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Local Ecology Research Papers

The Effects of Heterogeneous Habitat Substructure on the Diversity of Macroinvertebrate Communities Surrounding Circle Lake

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Absract

When assessing the health of a freshwater ecosystem, the macroinvertebrate community found within it can be extremely telling of an ecosystem's overall stability. These macroinvertebrate communities are influenced by more than just water chemistry, but also the types of habitats found in a given ecosystem. To address this, three different habitat types surrounding Circle Lake in Fairbault, Minnesota were sampled for aquatic insects to determine if habitats with more heterogeneous substructures support higher diversity than those that are more homogeneous. These habitats included Wolf Creek, a stream flowing between Circle and Fox Lake, the shoreline of an island in central Circle Lake, and a drainage ditch frequently dammed by beavers (Co. Ditch 32). No significant differences were noted between the substrate diversities and plant cover of the three habitats, although there were significantly different turbidity and leaf-pack levels. The only significant differences in taxonomic diversity were seen between Co. Ditch 32 and Wolf Creek, supporting the highest and lowest Shannon Index values, respectively. These results suggest no correlation between substructure heterogeneity and insect biodiversity, however, Co. Ditch 32's high Beck's Biotic Index score implies that water quality may play a more influential role in determining biodiversity in these specific communities.

Introduction

All over the world, macroinvertebrate species have served as a means of evaluating water quality and aquatic ecosystem health beyond the use of chemical tests alone. Certain insect taxa like Trichoptera, Ephemeroptera, and Plecoptera (collectively known as EPT) are extremely sensitive to adverse environmental conditions, and as such can be used as important indicators of ambient nitrogen (N), phosphorous (P), pH, and turbidity levels (Boyle, 2001; Merrit, 2008). Aside from good water quality, variable habitat types within an ecosystem are also important to promoting high species diversity, encouraging more complete niche fulfillment and more stable, healthy aquatic ecosystems.

The area my study focused on is that surrounding Circle Lake in Rice County, Minnesota. The Circle Lake area is a drainage outlet to numerous natural ravines as well as installed drainage ditches. Development of the land surrounding the lake, be that for use as housing or agricultural land, has influenced the types of habitats available to macroinvertebrate communities by clearing natural vegetation and affecting the influx of nutrients and eroded soil. This habitat alteration could lead to the loss of prime habitat for macroinvertebrates like those in the sensitive EPT group that play important roles as algal grazers and detrital shredders (Merrit, 2008). The sources of runoff in these small ravines are also a major contributor to the macroinvertebrates capable of living there. Much of the land surrounding Circle Lake serves as farmland for the growth of corn and soybeans. Drainage tiles placed under these fields drain away runoff potentially rich in nitrates, phosphorous, and pesticides that are deleterious to stream health. Previous research has shown that increasing nitrate levels are more likely to be fatal to early instar

Trichopterans, and at high enough concentrations, lead to behavioral shifts, migration, and ultimately death in later instar individuals (Camargo, 2005).

This information in mind, the objective of this study was to determine if habitat substructure diversity has an effect on the levels of macroinvertebrate biodiversity found there. My hypothesis is that those ecosystems that have higher substructure diversity will provide greater structural platforms for a number of functional feeding groups to exist in the same area.

Methods

Over the course of an eight-week sampling period (early-October to mid-November, 2013), I collected data from three different habitat types in and around Circle Lake (Fig. 1). At each habitat location, three replicate plots (5 m^2) were and flagged out for data collection. Each replicate plot was measured for physical characteristics including: 1) substrate type as defined by Stone (2006) and percent coverage of each type, 2) depth of leaf pack (cm) and percent coverage, 3) percent live plant coverage, and 4) secchi depth (cm).

Macroinvertebrates were collected at each plot using a dip-net on the substrate and vegetation. Only insect taxa will be considered for analysis. Collected specimens were preserved in 70% ethanol for identification in the lab. Specimens were identified to lowest possible taxon using Bouchard (2004), Hilsonhoff (1995), and Landwater (2010).

Data Analysis

Taxonomic and habitat diversity were calculated using the Simpson Diversity Index, as outlined in Brower (1998) and the NCEAS (2013). I also utilized the Beck's

Biotic Index (as described in Terrell (1989)) as a basic analysis of ecosystem health. One-way ANOVA tests were used to compare the mean taxonomic and habitat diversities, leaf pack depth, plant cover, and turbidity.

Results

Environmental Characteristics

Calculation of the Simpson Diversity of each habitat's substructure shows that Wolf Creek had the highest average substrate diversity at 1.709, followed by Co. Ditch 32 (1.4756), and finally Lakeside (1.4606) (Figure 2). ANOVA analysis of these means shows that there is no significant difference ($p=0.145$) between the substructure diversities of these three habitats.

Figure 3 shows that Wolf Creek had significantly higher ($p=1.74e-5$) leaf pack depths than either of the two other habitats. Co. Ditch 32 showed the highest rate of live plant coverage at an average of 53.46%, followed by Wolf Creek with 17.5%, and Lakeside with 0%. ANOVA analysis of these means showed no significant difference in these averages. Analysis of secchi depths showed that the readings at Wolf Creek and Co. Ditch 32 (>60 cm) were significantly greater ($p>2e-16$) than that of the Lakeside habitat (25.2 cm).

Taxonomic Diversity

A total of 18 taxa representing six orders were found across the three sampled habitats (Figure 4). Co. Ditch 32 was found to have the highest taxonomic diversity at 13 taxa, and Lakeside had the lowest with 6 taxa (Figure 5). Calculation of the taxonomic diversity of each habitat shows that Co. Ditch 32 also had the highest level of diversity, while Wolf Creek shows the lowest (Figure 6). Pairwise comparison of these diversity levels for each habitat reveals that the only significant (t=-2.896) differences seen are between Co. Ditch 32 and Wolf Creek.

Calculation of the Beck's Biotic Index of each location found Co. Ditch 32 to have the highest index rating, with Wolf Creek once again having the lowest rating (Table 1).

Discussion

The Effects of Habitat Structural Diversity on Macroinvertebrate Taxa

In searching for other studies related to my research, I have found that a number of other researchers have sought to find if different habitat substructures not only effects the macroinvertebrate community found within, but if it influences other ecosystem services like nutrient cycling (Reice, 1980). Many of these studies are finding, that water chemistry has a greater effect on colonization by macroinvertebrates than any one aspect of habitat substructure. In a study by Reice (1980), it was found that in gravel bottomed streams, it was diversity in substrate size rather than leaf pack cover that determined the number of species likely to colonize the habitat. Another study by Culp (1984) seems to show that substrate diversity was less important than levels of organic sedimentation providing nutrients within the ecosystem. These studies seem to support the findings of this research; looking at Wolf Creek, the habitat showing the highest habitat substructure diversity (albeit not significantly greater) actually exhibited the lowest level of biodiversity, contradicting my original hypothesis. The insignificant effect of leaf pack levels and plant coverage on insect diversity also seem to go against my hypothesis that the presence of these types of microhabitats would promote local diversification of functional feeding groups.

Significance of the Beck's Biotic Index

Based on the fact that my calculated biotic index values seem to be correlated with the observed biodiversity levels, I hypothesize that the macroinvertebrate communities surrounding Circle Lake are more influenced by water chemistry than habitat structure. This is important to note because, as mentioned in the introduction, land use around Circle Lake is predominantly agricultural, providing the possibility for heavy organic and inorganic pollution from farm runoff, as well as sedimentation. These combined factors, if left unchecked, could seriously harm sensitive taxa like those of the EPT groups.

Topics for Future Study

If I were to continue research on the communities surrounding Circle Lake, my primary goal would be to sample a wider range of habits surrounding the lake. Due to time constraints and weather conditions, several habitats like reed beds and several small ravines were unable to be sampled. In the future, I would also like to conduct cross-seasonal sampling. Because my sampling occurred in late October and early November, much of the aquatic insect activity is at it's low point for the year. Ideally, I would like to sample from late spring (April or May) until the time when this study was conducted.Finally, as a further improvement of my research, I would like to be able to identify my insect specimens to an even more specific taxonomic level. This would not only give me a more accurate representation of the levels of biodiversity in the habitats sampled, but it will also provide more insightful results when using other community-health metrics like the Beck's Biotic Index.

Conclusion

The results found suggest that the macroinvertebrate communities surrounding Circle Lake are influenced by factors beyond simply the diversity of habitat substructures examined by my research. The findings of my Beck's Biotic Index may suggest (along with the finding of other similar studies) that water chemistry has a much greater effect on what taxa are able to inhabit these freshwater ecosystems.

Acknowledgements

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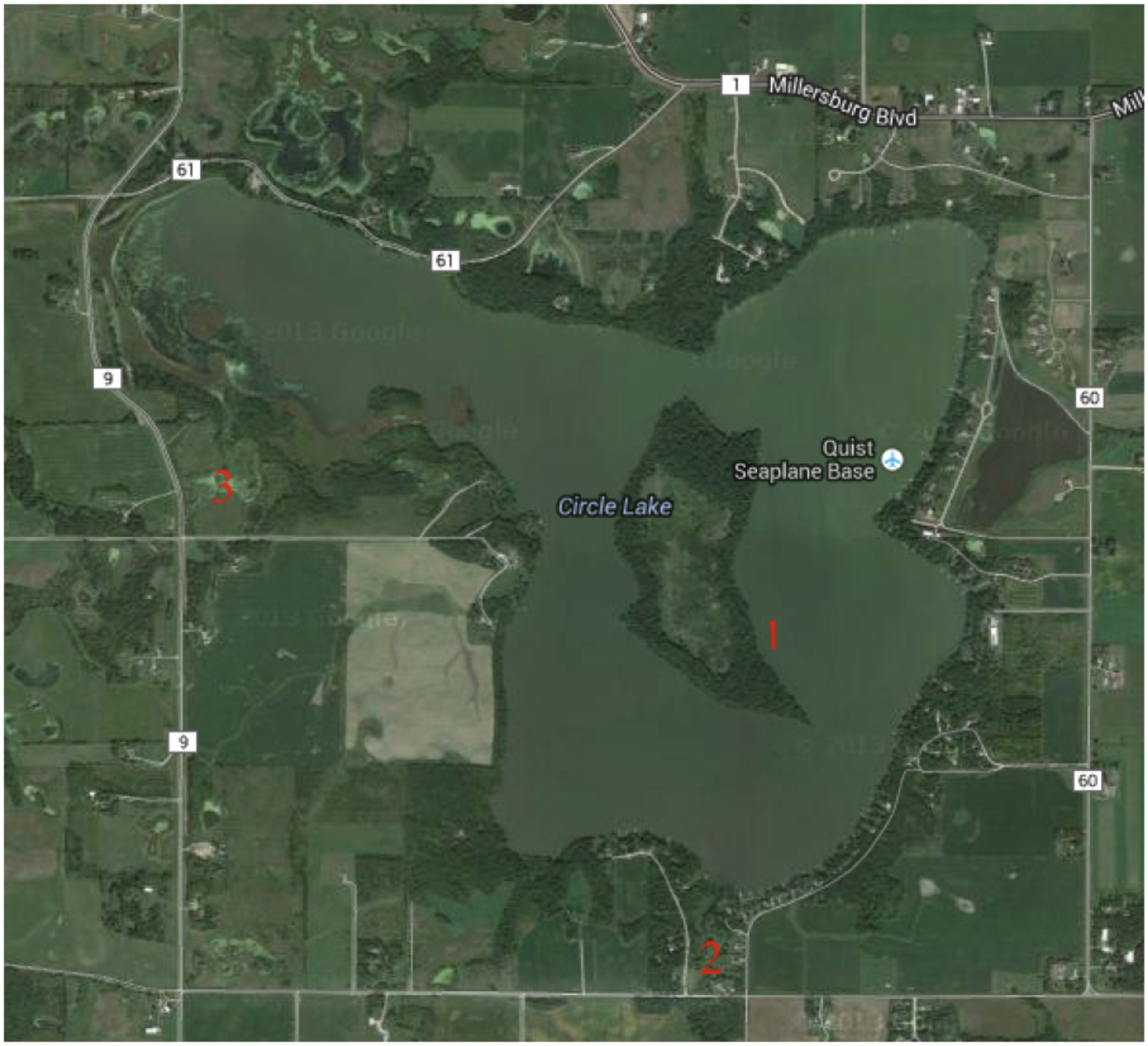
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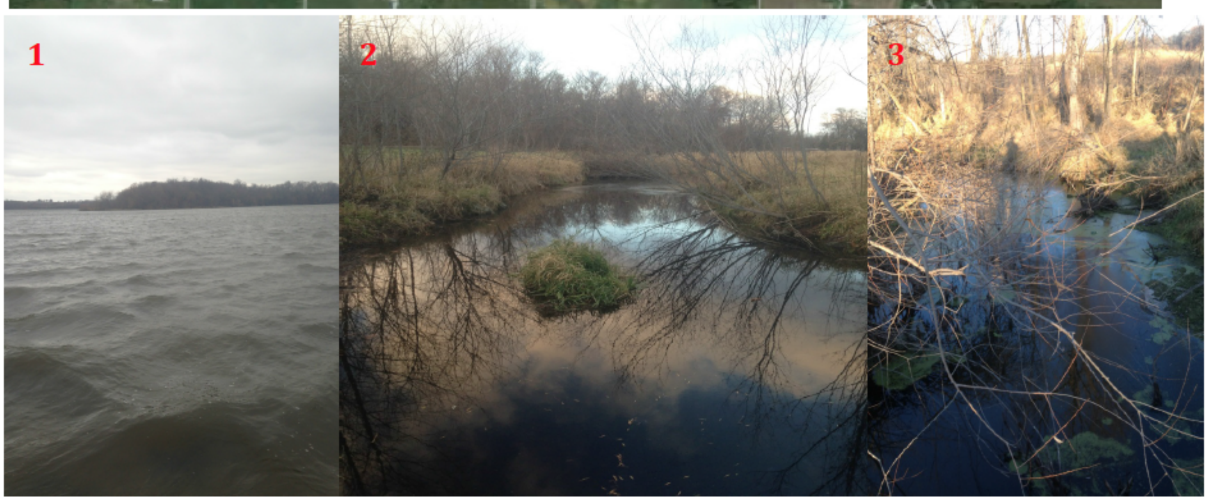
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Figure 1- Circle Lake and Sampling Sites
1) Lakeside plot- This habitat was devoid of emergent vegetation, with a substrate composed primarily of sand, gravel, and pebbles. 2) Wolf Creek- This habitat was characterized by flowing water, plentiful emergent vegetation, sand and silt substrate and large patches of leaf pack. 3) County Ditch 32- This site was characterized by some emergent vegetation, silty bottom with plentiful algae, and mostly still water. This water system is frequently dammed by beavers.

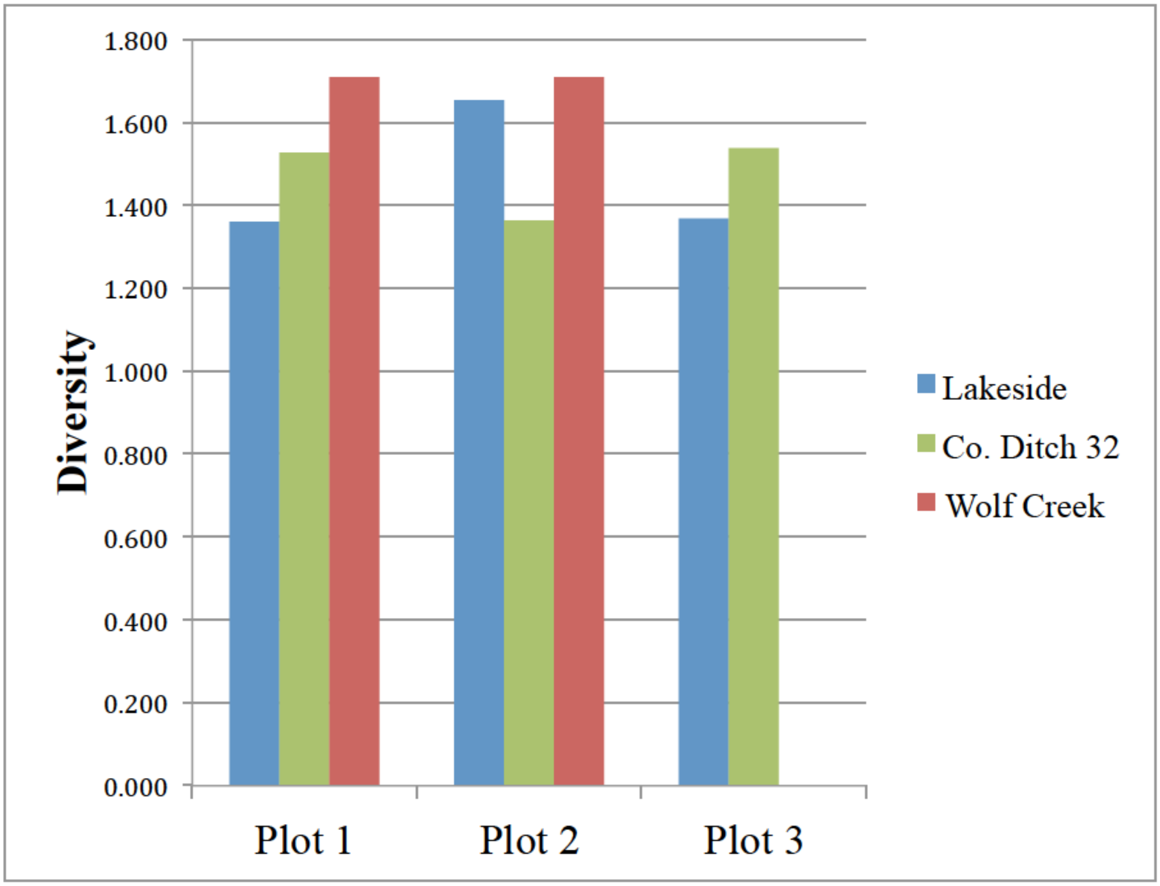

Figure 2- Simpson Diversity Index of habitat substructures in locations sampled Wolf Creek showed the highest average diversity (D=1.7094) amongst the three sites sampled. After ANOVA analysis of the mean diversity of each habitat, it was found that no one site was statistically more diverse than any other ($p=0.145$).

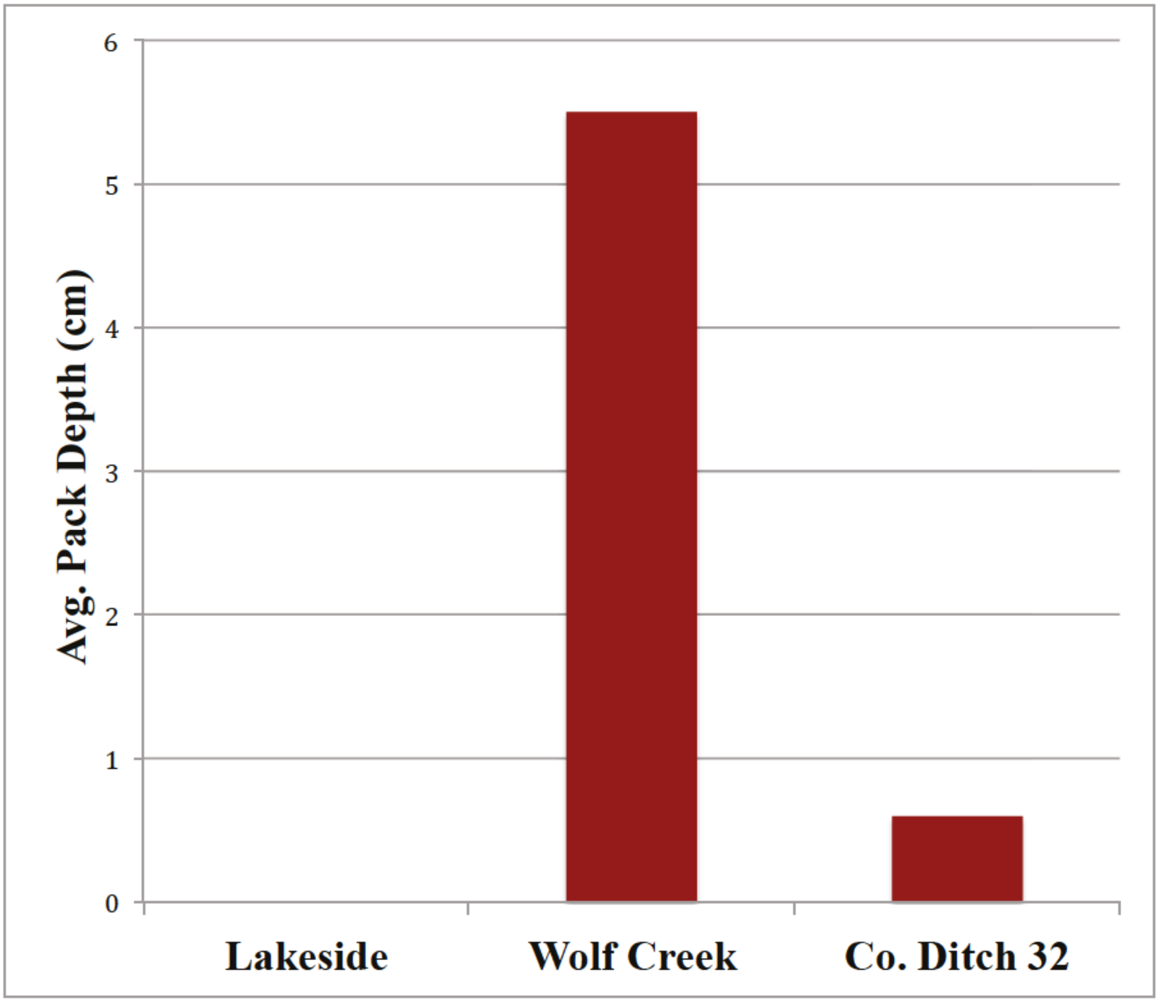

Figure 3- Mean leaf pack depth by sample location
Wolf Creek shows the greatest avaerage ($p<2e-16$) leaf pack depth of all three sites. Based on my hypothesis, this greater leaf coverage would provide greater habitat for important detritivores like some members of Ephemeroptera and Trichoptera.

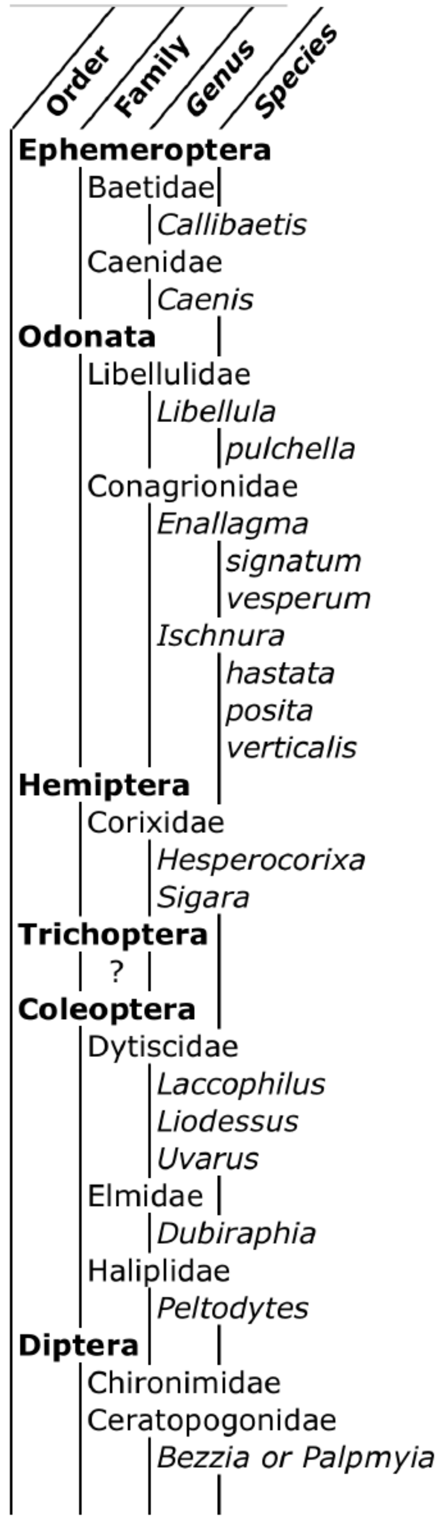

Figure 4- List of all taxa found across all sample locations
Across the three sites sampled, a total of 18 insect taxa were found and identified to lowest possible taxon. The most diverse order with six species identified was Odonata, followed closely by Coleoptera. Identification beyond order did not occur for Trichoptera because no actual insect was found, but several cases built by the insect larvae were found, and were thus counted as the presence of Trichopterans.

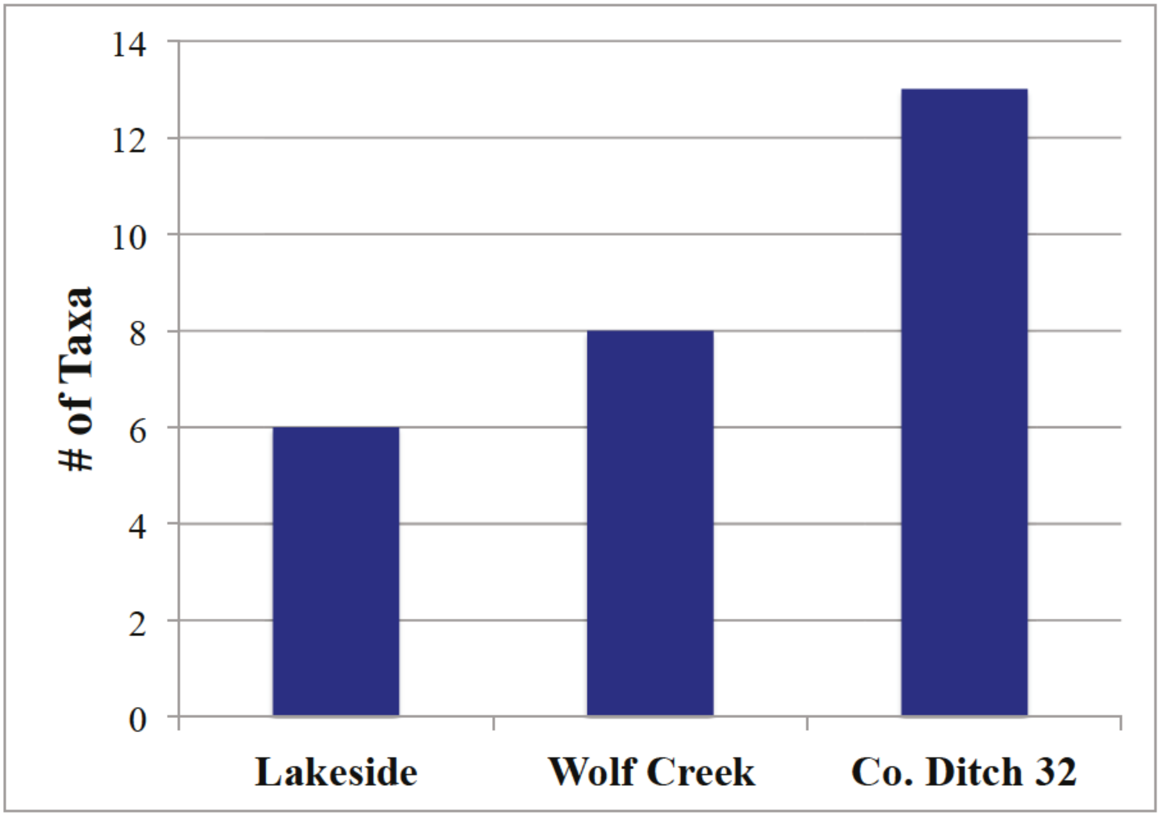

Figure 5- Taxonomic richness levels by habitat
Wolf Creek had the highest taxonomic diversity of the sites sampled in this study. This may be attributed to the relatively high substrate diversity noted in Figure 1. Other factors may include a lack of fish predators in this environment because of the ditch being cut off from the lake by beaver dams. The mostly still conditions of the water itself may also mean that organic compounds are more likely to stay in this water system, providing a boost to detritivores and primary producers.

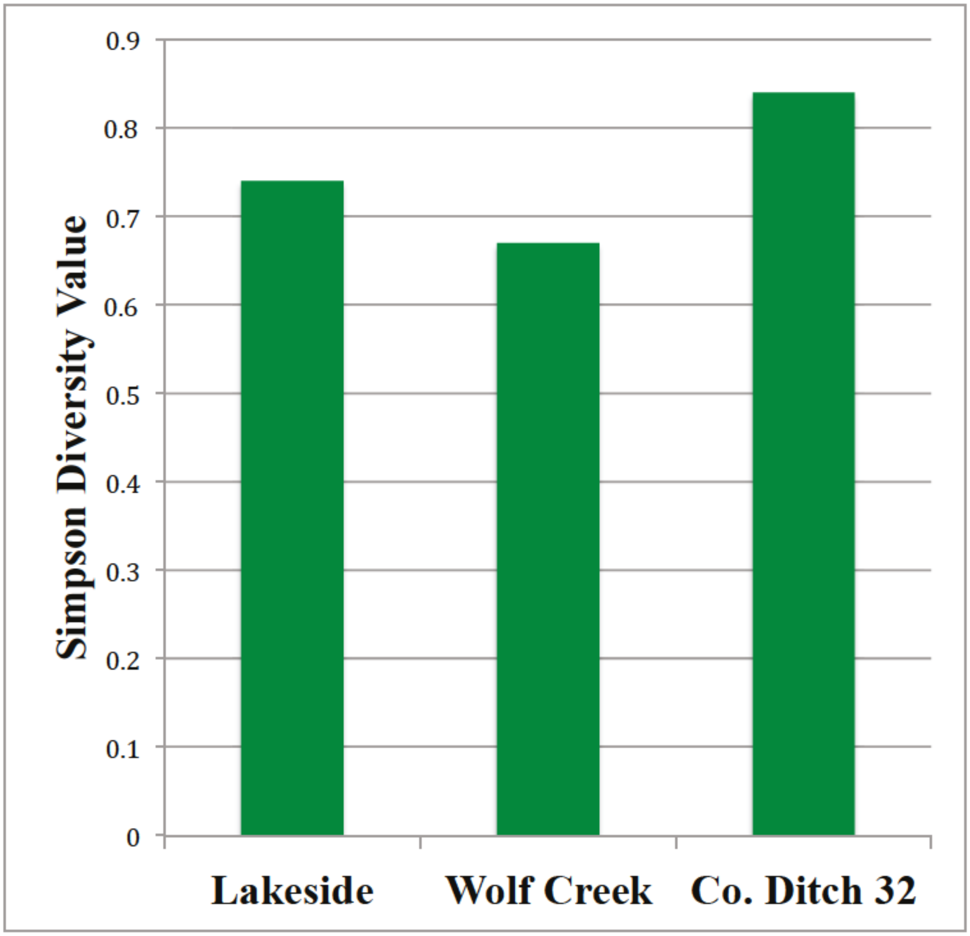

Figure 6- Taxonomic diversity by habitat type
Similar to Figure 5, we see Co. Ditch 32 exhibiting the highest level of taxonomic diversity among the three habitats sampled. The relatively low level of diversity seen in the Wolf Creek site seems to go against my hypothesis for this study that the high levels of substrate diversity seen in Figure 1 do not lead to high taxonomic levels that would be shown above.

Figure 1- Beck's Biotic Index Analysis

The Biotic Index values calculated for the three sample locations are as follows: Co. Ditch 32: 8, Wolf Creek: 5, and Lakeside: 6. Given these values paired with the biodiversity results shown in figure 6, there seems to be a corrilation between biotic index value and biodiversity level. Beause this index generally measures water quality based on the taxa present, the paralles between this table and Figure 6 suggest that insect biodiversity in these habitats may be more closely linked to water quality than the diversity of substructure of the habitat itself.

Index Value	Description
0	Grossly Polluted
1-5	Moderately Polluted
6-9	Clean- "Monotonous habitat/ in-stream velocity"
10 or greater	Clean