

The zooplankton community, made up of large numbers of tiny crustaceans and rotifers that live in the water column, is integral to the balance of the lake ecosystem. Herbivorous zooplankton can influence the species composition and abundance of phytoplankton (microscopic algae and cyanobacteria) directly by grazing and indirectly by altering the cycling of nutrients in the water column. This, in turn, can influence water clarity and ultimately the trophic status of a lake. Zooplankters are also the preferred food source of small fish and predatory invertebrates and thus function as a link between the primary producers and the upper trophic levels of a lake ecosystem.

According to the most recent CSLAP report on Loon Lake, the chl *a* concentrations and turbidity (which reflect phytoplankton biomass) of the water column have increased in recent years (CSLAP 2013). There are three plausible explanations for this increased turbidity. One is that algae are responding to increasing nutrient levels in Loon Lake; however, the 2013 CSLAP report shows that concentrations phosphorus, in the lake have remained relatively low. Another possibility is that the composition of the phytoplankton in Look Lake has shifted toward dominance by cyanobacteria, which use nutrients more efficiently and tend to be resistant to herbivores (See Section I). Finally, it is possible that the herbivorous zooplankton community of the lake may be losing its large grazers. *Daphnia pulex* and other large crustaceans are very effective grazers of medium to large size single celled algae. When in sufficient numbers, these herbivores are capable of keeping phytoplankton biomass under control. However, there are many cases in which the large herbivores have been decimated by zooplankton-eating fish (Vanni and Layne 1997). In Conesus Lake, large *Daphnia pulex* were historically abundant, reaching numbers of 36,000 individuals per m^3. Some time in the late 1970s, the zooplankton-feeding baitfish *Alosa pseudoharengus* (commonly know as the alewife) was accidentally introduced into the lake. Within five years of alewife introduction the *Daphnia* were all but gone from Conesus Lake and the phytoplankton biomass and turbidity had begun to increase. By 1987, about 9 years after the alewife introduction, chl *a* levels and water turbidity had nearly doubled and Conesus Lake had changed from a mesotrophic to a eutrophic state (Makarewicz 2009).

The changes described above for Conesus Lake were the impetus for this study of the Loon Lake zooplankton. Specifically, we set out to determine whether the zooplankton community was lacking the large herbivorous crustacean species that keep phytoplankton under control in other lakes. This question was part of a more comprehensive study of the species composition, average size, abundance, and biomass of the zooplankton community of Loon Lake, which had not previously been studied.

METHODS

Zooplankton samples were collected from Loon Lake on September 4th and 18th from depths of 1, 3, and 6 m. Quantitative samples were taken using a plexiglass Van Dorn bottle with a volume of 2.2 liters. The sample was then concentrated with a 63-micrometer mesh filter and preserved. Additional samples were taken using a 30 cm diameter net with a 63-micrometer mesh size. The samples were immediately preserved in a known volume of ethyl alcohol to achieve a final concentration of 50% ethanol.

For examination in the laboratory, the samples were concentrated using a nitex filter to a volume of 2 mL and then examined on an OLYMPUS CX31 microscope at 40x and 100x total magnification. A 0.1 mL Palmer Moloney slide or a 1.0 mL Sedgewick Rafter slide was used for quantitative analysis. Zooplankton species were provisionally identified using the key *Zooplankton of the Great Lakes: A Guide to the Identification and Ecology of the Common Crustacean Species* (Balcer et al. 1984) and *An Illustrated Key of Planktonic Rotifers in the Laurentian Great Lakes* (Grothe, 1977). Measurements of individual zooplankter size were made with a calibrated ocular micrometer at 100x magnification. The different species and the number of each species were then counted and used to assess the species richness, average zooplankton size, and zooplankton abundance of the lake. Biomass was calculated using the formula $\ln(W)=\ln(a)+b*\ln(L)$, where W=dry weight, a and b are constants specific to zooplankton species, and L=length in mm (Watkins 2011). The total biomass for a particular group was calculated by multiplying the individual dry weight times the number of individuals per m^3.

RESULTS

The most abundant zooplankton group in Loon Lake community were the rotifers with maximum numbers of 259,545 individuals per m^3 and average numbers of 38,192 / m^3 at 3 m and 145,227 / m^3 at 6 m. However, it is possible that our collections might have underestimated rotifer abundance because the mesh of the filtration systems used to concentrate the samples was too large (63 µm).

Cladocerans were second in numbers, followed by cyclopoid copepods and calanoid copepods (**Figure 1**). The dominant rotifers were in the genus *Keratella,* which made up 55% of all rotifers, followed by *Kelllicottia* at 26% and Polyarthra at 10% (**Tables 1 & 2**).

We distinguished 16 different crustacean morphotypes (cladocera and copepods). The identification of the copepods proved difficult and is considered provisional. Among the cladocera, we identified *Daphnia galeata*, *Bosmina longirostris*, *Eubosmina coregoni,, Ceriodaphnia* sp*., and Diaphanosoma* sp. The average cladocera abundance was 30,455 individuals/m^3, with *D. galeata* at 12,955 ind/m^3 comprising 43 % of the community and *B. longirostr*is making up 39% (**Table 2**). The average copepod abundance was 17, 841 ind /m^3, not counting the copepod nauplius larvae that were numerous in all samples (32, 689 ind/m^3). The most common copepod group was identified provisionally as the genus *Acanthocyclops*, which was 52% of the copepod numbers (**Table 2, Figure 2**).

The crustacean zooplankters of Loon Lake were found to be relatively large, especially compared to nearby Conesus Lake and Hemlock Lake, with the largest size 1.55 and 1.60 mm (**Figure 3**). The species with the greatest average length were the cyclopoid copepods *Cyclops scutifer* at 1.3 mm, followed by *Mesocylcops edax* and the various calanoid species, with an average length of 1.2 mm. Copepods, especially the larger species, tend to be predatory, feeding primarily on small cladocera, nauplius larvae, copepodites and rotifers. Among the herbivorous zooplankters, which are primarily in the cladocera, the *Daphnia* found in Loon Lake were large, with an average length of 1.13 mm (Range 0.52-1.60 mm). The average length of *Ceriodaphnia* was 0.69 mm (Ranged 0.47-0.90), and *Diaphanosoma* had a mean length of 0.59 mm (Range 0.55-0.67). *Bosmina longirostris* was the smallest, with an average length of 0.26 mm (Range 0.20-0.41).

Biomass calculations were performed on the cladocera using abundance and size data from this study. The average individual dry weight was calculated for each species from the average length using the following relationship: $W=\alpha L^{\beta}$ or in its logarithmic form, $Ln(W)=Ln(\alpha) + \beta Ln(L)$ (Watkins et al., 2011). The values used for the constants α and β were those recommended by Watkins and colleagues from Cornell University (2011). The total calculated herbivorous cladocera biomass was 93.04 mg/m^3, which is nearly 3x the calculated value for Conesus Lake (**Table 4**) based on abundance and size data for August 2009 from Makarewicz and Lewis (2009). Loon Lake *D. galeata* had the highest biomass by far with 79. 41 mg/m^3. This was considerably more than the numerically abundant *B. longirostris* at 4.37 mg/m^3 (85% of total vs. 4.7%), which shows that *Daphnia* is more important to the trophic dynamics of Loon Lake. In Conesus Lake, the *Daphnia* have been all but eradicated by large schools of predatory alewife, which left the small *B. longirostris* as the dominant cladoceran.

To evaluate the potential of the Loon Lake herbivores to effectively control phytoplankton biomass, we estimated the clearance rate of the whole community by first calculating a average clearance rate for each species, then multiplying it times the average abundance per m^3. Average length in mm (L) was converted to clearance rate in ml per individual per hour (CR) using the formula CR = 0.538 (L$^{1.55)}$, which is used commonly in the literature. The results were compared to that of Conesus Lake based on similar calculations. *Daphnia* are the most important herbivores in Loon Lake filtering 0.202 m^3/day, or 20.2% of each m^3 of water. The total filtering rate for the three dominant species was 0.241m^3/ day of each m^3 of lake water **(Table 4).** In Conesus Lake the total filtering rate by the same species was 0.175 m^3/ day. Thus, the Loon Lake cladocera are capable of filtering 24% of the water column each day, which is 1.38 X the filtering capacity of the Conesus Lake cladocera. The difference is due to the absence of large *Daphnia* in Conesus Lake, where sparse populations of the smallish *D. retrocurva* and large populations of *B. longirostris* seem to be relatively ineffective consumers of phytoplankton.

DISCUSSION

Our analysis of the zooplankton in Loon Lake revealed a large, capable herbivorous cladocera community dominated by the relatively large *Daphnia galeata*. The average size of the Loon Lake zooplankters was 0.828 mm, which is much bigger than that of some nearby lakes such as Conesus Lake (0.268 mm), and Hemlock Lake (0.34 mm) (**Figure 3**). Comparison of the potential clearance rates by the most common cladocerans *D. galeata*, *Ceriodaphnia sp.*, and *Bosmina longirostris* in Loon Lake and Conesus Lake yielded rates that were nearly 40% higher in Loon Lake (**Table 3**). The Loon Lake ecosystem sustains an abundant population of *D. galeata,* whereas in Conesus Lake a large population of the predatory alewife keeps the larger *Daphnia* in check. The greater numbers of small rotifers and of the smallish *B. longirostris* in Conesus Lake seems to be of limited effectiveness in clearing and ingesting phytoplankton, especially the larger cells. This conclusion is supported by the significant increases in chl *a* and water turbidity that occurred in Conesus Lake during the 1980's after large *Daphnia* were depleted (Makarewicz, 2000). This is a pattern that continues today (Makarewicz and Lewis, 2014).

Loon Lake has experienced increases in water column chl *a* and turbidity in recent years, presumably due to increases in phytoplankton biomass, even as phosphorus levels have remained low (CSLAP 2013). A major goal of this study was to determine whether the zooplankton community of Loon Lake was lacking the large herbivorous crustacean species that keep phytoplankton under control in other lakes. We have answered this question conclusively: the ecosystem sustains a healthy population of relatively large *Daphnia galeata*. In this respect, Loon Lake compares favorably with Conesus Lake and Hemlock Lake, where the alewife has depleted the large herbivorous *Daphnia*.

Conservation of a healthy *Daphnia* population should be a priority for Loon Lake management. The fish community has not been studied in great detail, but there are reports that the perch are "very aggressive due to large populations and limited baitfish found in this lake' (northeasticefishing.com/loon-lake-steuben-county-ny/). The abundance of large *Daphnia* is consistent with the observation of "limited baitfish". Efforts must be made to not allow any new baitfish species (and particularly ones like the alewife) to be brought into the lake, and to maintain/stock healthy populations of piscivorous fish that help keep baitfish populations in check.

The question remains as to why, despite the presence of a healthy zooplankton community, the phytoplankton biomass has increased in Loon Lake. A possible explanation for this apparent contradiction is the rise in dominance of cyanobacteria (blue green algae). There was a significant phytoplankton bloom in September when we conducted our study, and microscope observations indicated that cyanobacteria, including the potentially toxic *Microcystis* and species of *Anabaena,* were some of the dominant phytoplankton in the bloom. These cyanobacterial species form large colonies, too big to be eaten by cladoceran herbivores, and they can be toxic and thus unpalatable. Consequently, while the phosphorus of Loon Lake has remained low, the inability of the zooplankton to consume the large cyanobacteria may be responsible for the observed buildup of chl *a* and for increases in the turbidity of the water column.

Section II -Tables

Table 1: Average abundance of common crustaceans and rotifers reported as individuals per cubic meter.

Species	Individuals/ m3
Cladocera	
Ceriodaphnia	3,636
Bosmina	11,818
Daphnia	12,955
Diaphanosoma	1,136
Copepoda	
Nauplius larvae	32,689
Mesocyclopsx	1,591
Tropocyclops	545
Acanthocyclops	9,659
Calanoid spp.	1,932
Diacyclops	1,727
Rotifera	
Keratella	54, 773
Kellicottia	15,455
Polyarthra	9,545

Table 2. This table shows the average abundance in individuals per cubic meter for the most abundant crustaceans and rotifers at depths of 3 and 6 m.

Taxonomic Group	Ind. / m^3 3 m	Ind. / m^3 6 m	Ind. / m^3 Avg 3-6 m	% of total for group
Cladocera	17,273	43,636	30,455	
Daphnia	5,455	20,455	12,955	43
Ceriodaphnia	1,818	5,455	3,636	12
Bosmina	7,500	16,136	11,818	39
Cyclopoidea	23,182	12,500	17,841	
Acanthocyclops	13,636	5,682	9,659	52
Rotifera	38,182	145,227		
Keratella	18,409	91,136	54,773	55
Kelicottia	15,682	15,227	15,455	26
Polyarthra	3,636	15,455	9,545	10

Table 3: Calculations of individual and total biomass for the abundant cladoceran herbivores. The conversion to biomass using average length was based on the formula: $W = \alpha L^{\beta}$ or in its logarithmic form, $Ln(W)=Ln(\alpha) + \beta Ln(L)$ where L is the average length of individuals in an adult population.. Species-specific values for the coefficients α and β were obtained from Watkins et al., (2011). The individual biomass multiplied times the average numerical abundance of each species yielded its total biomass per cubic meter. The Conesus Lake biomass included was taken directly from Makarewicz and Lewis (2009).

Species	Ln(a)	b	Length (mm)	Wt. per ind. (µg)	Avg. ind/m^3 Loon Lake	Total Biomass (mg/m^3) Loon Lake	Avg. ind/m^3 Conesus Lake	Total Biomass (mg/m^3) Conesus Lake
Ceriodaphnia	2.56	3.34	0.584	2.15	3,636	7.82	22,88	9.43
Bosmina	2.37	2.12	0.26	0.37	11,818	4.37	25,96	23.25
Daphnia	1.61	2.84	1.13	6.13	12,955	79.41	1,03	0.95
Diaphanosoma	1.61	2.84	0.54	1.72	1,136	1.44	0	0
				Total	28,409	93.04	49,860	33.33

Table 4. Comparison of potential clearance rates for the most abundant cladoceran herbivores in Loon Lake and Conesus Lake. Then mL cleared by an individual in an hour was calculated for each species using the formula CR = 0.538 ($L^{1.55}$), where L is the average length of the animal. The clearance rate was then multiplied times the abundance of each species per cubic meter of lake water to get the total hourly clearance rate. The Conesus Lake abundance data is from August 2009 (Makarewicz and Lewis, 2009).

	Loon Lake	Conesus Lake
Bosmina CR (ml/ind/hr)	0.066	0.066
Daphnia CR (ml/ind/hr)	0.650 (*D. galeata, 1.13 mm*)	0.227 (*D. retrocurva 0.57 mm*)
Ceriodaphnia CR (ml/ind/hr)	0.29	0.29
Abundance *Daphnia*/m3	12,955	1,025
Abundance *Bosmina*/m3	11, 818	25,960
Abundance (*Ceriodaphnia*/m3)	3,636	22,875
CR (m3/All *Daphnia*/hr)	0.0084	0.0002
CR (m3/All *Bosmina*/hr)	0.0008	0.0017
CR (m3/All *CerioD*/hr)	0.0008	0.0053
Combined (m3/*Cladocera*/hr)	0.0101	0.0073
X 24 to estimate rate per day	0.2414	0.1746
Ratio CR Loon/Conesus	1.38	

Section II - Figures

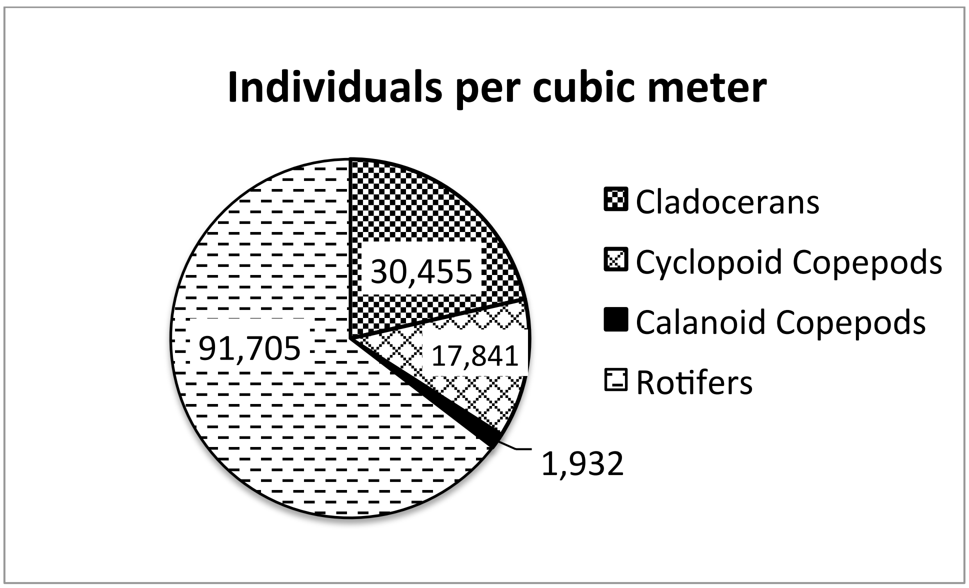

Figure 1. This pie chart shows the numerical abundance of the four main groups of zooplankton in Loon Lake.

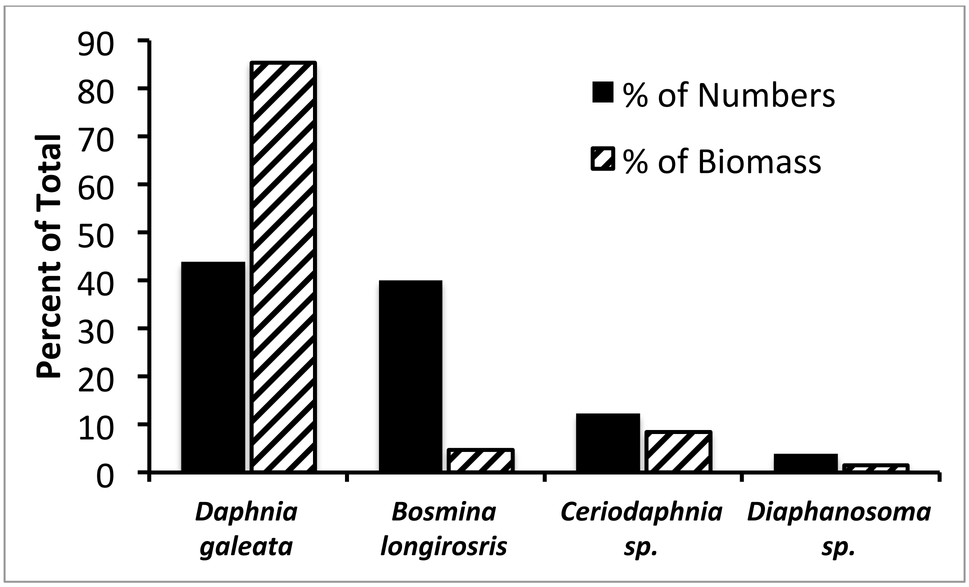

Figure 2.This bar graph shows the composition of the herbivorous cladoceran community. *Bosmina longirostris* was numerically abundant. However, due to its small individual biomass, it makes up only a small percent of the total biomass. *Daphnia galeata* was abundant and large and makes up 85% of the herbivorous cladocera biomass.

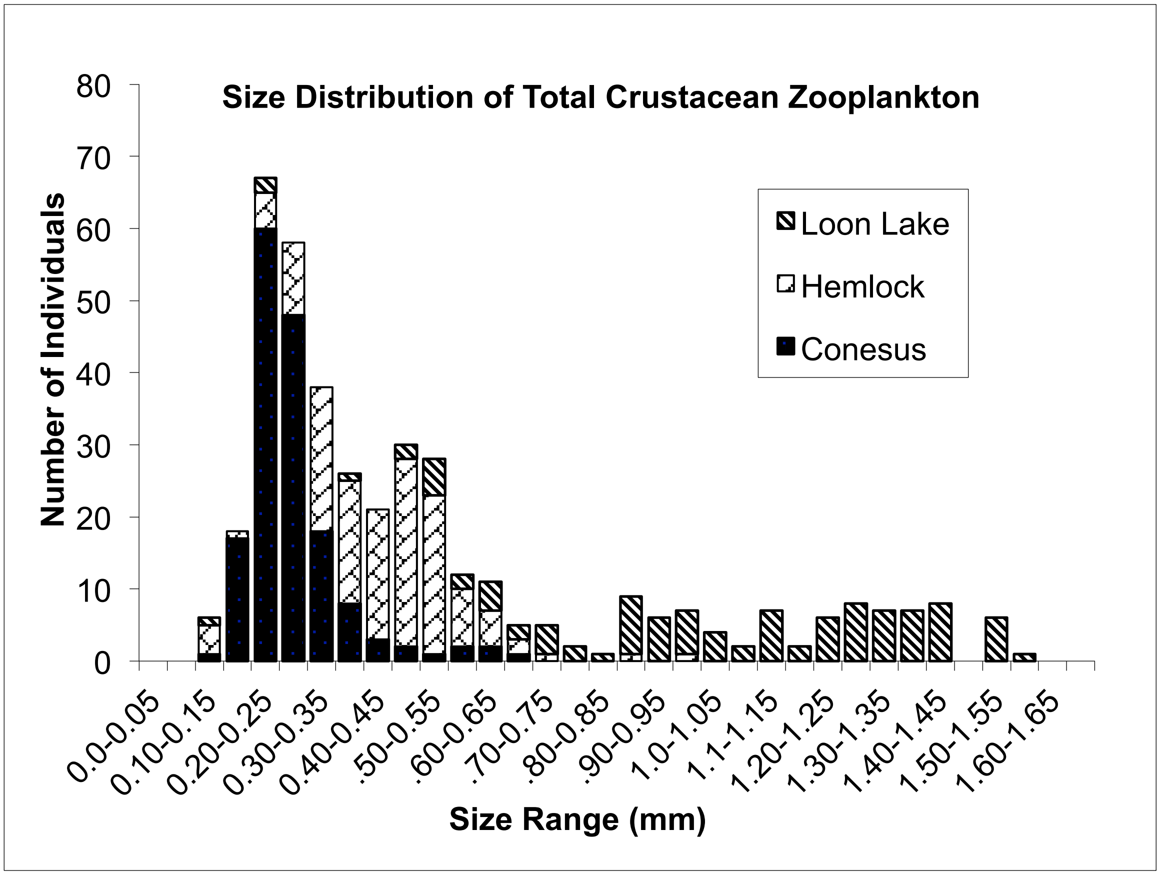

Figure 3. Crustacean zooplankton adult size compared for Loon Lake, Hemlock Lake and Conesus Lake, based on data collected in summer 2014. Sample size is 105, 214, and 104, individuals, respectively.

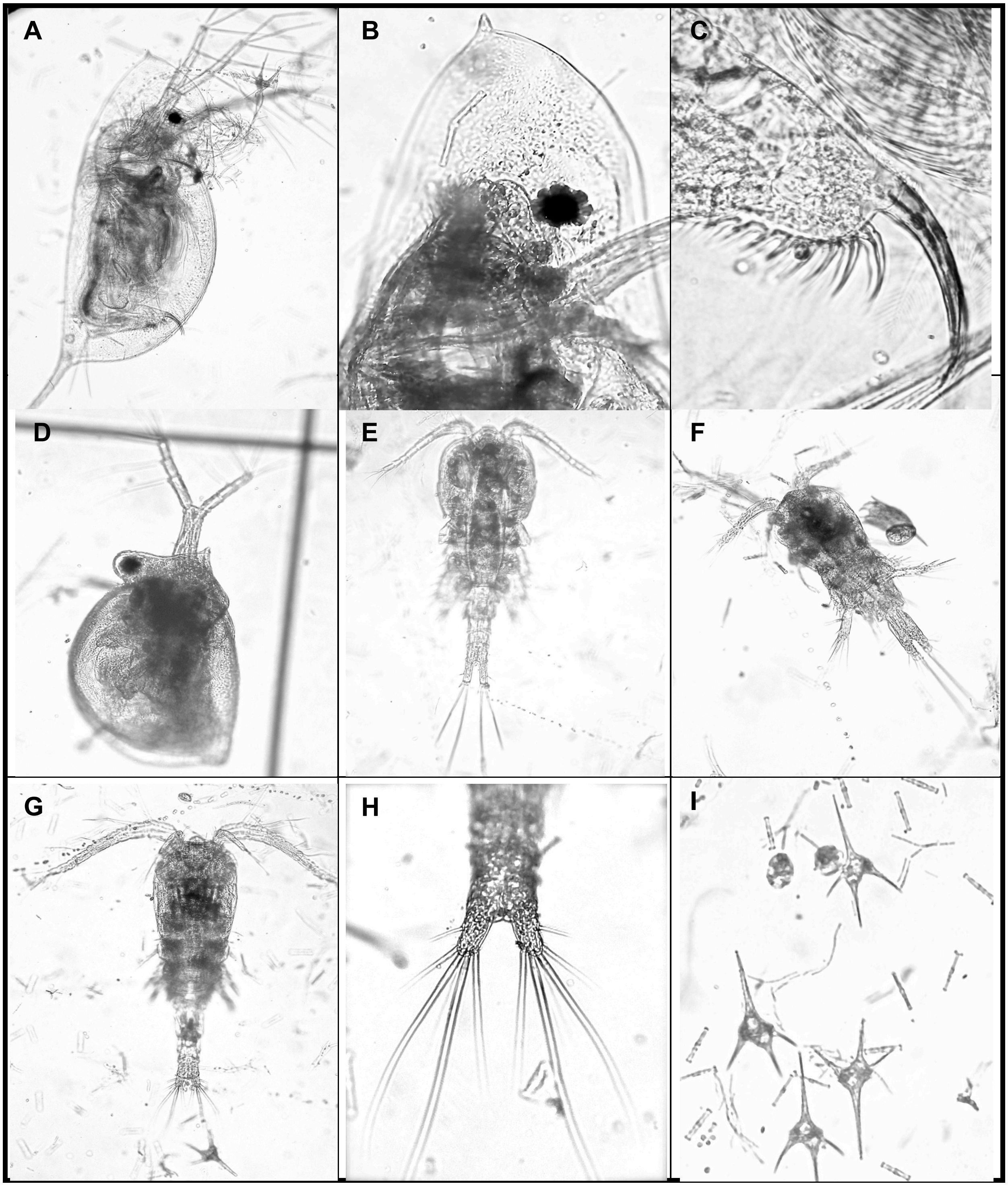

Figure 4. Images of some of the common crustacean species in Loon Lake. Cladocerans *Daphnia galeata* whole animal, head capsule and postabdominal claw (A-C) and *Ceriodaphnia* sp., (D); copepods *Diacylops thomasi* (E) *Acanthocyclops sp.* (F)*,* and *Mesocyclops edax* (G) with close up of *caudal rami* (H); some of the algae (dinoflagellates and diatoms) present in the Sep 4 collections are shown in (I).

Section III. Survey of Submerged Macrophyte Diversity

RESEARCH FINDINGS

We conducted a survey of the submerged macrophyte community in Loon Lake to establish a record of diversity and abundance, to identify possible threats by unknown invasive species and to determine the effects of mechanical weed harvesting on the dominance of the invasive Eurasian watermilfoil. Most of the macrophytes in Loon Lake were concentrated at depths of 2 and 3 m, where we collected 76.9% of the total biomass. Among the 12 species recorded, the most abundant was white-stem pondweed at 48.5% of the total biomass, followed by wild celery (also known as eelgrass) and clasping-leaf pondweed, making up 22.1% and 13.9%, respectively. There was a shift in dominance from water celery at 0.5-1 m to white stem pondweed at 2 m and clasping leaf pondweed below 3 m. The invasive Eurasian watermilfoil was only 1.5% of the collection. The mechanical harvesting program seems to be effective in controlling macrophyte biomass in Loon Lake. Additionally, the physical disturbance to the system caused by the harvester has not promoted dominance by the aggressive Eurasian watermilfoil, whose growth may be limited by the low nutrient levels of the lake.

CONCLUSIONS

- 12 species of macrophytes were collected in Loon Lake, ten of these are native and enjoy a wide distribution in regional lakes
- The most abundant species were wild celery and two pondweeds, white-stem and clasping-leaf, which favor low nutrient lakes; the invasive Eurasian watermilfoil and curly-leaf pondweed were not abundant
- The mechanical harvesting program seems to be effective in managing the macrophytes without disturbing the system in ways that would favor Eurasian watermilfoil
- These conclusions are tentative because only two collections were made when it was late in the growing season and after weeks of harvesting

INTRODUCTION

Macrophytes serve key functions in lake ecosystems as primary producers and by providing a link for nutrient exchange between the sediment and the water column. They are also important as an influence on the distribution and abundance of animals by providing habitat and food, and by serving as a nursery ground for open water fish populations.

Excessive growth of macrophytes can occur when there is an increase in the supply of phosphorus, nitrate, or other essential nutrients in a lake or when invasive species alter the ecological balance of the ecosystem, such as zebra mussels have done by increasing water clarity. Under these circumstances macrophytes can form dense beds along the shoreline that can pose obstacles to recreational activities such as boating, fishing and swimming. This is especially true for species like the invasive Eurasian watermilfoil (*Myriophyllum spicatum*), which form dense surface canopies that persist through most of the summer recreational season. Such concerns lead stakeholders in the Loon Lake/Wayland community to fund the purchase and operation of a mechanical weed harvester, which is active from late spring through most of the summer months each year.

From an ecological standpoint, mechanical weed harvesting is an ecological disturbance, with collateral effects that include resuspension of sediment and nutrients, increased turbidity and dispersal of plant fragments, to name a few. These conditions typically promote the dominance of "weedy" -natured plants that spread and grow very quickly, shading and outcompeting slower growing types. One such opportunistic species is Eurasian watermilfoil. The species is found in nearby and similar lakes such as Conesus Lake and Honeoye Lake, where it has demonstrated a large "ecological footprint", drastically changing and degrading the system.

We surveyed the submerged macrophyte community in Loon Lake with several goals in mind. Our primary goal was to describe the diversity and abundance of species, which had not been previously documented. Second, we wanted to identify possible threats to the lake ecosystem by unknown invasive species. Third, we wanted to determine whether prolonged use of a mechanical weed harvester had favored the dominance of the invasive Eurasian watermillfoil, despite the low nutrient concentrations that are typical in mesotrophic Loon Lake. The results were compared to descriptions of the macrophyte community in nearby Conesus Lake, which served as a reference for a system affected by high nutrient levels and invasive plants.

METHODS

Samples were collected in Loon Lake on the 4th and 18th of September, 2014 from depths of 0.5, 1, 1.5, 2, 3 and 5 m and from multiple locations around the lake (**Figure 1**). A pair of small rakes attached to rope was used to obtain the samples. At each depth the rake was tossed into the water and allowed to reach the bottom before being dragged and eventually pulled back in. Macrophytes brought to the surface were stored in labeled bags then refrigerated until further analysis could be conducted.

The samples were washed and separated by species, blotted dry and weighed to the nearest hundredth of a gram. Plants were identified to the species level using the guide *Through the Looking Glass…A Field Guide to Aquatic Plants* by Susan Borman, Robert Korth, and Jo Temte (Borman et al., 1997). The relative abundances of every species were calculated for each depth as well as for the entire collection. A Species diversity table was then created and compared with a species diversity table for Conesus Lake in 2012 (Bosch *et al.*, 2012). An index of community similarity (ICS) was also calculated using the equation; $ICS = \sum \min (pi, qi)$. The values pi and qi represent the proportion of each species in the two communities. A comparison of two communities yields an ICS value between 0 and 100%, with a 100% representing two identical communities and a 0% representing two communities having no species in common. The Simpsons Index of diversity, a measurement of species richness and relative abundance, was also calculated for Loon Lake using the equation; $D=1-\sum n(n-1)/N(N-1)$. Values for the Simpsons Index of Diversity and TSI were obtained for Conesus Lake so comparisons could be made between the two lakes.

RESULTS

Relative Species Abundance

A total of 92 samples were taken at six depths. We identified eleven species of suibmerged macrophytes in Loon Lake and one benthic alga (**Table 1**). Of these 12, the three dominant species were White-stem pondweed (*Potamogeton praelongus),* Wild celery or Eelgrass (*Vallisneria americana),* and Clasping-leaf pondweed *(Potamogeton* *richardsonii*) which made up 48.5%, 22.1% and 13.9% of the biomass, respectively. All other species had relative abundances under 6% of the total biomass collected (**Figure 2**). The invasive Eurasian watermilfoil was found only during collections on 9/18/14 at depths of 2 and 3 m, where we collected 41.84 blotted dry weight in grams of which milfoil was 1.51 % of the total.

Changes in the Community With Depth

The highest macrophyte biomass occurred at depths of 2 and 3 m (**Table 2, Figure 3**). At 2 m we collected 1300.4 grams of biomass or 47.0% of all collected mass, and at 3 m we collected 828.0 grams or 30% of all mass collected. Eurasian watermilfoil made up 0.22% of the macrophyte community at 2 m and 4.7% of the community at 3 m.

There was a shift in the dominant species with depth (**Figure 4**). At shallow depths, 0.5 m, 1 m, and 1.5 m, Wild celery dominated the community, comprising 60-75% of the total biomass. By 2 m there was a sharp decline in the abundance of Wild celery. Pondweeds began to dominate the community, with White-stem pondweed representing 50-80% of the biomass at 2 and 3 m and Clasping-leaf pondweed representing > 80% at 5 m. No macrophytes were obtained in collections below a depth of 5 m.

Community Indices Comparison

The species composition of the submerged macrophyte community in Loon Lake was compared to that of nearby Conesus Lake studied by Bosch and colleagues in 2012 (**Table 3**). Sixteen species were identified in Conesus Lake whereas 12 were found in Loon Lake. However, sampling in the 2012 study of Conesus Lake was more extensive and that could account for the diversity differences.

The Simpson's Diversity Index and the Index of Similarity were calculated for the two lakes. These calculations were based on the relative biomass of each species. Simpsons Index incorporates species richness and abundance into one value; more abundant species are "more important" and have greater influence on the value of the index. Values for this index range from 0 to 1, the higher the value the more species diversity (Bosch *et al.* 2012). We calculated a Simpson's Index of 0.69 for Loon Lake; compared to 0.32 for Conesus Lake reported by Bosch and colleagues. The evenness of the community was greater for

Loon Lake whereas the Conesus Lake community is dominated by Eurasian watermilfoil, which made up approximately 50 % of the macrophyte biomass lake wide and more than 90% in milfoil beds near the mouths of streams (Bosch *et al*., 2012). High dominance by one species lowers the diversity index, even if a greater number of species are present, and this was the case for the macrophyte community in Conesus Lake.

The index of community similarity between the two lakes was 17.95% out of a possible 100%, indicating a low level of similarity. As with the Simpson's Index, the community similarity metric is sensitive to the relative abundance of species and is thus affected by differences in milfoil dominance between the two lakes. In fact, the two lakes have ten species in common out of the total of 18 identified for the two lakes. The six in the Conesus Lake survey that were not present in our survey of Loon Lake are rare plants, and they are likely to be found in Loon Lake if a more intensive survey were conducted.

DISCUSSION

Over two days of collection in Loon Lake we identified 11 species of submersed macrophytes and 1 alga (*Chara sp*.), with three native species dominating the community (**Table 1**): Wild celery, White-stem pondweed, and Clasping-leaf pondweed. The two species of pondweeds are sensitive to eutrophication and they have declined or become locally extinct in lakes where nutrient levels have increased (Egerston *et al*., 2004). The only invasive macrophytes we found were Eurasian watermilfoil and curly-leaf pondweed (*Potamogeton crispus*), which represented 1.51%, 1.48% the total biomass, respectively.. Dominant species changed with depth from the shallow Wild celery to White-stem pondweed at middle depths and Clasping-leaf pondweed at 5 m depth (**Figures 3, 4**). The maximum depth of macrophyte habitation seems to be about 5 m.

An index of community similarity of 17.95% shows that the macrophyte communities of Loon Lake and Conesus Lake are dissimilar. Moreover, the Simpson's Index was found to be greater for Loon Lake than for Conesus Lake, even though six species in Conesus Lake were not found in Loon Lake. Both the similarity and the biodiversity indexes are affected by differences in relative species abundance. The species that most influenced our analysis was Eurasian watermilfoil, which makes up nearly half of the macrophyte biomass in Conesus Lake (Bosch *et al.,* 2012) but only 1.5% in Loon Lake. In fact, ten of the twelve species found in Loon Lake are also present in Conesus Lake, which indicates that the species diversity is very similar, as might be expected from the geographic proximity of the two lakes. Our study was constrained by a small sample size and by limited seasonal coverage and it is quite likely that more intensive sampling in Loon Lake will reveal an even greater overlap in diversity with Conesus Lake.

A mechanical harvesting program can be considered a significant physical disturbance to the lake system and specifically to the macrophyte community. Sediment and nutrient resuspension, removal of the plant canopy and its shading effect, and dispersal of plant fragments are just three of the many possible abrupt ecological changes caused by a typical harvester. Harvesting has been carried out through the summer season in Loon Lake for more than two decades. This intense disturbance may be expected to favor macrophyte species such as Eurasian watermilfoil that compete more effectively for nutrients, spread by fragmenting, grow rapidly and form canopies that shade competitors. This is apparently not the case in Loon Lake, where Eurasian watermilfoil, made up only 1.51% of our collected samples. The scarcity of milfoil in Loon Lake may be due to low nutrient levels. Total water column phosphorus concentrations for Loon Lake have been consistently around 14 µg/L over the last ten years (CSLAP, 2013). The summer average for Conesus Lake is characteristically between 20-25 µg/L, which is indicative of a more productive lake (Makarewicz and Lewis 2014). Madsen (1998) conducted a correlation analysis and showed that the total phosphorus (TP) concentration in lake water was a strong predictor of watermilfoil dominance. We expanded on Madsen's analysis with data from the Finger Lakes and from Loon Lake. The results of a Spearman's correlation analysis revealed a statistically significant positive relationship between TP and % milfoil (coefficient $r = 0.55$, $p = 0.027$), supporting Madsen's hypothesis that TP is a predictor of milfoil dominance. Loon Lake is the most extreme outlier in this data set with % milfoil that is well below the predicted value for its TP levels.

In summary, the macrophyte community of Loon Lake is dominated by native species that are known to thrive under low nutrient conditions. The invasive Eurasian water milfoil is present but not abundant. It is apparently kept in check by low nutrient levels, despite years of harvesting disturbance that would be expected to promote the rise of such opportunistic species.

Section III- Tables

Table 1. Species of submersed macrophytes, biomass collected and % of total biomass for each species collected in Loon Lake in September, 2014.

Species Name	Common Name	Species Total Mass (g)	Relative Abundance (% of Total)
Potamogeton perfoliatus	Clasping leaf pondweed	384.3	13.89
Elodea canadensis	Common Waterweed	87.42	3.16
Ceratophyllum demersum	Coontail	165.9	5.99
Potamogeton crispus	Curly-leaf pondweed	41.2	1.48
Myriophyllum spicatum	Eurasian watermilfoil	41.84	1.51
Chara sp.	Musk grass	2.32	0.08
Potomogton pectinatus	Sago pondweed	0.15	0.01
Najas flexilis	Slender Naiad	2.54	0.09
Potamogeton perfoliatus	Variable-leaf pondweed	72.05	2.60
Heterantheria dubia	Water stargrass	16.1	0.58
Potamogeton praelongus	Whitestem Pond Weed	1341.48	48.49
Vallisneria americana	Wild celery/Eelgrass	611.09	22.09

Table 2. Total blotted weight biomass collected and relative abundance of biomass at each depth. The sampling effort was comparable at each depth. Therefore we believe the distribution of biomass is indicative of an ecological trend.

Depth	Total biomass at depth	RA (%)
0.5	169.2	6.12
1	251.57	9.09
1.5	142.6	5.15
2	1300.41	**47.01**
3	828.01	29.93
5	74.6	2.70

Table 3. Submersed macrophyte species in Loon Lake and Conesus Lake. The Conesus Lake data is from Bosch *et al.,* (2012).

Species Name	**Common Name**	**Loon Lake**	**Conesus Lake**
Elodea canadensis	Common waterweed	✔	✔
Potamogeton crispus	Curly-Leaf pondweed	✔	✔
Vallisneria americana	Wild celery/Eelgrass	✔	✔
Ceratophyllum demersum	Coontail	✔	✔
Potamogeton pectinatus	Sago pondweed	✔	✔
Potamogeton richardsonii	Clasping Leaf Pondweed	✔	
Najas flexilis	Slender Naid	✔	✔
Potamogeton praelongus	White stem Pond Weed	✔	
Myriophyllum spicatum	Eurasian watermilfoil	✔	✔
Chara spp	Musk Grass	✔	✔
Potamogeton diversifolius	Variable-leaf Pondweed	✔	✔
Heteranthera dubia	Water Stargrass	✔	✔
Potamogeton zosteriformis	Flat Stem pondweed		✔
Potamogeton nodosus	Long Leaf		✔
Potamogeton gramineus	Variable Pondweed		✔
Ruppia sp.	Ditch Grass		✔
Potamageton illinoensis	Illinois Pondweed		✔
Racunculus longirostris	Water Crowfoot		✔

Section III - Figures

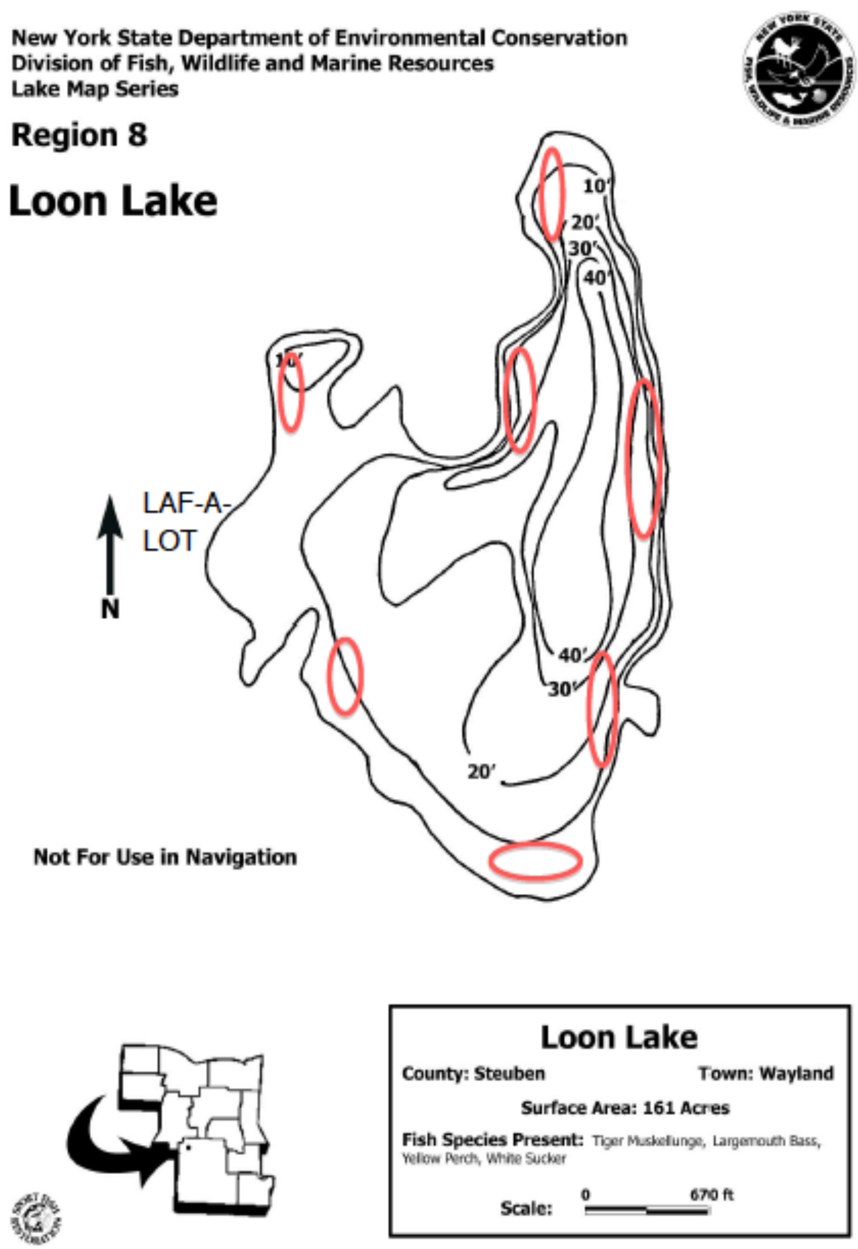

Figure 1. A bathymetric map with the general areas where samples were taken circled in red.

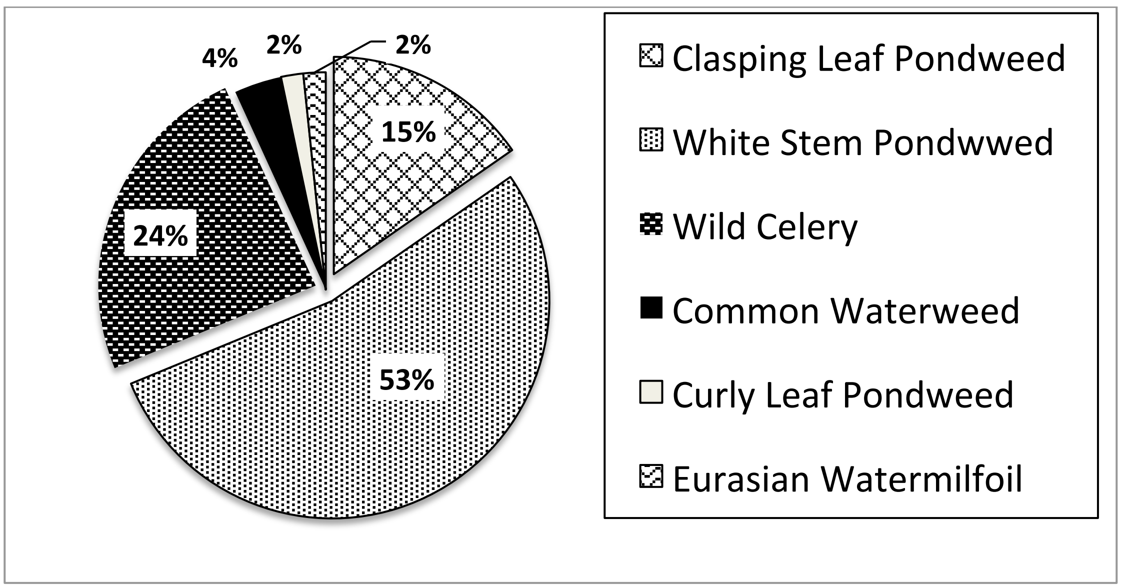

Figure 2. Pie chart showing the percent of the total wet weight collected that was comprised by each species. Six species not shown on the graph (Coontail, Muskgrass (an alga), Sago Pondweed, Slender Naiad, Variable Leaf Pondweed, Water Stargrass) were less than 1% of the total.

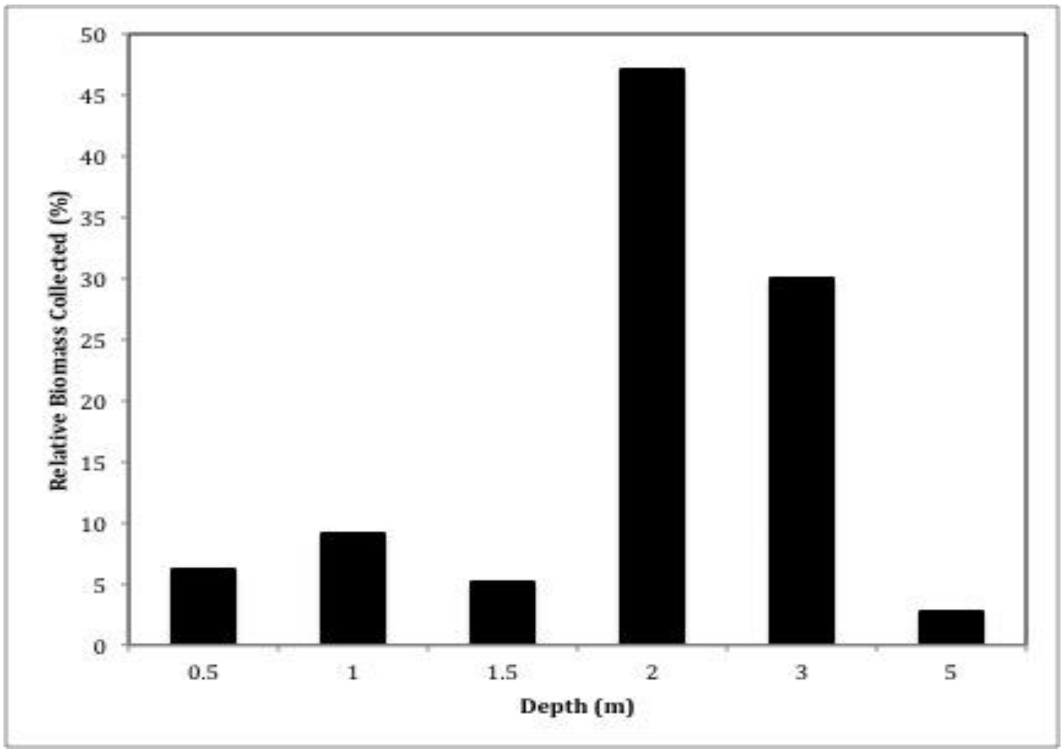

Figure 3: Percent of the total biomass that was collected at each depth sampled.

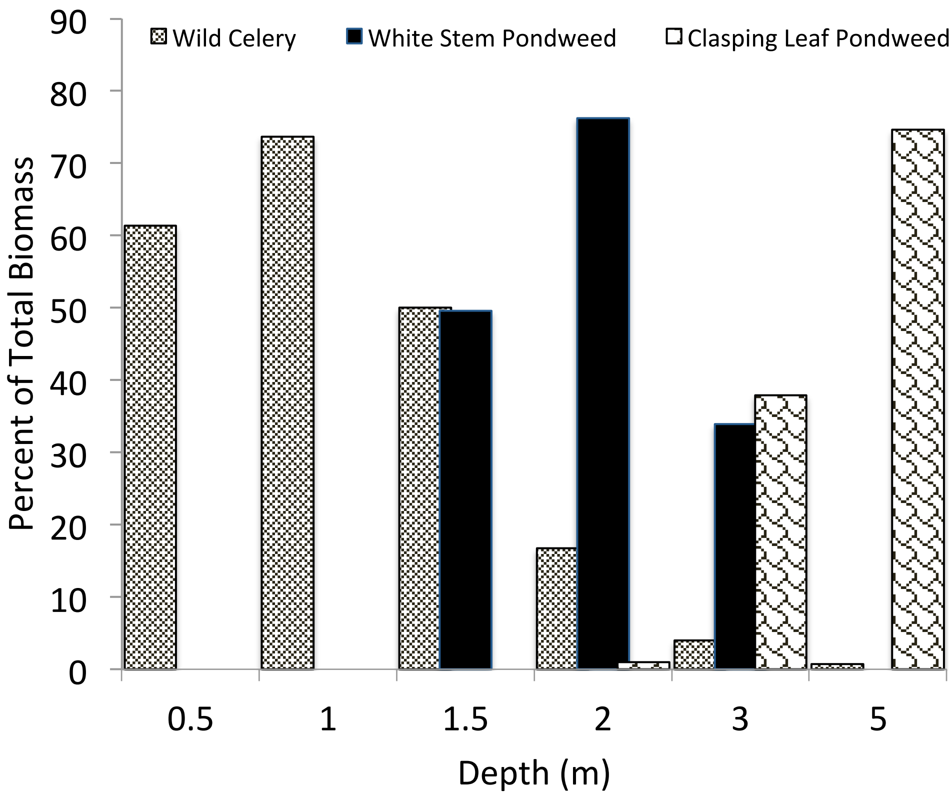

Figure 4. Changes in macrophyte species dominance with depth. The vertical axis is the % of total biomass for that depth.

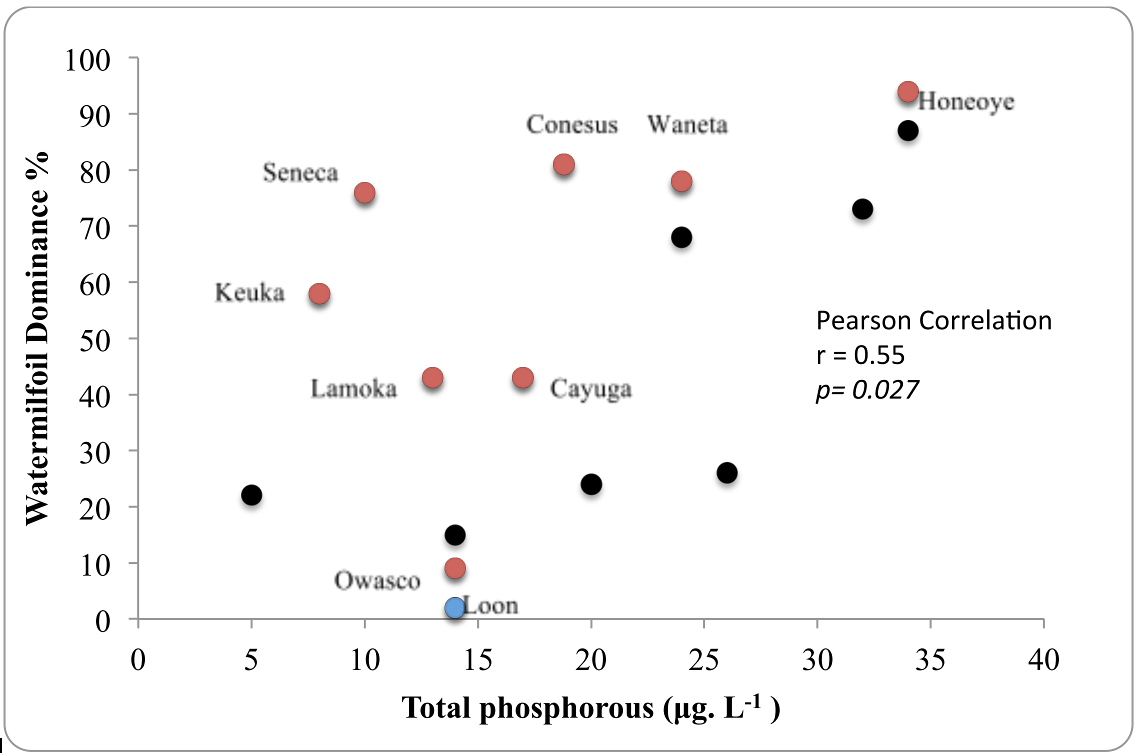

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Figure 5. This graph shows the correlation between the percent dominance of Eurasian watermilfoil (as % of total biomass) and the total water column phosphorous (µg/L) for 16 lakes. The black data points were taken from Madsen's work (1998). The red data points for the Finger Lakes were gathered from various sources, including Bosch and colleagues (2012). The blue data point represents Loon Lake (this study).

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