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Authors:	Alan Ching, Haley Kalis, Adriene Tenney, Lilly Coryell
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Instructor:	Jasmine Crumsey Forde
Teaching Assistants:	Corbin Kuntze Olivia Brinks
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3. [signature] — Haley Kalis
4. [signature] — Adriene Tenney

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Investigating the Effects of Vegetation and Location on Macroinvertebrate Community Composition in Grass Bay Nature Preserve, Cheboygan County, Michigan

Adriene Tenney, Lilly Coryell, Alan Ching, Haley Kalis

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

Abstract

Wetlands provide a variety of ecosystem services to humans, as well as providing habitat to organisms such as macroinvertebrates. Macroinvertebrates are ecologically important as water quality indicators, since their distribution is largely influenced by factors like water temperature, pH, dissolved oxygen, and substrate availability. In the following study, macroinvertebrate richness, evenness, and abundance was tested in an inland (enclosed) and coastal (open) freshwater fringe marsh, both in vegetated and non-vegetated areas to determine if there could be finer distinctions within fringe wetlands. Few prior studies have examined these differences within wetland types, specifically in fringe marshes. No significant difference was found between the Shannon-Wiener Diversity Index (E) values for richness or the Simpson's Diversity Index (D) values for evenness in the four total areas. However, there was significantly greater macroinvertebrate abundance in the enclosed marsh compared to the open marsh, and in vegetated compared to non-vegetated areas. Macroinvertebrate abundance was highest in the enclosed-vegetated site. These results may indicate location-specific factors affect abundance of macroinvertebrate communities. Determining how macroinvertebrate community composition differs between environments can yield important information for predicting water quality and future changes in communities due to climatic changes or anthropogenic factors in these environments. This information can be made more site-specific based on this study's finer look at communities within fringe marshes.

Introduction

Macroinvertebrates are an essential part of wetland ecosystems. They maintain integral environmental processes and provide many ecosystem services. Macroinvertebrate communities in streams can play a role in nutrient cycling, primary productivity, decomposition, and material distribution (Wallace and Webster, 1996). In addition, they are an important food source of many other organisms, such as fish and amphibians, and some taxa act as predators. Macroinvertebrates are a crucial intermediate level of the aquatic food web, providing bottom-up and top-down population controls.

Sensitivity to changes in water quality, such as pH, dissolved oxygen, water currents, etc. and vegetation in terms of type, size, and density allow for macroinvertebrates to be indicators of overall wetland condition (Faith and Norris, 1989). Some macroinvertebrates with narrower tolerance ranges, particularly Ephemeroptera and Plecoptera, are regarded as good water quality indicators when present in aquatic systems due to their sensitivity to organic pollutants and low dissolved oxygen concentrations (Timm, 1997). Macroinvertebrate taxa vary in their substrate requirements and wave tolerance (Burton et al., 2002). Further, the size distribution of substrates and nutrient composition (levels of PO_4, C, and N) can alter macroinvertebrate diversity. For example, larger-sized substrate was preferred by the macroinvertebrate populations while elevated levels of PO_4, C, and N resulted in algae blooms and subsequent depletion in dissolved oxygen proved detrimental to macroinvertebrate populations (Regan, 2015).

Wetlands exist on a continuum and their dominant features can change over time. Various types of wetlands have their own distinct characteristics and macroinvertebrate communities (Mitsch & Gosselink, 2000). Brazner et al. (2007) studied wetland water quality indicators in Great Lakes wetlands, specifically those classified as river-influenced, protected, and open-coastal. Hydrogeomorphology, influenced by hydrochemistry and lake connectivity, varied throughout the sites studied. Macroinvertebrates had the highest proportion of explained independent variance associated with differences in wetland type, indicating changes in macroinvertebrate diversity is due to difference in wetlands. Thus, the characteristics of coastal wetlands and their indicators are influenced by a multitude of factors. The great variety in wetland types creates challenges in creating a standard of ideal richness, evenness, and abundance for each (Calabro, 2013). More specific biotic indices, in this case the diversity and abundance of macroinvertebrates, can aid in determining these standards, and therefore can be used to define finer distinctions of quality within wetland types.

Marshes, shallow water areas consisting of herbaceous vegetation rooted in soil, are a type of wetland. Marshes in the Great Lakes region are primarily formed from river deltas. Barrier beaches, caused by wave activity, created shallow, protected areas in which the marshes could form (Mitsch & Gosselink, 2000). These habitats in Michigan go through successional stages, eventually climaxing in dominant woody forest plants (Dunbar, 1941). Since they experience great changes in vegetation over time, marshes are diverse ecosystems to be studied and are able to support a variety of organisms, including a diverse array of macroinvertebrates.

Protected marshes in particular provide an opportunity to observe how abiotic and biotic variation between different types of marshes may play a role in the composition of macroinvertebrates with limited anthropogenic effects. The marshes in the following study are located in Grass Bay, a protected nature preserve on the coast of Lake Huron, and are considered fringe marshes, or marshes located near large bodies of water. Investigating different exposures to wind and wave activity and vegetation density within fringe marshes can give more acute insights into how these characteristics impact macroinvertebrate community composition. The following study was designed to explore how macroinvertebrate richness, evenness, and abundance differ between coastal and inland fringe marshes of Grass Bay, in both vegetated and non-vegetated areas.

The marshes in Grass Bay vary in location, from coastal (open) to inland (enclosed). Open marshes are predicted to be more exposed to human disturbances, severe weather, and extreme physical conditions such as wind in the nearby Lake Huron. A study done near the Great Lakes found wave action reduces the survivability of several macroinvertebrate taxa. Since wave action is largely influenced by wind, there is likely to be a greater frequency of disturbance in open marshes, which could affect macroinvertebrate taxa diversity (Burton et al., 2002). It is therefore hypothesized there will be higher richness, evenness, and abundance of macroinvertebrates in enclosed marshes, protected by tree cover, as compared to open marshes.

In addition, the fringe marshes of Grass Bay have varying abundance of vegetation, with most concentrated at the edges. The vegetation may provide greater nutrient availability and substrate to macroinvertebrates, and can be used for habitat, food, spawning, and protection from predators (Kang and King, 2013). Therefore, it can be hypothesized that there will be higher richness, evenness, and abundance of macroinvertebrates in the vegetated areas over the non-vegetated areas of the marshes.

Methods

Grass Bay has been protected by the Nature Conservancy since 1979. It consists of shoreline and upland ecosystems along Lake Huron in Cheboygan County, Michigan. The bay stretches five miles east of the tip of Cheboygan State Park and goes past Cordwood Road. The bay reaches a depth of 20 feet (Tip of the Mitt Watershed Council, 2016). The area is known for its diversity of wildflowers and the presence of vulnerable wetland communities (Nature Conservancy). For this study, two sites were chosen at Grass Bay: a coastal (open) freshwater marsh and a inland (enclosed) freshwater marsh. Each marsh is surrounded by similar vegetation; comprised of beach grass (*Ammophila breviligulata*), dune willows (*Salix cordata*), beach cherries, juniper (*Juniperus*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*) and more, with larger pines and denser vegetation surrounding the enclosed marsh.

Study Sites

Samples were obtained from two sites in the Grass Bay Nature Preserve: an open and an enclosed freshwater fringe marsh (Figure 1). In each, water was collected in vegetation near the shore and more centrally, far from vegetation. The water was collected from the water surface in 125 mL nalgene bottles. This process was repeated 9 days later, and the data collected from the two days was compiled together.

Water Chemistry Analysis

Water samples were analyzed for total phosphorus, total nitrogen, chlorine, nitrate, ammonia (NH_4), dissolved organic carbon (DOC), and iron. An Ion Chromatograph from DIONEX (model AS-DV) was used to find nitrate concentrations (mg/L). An Inductively Coupled Plasma Mass Spectrometer from Axial Field Technologies (model ELAN DRC-e) was used to find total iron and chlorine concentrations (μg/L and mg/L, respectively). The Auto Analyzer 3 from SEAL was used to measure total nitrogen, total phosphorus, and NH_4 concentrations (mg/L). In addition, a YSI Professional Plus 5-in-1 water probe was used to determine the pH, Dissolved Oxygen (DO) level, conductivity (μs/cm), and temperature (℃) of the water (Table 4.1).

Macroinvertebrate Diversity

Benthic macroinvertebrates were sampled at the open and enclosed marsh sites, both within (near the edge) and away from vegetation (near the center). A total of four areas were sampled: open-vegetated (OV), open-non-vegetated (ONV), enclosed-vegetated (EV), and enclosed-non-vegetated (ENV). Six total samples were taken at each site. Samples were obtained using a dip net with a one meter long swoop underwater, disrupting the marsh floor by hitting it with the net three times along the length of the swoop: once at the beginning, once at the middle, and once at the end (Biological Monitoring Program, 2014). The collected macroinvertebrates were placed in an enamel tray with water, and as many as possible were identified in the span of three minutes. Because of difficulties in identifying larval macroinvertebrates to species, richness of macroinvertebrates was reported by order with the exception of Gastropoda, Hydrachnidae, Arachnida, and Clitellata. Only live specimen were counted. Macroinvertebrates were released back into their respective locations in each marsh.

Diversity Indices and Statistical Tests

Macroinvertebrate data was analyzed to obtain Shannon-Wiener Diversity Index values (E), Simpson's Diversity Index values (D) and total abundance values. Values were obtained for each of the six trials in the four sampled areas. Test of normality was conducted to determine normalcy of both E and D Values. A Kruskal Wallis test was conducted to compare the means of the E and D values for the four sampled areas. A Mann Whitney-U test was conducted to compare the mean E and D values between enclosed and open marshes, as well as between vegetated and non-vegetated areas. A T-Test was conducted to compare mean total abundance between open and enclosed, as well as vegetated and non-vegetated. ANOVA and a Tukey's Post hoc analysis was done to compare total mean values between the four sampled sites. The data was compared using an ɑ-value of 0.95, unless otherwise noted. All statistical tests were done using SPSS.

Results

1. *Site Hydrology*

Temperature, dissolved oxygen, conductivity, and pH values were similar between sites (Table 4.1). Total nitrogen content of water samples was found to vary greatly across sites (Table 4.2).

2. *Study Organism: Macroinvertebrates*

Macroinvertebrate community composition varied across all four sites (Table 5).

2.1 Macroinvertebrate Diversity (Richness and Evenness)

E values for all sites were found to not be normally distributed (p=.000). D values for the four sites were also found to not be normally distributed (p=.000) (Table 1). The data was found to have no significant difference between mean E values (Z=.000, p=1.000), or mean D values

(Z=-.462, p=.644) in open and enclosed marshes. There was no significant difference found between mean E values (Z=-1.127, p=.260), or mean D values (Z=-1.358, p=.175) in vegetated and non-vegetated areas of the marshes (Table 2.1). An insignificant result was found between E values (Kruskal-Wallis, p=.634) and D values (Kruskal-Wallis, p=.373) of all four sample sites (Table 3.1, Graph 1).

2.2 Macroinvertebrate Abundance

Macroinvertebrate total number of individuals, or abundance, differed across all four sites (F=8.188, p=.001). Differences occurred between the enclosed-vegetated site and the open-non-vegetated site (Tukey HSD, p=.001), the open-vegetated site (Tukey HSD, p=0.043), and the enclosed-non-vegetated site (Tukey HSD, p=0.006) with the enclosed-vegetated site having greater mean abundance in comparison to the others (Graph 2).

Vegetated areas showed greater macroinvertebrate abundance (Graph 3) than non-vegetated areas (t =3.425, p=.003). Enclosed marshes also showed notably greater macroinvertebrate (Graph 4) abundance than open marshes, significant at the 90% confidence level (t=-2.044, p=.054).

Discussion

This study suggests there is not a significant difference in the richness and evenness of macroinvertebrate taxa found between open and enclosed marshes or in vegetated and non-vegetated marshes (Table 2.1). Thus, both hypotheses are rejected. However, it was found that the total abundance of macroinvertebrates was significantly different between the open and enclosed marsh. The vegetated and non-vegetated total abundance also differed significantly with a confidence level of 0.9 (Table 2.2).

Macroinvertebrate Evenness and Richness

This study hypothesized that macroinvertebrate diversity would be significantly different between open and enclosed marshes. It was predicted enclosed marshes would be better protected from severe weather and disturbances leading to a greater diversity of macroinvertebrates. However, no significant difference was found between the richness and evenness of macroinvertebrates between the open and enclosed marsh. A plausible explanation could be the similarity of hydrology between the two marshes. The pH, DO, and temperature of the water were relatively similar across all sites. Although other factors may have varied (Chlorine, Total N, Total P, etc. see table 4.1), Faith and Norris (1989) found that certain factors may affect diversity whereas others may affect abundance. It is possible that in the case of Grass Bay, the similarity of pH, temperature, and DO may influenced similar macroinvertebrate diversity between the two sites (Table 5).

Both sites were areas of water discharge from the nearby lake (Grass lake), which may have contributed to the similarity in hydrology (Figure 2). In addition, several streams connected the two marshes. Hydrologic connectivity can facilitate movement of macroinvertebrates between the two marsh sites, allowing for a similarity in community diversity (Kang & King, 2013). The connectivity of the marshes may have allowed migration of macroinvertebrates from one marsh to the other causing a similar composition in macroinvertebrate diversity (Figure 3). It is also possible that both sites received migration of macroinvertebrates from Grass lake. In addition, the two marshes were physically close to one another, which allows adult macroinvertebrates to spawn in either site.

This study did not include substrate size or substrate composition as a factor contributing to macroinvertebrate diversity. However, a study conducted on macroinvertebrate communities in streams of Oregon found that substrate composition had no effect on macroinvertebrate abundance or diversity (Hawkins et al., 1982). Other studies found that substrate size had a greater influence on the diversity of macroinvertebrates (Hall et al., 2014; Faith and Norris 1989). If substrate size were similar between the two sites, it is likely the diversity of macroinvertebrate taxa would be similar. Further investigation of the substrate in the two areas may provide a better understanding as to how soil characteristics may affect the macroinvertebrate diversity of the marshes at Grass Bay.

Insignificant results were also found when comparing macroinvertebrate richness and evenness for vegetated and non-vegetated sites. This study hypothesized because vegetation can be used as shelter and is an integral source of resources, higher diversity of macroinvertebrates would be found in sites with vegetation. The results found here contradict results found in other studies on vegetated effects on wetland macroinvertebrate diversity. Studies done in other wetlands showed that richness was significantly different between vegetated and non-vegetated sites, with higher richness of macroinvertebrates in the vegetated areas. Kang and King (2013) explained vegetation may provide an area of refuge from predators, food resources, and building materials for macroinvertebrates. Thus, higher diversity of macroinvertebrates is often found closer to vegetation.

A plausible explanation for why this study found no difference in diversity of macroinvertebrates between vegetated and non-vegetated sites could be the “non-vegetated” sites were not completely devoid of vegetation. These sites had similar plant species that were also present in our vegetated sites, but in a lower abundance. It is possible that because vegetation type and water chemistry were similar, diversity of macroinvertebrates would also be similar between vegetated and non-vegetated sites, although abundance of macroinvertebrates may differ due to less vegetation in our non-vegetated sites.

In general, this study may have provided results contrary to results found in other studies due to inherent variation across wetlands that affect macroinvertebrate diversity. Evans and Norris (1997), in their study on macroinvertebrate diversity predictions using stereo-photography, stated that variables that affect macroinvertebrate diversity can be location specific and provide results contrary to common outcomes seen in literature. It is possible location-specific properties of Grass Bay influenced macroinvertebrate diversity to a different extent than in other wetlands and could be studied closer in the future.

Macroinvertebrate Abundance

This study concluded that macroinvertebrate abundance is significantly greater in enclosed marshes and vegetated portions along the edge of the marshes, as predicted. Macroinvertebrates often prefer to lay their eggs in vegetated areas to provide coverage from predators (Polatera et al, 2000). Since the samples in this study were taken in the spring, the larger abundance in vegetated areas could be due to the recent seasonal hatching events that occur for many macroinvertebrate populations. Further sampling later in the summer season could provide different results in abundance as adult macroinvertebrate populations migrate out of the vegetated areas.

The significantly larger abundance of macroinvertebrates within the enclosed marsh could be due to less exposure to harsh physical conditions. During sampling, the open marsh was subject to high winds, which resulted in increased water disturbance. Certain macroinvertebrates may be more sensitive to these conditions than others (Burton et al., 2002); thus, some macroinvertebrates may not have been able to survive the harsher environment. In Lake Huron coastal wetlands, it was found reduced water temperatures lead to decreased abundance and density of macroinvertebrates (Lawrence et al., 2016). Decreased temperature due to exposure to winds from Lake Huron could have a negative effect on macroinvertebrate abundance, although these populations could bounce back after some time or more hatchings. Again, it would be advantageous to return to the sites at a later date to form stronger conclusions.

The higher concentration of Total Nitrogen (TN) found in the enclosed and vegetated sites' water samples could account for increased abundance found in both these areas (Table 4.1). Elevated levels of TN can lead to increased abundance of more tolerant taxa of macroinvertebrates. Taxa that are more responsive to changes in nutrient concentration and those that have earlier sexual maturity and high fecundity will see an increase in abundance under increased TN (Cortelezzi et al., 2015). The presence of vegetation and the increased distance from Lake Huron could also trap the TN within these areas, allowing tolerant macroinvertebrates to utilize the nutrients.

Implications

Wetland systems are sensitive and often are the first to change in response to nearby environmental disturbances. Therefore, they require careful analysis to determine present conditions and how these will respond to changes over time. Evaluating macroinvertebrate communities can eliminate the need for costly chemical analysis in determining wetland quality (Calabro et al., 2013). The finding of differing abundances of macroinvertebrates across sites supports the idea of using macroinvertebrates as bioindicators of important nutrients, such as total nitrogen.

Macroinvertebrates can cause top-down and bottom-up effects on other trophic levels in their ecosystems. A higher abundance of macroinvertebrates could indicate differing abundances at trophic levels both above and below, due to predator-prey population dynamics in enclosed or vegetated areas. Increased abundances of macroinvertebrates would increase the food supply for higher trophic levels, such as predators like fish and birds, thereby influencing diversity on a larger scale. Macroinvertebrates provide food for these species, particularly for migratory birds during spring and fall migrations (Lawrence, el al 2016). Therefore, overall ecosystem diversity benefits from an increase in macroinvertebrate composition. In this study, fish and amphibians were observed at both sites (though not accounted for in the recorded data), and could have been supported largely by the macroinvertebrate communities. Further studies would be needed to confirm the impact of macroinvertebrates on the overall food web in Grass Bay.

Research has also found plants can be beneficial to macroinvertebrate communities if photosynthesis by these plants increase dissolved oxygen levels in the water or provide ideal substrates. However, if vegetation creates dense areas of decaying matter, such as the invasive *Typha* cattail, the decomposition will decrease oxygen levels in the water, harming the macroinvertebrate community and leading to shifts in composition (Lawrence, et al., 2016). Although Grass Bay is a protected area and invasive plants were not observed, finding significantly higher abundance in vegetated areas supports the idea that macroinvertebrates are at least somewhat dependent on vegetation. Further research on the vegetation type found at Grass Bay compared to other fringe marshes could provide a better understanding on how varying vegetation may affect macroinvertebrate composition, and whether vegetation abundance or vegetation type has a higher influence towards macroinvertebrate composition.

More detailed examinations of richness and evenness of the macroinvertebrate communities in Grass Bay would require identification of macroinvertebrates beyond order or family to have a more complete understanding of the community. Macroinvertebrates could further be broken down into functional feeding groups and pollution tolerance groups, which could provide more information on the diversity of ecological niches and water quality present. This study may also benefit from a larger sample size; with more data it may be possible to see stronger trends between the different sites tested.

Future studies in Grass Bay may seek to sample from the source lake (Grass Lake) and the streams that connect the enclosed and open marshes to identify how macroinvertebrates diversity and abundance may be different or similar to that of the study sites, due to their shared hydrogeology. Stable substrate type is also important in allowing macroinvertebrate communities to prosper (Lawrence, et al., 2016). Further examination could be done on the soils and vegetation found in the four Grass Bay sites to determine if there are significant differences in nutrient content or other factors that could help support the results found in this study. A potential follow-up study could include an area similarly protected as Grass Bay, but with a greater distinction between the vegetated and non-vegetated areas of the marsh. This may provide evidence similar to previous studies that suggest vegetated and protected areas are correlated with greater richness, evenness, and abundance. In addition, studies over longer time scales can provide insight into how seasonal changes and overall climate change impact the community composition of macroinvertebrates in fringe marshes, and in wetlands as a whole.

Conclusions

Wetland ecosystems are often sensitive and the macroinvertebrates that reside in them can be used as indicators of the condition of the wetland and its hydrology. Since wetlands are important to both the human and natural environment, the proper treatment and studying of wetlands is crucial. Many of the fossil fuels we depend on today, such as coal, are obtained through carboniferous wetlands formed in the past. In addition, they provide many ecological services such as flood protection, nutrient cycling, aquifer recharge, and much more (Mitsch and Gosselink, 2000). Though wetlands provide a plethora of services and goods, they are often drained for agricultural and urban development. Wetland destruction coupled with the lack of management and control has caused 50% of the total wetlands on earth to be lost (Davidson, 2014). Though management of wetlands has improved greatly, continued research about the abiotic and biotic characteristics and interactions of wetlands can provide information that may be useful for wetland conservation with greater distinctions between wetland types.

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Figures, Tables, and Graphs

Figure 1: Site Locations

Marsh sites at Grass Bay Nature Preserve. Site 1: Open Marsh; Site 2: Enclosed Marsh
Picture Obtained From: Google Maps, 2018

Figure 2:

The arrows depict the movement/flow of water into the two sites from Grass Lake

Figure 3:

Red/Blue arrows depict the possible movement of macroinvertebrates between the two marsh sites; Green arrow indicates the possible movement of adult macroinvertebrates between the two sites.

Table 1: Tests of Normality Results

Tests of Normality Results			
Value Tested	**Null Hypothesis**	**P-Value**	**Conclusion**
E Values	**The values are Normally Distributed**	**0.000**	**Reject Null**
D Values		**0.000**	**Reject Null**
Abundance		**0.157**	**Accept Null**

Table 2.1: D and E Value Comparison of Enclosed vs Open and Vegetated vs Non-Vegetated

Mann Whitney U Test Results				
Value Tested	**Comparison Between:**	**Null Hypothesis**	**P-Value**	**Conclusion**
Shannon's Diversity Value (E)	**Open vs Enclosed**	**There is no difference in E values between the Open and Enclosed**	**1.000**	**Accept Null**
Simpson's Diversity Value (D)	**Open vs Enclosed**	**There is no difference in D values between the Open and Enclosed**	**0.671**	**Accept Null**
Shannon's Diversity Value (E)	**Vegetated vs Non-Vegetated**	**There is no difference in E values between the vegetated and Non-vegetated**	**0.266**	**Accept Null**
Simpson's Diversity Value (D)	**Vegetated vs Non-Vegetated**	**There is no difference in D values between the vegetated and Non-vegetated**	**0.178**	**Accept Null**

Table 2.2: Abundance Comparison of Enclosed vs Open and Vegetated vs Non-vegetated

T-Test Results					
Value Tested	**Comparison Between:**	**Null Hypothesis**	**Std. Error**	**P-Value**	**Conclusion**
Abundance	**Open vs Enclosed**	**There is no difference in abundance macroinvertebrates between the Open and Enclosed**	**1.712**	**0.054**	**Reject Null***
	Vegetated vs Non-Vegetated	**There is no difference in abundance macroinvertebrates between the vegetated and Non-vegetated**	**5.167**	**0.003**	**Reject Null**
***Null rejected with 90% confidence**					

Table 3.1: E, D, and Abundance Values Comparison of All Four Sites

Kruskal Wallis Test Results				
Values Tested	**Comparison Between**	**Null Hypothesis**	**p-value**	**Conclusion**
Shannon's Diversity Values(E)	**OV vs ONV vs EV vs ENV**	**The distribution of Shannon's Diversity Values is the same across all areas**	**0.634**	**Accept Null**
Simpson's Diversity Value (D)		**The distribution of Simpson's Diversity Values is the same across all areas**	**0.373**	**Accept Null**

ANOVA Test Results				
Values Tested	**Comparison Between**	**Null Hypothesis**	**p-value**	**Conclusion**
Abundance	**OV vs ONV vs EV vs ENV**	**The distribution of abundance Values is the same across all areas**	**0.001**	**Reject Null**

Table 3.2: Abundance Comparison of All Four Sites

Post-Hoc Analyses for Abundance Kruskal Wallis Test			
Site1-Site2	**Null Hypothesis**	**p-values**	**Conclusions**
ONV-ENV	**The distribution of abundance value is the same in site 1 and site 2**	**0.806**	**Accept Null**
ONV-OV		**0.304**	**Accept Null**
ONV-EV		**0.001**	**Reject Null**
ENV-OV		**0.806**	**Accept Null**
ENV-EV		**0.006**	**Reject Null**
OV-EV		**0.043**	**Reject Null**

Table 4.1: YSI Professional Plus Readings

Site	**Temperature (C)**	**D.O. (mg/L)**	**Conductivity (µs/cm)**	**pH**
OV	20.7	2.81	347	7.24
ONV	20.9	3.29	323.7	7.67
EV	22.7	3.14	351.6	7.9
ENV	22	3.28	348.7	7.74

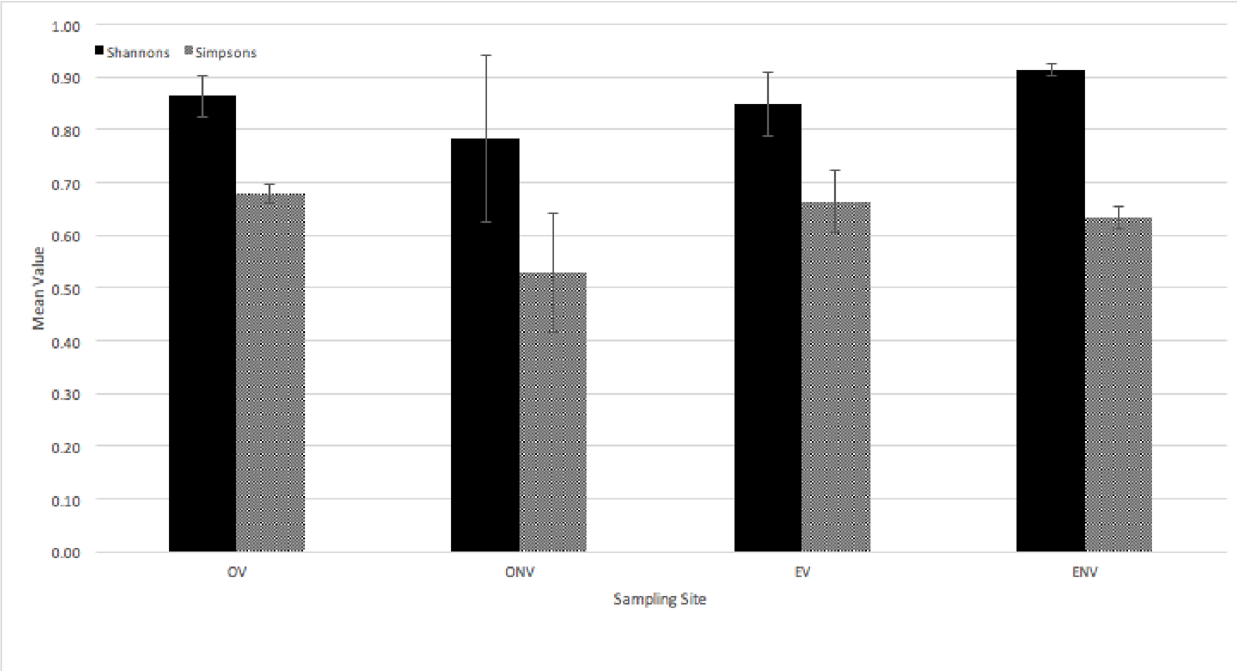
Table 4.2: Marsh Hydrology

Site	**Average Cl Concentration (mg/L)**	**Average NH_4 (mg/L)**	**Total P (mg/L)**	**Total N (mg/L)**	**Total Organic Carbon (TOC) (mg/L)**	**Iron Concentrations (µg/L)**
Open	21.18	13.39	14.25	350.45	8.595	914.39
Enclosed	33.47	12.81	9.56	**506.20**	13.245	717.37
Vegetated	26.54	15.97	14.85	**548.10**	11.9	920.81
Non Vegetated	28.12	10.23	8.96	308.55	9.94	710.95

Table 5: OTU Found In Each Site

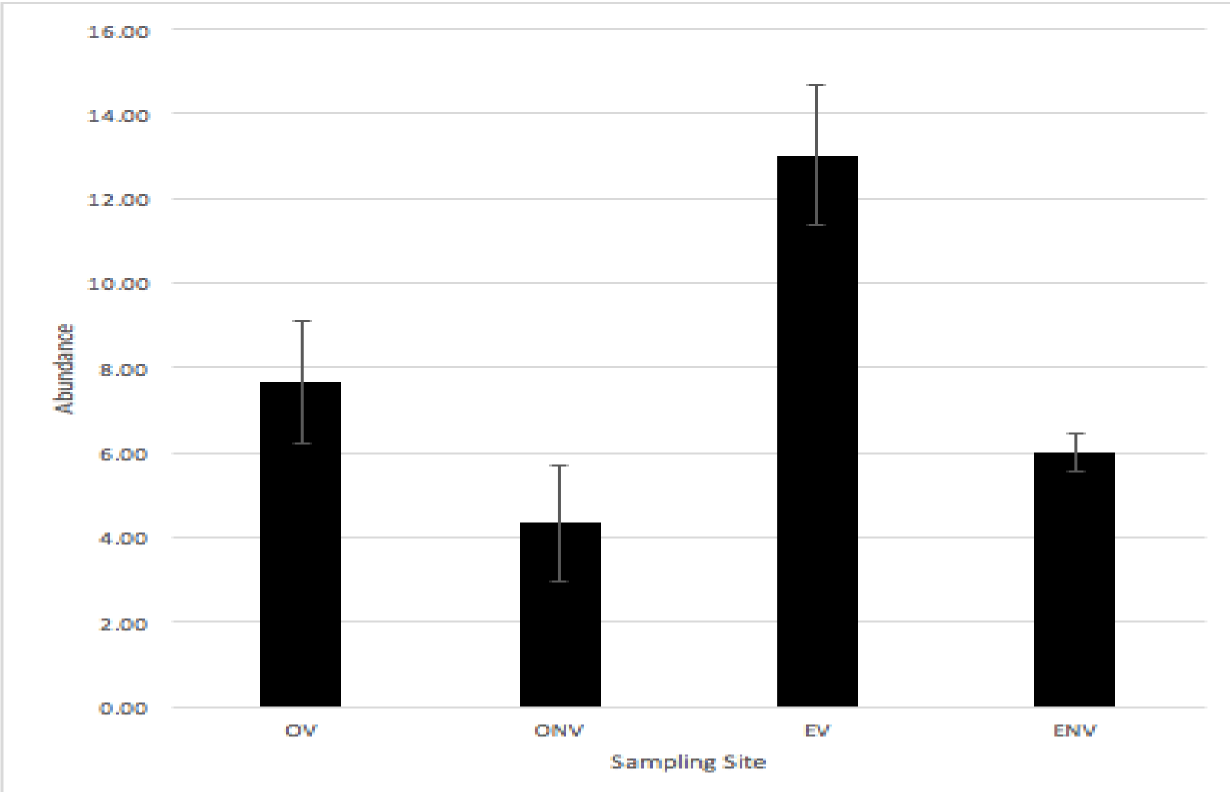
Site	**Open/vegetated**	**Open/Non-vegetated**	**Enclosed/vegetated**	**Enclosed/Non-vegetated**
Taxa	Hydrachnidae	Hydrachnidae	Hydrachnidae	Hydrachnidae
	Ephemeroptera	Gastropoda	Ephemeroptera	Ephemeroptera
	Diptera	Odonata	Diptera	Diptera
	Gastropoda	Amphipoda	Odonata	Odonata
	Trichoptera	Hemiptera	Amphipoda	Amphipoda
	Odonata	Trichoptera	Coleoptera	Clitellata
	Amphipoda		Hemiptera	Gastropoda
	Hemiptera		Gastropoda	Hemiptera
	Arachnida			
Total Number of Individuals	46	26	78	37

Graph 1:



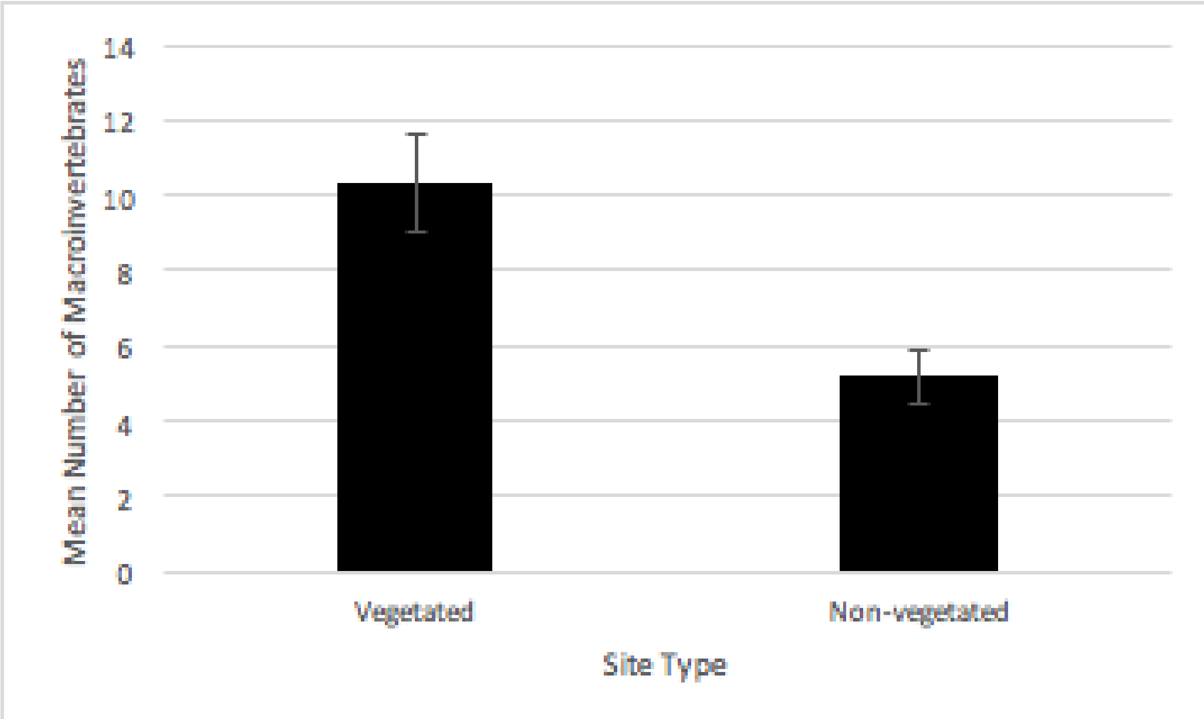
Graph 1. Mean value of E and D values of sampled sites. Mean value of E and D values are displayed on the y axis; OV: Open/Vegetated, ONV: Open/Non-Vegetated, EV: Enclosed/Vegetated, ENV: Enclosed/Non-Vegetated; OV: E=0.86 D=0.68, ONV: E=0.68 D=0.53, EV: E=0.85 D=0.66, ENV: E=0.91 D=0.63

Graph 2:



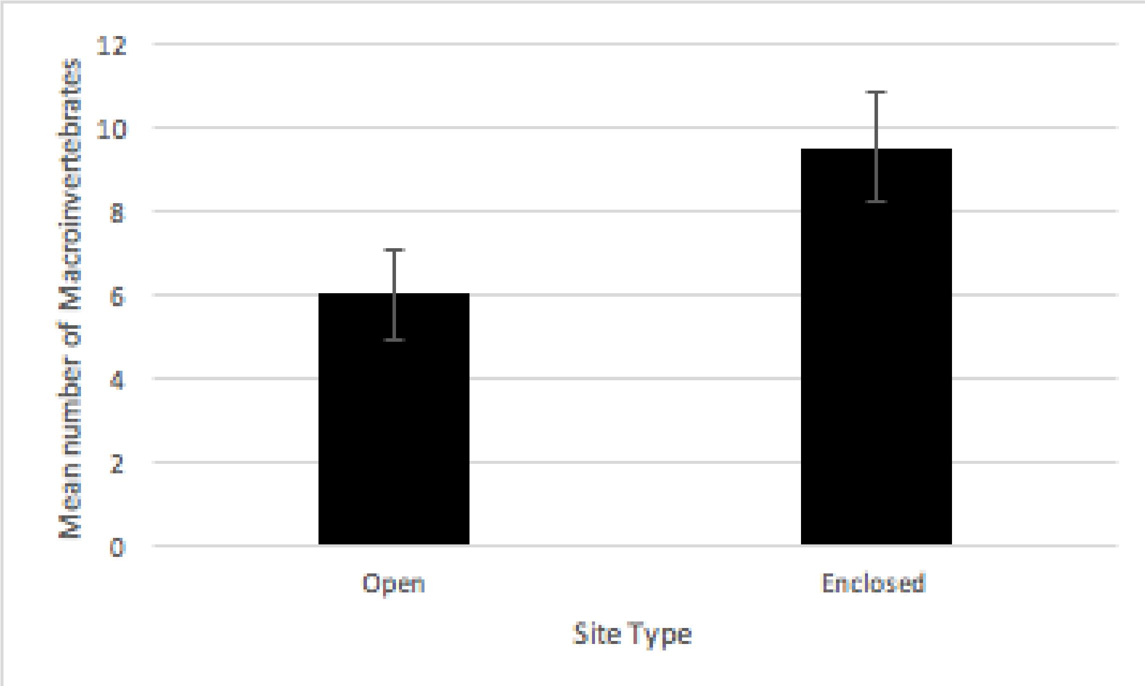
Graph 2. Mean Abundance of macroinvertebrates found at each sampled site. Y axis displays the mean abundance (# of macroinvertebrates) found; OV: Open/Vegetated, ONV: Open/Non-Vegetated, EV: Enclosed/Vegetated, ENV: Enclosed/Non-Vegetated; OV: 7.67, ONV: 4.33, EV: 13.00, ENV: 6.00

Graph 3:



Mean Macroinvertebrates found in Vegetated and Non-Vegetated Sites; Vegetated: Mean # of Macroinvertebrates=10.33, Std. Error = 1.316, Non-Vegetated: Mean # of Macroinvertebrates=5.17, Std. Error = 0.737; Mean macroinvertebrates were found by Averaging data of macroinvertebrates found in OV+EV (for Vegetated) and ONV+ENV (for Non-Vegetated).

Graph 4:



Mean Macroinvertebrates found in Open and Enclosed Sites; Open: Mean # of Macroinvertebrates=6, Std. Error = 1.073, Enclosed: Mean # of Macroinvertebrates=9.5, Std. Error = 1.334; Mean macroinvertebrates were found by Averaging all data of macroinvertebrates found in OV+ONV (for Open) and EV+ENV (for Enclosed)

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