Use of Native Wetland Plants on Floating Island Systems for the Phyto-remediation of Water with excess Nutrients

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Submitted To:

Alberta Real Estate Foundation

Highfield Investment Group

Submitted By:

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May 2020

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1.0 Introduction

Water represents one of the key components of life and one of the core components that determines the success and failure of ecosystems. Without water life would not exist on earth as it does today and the security of the human population worldwide depends on clean accessible water. Our concern for water and water resource management has revolved around control (i.e. pollution control has relied primarily on waste water treatment instead of source control, flood management is based on dykes and reservoirs rather than no-structural measures such land use (Pahl-Wostl et al. 2008). Water is wasted without thinking about its importance, or mismanaged without looking at the long-term consequences. Only when the quality and quantity of water available to us impacts us does society generally react, yet it has the potential to direct our entire existence.

With our abundance of water, water is not only wasted but contaminated. Contamination of water occurs through numerous anthropogenic activities (Lewtas et al. 2015). Contamination of water can lead to immediate consequences, or in many cases chronic long-term consequences that are the result of multi-use impacts. From harmful algae blooms (Hoagland et al. 2002) to the death of aquatic species we have seen numerous impacts from contaminating water here in Canada as well as worldwide. With growing populations worldwide, the urgency for clean water will only grow. With the potential impacts of climate change on our water supply, the urgency of protecting and cleaning water has never been more evident. Depending on the form of contamination there are many methods for remediating water including: physical engineering, chemical applications, and biological and ecological engineering (Lewtas et al. 2015).

1.1 Literature Review

1.1.1 Eutrophication and nutrient loading

Eutrophication of waterbodies causes pronounced deterioration in water quality and as a widespread problem (Lewtas et al. 2015). The impact in prairie lakes has been documented by Lewtas et al. (2015) in a review of prairie lakes in Manitoba, and has shown that these lakes and ponds have deteriorated in quality due to excessive nutrients, organic matter, and silts which increase primary producer biomass (algae) and reduce water quality (Lewtas et al. 2015). Improving water quality in situations with such large scale impacts involves looking at larger investments in restoration of many features of the waterbody as well as the entire watershed (Lewtas et al. 2015).

In many ways, algae blooms and eutrophication are symptoms of the problem and not the problem itself. Nutrient loading due to numerous industries (e.g., mining, agriculture, commercial/industrial activity, residential use, recreation, etc.) is the source of massive nutrient loads that move from catchments into our water bodies (e.g. wetlands, ponds, lakes, creeks, rivers, etc.). When the source can be identified and mitigated, downstream impacts can be reduced, but in many cases, we must find ways to remediate water where mitigation at the source is not possible.

1.1.2 Remediation of Water

Within this complex world of contaminated water there are a number of ways that water can be filtered and cleaned. The main methods used today focus on the physical (e.g., hypolimnetic withdrawal, dilution and flushing, hypolimnetic aeration and oxygenation, artificial circulation, dredging and removal of sediment), and chemical (e.g., P inactivation and copping, sediment oxidation and algicide) remediation (Lewtas et al. 2015). Some of these methods treat the symptoms while others allow true solutions. However there is another area of

remediation of water that is becoming a growing interest and this is in biological and ecological engineering (e.g., biomanipulation, floating treatment wetlands, removal of macrophytes, treatment wetlands) (Lewtas et al. 2015). Phyto-remediation holds a potential to create functioning ecosystems that allow for water to be remediated effectively and passively. This provides many benefits in addition to remediation of water such as wildlife habitat, natural ecosystem functions and nutrient cycling, and anthropogenic benefits.

1.1.3 Phyto-Remediation

Engineered wetland systems and floating island systems have been used all over the world to remove sediment and different contaminants from water. Engineered wetlands are generally defined as those constructed specifically with the purpose for use in water management and in relation to phytoremediation specifically for use to remediate water using plants. Floating island systems can be any form of buoyant mat or raft that allows plants to grow above the water and root into the water (Tanner et al. 2011, Solanki et al. 2017). These mats can displace algae, shade the water surface, and buffer water turbulence (Tanner et al. 2011). The advantage of these floating island systems revolves around their ability to tolerate wide fluctuations in water depth. This allows them to easily be retrofitted on to existing stormwater facilities or placed on ponds, lakes, and water ways with out concern for water depth changes (Tanner et al. 2011) that would otherwise kill emergent wetland plants. This opens doors to treating water in a passive manner in locations with water that is either too deep or does not have shallow emergent zones (or enough) to effectively allow for water to be remediated passively through plants.

The effectiveness of wetland plants in uptake and removal of nutrients and metals from water is well documented. Some of the prominent nutrients known to be remediated by wetland plants include: nitrogen, (Hubbard 2010, Tanner et al. 2011, Lewtas et al. 2015, Pavlineri et al. 2017, Solanki et al. 2017), phosphorus (Hubbard 2010, Tanner et al. 2011, Lewtas et al. 2015, Pavlineri et al. 2017, Solanki et al. 2017), and selenium (Tannas et al. 2017, Tannas et al. 2020). Although, less studied there is also some evidence to suggest potassium (Saidin et al.) and sulphate (Saidin et al. , Zhao et al. 2012) are taken up by wetland plants and may be useful for remediation.

While there has been a lot of research into engineered wetlands and floating islands for use in phytoremediation of water there has been very little work done targeting the diversity of wetland plants that exist within North America and specifically Canada. Generally, we only have good information on a single species cattail (*Typha latifolia*) which grows in much of North America, but is not effective in all situations and may have limited ability to address some contamination issues. In addition, cattail has been listed as an undesirable species for use in many locations due to is aggressive nature (Livingston 1989), growth form and the specific ecological needs of a project. Outside of this specific species a literature review of species tested on floating island systems (Pavlineri et al. 2017) listed four species native to Canada that have been previously for phosphorus and/or nitrogen uptake: common rush (*Juncus effusus*), common great bulrush (*Schoenoplectus tabernaemontani*), common duckweed (*Lemna minor*), and common reed (*Phragmites australis*). Of these species one, is challenging to use as it has a Eurasian subspecies that is a highly invasive weed (common reed) that is regulated under the Alberta Weed Control Act (Alberta_Government 2008).

Within Western Canada there are hundreds of different species of native wetland plants that are all adapted to different environmental conditions (i.e., salinity, pH, nutrients, temperatures, oxygen levels, and climates). Unfortunately, our understanding of which species are adapted to solving our specific problems is unknown. In addition to this many of these plants have different unique growth forms and appearances that can be ornamental or provide critical wildlife habitat. If we can pair water treatment with aesthetically pleasing wetland

systems it is possible to create a beneficial system that will result in cost effective treatment of water that can occur in public spaces as well as in agricultural and industrial locations.

1.2 Project Objectives

This project is focused on understanding how we can use native plants as a tool in cleaning water from the impacts of nutrient loading found in agricultural and urban settings within Western Canada. Our objective is to determine:

1) The effectiveness of each species in removing specific contaminants or potential contaminants in water
2) Determine the water use efficiency of each plant species
3) Determine the viability of each species to be used in floating island systems to remove contaminants

2.0 Methods

This project used a batch mesocosm style (Tanner et al. 2011) with floating islands custom built by GP Restoration Solutions Inc. out of Cremona Alberta that consisted of a solid frame with a growing medium (approximately 7.5cm thick of peat). Plants were then established for 4 months before the trial started to allow them to acclimatize and root out through the island. The plants were not fully mature at the project initiation but being grown in a greenhouse their root systems were close to the size of a mature plant.

2.1 Project Design

2.1.1 Tanks and Island Configuration

Treatment tanks were sent up in an environmentally controlled greenhouse at Olds college. Each tank was filled with 250 L of distilled water. Tanks were set up in four rows within the climate-controlled greenhouse with one row for each species. A set of floating islands was custom built out of plastic pipe and non-woven geotextile fabric with a plastic mesh to hold the fabric in place on the island. Island dimensions were 71 cm x 47 cm of growing area with an additional 7.62 cm pipe wall surrounding this growing area. This configuration filled each tank leaving only a small area on the side accessible for testing the water. The islands were then filled with peat moss as a growing medium for the plants. Five plants were then planted in each island. There were four islands planted with each of the following species: cattail (*Typha latifolia*), wheat sedge (*Carex atherodes*), water sedge (*Carex aquatalis*), smartweed *(Persicaria amphibia var. emersa)*, and sweet flag *(Acorus calamus*).Configuration of mesocosms with floating islands shown in Appendix A. Plants were planted in the islands as plugs (180cc) on November 1st 2018 and then grown out in tap water within the tanks until February 2019. At this point the plants had grown out into the islands and put their roots down into the water. Although not completely mature the plants had root systems established into the water. At this point the distilled water was placed into the tanks and the control tanks were set up in the greenhouse. A control tank with distilled water (Control A) and a control tank with the nutrient solution (Control B) were placed in the greenhouse. All tanks were aerated.

2.1.2 Treatments

Prior to spiking the tanks with the nutrient solution, all plants were defoliated to two inches to simulate the start of a growing season and remove any confounding information from top growth metrics. All tanks with plants as well as Control B were treated with a nutrient solution (Hoagland Solution; (Hoagland and Arnon 1950) . The solution was added at a rate 5.1 times the concentration normally used in hydroponics to simulate a nutrient loading situation. This solution was added in three components, of which each was made at Olds College. Table 2.1-1 below shows the salts added to create the solution and how much of this solution was then added to each L of water within the tanks.

This set of three solutions was then added to each tank to create the solution described above in Table 2.1-1 which was 5.1 times higher than that generally used in hydroponic operations. Tanks were spiked between February 25-27th 2019, due to the length of time to create the solution in the lab. A pre-treatment sample of water and vegetation was completed on February 13th 2019 and the first post treatment water sampling occurred on March 4, 2019. Water within each tank was oxygenated daily to ensure that the system did not go anerobic.

Table 2-1: Components of the Hoagland Solution prepared for 6700L of water

Solution	Nutrient	Solution (g/L)	Total added per L of Water (g)
A	KNO_3	82.15	1021.17
	$Ca(NO_3)_2.4H_2O$	118.08	
B	$NH_4H_2PO_4$	28.8	461.142
	$MgS0_4.7H_2O$	61.62	
C	H^3BO_3	0.284	0.612
	$MnCl_2.4H_20$	0.099	
	$ZnSO_4.7H_20$	0.055	
	$(NH_4)6Mo7O24.4H2O$	0.124	
	$CuSO_4.5H_20$	0.05	
D	F_3Cl_3	15 (24mL)	52.2
	NaHO	5	
	EDTA	32.2	

*As per the Hoagland Formula: 60g of FeCl3 was dissolved in 100mL of RO water then 24mL (approximately 15 g) of the concentrated FeCl3 was added to the NaHO and EDTA solution which had been dissolved in 800mL of RO water. Once the FeCl3 had been added to the NaHa/EDTA solution, RO water was added to the beaker to make 1000mL of Solution D.

2.1.3 Monitoring

Environmental monitoring: Environmental monitoring was completed every Thursday (temperature) before YSI testing and when entering the greenhouse to do a random environment check on days when testing was not being done. The temperature within the greenhouse was maintained between 18°C and 28°C (with a few exceptions) providing a natural level of temperature variation expected in summer growing conditions. Environment checking started Feb 21, 2019 and ended when project was completed on August 1st, 2019.

Plant growth metrics: Growth metrics (tiller height and tiller numbers) were assessed weekly (Thursday). Tiller heights were assessed based on the tallest tiller from each Island. Tiller numbers was a count of the total number of tillers on each island.

Water Sampling: Every Wednesday distilled water was added to each tank to top it up to the full line. The amount of water added was recorded for each tank to provide information on evapotranspiration potential of each species. Water volumes added were recorded to understand water use of each species through evapotranspiration rates. Water sampling was completed prior to spiking nutrients into the tanks (February 13, 2019) then the tanks were spiked between February 25-27th 2019. Water sampling was then completed again 6-8 days after the initial spiking (March 4, 2019) and monthly throughout the experiment (Thursdays) including at experiment completion. A pooled 500ml sample of water taken for each species (125ml from each tank) which was submitted to A&L labs for analysis. Lab results assessed; Total Alkalinity, Bicarbonate, Carbonate, Nitrate, Aluminium, Boron, Calcium, Chloride, Copper, Iron, Magnesium, Manganese, Phosphorus, Potassium, Sodium, Sulphur, Zinc, Conductivity, pH, pHc, Total Dissolved Solids, Sodium Adsorption Ratio, Adjusted SAR, Hardness, Saturation Index, Sulphur, and Residual Sodium Carbonate. For most metrics reporting was completed in ug/ml.

Final Vegetation Sampling: Plant material was taken from the shoots and roots and analyzed from each tank for nutrient composition. A soil sample was analyzed (peat) for nutrients to understand what nutrients were bound up in the peat and submitted to the lab for analysis. In addition, a 25 X 25 cm sample (Roots and shoots) was

taken from each island and the sample dried and weighed to determine dry matter weight at the end of the experiment.

2.2 Analysis

2.2.1 Data Analysis

For tiller heights and tiller numbers, growth curves for each species were produced to show the growth rates to be compared against the nutrient concentrations within the water. Similarly, water analysis was taken from the monthly lab results and plotted to show trend lines of the nutrient concentrations with the water throughout the experiment. Vegetation sampling data was used to calculate total biomass for each species on a per square meter basis. This was then used to calculate the amount (in grams) of each nutrient that was stored in a square metre of plant shoots. The nutrient concentration in the roots of different plant species was not analyzed statistically, but a comparison between the mean root and shoot concentrations of main macronutrients was presented.

2.2.2 Statistical Analysis

Only samples from the final sampling event in August were included in the water and shoot nutrient statistical analysis. One-way Analysis of Variance (ANOVA) was used to compare nutrient concentrations in water samples between plant species and control tanks. Two tanks were excluded from the water analysis because it was suspected that the nutrient solution they were spiked with was not consistent with the rest of the tanks. The excluded samples were “T1C-WS-1-W” (wheat sedge) and “T2C-CT-3” (cattails). Response variables analyzed in water samples included: calcium (µg/ml), iron (µg/ml), magnesium (µg/ml), manganese (µg/ml), sulphur (µg/ml), sulphate (µg/ml), zinc (µg/ml), nitrate-N (µg/ml), potassium (µg/ml), phosphorous (µg/ml), total dissolved solids (TDS; µg/ml), and sodium adsorption ratio (SAR).

One-way ANOVA was also used to compare the nutrient content of plant shoot tissues sampled at the end of the experiment. Two different analysis types were run: 1) a comparison of the nutrient concentration in shoot tissues measured in percent; and 2) a comparison of the amount of nutrients (in grams) stored in one square meter of each plant. Response variables analyzed in the comparison of nutrient concentration in shoot tissue samples included: nitrogen (%), potassium (%), phosphorous (%), calcium (%), iron (ppm), magnesium (%), manganese (ppm), zinc (ppm), sulphur (%), and sodium (%).Response variables analyzed in the comparison of the nutrient content in one square metre of plant tissue included: nitrogen (g/m^2), potassium (g/m^2), phosphorous (g/m^2), calcium (g/m^2), iron (g/m^2), magnesium (g/m^2), manganese (g/m^2), zinc (g/m^2), sulphur (g/m^2), and sodium (g/m^2).

A Two-way ANOVA was used to compare the water usage of different plant species in each month of the experiment. The amount of water added to each tank per month was converted to L/m^2 by dividing one square metre by the area of one floating island and multiplying the total use per month. The results from both control tanks were combined for this analysis.

If the effect of an independent variable was found to be statistically significant in the ANOVA, a post-hoc test was performed by calculating the Tukey adjusted comparisons of each factor. A 0.05 significance level was used for all tests. When possible, issues of normality were corrected by log transforming the response variable. In these cases, analysis was performed on the log transformed values which were back transformed for reporting. Values presented in the results are the means of each group with their sample standard deviation. Statistical analysis was performed using R software version 3.4.3 (R_Core_Team 2017), and post-hoc tests were performed with the package “emmeans” (Lenth 2019). Summary stats that include results from post hoc tests

and main ANOVA tests are included in Appendix B. In some cases, models did not meet the assumption of normality of the residuals and these results should be interpreted with some caution. These models were as follows:

- Concentration of manganese in water
- Concentration of zinc in shoot tissue
- Total zinc and sodium content in shoots (g/m^2)

3.0 Results

3.1 Nitrate/Nitrogen

Nitrate concentrations in the residual water for each plant species/control over the course of the experiment are visualized in Figure 3.1 . A decline in nitrate concentration throughout the experiment was found for all species except Smartweed, which saw an increase in nitrate on the last sampling date. A greater decline in nitrate was seen in the cattails, wheat sedge and sweet flag treatments, as found in the significance tests on the final sampling date.

The concentration of nitrate in water was significantly affected by the plant species/control type ($p < 0.001$). The post hoc test revealed there were differences in the mean concentration of nitrate remaining in water both between species and the control tanks (Figure 3.2Figure 3.2). Of the different plant species, cattails (171 µg/ml ±31), wheat sedge (268 µg/ml ±34), and sweet flag (308 µg/ml ±29) had the lowest levels of nitrate remaining in water. All of these species had lower levels of nitrate remaining in water than both water sedge (531 µg/ml ±89) and smartweed (711 µg/ml ±127).

Both the percent of nitrogen stored in plant shoots and total amount of nitrogen stored in plant shoots differed depending on the species ($p < 0.001$). Cattails (3.37% ±0.22) and Smartweed (3.51% ±0.27) both stored nitrogen in their shoots at higher concentrations than water sedge (2.45% ±0.26), but could not be differentiated from wheat sedge (3.04% ±0.53) or sweet flag (3.14 ±0.16). When looking at the total amount of nitrogen stored in shoot biomass, cattails stored more than any other species (288 g/m^2 ±44), at an amount approximately three times greater any other species (Figure 3.2).

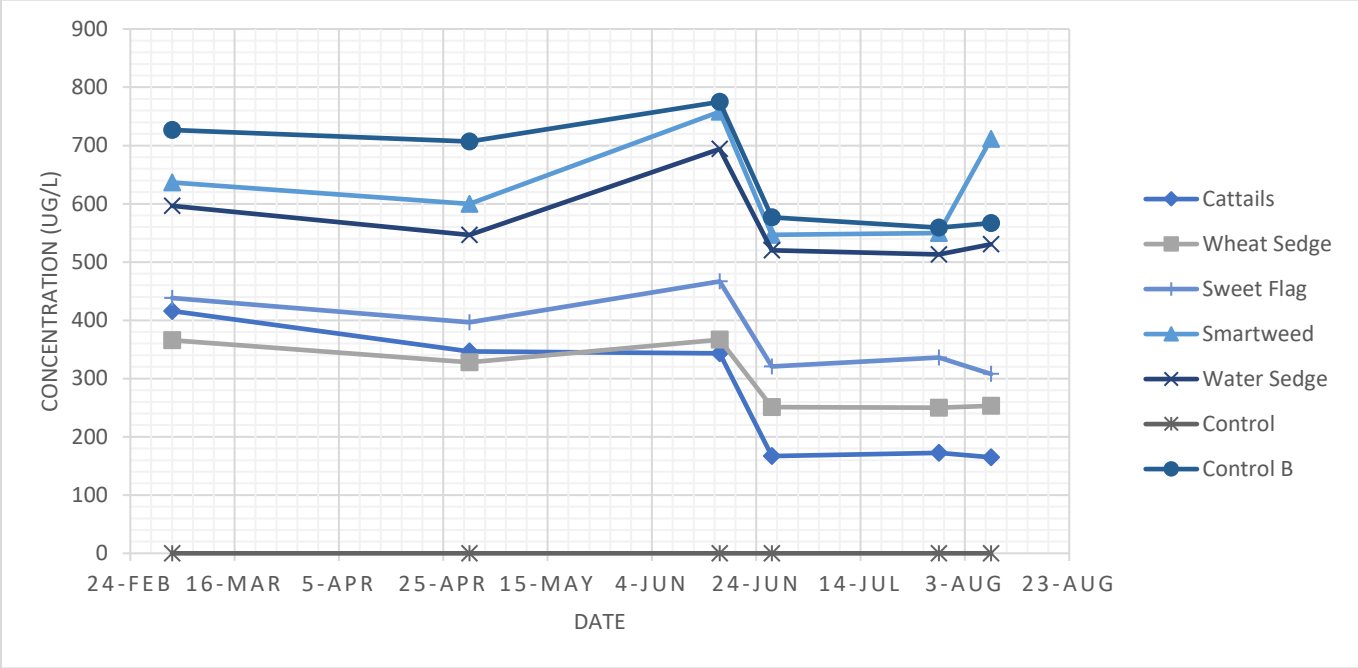

Figure 3.1: Changes in water nitrate concentration for each treatment tank and controls (water samples composited from the three replicates).

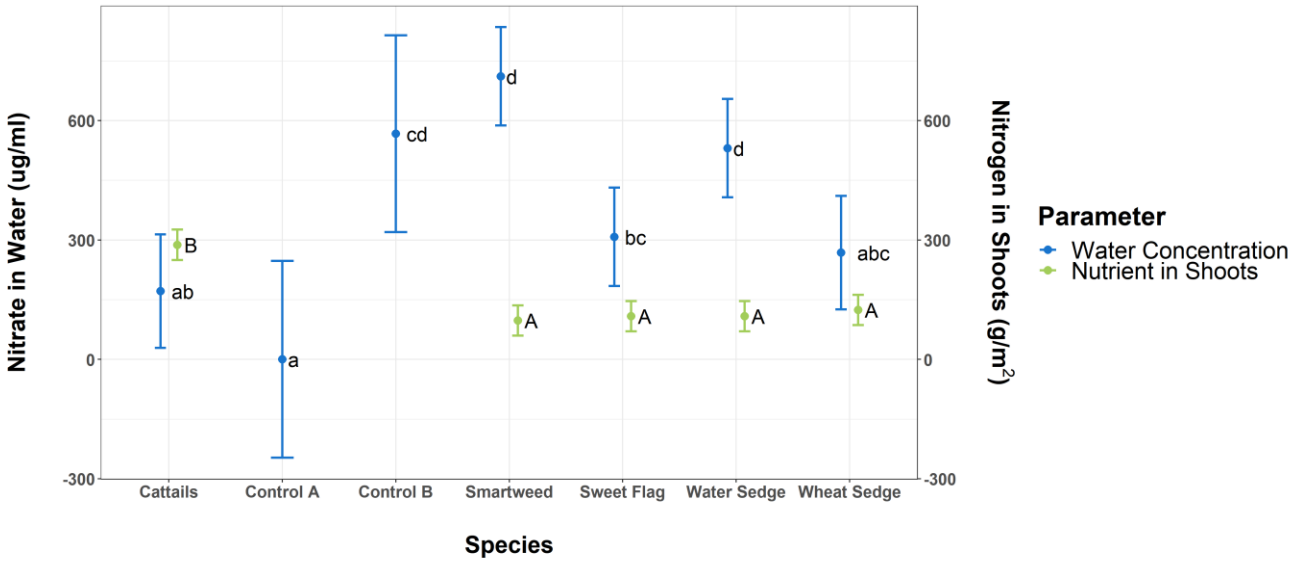

Figure 3.2: Mean nitrate concentration in water and nitrogen content in shoots for each plant species and control tank at the conclusion of the trial. Confidence intervals are based on the pooled variance of the ANOVA test. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

3.2 Phosphorous

Phosphorus concentration in the treatment tanks declined over the course of the experiment for each species (Figure 3.3). The nutrient spiked control tank also saw a decrease in phosphorus. The largest measured decrease in phosphorus concentration was found in the cattail treatment tanks.

The concentration of phosphorous in water was significantly affected by the plant species/control type ($p < 0.001$). The post hoc test revealed there were differences in the mean concentration of phosphorous remaining in water both between species and the control tanks (Figure 3.4). Of the different plant species, cattails had the lowest concentration of phosphorous remaining in water (12 µg/ml ±3). Sweet flag (101 µg/ml ±21) had a lower concentration of phosphorous than smartweed (141 µg/ml ±11), but was undifferentiated from water sedge (112 µg/ml ±6) and wheat sedge (124 µg/ml ±9).

Both the percent of phosphorous stored in plant shoots and total amount of phosphorous stored in plant shoots differed depending on the species ($p < 0.001$). Sweet flag (0.69% ±0.05) stored phosphorous in its shoots at higher concentrations than wheat sedge (0.28% ±0.06) and smartweed (0.40% ±0.04), but could not be differentiated from water sedge (0.63% ±0.23) or cattails (0.51% ±0.04). When looking at the total amount of phosphorous stored in shoot biomass, cattails (43 g/m^2 ±9) stored more than smartweed (11 g/m^2 ±1), wheat sedge (12 g/m^2 ±5), and sweet flag (24 g/m^2 ±7), but could not be differentiated from water sedge (28 g/m^2 ±14) (Figure 3.4).

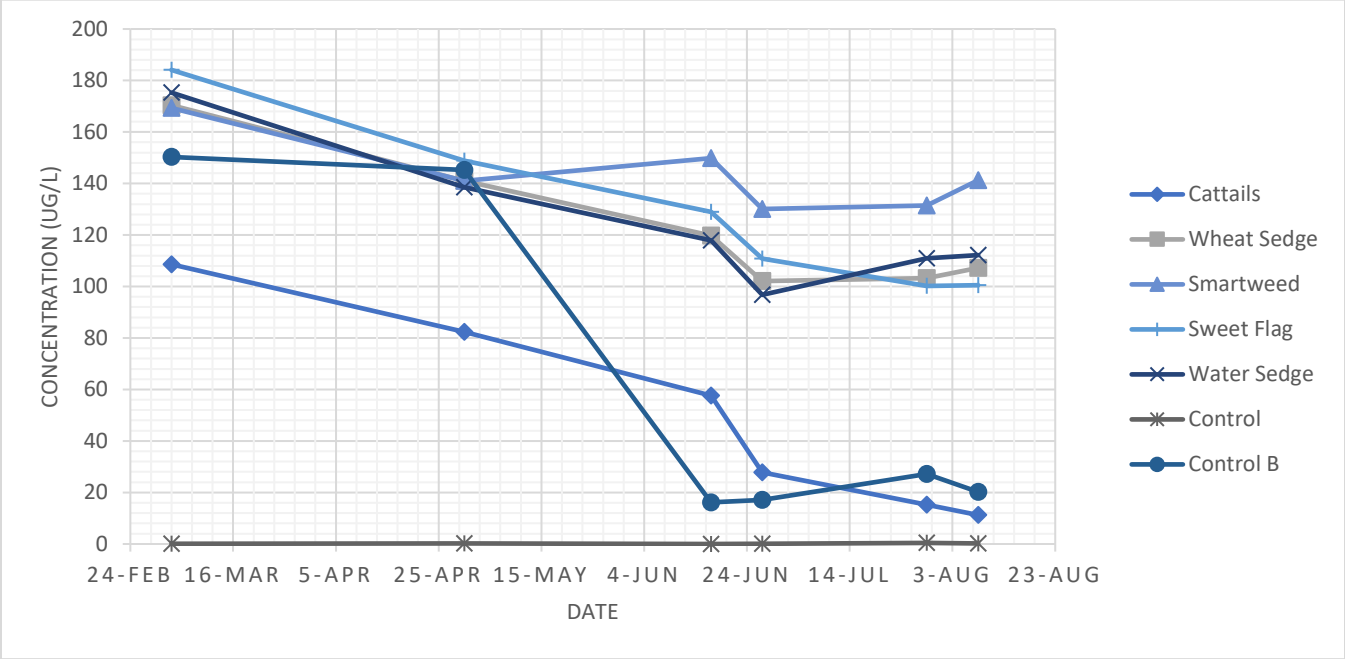

Figure 3.3 Changes in phosphorus concentration in the residual water for each species treatment and control tanks (water samples composited from the species replicates).

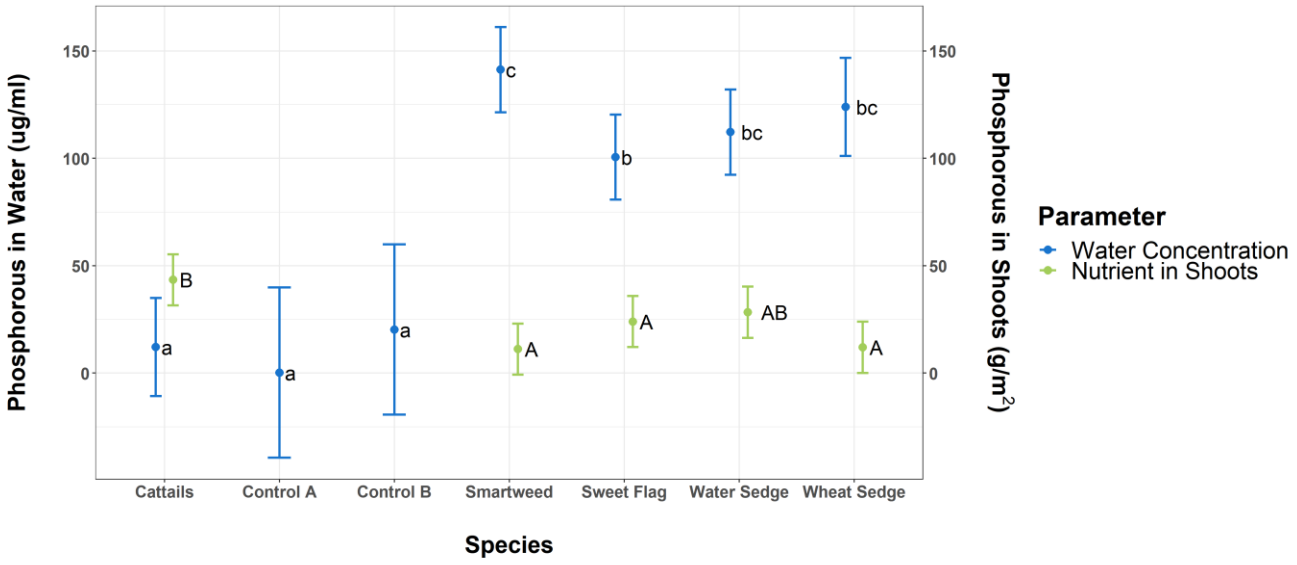

Figure 3.4: Mean phosphorous concentration in water and phosphorous content in shoots for each plant species and control tank at the conclusion of the trial. Confidence intervals are based on the pooled variance of the ANOVA test. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

3.3 Potassium

Potassium concentration in the treatment tanks was observed to consistently decline over the course of the experiment for each species (Figure 3.5). Potassium concentration in the cattail treatment tanks had the largest

decrease by the end of the experiment. The potassium concentration in the nutrient spiked control on the first sampling date did not correspond with the expected concentration after being spiked with the nutrient solution. A sampling error may be the cause, as the subsequent samples for the Control B tank were consistent and had an elevated concentration of potassium.

The concentration of potassium in water was significantly affected by the plant species/control type ($p < 0.001$). The post hoc test revealed that every species and control treatment had a different concentration of potassium remaining in water (Figure 3.6). Of the different plant species, cattails had the lowest potassium concentration remaining in water (131 µg/ml ±47), followed by wheat sedge (289 µg/ml ±24), and sweet flag (385 µg/ml ±9).

Both the percent of potassium stored in plant shoots and total amount of potassium stored in plant shoots differed depending on the species ($p < 0.001$). The species that stored potassium in their shoots at the highest concentration were cattails (3.47% ±0.20) and sweet flag (3.47% ±0.33). When looking at the total amount of potassium stored in shoot biomass, cattails stored more than any other species (297 g/m^2 ±47) (Figure 3.6). Sweet flag (119 g/m^2 ±18) stored more potassium in its shoots than smartweed (44 g/m^2 ±3), but could not be differentiated from water sedge (78 g/m^2 ±20) or wheat sedge (110 g/m^2 ±51) (Figure 3.6).

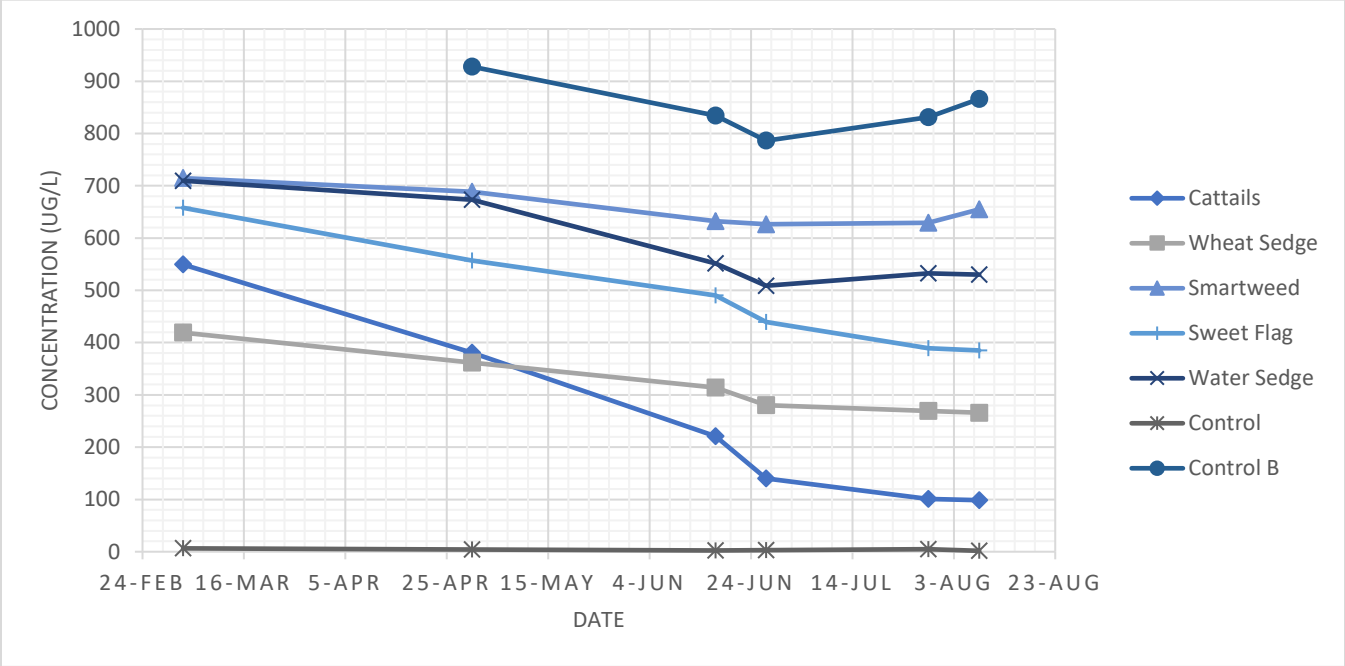

Figure 3.5: Changes in potassium concentration in the residual water for each species treatment and controls (water samples composited from the species replicates). The data point for Control B from 04MAR2019 was omitted from the figure due to an undermined error.

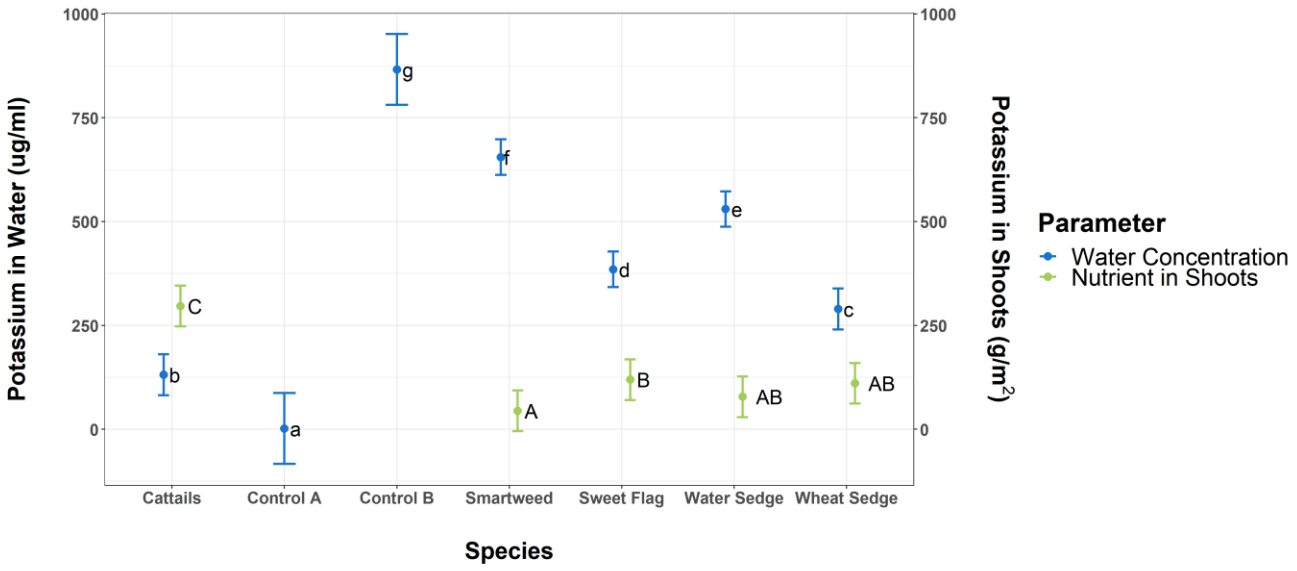

Figure 3.6: Mean potassium concentration in water and potassium content in shoots for each plant species and control tank at the conclusion of the trial. Confidence intervals are based on the pooled variance of the ANOVA test. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

3.4 Sulphate/Sulphur

Sulphate concentration in the treatment tanks had a varied response observed over the course of the experiment for each species (Figure 3.7). An overall increase in sulphate was observed in both control tanks over the course of the experiment. Similarly, an increase in sulphate was found in the residual water for smartweed, sweet flag and water sedge. Two treatments, cattail and wheat sedge were observed to have a small decrease in sulphate concentration in the residual water.

The concentration of sulphate in water was significantly affected by the plant species/control type ($p < 0.001$). The post hoc test revealed there were differences in the mean concentration of sulphate remaining in water both between species and the control tanks (Figure 3.8). Of the different plant species, cattails had the lowest levels of sulphate remaining in water (387 µg/ml ±40), followed by sweet flag (668 µg/ml ±34), and wheat sedge (669 µg/ml ±32). These species had lower levels of sulphate remaining in water than both smartweed (786 µg/ml ±25) and water sedge (796 µg/ml ±36).

Both the percent of sulphur stored in plant shoots and total amount of sulphur stored in plant shoots differed depending on the species ($p < 0.001$). Cattails (0.64% ±0.09) stored sulphur in their shoots at higher concentrations than smartweed (0.27% ±0.05) or sweet flag (0.28% ±0.04), but could not be differentiated from wheat sedge (0.46% ±0.15) or water sedge (0.45% ±0.08). When looking at the total amount of sulphur stored in shoot biomass, cattails stored more than any other species (56 g/m^2 ±16) (Figure 3.8). Both water sedge (20 g/m^2 ±7) and wheat sedge (18 g/m^2 ±4) stored more sulphur in their shoot biomass than smartweed (7 g/m^2 ±1) or sweet flag (10 g/m^2 ±2) (Figure 3.8).

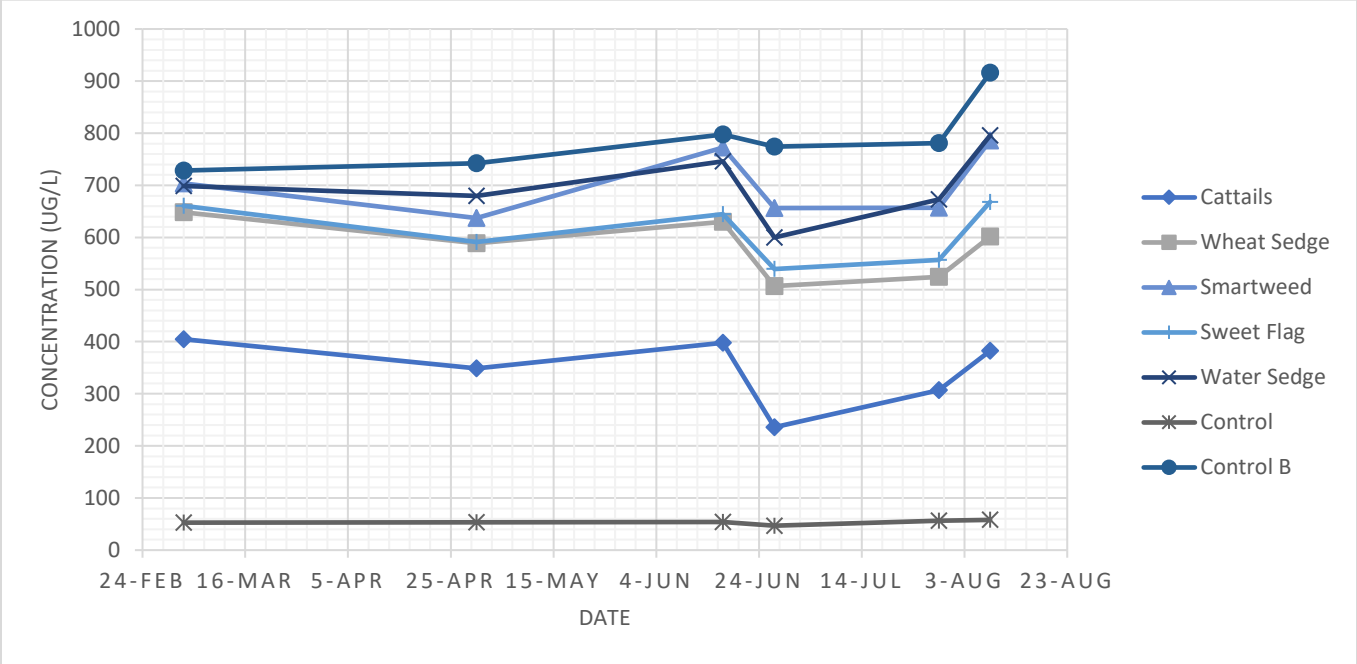

Figure 3.7: Changes in sulphate concentration in the residual water for each treatment tank and controls (water samples composited from the species replicates).

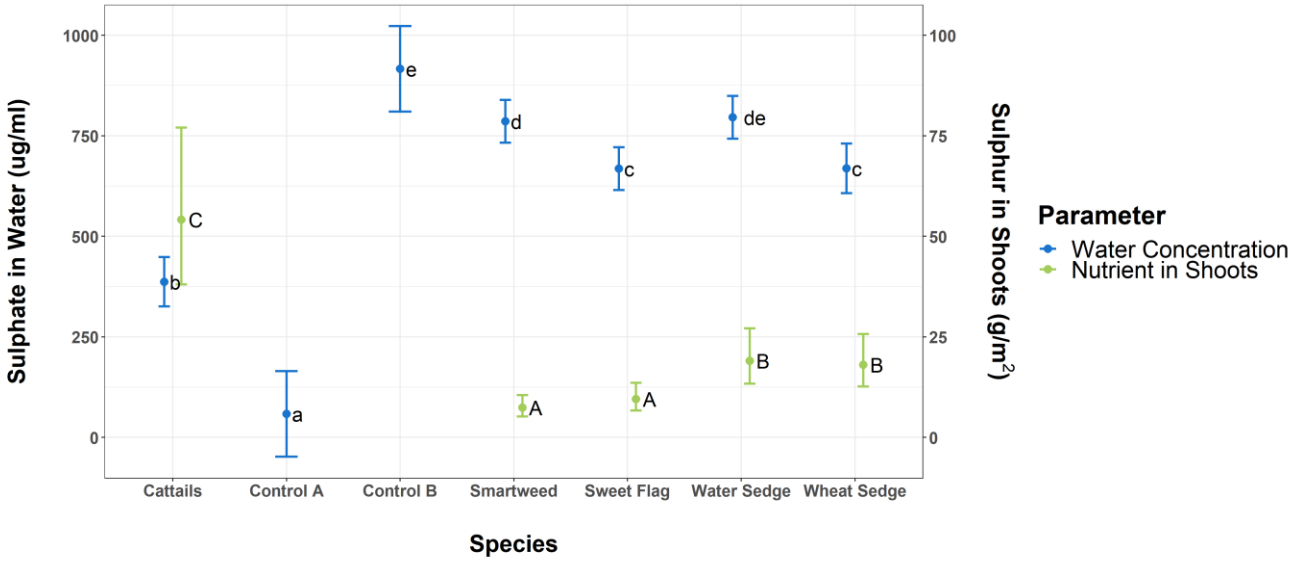

Figure 3.8: Mean sulphate concentration in water and sulphur content in shoots for each plant species and control tank at the conclusion of the trial. Confidence intervals are based on the pooled variance of the ANOVA test. Values were back transformed from the log scale. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

3.5 Other Nutrients

Micro-nutrients were also examined within the plant tissues and residual water concentrations of the tanks and included Boron, Calcium, Copper, Iron, Magnesium, Manganese, and Zinc (Table 2-1). The water concentrations for these metals in the water over the course of the experiment was examined. There were either no significant trends in the water concentrations or final samples taken from the plant tissues, or the control results had unexpected differences from the treatments. The concentrations of these micronutrients were added in very small amounts as part of the Hoagland solution.

Boron concentrations in the tanks started very low initially in the experiment. Minimal decreases were seen for all species treatments, and both controls had minimal increases in boron concentrations by the end of the experiment. Calcium concentrations decreased for the wheat sedge, cattail, and sweet flag treatments. The nutrient spiked control had the largest decline in calcium concentration by the end of the experiment. Copper started at very low concentrations in the treatment tanks, and were observed to decrease in all treatments. The nutrient spiked control did not have similar initial levels of copper concentrations at the beginning of the experiment. Small decreases in iron concentrations were seen over the duration of the experiment for all species except water sedge. Similar to copper, the spiked control did not have comparable initial levels of iron concentrations at the beginning of the experiment. Magnesium concentrations in the tanks decreased over the experiment in the wheat sedge and sweet flag treatments. Increases in magnesium concentrations were observed for the other species and control tanks by the end of the experiment. Manganese concentrations started off very low (below 0.15 ug/L), marginal decreases were observed for three species and the nutrient spiked control. Zinc concentrations in the tanks were observed to increase slightly over time for all of the plant species, except cattails.

Table 3-1: Differences in water micronutrient concentrations from the final sampling date and initial analyzed samples. Negative numbers represent a decrease in the micronutrient concentration by the end of the experiment, and positive numbers represent an increase. Initial samples analyzed were a composite from the treatment replicates, and the final analysis is an average of the results from each treatment replicate.

Species	Boron (ug/ml)	Calcium (ug/ml)	Copper (ug/ml)	Iron (ug/ml)	Magnesium (ug/ml)	Manganese (ug/ml)	Zinc (ug/ml)
Wheat Sedge	-0.048	-59.950	-0.115	-0.473	-18.780	-0.075	0.383
Smartweed	-0.055	18.075	-0.110	-0.155	15.500	0.010	1.028
Cattails	-0.068	-65.250	-0.080	-0.808	2.550	-0.080	-0.238
Sweet Flag	-0.045	-21.925	-0.120	-0.775	-4.550	0.010	1.478
Water Sedge	-0.068	44.725	-0.120	0.065	15.400	-0.090	0.468
Control A	0.040	-21.650	0.010	0.100	2.060	0.000	0.010
Control B	0.040	-146.400	-0.070	-0.090	18.600	-0.060	-0.300

3.6 Plant Tissue Nutrient Composition

The mean concentration of nutrient stored in shoot tissues was compared to the mean concentration of nutrient stored in root tissues for each plant species. For all nutrients, plants tended to have a higher or equal

concentration of nutrient in their roots than their shoots. The only cases where this was not true was in smartweed and water sedge which stored potassium or sulphur in higher concentrations in their shoots, respectively.

Table 2: Concentration of different nutrients in the shoot and root tissue of different plant species.

Species	Nitrogen		Sulphur		Phosphorus		Potassium	
	Shoot %	Root %	Shoot %	Root %	Shoot %	Root %	Shoot %	Root %
Cattail	3.37	3.70	0.64	0.64	0.51	0.76	3.47	5.24
Smartweed	3.51	3.67	0.27	0.37	0.40	0.71	1.60	1.40
Sweet Flag	3.14	3.14	0.28	1.02	0.69	1.89	3.47	7.80
Water Sedge	2.45	3.86	0.45	0.44	0.63	1.14	1.78	2.86
Wheat Sedge	3.04	3.26	0.46	0.59	0.28	0.74	2.57	2.78

3.7 Water Use

The water usage of a plant species was affected by the month of sampling ($p < 0.001$), with the difference between plant species and the control tanks becoming more differentiated as the experiment progressed. Tukey adjusted comparisons were conducted between species for each month separately. In the first month of the experiment there was no difference in water use between any of the species and control tanks. Beginning in month 2, cattails began to use more water than the control tanks and any other species. Water sedge and wheat sedge began to use more water than the control tanks beginning in month 4, and by month 5 of the experiment every species was using more water than the control tanks.

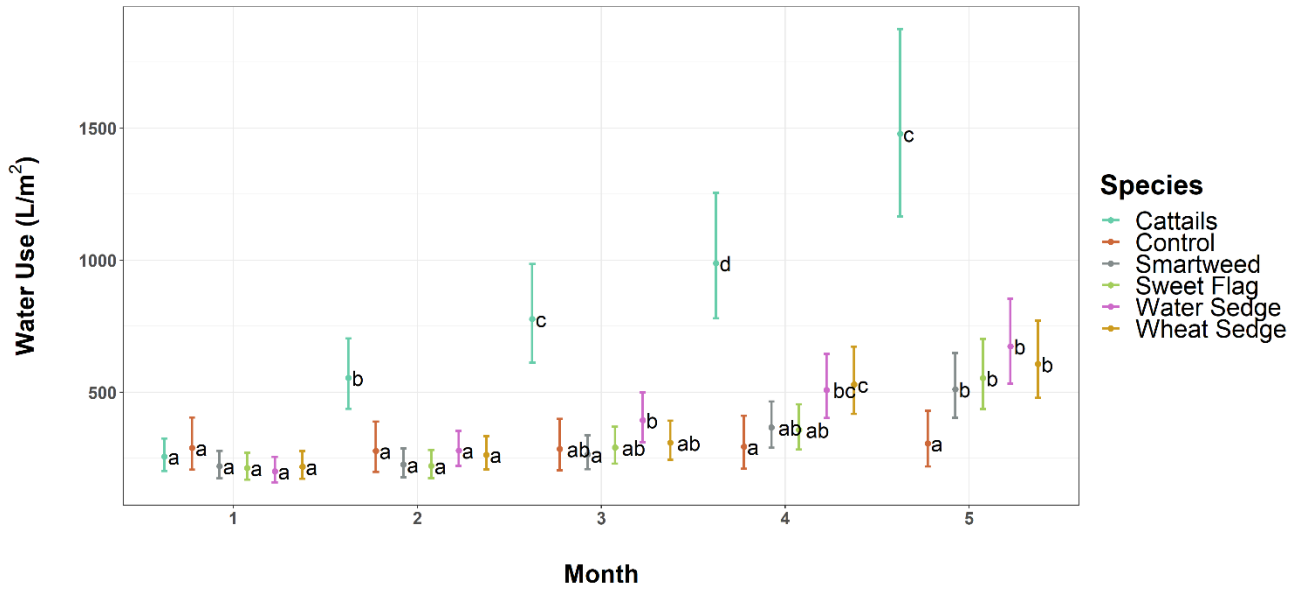

Figure 9: Mean water use for each plant species and control tank. Confidence intervals are based on the pooled variance of the ANOVA test. Values were back transformed from the log scale. Means sharing a grouping letter within each month are not significantly different (Tukey-adjusted comparisons between species in each month).

4.0 Discussion

4.1 Nitrogen

The concentration of nitrogen within plant shoots differed depending on the species, with higher concentrations being stored in cattails and smartweed than in water sedge. Sweet flag and wheat sedge could not be differentiated from the other species in terms of the concentration of nitrogen stored in shoots. When the productivity of each species was taken into account, there was a clearer differentiation between the total amount of nitrogen able to be taken in to the shoots of each species, with cattails being able to store more than any other species. Species with greater biomass production have been found to have increased nutrient removal rates (Pavlineri et al. 2017). The high biomass production of cattail drives its effectiveness for the uptake of nitrogen. While the concentration of nitrogen within shoot growth was not highly differentiated between the different species, the total nitrogen stored within cattail and the low concentration of nitrogen in the residual water show its effectiveness. This makes cattail the most ideal species for uptake of nitrogen in water on floating island systems. However, in certain cases, it may not be appropriate to use cattail in remediation efforts because it can be seen as an undesirable species. Alternative species to cattail would be sweet flag and wheat sedge which followed cattail in their ability to removed nitrogen from the water, but these species did not store significantly more nitrogen in their shoots than water sedge or smartweed.

Plant uptake of nitrogen does not act alone, instead there is a complex ecosystem functioning in the water of wetlands with the microbial biomass acting symbiotically with plants. Biofilm on physical surfaces within the experimental tanks could have influenced nutrient uptake (Tanner and Headley 2011). The microorganisms that make up biofilm can act as an oxygen and carbon source and enhance nitrogen removal rates through the nitrification/denitrification processes (Pavlineri et al. 2017). Within the tanks in this experiment there was no control of the microbial biomass, instead it was allowed to grow and interact with the plants replicating a more real-world condition. Nitrogen fixation was also allowed to occur, showing how nitrogen fixing plants react within nutrient rich environments. Results on nitrogen fixation were inconsistent between the two nitrogen fixing species observed, for sweet flag the nitrogen concentration in the water was lower in than for smartweed, but both had similar amounts of nitrogen stored in their shoots.

The benefits of using nitrogen fixers and species tolerant of low nitrogen conditions (water sedge) are additional considerations when evaluating which species are best suited for a given environment. These plants may perform more effectively than nutrient hungry species like cattail that are not adapted to conditions without available nitrogen.

In the nutrient spiked control (Control B), there was an algae bloom observed that corresponded with a large consumption of nutrients from the water. Nitrogen and phosphorus uptake into the algae bloom likely impacted the results of this experiment. In Control B, nitrogen levels were reduced with a loss of 160ug/ml (22%) over the course of the experiment, which may have led to not finding significant difference between nitrogen removal from the control and all the plant species other than cattail.

4.2 Phosphorous

Phosphorus reduction in the water was only significantly different for the cattail treatment compared to the four other plant species. However, the concentration of phosphorus in the water was not significantly different between cattails and the Control tank B (nutrients added) which has been found in similar experiments due to algae blooms in control tanks (Tanner et al. 2011). An abundance of algae growth occurred in Control tank B,

which likely consumed large amounts of phosphorous in the water, with 130 ug/mL (87%) loss of phosphorus over the duration of the experiment, Control B was not found to be significantly different than Control A that had no nutrients added. While this limited the interpretation of the results in the trials it does not confound the results within the vegetated tanks as the algae bloom was supressed by the shade of the islands and plant growth in the other tanks which was also found in the experiment conducted by Tanner et al. (2011). While cattails removed the most phosphorus from the water (97 ug/mL), the other species were also effective at removing phosphorus with removals ranging from 28 to 83 ug/mL. Sweet flag, wheat sedge, and water sedge followed cattails in their ability to uptake phosphorus with reductions of 45, 37, and 36 % observed, respectively. While these results weren't mirrored exactly in the biomass uptake, they were similar with the total amount of phosphorus in shoots, but the greatest was in cattails, followed by water sedge. Phosphorus concentrations in the shoots were highest in sweet flag, followed by water sedge and cattails. The differences in biomass uptake of phosphorus may be accounted for through root storage. In similar mesocosm experiments investigating phosphorus uptake by plants, there are mixed findings in phosphorus reductions. There are studies that have found that more phosphorus is retained in floating wetland systems through absorption to fine suspended sediments that adhere to biofilm around the roots and physical surfaces in the systems (Tanner and Headley 2011). While White and Cousins (2013) concluded that most phosphorus reductions they observed was through plant uptake and entrapment in the microbial populations among the plant roots.

4.3 Potassium

The concentration of potassium in the water was reduced the greatest by the cattail treatments by the end of the experiment. Wheat sedge and sweet flag followed when examining the final water concentrations and the overall reductions in the potassium concentrations. Cattails also stored more potassium in the shoots, with more than double the weight of potassium stored than sweet flag, which showed the second largest amount stored. Both these species stored similar concentrations of potassium in their shoots, emphasizing the influence of biomass productivity on the ability of different macrophytes to store potassium. In a similar phytoremediation experiment, Saidin et al. (2013) had mixed success in finding macrophytes that reduced potassium concentrations in wastewater, only one of three species they examined reduced potassium levels in the water. This experiment by Saidin et al. (2013) emphasized the importance of maintaining favourable growing conditions to promote plant growth, otherwise decomposition has the unintentional potential to release nutrients. This may be where consideration of the nitrogen fixation ability of sweet flag may be important as it can maintain higher nitrogen levels without nitrogen being available in the environment. The potential loss of potassium back into the ecosystem (Saidin et al. 2013) emphasises the importance of harvesting plant material in some cases and specifically this must be done in the growing season when plants are actively growing so that nutrients cannot be released back into the environment when the plants die back during the dormant season.

4.4 Sulfate

The concentration of sulfate within plant shoots differed depending on the species, with higher concentrations being stored in cattails than in smartweed or sweet flag. Water sedge and wheat sedge could not be differentiated from the other species in terms of the concentration of sulfate stored in shoots. When the productivity of each species was taken into account, there was a clearer differentiation between the total amount of sulfate able to be taken in to the shoots of each species, with cattails being able to store more than any other species. Water sedge and wheat sedge stored less sulphate in their shoot biomass than cattails but more than smartweed or sweet flag. Similar to the other nutrients in this experiment, the high biomass production of cattail drives its ability to store more sulphate per square metre than other species. Cattail's

effectiveness was also demonstrated by the lower concentration of sulphate in the residual water than any other species. A similar study by Zhao et al. (2012) demonstrated that sulphates could be taken up by floating island plants in eutrophic rivers, with the most sulphate being taken up by plants with a higher biomass.

Water sedge or wheat sedge could be considered as an alternative to cattail, as they stored the second highest amount of sulphate in their shoots per square metre. Of these two species, only wheat sedge had a lower concentration of sulphate in residual water than the spiked control (control B), and therefore may be the better candidate of the two. It is not known why there appeared to be an increase of sulphate levels in water tanks near the end of the experiment, but this trend was observed in all tanks except for Control A, indicating that the effect was consistent between treatments and may not have affected comparisons between them.

4.5 Other Nutrients

The micronutrient uptake by the four plant species was quite small in magnitude compared to the macronutrient removals from water. Cattail more consistently removed larger proportions of the metals from the water. The Hoagland solution added to the treatments is generally used as a nutrient solution for optimal growth of hydroponics. While this solution was added at 5 times the optimal concentration, this solution is not a significant source of metals. As this experiment was primarily focused on macronutrient uptake and effectiveness of different native plant species, the concentrated Hoagland Solution worked well for this context and limited conclusions can be made about metal uptake. Some metals were found to increase in some of the treatments and control tanks. The reductions observed for some metals, shows potential for further exploration. Tanner and Headley (2011) found copper concentrations were reduced by up to 75% in floating wetlands islands with simulated stormwater runoff. Few studies in the scientific literature examine metal removal by floating vegetated islands (Borne and Fassman 2011). In addition, further exploration of heavy metal uptake of macrophytes native to Alberta are needed. Most common macrophytes used for heavy metal uptake (e.g., water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*); (Rezania et al. 2016) are not native to Alberta. The metals studied in this experiment were generally trace nutrients and more work will be required in the future to study other metals not represented within this experiment.

4.6 Water Use

Cattail took up the most water with around double the water use of the other species in their fifth month of growth. This aligns with the fact that cattail is generally the largest and fastest growing species with the most biomass available for transpiration to occur. The increase in water use from day 1 of the experiment to the end is heavily tied to the fact the plants started as young plants and matured in months 4 and 5. This means the increase in water use represent the increases in transpiration over time of maturing plants. When plants are mature (months 4 and 5) all species used significantly more water than the control tanks with water alone. This increased water use due to transpiration is supported in previous research into wetland plants including cattail (Pauliukonis and Schneider 2001). The water use results suggest that in mature plants (month 5), secondary to cattail (1490 L/m^2/month), could be water sedge (677 L/m^2/month) and wheat sedge (626 L/m^2/month). Though these two species did not have significantly higher water use than smartweed (533.4L/m^2) and sweet flag (555.5L/m^2) in month 5, water sedge used significantly more water in than smartweed in month 3 and wheat sedge used significantly more water than smartweed or sweet flag in month 4. Our results indicate that the benefit of using evapotranspiration instead of purely evaporation is significant if the intended goal is water removal. These results show what the maximum potential of water removal is under ideal conditions.

In cases where water conservation is important, avoiding the use of cattail would be crucial and minimizing the use of water sedge and wheat sedge would be beneficial. In stormwater pond systems where water removal through evaporation is the goal, there is the possibility to accelerate water removal by 4.9 times the reference control rate by using cattails and up to 2.0 or 2.2 times the reference control rate by using wheat sedge or water sedge respectively. The lowest water use was realized by sweet flag and smartweed, which removed water at rates of 1.8 and 1.7 times evaporation alone (307.2L/m^2). In this case, selection of the sedges, sweet flag and smartweed may be necessary in order to minimize water loss when remediating water.

4.7 Plant Tissue Nutrient Composition

Examining macronutrient storage between roots and shoots for most species generally showed similar ratios of nutrient concentrations, with roots having slightly higher concentrations of macronutrients. Macronutrient concentrations found in the plant tissues for this study were higher for both roots and shoots than similar studies that reported plant tissue nutrient concentrations (Tanner and Headley 2011, White and Cousins 2013). Total biomass data for roots was not investigated for this experiment but a similar study showed total nutrient allocation was correlated with biomass production (Garcia Chance et al. 2019). Both species that Garcia Chance et al. (2019) examined had greater shoot biomass production than roots, and as a result more nutrients were accumulated in the shoots. For their study, peak uptake occurred in September. Up to 33% of nutrient mass was accumulated in the roots for both species examined by Garcia Chance et al (2019), but the allocation ratio of roots to shoots decreased by the end of the growing season, with greater accumulation in the shoots by the end of their study (20 weeks). Further comparison with studies on vegetation nutrient allocation found nutrient accumulation in plant tissues may be affected by species or nutrient availability in the water source (White and Cousins 2013, Garcia Chance et al. 2019). White and Cousins (2013) found roots accumulated greater nutrients than shoot tissues. This result was also found by Tanner and Headley (2011), with nearly half the nutrients accumulated in the root tissues for the both species they studied, common rush and golden canna (*Canna flaccida*). Nutrient accumulation allocation in plant tissue is an important dynamic to understand, and will guide harvest of biomass at the end of the growing season to increase nutrient removal capacities managing feasibility. There is general agreement that whole plant harvest will maximize nutrient removal capacities of floating wetland systems (White and Cousins 2013, Pavlineri et al. 2017, Garcia Chance et al. 2019). However in many cases harvesting roots can be exceedingly challenging and so selection of species that store the highest percentage of nutrients above ground is desirable.

5.0 Research Impact

The results from this experiment shows great potential for removing nutrients for in-situ water treatment using vegetated floating islands. Floating treatment islands can play a role in land stewardship for industries and land development situations that have negative influences on water quality. Improving water quality at the source of contamination is important goal for developing sustainable communities. Stage Two of this research program aims to quantify the capacity of different native plant species to remove nutrients from feedlot effluent. This research will continue to provide the evidence for the application of vegetated treatment islands for practical situations. Clean water is imperative for sustainable communities, and vegetated treatment islands can be implemented in agricultural and urban environments as a water management tool.

6.0 Recommendations

Out of this experiment we have a number of recommendations both for future research as well as for implementation of Phyto-remediation using Floating Island Systems.

6.1 Future Research

Generally, the experimental design was functional and allowed for effective assessment of the potential uptake of nutrients by plants, but a number of improvements to the methodology are recommended for future research in particular.

1) All tanks should be sampled at day 1 after spiking with nutrients. Waiting one day for sampling will allow for nutrients to more uniformly mix throughout the tank, but minimal uptake will have occurred. This data will then be available to use as a covariate in the final analysis eliminating issues with different starting levels of nutrients between tanks. This will be critical when moving into natural water testing where there will be variations in the water ending up in each tank.
2) Algae blooms are a critical issue in testing and as we noted in this experiment the control tank B had an algae bloom which changed the nutrient profile within the tank. The algae removed much of the nitrogen and phosphorus making comparisons with control tank B unreliable. Elimination of the algae bloom through chemical means will prevent this issue although it could impact nitrogen fixing bacteria in some species. An alternate approach to chemical control would be a shade (equivalent size of the experimental islands) placed within the control tanks to limit photosynthesis.
3) Note nitrogen fixing bacteria and their relationship with some species. This may not impact results as much as interpretation. If these bacteria are killed as noted above during control of algae blooms the results will not show real world implications for this species. Avoiding killing bacteria is desirable and selection of methods to limit algae blooms while allowing growth from bacteria will provide more real world results.
4) Ammonia analysis should be completed for effluent and likely agricultural wastewater.
5) The same size tank or larger is necessary for wetland plants to be tested. Smaller tanks may be good for smaller scale testing of uptake and concentrations within the plant biomass of younger plants. Due to significant water use by the plants and large biomass production for some species larger tanks are necessary for analysis of nutrient uptake and water use.

6.2 Recommendations for Implementation

There were a number of clear results within this experiment that can be implemented in real world situations. However careful assessment of each application is required to ensure the right recommendations are implemented.

1) **Shoot biomass:**
   Shoot biomass is the most important for nutrient removal and will require harvesting to remove the nutrients from the waterbody. Species that uptake significant nutrients in their roots are not as useful as this biomass is not easily removed. Without removal of biomass produced annually, nutrients or metals accumulated may be returned to the water over time. However, it will be important to account for nutrients that are bound up in an organic form and cannot be released easily (potential for root tissue). Therefore, focus on species with substantial shoot concentrations of the target nutrient in addition to large biomass production is recommended.

2) **Nitrogen removal:**
Nitrogen removal is possible using several species. Depending on the project requirements cattail or the large sedges can effectively remove nitrogen. Nitrogen removal is not recommended using nitrogen fixing species as they do not uptake nitrogen purely form the water and as such the nitrogen concentration in their biomass is not related to the amount removed in water. This means that depending on the specific conditions they may or may not remove nitrogen from the ecosystem.
3) **Nitrogen deficient systems:**
Nitrogen fixing species may be required in other projects where nitrogen is deficient in the system and another nutrient or metal needs to be removed.
4) **Phosphorus uptake:**
Phosphorus uptake is possible, and cattails had the highest uptake from the water but storage was not significantly higher than water sedge. This provides two species that are good options for phosphorus collection in shoots. However, cattail was the only species that ended up with phosphorus levels that were not significantly different than the untreated control.
5) **Potassium:**
Potassium is best removed by cattail although there was significant removal from all other species, this rate was lower than that of cattail and would require significantly more surface area (double to triple) to put as many grams of potassium into shoots. However, the best candidates from the other species are sweet flag and wheat sedge.
6) **Sulphate:**
Cattail had the best ability to remove sulphate effectively from the water and store it in its shoots. Within the water concentrations sweet flag and wheat sedge showed the best potential to reduce sulphur outside of cattail.
7) Best Species:
Cattail - All around the most effective species due to its productivity and biomass production. Although it did not necessarily have the highest concentrations of nutrients within its biomass it was able to make up for this in many cases with its biomass. However, some metrics did not favor it.
Wheat Sedge and Water Sedge - These two species tend to have the next best characteristics for many metrics. They may be useful in nitrogen deprived systems as they do not have the requirements for nitrogen that cattail does.
Sweet flag – This species was effective in a number of metrics and as a nitrogen fixer it can be effective in uptake where no nitrogen is available.
Smartweed – This species did not preform as effectively as other species in almost any metric although it did take up manganese fairly well.

Acknowledgements

Funding, support and materials for this research was provided by:

High Field investment Group

Certification Page

I hereby certify that:

The requested surveys and reporting were completed by qualified professionals (Steven Tannas, Daina Anderson and Jamie Kalla) who considered all factors and influences that are within the scope of this assessment.

No person at Tannas Conservation Services Ltd., or associated sub-consultant working on this project have any contemplated interest in the property being assessed.

This report has been completed in conformity with the standards and ethics of the Alberta Institute of Agrologists and the Alberta Society of Professional Biologists.

Respectfully submitted:

Steven Tannas PhD. P.Ag.

President: Tannas Conservation Services Ltd.

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Appendix A

Photo Log

Photo 1: Water sedge (*Carex aquatilis*) at the beginning of the experiment (February 18, 2019).

Photo 2: Water sedge (*Carex aquatilis*) at the end of the experiment (August 1, 2019).

Photo 3: Wheat sedge (*Carex atherodes*) at the beginning of the experiment (February 18, 2019).

Photo 4: Wheat sedge (*Carex atherodes*) at the end of the experiment (August 1, 2019).

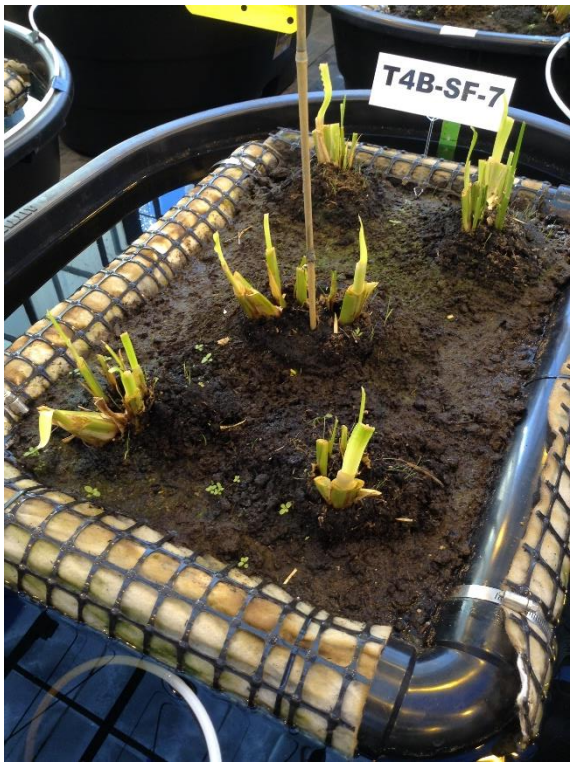

Photo 5: Sweet flag (*Acorus calamus*) at the beginning of the experiment (February 18, 2019).

Photo 6: Sweet flag (*Acorus calamus*) at the end of the experiment (August 1, 2019).

Photo 7: Smartweed (*Polygonum amphibium*) at the beginning of the experiment (February 18, 2019).

Photo 8: Smartweed (*Polygonum amphibium*) at the end of the experiment (August 1, 2019).

Photo 9: Cattail (*Typha latifolia*) at the beginning of the experiment (February 18, 2019).

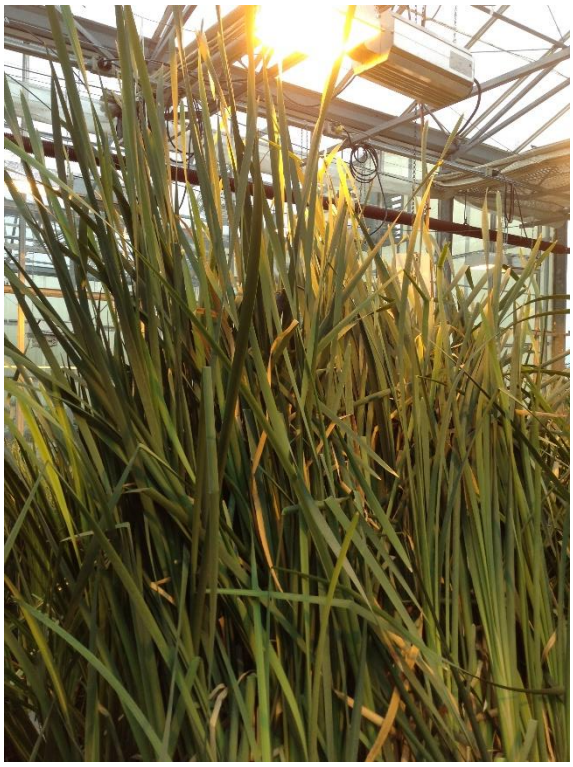

Photo 10: Cattail (*Typha latifolia*) at the end of the experiment (August 1, 2019).

Photo 11: Control tanks on March 1, 2019. Control A is the bottom tank, Control B is the top tank.

Photo 12: Control tanks on August 1, 2019. Control A is the bottom tank, Control B is the top tank.

Photo 13: *Acorus calamus* roots on August 8, 2019

Photo 14: *Carex aquatilus* roots on August 8, 2019

Photo 15: *Carex atherodes* roots on August 8, 2019

Photo 16: *Polygonum coccinium* roots on August 8, 2019

Photo 17: *Typha latifolia* roots on August 8, 2019

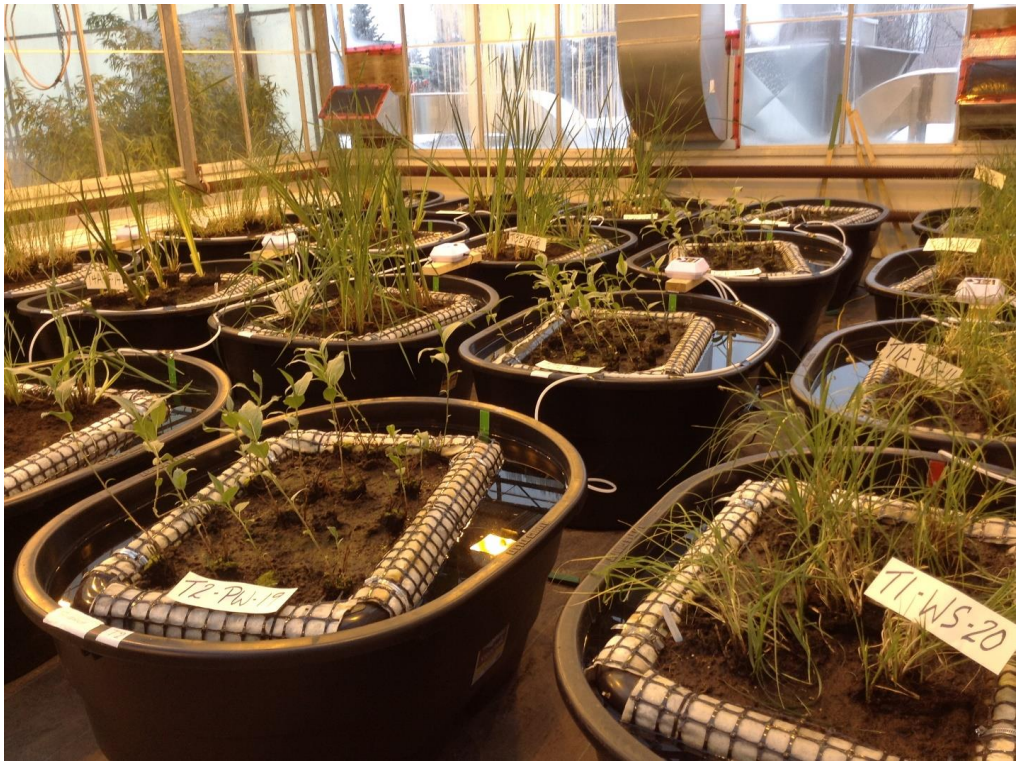

Photo 18: View of the experimental setup within the greenhouse.

Appendix B

Summary Statistics

ANOVA and Post hoc Test Results

Concentration of Nutrients in Water

Table 1: Mean phosphorous (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	0.23	12.48563	13	-39.421	39.88104	a
Cattails	12.14333	7.208584	13	-10.7492	35.03587	a
Control B	20.26	12.48563	13	-19.391	59.91104	a
Sweet Flag	100.555	6.242817	13	80.72948	120.3805	b
Water Sedge	112.2	6.242817	13	92.37448	132.0255	bc
Wheat Sedge	123.9333	7.208584	13	101.0408	146.8259	bc
Smartweed	141.275	6.242817	13	121.4495	161.1005	c

Table 2: Mean potassium (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	1.71	26.9165	13	-83.7696	87.18962	a
Cattails	131.19	15.54025	13	81.83832	180.5417	b
Wheat Sedge	289.3	15.54025	13	239.9483	338.6517	c
Sweet Flag	385.05	13.45825	13	342.3102	427.7898	d
Water Sedge	530.2	13.45825	13	487.4602	572.9398	e
Smartweed	655.05	13.45825	13	612.3102	697.7898	f
Control B	866.2	26.9165	13	780.7204	951.6796	g

Table 3: Mean nitrogen (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	-1.13687E-13	77.84864589	13	-247.2265043	247.2265043	a
Cattails	171.4333333	44.94593666	13	28.69704453	314.1696221	ab
Wheat Sedge	268	44.94593666	13	125.2637112	410.7362888	abc
Sweet Flag	307.825	38.92432294	13	184.2117479	431.4382521	bc
Water Sedge	530.525	38.92432294	13	406.9117479	654.1382521	d
Control B	566.7	77.84864589	13	319.4734957	813.9265043	cd
Smartweed	711.25	38.92432294	13	587.6367479	834.8632521	d

Table 4: Mean total dissolved solids (ug/ml) and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	186.082	189.0645481	13	-414.3365014	786.5005014	a
Cattails	1380.49	109.1564677	13	1033.838217	1727.141783	b
Wheat Sedge	1987.167667	109.1564677	13	1640.515883	2333.81945	c
Sweet Flag	2283.44425	94.53227403	13	1983.234999	2583.653501	c
Water Sedge	3302.9595	94.53227403	13	3002.750249	3603.168751	d
Smartweed	3570.5935	94.53227403	13	3270.384249	3870.802751	d
Control B	3599.8	189.0645481	13	2999.381499	4200.218501	d

Table 5: Mean SAR and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control B	0.222	0.035746705	13	0.108478013	0.335521987	a
Smartweed	0.26	0.017873353	13	0.203239007	0.316760993	a
Control A	0.277	0.035746705	13	0.163478013	0.390521987	ab
Wheat Sedge	0.418	0.02063837	13	0.35245805	0.48354195	bc
Water Sedge	0.42825	0.017873353	13	0.371489007	0.485010993	c
Cattails	0.532	0.02063837	13	0.46645805	0.59754195	d
Sweet Flag	0.5775	0.017873353	13	0.520739007	0.634260993	d

Table 6: Mean calcium (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	33.1	30.46833	13	-63.6593	129.8593	a
Cattails	243.1333	17.5909	13	187.2693	298.9973	b
Wheat Sedge	279	17.5909	13	223.136	334.864	b
Sweet Flag	300.075	15.23417	13	251.6954	348.4546	b
Control B	328.5	30.46833	13	231.7407	425.2593	b
Water Sedge	482.225	15.23417	13	433.8454	530.6046	c
Smartweed	489.375	15.23417	13	440.9954	537.7546	c

Table 7: Mean iron (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	0.1	0.23565	13	-0.64836	0.84836	ab
Cattails	0.15	0.136052	13	-0.28207	0.582066	a
Control B	0.19	0.23565	13	-0.55836	0.93836	abc
Sweet Flag	0.375	0.117825	13	0.00082	0.74918	ab
Smartweed	0.805	0.117825	13	0.43082	1.17918	bcd
Water Sedge	1.025	0.117825	13	0.65082	1.39918	cd
Wheat Sedge	1.31	0.136052	13	0.877934	1.742066	d

Table 8: Mean magnesium (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	20.75	9.464089	13	-9.30542	50.80542	a
Cattails	105.8	5.464094	13	88.4475	123.1525	b
Sweet Flag	158.15	4.732044	13	143.1223	173.1777	c
Wheat Sedge	162.9667	5.464094	13	145.6142	180.3192	c
Smartweed	188.8	4.732044	13	173.7723	203.8277	d
Water Sedge	192.3	4.732044	13	177.2723	207.3277	d
Control B	203.3	9.464089	13	173.2446	233.3554	d

Table 9: Mean manganese (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	-6.24989E-17	0.03782551	13	-0.120123717	0.120123717	abc
Control B	3.84479E-17	0.03782551	13	-0.120123717	0.120123717	abc
Water Sedge	5.44414E-17	0.018912755	13	-0.060061858	0.060061858	a
Cattails	6.33995E-17	0.021838569	13	-0.06935346	0.06935346	ab
Sweet Flag	0.1	0.018912755	13	0.039938142	0.160061858	c
Wheat Sedge	0.1	0.021838569	13	0.03064654	0.16935346	bc
Smartweed	0.14	0.018912755	13	0.079938142	0.200061858	c

Table 10: Mean sulphate (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	58.02	33.51019076	13	-48.39941455	164.4394146	a
Cattails	386.7	19.34711765	13	325.2587224	448.1412776	b
Sweet Flag	668.175	16.75509538	13	614.9652927	721.3847073	c
Wheat Sedge	668.9	19.34711765	13	607.4587224	730.3412776	c
Smartweed	786.15	16.75509538	13	732.9402927	839.3597073	d
Water Sedge	795.75	16.75509538	13	742.5402927	848.9597073	de
Control B	916.2	33.51019076	13	809.7805854	1022.619415	e

Table 11: Mean zinc (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control B	0.04	0.747657	13	-2.33436	2.41436	a
Control A	0.07	0.747657	13	-2.30436	2.44436	a
Cattails	0.093333	0.43166	13	-1.2775	1.464171	a
Water Sedge	0.8475	0.373829	13	-0.33968	2.03468	a
Wheat Sedge	1.09	0.43166	13	-0.28084	2.460838	a
Smartweed	1.5675	0.373829	13	0.38032	2.75468	a
Sweet Flag	1.8675	0.373829	13	0.68032	3.05468	a

Table 12: Mean sulphur (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	19.34	11.17006	13	-16.1331	54.81314	a
Cattails	128.9	6.449039	13	108.4196	149.3804	b
Sweet Flag	222.725	5.585032	13	204.9884	240.4616	c
Wheat Sedge	222.9667	6.449039	13	202.4862	243.4471	c
Smartweed	262.05	5.585032	13	244.3134	279.7866	d
Water Sedge	265.25	5.585032	13	247.5134	282.9866	de
Control B	305.4	11.17006	13	269.9269	340.8731	e

Table 13: Mean sodium (ug/ml) concentration and pooled standard error in water samples taken from controls and plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Control A	8.3	3.255033	13	-2.03711	18.63711	a
Control B	20.89	3.255033	13	10.55289	31.22711	ab
Smartweed	26.845	1.627516	13	21.67644	32.01356	b
Wheat Sedge	35.70667	1.879294	13	29.73853	41.6748	c
Cattails	39.60333	1.879294	13	33.6352	45.57147	c
Water Sedge	44.04	1.627516	13	38.87144	49.20856	cd
Sweet Flag	49.7475	1.627516	13	44.57894	54.91606	d

Concentration of Nutrients in Shoot Tissue

Table 14: Mean percent nitrogen and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Water Sedge	2.4525	0.158251	15	1.98777	2.91723	a
Wheat Sedge	3.0425	0.158251	15	2.57777	3.50723	ab
Sweet Flag	3.135	0.158251	15	2.67027	3.59973	ab
Cattails	3.3675	0.158251	15	2.90277	3.83223	b
Smartweed	3.5125	0.158251	15	3.04777	3.97723	b

Table 15: Mean percent potassium and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	1.5975	0.197662	15	1.017032	2.177968	a
Water Sedge	1.7775	0.197662	15	1.197032	2.357968	ab
Wheat Sedge	2.57	0.197662	15	1.989532	3.150468	b
Cattails	3.4675	0.197662	15	2.887032	4.047968	c
Sweet Flag	3.47	0.197662	15	2.889532	4.050468	c

Table 16: Mean percent phosphorous and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Wheat Sedge	0.28	0.055689	15	0.11646	0.44354	a
Smartweed	0.4025	0.055689	15	0.23896	0.56604	ab
Cattails	0.505	0.055689	15	0.34146	0.66854	abc
Water Sedge	0.63	0.055689	15	0.46646	0.79354	bc
Sweet Flag	0.685	0.055689	15	0.52146	0.84854	c

Table 17: Mean percent calcium and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Cattails	0.785	0.128527	15	0.407559	1.162441	a
Wheat Sedge	1.0525	0.128527	15	0.675059	1.429941	a
Sweet Flag	1.0575	0.128527	15	0.680059	1.434941	a
Water Sedge	1.24	0.128527	15	0.862559	1.617441	ab
Smartweed	1.755	0.128527	15	1.377559	2.132441	b

Table 18: Mean iron (ppm) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Cattails	75.75	9.549651	15	47.70587	103.7941	a
Sweet Flag	112.25	9.549651	15	84.20587	140.2941	ab
Wheat Sedge	126.25	9.549651	15	98.20587	154.2941	b

Smartweed	146.75	9.549651	15	118.7059	174.7941	b
Water Sedge	205.25	9.549651	15	177.2059	233.2941	c

Table 19: Mean percent magnesium and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Cattails	0.24	0.038923	15	0.125696	0.354304	a
Water Sedge	0.3625	0.038923	15	0.248196	0.476804	ab
Wheat Sedge	0.4125	0.038923	15	0.298196	0.526804	bc
Smartweed	0.5625	0.038923	15	0.448196	0.676804	cd
Sweet Flag	0.5825	0.038923	15	0.468196	0.696804	d

Table 20: Mean manganese (ppm) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Cattails	64.5	56.45895	15	-101.301	230.301	a
Water Sedge	140	56.45895	15	-25.801	305.801	a
Wheat Sedge	237.25	56.45895	15	71.44896	403.051	a
Sweet Flag	303	56.45895	15	137.199	468.801	a
Smartweed	598.5	56.45895	15	432.699	764.301	b

Table 21: Mean zinc (ppm) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Sweet Flag	33.25	36.47962	15	-73.8784	140.3784	a
Cattails	39.25	36.47962	15	-67.8784	146.3784	ab
Smartweed	72.25	36.47962	15	-34.8784	179.3784	ab
Wheat Sedge	167.75	36.47962	15	60.62156	274.8784	ab
Water Sedge	198.25	36.47962	15	91.12156	305.3784	b

Table 22: Mean percent sulphur and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	0.2675	0.045442	15	0.134051	0.400949	a
Sweet Flag	0.28	0.045442	15	0.146551	0.413449	a
Water Sedge	0.4475	0.045442	15	0.314051	0.580949	ab
Wheat Sedge	0.4575	0.045442	15	0.324051	0.590949	ab
Cattails	0.6425	0.045442	15	0.509051	0.775949	b

Table 23: Mean percent sodium and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Wheat Sedge	0.01	0.003708	15	-0.00089	0.020889	a
Smartweed	0.01	0.003708	15	-0.00089	0.020889	a
Water Sedge	0.0125	0.003708	15	0.001611	0.023389	ab
Sweet Flag	0.0175	0.003708	15	0.006611	0.028389	ab
Cattails	0.0275	0.003708	15	0.016611	0.038389	b

Mass of Nutrients per m^2

Table 24: Mean nitrogen content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	97.69968	12.98458	15	59.56832	135.831	a
Water Sedge	108.268	12.98458	15	70.13664	146.3994	a
Sweet Flag	108.3164	12.98458	15	70.18504	146.4478	a
Wheat Sedge	123.9927	12.98458	15	85.86136	162.1241	a
Cattails	287.8331	12.98458	15	249.7017	325.9644	b

Table 25: Mean potassium content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	44.25836	16.64243	15	-4.6149	93.13162	a

Water Sedge	78.01748	16.64243	15	29.14422	126.8907	ab
Wheat Sedge	110.5073	16.64243	15	61.63406	159.3806	ab
Sweet Flag	119.177	16.64243	15	70.3037	168.0502	b
Cattails	296.5329	16.64243	15	247.6597	345.4062	c

Table 26: Mean phosphorous content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	11.15244	4.055612	15	-0.75753	23.06241	a
Wheat Sedge	12.00168	4.055612	15	0.091705	23.91165	a
Sweet Flag	24.00684	4.055612	15	12.09687	35.91681	a
Water Sedge	28.34268	4.055612	15	16.43271	40.25265	ab
Cattails	43.4176	4.055612	15	31.50763	55.32757	b

Table 27: Mean calcium content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Sweet Flag	36.7702	6.879942	15	16.56611	56.97429	a
Wheat Sedge	42.52268	6.879942	15	22.31859	62.72677	ab
Smartweed	49.50768	6.879942	15	29.30359	69.71177	ab
Water Sedge	53.8478	6.879942	15	33.64371	74.05189	ab
Cattails	68.073	6.879942	15	47.86891	88.27709	b

Table 28: Mean iron content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Sweet Flag	38.65616	7.198311	15	17.51713	59.79519	a
Smartweed	40.88452	7.198311	15	19.74549	62.02355	a
Wheat Sedge	52.5594	7.198311	15	31.42037	73.69843	a
Cattails	64.21756	7.198311	15	43.07853	85.35659	ab
Water Sedge	90.7338	7.198311	15	69.59477	111.8728	b

Table 29: Mean magnesium content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	15.67152	2.092921	15	9.525311	21.81773	a
Water Sedge	16.07388	2.092921	15	9.927671	22.22009	a
Wheat Sedge	16.74936	2.092921	15	10.60315	22.89557	a
Cattails	20.21708	2.092921	15	14.07087	26.36329	a
Sweet Flag	20.33716	2.092921	15	14.19095	26.48337	a

Table 30: Mean manganese content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Cattails	59.39912	23.86166	15	-10.6746	129.4728	a
Water Sedge	61.55444	23.86166	15	-8.51927	131.6282	a
Wheat Sedge	96.64636	23.86166	15	26.57265	166.7201	ab
Sweet Flag	108.0038	23.86166	15	37.93005	178.0775	ab
Smartweed	167.6513	23.86166	15	97.57757	237.725	b

Table 31: Mean zinc content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Sweet Flag	11.29636	19.42803	15	-45.7573	68.34998	a
Smartweed	20.6156	19.42803	15	-36.438	77.66922	a
Cattails	33.41736	19.42803	15	-23.6363	90.47098	a
Wheat Sedge	67.96284	19.42803	15	10.90922	125.0165	a
Water Sedge	93.17372	19.42803	15	36.1201	150.2273	a

Table 32: Mean sulphur content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons). Analysis was performed on log transformed values which were back transformed for reporting.

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	7.35531578	0.885437534	15	5.165002806	10.47447064	a
Sweet Flag	9.505215867	1.144243857	15	6.674691895	13.53607479	a
Wheat Sedge	18.02000275	2.169259251	15	12.65389108	25.66171125	b
Water Sedge	19.04041656	2.292097306	15	13.37043954	27.11485001	b
Cattails	54.09273642	6.511717588	15	37.98465541	77.03174087	c

Table 33: Mean sodium content (g/m^2) and pooled standard error in shoot samples taken from plant species. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Smartweed	0.27912	0.331552	15	-0.69454	1.252778	a
Wheat Sedge	0.418	0.331552	15	-0.55566	1.391658	a
Water Sedge	0.53132	0.331552	15	-0.44234	1.504978	a
Sweet Flag	0.59896	0.331552	15	-0.3747	1.572618	a
Cattails	2.39676	0.331552	15	1.423102	3.370418	b

Water Usage

Table 34: Mean water usage (L/m^2) and pooled standard error in tanks of different plant species grouped by month. Means sharing a grouping letter are not significantly different (Tukey-adjusted comparisons).

Species	Month	Mean	Standard Error	Degrees of Freedom	Lower Confidence Limit	Upper Confidence Limit	Group
Water Sedge	1	201.1696	17.71542	80	158.6311	255.1151	a
Sweet Flag	1	214.0908	18.85329	80	168.8201	271.5013	a
Wheat Sedge	1	218.5849	19.24905	80	172.3639	277.2005	a
Smartweed	1	219.8647	19.36176	80	173.3731	278.8236	a
Cattails	1	256.5611	22.59332	80	202.3098	325.3604	a
Control	1	289.1664	36.0124	80	206.6512	404.6297	a
Sweet Flag	2	222.0493	19.55414	80	175.0957	281.594	a
Smartweed	2	226.2196	19.92138	80	178.3842	286.8825	a
Wheat Sedge	2	262.9923	23.15967	80	207.3811	333.5162	a
Control	2	277.8625	34.60462	80	198.5729	388.8122	a
Water Sedge	2	278.9644	24.5662	80	219.9758	353.7714	a
Cattails	2	554.8539	48.86162	80	437.5269	703.6432	b

Smartweed	3	265.1186	23.34691	80	209.0578	336.2127	a
Control	3	285.3564	35.53791	80	203.9284	399.2984	ab
Sweet Flag	3	291.3552	25.65736	80	229.7465	369.4849	ab
Wheat Sedge	3	309.1465	27.2241	80	243.7757	392.0471	ab
Water Sedge	3	394.5983	34.74917	80	311.1583	500.4136	b
Cattails	3	776.6912	68.39708	80	612.4554	984.9683	c
Control	4	293.6732	36.57366	80	209.8719	410.936	a
Sweet Flag	4	358.2033	31.54415	80	282.4592	454.2589	ab
Smartweed	4	366.745	32.29635	80	289.1947	465.0912	ab
Water Sedge	4	509.3122	44.85112	80	401.6153	645.8891	bc
Wheat Sedge	4	529.9965	46.67262	80	417.9257	672.1201	c
Cattails	4	989.0558	87.09836	80	779.9143	1254.281	d
Control	5	306.866	38.21668	80	219.3001	429.3967	a
Smartweed	5	511.6231	45.05463	80	403.4375	648.8198	b
Sweet Flag	5	553.5145	48.74367	80	436.4707	701.9447	b
Wheat Sedge	5	607.2771	53.47811	80	478.8649	770.1242	b
Water Sedge	5	673.9153	59.34642	80	531.4121	854.6321	b
Cattails	5	1478.349	130.1866	80	1165.744	1874.783	c

One Way ANOVA Results

Table 35: One Way ANOVA results from testing the concentration of nutrients in water in different plant species (and controls)

Response Variable	Degrees of Freedom	F Value	P Value
Phosphorous	6, 13	50.671	2.855e-08
Potassium	6, 13	218.54	2.779e-12
Nitrate	6, 13	24.368	2.331e-06
TDS	6, 13	86.028	1.052e-09
SAR	6, 13	39.023	1.411e-07
Calcium	6, 13	55.273	1.669e-08
Iron	6, 13	10.565	0.0002323
Magnesium	6, 13	69.967	3.848e-09
Manganese[1]	6, 13	8.04	0.0008957
Sulphate	6, 13	117.22	1.486e-10
Zinc	6, 13	2.5752	0.07209
Sulphur	6, 13	117.22	1.486e-10
Sodium	6, 13	37.266	1.865e-07

1. Issues with data normality in model

Table 36: One Way ANOVA results from testing the concentration of nutrients in shoots of different plant species

Response Variable	Degrees of Freedom	F Value	P Value
Phosphorous	4, 15	8.7912	0.0007313
Potassium	4, 15	20.406	6.28e-06
Nitrogen	4, 15	6.6433	0.002771
Calcium	4, 15	7.8922	0.001242
Iron	4, 15	25.118	1.693e-06
Magnesium	4, 15	13.491	7.377e-05
Manganese	4, 15	13.27	8.103e-05
Zinc[1]	4, 15	4.3464	0.01564
Sulphur	4, 15	11.443	0.0001843
Sodium	4, 15	3.9545	0.02189

1. Issues with data normality in model

Table 37: One Way ANOVA results from testing the nutrient content (g/m^2) in shoots of different plant species

Response Variable	Degrees of Freedom	F Value	P Value
Phosphorous	4, 15	10.711	0.0002632
Potassium	4, 15	34.556	2.094e-07
Nitrogen	4, 15	38.219	1.064e-07
Calcium	4, 15	3.0238	0.05155
Iron	4, 15	8.7095	0.0007662
Magnesium	4, 15	1.1924	0.3543
Manganese	4, 15	3.4113	0.03572
Zinc[1]	4, 15	3.1211	0.04695
Sulphur[2]	4, 15	41.305	6.287e-08
Sodium[1]	4, 15	6.9806	0.002212

1. Issues with data normality in model
2. Analysis performed on log transformed values

Table 38: Two Way ANOVA results from testing the water usage (L/m^2) in tanks of different plant species by month. Analysis was performed on log transformed response values

Independent Variables	Degrees of Freedom	F Value	P Value
Species	5, 80	64.8464	< 2.2e-16
Month	4, 80	123.2716	< 2.2e-16
Species*Month	20, 80	4.9198	1.374e-07