Efficacy of emergent plants as a means of phosphorus removal in a treatment wetland, Cooperstown, New York

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INTRODUCTION

In 2003, a wetland was restored along the outskirts of the village of Cooperstown, NY. Designed as a wildlife habitat, but built with the intention of polishing wastewater from the Cooperstown Wastewater Treatment Facility, effluent was first pumped into the wetland in June 2010. Initial studies suggest that the wetland retained about 35% of the effluent's phosphorus and nitrogen over the course of its first year of operation (Albright and Waterfield 2011). The purpose of this study is to evaluate and compare the phosphorus content in plant tissue between this treatment wetland and a nearby control wetland.

As water bodies become enriched with nutrients, excess phosphorus can act as a pollutant (National Research Council 1996). Wetlands have the natural ability to remove pollutants from wastewater. Constructed wetlands, used to polish wastewater, have been in operation since the 1950s (Kadlec and Wallace 2009). Many wetland plants strip nutrients, such as phosphorus, from effluent and use them for growth. Biotic uptake accounts for short-term removal of phosphorus from wastewater, while sorption onto soil particles and accretion of wetland soils account for long-term removal (Cronk and Fennessey 2001). The amount of phosphorus a wetland can retain depends a great deal upon the types of vegetation within it. Vegetation in a nutrient-enriched wetland, such as this treatment wetland, has the potential to incorporate more nutrients than the same vegetation would in a natural wetland (Guntenspergen et. al. 1989). This luxuriant uptake causes plants to store more phosphorus in their tissue than is needed for growth (Kadlec and Wallace 2009), allowing them to act as a phosphorus sink.

North America has a rich history of constructing large-scale free water surface treatment wetlands over the last 20 years (Kadlec and Wallace 2009). These wetlands have areas of open water and emulate natural wetlands; however, they are usually engineered to effectively reduce nutrients in wastewater. The treatment wetland in Cooperstown was designed for wildlife habitat rather than for wastewater treatment. As such, it is substantially deeper than those designed for treatment (California Stormwater Quality Association 2003) and the flow regime was not designed to maximize effluent contact with plants. Also, specific plants were not implemented to maximize phosphorus removal from the effluent. The Cooperstown treatment wetland contains many naturally occurring species of plants, including reed canary grass (*Phalaris arundinacea*) and cattails (*Typha* spp.). These emergent species are widespread, able to tolerate a range of conditions, and have been shown to be effective in wastewater treatment wetlands (Guntenspergen et. al. 1989).

In the summer of 2010, Olsen (2011) investigated the phosphorus content in reed canary grass leaves within the Cooperstown treatment wetland and at an adjacent site which was not

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influenced by effluent. Her studies suggest a higher percentage of phosphorus in leaves taken from plants in the treatment wetland than in the adjacent site. The research done in this study expands on her work by adding more sample sites, investigating cattails as well as reed canary grass, and by comparing these data to a nearby control wetland which was constructed at the same time as the treatment wetland and does not have effluent being pumped into it.

METHODS

Plant sampling:

Reed canary grass and cattails were chosen for this experiment for several reasons. Both species are abundant at each wetland, allowing for multiple sampling sites. Also, they both reportedly possess the ability to polish wastewater relatively well (Cronk and Fennessey 2001). As displayed in Figure 1, six primary sample sites were chosen at both the treatment wetland (TW) (Figure 1A) and control wetland (CW) (Figure 1B). The primary sites were each 3 m^2 and were spread out along the outer edge of the wetlands. Within each primary site, sub-sampling was performed by partitioning the 3 m^2 site into thirds, creating a total of 18 sub-samples for each wetland. Within each sub-sample, reed canary grass plants were sampled in triplicate and cattail plants were sampled in duplicate. Plants were collected in their entirety, being cut at their stem (1-2 cm from the ground) and placed into a labeled paper bag. These bags were then loaded into a forced air convection oven and allowed to dry overnight at 105° C. Each sample was then finely ground to a homogenous mixture using a Krupps coffee bean grinder and placed in an 8oz. museum jar for storage and future analysis.

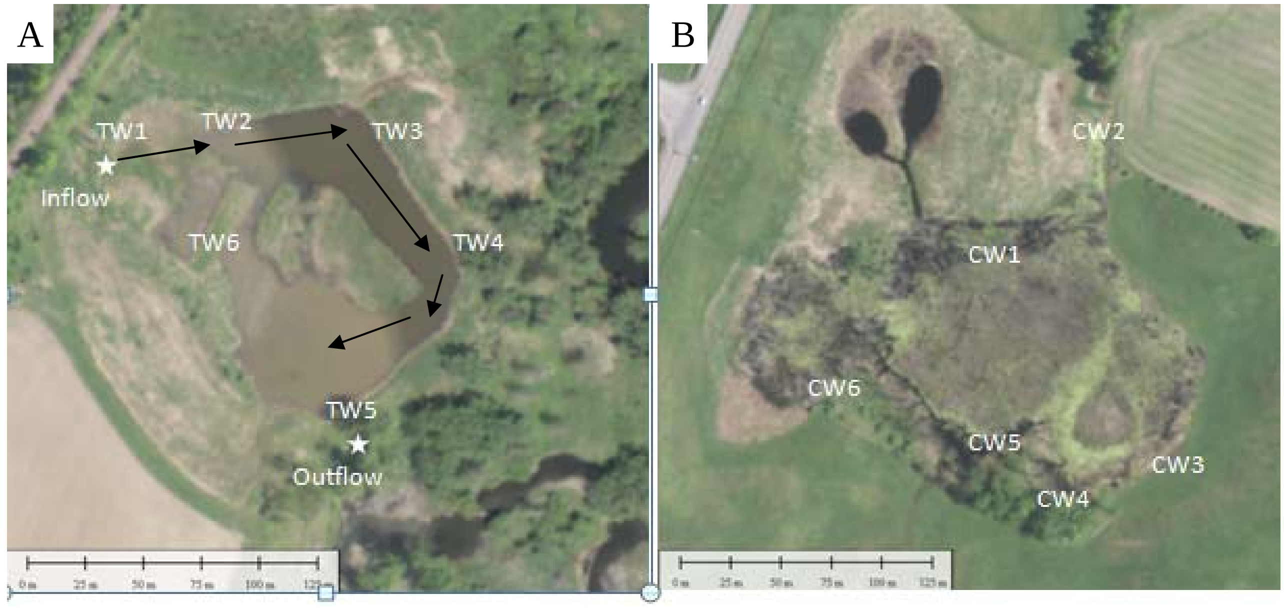

Figure 1. A: Sample sites at the treatment wetland (TW). Points of inflow and outflow are represented by stars. The general flow pattern of effluent is represented by black arrows (Robb, 2012). Effluent enters the wetland near TW1. The outfall structure is near TW5. B: Sample sites at the control wetland (CW).

Sample Analysis:

Methods for dry ashing, acid extraction and phosphorus concentration determination were taken from Bickelhaupt and White (1982). About 0.5 g of sample was used for analysis. The dry weight was recorded and used to later calculate the percentage of phosphorus in each sample (Bickelhaupt and White 1982). Samples were dry ashed at 475° C for 4 hours in dried, tared crucibles. The weight of the sample subsequent to dry ashing was recorded and used to calculate carbon lost on ignition. 6N HCl was added to the dry ashed samples and they were boiled gently until dried. This was repeated twice more. Ten ml of 6N HCl was added and the ash was scraped onto 110mm diameter Whatman® 42 filters which had been folded into 66mm polypropylene funnels. Filters were rinsed and the samples diluted to 100 mL with deionized water. The vanadomolybdophosphoric acid colorimetric method (Bickelhaupt and White 1982) was used to determine the phosphorus content of each acid extraction. The absorbency of each sample was determined through the usage of a Milton Roy Spectronic spectrophotometer 501 at 440 nm wavelength. The concentration vs. absorbency relationship of standard solutions of known concentration was used to find the phosphorus content of each sample. An equation from Bickelhaupt and White (1982), as seen in below, was employed to express phosphorus in the plant tissue as a percentage of the tissue dry weight.

$$\%\ \text{P in sample} = \frac{(ppm\ P\ in\ solution) * volume\ \left(ml\right) * 0.0001}{sample\ dry\ wt.\ (g)}$$

Paired t-tests were used to evaluate and compare the phosphorus content between the tissue of plants collected in the treatment and the control wetlands.

RESULTS AND DISCUSION

A comparison of the overall mean phosphorus content of plant tissue of both cattails and reed canary grass at each site is provided in Figure 2. There was no significant difference between percent phosphorus concentration in the plant tissue from the treatment and the control wetland for either species.

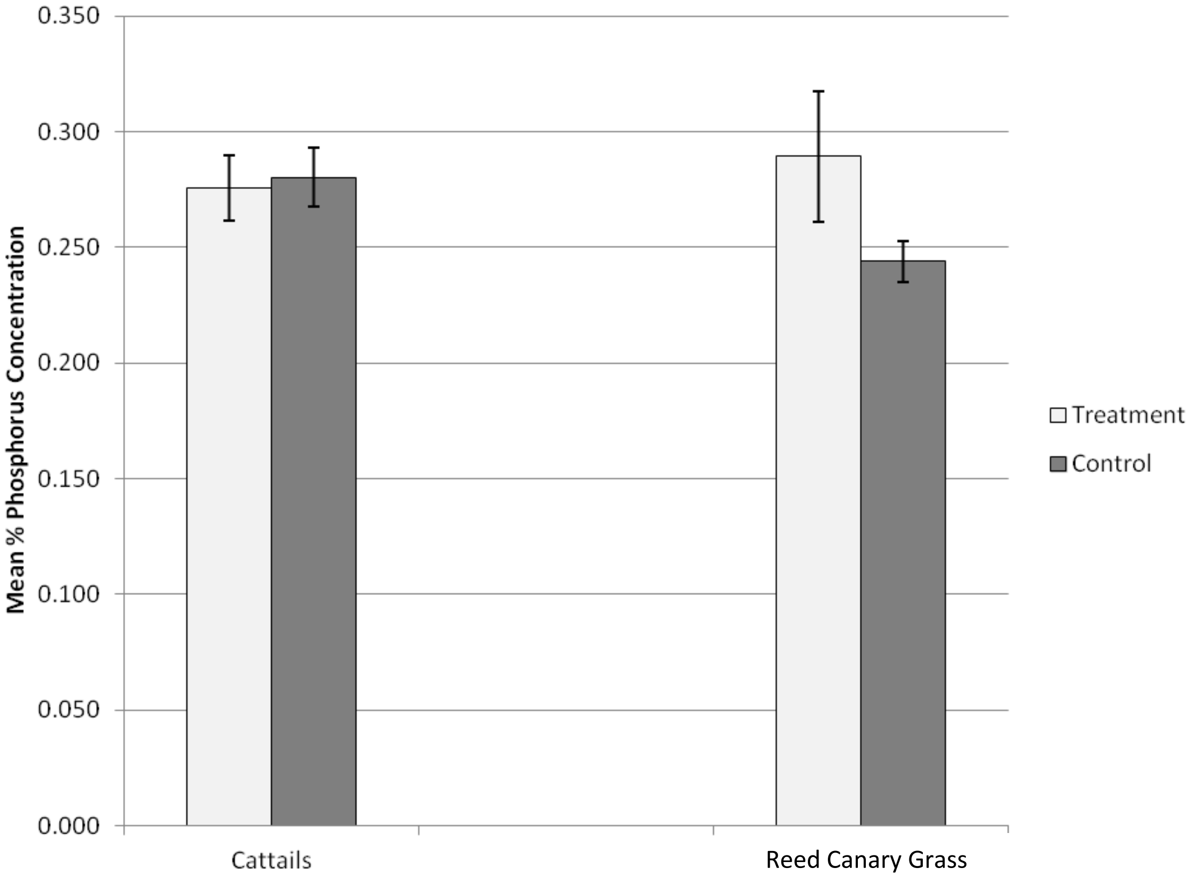

Figure 2. Average phosphorus concentration of plant tissue in cattails and reed canary grass at both wetlands. Error bars represent standard error.

The general flow pattern of effluent through the treatment wetland can be seen in Figure 1 (Robb 2012). This was determined, in part, by the observed pattern of nutrient concentrations across the wetland. This suggests that spatial distribution of the nutrients across that wetland may be reflected in plant tissue content. Coinciding with nutrient data collected from the treatment wetland (Figure 3), the percent phosphorus concentration in reed canary grass was highest at the site nearest the point at which the effluent entered the wetland (TW1), it trended downward to the site nearest the outfall (TW5), and it was lowest at the site out of the flow path (TW6). Cattail did not display a similar pattern. In the control wetland (Figure 4), phosphorus concentrations were somewhat less variable than they were in the treatment wetland. All data, including the phosphorus content of plant tissue and the percent carbon lost on ignition, for both cattail and reed canary grass at both the treatment and control wetlands, are summarized in Table1.

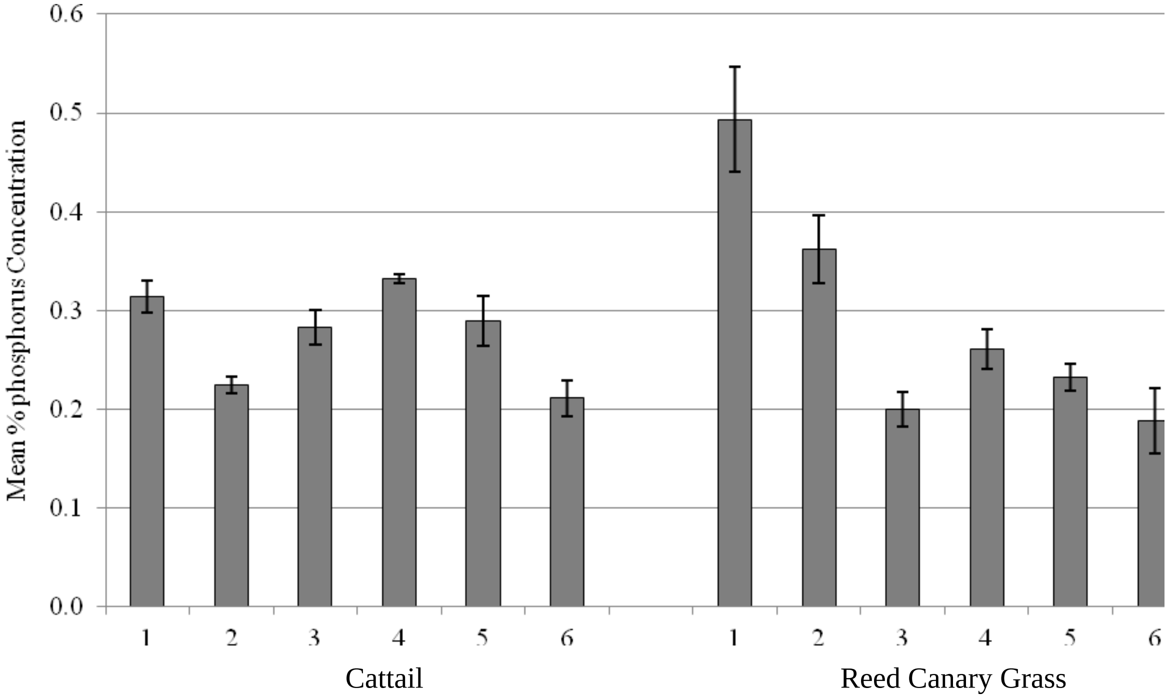

Figure 3. The average phosphorus concentration of plant tissue in sample sites 1-6 at the treatment wetland. Error bars represent standard error. See Figure 1 for site locations.

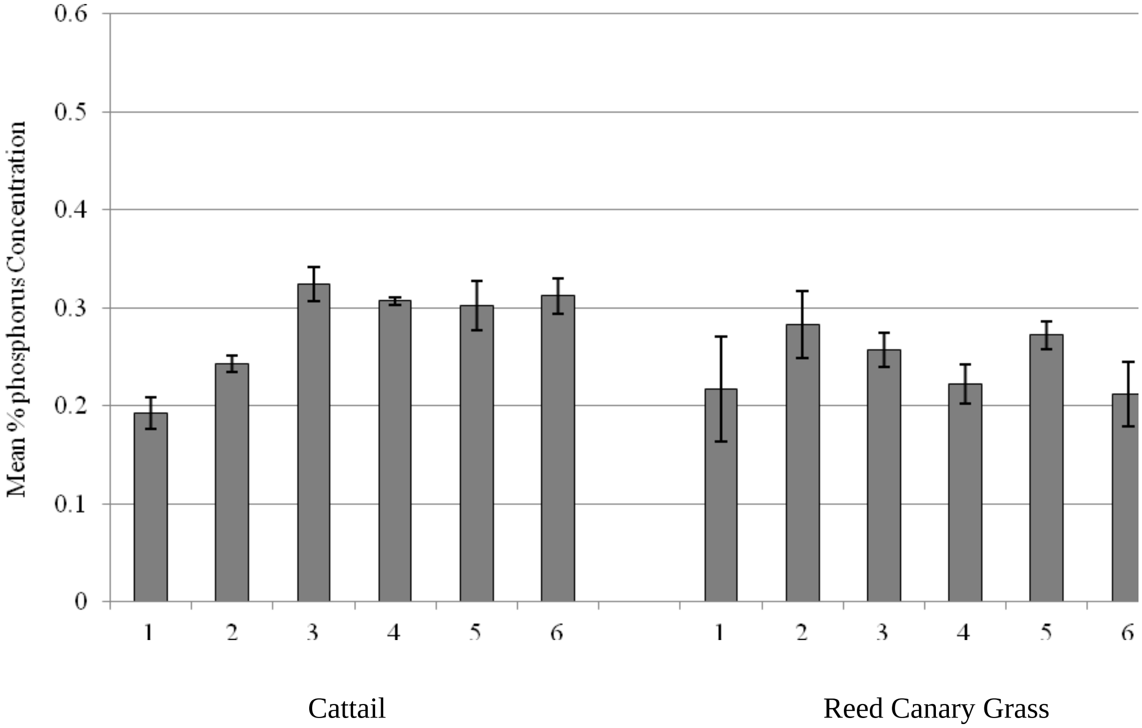

Figure 4. The average phosphorus concentration of plant tissue in sample sites 1-6 at the control wetland. Error bars represent standard error. See Figure 1 for site locations.

	Cattails				Reed canary grass			
	Control Wetland		Treatment Wetland		Control Wetland		Treatment Wetland	
Site	% P of Dry Weight	C Loss on Ignition (%)	% P of Dry Weight	C Loss on Ignition (%)	% P of Dry Weight	C Loss on Ignition (%)	% P of Dry Weight	C Loss on Ignition (%)
1a	.184	93.3	.338	89.7	.194	96.6	.407	92.6
1b	.190	93.2	.310	87.2	.208	96.5	.481	91.3
1c	.204	92.9	.296	89.2	.248	95.7	.590	90.8
2a	.253	92.0	.205	92.5	.274	95.1	.415	90.2
2b	.204	93.1	.191	89.7	.275	94.7	.373	91.4
2c	.274	91.8	.275	89.7	.301	94.1	.296	92.5
3a	.351	92.4	.271	89.9	.248	94.8	.171	92.1
3b	.301	91.4	.263	89.6	.291	95.2	.196	92.5
3c	.320	92.6	.317	89.2	.233	95.5	.232	93.3
4a	.292	92.0	.248	97.3	.217	96.3	.227	91.6
4b	.283	91.6	.339	88.1	.230	96.5	.296	94.0
4c	.346	92.1	.409	89.4	.219	96.5	.259	92.9
5a	.258	91.8	.328	88.9	.253	96.4	.239	93.2
5b	.326	90.8	.255	89.2	.241	96.0	.252	92.9
5c	.324	91.4	.285	87.7	.322	95.4	.206	93.8
6a	.326	93.3	.182	92.2	.247	96.6	.123	94.0
6b	.295	94.6	.201	91.4	.203	96.5	.214	94.6
6c	.316	93.4	.249	91.6	.186	96.9	.228	93.0

Table 1. The phosphorus concentration of plant tissue of cattail and reed canary grass at each sub-sample site of the treatment and control wetland (as percent of dry weight. The carbon loss on ignition is the organic mass lost during dry ashing.

DISCUSSION

A t-test determined there was no significant difference in phosphorus concentrations of plants between the treatment and control wetlands; however, in the treatment wetland there seemed to be a pattern between ambient phosphorus levels in the effluent across the wetland (Robb 2012) and reed canary grass phosphorus concentrations. Percent phosphorus concentrations for plants in the control wetland range from 0.184 to 0.351%. This compares well with a study done by McJannet & Keddy (1995), which analyzed 41 wetland plant species and suggested that phosphorus concentrations can range from 0.20 to 0.40%. In the treatment wetland, there was a wider spectrum of phosphorus concentrations, ranging from 0.123 to 0.590%. These values coincide with Kadlec and Knight's (1996) reported values of 0.08 to 0.63% phosphorus concentrations for plants in constructed wetlands.

REFERENCES

Albright, M.F. and Waterfield, H.A. 2011. Monitoring the effectiveness of the Cooperstown wastewater treatment wetland. *In* 43rd Ann. Rept. (2010). SUNY Oneonta Biological Field Station, SUNY Oneonta.

Bickelhaupt, D.H. and E.H. White. 1982. Laboratory Manual for Soil and Plant Tissue Analysis. State University of New York, Environmental Science and Forestry.

California Stormwater Quality Association. Constructed Wetlands, Cabmphandbooks.com. 2003. http://www.cabmphandbooks.com/Documents/Development/TC-21.pdf.

Cronk, J.K. and M.S. Fennessey. 2001. Wetland Plants, Biology and Ecology. Lewis Publishers. Boca Raton, London, New York, Washington, D.C.

Guntenspergen, G.R., Stearns, F. and J.A. Kadlec. 1989. Wetland vegetation. *In* Constructed Wetlands for Wastewater Treatment. D.A. Hammer, Ed. 73-88. Lewis Publishers. Chelsea, Michigan.

Jaisingh, L.R. 2000. Statistics for the Utterly Confused. McGraw-Hill. New York.

Kadlec R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishers. Boca Raton, Florida.

Kadlec, R.H. and S.D. Wallace. 2009. Treatment Wetlands, 2nd Ed. Taylor and Francis Group. Boca Raton, Florida.

McJannet, C.L., P.A. Keddy, F.R. Pick. 1995. Nitrogen and phosphorus tissue concentrations in 41 wetland plants: a comparison across habitats and functional groups. Functional Ecology 9: 231-238

National Research Council (U.S.). Committee on Inland Aquatic Ecosystems. 1996. National Academy Press. Washington, D.C.

Olsen, B. 2011. Phosphorus content in reed canary grass (*Phalaris arundinacea*) in a treatment wetland, Cooperstown, NY. *In* 43rd Ann. Rept. (2010). SUNY Oneonta Biological Field Station, SUNY Oneonta.

Robb, T. 2012. An Insight into a Complex System: Cooperstown Wastewater Treatment Wetland, 2011. *In* 44th Ann. Rept. (2011). SUNY Oneonta Biological Field Station, SUNY Oneonta.