Macroinvertebrate Assemblage in the littoral Zone of Green Lake, Fayetteville, NY; in Comparison with Three Nearby Lakes

Elizabeth A. Mosher

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Macroinvertebrate Assemblage in the Littoral Zone of Green Lake, Fayetteville, NY; in Comparison with Three Nearby Lakes.

by

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With Honors

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ABSTRACT

Macroinvertebrates were collected and identified to the genus level from ten sites at Green Lake, Fayetteville, NY. Green Lake is a meromictic plunge pool formed 11,000 years ago by a glacial waterfall. Due to the nature of its creation it has a very unique benthic habitat for macroinvertebrates. The data collected were compared to three local lakes of varying human disturbance, Onondaga Lake (most disturbed), Otisco Lake (mildly disturbed) and Cazenovia Lake (least disturbed). The comparison of Green Lake to Onondaga Lake is especially appropriate because they both have very high specific conductance levels (2,470 µS/cm and ~1,600 µS/cm, respectively). Genera richness did not differ between Green and Onondaga Lakes or between Green and Otisco Lakes. Green Lake had greater COTE (Coleoptera, Odonata, Trichoptera and Ephemeroptera) richness and number of intolerant taxa than Onondaga Lake according to the nonparametric Kruskal-Wallis test and post hoc Dunn’s test. The differences could be caused by differing lake morphology or habitat types in each lake. Both Onondaga Lake and Green Lake have high conductivity levels relative to Cazenovia and Otisco Lakes, but the conductivity in each lake is driven by different ions (Green Lake: Ca²⁺ and SO₄²⁻; Onondaga Lake: Cl⁻). The difference in ions in each lake may cause the changes observed.
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Table 1: The latitude and longitude of each of the ten Green Lake sites sampled in October of 2016. Site 4 coordinates are adjusted for the movement of the site.

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I would like to thank Zach Smith for allowing me to participate in this project, and for all of the guidance during the entire process. You helped me to have a project in the first place, went out to sample with me, helped me in the lab, helped me with R (which is, in fact, evil) and somehow read my awful writing and gave me some really great feedback! I know this took a lot of your time, so thank you!

And also thank-you to Dr. Neil Ringler for being my honors advisor and mentor I know I haven’t been the most communicative advisee, but hopefully the result is something you can be proud of.

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Thanks to my best friend Allee Jimenez for sitting with me through late nights in the library while I tried to work through R code and write intelligent things down, but mostly thank you for dropping everything to go and get Chipotle with me when I needed (wanted?) a break.
INTRODUCTION

Green Lake, located within Green Lakes State Park, Fayetteville, NY is a meromictic glacial plunge pool. The lake was one of many lakes formed (e.g. Glacier Lake, Round Lake and Green Lake) during the Wisconsin glaciation approximately 11,000 years ago (Coon 1960). The meltwater from this glacier caused large volumes of water to flow through the entire area. The meltwater formed many large waterfalls, which bore through the Silurian Syracuse shale formation. One of the resulting plunge pools became Green Lake.

Due to the nature of its formation, Green Lake has a relatively small surface area (SA = 0.26 km$^2$) in relation to its depth (max depth = 52.5 m) (Brunskill and Ludlam 1969). Specific conductivity levels in the epilimnion are relatively high (2,470 µS/cm) compared to most freshwater lakes (Brunskill and Ludlam 1969). Aside from the north end beach, the littoral zone (0.5 m depth) of Green Lake is a narrow shelf, being only a few meters wide, and then drops off (40° angle) to depths greater than 15 m (Brunskill and Ludlam 1969). The habitat is mostly sand and silt and in some areas contain calcified beds of chara spp. and marl. There are also large amounts of woody debris from surrounding conifer species.

Aside from a minor study of order level zoobenthos (Eggleton 1956) no other comprehensive study of macroinvertebrates has been conducted within Green Lake. Macroinvertebrates are a great indicator of water quality and condition (Rosenberg et. al. 1993). Green Lake is approximately 16.90 km east of Onondaga Lake, which is currently recovering from long term industrial and municipal pollution (Effler 1996). Both lakes have high conductivity, and previous studies (Wagner 1989, Johnson 2009, Kirby 2013, Smith 2015) have shown that the macroinvertebrates in Onondaga Lake have low diversity, richness and are generally pollution
tolerant. The ions responsible for the high conductivity in each lake are different. The ions controlling conductivity in Green Lake are $\text{Ca}^{2+}$ and $\text{SO}_4^{2-}$ and in Onondaga the conductivity is driven by $\text{Cl}$ (Brunskill and Ludlam 1969, Effler 1996). In this paper, the benthic macroinvertebrate assemblages found in Green Lake are compared to the assemblages described by Smith (2015) in three local lakes.

METHODS

SITE SELECTION

Sites were selected following a similar procedure outlined in Smith (2015). In ArcGIS 9.0, the longest possible uninterrupted line was drawn through the center of the lake (Figure 1). The line was divided into five sections and four parallel lines drawn at the boundary of each section. Ten sampling sites were defined by the intersection of these lines with the 0.5m depth contour within the lake (Table 1).

BENTHIC MACROINVERTEBRATE SAMPLING

Each site was located using a handheld GPS. Habitat and water chemistry variables were collected prior to macroinvertebrate sampling. Once at the site, a PVC square with an area of 0.125m$^2$ was used to mark the sample area (Smith 2015 sample size 0.25m$^2$). A kick sample was collected at each site within the PVC marker at a water depth of 0.5m. The substrate was disturbed for one minute with the sampler's foot and a kick net (400µm mesh; dimensions: 0.45 x 0.25m) was pulled through the water to collect the materials from the disturbance. A 420µm sieve was used along with water at the site to rinse the sample of sediment. The sample was placed in a WhirlPak, and covered in 90% ethanol (enough to cover the sample by several cm). If
the sample was too large to fit into one WhirlPak, additional WhirlPaks were used. The samples were also stained with Rose Bengal dye for easier laboratory processing. The samples were stored in a walk-in refrigerator at SUNY-ESF to further prevent decomposition of the samples.

LABORATORY PROCESSING

The first replicate of each of the ten sites was processed using the methods outlined in Smith (2015). Smith (2015) had 16 sites and each site was represented by the average abundance of taxa from two samples collected at each site. The sample was emptied into a 420µm sieve and rinsed with tap water until the water ran clean. Using USEPA methods (USEPA 2012) the sample was put into a white pan with a grid consisting of fifteen equal-sized squares. The sample was spread out evenly among the fifteen squares. Using a random number generator in Microsoft Excel, one of the fifteen squares was selected, and the sample that was contained within that square was removed and weighed using a small scale. This sample material was then separated into several small plastic petri dishes and macroinvertebrates were sorted from the substrate under a dissecting microscope. Each dish was sorted methodically starting at the bottom from left to right, until the entire dish had been picked through, and macroinvertebrates separated. An additional, more rapid, pass was made to make sure all macroinvertebrates had been collected. The macroinvertebrates were put in small plastic vials for later identification. Squares were randomly selected and sorted until a minimum of 100 organisms had been collected; each selected square was sorted in its entirety. All organisms were identified to genus when possible and in some cases, species using Peckarsky et al. 1990 and Jonkinen 1992. Chironomids were extracted from the sample but were not identified beyond the family level, voucher specimens stored in a SUNY ESF refrigerator.

METRICS AND CALCULATIONS
The macroinvertebrate assemblages found in Green Lake were compared to the assemblages found by Smith (2015), who sampled macroinvertebrate assemblages from Onondaga Lake, Otisco Lake, and Cazenovia Lake in 2014. The majority of the taxa identified by Smith (2015) were identified to the genus level. The chironomids, identified to genus level by Smith (2015), were left at the family level for analysis in this study.

R statistical software was used to compare four macroinvertebrate metrics representing the macroinvertebrate assemblages found within the four lakes. A Shapiro-Wilkes test was used to assess the normality of the data. If the data were normal, the metrics were compared using ANOVA. The post hoc Tukey HSD test was performed when the ANOVA test was significant (\( \alpha < 0.05 \)). However, non-normal data were compared with the non-parametric Kruskal-Wallis test. The post hoc Dunn’s test was performed when the Kruskal-Wallis test was significant (\( \alpha < 0.05 \)).

The estimated density of organisms found in a 1m\(^2\) area was compared among lakes. The number of organisms per sample was estimated by dividing the average number of organisms identified in each square during the sorting process by 15 (i.e. the total number of squares in the sorting tray). This number was then multiplied by 8 (sampling area 0.125 m\(^2\) x 8 = 1m\(^2\)) to represent an estimated density 1m\(^2\). Genera richness, or the total number of unique genera found in sample, was also assessed. Anthropogenic disturbance has been shown to lower macroinvertebrate richness (Gerritsen et al. 2000, Lewis et al. 2001, Blocksom et al. 2002, Heatherly et al. 2005, Kamman and Vermont Department of Environmental Conservation 2007, Shah et al. 2011, Smith et al. 2012). Additionally, a measure of Coleoptera, Odonata, Trichoptera and Ephemeroptera (COTE) genera richness was used to compare the number of taxa, considered to be sensitive to environmental degradation, present in each lake. COTE have been used as indicator species of lentic systems (Kamman and Vermont Department of Environmental
Conservation 2007) just as EPT (Ephemeroptera, Plecoptera and Trichoptera) have been used in lotic systems (Lenat 1988, Beck and Hatch 2009, Smith et al. 2012). Finally, the Shannon-Weiner index, a common diversity measure (Gotelli 2008) was used to assess diversity within each lake (Equation 1).

**EQUATION 1:**

\[ H' = \sum_{i=1}^{S} p_i \ln p_i \]

Where:
- \( S \) = total number of genera
- \( p_i \) = the proportion of the sample represented by species \( i \)

Nonmetric Multidimensional Scaling (NMDS) was also used to compare the assemblages found within each lake. This ordination plots sites based on assemblage similarity. The closer two points, the more similar the assemblage. The points for each lake were encompassed in a polygon to emphasize lake distributions; as opposed to a scatter of points representing each sampling location from the four study lakes. Specific conductivity, temperature, pH, and the distance the samples were collected from shore were overlaid on to the NMDS plot.

**RESULTS**

**TAXA**

Green Lakes had several species not found in any of the three other lakes: *Boyeria spp.* (Aeshnidae), *Setades spp.* (Leptoceridae) and *Microcyloepsus spp.* (Elmidae). Cazenovia, Otisco, Onondaga and Green Lake all had several snails in common including *Physa spp.* and *Amnicola limosa*. Green Lake, Cazenovia Lake and Otisco Lake benthos all contained *Stenonema spp.* (Heptageniidae) and *Sialis spp.* (Sialidae) while neither were found in the benthos of Onondaga. The only COTE taxa Onondaga and Green Lake benthos have in common were *Oecetis spp.*
(Leptoceridae) and *Enallagma* spp. (Coenagrionidae). Onondaga and Green Lake shared no unique taxa.

**NDMS Plot**

The Non-metric Multidimensional Scaling plot (NMDS) (created using the vegan package in R) shows differences among the lakes along the x-axis, but Green and Onondaga Lakes are most similar (Figure 2). The distribution along the x-axis can be explained by temperature and conductivity; no environmental parameters that were measured can account for the y-axis distribution. The polygons for Onondaga, Cazenovia and Otisco overlap the most. Green Lake barely overlaps Onondaga, signifying that it has a relatively unique macroinvertebrate assemblage. The stress value was moderately high (stress = 0.13) but below the 0.20 threshold considered uninterpretable by McCune et al. (2002).

**Metrics**

**Density**

The density data were non-normal (Shapiro-Wilk p ≤ 0.01). The Kuskal-Wallis test showed that there was not a significant difference in the density (Figure 3) among any of the lakes (p = 0.98, df = 3). Median density: Green Lake = 4382, Onondaga Lake = 2359, Otisco Lake = 2599, and Cazenovia Lake = 2519.

**Genera Richness**

The Shapiro-Wilk Normality test was normal (p = 0.13) for genera richness. ANOVA resulted in a significant difference in genera richness. The Tukey HSD post hoc test showed a significant difference in richness (Figure 4) between each lake compared with Cazenovia Lake (17.1 taxa on average) (all, p ≤ 0.01), Otisco (10.5 taxa on average) and Onondaga (6.5 taxa on
average) were significantly different \((p = 0.01)\). Green Lake (9 taxa on average) and Onondaga and Green Lake and Otisco were not different \((p = 0.32 \text{ and } p = 0.73, \text{ respectively})\).

**COTE Genera Richness**

The COTE genera richness were non-normally distributed (Shapiro-Wilk \(p \leq 0.01\)). The Kuskal-Wallis test showed a significant difference in COTE genera richness (Figure 5) among some of the lakes \((p \leq 0.01, df = 3)\). Dunn's test showed a significant difference between all of the lakes (GRN-CAZ \(p = 0.04\), ONON-CAZ \(p < 0.01\), OT-CAZ \(p = 0.02\), ONON-GRN \(p = 0.03\), OT_ONON \(p = 0.01\)) except Otisco and Green Lake \((p = 0.49)\). Green Lake had a median COTE richness of 3.6. Onondaga had the lowest median COTE richness (1.5) and Cazenovia had the highest (4.9). Otisco had a median COTE richness of 3.2.

**Shannon-Weiner Diversity Index**

The data were not normally distributed \((p \leq 0.01, df = 3)\). Shannon-Weiner diversity (Figure 6) at Green Lake (median 1.2) was not significantly different from Cazenovia (median 1.5) or Otisco (median 1.2) \((p = 0.13 \text{ and } p = 0.31, \text{ respectively})\). Onondaga (median = 0.8) diversity was significantly lower than Green Lakes \((p \leq 0.01)\) and Cazenovia Lake \((p \leq 0.01)\). Otisco Lake diversity was significantly \((p = 0.03)\) lower than Cazenovia Lake.

**DISCUSSION**

The macroinvertebrate assemblage in Green Lake was different compared to the other three lakes. Green Lake is most similar to Onondaga Lake, and the NMDS plot indicates that of the habitat variables measured, temperature and conductivity, have the strongest correlation. Temperature can be disregarded, as the differences in temperature were most likely due to sample time; Green Lake was sampled in October whereas the other three were sampled in July.
(Smith 2015). The conductivity of Green Lake was on average 2,136 µS/cm and in Onondaga it was on average 1,662 µS/cm. The specific conductivity in Green Lake and Onondaga Lake are driven by different ions; Green consists mainly of Ca\(^{2+}\) and SO\(_4^{2-}\), whereas Onondaga's conductivity consists almost entirely of Cl\(^-\) (Brunskill and Ludlam 1969, Effler 1996). Perhaps not conductivity in general, but specific ions influence taxa composition. Even though both of these lakes have high conductivity, the polygons in the NMDS plot do not overlap that much, meaning something besides conductivity is affecting the assemblage. Conductivity has been shown to be an indicator of watershed disturbance (Dow and Zampella 2000), but this does not mean that conductivity itself changes macroinvertebrate assemblages. Although conductivity is much higher in Green Lake, diversity, COTE richness, and abundance are comparable to that of Cazenovia and Otisco Lake which have lower conductivity values (on average, 280 µS/cm and 373 µS/cm, respectively).

Average genera richness in Green Lake (9 taxa) was not significantly different from Onondaga (6.5 taxa, \(p = 0.32\)). There was also no significant difference in density among any of the lakes (\(p = 0.98\), df = 3). COTE (Coleoptera, Odonata, Trichoptera and Ephemeroptera) taxa are typically the most sensitive taxa in lentic systems, and low COTE richness is an indicator of poor water quality (Kamman and Vermont Department of Environmental Conservation 2007). Since Green Lake lacked abundant taxa outside of the COTE group, it had lower overall richness than Cazenovia and Otisco. Overall COTE richness is relatively high in Green Lake compared to the low COTE richness of the much larger Onondaga Lake. Lake area has been shown to have a positive correlation with increased richness (Allen et. al. 1998). Green Lake has a significantly lower surface area (\(SA = 0.26 \text{ km}^2\)) than Onondaga (\(SA = 12 \text{ km}^2\)), yet the richness is not significantly different, conflicting with the findings of Allen et. al. 1998. One would expect Onondaga to have higher richness than Green Lake based on size alone. Perhaps Onondaga just needs more time to
recover from historical pollution, or the low richness is due to something else entirely. Further studies could be done on the richness of small vs. large lakes.

Shannon-Weiner diversity was very low in Onondaga (median = 0.8), but Green Lake (median = 1.2) had similar diversity to Otisco (median = 1.2) and Cazenovia (median = 1.5). Onondaga having the lowest diversity may be a result of historic anthropogenic disturbance (Smith 2014). Green Lake, Otisco Lake, and Cazenovia Lake are less impacted and therefore expected to have higher diversity.

CONCLUSION

Green Lake had high COTE richness, density, and diversity, much like Otisco and Cazenovia Lakes (Smith 2015). However, Green Lake had low genera richness counts comparable to Onondaga Lake. The low richness could perhaps be due to unusual shoreline habitat rather than poor water quality. If the water quality were poor, we would expect the COTE richness to be low, lower than the relatively undisturbed Otisco and Cazenovia Lakes. Further research should focus on how conductivity is affected by these different ions (Ca$^{2+}$, SO$_4^{2-}$, and Cl) and how these ions effect macroinvertebrates. More needs to be known about macroinvertebrate assemblages in high conductivity environments (both naturally occurring and disturbance driven). Trophic levels of Green Lake should be studied to see if there is a lack of abundance of predators/food. Green Lake's unexpectedly rich macroinvertebrate assemblage may be caused by a unique trophic system of predators and/or food. Anually, there is stocking of rainbow trout, which may change the naturally occurring system. Fish diversity and abundance may be different in Green Lake leading to different predatory stress on the macroinvertebrates compared to Onondaga Lake. One
study hypothesized that certain keystone vertebrate predators shaped the benthic macroinvertebrate assemblages (Thorp and Bergey 1981).

Overall, Green Lake in Fayetteville, NY is a unique system that geologists, chemists and limnologists have studies for decades. We found that it has a high diversity of macroinvertebrates similar to less disturbed local lakes, but has low richness, much like the anthropogenically disturbed Onondaga Lake (Smith 2015). Future studies of Green Lake should focus on littoral habitat types and the macroinvertebrates that inhabit them, and compare this to other local lakes.
LITERATURE CITED


