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Authors:	Alayna Aire, Theresa Benton, Gavin McGregor, Jessica Thomas
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Instructor:	Jasmine Crumsey Forde
Teaching Assistants:	Corbin Kuntze Olivia Brinks
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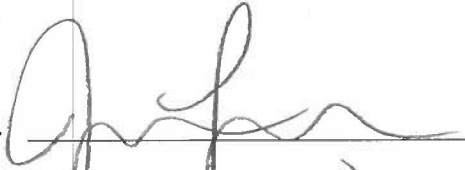


1st North Fishbar Bay, MAPIC Bay & South Fishbar Bay

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JESSICA THOMAS  
 Theresa Benton  
 Gavin McGregor

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# Comparing Water Quality and Macroinvertebrates of Maple Bay, North Fishtail Bay, and South Fishtail Bay in Douglas Lake

Alayna Alie, Theresa Benton, Gavin McGregor, Jessica Thomas

University of Michigan Biological Station  
EEB 381: General Ecology  
June 14, 2018  
Professor: Jasmine Crumsey-Forde

**Abstract:** *With the development of residential areas along lake shorelines in recent decades, there is an increased potential for alterations of natural aquatic systems. These alterations, whether positive or negative, may impact the abundance and diversity of aquatic life in lake ecosystems. To test if lakeside communities have an effect on the macroinvertebrate diversity and water quality, we sampled and tested three bays in Douglas Lake: Maple Bay, North Fishtail Bay and South Fishtail Bay; each with varying human interaction. Our water samples, taken at 1-1.2 meters deep in the lakes' water column, were tested for nitrogen, phosphorus and chloride levels, as well as properties including pH, dissolved oxygen, temperature, and turbidity. We also tested the diversity and abundance of benthic macroinvertebrates across sampled locations. We hypothesized that lakeside communities would have a negative effect on both water quality and macroinvertebrate species diversity. Therefore, we expected to see the highest species diversity and water quality in North Fishtail Bay and the lowest in Maple Bay. From our research we found that both human interactions and abiotic environmental conditions play an important role in macroinvertebrate diversity. We interpreted that lakeside communities with more human activity have higher nutrients through runoff which has led to more vegetation in the areas and promotion of macroinvertebrate life. Our study highlights the importance of maintaining the structure and diversity of natural aquatic systems while extracting the freshwater resources needed.*

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## Introduction

Natural aquatic systems provide many ecological services in society today; often, these services and human benefits out-prioritize the natural benefits that also come with sustaining a healthy aquatic ecosystem. Ecological services provided by aquatic systems include flood control, transportation, recreation, purification of human and industrial wastes, habitats for plants and animals, and production of fish and other foods and marketable goods (Baron et al., 2003). However, when these systems are altered or destroyed, ecosystem services can be costly or impossible to replace. In today's society, the structure and diversity of aquatic ecosystems are being altered at a higher rate than ever before (Baron et al., 2003).

With the development of residential areas along shorelines in recent decades, there comes the potential for alterations in chemical properties of natural aquatic systems. These alterations, positive or negative, impact the aquatic life which reside in said systems (Carpenter et al., 1998). Fertilizer runoff can increase levels of nitrogen, which increase plant biomass—especially algae—and deplete the water of other nutrients. When these plants die, large amounts of oxygen are consumed by the bacteria decomposing the plant matter. This results in decreased levels of dissolved oxygen (hereby DO) in the water, which increases mortality in aquatic organisms (Cheng et al., 2009). Construction site runoff contributes to siltation of the water, which can lead to higher turbidity (Carpenter et al., 1998). Each of these effects alter the natural habitat of the aquatic organisms which reside in the area, including various macroinvertebrate species. As humans continue to develop living spaces near bodies of water, construction sites become more abundant and fertilizers are used more frequently. By understanding the impact of these alterations on macroinvertebrate diversity and water quality, society can begin to take steps to preserve the natural habitat and potentially reverse any existing damage.

Macroinvertebrates tolerate a narrow range of conditions, and are used as bioindicators of water quality (Griffin, 2015). Observing the diversity and abundance of macroinvertebrates can reveal information about water quality and potentially help us understand how nearby human development has impacted these features. Our research attempts to reveal the impact lakeside communities have on water quality and macroinvertebrate communities in the various bays of Douglas Lake.

One way to quantitatively evaluate bioassessment using macroinvertebrate diversity is by calculating the Ephemeroptera, Plecoptera and Trichoptera (EPT) Index. The EPT Index measures the percentage of macroinvertebrates belonging to the orders of Ephemeroptera, Plecoptera and Trichoptera (commonly known as mayflies, stoneflies, and caddisflies, respectively) out of the total macroinvertebrates collected. This index, used by the Environmental Protection Agency (EPA), often indicates health of an aquatic system, as these three orders are the most sensitive to overall water quality and pollutants (Kitchin, 2004). In 2016, the EPA published predictions based on a variety of studies about the effects of perturbation on the richness and composition of multiple taxa and organisms, and stated that percent composition and total number of EPT organisms would likely decrease with increased perturbation. Lenat (1984) found that a higher concentration of nutrients due to agricultural runoff in streams led to a relatively low percentage of EPT organisms when compared with streams containing lower nutrient levels.

Due to the increase in human activity on Douglas Lake in recent decades, we tested whether lakeside communities have an effect on the water quality, which, in turn, could potentially affect macroinvertebrate diversity. Specifically, our study will measure water quality and properties by testing levels of nitrate, nitrite, phosphate, chloride, dissolved oxygen, as well

as pH, salinity, turbidity, and temperature. We expected a negative correlation between the presence of lakeside communities and water quality. We also expect a positive correlation between water quality and macroinvertebrate diversity.

## **Materials & Methods**

Located in Northern Michigan, Douglas Lake (45.58°N, -84.696° W) was formed about 14,000 years ago by the movement of glaciers (Dreimanis, 1977). The lake has a surface area of 13.74 km<sup>2</sup> and a maximum depth of 24.38 meters, making it the 28th largest lake in Michigan (Cwalinski, 2004). Much of the land surrounding Douglas Lake is owned by the University of Michigan, and the shore of South Fishtail Bay is inhabited by The University of Michigan Biological Station (UMBS). The western edge of the lake—along with Maple Bay, Marl Bay, and Nuttings Bay—is largely residential. This development began in the late 1800s and has continued to persist over the years (A. Schubel, *personal communications*; Figure 1).

On May 26th, 2018 we collected water samples and placed a macroinvertebrate trap at three different points in each bay to collect macroinvertebrates. We sampled at three bays of the lake with various amounts of lakeside human activity: North Fishtail Bay (control; little to no human interaction), South Fishtail Bay (seasonal; periodic human interaction), Maple Bay (yearly; constant interaction). All samples were taken at approximately 1.1 to 1.2 meters deep. We attempted to sample and place our traps at the same distance from the shore at each bay, but due to the fluctuating bathymetry of the lake, our sampling distances ranged from 29 to 52 meters from the shoreline.

### *Water Quality*

To determine the quality of the water in the three bays, we collected and tested three water samples from separate locations in each bay. Samples were taken from the lower level of

the water column, where the macroinvertebrate traps would be set, using a Van Dorn Sampler. There are similar, low levels of vegetation density in each sampling site. As varying vegetation amounts between sites could affect the levels of nutrients and DO in the water, it was important that this variable was controlled before water samples were taken for analysis. This water was then tested for pH, temperature, and salinity with a Oakton PCTSTestr® 50 Series; turbidity was measured with a Hach 2100Q Portable Turbidimeter; and dissolved oxygen was measured with a YSI Model 55 Probe. 125mL of water from each site was preserved on ice for further lab analysis. A GPS was used to record the exact locations of sampling. Samples were processed with the Millipore Vacuum Manifold using a 0.41 micron filter, and the Seal Analytical AA3 was used to determine the levels of nitrate using EPA Method 353.4 and ammonium using EPA Method 350.1. Inductively coupled plasma mass spectrometry (ICP-MS) Elmer Model ELAN DRC-e was used to detect levels of chloride, and the Dionex Model Integriion High Performance Chromatography HPIC was used to find levels of phosphate and nitrite using Method 300.1.

We ran a Kruskal-Wallis test on pH, and ANOVA tests on temperature, turbidity, and DO to determine whether these qualities differed significantly between our locations. ANOVA tests for various nutrients, including phosphate, nitrate, nitrate, ammonium, and chloride, were also run to determine which variables had a significant statistical difference between the three bays.

### *Macroinvertebrates*

In order to determine benthic macroinvertebrate diversity in the sampled bays, Hester-Dendy samplers were placed in each of the nine locations where water samples were taken (Figure 2). When determining the locations for the Hester-Dendy samplers, the substrate at each location had to be considered. Fairchild and Holomuzki (2005) found that the preferred substrate

for many different macroinvertebrate species is more jagged surfaces, such as benthic levels made of rocks or grooves within artificial substrates, as opposed to strictly flat surfaces such as sand. As the majority of Douglas Lake consists of sandy substrate, we decided to keep this variable constant among all of the trap placements rather than changing our depth and distance variables to find more jagged environments. The Hester-Dendy samplers were created by attaching a 0.635 cm rope to a 35.6 cm Fun noodle®, leaving approximately 1.3 meters of rope from the flotation device to the base of the trap. The base of the traps were comprised of an eye bolt placed through the center of seven, 7.4 cm x 7.4 cm tempered hardboards, each board separated by 1.905 cm spacers. The bases of the traps were then anchored to bricks, with the entirety of the trap using the same rope. The Hester-Dendys were placed at the time of water sampling and left in the lake for a week to allow time for inhabitation by macroinvertebrates. At the end of a week, the Hester-Dendy samplers were removed from the lake using a D-frame net to minimize loss of organisms during retrieval. Macroinvertebrates were collected from each Hester-Dendy—as well as the outside of the bricks used to weigh down the traps—and were immediately placed into a specified jar corresponding to each sampling site that contained a 70% ethanol solution to prevent predation during the collection process.

Counts for the macroinvertebrate species were recorded and the Shannon and Simpson indices were calculated to find richness and evenness, respectively, for each bay. ANOVA tests were run to determine whether there was a significant difference in these two values between the three bays. Using linear regression, the diversity indices for each bay were compared to pH, temperature, turbidity, and chlorine, which were the water qualities that showed significant statistical difference between bays.

## **Results**

### *Water Quality*

We predicted that phosphorus, nitrogen, nitrite, ammonium, and chlorine levels would be higher in Maple Bay due to human activity and salt and fertilizer runoff into the lake. We found that there was no significant difference in phosphorus, nitrogen, nitrite, or ammonium between the three bays. There was a significant difference in chlorine levels between the three bays ( $p < 0.05$ ; Tables 1, 2). Temperature, turbidity, and pH were also found to be significantly different between the bays ( $p < 0.15$ ; Tables 1, 2). Generally, Maple Bay was found to be significantly more basic than North Fishtail Bay, but North Fishtail Bay had significantly higher water temperatures than Maple Bay. North Fishtail Bay also had significantly higher chlorine levels than both Maple Bay and South Fishtail Bay.

While turbidity was initially found to be significantly different between the bays, a Tukey's Procedure was run to determine which bays differed, and the results were inconclusive. As Tukey's Procedure is more sensitive in pairwise comparison than the ANOVA that was initially run, it was determined that while turbidity may still correlate with differing diversity levels, it was not significantly different between bays.

### *Macroinvertebrates*

#### a. Diversity Indices

We predicted that the diversity (according to both the Shannon-Weiner and Simpson Indices) of macroinvertebrates would be lowest in areas with increased human activity due to contamination and habitat disruption. We found, however, that Maple Bay, which has the most human presence, had the highest Shannon-Weiner Diversity Index value, as well as the highest Simpson Diversity Index value (Table 3). The Shannon-Weiner value for Maple Bay was found to be significantly higher than the Shannon-Weiner values for North Fishtail Bay and South



Fishtail Bay ( $p < 0.05$ ; Table 4). There was no significant difference between the Shannon-Weiner values of North Fishtail and South Fishtail bays. The Simpson value of Maple Bay was found to be significantly higher than that of North Fishtail Bay, but not of South Fishtail Bay (Table 4).

b. EPT Index

We predicted that the EPT Index would be lowest in areas with increased human activity. We found, though, that Maple Bay had the highest value (Table 3). South Fishtail Bay and North Fishtail Bay had much lower values. A relatively large number of zebra mussels (105) was found at South Fishtail Bay (Figure 3), so EPT Index was calculated again for all three bays without the zebra mussel counts (Table 3).

c. Relationships between diversity indices and water quality

Linear regression analyses were run to compare Shannon-Weiner and Simpson indices to the water qualities that were found to be significantly different between bays. Water temperature was found to be statistically significant and showed a negative correlation to both Simpson and Shannon-Weiner indices (Table 5; Figure 4). Turbidity showed a significant positive correlation with the Simpson index values, and no significant correlation with the Shannon-Weiner index values (Table 5; Figure 5).

Although pH and chlorine were initially found to significantly vary between bays, when they were run against the Shannon-Weiner and Simpson indices, there was no correlation found except for one driven solely by North Fishtail Bay's diversity levels of 0.00. For this reason, the North Fishtail Bay data points were removed, which resulted in a conclusion of no significant linear relationship.

## **Discussion**

Based on our data analysis, we have rejected our null hypothesis that lakeside communities have no effect on the water quality and macroinvertebrate species diversity in the various bays around Douglas Lake, and are favoring our alternative hypothesis that lakeside communities and the abiotic environment have an effect on water quality and macroinvertebrate diversity.

### *Water Quality*

We found that there was no significant difference in phosphorus, nitrogen, nitrite, or ammonium between the bays we tested. We concluded that there was a significant difference in chlorine levels, temperature, and pH between the bays, and while turbidity results initially appeared to be significant, further tests determined that turbidity did not vary significantly.

Cheng et al. (2009) also found few significant differences in water quality and diversity when comparing areas with more and less human interaction. This study, however, did find higher levels of DO in the area with less human interaction and lower levels of DO in areas with more human interaction. We predicted that we would see a similar correlation, but we did not find a significant difference in DO between sites. Coy (2017) found that an increase in human activity resulted in an increase in pH, nitrate, and phosphate. Our study found similar results in pH, where the highest levels of pH were recorded in the bay with the largest lakeside community and highest human activity, however, we did not have similar results regarding nitrate and phosphate changing with changes in amount of human activity. Our statistical results for any difference in nitrogen levels between the bays corresponds with the study by Lenat et al. (1994), wherein both studies concluded nitrogen levels do not differ between developed and undeveloped areas. One potential reason for a difference between our results and the results found by Coy and Cheng et al. is that our study was confined within the boundaries of one lake,

whereas the other two studies had comparisons of water quality and diversity among various water bodies. Specifically, the study done by Coy (2017) had a large variability between phosphate and nitrate among different bodies of water, not necessarily between sites within the same water body.

Hecht-Leavitt (2011) found that water quality was better (lower levels of nitrogen and phosphorus), in lakeside areas with more houses. This was hypothesized to be due to that fact that people would generally avoid living near eutrophied lakes, which have decreased clarity and aesthetic appeal. This is similar to our results in that we also did not see increased levels of phosphorus and nitrogen in the bay with the most houses present.

Since the mid-1970s, the Michigan legislature has enacted progressively tighter limitations on the amounts of phosphorus allowed in cleaning products and detergents, reducing the allowed amount to no greater than 0.5% by weight by 2010 (Hartig et al., 1982). Schindler et al. (2016) found that similar bans and limitations around the world on phosphorus-containing products have greatly reduced the amounts of phosphorus in runoff to freshwater bodies in nine countries. The laws in Michigan could have had similar effects, explaining the lack of significantly high phosphorus levels in the residential bay.

### *Macroinvertebrates*

#### a. Diversity Indices

We found that Maple Bay, the bay with the most human interaction, had the highest Shannon-Weiner Diversity Index value, as well as the highest Simpson Diversity Index value. Lenat et al. (1994) found different results regarding diversity and abundance in developed and undeveloped areas in the Piedmont ecoregion of North Carolina. This study concluded that there was a higher diversity and abundance in areas that were undeveloped compared to areas that are

developed. One variable that can potentially be attributed to the different results between our two studies is the difference where the tests were conducted in terms of water body type. Lenat et al. (1994) performed their experiment through different streams, including forested, agricultural, and urban. Our experiment focused on lake macroinvertebrate diversity and considered only the different degrees of lakeside development.

b. EPT Index

We found that Maple Bay also had the highest EPT Index value out of all three sampled bays. A study by Hazelton (2014) on Carp Lake River and Little Black River compared the EPT indices of two rivers with varying levels of human development. Carp Lake River is mostly undeveloped with an old golf course nearby which was in the process of being sold. In contrast, Little Black River is highly developed, running through multiple farms and a golf course. Hazelton (2014) found that Carp Lake River (CLR) had a higher EPT Index than Little Black River; finding approximately twice the amount of species in CLR. Coy (2017) had similar findings when comparing EPT Index values and different levels of human activity at twenty-two sites on various lakes and streams in Northern Michigan. Coy found that with increased human activity there was a decrease in EPT index values. Hazelton and Coy's studies both contradict what we found in Douglas Lake, but this may be because of the levels of pollutant runoff entering these sites tested are much higher than what would be possible at Douglas Lake due to their sites proximity to developed land that require copious amounts of fertilizers, specifically farms and a golf course. Presumably, the amount of fertilizer and other pollutant runoff sourced from such sites would be much higher than any coming from the private, residential lakefront land in our study.

Roback (1965) and Ross's (1944) findings, however, complement our findings. They note that although caddisflies are normally known for living in clean water they also thrive in fairly polluted aquatic habitats. In our samples of Douglas Lake we found two caddisflies: one in Maple Bay and one in South Fishtail Bay, which were the bays with the highest levels of human interaction.

c. Relationships between diversity indices and water quality

We found water temperature to be statistically significant and showed a negative correlation to both Simpson and Shannon-Weiner indices. Turbidity showed a significant positive correlation with the Simpson values, and no significant correlation with the Shannon-Weiner values. No correlation was found between the indices and either pH or chlorine after outliers were accounted for.

A study done on algal diversity by Archibald (1972) shares similar results about water quality and diversity, where the author concluded there was no significant correlation between the quality of water and algal diversity. The author acknowledges, however, that while diversity among algal species is not a good indicator of water quality, multiple other studies suggest that diversity among invertebrates can be a good indicator of water quality. This evidence of this statement can be seen in a study of macroinvertebrate diversity and water quality by Cao et al. (1996). The authors state that heavily polluted sites result in a significant reduction in species richness. Our study measured two of the same water qualities, including pH and ammonium, but did not find any correlation between pH and macroinvertebrates diversity, nor any significant difference in ammonium levels between the three bays. The major differences in results could relate to the setup of the experiment, wherein Cao et al. (1996) measured macroinvertebrate diversity through diversity indices as well as biotic indices in rivers with different ranges of

pollution. Our study focused on the differences in water quality and resulting macroinvertebrate diversity within differing degrees of lakeside communities and human interaction.

Other studies have also found that temperature was a major determining factor in the diversity of macroinvertebrate species. Gezon et al. (2012) found that temperature was the most important variable in the distribution of macroinvertebrate species, and that increased temperatures led to increased diversity. In that study, however, the upper temperature measured was 19°C, which is quite close to the average temperature (21.6°C) in the bay at which we found the most diversity. Gezon et al. (2012) observed a decrease in diversity as temperature went below that point, and our study found that diversity decreased past that point. This indicates a small range at which many macroinvertebrate species can live at peak diversity. As waters warm due to climate change, these results may offer reason to believe that macroinvertebrate diversity will decrease with said warming.

We believe that we saw increased macroinvertebrate diversity in Maple Bay due to an increase in nutrient-rich runoff into that region of the lake. While we did not see a statistically significant difference in phosphorus and nitrogen levels, it is possible that nutrients which were not tested for could be present at increased levels in Maple Bay. This could potentially lead to more vegetation in the area, promoting macroinvertebrate life by providing sheltered spaces (Strayer, 2006). A vegetation map of Douglas Lake indicates a larger proportion of algae species (specifically muskgrass) and a larger vegetated area in general present in Maple Bay than in either North Fishtail or South Fishtail bays (A. Schubel, *personal communications*; Figure 6). Although we did not encounter this increased level of vegetation, it is possible that it is present in regions of the bay we did not test, such as closer to the shoreline, and still influenced the aquatic life throughout the bay.

The increased macroinvertebrate diversity in Maple Bay could also be explained by the existence of man-made structures. As mentioned, most of the substrate in the bays we tested was sand, which offers fewer surfaces for macroinvertebrates to hide in and attach to. Man-made structures such as the many personal docks, buoys, and boats in Maple Bay could offer alternative, more ideal habitation for macroinvertebrates which are not so prevalent in North Fishtail or South Fishtail bays.

### *The “Big Picture”*

Today, the challenge society faces with regards to aquatic ecosystems is extracting aquatic resources and utilizing ecological services, while still protecting and maintaining the structure and diversity of the system. Ecologists, who have studied the overall impact on freshwater resources, have recognized that: human activities highly alter water movement through the biosphere, water is extensively used by humans, poor water quality is prevalent in many aquatic ecosystems, and freshwater plant and animal species are at the greatest risk of extinction due to human activities (Baron et al., 2003).

At Douglas Lake we found that human interactions have no negative effects on the macroinvertebrate communities. Additionally, the areas with higher human interactions have a higher abundance and diversity of macroinvertebrate species, which contradicts what many other researchers have found. Future studies should research what variables differentiate Douglas Lake from other aquatic ecosystems, and why human interaction has caused the opposite effect on water quality and macroinvertebrate communities.

### *Errors, Variables, and Improvements*

This study could have been improved in a number of ways to increase confidence in our conclusions. We noted a couple of errors in our experimentation, and confounding and noisy

variables that could be modified to improve our study. In the initial stages of our experiment, when sampling the lake water, we failed to include Nalgene control bottles in our cooler to ensure there were no outside contaminants affecting the samples. Another error made when sampling the lake water occurred during our first temperature measurement at North Fishtail Bay. The temperature reading is likely higher than all other location due to a lack of consistency in time between collecting the sample and taking the measurement. In this location, we took more time to take the temperature reading which could have allowed the sample to warm up slightly. While this did not impact our correlation significantly, a more accurate reading would have been preferred.

A couple of improvements could be made in the placement and retrieval of the Hester-Dendy traps. While we recorded the GPS points at which we placed the traps, we failed to record exactly which trap was deployed in which spot. This became problematic when retrieving the traps from North Fishtail Bay, as two were found in one of our GPS locations and one was completely missing. Presumably, as no other Hester-Dendy we placed throughout the lake had moved from its spot, these changes were due to human interference rather than natural causes, such as currents or wind. Evidently, the missing Hester-Dendy eliminated one data collection point in North Fishtail Bay, reducing the sample size. The moved Hester-Dendy also could have negatively affected our results, as macroinvertebrates could have been knocked from the trap as it was transported to its new location. Another mishap with the Hester-Dendy traps occurred in South Fishtail Bay, as the wooden slats from the trap were missing upon collection. We were able to collect macroinvertebrates from the outside of the brick used to weigh down the trap, as we had done consistently with the other traps as well, but it is very possible that the missing slats from the trap greatly reduced the number of macroinvertebrates collected at that site. Another



noisy variable is in the variation of trap distance from the shore, in order to ensure similar depths.

In the first Hester-Dendy retrieval at North Fishtail Bay, it took a couple attempts to get it out of the water successfully with the D-frame net, which could have led to macroinvertebrate sample loss in the trap. We could have prevented this by practicing proper retrieval of the traps before collecting our samples.

Another error in our experimentation was our small sample size, which is due to the short time period we had for the study. The limited amount of time the Hester-Dendy traps were able to be left out is a noisy variable in our data analysis, and may have negatively affected the number of macroinvertebrates that encountered them. Had they been left out longer, there is the possibility that more macroinvertebrates would have been collected, contributing to a larger sample size. A larger macroinvertebrate sample size could have led to more accurate and representative diversity indices. This would be especially beneficial for the traps in which only one or two species were found.

The final error of experimentation we have noted is in our identification of macroinvertebrates. Prior to this study, none of the members of our group had experience with identifying macroinvertebrates. Though we are fairly confident in the identifications we made, an expert in macroinvertebrates would have been better suited to do this part of our experiment, to ensure that everything would be correctly identified.

## **Conclusion**

Our study investigated the effects lakeside communities have on water quality and macroinvertebrate diversity in Douglas Lake. While a negative correlation between diversity and the presence of lakeside communities was expected, we found that diversity was positively

correlated with presence of humans. Temperature was also found to be an important determinant in macroinvertebrate diversity.

In our study we found many caddisflies, damselflies, and mayflies in their nymph stages, as our study period aligned well with this stage of those organisms' life. If this study were to be conducted in the summertime or later in the year, we would expect to see different counts of macroinvertebrates, and potentially different macroinvertebrates altogether, in the later stages of their life cycle. The summer lake turnover could also alter the nutrient levels and almost certainly the DO levels compared to what was found in this study. These two aspects of seasonality could be interesting considerations in future studies.

After seeing a positive correlation between lakeside communities and macroinvertebrate diversity in our study, we note that there is a potential beneficial relationship between humans and aquatic ecosystems. As described by Baron et al. (2003), a current challenge that society faces is finding a way to use resources from water systems without disrupting or damaging the natural system. The patterns seen in Douglas Lake demonstrate how maintaining this positive correlation is possible through conscious actions and awareness of sustaining a healthy aquatic system.

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Tables

Locations	pH	Temperature (°C)	Turbidity (NTU)	Chlorine (mg/L)
North Fishtail Bay	8.34	28.1	2.38	10.44
	8.5	23.6	1.44	10.39
	8.42	23	2.86	10.12
Maple Bay	9.18	21.3	10.9	9.42
	9.23	21.7	4.92	9.85
	9.23	21.7	3.57	9.57
South Fishtail Bay	9.22	23.5	8.41	9.62
	9.21	23.6	7.83	9.60
	9.22	24.3	4.31	9.74
Outcome of significance tests	p=0.113 x <sup>2</sup> =4.35	p=0.111 F=3.24	p=0.134 F=2.87	p=0.003 F=16.92

**Table 1.** Values for the water qualities found to be significant based on outcomes of Kruskal-Wallis (pH) and ANOVA (Temperature, Turbidity, and Chlorine) tests.

Locations	pH	Temperature	Turbidity	Chlorine
NFT-SFT	--	--	--	p=0.005
NFT-MB	p=0.072	p=0.102	--	p=0.007
SFT-MB	--	--	--	--
Alpha	0.1	0.15	0.15	0.1

**Table 2.** Results of Tukey’s Test on water qualities determined to be significantly different between North Fishtail Bay (NFT), South Fishtail Bay (SFT), and Maple Bay (MB). Dashed boxes indicate no significant difference in the given quality.

Locations	Shannon-Weiner Index	Simpson Index	EPT Index	Adjusted EPT Index
NFT	E=0.00	D=0.00	0.00%	0.00%
SFT	E=0.19	D=0.12	1.79%	28.57%
MB	E=0.83	D=0.69	29.55%	54.17%

**Table 3.** Diversity indices calculated for North Fishtail Bay (NFT), South Fishtail Bay (SFT), and Maple Bay (MB) based on counts displayed in Figure 1. EPT was calculated twice, with the adjusted value not including zebra mussel counts, which were found to be very high in SFT.

Locations	Shannon-Weiner Index	Simpson Index
NFT-SFT	--	--
NFT-MB	p=0.002	p=0.008
SFT-MB	p=0.008	--

**Table 4.** Results of Tukey’s Test on the diversity indices of North Fishtail Bay (NFT), South Fishtail Bay (SFT), and Maple Bay (MB). Dashed boxes indicate no significant difference in the given quality.

Correlations	Statistical Outcomes	R <sup>2</sup> -value	α-value
Temp.-Simpson	p=0.028 t=-2.87	R <sup>2</sup> =0.579	α=0.05
Temp.-Shannon	p=0.019 t=-3.18	R <sup>2</sup> =0.627	α=0.05
Turb.-Simpson	p=0.123 t=1.79	R <sup>2</sup> =0.348	α=0.15
Turb.-Shannon	p=0.185 t=1.50	R <sup>2</sup> =0.272	α=0.15

**Table 5.** Results of linear regressions between the Simpson and Shannon-Weiner (Shannon) diversity indices and temperature (Temp.), and turbidity (Turb.). Different α-values, indicated in the table, were used to evaluate each characteristic based on the values used to determine their significance in previous tests. pH and chlorine were not included, as the correlations initially reported were only driven by the 0.00 values from North Fishtail Bay, and had no significant correlation besides.



Figures

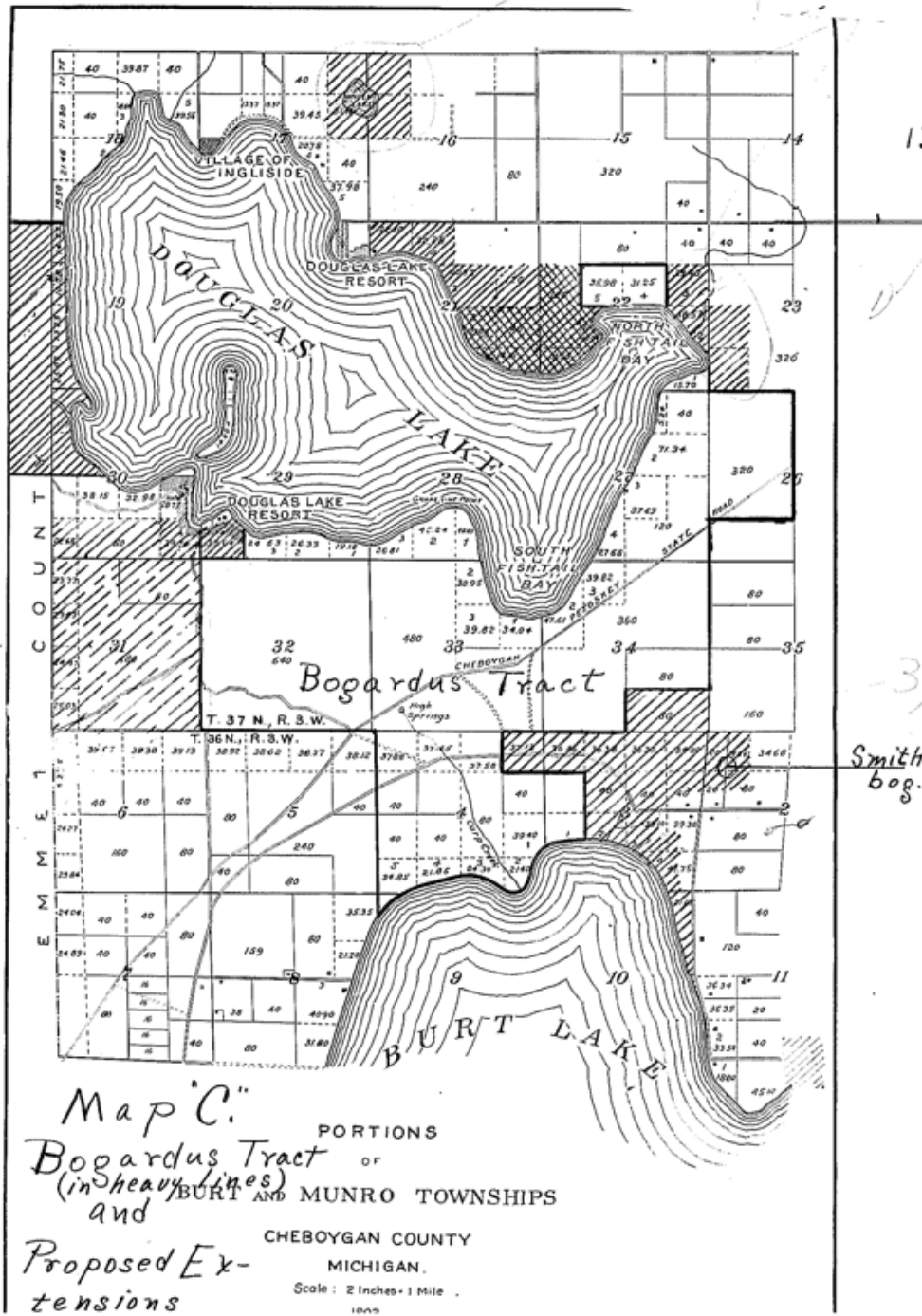


Figure 1. Map of Douglas Lake from 1902 showing the Douglas Lake Resort and Village of Ingliside; some of the first human developments along Douglas Lake shores.

## Map of Douglas Lake Testing Sites

Map by G. McGregor, A. Alie, T. Benton, J. Thomas



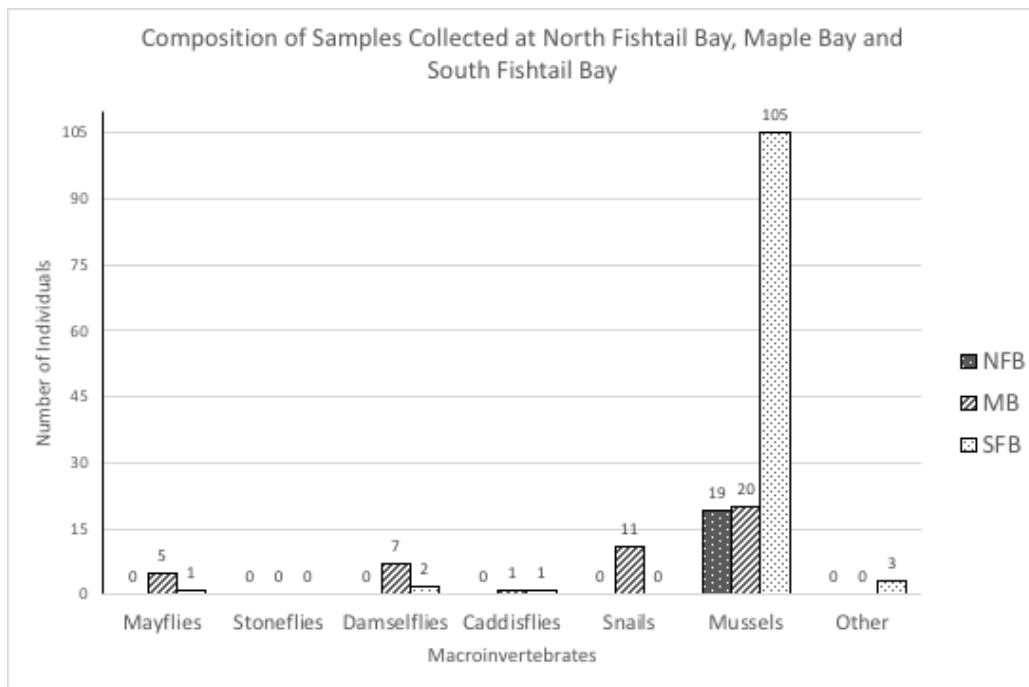
### Legend

 Test Sites

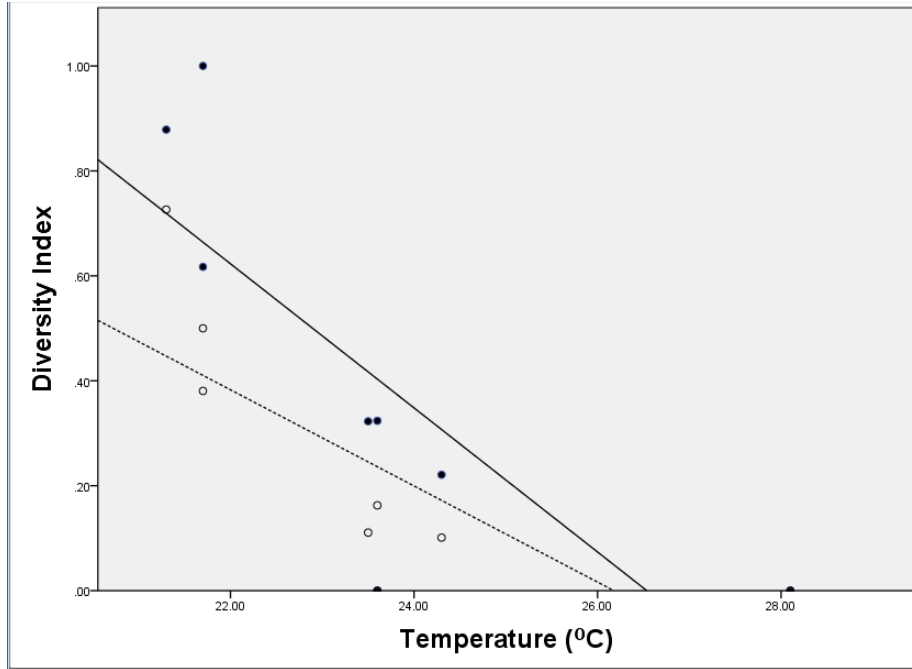
0 0.5 1 2 Kilometers

1 centimeter = 326 meters

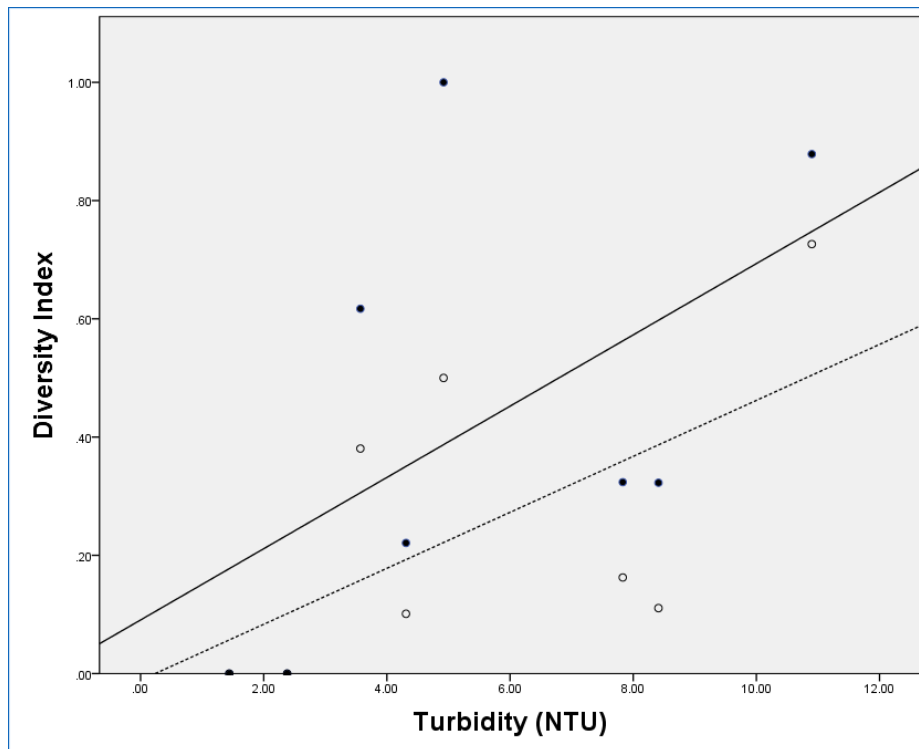
**Figure 2.** Map of Douglas Lake displaying the GPS locations of both the water testing sites and the Hester-Dendy placements.



**Figure 3.** The number of macroinvertebrates of various species collected at North Fishtail Bay, Maple Bay and South Fishtail Bay in Hester- Dendy traps.



**Figure 4.** The linear correlation between temperature and the Shannon-Weiner index (solid circles; solid line) and the Simpson index (hollow circles; dashed line).



**Figure 5.** The significant linear correlation between turbidity and the Simpson Index values (hollow circles, dashed line). The linear relationship between turbidity and the Shannon-Weiner Index values (filled circles, solid line) is shown, though it was not determined to be a significant relationship.

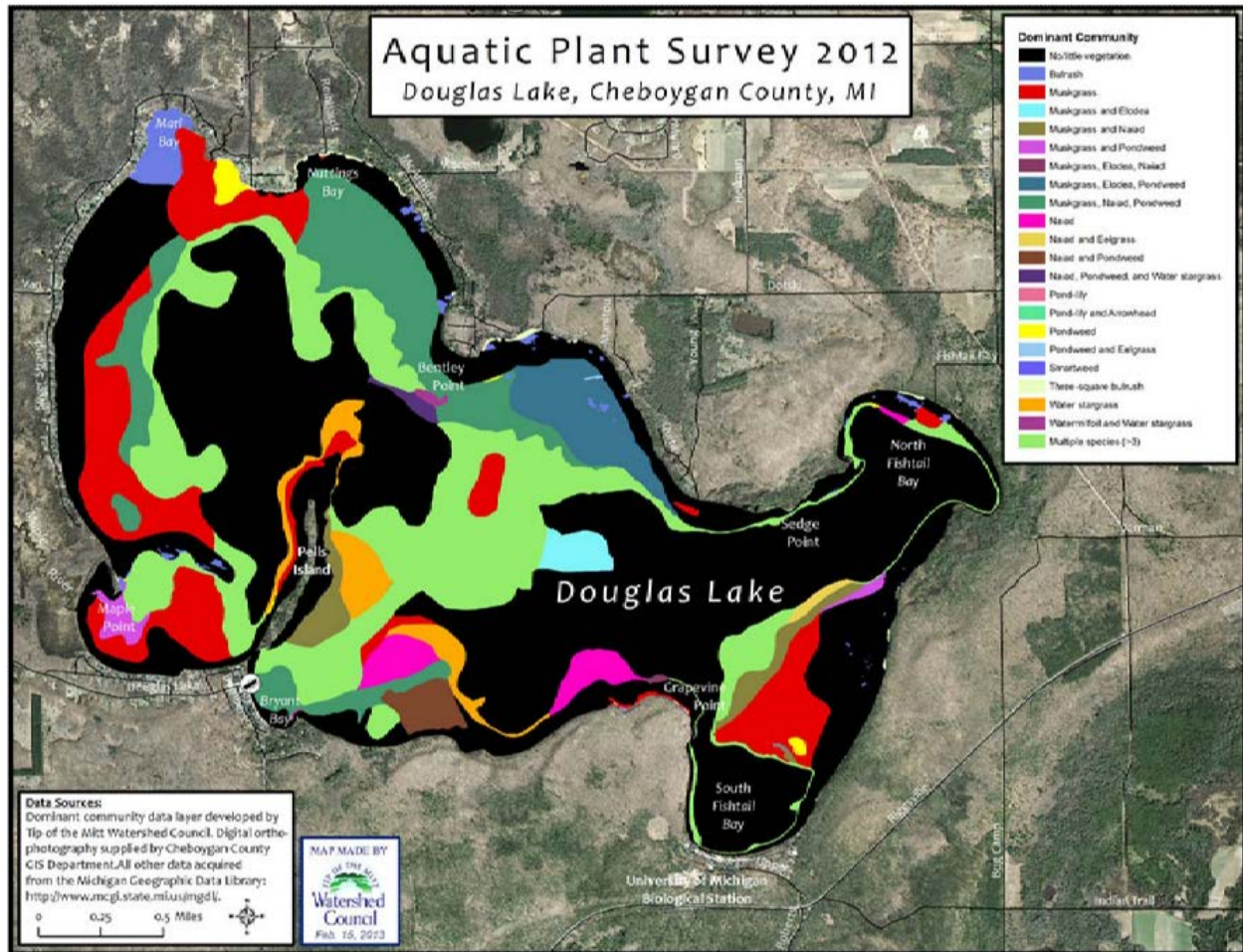


Figure 6. A vegetation map indicating the plant life present in Douglas Lake.