How do invasive cattail (*Typha x glauca*) management treatments affect nutrient cycling and potential for reinvasion?

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Abstract

In the last 50 years, industrial agriculture has largely contributed to the quadrupling of biologically available nitrogen and phosphorus through the excessive use of fertilizers. Excess nutrients run-off into wetlands, causing water and soil enrichment that promotes plant invasions. *Typha X glauca*, is a common invasive plant throughout eastern North America, where managers use harvesting, mowing, or herbiciding to control its dominance, but it is unknown how these treatments effect nutrient cycling. This study tested how these treatments affect wetland nutrient content (NO_3^-, NH_4^+, PO_4^-) in soil pore water, native and *Typha* density, and light attenuation curves. After 17 days, herbicide had higher PO_4^- concentrations (p=0.004) than harvest treatments, and 24 days after treatment, herbicide had higher phosphate concentration (p=0.05) than all other treatments. Harvest treatments promoted higher native density than mowing or herbiciding, which may be a result of increased light penetration to the soil surface. Together, these data suggest that harvesting has multiple benefits and should be considered by managers aiming to reduce *Typha* density, increase native abundance, and avoid leaching nutrients downstream.

Introduction

Wetlands are situated between terrestrial and aquatic systems where they play a role in flood abatement, biological productivity, and improvement of water quality (Zedler and Kercher 2005). When terrestrial run-off containing pollutants and nutrients enter a wetland, they can be retained, transformed, or buried through biogeochemical processes. Nitrogen in wetlands can be transformed into NO_3^-, nitrous oxide (N_2O), organic nitrogen, or NH_4^+ through microbial processes, which can either be taken up through the roots of plants, released into the atmosphere, or exported downstream to freshwater aquatic

systems. For example, Great Lakes coastal wetlands retain an estimated 53,000 tons of nitrogen per year, providing an important ecosystem service by improving Great Lakes water quality (Sierszen et al., 2012). Likewise, wetlands play a key role in the phosphorus cycle by sequestering phosphorus that binds to soil particles, uptake into plant tissues, or release to downstream systems (Zedler and Kercher, 2005). The usage and storage of nitrogen and phosphorus in wetlands prevents nutrient enrichment and algal blooms that can lead to eutrophication within the wetland and in adjacent aquatic systems (Zedler and Kercher, 2005).

Globally, biologically available nitrogen and phosphorus have increased dramatically with the widespread implementation of industrial agriculture. The amount of land-based nitrogen that enters the nitrogen cycle doubled with the introduction of fertilizer manufacturing in the 1960s, increased use of nitrogen-fixing crops, and fossil fuel burning (Vitousek et al., 1997). The global demand for phosphorus is projected "to increase by 50-100% by 2050" due to dietary changes and food demand (Cordell et al., 2009). While wetlands can transform N and P and reduce their export downstream to aquatic systems, excessive nutrient loading from agricultural and urban runoff tends to promote invasion by dominant macrophytes (Zedler and Kercher, 2004). If water levels decrease, aerobic conditions would release nutrients that would not have been available before (Zedler and Kercher, 2005). The release of these nutrients promotes invasive species that can out compete native species due to their tolerance to a wide range of environmental factors and competitive dominance (Zedler and Kercher, 2005).

Wetlands throughout eastern North America and the Great Lakes region are experiencing an increase in hybrid cattail (*Typha X glauca*) (Galatowitsch et al., 1999), which expands in response to nutrient enrichment (Woo and Zedler 2002) and hydrologic changes (Boers and Zedler 2008, Lishawa et al. 2010). In a Great Lakes coastal wetland, *Typha x glauca* was associated with nutrient-rich soils, low biological diversity, high litter biomass, and high levels of soil organic matter (Tuchmann et al., 2009). Larkin et al. (2013) and Tuchmann et al. (2009) also found that *Typha* enriches its soils, generating plant-soil feedbacks that sustains its dominance.

Another mechanism by which *Typha x glauca* further displaces native species is through dense litter accumulation. *Typha* litter accumulates on the wetland surface,

creating a thick canopy that does not allow sunlight to penetrate and reduces native seed germination (Vaccaro et al. 2009). Also, lower species richness, biomass accumulation of plant species and nutrient levels in wetlands can result by the combination of *Typha* litter and living *Typha* instead of one or the other (Larkin et al., 2011).

Because *Typha x glauca* alters biodiversity and ecosystem function, it is a large management concern, though information on how to effectively manage the species is limited. It is unknown which treatments are most effective at managing the regrowth of *Typha* and reducing nutrient levels in wetlands. However, there are studies that have analyzed the effectiveness of mechanical, biological, or chemical treatments other wetland invaders.

Wilson et al. (2007) tested how effective mowing can reduce regrowth of alligator weed (*Alternanthera philoxeroides*) in wetlands. While mowing did not affect the abundance of *A. philoxeroides,* it resulted in higher below-ground biomass and higher ratio of stem to leaf biomass, which may reduce native species and promote *A. philoxeroides* dominance (Wilson et al., 2007). Management treatments are typically implemented to reduce the abundance of invasive species, though their effects on nutrient cycling are seldom studied. Findlay et al. (2002) investigated the effects of removal treatments on nutrient cycling in common reed (*Phragmites australis*) dominated wetlands. One year post herbicide treatment, Findlay et al. (2002) found ammonium concentrations in porewater to be four times higher to reference communities. While herbiciding reeds in the marsh promoted greater plant diversity, it might promote further invasion or export of nitrogen to aquatic systems by increasing porewater concentrations. In the Florida Everglades, Martin et al. (2010) analyzed how the application of biological and herbicidal treatments to an Australian tree (*Melaleuca quinquenervia*) can affect nutrient cycling. There was no difference in the nitrogen availability between sites that received the biological and herbicidal treatments (Martin et al., 2010). Phosphorus availability differed for sites before and after a fire occurred on the sites. Before the fire occurrence, the non-invaded and biological treated sites had higher phosphorus levels at soil depths 5-cm – 15-cm (Martin et al., 2010). After the fire disturbance, the phosphorus levels were higher in the herbicidal treated sites. Higher levels of phosphorus in herbicidal treatments can lead to eutrophication of aquatic systems near-by.

This study tested how mowing, harvesting, and applying herbicide affected *Typha x glauca* and native regrowth, and how these treatments changed short-term (~3 weeks) pore water nutrient levels. Harvest involves cutting down the *Typha* and removing the litter, which may lead to less nutrients available in the soils and waters because there is no litter that can decompose and release nutrients. Mowing and herbiciding however leave cut above-ground biomass either on the marsh surface or as standing dead, which could increase pore water nutrients as the litter decomposes. Thus, I hypothesized that harvesting will result in lower nitrogen and phosphorus levels than the mowing and herbicide treatments, and will also increase native regrowth as light will be able to penetrate to the soil surface.

Materials and Methods

Experimental Setup

The experiment was conducted at the University of Michigan Biological Station (Pellston, Michigan, USA) during June-August, 2013 using 16 mesocosms that were initiated in 2002. Each mesocosm is a box frame that measures 1-m wide, 2-m long, and 1-m deep. The mesocosms are lined with rubber pond liners that measure 1-mm thick and counter-sunk into the ground. The mesocosms were filled with hydric soils from a nearby wetland and mixed with 20 % Rubicon sand. The mesocosms were planted with 11 native species from Cheboygan Marsh in year 2003, and subsequently invaded with *Typha X glauca* planted at 16 stems/m^2 in 2004. The mesocosms have been subjected to different water levels and *Typha* litter addition in the past decade to investigate the effect these factors have on the vegetation community, *Typha* dominance, and nutrient cycling (Larkin et al. 2011, Lawrence et al. *in prep*).

Management treatments Each treatment (herbicide, mow, harvest, control) had 4 mesocosms as replicates. Treatments were assigned to each mesocosm based on pre-treatment *Typha* density and litter abundance and stratified across historical water level and litter manipulations in order to address initial variability and reduce confounding

factors. Water levels were maintained at 5-cm above the soil surface throughout the duration of the experiment (June 20-August 16, 2013).

We implemented the treatments during the week of July 8, 2013. We manually applied a glyphosate-based herbicide (Shore Klear™) to each plant. We used an aquatic weed mower (RedMax® model GZ23N) to cut all vegetation at the soil surface for the mowing and harvest treatments. Cut biomass was left on the soil surface for mow treatments, and removed from harvest replicates. Removed biomass was dried, and weighed from the harvest replicates. Dried biomass was homogenized and subsampled to quantify N and P removed during harvest.

Response Variables

During the pre- and post-treatment stages, we measured response variables to see if pore water nutrient concentrations were affected by management treatment. Photosynthetically active radiation (PAR) penetrating through the canopy also may affect the regrowth of *Typha* and native species.

a. *Quantification of Vegetation*

We quantified the vegetation in each mesocosm using at least four, 0.1-m wide and 2-m long transects per mesocosm. The vegetation rooted within each transect was identified and the height of each plant stem was recorded. The method utilized by Larkin et al. (2011) was used to estimate biomass, which converts the height of each individual stem into a biomass estimate based on established allometric equations. We added all native species (*C. aquatilis*, *C. hystericina*, *C. viridula*, *E. erythropoda*, *E. smallii*, *J. alpinoarticulatus*, *J. balticus*, *J. nodosus*, *S. acutus*, *S. cyperinus*, *S. pungens*, and *S. tabernaemontani*) together to compare native vs. *Typha* responses. We scaled stem density (#) and biomass (g) for each species and scaled it to 1-m^2.

b. *Photosynthetically Active Radiation (PAR)*

We used a LI-COR model LI-189 photometer to determine the amount of PAR penetrating to different depths within the canopy of each mesocosm pre- and post-

treatment. We collected PAR data on overcast days with constant diffuse light and used the percent reduction in PAR at 1-m, 0.5-m, and the soil surface relative to 2-m (above the plant canopy) to compare light attenuation curves post treatment PAR estimates were collected 26 days after treatment implementation.

Sampling preparation and analysis

Two pore water samplers constructed of PVC pipe with diameter of 2-cm were installed to 10-cm depth in the soil in each mesocosm. Each sampler had four holes drilled 1.5-cm from the bottom to allow water infiltration and were covered with three pieces of mesh to limit sediment contamination of samples. The water found inside the samplers was pumped using a hand-held air pump that collected the water into acid-washed 50-mL centrifuge tubes. The tubes were stored in a container to keep the porewater samples in the dark. The samples were then centrifuged and filtered within 24 hours of sample collection. Pore water samples were collected prior to the application of the treatments, and 10, 17, and 24 days after the treatments took place. The analytical laboratory of University of Michigan Biological Station analyzed the pore water samples for the concentrations of NO_3^-, NH_4^+, and PO_4^{-3} through the use of a spectrophotometer (SEAL AutoAnalyzer 3).

Statistical Analyses

Average nutrient concentrations were compared across the four treatments (herbicide, mow, harvest,control)for each sample date (pre-treatment, post-10, post-17, post-24). Treatment differences among nutrient concentrations, % PAR, *Typha* and native density were tested using ANOVA analysis if the data passed normality and equal variance tests. If the data did not pass, data were subjected to Kruskal-Wallis rank tests.
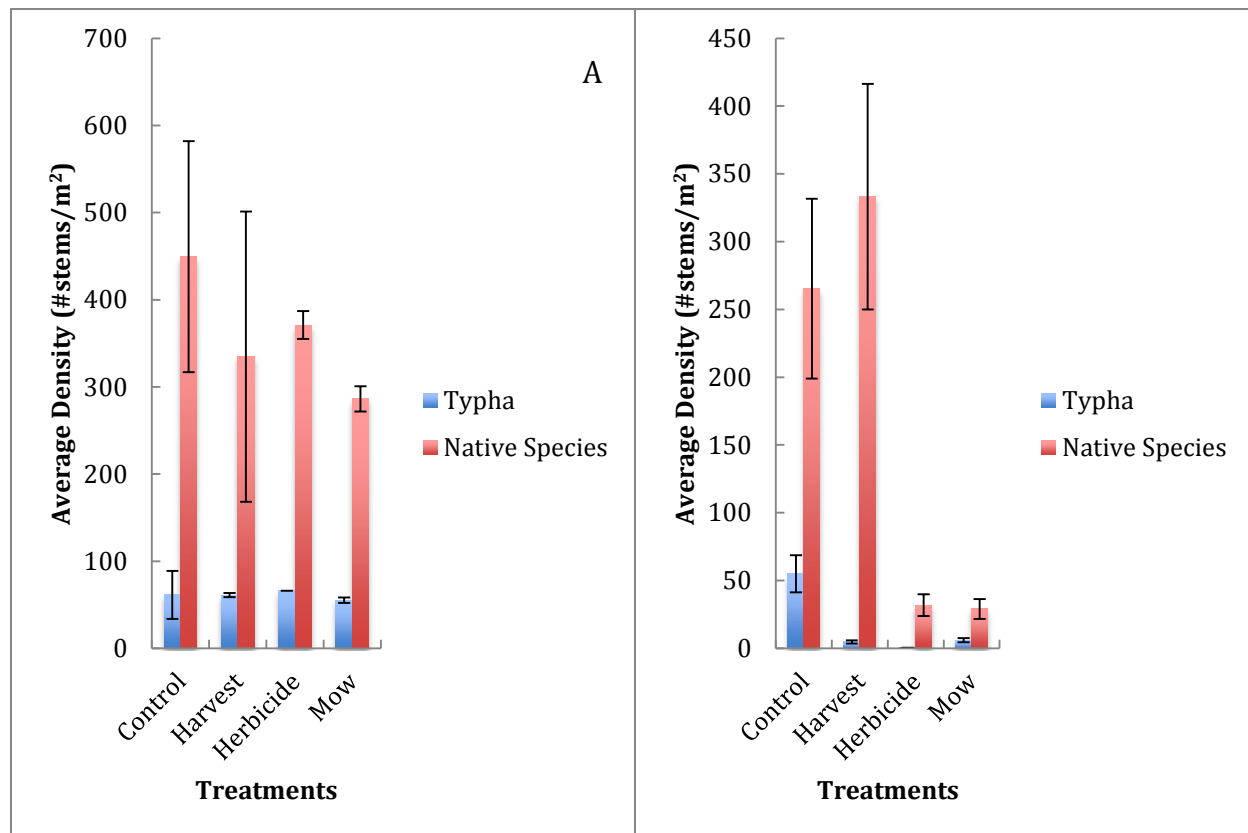
Results

Figure 1. A)There was no significance found among the treatments during the pre-treatment stage. Each treatment had similar densities of *Typha*. B) Post-treatment, there were significantly fewer *Typha* in the harvest, herbicide, and mow compared to controls. For native species, there was significantly higher native density in the harvest than in the mow and herbicide treatments.

Density of Vegetation

The density data derived from the quantification of native species and *Typha* found in each mesocosm. In the pre-treatment stage, the average density of *Typha* for the control was 61.25 (#stems/m^2) while the mean *Typha* density of harvest, herbicide, and mow were 61, 66, and 55.25 (#stems/m^2). After the treatments were applied, mean *Typha* density for the control was 55 (#stems/m^2). The average *Typha* densities for the harvest, herbicide, and mow after application were 4.75, 0.25, and 6 (#stem/m^2). The mean native density ranged at about 300-450 (#stems/m^2) during pre-treatment. In the post-treatment stage, the mean native density for control was 265.3 (#stems/m^2) while the average native densities for the harvest, herbicide, and mow were 333.2, 31.85, 29.05 (#stems/m^2).

Photosynthetically Active Radiation (PAR)

Pre-treatment, PAR was reduced to ~85% at 1-m, ~65% at 0.5-m, and between 25-30% at the soil surface for each treatment (Fig. 2). Post treatment, control measured 89.1% at 1-m while the rest of the treatments had percent reductions fall between 95-100%. At 0.5-m, the harvest and mow treatments had percentages of 98.7% and 94.8% of sunlight reduction and the control and herbicide had percent reductions at around 70%. PAR reduction at 0.5-m differed among treatments (p=0.010), with greater PAR penetration for herbicide compared to harvest. At the soil surface, control, mow, and herbicide had percentages ranging from 20-40%, while harvest had 70.1% of PAR penetrating, but due to high variability among replicates, averages did not differ among treatments (p>0.05).
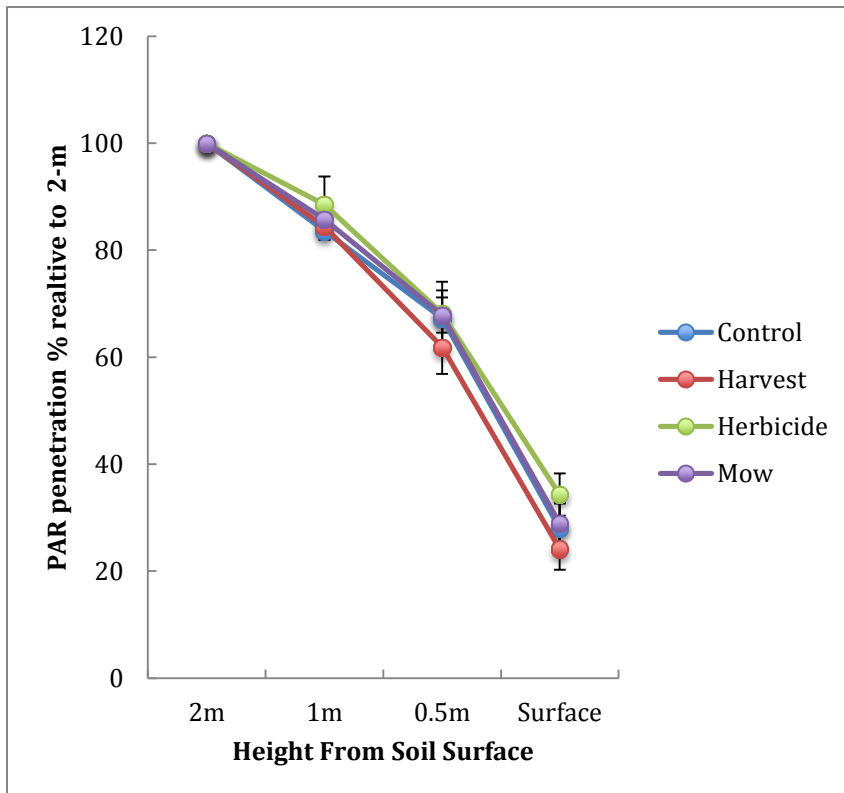

Figure 2. Pre-treatment light attenuation curves. PAR relativized 2-m to estimate 1m, 0.5m, and surface percentages. There were no significant differences among the treatments.
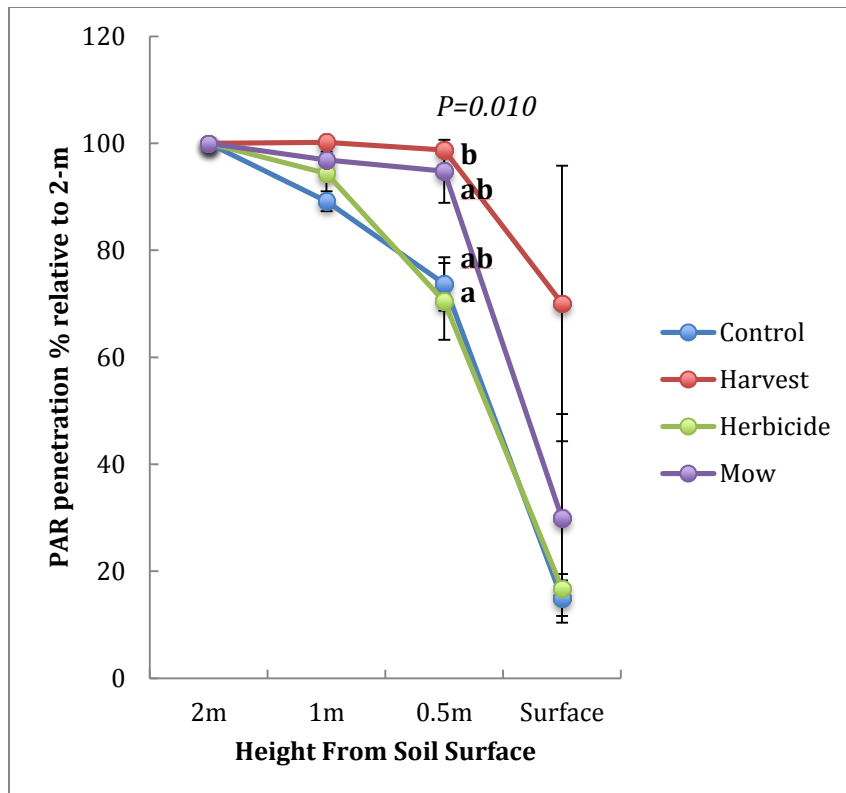
Figure 3. Post-treatment light attenutation curvers. There were significant differences between herbicide and harvesting (p=0.010). Herbicide had a lower sunlight reduction percentage than harvest.

Pore Water Nutrient Concentrations

The pre-treatment stage had average ammonium concentrations at about 500 (μg-N/L) (Fig. 4). 10 days post- treatment, harvest and mow had ~1300 (μg-N/L) and the control and herbicide ranged between 500-550 (μg-N/L). The mow treatment tended to have higher ammonium concentrations (991.8 (μg-N/L)) 17 days of treatment, but there were no statistical differences (p=0.46). At 17 and 24 days, the harvest treatment tended to have lower concentrations (43.0 and 40.7 (μg-N/L)) than the other treatments. After 24 days of treatment, herbicide had an ammonium concentration of 1825.4 (μg-N/L) that tended to be higher than the other treatments, but was not statistically different (P=0.49)
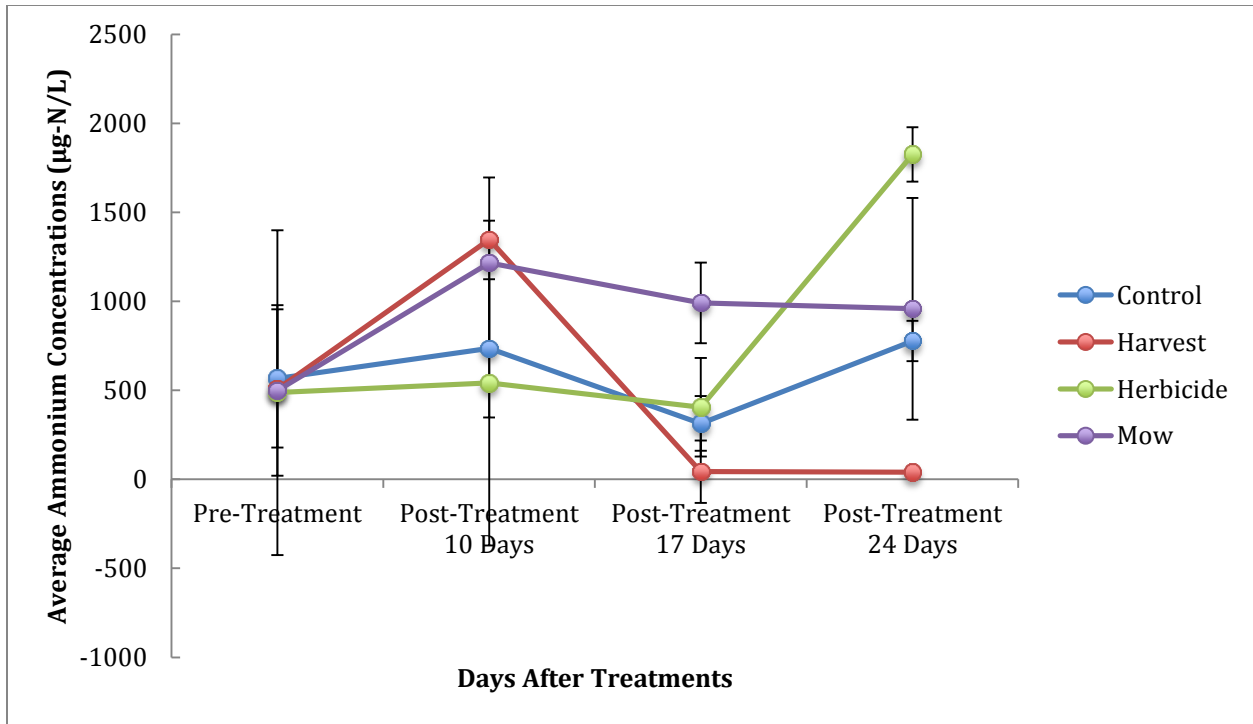
Figure 4. The mean ammonium concentrations among the treatments were found not to have any significance.

Pre-treatment nitrate concentrations differed among treatments, with herbicide having greater concentrations than control replicates (p=0.050; Fig. 5). After 17 and 24 days, each management treatment had average nitrate concentrations range between 2-6 (µg-N/L).
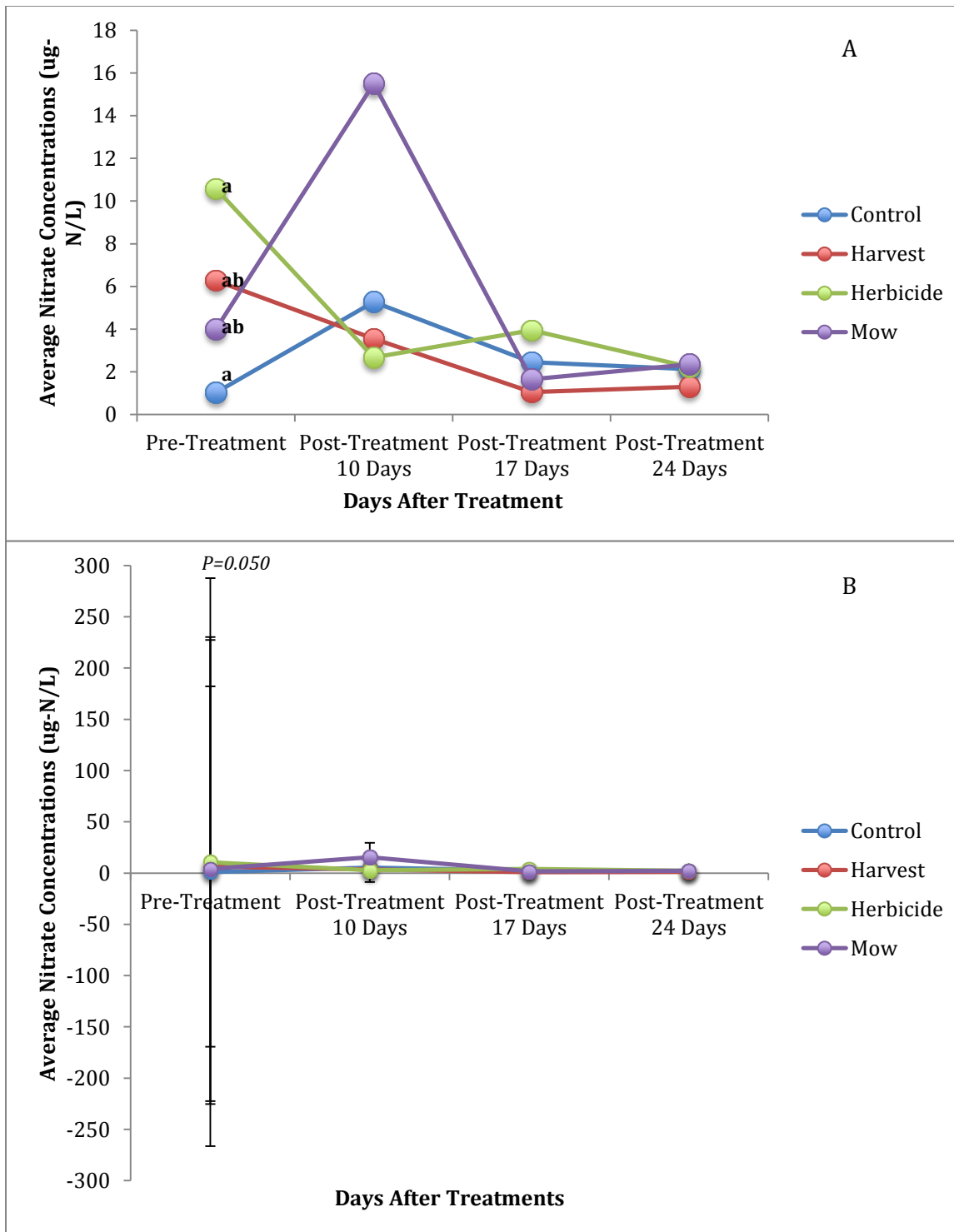
Figure 5. A) The overall trends created by the average nitrate concentrations. B) The standard errors of each concentration. The herbicide and control treatment were significantly different from one another though there was also large variability with other treatments.

Pre-treatment average phosphate concentrations were found to be variable with herbicide measuring at 127.8 (µg-P/L) while the rest were ranged from 25-50 (µg-P/L). After 17 days, the herbicide treatment had significantly higher levels of phosphate concentrations (p=0.004) than mow and harvest (Fig. 6). At 24 days, the herbicide treatment had significantly higher phosphate concentrations (p=0.05) than other treatments.
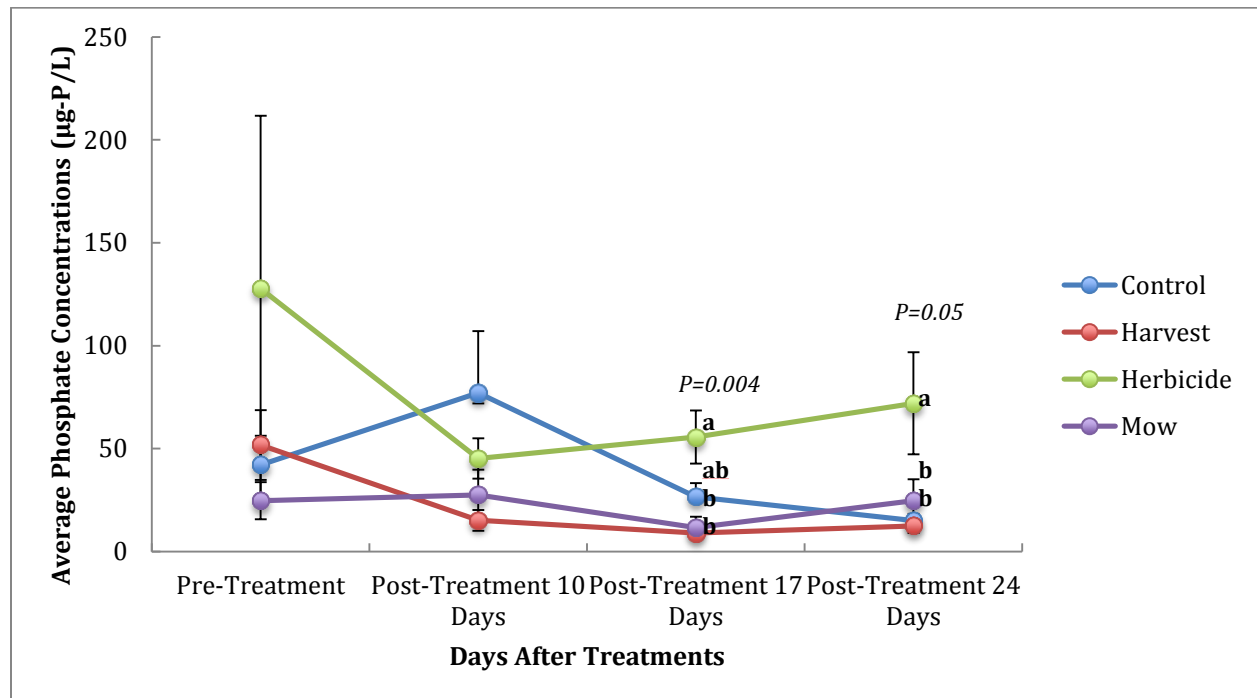

Figure 6. Herbicide had higher phosphate concentrations after 17 and 24 days of applying the treatments.

Discussion

The herbicide, mow, and harvest treatments are commonly used management techniques that aim to control invasive plant species in wetlands. However, little is known on how these managements can affect wetland nutrient cycling. We initially hypothesized that 1) harvest would reduce N and P concentrations in pore water compared to herbiciding and mowing, and 2) that harvest would reduce the regrowth of *Typha* while increasing native density. The rationale behind these hypotheses was that both herbiciding and mowing leave behind litter at the soil surface that eventually decomposes in the water

and leaches nutrients into the system, which results in an increase of *Typha* density as well as N and P concentrations (Larkin et al., 2011).

Preliminary analysis of our data suggests that our hypotheses can be supported. Harvest had significantly higher native species density than herbicide and mow treatments. When compared to harvest, herbicide had a significantly lower sunlight percent reduction or less light penetrating through the plant canopy in each herbicided mesocosm. Herbicide also differed significantly by having higher phosphate concentrations after 17 and 24 days of applying the treatments than harvest and mow. Instead of using herbicide that can further enrich wetland soils that could lead to a re-introduction of *Typha* as well as cause algal blooms that cause eutrophication, harvest appears to be the most effective technique at increasing native density and lowering N and P concentrations.

Future analyses will also test our hypotheses. We will investigate vegetative, pore-water nutrient concentrations, and the vegetation response to our treatments one-year after treatment. We collected pre-treatment below-ground and litter biomass, and will quantify these parameters during the 2014 growing season for pre- vs. post-treatment changes. To further control potentially confounding variables, the experiment could be implemented in pots in a greenhouse. Other variables could be important as well; soil temperature was supposed to be collected for this experiment, however temperature sensors malfunctioned and did not record the temperature after applying the treatments. Future studies may investigate how temperatures can affect the growth of wetland plant species.

Acknowledgements

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