Effects of Invasive *Typha* on Aquatic Environments and Biota

Peter Sonnega

University of Michigan Biological Station
RLW EEB321/ENV331
8/17/2017
Prof. Amy Schrank

Abstract

ABSTRACT:

Invasive cattail hybrids, *Typha x glauca*, pose a significant threat to the biodiversity of northern Michigan coastal wetlands. *Typha* quickly dominates the environment, leading to a decrease in local plant diversity. In this study, we examined whether the presence of invasive *Typha* led to a decrease in aquatic macroinvertebrate abundance and diversity, chlorophyll-a content, and nutrient levels at a coastal wetland in St. Ignace, MI. We collected and compared samples from three plots where *Typha* was absent and three plots where *Typha* had already invaded and established itself. *Typha*-invaded waters were associated with lower abundance and diversity of aquatic macroinvertebrates. Our results suggest that *Typha* invasion is detrimental to the fitness of many different macroinvertebrates by reducing food resources available and dramatically altering the environment. We advocate further investigation into *Typha*-invaded wetland management such that biodiversity is preserved.

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ABSTRACT:

Invasive cattail hybrids, *Typha X glauca*, pose a significant threat to the biodiversity of northern Michigan coastal wetlands. *Typha* quickly dominates the environment, leading to a decrease in local plant diversity. In this study, we examined whether the presence of invasive *Typha* led to a decrease in aquatic macroinvertebrate abundance and diversity, changes in chlorophyll-a content, and/or changes in nutrient levels at a coastal wetland in St. Ignace, MI. We collected and compared samples from three plots where *Typha* was absent and three plots where *Typha* had already invaded and established itself. *Typha*-invaded waters showed a significantly lower abundance (Z=-3.38, p=0.001) and diversity (t=4.55, df=22, p<0.000) of aquatic macroinvertebrates. Contrarily, we observed no significant difference in chlorophyll-a content (Z=0, p=1), nitrate (t=-0.478 df= 4 p=0.658), ammonium (t=-.336 df=4 p=.754), phosphate (t=-0.79 df= 4 p=0.474, and total phosphorus (t= -.085 df=4 p=.936). Our results suggest that *Typha* invasion is detrimental to the fitness of many different macroinvertebrate taxa by dramatically altering the environment while leaving the nutrient levels and abundance of algae unchanged.

INTRODUCTION:

The northern tip of the Lower Peninsula of Michigan as well as the southern coasts of the Upper Peninsula are home to many species-rich coastal wetlands. Habitats such as these provide ecological importance by maintaining biodiversity and species richness throughout the world.

Wetlands provide refuge and an abundance of food sources to dozens of different species, including migratory birds, larval fishes and amphibians (Costea, 2008). Additionally, wetlands play a crucial role in the cycling of nutrients, such as nitrogen removal from soil via denitrifying microbial communities (Geddes et al., 2014). There are also wetland products that more directly apply to humans, such as fisheries and sediment maintenance (Mitsch and Gosselink, 2000). These delicately balanced functions are vital to the biosphere and mankind.

Unfortunately, the ecological functions of these wetlands and their wildlife populations are threatened by invasive species, among them the competitively dominant cattail, *Typha X glauca*- hereafter referred to as *Typha*. (Albert et al., 2015). *Typha* is a hybrid of *T. latifolia* and *T. angustifolia*. Although *Typha* is nearly sterile, it reproduces quickly via vegetative propagation and expands using its rhizomes to create monotypic swaths (Boers et al., 2006). Due to this, areas invaded by *Typha* quickly become covered by the cattails and the surrounding ecosystem's plant diversity often suffers. Past research has shown that the presence of *Typha* negatively affects the wetland plant communities and the environment's physical structure by changing the plant composition or increasing the litter accumulation (Albert et al., 2016; Farrer and Goldberg, 2009; Larkin et al., 2012). More specifically, the litter that *Typha* leaves behind decreases interspecific competition between itself and other macrophytes while not affecting the intraspecific competition (Larkin et al., 2012). While it's clear that *Typha* quickly becomes the dominant macrophyte of many wetland environments, little research has been done regarding how it affects the other biota and water quality in these ecosystems.

A large part of the animal biota that inhabit wetlands includes aquatic macroinvertebrates, small organisms visible to the naked eye that live in the benthic zone or water column. They play a critical role in wetland ecosystems, as many fish and bird communities depend upon them as a food source (Lawrence et al., 2016). When their environment is altered, it follows that the macroinvertebrate community dynamics will change as well. A study done in northern Great Lakes coastal wetlands showed that the shallower and cooler waters caused by *Typha* invasion were associated with decreased aquatic macroinvertebrate density and biomass (Lawrence et al., 2016). This follows trends shown in other studies highlighting that the presence of dominant invasive macrophytes such as *Typha* and milfoil often lead to decrease in native species abundance (Gallardo et al., 2015; Stiers et al., 2011). Since *Typha* decreases plant species richness (Albert et al., 2016; Lawrence et al., 2016), it follows that macroinvertebrates may decline in these habitats given the lack of different feeding options.

The copious litter created by *Typha* not only affects the aquatic macroinvertebrate communities, but can alter the algal communities by changing the water chemistry and temperature (Farrer and Goldberg, 2009; Larkin et al., 2012). Another factor that could impact algae abundance in *Typha*-invaded areas could be the decreased light penetration due to increased shade created by the cattails (Lawrence et al., 2016). With decreased light and increased competition for resources, it is likely that algal communities could suffer in *Typha*-invaded waters.

The nutrient content of wetland water and soil, specifically nitrogen and phosphorus, has the potential to be greatly impacted by *Typha* invasion, however there has been little research in this area. The cycling of nitrogen is dependent upon multiple factors, including the size of nitrifying bacterial communities and the rate of assimilation by photosynthetic organisms. Past research has shown that after *Typha* has established itself in a wetland, processes such as denitrification can decrease or ultimately be lost (Geddes et al., 2014). This would then increase the amount of nitrate in the water. However, it is also possible that *Typha* invasion increases the amount of production and thus increases the assimilation of nutrients such as nitrate.

Our research will attempt to build on past research illustrating the negative effects of *Typha* invasion upon macroinvertebrate diversity and abundance as well as investigate how it impacts the phytoplankton communities and water nutrient levels. We predict that macroinvertebrate abundance and diversity will be lower in *Typha*-invaded waters due to the predicted decrease in plant species richness and temperature. We also hypothesize that there will be a decrease in chlorophyll-a content in the *Typha*-invaded water since the algae will experience a decrease in light available to them as well as increased competition for resources. Given the complex nature of nutrient cycles and how they interact with *Typha*, it is difficult to predict what the nutrient levels are in *Typha*-invaded waters. Still, the increase in plant biomass could increase the levels of nutrient assimilation so we predict lower levels of nutrients in *Typha*-invaded waters.

METHODS:

To sample macroinvertebrate populations, chlorophyll-a content, and nutrient levels, we selected wetland marshes in St. Ignace, MI along the coast of Lake Michigan. Loyola’s Restoration Ecology Research Group, (aka “Team *Typha*”), had previously mapped out three 64m x 32m rectangular plots of both *Typha*-invaded and *Typha*-absent waters (Fig. 1). The *Typha*-invaded plots were labeled “Control” while the *Typha*-absent plots were labeled “Native.” We sampled four different subplots marked by orange flagging tape located nearest to the corners of each plot (A-D). The ArcGIS Collector app was used to help locate each subplot. Sampling took place during similar times in the afternoons of July 24, 2017- July 31, 2017.

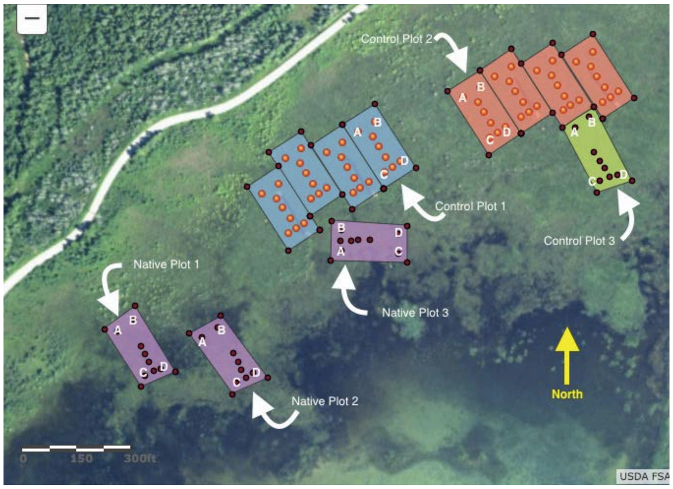

Figure 1. The locations of the six plots sampled at the St. Ignace site. Subplots sampled are labeled with letters A-D. Other dots within the plots represent the locations of fishing traps used for other research.

Macroinvertebrate Collection

We collected a sample of the macroinvertebrate populations at each subplot by conducting three 1-meter sweeps of the surrounding benthic biota using a D-net (Fig. 2). The contents of the net were emptied onto gridded enamel pans. Our group's three members sorted through the enamel pans for macroinvertebrates using forceps, eyedroppers, and spoons for ten minutes so that we collected macroinvertebrates for thirty person minutes at each subplot. The collected macroinvertebrates were stored in plastic bottles of 95% ethanol. Afterward, the orders of the specimens from each subplot were identified and tallied to measure abundance and diversity (H'). The Shannon-Wiener diversity index equation was used to quantify the diversity of orders observed at each subplot (Fig. 3).

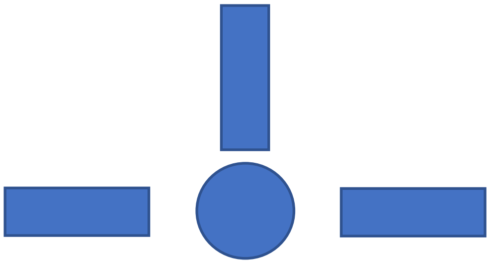

Figure 2 depicts the research group member as the circle in the middle. The rectangles represent the three meter-long-sweeps done in different directions. The total area swept by this procedure is roughly one-meter squared.

$$H' = \sum_{i=1}^{s} -(n_i/N) \ln (n_i/N)$$

Figure 3 depicts the Shannon-Wiener index equation. In this equation, S is the total number of species present, n_i is the number of individuals of species i in the sample, and N is the total number of individuals in the sample.

Chlorophyll-a Content

To measure the chlorophyll-a content, we used a 60-milliliter chlorophyll-a syringe and filter papers to take a 60-milliliter sample of the water and pass it through the filter paper. This was done once at each subplot. Filter papers were stored in aluminum foil and kept on ice until they could be taken to the UMBS chemical lab for analysis of chlorophyll-a concentration.

Nutrient Levels

We used the 60-milliliter syringe to gather 240 milliliters of water to be analyzed from each plot. At each subplot, we filled the syringe with 60 milliliters of water and added it to acid-washed bottles holding the composite water sample for each separate plot. From there, the water samples were brought back to the UMBS chemical lab and analyzed for total phosphorus (TP), phosphate (PO_4), nitrate (NO_3) and ammonium (NH_4) content. Additionally, we used a YSI Multiparameter to record the water's pH, conductivity (µS), temperature (°C), and dissolved oxygen (%) once from each subplot.

Statistical Analysis

For each category of data collected, we checked whether the data were normally distributed using a Shapiro-Wilk test of normality in SPSS Statistical Software to see if an independent two-sample t-test would be appropriate. If data were not normally distributed, a Mann-Whitney test was conducted instead to compare the means. Tests were run comparing the mean macroinvertebrate diversity, chlorophyll-a content, and nutrient levels between the twelve native and twelve control subplots. Furthermore, we conducted one-way ANOVA tests to compare the YSI measurements between each control plot and each native plot to see if there were any differences among similar plots. We also ran a test to compare mean YSI measurements between native and control plots.

RESULTS:

The abundance of macroinvertebrates was significantly higher in native plots than in control plots (Z=-3.38, p=0.001) (Fig. 4 & Fig. 5). We also found that macroinverterbrates were significantly more diverse in the native plots compared to the control plots (t=4.55, df=22, p<0.000) (Fig. 5 & Fig. 6). We observed fourteen orders listed in figure 5 and the odanata were further grouped into suborders of anisoptera and zygoptera.

ANOVA tests showed significant differences in the dissolved oxygen measurements among native plots (F=11.010, df=11, p=0.004). In the control plots, there was a significant difference in the pH (F=8.456, df=11, p=0.001), conductivity (F= 5.039, df =11, p=0.034), temperature (F=8.456, df= 11, p=0.009), and dissolved oxygen (F=10.758, df=11, p=0.004) measurements. We observed a significantly higher pH (t=-2.800, df= 22, p=0.013), lower conductivity (t=2.099, df= 22, p=0.048), higher temperature (t= -8.528, df=22, p<0.000), and higher dissolved oxygen (t= -6.672, df=22, p<0.000) measurements in the native plots compared to the control plots. The lower water temperatures in the native plots are illustrated in Figure 7.

We did not observe a significant difference in chlorophyll-a content (Z=0, p=1), nitrate (t=-0.478 df= 4 p=0.658), ammonium (t=-.336 df=4 p=.754), phosphate (t=-0.79 df= 4 p=0.474, and total phosphorus (t= -.085 df=4 p=.936). The results of these tests are shown in Table 1.

DISCUSSION:

The data corroborate our hypothesis that areas invaded by *Typha* exhibit lower abundance and diversity of aquatic macroinvertebrates. In Lawrence et al., 2016, similar results were observed where there were significantly fewer aquatic macroinvertebrates and lower amounts of diversity in *Typha* invaded areas. It is interesting to note that some of the most benthic biota such as ephermoptera and zygoptera were much less abundant in the control plots (Fig.5). This supports other research studying the impact of invasive aquatic plants that show that the abundance of these biota sensitive to an unstable environment, such as the one created by *Typha* litter, can be decreased or completely erased in response to invasion (Stiers et al., 2011). It appears that the invasion of *Typha* similarly negatively impacts macroinvertebrate communities by reducing or wiping out the presence of different taxa. For example, we observed hirudinea and diptera in the native plots but not in the control plots (Fig. 5). We also observed far more odanata, hemiptera, and gastropoda in the native plots, but fewer isopoda and chironomids. It’s clear that the presence of *Typha* changes the community composition while reducing biodiversity of aquatic macroinvertebrates.

As *Typha* establishes itself in an area, the water tends to decrease in temperature due to decreased light penetration. We observed this decrease in temperature in our own plots (Fig. 7) and showed it to be statistically significant. Past study has shown that there is a strong positive correlation between feeding rates and water temperature in exothermic organisms (Wotton, 1995). This means that if the water is significantly colder, then macroinvertebrates would consume food at a slower rate, therefore decreasing their growth rate and potentially exposing themselves to predation for longer periods. Therefore, the cold waters we observed could conceivably contribute to the decrease in macroinvertebrate biodiversity in *Typha*-invaded waters.

The extremely high p-values we obtained from the test comparing the means of the chlorophyll-a content (p=1), nitrate (p=0.658), ammonium (p=0.754), phosphate (p=0.474), and total phosphorus (p=0.936) between native and control plots indicates that the levels of each of these are extremely similar with no observable trends. Although we expected to see a decrease in algal abundance in control plots, it could be that *Typha* causes a shift in algal community composition instead. Algae communities can respond very quickly to selective pressures, often leading to a bloom of algae resistant to the selection as other species are eliminated, a phenomenon demonstrated in trophic cascades where the abundance grazers that feed upon the algae is increased (Agrawal, 1998). If we were to examine the algal community composition present in both types of plots, it is possible that we would see algae better adapted for the colder, more shaded environment created by *Typha*-invasion in the control plots. Furthermore, the similarity in chlorophyll-a content between plots helps explain the similarity in nutrient levels, as there are likely similar rates of nutrient uptake by algae within both types of plots.

Conversely, the other water quality differences we observed between plots could be possibly be considered negligible. While the increase in dissolved oxygen in native plots support the notion that there is a greater abundance of algae in these plots, we did not observe a significant difference in the chlorophyll-a content between plots. We can possibly attribute these differences to other factors such as increased mixing with the open water in the native plots as well as potentially greater submerged macrophyte abundance (Albert et al., 2016; Lawrence et al., 2016). Additionally, although the differences we observed in pH and conductivity between plots was statistically significant, the range of values in pH (7.0-7.4) and conductivity (373-475 μS) fall within standard ranges for freshwater wetlands (Dodds and Whiles, 2010).

Further research could go into correcting many of the limitations that could have potentially skewed our results. Given our time constraints, we were not able to sample at different types of wetlands. The wetlands were open to the Mackinac Straits where waves caused by storms and boat traffic mix the wetland's water with lake water, which could have created a confounding variable in our measurements of wsater chemistry. Future projects could involve investigating different types of *Typha*-invaded wetlands, such as an inland marsh. This would also serve to increase our small sample size (n=12).

Our research demonstrates how *Typha* invasion negatively impacts a wetland community's aquatic macroinvertebrate biodiversity and abundance but does not change the algal abundance or nutrient levels of the water. Unfortunately, damage to macroinvertebrate communities has harmful effects on the wetland community at large, including higher predators. Should macroinvertebrate abundance and diversity continue to increase as *Typha* spreads, it could lead to the loss of several different fish, bird, and amphibian communities. This only furthers the need for large-scale experimentation with regards to management of *Typha*-invaded wetlands.

FIGURES:

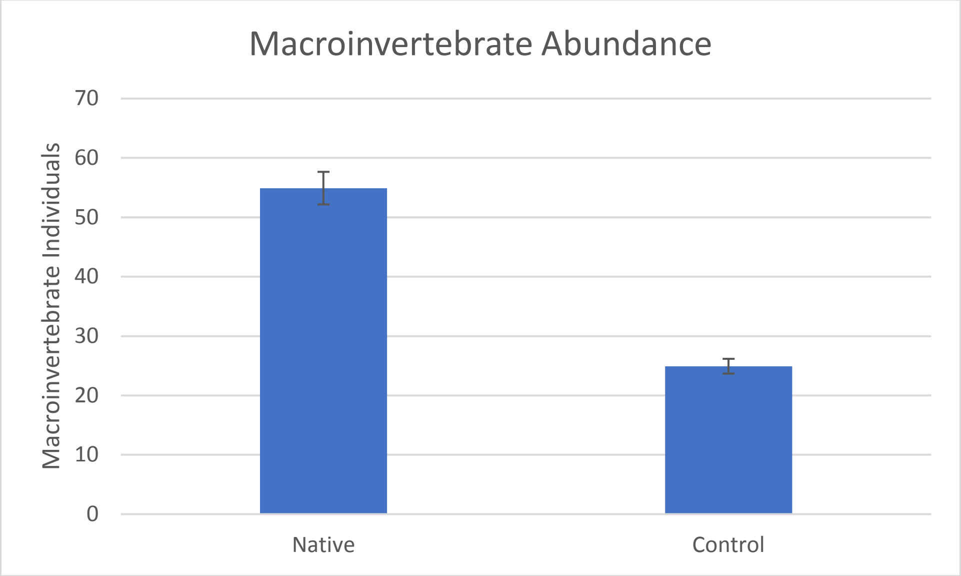

Figure 4. Macroinvertebrate abundance is higher in the native plots (mean = 55.0 individuals) compared to the control plots (mean = 24.92 individuals) (Z=-3.38, p=0.001, n=12). The error bars show 2 standard errors.

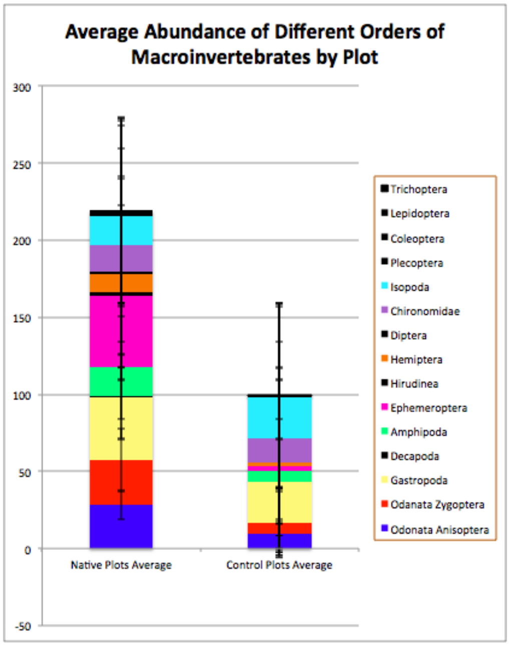

Figure 5. The average number of collected individuals at each subplot grouped by order at each subplot. There appears to be a greater richness and a greater abundance of multiple orders including Ephemeroptera, Hemiptera, and Odanata.

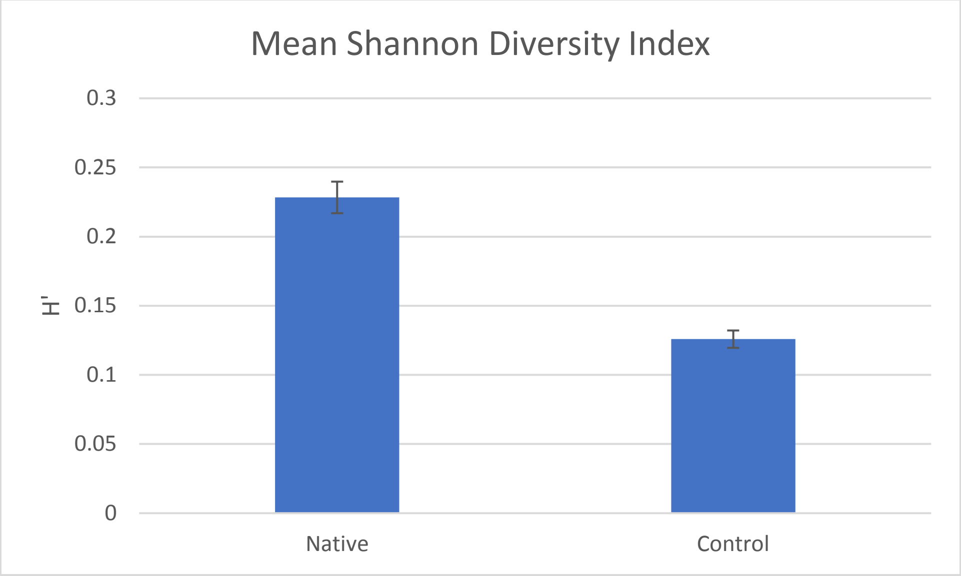

Figure 6. The mean Shannon diversity index of native plots (mean H'=0.228) is greater compared to the control plots (mean H'=0.125) (t=4.55, df=22, p<0.000). The error bars show 2 standard errors.

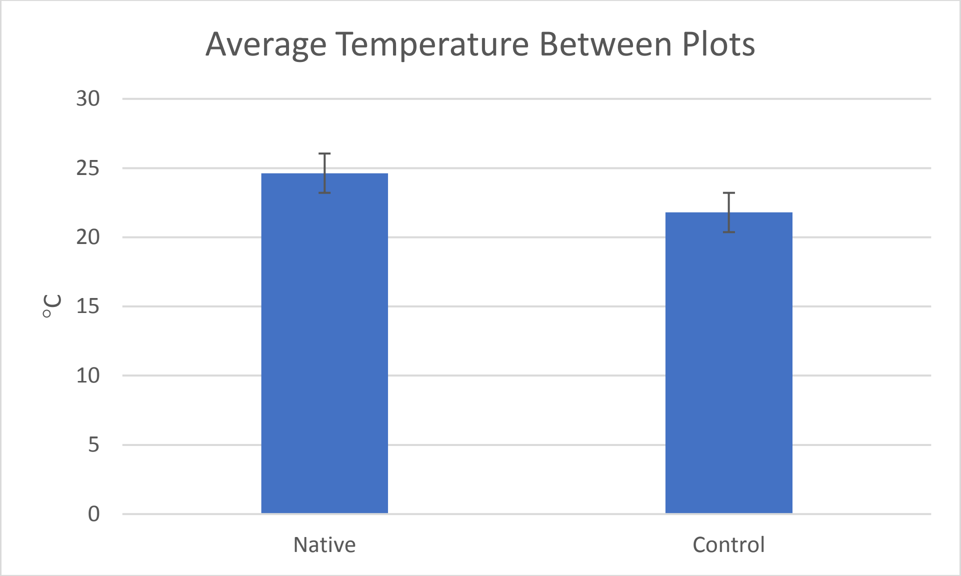

Figure 7. The mean water temperature of native plots (mean= 24.63 °C) is significantly higher than the control plots (mean= 21.79 °C) (t= -8.528, df=22, p<0.000). The error bars show 2 standard errors.

	Chlorophyll-A	Nitrate	Ammonium	Phosphate	Total Phosphorous
Mann-Whitney U Test					
Z	0	n/a	n/a	n/a	n/a
P-Value	1	n/a	n/a	n/a	n/a
T-Test					
t- statistic	n/a	-0.478	-0.336	-0.79	-0.085
P-Value	n/a	0.658	0.754	0.474	0.936
Degrees of Freedom (df)	n/a	4	4	4	4

Table 1. The results of the Mann-Whitney U test for chlorophyll-a content and the independent two-sample t-test for each nutrient measurement. None of the p-values observed were statistically significant.

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