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Land Use and Macrophyte Populations in Northern Michigan Lakes

Abstract

This study explored the relationships between aquatic macrophyte communities and land use in three Northern Michigan lakes. It was hypothesized that differences in land use surrounding the three lakes affect the density and diversity of aquatic macrophyte populations due to greater nutrient input from developed land. To test this hypothesis percent coverage and diversity (measured with the Shannon-Wiener Diversity Index) of aquatic macrophyte taxa were compared to land use within a 1 km radius of the three lakes. Land use data from GIS were grouped as either developed or undeveloped. Prior to data collection, it was observed that there was a considerable difference in land use surrounding the three lakes. However, data showed that there was no significant difference in land use among the three lakes. There was also no significant difference found in the density or diversity of aquatic macrophytes. Aquatic macrophytes are one component of lake ecosystems that are very sensitive to changes in nutrient inputs, and thus are important indicators of watershed health.

Introduction

Freshwater lakes and the land surrounding them are being increasingly impacted by human developments such as residency, agriculture and industry (Federal Reserve Bank of Chicago and Great Lakes Commission 1995). These developments can change the composition of the ecological community within the lake by altering factors including the nutrient inputs and levels of primary productivity (Herring et. al 2006). Nutrient input from highly developed land is greater than that of forested areas, as forests have plants which can take up the extra nutrient input, thus making nutrient input from developed land more variable across sites (Beaulac and Reckhow 1982). Eutrophication occurs when nutrient enrichment results in increased primary productivity of aquatic plants. This, in turn, has an effect on the composition and abundance of organisms that live in lakes (Jackson and Harvey 1993). Aquatic macrophytes, (hereafter referred to as macrophytes) or aquatic plants visible to the unaided eye, are important to many different species which make up lake ecosystems, including game animals such as fish and waterfowl (Crowder and Painter 1991). They are an important source of food and habitat for these species.

Macrophytes are sensitive to changes in abiotic conditions, making them good indicators of watershed health (United States Environmental Protection Agency 2006). Input from agricultural, residential and commercial areas affect nutrient levels in the water, and these added nutrients are in turn taken up by macrophytes (Zhang and Mei 1996). In shallow aquatic systems macrophytes are often the dominant primary producers (Likens 1971). Therefore, macrophyte abundance is predicted to be greater in areas with more nutrient input. This study aims to look at how patterns in land use around three lakes in Northern Michigan are related to near-shore macrophyte communities.

We hypothesized that differences in land use surrounding the three lakes would have an effect on the density and diversity of macrophyte populations in shallow areas near the shore. Prior to data collection, it was presumed that the most diversity and density of macrophytes would be found in Paradise Lake, followed by Burt Lake, and then Douglas Lake.

Methods

Observations for this study were taken in late spring (May 25-June 2) on three northern Michigan lakes (Figure 1): Emmet County's Paradise Lake (N45˚ 41.25', W84˚ 45.14'), and Cheboygan County's Douglas Lake (N45˚ 34.91', W84˚ 41.91') and Burt Lake (N45˚ 284.06', W84˚ 39.78') (Figure 2). Paradise Lake was presumed to be mostly residential as it has many businesses and restaurants located on its shore; it is also the smallest of the three lakes surveyed, giving it the least area for the diffusion of nutrients. Douglas Lake is the most undeveloped and least residential lake. Burt Lake, the largest of the three lakes, contains some residential land and some areas of preserved wetlands and woodlands (University of Michigan Biological Station). A site on the west side of all three lakes was used for consistency and similar habitats were selected across all three lakes; the similar habitat found consisted of a rocky shore and sandy bottom. In a similar study, species diversity and density as percent coverage were measured in similar habitats in two lakes in China (Jin et. al 2007). At each site, a spot was randomly selected within the common habitat and four 10 meter transects were randomly set up perpendicular to and beginning 1 meter away from the shore. The depth of water never exceeded 1.5 m in any transects. A 0.5m x 0.5m quadrat was placed on alternating sides of each transect every 0.5 meters. Within each quadrat macrophytes were identified to genus level, or species level when possible, and percent coverage of each taxa was estimated. Macrophyte taxa and percent coverage for each taxa were recorded.

Data sets of 1992 Land Use Surveys of Cheboygan and Emmet Counties downloaded from the Michigan Department of Information Technology Center for Geographic Information gave the area, in polygons, of forests, wetlands, agricultural, shrublands, residential and commercial land uses. Forests, wetlands and shrublands were categorized as undeveloped, while residential, commercial, and agricultural areas were categorized as developed. The area of each polgygon was calculated using ArcGIS (ArcGlobe Version 9.1) in acres and converted to a percentage of total land area around each lake. Data on land use within a 1 km radius around each lake was used to maintain a consistent standard across all lakes (Tong and Chen 2002).

All data were analyzed using SPSS version 14.0. Chi-square tests were used to compare the average percent coverage and to compare the Shannon-Weiner diversity, (Figure 3) from each transect across the three lakes. A Chi-square test was conducted to determine if the mean density of *Poa* spp.(grasses) and *Chara* spp.(a genus of algae) differed across the lakes. Chi-square tests were used to compare land use by relative percentage of forest, wetland, agricultural land, shrubland and residential areas of the three lakes. Proportion of land use (developed or undeveloped) was log transformed and nonparametric Spearman's Correlations were run to examine the relationships between land use and species richness, diversity, and percent area covered. The significance level (alpha) was set at $p \leq 0.05$ for all statistical tests.

Results

In Paradise Lake, *Poa* spp., *Chara* spp., *Potamogeton crispus,* and *Potamogeton richardsonii* were found. In Douglas Lake, *Poa* spp., *Chara* spp. *Certophyllum demersum, Lycophs americanus, Potamogeton illinoensis* and an unidentified taxa (listed as unknown) were found. In Burt Lake, *Poa* spp*., Chara* spp*., Schoenoplectus acutus* and an unidentified moss were found (Figure 3).

Only two taxa were observed across all three lakes, *Poa* spp. and *Chara* spp. These taxa composed the majority of observed macrophytes in all three lakes (Figures 4, 5 and 6). Although other taxa were observed, their percent coverage relative to those mentioned above were low, except in Burt Lake, where a large number of *Schoenoplectus acutus* were present as well (Figure 6).

The data showed that there is no significant difference with respect to macrophyte diversity and abundance between the three lakes. Macrophyte diversity, measured by the Shannon-Weiner Index (H), showed no significant difference across lakes (Chi-square p=0.397) (Figure 7). Douglas Lake macrophyte diversity was (mean ± standard deviation) -0.78019947 (± 0.525232121). Paradise Lake macrophyte diversity was -0.78541557 (± 0.451744172). Burt Lake macrophyte diversity was -1.0541 (± 0.71278). Percent coverage of macrophytes showed no significant difference across lakes (Chi-square p= 0.347). Douglas Lake percent coverage of macrophytes was 2.5375% (± 1.2092525%). Paradise Lake percent coverage of macrophytes was 6.3875% ± (6.5703088%). Burt Lake percent coverage of macrophytes was 4.6% (± 5.5970975%). There was no significant difference for percent coverage of *Poa* spp. (Chi-square p = 0.456) and *Chara* spp. (Chi-square p = 0.525), which were the only taxa present in all three lakes. Douglas Lake percent coverage of *Poa* spp. was 1.631250% (± .8340101%). Paradise Lake percent coverage of *Poa* spp. was 3.11% (± 4.423%). Burt Lake percent coverage of *Poa* spp. was 1.06% (± 1.186%). Douglas Lake percent coverage of *Chara* spp. was .775% (± .9133273%). Paradise Lake percent coverage of *Chara* spp. was 2.89% (± 3.687%). Burt Lake percent coverage of *Chara* spp. was 1.26% (± 1.878%).

The data showed that there is no significant difference with respect to land use between the three lakes. Land use of forested areas showed no significant difference across lakes (Chi-square p = 0.324). Land use of wetlands showed no significant difference across lakes (Chi-square p = 0.285). Land use of agriculture showed no significant difference across lakes (Chi-square p = 0.285). Land use of commercial areas showed no significant difference across lakes (Chi-square p = 0.199). Land use of shrublands showed no significant difference across lakes (Chi-square $p = 0.238$). Land use of residential areas showed no significant difference across lakes (Chi-square $p= 0.301$).

The data from the Spearman's Correlations showed no significant relationship between land use and species richness, diversity, and percent area coverage of macrophytes. Developed land showed no relationship with species richness (Spearman's Correlation $p = 0.922$, $R^2 = 0.011$) (Figure 8). Undeveloped land showed no relationship with species richness (Spearman's Correlation $p = 0.588$, $R^2 = 1.915$ E-4) (Figure 9). Developed land showed no relationship with macrophyte diversity (Spearman's Correlation $p = 0.301$, $R^2 = 0.059$) (Figure 10). Undeveloped land showed no relationship with macrophyte diversity (Spearman's Correlation $p = 0.279$, $R^2 = 0.061$) (Figure 11). Developed land showed no relationship with percent area coverage of macrophytes (Spearman's Correlation $p = 1.00$, $R^2 = 0.004$) (Figure 12). Undeveloped land showed no relationship with percent area coverage of macrophytes (Spearman's Correlation $p = 0.784$, $R^2 = 0.005$) (Figure 13).

Discussion

Contrary to our expectations, we found no significant differences between the lakes with regard to macrophyte diversity and abundance. Even though the lakes sampled varied in size and were hypothesized to vary in degree and type of development, there was no significant difference in land use between the three lakes. Similar land use may account for the observed similarity between the lakes with respect to diversity and abundance of macrophytes.

Further investigation of the GIS data revealed that each of the three lakes is separated from the agricultural areas by a large vegetational buffer zone. These buffer zones, composed of wetlands and forests, protect the lakes from runoff by absorbing nutrient inputs from surrounding areas before they are able to reach the lake. Peterjohn and Correll (1984) examined the nutrient retention capabilities of riparian forests and observed much higher nutrient retention in forested land than cropland. Thus, the presence of forest buffer zones around these lakes in Northern Michigan may explain the observed similarity in nutrient levels as seen through macrophyte productivity. The similarity in buffer zones could mitigate the effects of differences which were presumed to exist in the land use, increasing the similarity of nutrient input across the three lakes.

Additionally, topography of the area was not taken into account as an important factor in the diffusion of nutrient runoff, unlike the study by Soranno *et al.* (1996), which examined topographic effects. In that study, topographic characteristics of some source areas surrounding bodies of water resulted in greater contribution to nutrient inputs than others. The topography within the Cheboygan River/Lower Black River Watershed, of which these three lakes are a part, is mostly level and contains relatively little topographic variation. This may result in more balanced contribution of nutrients from surrounding sources, acting as a control for this study. Relatively level topography may also, however, decrease the overall rate of nutrient runoff into the lakes (Soranno et al. 1996), which may help to account for the low levels of nutrient input observed through measuring macrophyte abundance and diversity.

Precipitation and soil type are also two important factors in the contribution of nutrient runoff which were not considered in this study. Beaulac and Reckhow (1982) did a literature review that showed the importance of taking climate, geography and soil type into account when measuring nutrient input. They found that drier regions tend to release less nutrient input than very humid regions. Another insight from this study was that glaciated areas tend to release less nutrient input than other types of sedimentary soil. Northern Michigan is not considered to have a hot and humid climate. The lack of precipitation in Northern Michigan may account for a decrease in nutrient input, as nutrients are not continually being washed downstream by runoff from rainwater. The soil composition of Northern Michigan also counteracts nutrient input, as the characteristic sandy soil and glacial till are a medium through which nutrients cannot move as easily as in other sedimentary deposits.

Further, the data were collected in the early spring, which may have been too early in the growing season to observe full macrophyte development and abundance. The growing season for macrophytes is generally June through October in areas similar to Northern Michigan (Rooney 2002). In a study of Lake Geneva, Switzerland, maximum macrophyte biomass was not reached until the end of July; in early June, biomass was approximately 10% of the maximum (Lehmann *et al.* 1994). Growing seasons can be highly variable for each species given specific conditions such as air temperature and light availability, but typically are only in the beginning stages during late spring, when this study was conducted. In the future, observations over a longer period of time, including times of maximum biomass accumulation would be beneficial to similar studies.

Anthropogenic effects have been shown to have an impact on the composition of freshwater environments through increased nutrient input as a result of development. The area of interest to this study was shown to be comprised mostly of undeveloped land which acted as buffer zones for the relatively less abundant developed land. Data showed no sign of eutrophication, as measured by macrophyte abundance, diversity, and percent coverage in these lakes. Despite nearby development, nutrient inputs to the lakes may have been reduced as a result of absorption by natural vegetation. This has implications for the planning of development around lake ecosystems, as it shows the importance of incorporating natural vegetation to protect lakes from excess nutrient runoff.

Conclusion

The hypothesis that differences in land use surrounding the three lakes would have an effect on the density and diversity of macrophyte populations was not supported by the data. There was no significant difference in land use within a 1 km radius of each lake. Prior to data collection the lakes were presumed to have different relative levels of use, but the data showed that they are actually similar in land use. Because the hypothesis that the patterns of macrophyte abundance and distribution would vary across lakes was dependent on differences in land use, this hypothesis was not supported. The presence of buffer zones, similar topography, low precipitation, glaciated soil type, and timing of the macrophyte growing season are also likely to account for the similarities found between macrophyte abundance and diversity in Paradise, Douglas, and Burt Lakes. As anthropogenic nutrient input to ecosystems increases, it will be progressively more important to understand the effects of human development on ecosystems. Lakes and other ecosystem components are vulnerable to high levels of nutrient input, and the effects of human development on each component must be understood individually in order to protect ecosystem diversity and function.

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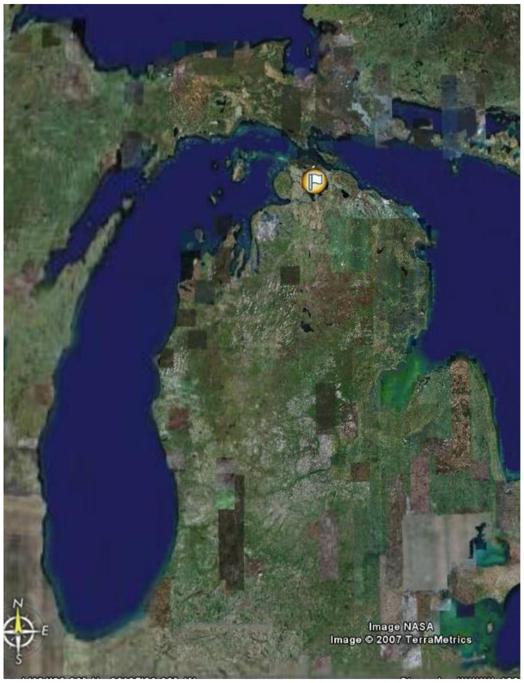

Figure 1. Study sites located in the Northern Lower Peninsula of Michigan

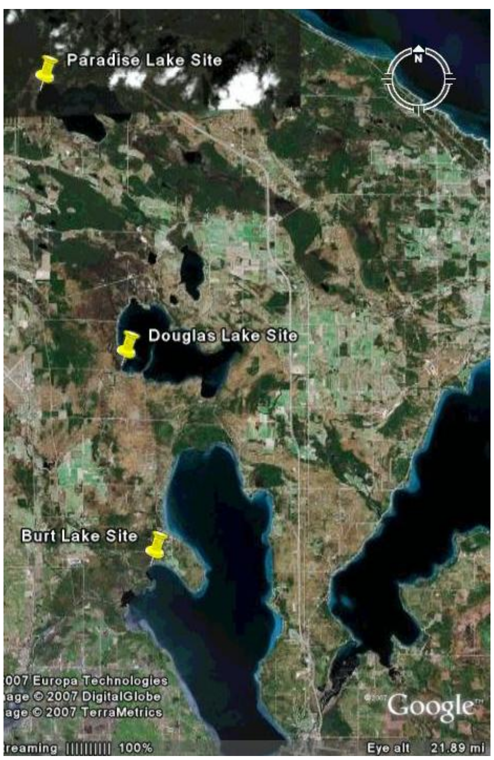

Figure 2. Aerial map of Paradise, Douglas, and Burt Lake study sites

Lake	Scientific Name	Common Name
Douglas Lake	*Poa* spp.	Grasses
	Chara spp.	Stonewort or Muskgrass
	Certophyllum demersum	Coontail
	Lycophs americanus	Water horehound
	Potamogeton illinoensis	Illinois pondweed
	Unknown	Opposite leaf pattern, firm and linear leaves, upper leaves clustered into a rosette
Paradise Lake	*Poa* spp.	Grasses
	Chara spp.	Stonewort or Muskgrass
	Potamogeton crispus	Curly-leaf pondweed
	Potamogeton richardsonii	Clasping-leaf pondweed
Burt Lake	*Poa* spp.	Grasses
	Chara spp.	Stonewort or Muskgrass
	Schoenoplectus acutus	Hardstemmed bulrush
	Unidentified moss	Composed of small green circular segments

Figure 3. Table of macrophyte species observed in each lake

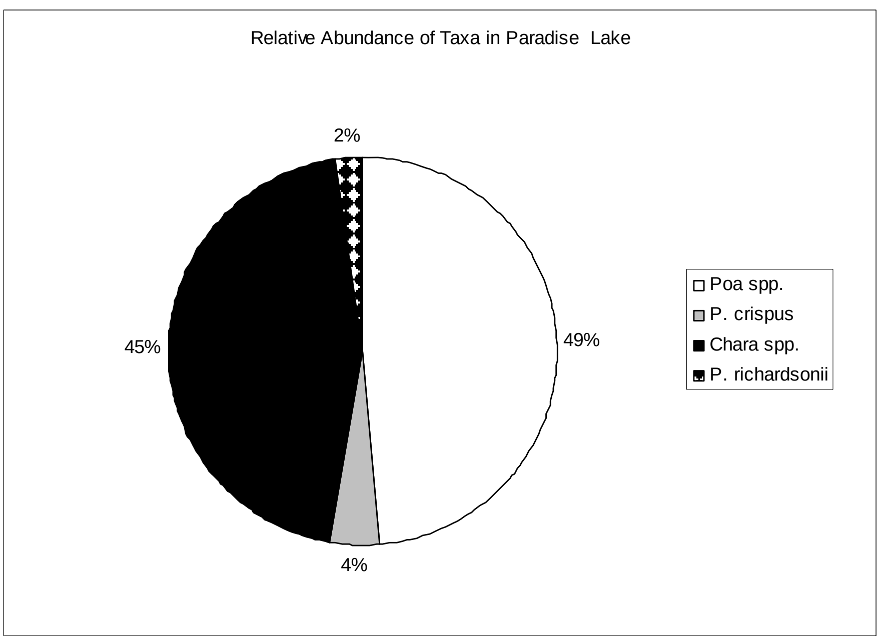

Figure 4. Relative Abundance of macrophyte Taxa in Paradise Lake. Composition dominated by *Poa* spp. and *Chara* spp.

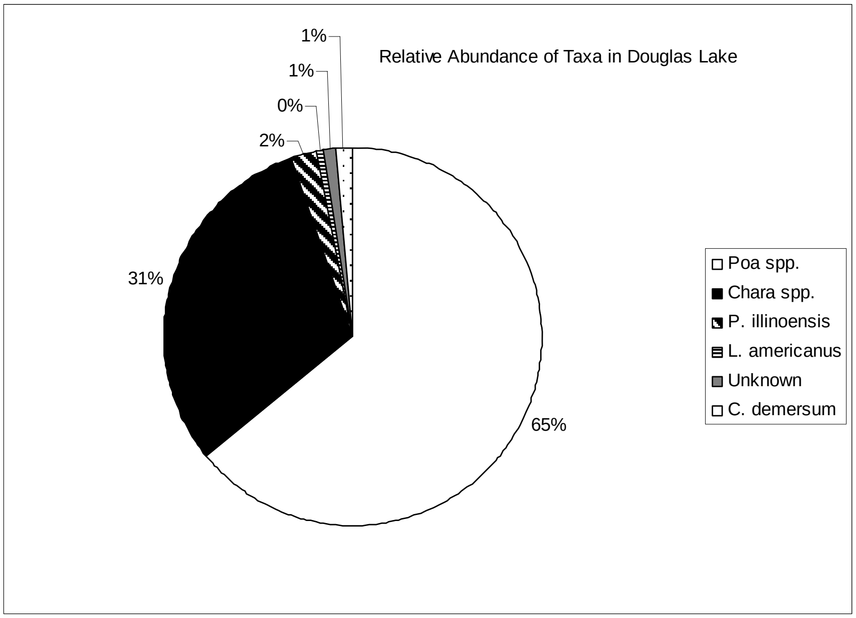

Figure 5. Relative Abundance of macrophyte Taxa in Douglas Lake. Composition dominated by *Poa* spp. followed by *Chara* spp.

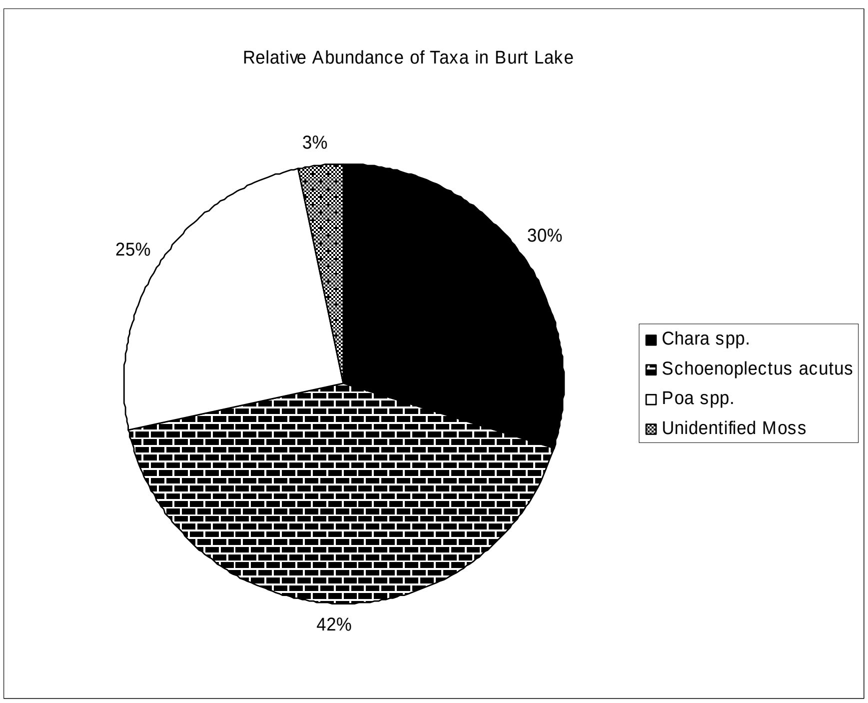

Figure 6. Relative Abundance of macrophyte Taxa in Burt Lake. Composition dominated by *Schoenoplectus acutus, Poa* spp., and *Chara* spp.

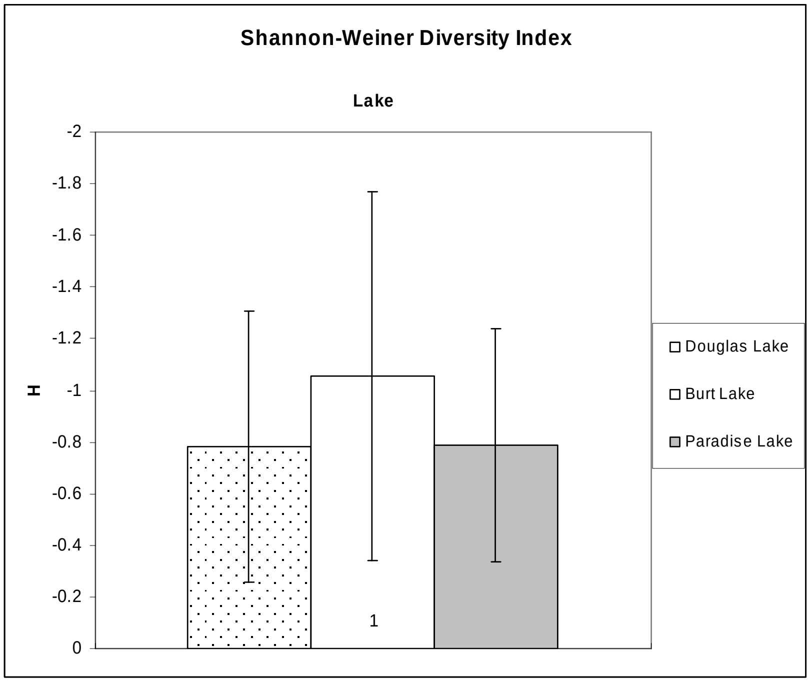

Figure 7. Comparison of Shannon-Weiner Diversity Index (H) between the lakes. No significant difference observed between Paradise, Douglas, and Burt Lake.

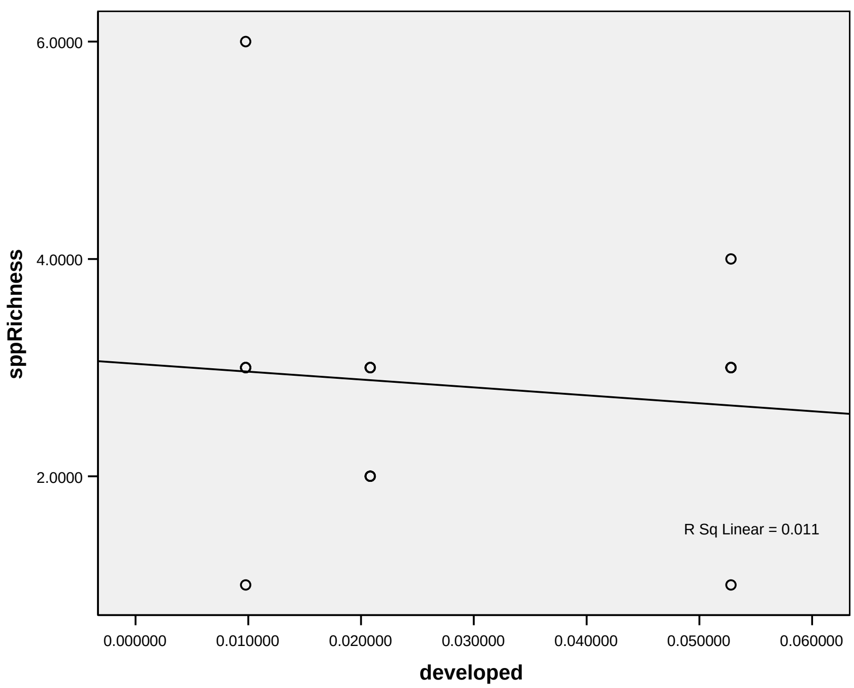

Figure 8. Correlation between developed land and species richness across all three lakes. Low R^2 shows weak correlation.

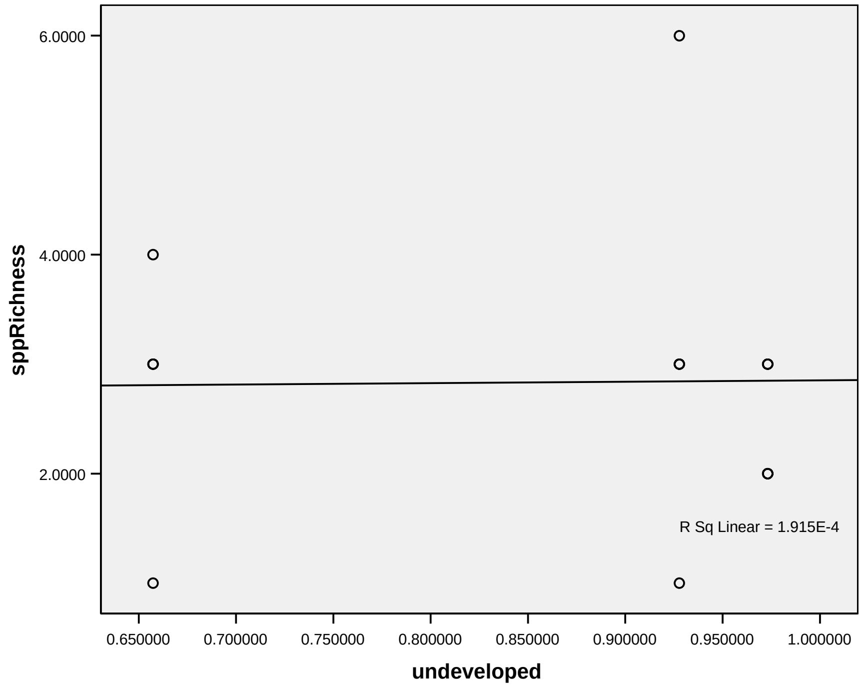

Figure 9. Correlation between undeveloped land and species richness across all three lakes. Low R^2 shows weak correlation.

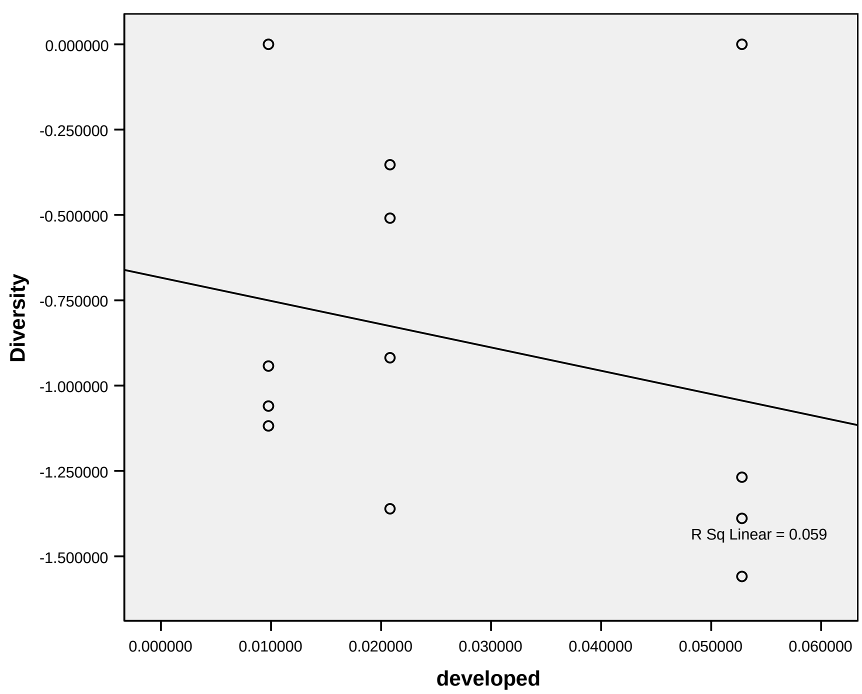

Figure 10. Correlation between developed land and diversity (Shannon-Weiner Index) across all three lakes. Low R^2 shows weak correlation.

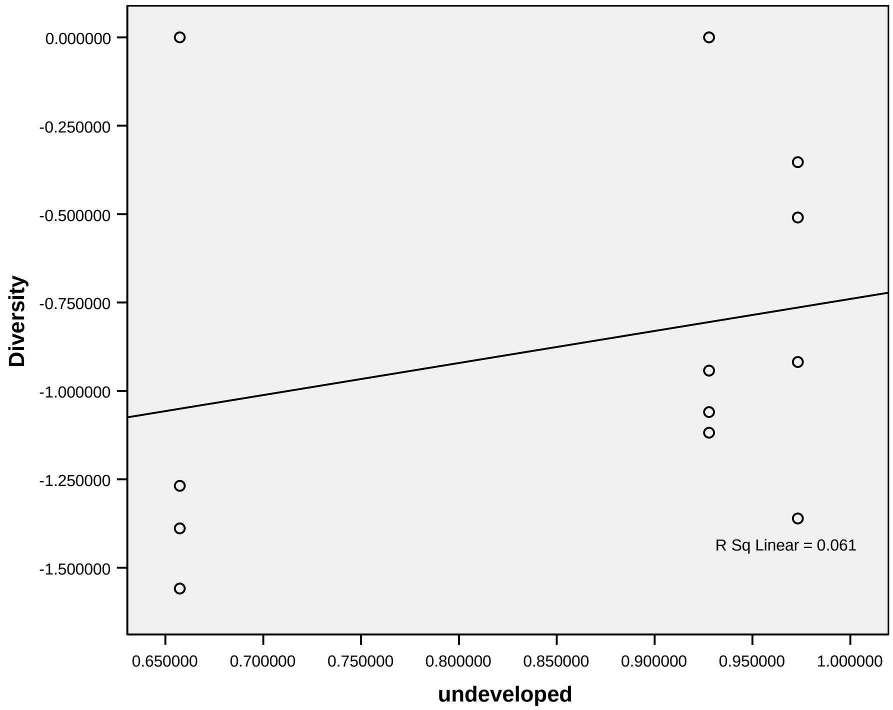

Figure 11. Correlation between undeveloped land and diversity (Shannon-Weiner Index) across all three lakes. Low R^2 shows weak correlation.

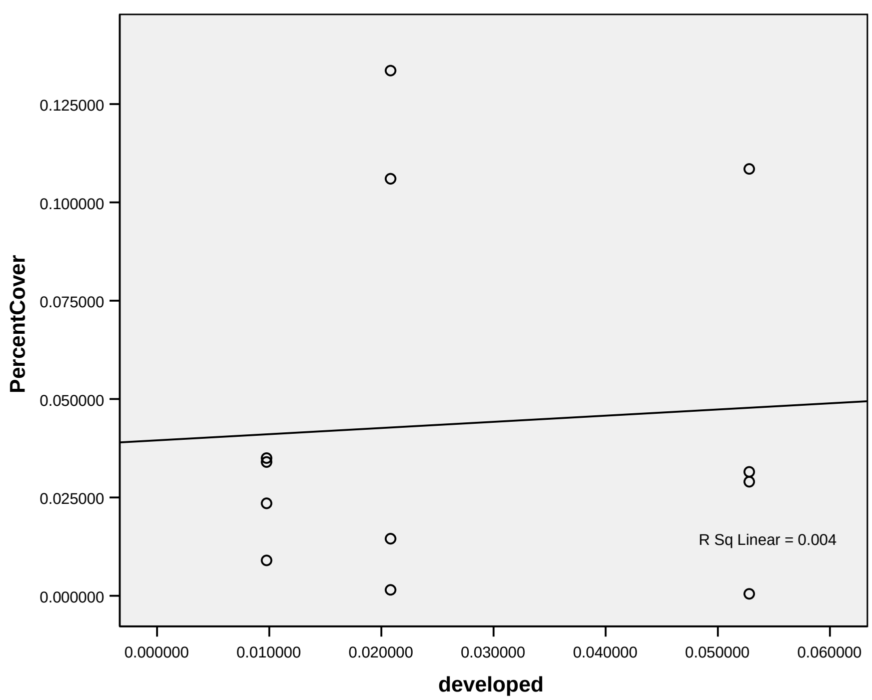

Figure 12. Correlation between developed land and macrophyte percent cover across all three lakes. Low R^2 shows weak correlation.

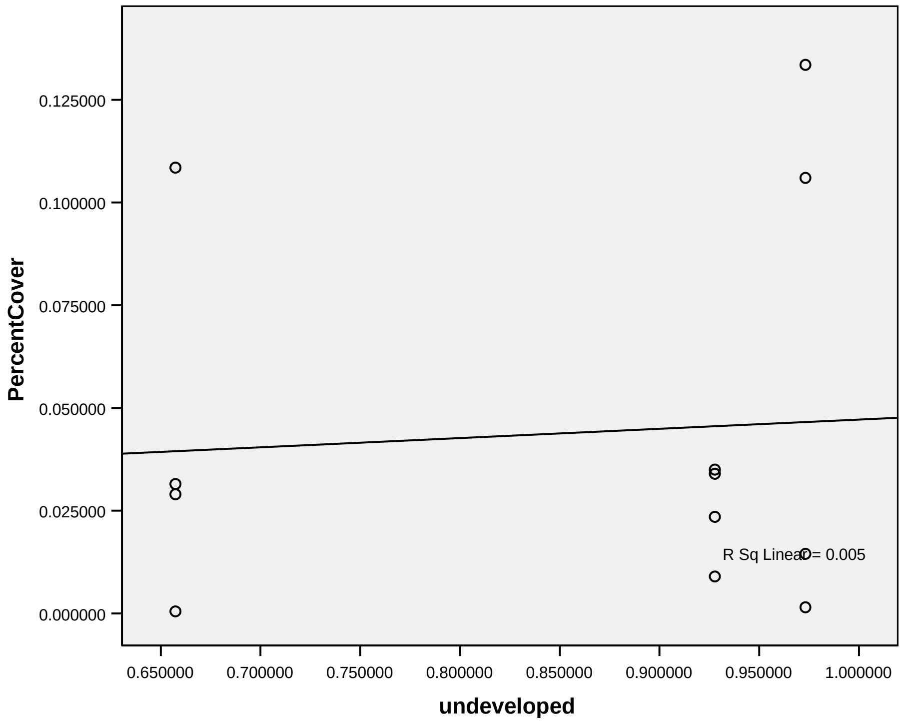

Figure 13. Correlation between undeveloped land and macrophyte percent cover across all three lakes. Low R^2 shows weak correlation.