2009

Mercury Uptake by Aquatic Macrophytes in Urban and Rural Watersheds, Albany County, NY

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Recommended Citation

Neumann, Bernd G., "Mercury Uptake by Aquatic Macrophytes in Urban and Rural Watersheds, Albany County, NY" (2009). *Geology Theses and Dissertations*. 63.
http://scholarsarchive.library.albany.edu/cas_daes_geology_etd/63

Mercury Uptake by Aquatic Macrophytes in Urban and Rural Watersheds
Albany County, NY

Abstract of

a thesis presented to the Faculty

of the University at Albany, State University of New York

in partial fulfillment of the requirements

for the degree of

Master of Sciences

College of Arts & Sciences

Department of Atmospheric and Environmental Sciences

Bernd G. Neumann
2009

ABSTRACT

Plants growing in metalliferous soils may restrict metal uptake and transport depending on metal concentration, sediment characteristics, and plant species. As native plants are replaced by invasives, different patterns of metal cycling can occur, making continued study of this process important. Sediments and tissues of four aquatic plant species/genera: *Phragmites australis (common reed)*; *Iris versicolor (blueflag iris)*; *Typha latifolia (broadleaf cattail); and genera Cyperus sp. (sedge*) from three urban and two rural sites in Albany County, NY were analyzed for total mercury (Hg_T) by cold vapor atomic absorption spectroscopy. Sediments were also measured for organic carbon (OC) by coulometry. Sediment Hg_T ranged from 54 to 483 ng/g and root tissues ranged from 11 ng/g to 354 ng/g. Strong Hg partitioning was found between roots and other tissues by comparing sediment:root and root:rhizome Hg concentration ratios which ranged from 1:1 to 10:1 and 1:1 to 18:1, respectively, indicating strong Hg partitioning among sediment, root, and rhizome. However, the two sites with the highest Hg sediment levels (356 ng/g and 483 ng/g), had markedly different sediment:root ratios (3.5:1 and 1.5:1, respectively) that correlated directly with sediment OC levels (4.51% and 1.87%, respectively). These results suggest that sediment OC may limit the bioavailability of Hg to plants as Hg becomes bound to OC in sediment. Since sediment Hg can exist in several forms, sequential chemical extraction may be a better predictor of Hg available for plant uptake than Hg_T. Root plaques were observed on samples of common reed at two different sites. One sample had the highest Hg_T seasonal root concentration for *common reed* at that site, samples from the other site had both the highest and lowest seasonal Hg_T concentrations. While SEM microprobe analysis revealed concentrations of iron (Fe) and Manganese (Mn), it is inconclusive if root plaques are an important adheration site for Hg.

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Acknowledgements

I would like to thank my advisor and committee chair, Dr. John Arnason for his assistance and guidance on this project, which graciously continued beyond his time at the University at Albany. I would also like to thank my committee members, Dr. George Robinson and Dr. William Kidd for their thoughtful input and suggestions. Portions of this research were made possible with financial support from the Edmund Niles Huyck Preserve and the Geological Society of America. Thanks to the staff and scientific grant committee of the preserve for providing a picturesque place to do field and lab work. Thanks to all those who helped me in the lab and in the field, including Audrey Kropp and the staff at the Huyck Preserve, Judith Kricheff, Christine Vanderlan, and Dr. Sarah Grote. Finally, thank you to my friends and family for their encouragement and support.

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1. INTRODUCTION

1.1 Mercury in the Environment

Mercury (Hg) is a naturally-occurring heavy metal that is a pollutant toxic to most organisms, including humans, and can enter the environment from a variety of natural and anthropogenic sources. Natural inputs include degassing and the wind capture of dust particles from mercury-rich soils and sediments, volcanic eruptions, forest fires, biogenic emissions, and degassing from water surfaces. Anthropogenic sources include metal production, chlor-alkali and pulp industries, waste incineration, and coal, peat, and wood burning (Morel et al, 1998). Through these activities, Hg can become mobilized and released into the land, water, and air (EPA, 1997).

Mercury is pervasive in that it cannot be destroyed or broken down. Thus, once deposited, it can remain as a record of environmental deposition or accumulation for many years (e.g., Arnason, 2004). Hg in the atmosphere is mainly in the form of elemental Hg vapor and can remain in the atmosphere for up to a year, resulting in long-range atmospheric transport. Hg is primarily redeposited to surface waters and land by wet deposition, and can be emitted back to the atmosphere as a gas, or redeposited elsewhere. Once interspersed in the environment, Hg undergoes a series of physical and chemical reactions, some of which are not completely understood. Hg in water, soils, sediments, plants, and animals exist as inorganic Hg salts and more toxic organic forms, such as methylmercury (EPA, 1997). Based on lake sediment records, it is estimated that the input of Hg into surface lands and waters has tripled over the last 150 years (Morel et al, 1998).

1.2 Background and Importance of Mercury Uptake by Aquatic Macrophytes

Mercury uptake and storage has been documented in wild plants in their natural environment (Windham et al., 2003) and those growing within laboratory environments under controlled conditions (Kamal et al., 2004). Plants may remove Hg and other metals from contaminated soils and temporarily reduce the input of mercury into the surrounding environment. Metal concentrations in plants primarily occur due to the absorption of metals from sediments into root tissues, in some cases transported throughout the rest of the plant (Baker, 1981). As with many other metals, some Hg accumulation may be attributed to atmospheric deposition onto above ground plant (leaf) surfaces (Tyler and Olsson, 2006).

There are several reasons to study the role of plants in the chemical cycling of mercury. The ability of plants to absorb Hg from soils and sediments allows them to serve as biological indicators of contamination, in cases where roots are in contact with polluted soils and sediments. Species and varieties that have the ability to move high concentrations of Hg through their tissues may be useful in phytoremediation. Mercury is the only metal to be a liquid at room temperature, leading to its pervasiveness as an environmental pollutant, and making phytoremediation an attractive remediation option (Morel et al, 1998). However, terrestrial plants cycle Hg at varying rates, with few taxa known to accumulate mercury at concentrations at or above substrate concentrations. Other factors may affect relationships between vegetation and Hg cycling in the environment, including individual plant growth rates, and plant community composition (Windham et al., 2003).

Plants growing on metaliferous soils cannot avoid metal uptake, but rather regulate it to some degree (Baker, 1981), employing three different strategies. These are the excluder, indicator, and accumulator strategies, and are based on plant response to an increase in soil metal concentration. Baker, 1981, makes these classifications by comparing the root concentration with the below-ground stem (rhizome) concentration, or above ground tissues, which then may be expressed as a ratio of root to rhizome concentration. Plants that function as accumulators have root and rhizome concentrations that far exceed surrounding soil concentrations, indicating hyper accumulation of metals. Indicators have root and rhizome concentration that is indicative of sediment concentration. Excluders maintain a low rhizome concentration compared to that of the root, until a critical soil concentration is reached, at which point unrestricted metal transport ensues through the rest of the plant (Baker, 1981; Windham et al, 2003).

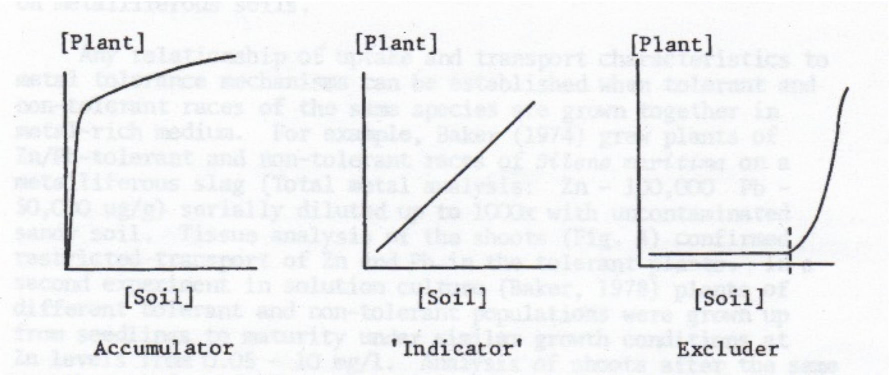

Figure 1. The three strategies employed by plants in metaliferous soils. X axis denotes soil concentration and Y axis denotes rhizome concentration. (Source: Baker, 1981)

Windham et al, 2003, studied patterns of metal partitioning within two different wetland plant species. As is typically the case with macrophytes, the highest concentrations of metals were in roots, with lesser concentrations in other tissues (Baker, 1981; Windham et al, 2003). In the case of Hg, Windham et al, 2003, found *Phragmites* *australis* (common reed) and *Spartina alterniflora* (cord grass) to function as excluders, after documenting metal partitioning among tissues. *Common reed* concentrations ranged from highest to lowest in the following order: root > rhizome > leaf > stem. During bimonthly monitoring over a full growth season (April-October), root tissue was the dominant Hg accumulator. The partitioning was similar for *cord grass.*

Coquery and Welbourn (1994) found similar results in their studies of *Eriocaulon septangulare* (pipewort), grown in a controlled laboratory environment using wild plants and sediment collected from the shorelines of Bentshoe Lake, Ontario. An aqueous solution of $HgCl_2$ was used to spike a portion of the sediment. Roots accumulated Hg but there was little or no transport to the rest of the plant. This study and the work outlined in Windham et al, (2003) demonstrate the potential for metal exclusion in commonly-occurring aquatic plants.

1.3 Seasonal Variability

Existing literature indicates some seasonal variability to the amount of Hg accumulated by aquatic macrophytes. Windham et al, 2003, showed Hg concentrations in roots of *common reed* ranged from 0.59 (April) to 1.650 mg/kg (August). These results were for plants from a contaminated marsh, and are much higher than the root concentrations reported from the more pristine conditions noted in Coquery and Welbourn, 1995. The root concentrations rose throughout the growing season (peaking in August) whereas leaf and rhizomes showed no consistent trend. Stem concentrations showed a steady decline. In the same study, Windham et al, 2003, showed *S. alterniflora* root concentrations also had seasonal variability with no apparent trend.

1.4 Effects of Sediment Characteristics

Some research has suggested that sediment characteristics may have the ability to promote or restrict Hg uptake by plants. In their study of *pipewort* in Bentshoe Lake, Ontario, Coquery and Welbourn, 1995, examined relationships between organic matter in sediments and metal uptake. Under the terminology outlined by Windham et al, 2003, *pipewort* may be classified as an excluder when considering the entire plant. However, the roots appeared to be accumulators of Hg, although concentrations were not closely correlated with sediment levels.

Sediment concentrations in the lake ranged from 0.009 to 0.219 ug/g whereas root concentrations had a narrow range, 0.09 to 0.13 ug/g (Coquery and Welbourn, 1995). Their findings indicated that some of the Hg is bound to the sediment and not available for uptake. Organic material (OM) content seemed to limit the availability of Hg to the plants, and a positive correlation was drawn between sediment OM and Hg content, but a statistically significant relationship was found in only one of the two basins studied (Coquery and Welbourn, 1995).

Additionally, Coquery and Welbourn, 1995, observed Fe and Mn plaque on root samples from 2 of the 13 sample sites. This material could potentially bind with some Hg, which would increase the amount of total Hg concentration measured in the root sample, and some of the highest Hg root concentrations were found in plants from these sites. Others have reported a mineral residue left behind after digestion of root samples, possibly from a similar mineral plaque (Windham et al, 2003).

1.5 Atmospheric deposition on leaves

Mercury measured in leaves may have two sources, transport from soils and atmospheric deposition. Greger et al, 2005, showed that for six terrestrial plant species, no Hg was detected in transpiration aerosols, leading to the hypothesis that large fractions of leaf concentrations may be due to aerial Hg deposition.

Tyler and Olsson, 2006, studied the leaves of the tree *Fagus sylvatica* (European beech) in a remote northern European forest. There were no local Hg point sources or heavy industry near the study area. After washing a portion of the leaves in a weak acidic and detergent solution, some elements were reduced down to 20 to 50% of their original concentrations. No significant losses were found with alkali, alkaline-earth elements, and several transition metals. Hg was included in the analysis and was not affected by the leaf washing.

Millhollen et al, 2006, showed that foliar Hg concentrations were mainly the result of atmospheric deposition in several native grasses in a lab experiment. Four tallgrass prairie species were subjected to different soil Hg concentrations, and different atmospheric Hg and CO_2 conditions in enclosed environments. They hypothesized that some leaf mercury might be due to evasion from Hg contaminated soils, but found little evidence in support. However, they were able to discern that atmospheric concentration does influence foliar concentration more than sediment concentration. In addition, elevated atmospheric CO_2 conditions were shown to reduce Hg uptake by leaves (foliar uptake), an effect that decreased when Hg concentrations rose. The authors suggested that this was caused by reduced stomatal conductance due to the reduced carbon dioxide gradient, and noted that this effect had been observed at elevated CO_2 concentrations in other studies involving plants and mercury. Thus, two main conclusions emerge: first, mercury can enter leaves from the atmosphere, and second, entry is through stomatal pores.

1.6 Release of Hg through transpiration and senescence

Some studies have examined the release of Hg back into the environment through transpiration. Greger et al, 2005, used a controlled experiment to examine transpiration of Hg in 6 species of terrestrial plant. The experiment effectively separated the root from the rest of the plant in a "pod" type structure by using a rubber membrane and measured gaseous emissions from the plant. In this case, no significant release of Hg was detected. Even though root concentrations increased, a very small amount was moved to the rhizome and no detectable amount of Hg was released to the air from above ground tissues (shoot, stem, leaves).

In contrast, Windham et al. (2001) found some evidence for release of Hg through transpiration from *S. alterniflora* (*cord grass)* and *common reed in* work conducted in a contaminated low marsh (an area of marsh flooded twice daily from tides) from May to July. Leaves produced earlier in the growing season had higher concentrations of Hg than leaves produced later and the lower leaves contained the most Hg. Release for both species was greatest in May and was best predicted by leaf concentration. Additionally, the amount of Hg released from *cord grass* was greater than that released from *common reed* by 2 to 3 times (Windham et al, 2001).

Tyler, 2005, studied *European beech* tree leaves as they progress through the natural processes of growth, senescence, and detachment. Hg content in leaf litter of the study year was 65 ng/g and higher in previous years (106 ng/g), about half the level of underlying soils (209 ng/g;Tyler, 2005). It is unclear whether decomposing leaves were contributing Hg to the forest soils.

1.7 Study Objectives and Species Studied

In this study, the total mercury (Hg_T) concentrations of aquatic macrophytes and their associated sediments from the Patroon Watershed, and the Edmund Niles Huyck Preserve are reported. This was accomplished by measuring levels of Hg in four different genera/species of aquatic macrophyte: *Cyperus sp.* (*sedge*)*, Iris versicolor* (*blueflag iris*), *Typha latifolia* (*broad-leaf cattail*), and *Phragmites australis* (*common reed*) in both an urban and rural watershed, during 3 different times over the 2007 growing season. Additional data were also gathered on sediment concentration and sediment organic carbon content.

My research goals are 1) to measure the partitioning of Hg between sediment and four common aquatic macrophyte species as a function of season and geographic location; and 2) to determine the effects of sediment Hg concentration and organic carbon content on plant uptake and tissue partitioning.

1.8 Patroon Creek Watershed: Urban Watershed

Portions of the Patroon Creek watershed, within the city of Albany, are heavily contaminated by Hg as the result of an upstream point source, the Mereco Refining Company Superfund site (Arnason, 2004). Many species of aquatic plants can be found existing within this watershed and a variety of Hg concentrations in several of these species have been measured. However, the wide range of Hg levels makes establishing a baseline for “background” concentrations difficult, in order to assess the severity of contamination. Areas without a localized point source can have a more homogenous background Hg concentration from the result of atmospheric deposition and the presence of Hg bearing rocks and sediments.

1.9 Edmund Niles Huyck Preserve: Reference Watershed

The amount of Hg absorbed by plants may vary by Hg levels, species, and sediment characteristics. In order to ascertain Hg background levels for aquatic plants and sediments in the absence of a point source, it is necessary to study relatively pristine watersheds.

The Edmund Niles Huyck Preserve was selected as a reference watershed for assessing local background levels for several reasons. Both the Patroon and Creek watershed, and the Huyck Preserve portion of the Ten Mile Creek watershed are located in relatively close geographic proximity to each other (approximately 30 km apart), are similar in size, and similar in climate. With the exception of one species, the same species of aquatic plant used in this study were found at each watershed. For this exception, specimens from the overall genus, *Cyperus sp.* (Sedge), were found at each watershed.

2. STUDY AREA AND METHODS

2.1 Study Areas

Edmund Niles Huyck Preserve

The Edmund Niles Huyck Preserve and Biological Research Station is a private organization that includes 800 ha of protected lands and water bodies. Now largely forested, most of the property is former agricultural lands that have returned to forest via natural succession and plantations. The preserve is located on the western edge of the Helderberg Plateau in the towns of Rensselaerville and Berne in southwestern Albany County, New York (Figure 2 and Appendix A). The preserve is within the upper reaches of the Tenmile Creek Watershed (a tributary of Catskill Creek), which consists of predominantly well-forested and post-agricultural lands with no industrial or urban inputs (Madden et al. 2007; Wyman, 1988). Within preserve boundaries are several water bodies including the 44 ha Lake Myosotis, the 4 ha Lincoln Pond, and the 4 ha Bryan Swamp. Bryan Swamp accepts drainage from the watershed and ultimately drains into Tenmile creek, whereas Lake Myosotis and Lincoln Pond are impoundments along the creek. Hagaman Creek also drains into Lake Myosotis, and there are at least fifty smaller intermittent streams which flow within the preserve during times of snow melt or heavy rains (Wyman, 1988).

The geology of the Huyck Preserve and surrounding Tenmile Creek Watershed consists of Silurian and Devonian limestones from the Helderberg Group, sandstones and shales from the Kiskatom Formation, and shales of the Lower Hamilton Group. During the last glaciation, the area underwent a period of glacial scouring and deposition of glacial till directly on bedrock. Evidence exists that the basins of Lincoln Pond and Lake Myosotis are glacial in origin (Madden, 2004; Wyman, 1988).

The lands of the Huyck Preserve are part of what was once known as the “Manor of Rensselaer Wyck” which was established in 1629. In 1785, the Manor was surveyed and subdivided into many 65 ha lots which were leased to settlers in the Town of Rensselaerville. Much of the land was clear-cut of trees to provide raw materials for early industry and open lands for farming. The two dams on preserve property, which create the impoundments of Lake Myosotis and Lincoln Pond, were built around 1800 to provide a water supply for local mills. In 1870, the first felting mill of North America was founded by the partnership of Waterbury and Huyck at the foot of the Rensselaerville Falls, which is now part of the current preserve property. Due to successive periods of flooding causing damage to the mill and its dams, the mill was only in operation for approximately 9 years (Wyman, 1988).

Early felt mills frequently used mercury in the felt curing process, and the Waterbury and Huyck felt mill might be a historical point source of Hg within the preserve. Although there appears to be no historical account on the use of mercury within the operations of this mill, the author’s previous research has shown mercury concentrations in soils and sediments from within and around the mill foundation to be many times above the local background concentration (Neumann, 2008). It is not expected that this affects the work described in this report as the closest sampling site for aquatic macrophytes and sediments described here is located at least 300m upstream from the mill location.

Patroon Creek Watershed

The Patroon Creek Watershed (Figure 2 and Appendix B), Albany County, New York, is a heavily urbanized, industrial watershed approximately 33 km^2 in area, located within the Towns of Colonie and Guilderland, and the City of Albany. Parts of the watershed are heavily polluted by mercury as the result of a point source, Mercury Refining, Inc (Mereco), a former mercury refinery listed on the National Priorities List (Superfund), and by Cadmium (Cd), Lead (Pb), and depleted Uranium (U) as a result of another point source, National Lead Industries (NLI). The watershed is drained by the Patroon Creek, which originates primarily in the Albany Pine Bush Preserve, and flows eastward through urban neighborhoods and industrial parks before emptying into the Hudson River at the City of Albany (Arnason and Fletcher, 2003). A tributary originating at Murray Pond, which drains some of the northern watershed, will be referred to as the North Branch. Due to years of various pollution problems (sewage drainage, industrial storm water drainage, and illegal dumping) Patroon Creek was recently listed as one of the ten most severely impacted streams in New York State (Bode et al, 1995).

Most of the watershed, including the Hg point source is underlain by a layer of eolian and lacustrine sand. The highly permeable sand layer grades down into a low permeable deposit of lake silt and clay (Dineen, 1982; Dineen and Hansen, 1983). These unconsolidated deposits overlie bedrock comprised of the Austin Glen Member of the Ordovician Normanskill Formation and Cohoes Melange (Kidd et al, 1995). Bedrock outcrops have only been noted downstream of an impoundment known as Patroon Reservoir (also known as Three-Mile Reservoir) (Arnason and Fletcher, 2003).

There are three impoundments located along the main branch of Patroon Creek: Rensselaer Lake, at the headwaters of the creek, Patroon Reservoir, less than 1 km east of Central Avenue along Interstate 90, and Tivoli Pond, located in Tivoli Park, west of Northern Boulevard. These impoundments were constructed by the City of Albany in the mid to late 1800s and most supplied water to the city until the 1920s (Audette, 2004; Arnason and Fletcher, 2003; Sheehan, 1998). The North Branch and two of these impoundments, Patroon Reservoir and Tivoli Pond, were used as sampling sites for this report, and are described in further detail below.

The North Branch tributary is approximately 1.5km long, and originates at Murray Pond in the Town of Colonie. The tributary primarily runs above ground and flows within several hundred meters of the Mereco site. The North Branch tributary is the closest sampling location to the Mereco point source.

The Patroon Reservoir lies approximately 1 km downstream from the NLI site and 1.8 km downstream from the Mereco site. This small reservoir (1.3 ha) is bounded on the west end by a continually forming sediment delta, and to the east by a stone and concrete spillway. The reservoir has been the subject of past sediment coring to examine the extent of pollution by mercury and other contaminate heavy metals. In 1999, a 3m sediment core was retrieved from the floor of the reservoir in which total mercury concentration (Hg_T) in the core ranged from below detection (0.2 mg kg^{-1}) to more than 6.0 mg kg^{-1} (Arnason and Fletcher, 2003).

Tivoli Pond is located approximately 2.2 km downstream from the Patroon Reservoir. The pond is the smaller of two water bodies that were constructed in 1851 to supply water to the City of Albany. They were abandoned as a reservoir in 1890 and quickly became vegetated and sedimented. The area was then used for disposal of sewage, and other wastes for the next 85 years. In the 1970's, work began to turn the remaining Tivoli Pond and surrounding area into the urban park and nature preserve that exists today (Miller and Matthews, 1978; Sheehan, 1998).

2.2 Aquatic Macrophyte and Sediment Sampling

Methodology was designed to sample a variety of aquatic plants from two distinct types of watersheds, urban and rural. Sampling at the Patroon Creek watershed included urban sites that were both very likely to be affected (North Branch tributary; Patroon Reservoir), and less likely to be affected (Tivoli Pond) by the Hg point source. Sites were based on location, relationship to potential point sources, accessibility, and occurrence of flora. Three sites were selected from the Patroon Creek watershed and two from the Huyck Preserve comprising a mix of urban and rural locations.

Samples of four different species of aquatic macrophyte, *Cyperus sp.* (sedge)*, Iris versicolor* (blueflag iris), *Typha latifolia* (broad-leaf cattail), and *Phragmites australis* (common reed) were collected together with their associated sediments from a total of five sites within the Huyck Preserve and Patroon Creek watershed. Sites inside the Huyck Preserve included the northern edge of Bryan Swamp, and the northeast side of Lake Myosotis. Sites within the Patroon Creek watershed included the North Branch tributary, approximately 300m south-southeast of the Mereco point source, the sediment delta along the west side of Patroon Reservoir, and the northern shore of Tivoli Pond. Only one site, Bryan Swamp, contained samples of all four taxa whereas the remainder of the sampling sites were lacking in one or more genera/species. Bryan Swamp was the only location found within the 800 ha Huyck Preserve to contain *common reed*, while the sampling area at North Branch was so densely infested with this species that none of the other genera/species were found. Lake Myosotis was lacking specimens of *common reed*, the sediment delta at Patroon Reservoir did not contain *sedge*. and *blueflag iris* was absent from Tivoli Pond.

Each plant collected was divided into 3-4 four sections: roots, rhizomes (when present and discernable), above-ground stems, and leaves. No above-ground stems were collected for *blueflag iris*, and no rhizome tissue was separated from the clumps of *sedge*..

Samples were collected three times during the 2007 growing season: spring (late May to mid June), summer (late August to early September), and fall (early to mid November). Samples were removed from the ground with a metal shovel, freed of remaining sediment and debris by hand, and placed in clean, labeled polyethylene bags for later processing. Root and sediment sample depth was 0-10cm, measured from the sediment surface.

To create a representative sample, several sediment samples from each plant collection point were combined to create a representative composite sediment sample. Each time a round of plant sampling was completed, a composite sediment sample was collected from each site, thus, there are a total of three sediment samples per site for the 2007 growing season.

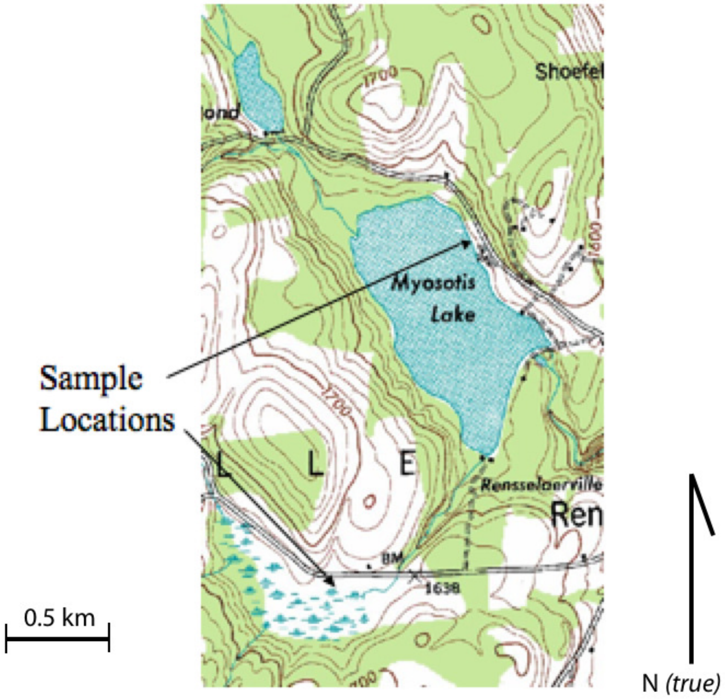

Figure 2. USGS Quadrangle portion showing sample locations at the E.N. Huyck Preserve. (Source: USGS Rensselaerville, NY 7.5 Minute Quardangle, 1946)

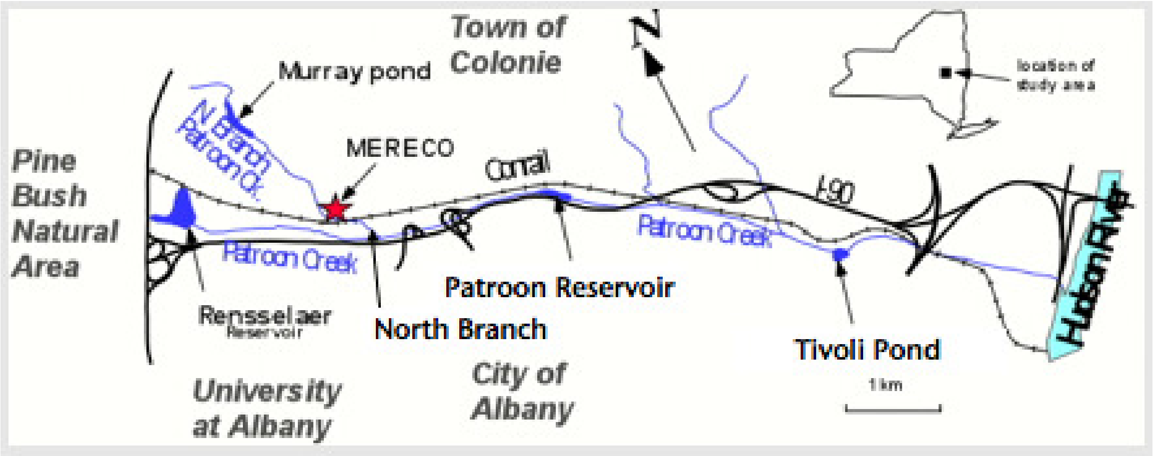

Figure 3. Map showing portions of the Patroon Creek watershed and sampling locations. Northerly pointing arrows show sample locations at North Branch, Patroon Reservoir, and Tivoli Pond. The red star shows the location of the Mereco point source. (Source: Fletcher, 2003)

Table I. Species sampled from the Edmund Niles Huyck Preserve

Site	Scientific Name	Common Name
Bryan Swamp	*Phragmites australis*	*common reed*
	Typha latifolia	*broadleaf cattail*
	Iris versicolor	*blueflag iris*
	Cyperus sp.	*sedge*
Lake Myosotis	*Typha latifolia*	*broadleaf cattail*
	Iris versicolor	*blueflag iris*
	Cyperus sp.	*sedge*

Table II. Species sampled from the Patroon Creek Watershed.

Site	Scientific Name	Common Name
North Branch	*Phragmites australis*	*common reed*
Patroon Reservoir	*Phragmites australis*	*common reed*
	Typha latifolia	*broadleaf cattail*
	Iris versicolor	*blueflag iris*
Tivoli Pond	*Phragmites australis*	*common reed*
	Typha latifolia	*broadleaf cattail*
	Cyperus sp.	*sedge*

Additional data collected included sediment temperature and pH; water temperature and pH, water conductivity and mg/l of dissolved oxygen. Dissolved oxygen was measured by a YSI™ Model 85 handheld dissolved oxygen meter that was calibrated before each use, and specific conductance was measured with a YSI™ Model 30 handheld conductivity meter. Dissolved oxygen and conductivity measurements were taken in the field during sampling for sites within the Huyck Preserve, and Tivoli Pond. Data for the remaining sites were obtained from a records of monthly Patroon Creek monitoring stations (Arnason, unpublished).

2.3 Aquatic Macrophyte and Sediment Processing and Analysis

Before processing, plant samples were washed with tap water, and given a final rinse of de-ionized water. Once free of remaining sediment and debris, plants were separated into their different morphological sections (root, rhizome, stem, leaf). Each sample was weighed wet, dried in an oven at $40^{o}C$ for 1 to 2 weeks, and reweighed. Percent water is the difference between wet and dry weights divided by wet weight x 100. (Sample wet and dry weights, and % water can be found in Appendix I.)

Dried plant samples were mechanically pulverized and homogenized in a tungsten-carbide shatter-box and reduced to a fibrous powder. Sediment samples were passed through a #10 sieve before being crushed and homogenized by mortar and pestle. A 0.25g portion of each sample was digested in 9ml of 70% nitric acid using microwave digesting methods. The resulting solution was diluted to 50mL with 18.3 MΩ deionized water and analyzed for Hg_T by a Leeman Labs™ Hydra AA analyzer with autosampler. Calibration standard solutions (0, 10, 100, 1000 pg/mL Hg) were used to calibrate the instrument. Certified standard reference materials (NIST 1573a “Tomato Leaves” and NIST 2709 “San Joaquin Soil”), laboratory blanks, spikes, and duplicates were measured for quality control. Hg concentrations for sediments and plant tissues are reported on a dry weight basis.

Samples were analyzed for Hg_T in groups spanning several analyses, as they became available. Relative precision was 5.3% or better, spike recoveries ranged from 86% to 125%, the limit of detection (LOD) was 4 ng/g, and the limit of quantification (LOQ) was 9 ng/g. Relative accuracy or bias ranged from 2.1% to 21.8% and the mean standard deviation was 2.43 ng/g. The NIST 2709 standard used for determining accuracy in sediment contained significantly higher concentrations of Hg than the samples, therefore for each sediment analysis, samples of NIST 2709 were diluted by a factor of 10. Concentrations below the LOD are reported as <4 ng/g, and concentrations between the LOD and the LOQ are reported as 4<X<9 ng/g.

Sediment samples were also analyzed for organic carbon (OC) by coulometry. A 0.010g portion of sample was loaded into a coulometer and was oxidized by incineration at 1030 ˚C. The resulting CO_2 is then combined with ethanolamine to form a strong titratable acid. This provides the percentage of total carbon (TC). A 0.020g portion of each sample was again loaded into the coulometer and each sample was oxidized by acid, and then again combined with ethanolamine to form a strong titratable acid. The resulting mixture was titrated for total inorganic carbon (TIC). Organic carbon was derived by subtracting inorganic carbon from total carbon (OC = TC-IC).

Sediment samples were also analyzed for OC by Loss-on-Ignition (LOI). For OC analysis by LOI, a 4g portion of each sediment sample was weighed out, dried at 105^{o}C for 2 hours, cooled in a dessicator, re-weighed, and then heated at 360^{o}C for 2 hours. Heated samples were again cooled in a dessicator, and re-weighed. Percent LOI is the difference between dried weight and the post-LOI weight divided by dried weight. OC results listed in this report were derived by coulometry. LOI results are listed in Appendix G along with a comparison of the two methods.

2.4 Analysis of Root Plaques

In the Patroon Creek watershed, root plaques were found on some samples of common reed: the spring sample from Patroon Reservoir, and the summer and fall samples from

Tivoli Pond. Plaques were medium to dark grey, semi-metallic in appearance, and appeared to coat most of the root surface. Root plaques were found only on samples of *common reed*, and only within the Patroon Creek watershed. A reddish discoloration was noted on the roots of several samples of *cattail*, also within the Patroon Creek watershed, but did not appear to be a mineral plaque as described above. Plaques were not removed from the root surface before Hg_T analysis.

SEM microprobe analysis of root plaque was completed on two samples of *common reed*: Patroon Reservoir, spring sample and Tivoli Pond, summer sample. Samples were washed with tap water and then rinsed with de-ionized water. Removal of root plaque was accomplished by two methods. Plaque from the Patroon Reservoir sample was scraped off the root surface with a scalpel blade. The Tivoli Pond sample was prepared by partially dissolving the root tissue in household bleach, drying at 40^{o} C for several days until dry, and scraping off the root plaque with a scalpel blade. Sample material was mounted on a glass disk with double-sided tape and then analyzed by SEM microprobe at Rensselaer Polytechnic Institute in Troy, NY.

3. RESULTS

3.1 Total Mercury in Aquatic Macrophytes and Sediments: Huyck Preserve

Bryan Swamp

All species studied were found at Bryan Swamp, and generally in abundance except for *common reed.* One small stand of approximately 6 to 12 plants were located growing along the northern edge of the swamp.

Sediment concentrations at Bryan Swamp ranged from 43 ng/g to 78 ng/g with an average concentration of 59 ng/g. Plant tissue concentrations ranged from below detection (<4 ng/g) to 47 ng/g (*sedge* root, spring). Organic carbon content of Bryan Swamp sediments ranged from 3.28% to 5.89% with an average content of 4.14%. Sediment characteristics can be found in Table III.

The concentration of Hg_T varied widely by plant tissue type. In most cases, roots had the highest concentration, relative to other tissues. There were two instances where leaf samples had the highest concentration, *common reed* – spring, and *iris* – spring.

Root concentrations were highest in the spring and summer, except for *iris*, which remained unchanged. Rhizome and stem concentrations generally remained between the LOD and the LOQ throughout the study. Leaf concentrations were highest in the spring except for *cattail*, which was highest in the fall.

Root concentrations were generally lowest in the fall except for *blueflag iris*, which remained steady throughout the growing season. Leaf concentrations were highest in the spring, except for *cattail,* for which leaf concentration was highest in the fall. All plant Hg concentrations for Bryan Swamp can be found in Table IV.

Table III. Sediment and water characteristics at Bryan Swamp, 2007.

	Hg_T (ng/g)	%OC	Sedx pH	Sedx Temp (C^o)	Water pH	Water Temp (C^o)	DO (mg/L)	Spc. Cond. (µS)
Spring	43	5.88	6.8	16.5	7	26	2.5	329
Summer	78	3.28	6.8	20.6	7	22.3	9.5	458
Fall	57	3.28	6.7	5.5	7	4.5	2.9	250

Table IV. Hg_T concentrations from aquatic macrophytes at Bryan Swamp, 2007 (N/A = sample concentration was not available).

Bryan Swamp	Hg_T in ng/g			
Common reed	Root	Rhizome	Stem	Leaf
Spring	32	14	4<X<9	32
Summer	33	<4	4<X<9	4<X<9
Fall	23	4<X<9	4<X<9	16
Cattail	Root	Rhizome	Stem	Leaf
Spring	42	4<X<9	4<X<9	10
Summer	40	4<X<9	9	4<X<9
Fall	26	13	4<X<9	16
Blueflag iris	Root	Rhizome		Leaf
Spring	17	14		26
Summer	14	4<X<9		4<X<9
Fall	15	4<X<9		4<X<9
Sedge	Root		Stem	Leaf
Spring	47		N/A	32
Summer	31		12	15
Fall	18		9	24

Lake Myosotis

All species studied except for *common reed* were found in abundance at Lake Myosotis. Sediment concentrations at Lake Myosotis ranged from 46 ng/g to 69 ng/g with an average concentration of 54 ng/g. Plant tissue concentrations ranged from below detection to 40 ng/g (sedge root, spring). Organic carbon content of Lake Myosotis sediments ranged from 3.38% to 6.8% with an average content of 4.73%. Sediment characteristics for Lake Myosotis can be found in Table V.

Concentration of Hg_T varied widely by plant tissue type with roots generally having the highest concentration. Root concentrations were highest in the fall except for *cattail,* which was highest in the spring. Rhizome concentrations remained below the LOD for *cattail*, and were varied for *blueflag iris*. Stem concentrations were below the LOD for *cattail* and rose throughout the study for *sedge*. Leaf concentration was highest in the fall for all species.

Root concentrations were lowest during summer for *cattail*, in the fall for *sedge*, and for *blueflag iris* during spring. Rhizome concentrations were lowest in the summer for *iris* and stem concentrations were lowest for *sedge* in the spring. Leaf concentrations varied little for *cattail* and *blueflag iris* and had risen by fall for *sedge*. Hg_T concentrations for plants at Lake Myosotis can be found in Table VI.

Table V. Sediment and water characteristics at Lake Myosotis, 2007 (N/A = data was not available).

	Hg_T (ng/g)	%OC	Sedx pH	Sedx Temp (C^o)	Water pH	Water Temp (C^o)	DO (mg/L)	Spc. Cond. (µS)
Spring	46	6.79	6.6	17	6.9	26.8	9.4	112
Summer	47	4.03	6.5	N/A	6.5	25	10.2	122
Fall	69	3.38	6.7	8	6.8	8.5	4.83	131

Table VI. Hg_T concentrations from aquatic macrophytes at Lake Myosotis, 2007.

Lake Myosotis	Hg_T in ng/g			
Cattail	Root	Rhizome	Stem	Leaf
Spring	24	<4	<4	<4
Summer	22	<4	<4	<4
Fall	25	<4	<4	10
Blueflag iris	Root	Rhizome		Leaf
Spring	11	12		4<X<9
Summer	16	4<X<9		4<X<9
Fall	22	10		10
Sedge	Root		Stem	Leaf
Spring	40		4<X<9	4<X<9
Summer	29		9	4<X<9
Fall	25		20	17

Temporal and Spatial Variations: Huyck Preserve

As the growing season progressed, root Hg_T concentrations either declined or remained constant (within 5 ng/g) for most species with the exception of *blueflag iris*, which was constant at Bryan Swamp (within 3 ng/g), but steadily increased at Lake Myosotis.

Rhizome and stem concentrations were low, and seemed to vary little. The only exception was stem concentration in *sedge* at Lake Myosotis, which was below the LOQ in spring, and rose to 20 ng/g by fall.

Leaves seemed to be the most variable tissue between the two sites. Leaf concentrations varied much throughout the study at Bryan Swamp, but generally remained steady at Lake Myosotis.

Cattail concentrations were approximately twice as high at Bryan Swamp versus Lake Myosotis. Root concentrations fell over the growing season at Bryan Swamp, and by fall, were similar to root concentration at Lake Myosotis. No clear distinction in *blueflag iris* and *sedge* Hg concentrations between Bryan Swamp and Lake Myosotis were apparent. A comparison of *common reed* between the two sites could not be made since it only occurred at Bryan Swamp. The P value for root concentrations of Bryan Swamp and Lake Myosotis indicated non-significance between the two sites. A list of P values for the Kruskal-Wallis test can be found in Table XIII.

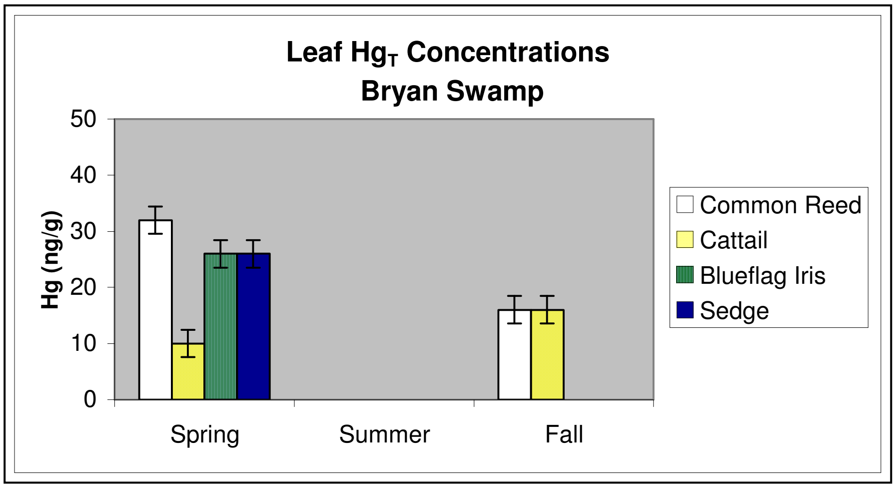

Figure 4. Leaf concentrations at Bryan Swamp, 2007 (concentrations below the LOQ are not shown; error bars indicate mean standard deviation).

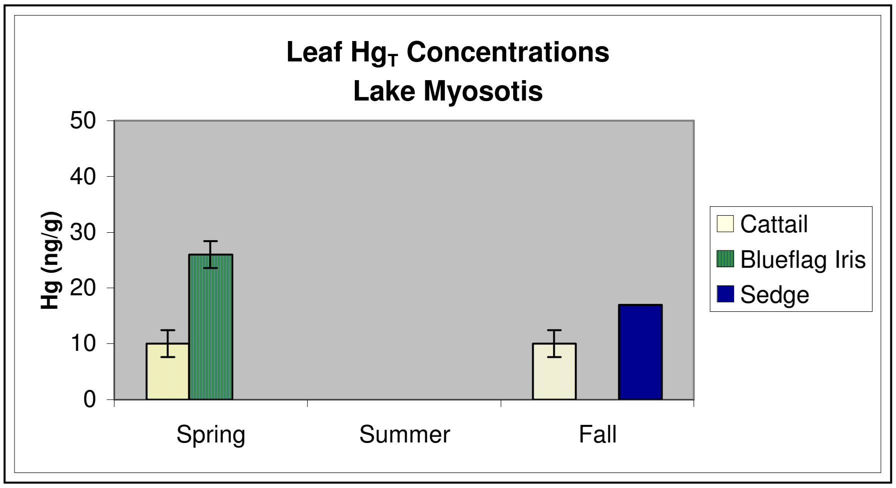

Figure 5. Leaf concentrations at Lake Myosotis, 2007 (concentrations below the LOQ are not shown; error bars indicate mean standard deviation).

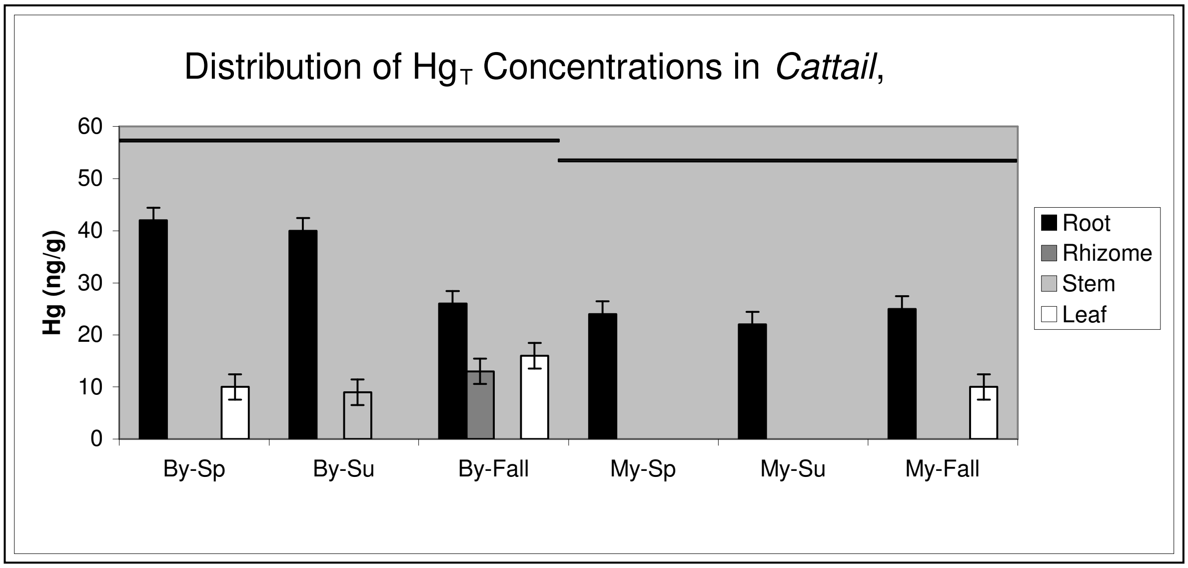

Figure 6. *Cattail* concentrations at Bryan Swamp (left) and Lake Myosotis (right), 2007. Mean sediment concentration at each site are shown by the horizontal lines (concentrations below the LOQ are not shown; error bars indicate mean standard deviation)

3.2 Total Mercury in Aquatic Macrophytes and Sediments: Patroon Creek Watershed

North Branch

Of the four species studied, only common reed was found at North Branch. Populations were prolific and dense, and likely impeded the growth of other species.

Sediment concentrations at North Branch ranged from 421 ng/g to 567 ng/g with an average concentration of 483 ng/g. Plant tissue concentrations ranged from 8 ng/g (*common reed* rhizome, fall) to 354 ng/g (*common reed* root, fall). Organic carbon content of North Branch sediments ranged from 1.63% to 2.14% with an average content of 1.87%. Sediment characteristics for North Branch can be found in Table VII.

The pattern of the highest to lowest concentrations in respect to plant tissue type followed the pattern: root>leaf>rhizome>stem. Root concentration was lowest in the spring and rose throughout the growing season. Rhizome and stem concentration varied little, and leaf concentration was the same in spring and summer, and highest in the fall. Hg_T concentrations for common reed at North Branch can be found in Table VIII.

Table VII. Sediment and water characteristics at North Branch, 2007 (N/A = data was not available).

	Hg_T (ng/g)	%OC	Sedx pH	Sedx Temp (C°)	Water pH	Water Temp (C°)	DO (mg/L)	Spc. Cond. (µS)
Spring	421	2.14	N/A	N/A	7.6	23	7.83	995
Summer	567	1.84	N/A	N/A	7.3	17.3	8.77	1118
Fall	462	1.63	7.67	N/A	7.3	11	8.58	1050

Table VIII. Hg_T concentrations from aquatic macrophytes at North Branch, 2007.

North Branch	Hg_T in ng/g			
Common Reed	Root	Rhizome	Stem	Leaf
Spring	240	17	14	24
Summer	333	18	10	25
Fall	354	4<X<9	4<X<9	33

Patroon Reservoir

Sediment concentrations at Patroon Reservoir ranged from 218 ng/g to 587 ng/g with an average concentration of 356 ng/g. Plant tissue concentrations ranged from below detection to 121 ng/g (*common reed* root, spring). Organic carbon content of Patroon Reservoir sediments ranged from 2.32% to 7.05% with an average content of 4.51%. Sediment characteristics for Patroon Reservoir can be found in Table IX.

Concentration of Hg_T varied by plant tissue type. The pattern of the highest to lowest concentrations in respect to plant tissue type was root>rhizome>leaf>stem for samples collected in the spring, and root>leaf>rhizome>stem or root>leaf>stem>rhizome for the remaining samples.

Root concentrations were highest in the fall except for *common reed,* which was highest in the spring. Rhizome and stem concentrations were low, with most close to, or below the LOQ. The exception was the spring rhizome concentration for common reed (54 ng/g). Leaf concentrations were highest in the fall for all species except *blueflag iris*, which remained steady.

Root concentrations were lowest during summer for common reed and *cattail* , and were lowest for *blueflag iris* during spring. Leaf concentrations were lowest in the spring for all species except for *blueflag iris,* which remained steady. Hg_T for plants at Patroon Reservoir can be found in Table X.

Table IX. Sediment and water characteristics at Patroon Reservoir, 2007 (N/A = data was not available).

	Hg_T (ng/g)	%OC	Sedx pH	Sedx Temp (C^o)	Water pH	Water Temp (C^o)	DO (mg/L)	Spc. Cond. (μS)
Spring	218	2.32	N/A	N/A	7.7	23.4	7.49	1014
Summer	264	4.16	N/A	N/A	7.3	15.3	9.9	996
Fall	587	7.05	7.63	22	7.4	12	12.1	970

Table X. Hg_T concentrations from aquatic macrophytes at Patroon Reservoir, 2007.

Patroon Reservoir	Hg_T in ng/g			
Common reed	Root	Rhizome	Stem	Leaf
Spring	121	54	4<X<9	13
Summer	75	11	4<X<9	19
Fall	105	<4	<4	22
Cattail	Root	Rhizome	Stem	Leaf
Spring	53	13	4<X<9	4<X<9
Summer	47	4<X<9	4<X<9	11
Fall	62	11	<4	14
Blueflag iris	Root	Rhizome		Leaf
Spring	20	12		11
Summer	55	4<X<9		12
Fall	56	10		10

Tivoli Pond

Sediment concentrations at Tivoli Pond ranged from 57 ng/g to 53 ng/g with an average concentration of 56 ng/g. Plant tissue concentrations ranged from below detection to 107 ng/g (*common reed* root, mid-fall). Organic carbon content of Tivoli Pond sediments ranged from 2.37% to 3.63% with an average content of 3.11%. Sediment characteristics for Tivoli Pond can be found in Table XI.

Concentration of Hg_T varied by plant tissue type. The pattern of the highest to lowest concentrations in respect to plant morphology was generally root>leaf>stem>rhizome or root>leaf>rhizome>stem except for the spring *cattail* sample, which had a pattern of root>rhizome>leaf>stem and the *sedge* summer sample which had a pattern of root>stem>leaf.

Root concentrations were highest during spring and fall for Common reed, and during spring for *cattail* and *sedge*. Rhizome and stem concentrations were generally close to or below the LOQ except for the *sedge* summer sample (34 ng/g). Leaf concentrations were highest for all species during summer.

Root concentrations were lowest for *common reed* during summer, and fall for *cattail* and *sedge*. Leaf concentrations were lowest during spring for all species. Hg_T concentrations for all plants at Tivoli Pond can be found in Table XII.

Table XI. Sediment and water characteristics at Tivoli Pond, 2007 (N/A = data was not available).

	Hg_T (ng/g)	%OC	Sedx pH	Sedx Temp (C^o)	Water pH	Water Temp (C^o)	DO (mg/L)	Spc. Cond. (µS)
Spring	57	3.63	N/A	N/A	7.2	18.5	10.9	971
Summer	57	3.34	7.9	20.1	7.3	21.4	7.64	770
Fall	53	2.37	7.7	21.6	7.6	6.6	8.62	970

Table XII. Hg_T concentrations from aquatic macrophytes at Tivoli Pond, 2007. N/A = sample concentration was not available.

Tivoli Pond	Hg_T in ng/g			
Common Reed	Root	Rhizome	Stem	Leaf
Spring	102	4<X<9	4<X<9	13
Summer	70	4<X<9	4<X<9	22
Fall	107	10	4<X<9	18
Cattail	Root	Rhizome	Stem	Leaf
Spring	85	12	4<X<9	8.31
Summer	57	4<X<9	4<X<9	20.1
Fall	53	<4	<4	14.9
Sedge	Root		Stem	Leaf
Spring	65		N/A	18
Summer	43		34	29
Fall	35		4<X<9	24

Temporal and Spatial Variations: Patroon Creek Watershed

Common reed root concentrations between Patroon Reservoir and Tivoli Pond were similar, and had a similar pattern throughout the growing season. Root concentration of Hg_T during spring and fall was similar, but dipped slightly during summer. *Common reed* root concentration at North Branch climbed steadily during the season. Rhizome and stem concentrations generally remained low for all species at all sites. Leaf concentration rose over the growing season at all three sites. Despite the significantly higher root concentrations at North Branch in comparison to other sites, there were no discernable visual effects in plant appearance or growth.

Cattail root concentration declined at Tivoli and began to decline at Patroon, but rose slightly during fall, whereas leaf concentration rose steadily at Patroon. At Tivoli, leaf concentration had risen by summer, but had fallen slightly by fall.

Blueflag iris was only found at Patroon Reservoir. Root concentration more than doubled between spring and summer while leaf concentrations remained steady. *Sedge* was only found at Tivoli Pond. Root concentration fell over the growing season while leaf concentration was generally steady. The P value for root concentrations between Patroon Reservoir and Tivoli Pond was 0.05. A list of P values for the Kruskal-Wallis test can be found in Table XIII.

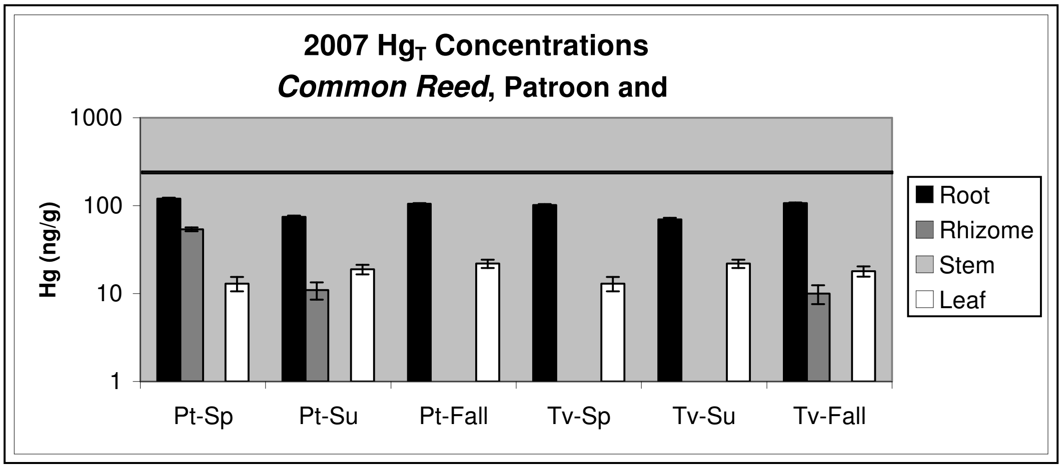

Figure 7. *Common reed* concentrations at Patroon Reservoir (left) and Tivoli Pond (right), 2007. (Mean sediment concentration at each site are shown by the horizontal lines; error bars indicate average standard deviation; concentrations below the LOQ are not shown, including all stem concentrations).

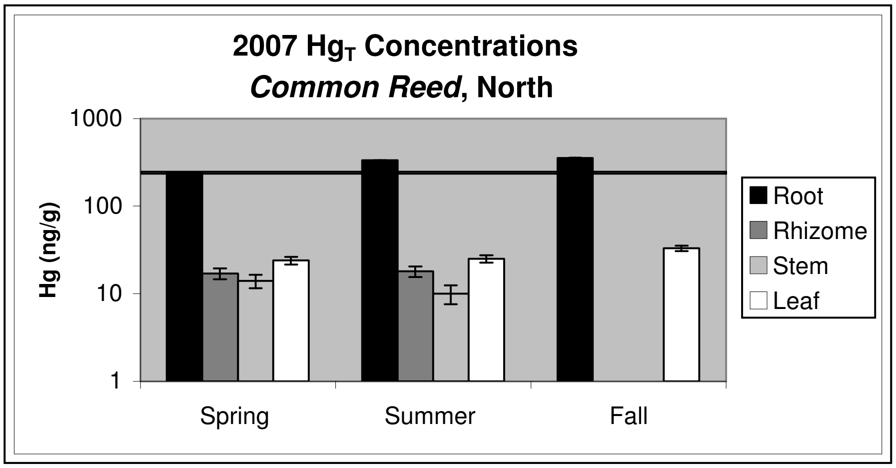

Figure 8. *Common reed* concentrations at North Branch, 2007 (Mean sediment concentration is shown by the horizontal line; error bars indicate average standard deviation; concentrations below the LOQ are not shown).

3.3 Differences in Hg$_T$ Between Species/Genera

The Hg$_T$ concentrations between species/genera varied widely. In instances of low sediment concentration, all species/genera had similar amounts of Hg in their root, rhizome, stem, and leaf tissues. As sediment concentration increased, the tissue concentrations became more varied. This was predominately observed with root tissues as roots almost always had the highest concentration of Hg.

An example of this was observed in *common reed,* which occurred at all study locations except Lake Myosotis. At Bryan Swamp and Tivoli Pond, where Hg$_T$ sediment concentrations were relatively low (42.7 to 77.6 ng/g), root concentrations were also low (22.9 to 85.2 ng/g). Sediment concentrations at Patroon Reservoir were higher (218 to 587 ng/g), but common reed root concentrations were not much higher (74.7 to 121 ng/g) than those at Tivoli Pond or Bryan Swamp. Sediment concentrations at North Branch (421 to 567 ng/g) were similar to those at Patroon Reservoir, however, *common reed* root concentrations were much higher (240 to 354 ng/g) and increased over the growing season. The P value for root and leaf concentrations by species was <.001 and .003, respectively. For concentration means by tissue, the P value was <.001. A list of P values for the Kruskal-Wallis test can be found in Table XIII.

3.4 Temporal and Spatial Variations Between Huyck Preserve and Patroon Creek

Common reed root concentrations at Patroon were higher than those at Huyck by a factor of 3 when compared with concentrations at Patroon Reservoir and Tivoli Pond, and a factor of 10 when compared with North Branch. Root concentration at North Branch rose steadily over the growing season, while all other sites showed either a pattern of decline (Huyck), or decline followed by a slight rise (Patroon Reservoir, Tivoli Pond). Rhizomes and stems were usually low in concentration with no apparent trends. Leaf concentrations at Huyck were similar to Tivoli, but rose during the growing season at Patroon and declined at Huyck.

Cattail was found at all sites except for North Branch. *Cattail* root concentrations were approximately 1.5 to 2 times higher at Patroon when compared to Huyck, and showed a general pattern of decline in concentration during the growing season with the exception of the fall samples at Tivoli, which were slightly elevated. Rhizome and stem concentrations were generally low with no distinguishable patterns. Leaf concentrations and patterns were similar to those of roots.

Blueflag iris was found at both Huyck sites, and at Patroon Reservoir. Root concentrations and patterns for *blueflag iris* were varied between the two watersheds.

Concentrations were similar between Bryan Swamp and Lake Myosotis, but were approximately 3 to 4 times higher at Patroon Reservoir. While concentration remained steady during the growing season at Bryan Swamp, it became elevated Myositos and Patroon. Rhizome and leaf concentrations were generally close to, or below the LOQ with no distinguishable trends except for an elevated spring concentration (25.6 ng/g) at Bryan Swamp.

Sedge was found at both Huyck sites and at Tivoli Pond. *Sedge* root concentrations were approximately 1.5 to nearly 2 times higher at Tivoli, however concentration patterns were similar. Stem concentrations were generally close to, or below the LOQ with no distinguishable patterns, except for occasional elevated concentrations (20 ng/g – fall sample, Lake Myosotis; 34 ng/g – summer sample, Tivoli Pond). Leaf concentrations varied and were generally higher at Bryan Swamp and Tivoli Pond than Lake Myosotis by a factor of 2. The P values of root and leaf concentration by site were both <.001. A list of P values for the Kruskal-Wallis test can be found in Table XIII.

Table XIII. Kruskal-Wallis tests between various root, leaf, species, and site concentrations (NS indicates non-significance).

Description	H	df	Pvalue
Roots by species	17.704	3	<.001
Roots of *common reed* by site	9.462	4	0.051
Roots by site	28.002	4	<.001
Leaves by species	13.427	3	0.003
Concentration means by tissue	88.5	4	<.001
Roots: Bryan & Myosotis	0.922	1	NS
Roots: Patroon & Tivoli	7.803	3	0.05

Table XIV. Pearson correlations between sediment and root concentrations (NS indicates non-significance).

Descritiption	n=	r value	Pvalue
Common reed	12	0.75	<.005
Cattail	12	0.333	NS
Iris	9	0.861	<.005
Sedge	9	-0.284	NS

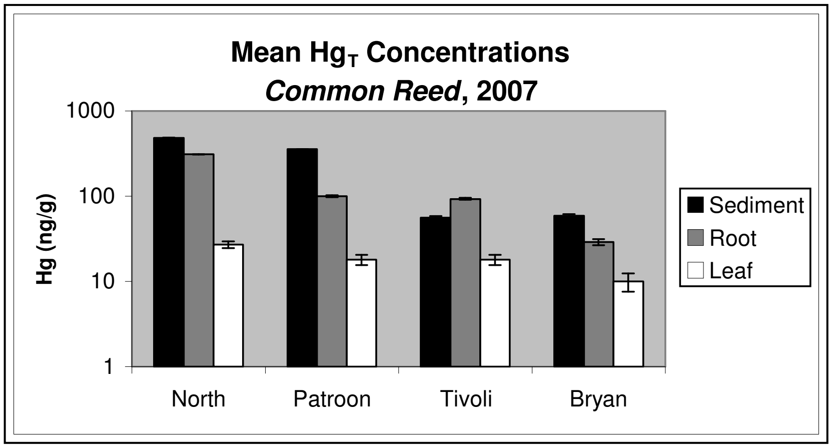

Figure 9. *Common reed* mean root and leaf concentrations for Bryan Swamp, North Branch, Patroon Reservoir, and Tivoli Pond (error bars indicate mean standard deviation). P value = <.005 for sediment and root correlation.

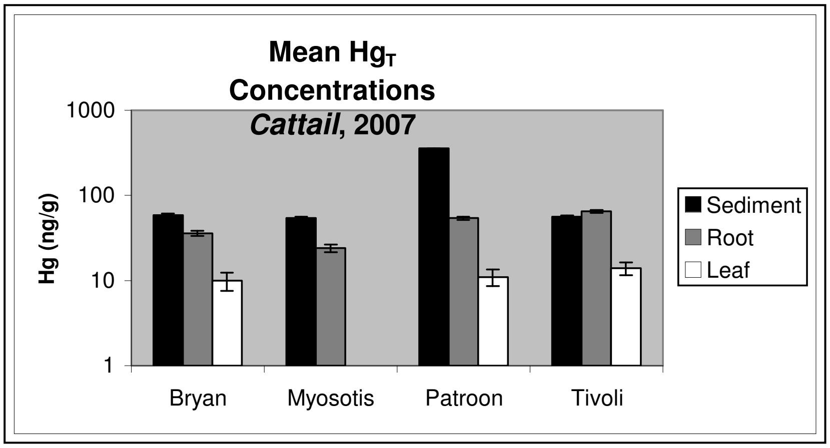

Figure 10. Mean sediment concentrations and *Cattail* root and leaf concentrations for Bryan Swamp, Lake Myosotis, Patroon Reservoir, and Tivoli Pond (error bars indicate average standard deviation; concentrations below the LOQ are not shown). P value indicated non-significance for sediment and root correlation.

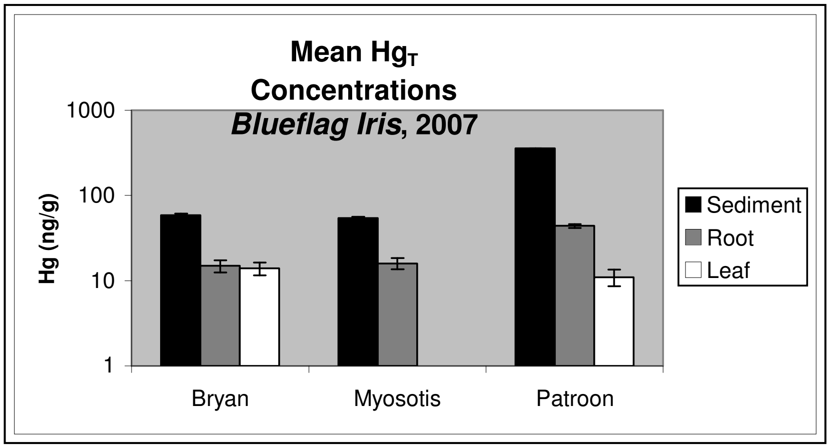

Figure 11. Mean sediment concentrations and *blueflag iris* root and leaf concentrations for Bryan Swamp, Lake Myosotis, and Patroon Reservoir (error bars indicate average standard deviation; concentrations below the LOQ are not shown). P value = <.005 for sediment and root correlation.

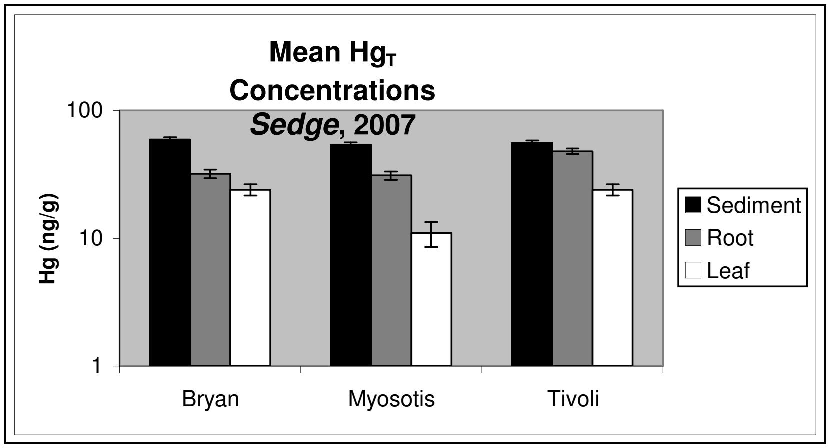

Figure 12. Mean sediment concentrations and *sedge* root and leaf concentrations for Bryan Swamp, Lake Myosotis, and Tivoli Pond (error bars indicate average standard deviation). P value indicated non-significance for sediment and root correlation.

3.5 Correlations with Sediment Cores

A previous study by Fletcher and Arnason, 2003, analyzed two sediment cores from Patroon Reservoir in order to assess the contamination from the Hg point source. Core 2 was extracted from the west end of the reservoir, in an area filled with sediment, and Core 14 was extracted from the east end, adjacent to a spillway and dam. Core locations are found in Appendix C. Core 2 was analyzed from approximately 0 to 225 cm and yielded concentrations generally in the 50 to 200 ng/g range, with a spike of approximately 450 ng/g at 132 to 134cm, and 2450 ng/g at 26 cm. Core 14 was analyzed from approximately 65 to 170 cm, and yielded concentrations generally from 250 ng/g to 2000 ng/g, with a spike of 6250 ng/g at 80 to 82 cm, 3000 ng/g at 106 to 108 cm, and 2250 ng/g at 142 to 144 cm (Fletcher and Arnason, 2003).

Sediment samples from Patroon Reservoir ranged from 218 to 587 ng/g and root samples ranged from 20 to 127 ng/g. These values are similar to those in Core 2, but lower than those in Core 14.

3.6 Hg Speciation

Previous work on solid-phase Hg speciation was completed on Core 2 and Core 14. Core 2 was analyzed for speciation at 24 to 26cm, 26 to 28cm, and 132 to 134cm, indicating an average of 71% elemental Hg, 13% inorganic Hg, and 16% organic Hg. Core 14 was analyzed at 80 to 82cm, 106 to 108cm, and 142 to 144cm with an average of 89% elemental Hg, 7% inorganic Hg, and 4% organic Hg (Fletcher, 2003). Charts of the speciation data can be found in Appendix D. Mercury speciation for aquatic macrophytes and sediments from the Patroon Creek watershed and the Huyck Preserve was not completed. All samples were analyzed for total mercury (Hg_T) only.

3.7 Correlations Between Sediment and Root Concentration

Root concentration varied by species, site, and sediment concentration. No clear trends in root and sediment concentration were apparent at the Huyck Preserve (mean sediment:root ratios ranged from 1.7:1 to 4:1), while at the Patroon Creek watershed, results varied (mean sediment:root ratios ranged from 1.6:1 for common reed at North Branch to 8:1 for blueflag iris at Patroon Reservoir). For Patroon Reservoir and Tivoli Pond, root concentrations seemed to correlate with sediments only when sediment concentrations were lower, as the sediment:root ratio increased with increasing sediment concentration. At North Branch, root concentration seemed to correlate more consistently with sediments (sediment:root ratio ranged from 1.3:1 to 1.7:1 during the study). P value for sediment and root correlations for both common reed and blueflag iris were <.005. P values for cattail and sedge indicated non-significance. A list of P values for Pearson correlations between sediment and root concentrations can be found in Table XIV.

3.8 Correlations Between Root Concentration and Organic Carbon

All samples had measurable amounts of organic carbon but no measurable amounts of inorganic carbon. When comparing mean organic carbon content by site during the 2007 growing season, Lake Myosotis consistently had the highest content (4.73%) followed by Patroon Reservoir (4.51%), Bryan Swamp (4.14%), and Tivoli Pond (3.11%). North Branch had the lowest mean organic carbon content (1.87%). Table XI shows sediment organic carbon content by site and season.

While Hg_T sediment concentrations were similar between Bryan Swamp and Tivoli Pond (mean of 59 vs. 56 ng/g, respectively), root concentrations in *common reed* differed (mean of 29.4 vs. 90.1 ng/g, respectively). The organic carbon content at Bryan Swamp is higher than that of Tivoli Pond (mean of 4.14% vs. 3.11%, respectively). Mean Hg_T root concentration at Patroon Reservoir was similar to the mean concentration at

Tivoli Pond (100 vs. 90.1, respectively) however Patroon had a much higher mean sediment concentration (356 ng/g) and a higher mean organic carbon content (4.51%).

Mean sediment concentration at North Branch (483 ng/g) was significantly higher than Bryan Swamp (59 ng/g) and Tivoli Pond (56 ng/g), but were similar to those at Patroon Reservoir (356 ng/g). Mean *common reed* root concentrations at North Branch were also significantly higher (309 ng/g) than those at Patroon Reservoir (100 ng/g), or any other site where *common reed* occurred. However, mean organic carbon content was lower at North Branch (1.87%) than any other site. This would suggest an inverse relation between organic carbon content and *common reed* root concentration.

This can be illustrated when sediment organic carbon content is plotted against *common reed* Hg_T root concentration as shown in figure 13. This relationship can be further illustrated when root concentration and sediment concentration are plotted as a ratio (sediment:root) against sediment concentration per unit of organic carbon. Figure 14 shows that there is more Hg_T available per unit of organic carbon at North Branch then at other sites with *common reed*.

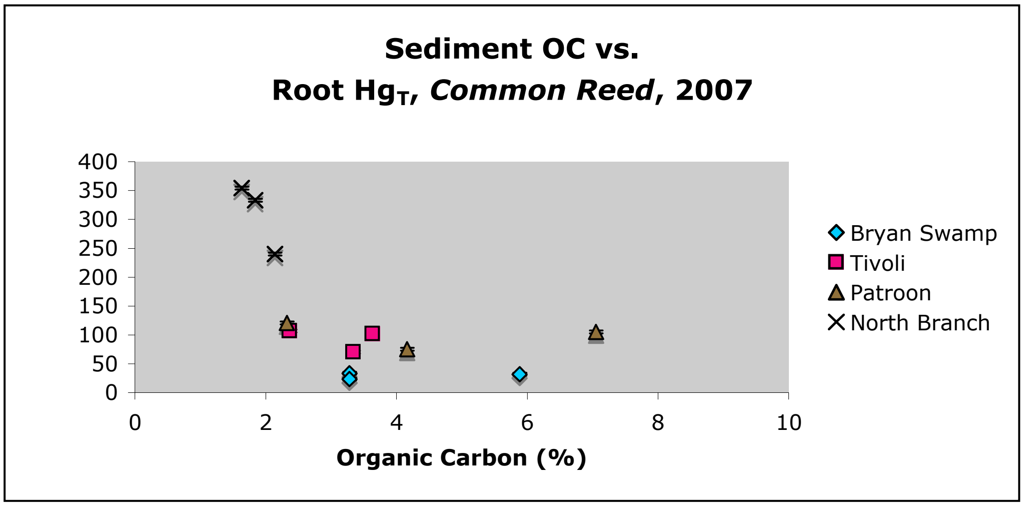

Figure 13. Root Hg versus sediment organic carbon for *common reed*.

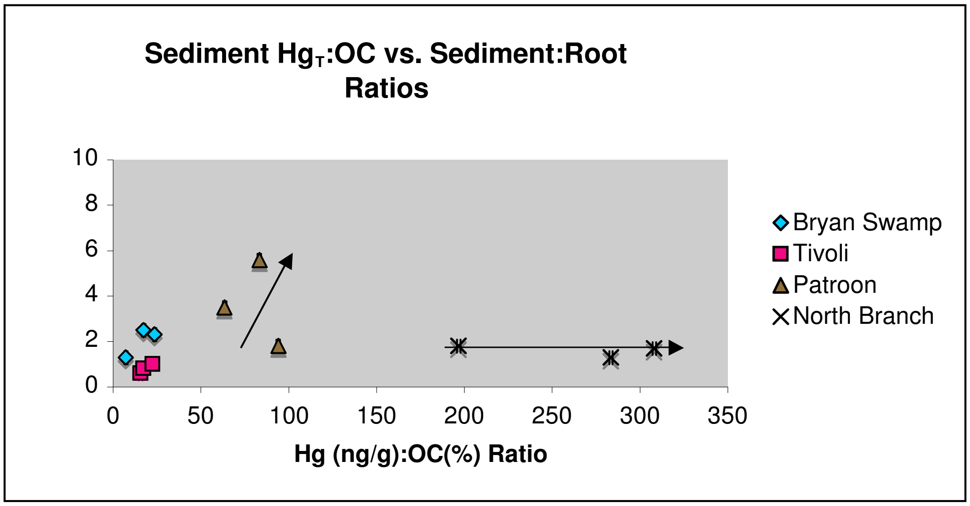

Figure 14. Sediment:Root ratio versus Hg_T:OC ratio for *common reed*.

This relationship was observed, although not as strongly, with *cattail*. Root concentration showed a general trend of increase which coincided with a decrease in sediment organic carbon. Although mean sediment concentrations are higher at Patroon Reservoir than Tivoli Pond (356 vs. 55.8 ng/g), mean *cattail* root concentrations were slightly higher at Tivoli (65 vs. 54 ng/g). Mean root concentrations at Bryan Swamp were slightly higher than those at Lake Myosotis (35 vs. 24 ng/g). Bryan Swamp sediment had a lower organic carbon content 4.14% vs. 4.73%). A similar relationship was observed with *iris* between sites at the Huyck Preserve and Patroon Reservoir, and with *sedge* between the Huyck Preserve sites and Tivoli Pond.

Table XV. Sediment organic carbon content by coulometry.

	Bryan Swamp	Lake Myosotis	North Branch	Patroon Reservoir	Tivoli Pond
Spring	5.88%	6.8%	2.14%	2.32%	3.63%
Summer	3.28%	4.03%	1.84%	4.16%	3.34%
Fall	3.28%	3.38%	1.63%	7.05%	2.37%
Mean	4.14%	4.73%	1.87%	4.51%	3.11%

3.9 Occurrence of Root Plaque

Aquatic plants have the ability to oxidize one or more elements around their roots, resulting in the formation of a root plaque. The plaque is usually iron oxide, but can also contain a wide variety of other elemental oxides, the most common being oxides of manganese, copper, aluminum, and zinc (St-Cyr and Crowder, 1990; Batty et al, 2002). In the case of iron, roots of aquatic plants draw soluble Fe via transpiration to their surfaces, where the metal precipitates. Oxidation is thought to occur through normal root function, forming a coating, or root plaque. Besides the amount of soluble metals available, the plaque that accumulates may be the result of several factors including proximity to flowing water, percent of organic matter in sediment, and oxidation potential of the root surface (St-Cyr and Crowder, 1989; Wang and Peverly, 1996). Since the formation of this coating is important to the fate of Fe and sometimes other elements, root plaques can be an important part of the biogeochemistry of wetlands (Wang and Peverly, 1996).

Plaques found on common reed roots from Patroon Reservoir (spring sample) and Tivoli Pond (summer and fall samples) were scanned and analyzed by SEM microprobe to give an overview of the elemental composition. The sample from Patroon Reservoir consisted of Fe and Al, while the sample from Tivoli Pond contained Fe and Mn. Some concentrations of Si, and Ca were detected on the Patroon sample, possibly the result of strongly adhered sediment particles which remained after washing. Amounts of Cl, Si, and Na were detected on the Tivoli sample, possibly a combination of soil particles and residue from the bleach. SEM microprobe scan graphs showing root plaque composition can be found in Appendix H.

Of the samples containing root plaques, total mercury in the Patroon sample (spring) was the highest of all three measurements (121 vs. 75 and 105 ng/g) while Hg_T in the Tivoli samples (summer and fall) were both the highest and lowest of all three measurements (70 and 107 vs. 102 ng/g). While root plaque could potentially be an adsorption site for Hg, more samples and evaluation would be needed to reach a definitive conclusion.

4. DISCUSSION

4.1 The Relevance of Mercury Concentrations in Aquatic Macrophytes

Much research has been conducted on the accumulation and persistence of Hg into foodwebs, mainly through the study of fish and the organisms that feed on them (EPA, 1997). However, soils and sediments can accumulate Hg for years and be taken up by both aquatic and land plants, thus providing another entry point into the food web (Szabo and Fodor, 2006; Weiss, et al, 2003). From here, contaminant fate becomes less certain depending on species, exposure time, concentration, and sediment characteristics. Hg may only be taken up into the root with minimal amounts passed into other tissues, through the entire plant, or received through stomatal openings on leaf surfaces. Varying soil constituents, such as increased organic carbon, may increase the fraction of Hg bound to sediments and lower the amount of Hg that can be taken up into plant tissues.

With these variables taken into consideration, plants that are known Hg accumulators can be studied and used as indicators of contamination issues. The multitude of inputs putting anthropogenic Hg into the atmosphere makes it necessary to study several areas for atmospheric Hg deposition. Thus, the importance of sampling multiple urban and rural sites to determine differences in atmospheric deposition levels. This objective was met by having three sites in an urban setting, two of which are close to an Hg point source, and two sites in a rural location, free of known Hg point sources.

4.2 Similarities and Differences from Previous Work

This study shares similarities with other work, in that it examines Hg uptake in a variety of aquatic plants. Thus, some similar results were expected. Strong Hg partitioning was observed between the root and other tissues. This was predicted by Baker, 1981, as being one of three responses to the exposure of metaliferous sediments and observed by Windham et al, 2003, and others. Similarly, variance of sediment:root partitioning was observed, possibly due to different amounts of sediment organic carbon as suggested by Coquery and Welbourn, 1995.

Conversely, some details of this study have distinct differences to the previous work of others. Although this is a small study, the collection sites are in one general geographic area, but span three distinct areas: rural, urban – close to an Hg point source, and urban – further from and seemingly unaffected by an Hg point source. These differences may provide useful information in determining changes by area in atmospheric deposition. Additionally, this study provides data on Hg concentrations in *blueflag iris*. A literature search provided no previous data for this plant.

4.3 Edmund Niles Huyck Preserve as a Reference for Patroon Creek

It was suspected that the $Hg_{(T)}$ concentrations in plants and sediments from the Huyck Preserve would provide a useful reference for evaluating background Hg_T concentrations between an urban environment (Patroon) and a rural one (Huyck). While the concentration of total mercury in sediments is chiefly a function of atmospheric deposition rate and sediment composition (how much of the sediment was derived from Hg bearing rocks), the concentration of mercury in plants tends to be a function of multiple factors including atmospheric deposition rate, sediment composition and characteristics, Hg speciation, and plant species. In addition, point sources, either natural or anthropogenic, can contribute significant amounts of Hg to plants and sediments within a watershed (Arnason, 2004).

Sediments

Sediment concentrations in the Patroon Creek watershed vary due to Hg contamination from a local point source. Sediment concentrations at Tivoli Pond (53.1 to 57.3 ng/g), the site located furthest from the point source, are similar to concentrations at the Huyck Preserve (42.7 to 77.6 ng/g), while sediments at Patron Reservoir (218 to 587 ng/g) and North Branch (421 to 567 ng/g), are higher.

The Hg_T concentrations at Tivoli Pond and in the Huyck Preserve sediments are similar to concentrations observed in stream sediments elsewhere within Albany County. Concentrations were similar in the Coeymans Creek (30 to 90 ng/g), and the nearby Ten Mile Creek (50 ng/g), approximately 5 miles downstream of the Huyck Preserve (personal communication, James Swart, NYSDEC unpublished data).

Aquatic macrophytes

Hg_T concentrations of *common reed, iris, cattail*, and *sedge* are generally higher in the Patroon Creek watershed when compared to the samples from Bryan Swamp and Lake Myosotis. The differences vary by species, morphology, and location. Root concentrations were always 1.5 to 3 times higher for all species/genera at both Tivoli Pond and Patroon Reservoir than at Huyck, with the remainder of the plant being similar. At the North Branch tributary, *common reed* root concentrations were approximately 2 to

5 times higher than Patroon and Tivoli, and 10 times higher than at Bryan Swamp with the remainder of the plant 1.5 to 2 times higher.

Probably the most interesting comparison is with *cattail*. Tivoli Pond, Bryan Swamp, and Lake Myosotis all have similar sediment concentrations (averages of 55.8, 59.1, 53.9 ng/g, respectively). Average root concentration was highest at Tivoli (2 times higher than at both Huyck Preserve sites). Average rhizome and stem concentrations were similar (within 3 ng/g or not detected). Average leaf concentrations were highest at Tivoli and Bryan Swamp (14.4 and 10.5 ng/g, respectively) and lowest at Lake Myosotis (5.45 ng/g). A similar pattern was observed in average concentrations in *sedge*. Root and stem concentrations were 1.5 to 2 times higher at Tivoli and leaf concentrations were the same at Tivoli and Bryan Swamp, 23.8 ng/g, and 10.9 ng/g at Lake Myosotis.

The reasons for the difference in plant concentrations between the Huyck Preserve and the Patroon Creek watershed may be the result of several variables. For example, sediment concentrations at Tivoli Pond and Huyck are similar, but root concentrations are higher at Tivoli. Factors such as differing sediment characteristics may be the reason for this difference. In some cases, leaf concentrations at Bryan Swamp were more similar to areas of the Patroon Creek watershed than Lake Myosotis. As noted by Tyler and Olsson, 2006, a significant portion of metal concentration in leaves may be the result of aerosol deposition rather than concentration being entirely the result of translocation through plant tissues. It is possible that Patroon and Bryan Swamp receive similar amounts of atmospheric deposition, which would be more than Lake Myosotis. This hypothesis could be tested by additional sampling at these areas, and by artificially reducing exposure of some leaf surfaces to atmospheric deposition.

4.4 Total Mercury Concentrations within Other Watersheds in the Northeast

Sediments

The Hg_T concentrations in the sediments at Bryan Swamp, Lake Myosotis, and Tivoli Pond (42.7 to 77.6 ng/g) are similar to concentrations observed in stream sediments elsewhere within Albany County. Concentrations were similar in the Coeymans Creek (30 and 90 ng/g), 10 and 20 miles south of the Patroon Creek Reservoir, respectively, and the nearby Ten Mile Creek (50 ng/g), approximately 5 miles downstream of the Huyck Preserve (personal communication, James Swart, NYSDEC unpublished data).

The sediments at Huyck and Tivoli Pond are less than, or within the lower range of concentrations observed in lakes of the Adirondacks (80 to 500 ng/g; Lorey and Driscoll, 1999) and of the Appalachians of Vermont and New Hampshire (60 to 660 ng/g; Kaman and Engstrom, 2002), while the Patroon Reservoir and the North Branch tributary sediments (218 to 587 ng/g) are within the middle to high range. The lakes in the Adirondack and Appalachian Mountain studies are remote and free of point source contamination. Therefore, Hg_T at the Huyck Preserve is likely derived from atmospheric deposition, and not any particular point source (Arnason, 2004). The same assumption can be made concerning Tivoli Pond. At Patroon Reservoir and North Branch, the higher Hg_T concentrations are likely due to a combination of factors: the Mereco point source, and atmospheric deposition. In comparison with Hg concentrations in common geologic formations, average concentrations in the Earth's crust, typical granites, and typical shales, are 80, 100, and 400 ng/g, respectively (Krauskopf and Bird, 1995).

Aquatic macrophytes

As seen in the data presented here, and the data of others, the amount of total mercury in plant tissues varies widely. Windham et al, 2003, studied Hg in *common reed* within the Hackensack Medowlands of northeastern New Jersey, a wetland contaminated with heavy metals. While sediments had Hg levels of 2910 ng/g, *common reed* had root levels that varied from 590 (April) to 1650 (August) ng/g over the 1999 growing season. The patterns of concentration were similar to those observed in Albany County watersheds, with the dominant pattern being either Root>Rhizome>Stem>Leaf or Root>Rhizome>Leaf>Stem.

Heyes et al, 1998, studied Hg concentrations in a species of *sedge*, *Carex rostrata*. Only the stems were studied on plants from a wetland in northwestern Ontario, Canada, but showed similar concentrations (21.9 ng/g) to *sedge* found in Albany County watersheds (4.93 to 34.1 ng/g).

Data could not be found for total mercury values within *cattail* in northeastern watersheds. Sundberg-Jones and Hassan, 2007, studied Hg_T concentrations on *Typha angustifolia* (narrow-leaf cattail). In the study, *narrow leaf cattail* was grown in constructed wetland plots as part of a larger study to measure the potential for phytoremediation of waste water effluent from flue gas desulfurization equipment in fossil-fueled power plants. Sediment concentration in the constructed plot was 30 ng/g, root concentration was reported at approximately 100 ng/g (±100 ng/g), and rhizome concentration was similarly 100 ng/g (±20 ng/g) (Sundberg-Jones and Hassan, 2007). Stem and leaf concentrations were not reported, but a general decline in concentration was noted from roots to the top of the plant.

A thorough search of available literature could not find data on total mercury concentrations for *iris*.

4.5 Relationships Between Root Concentration and Organic Carbon

As shown by figures 13 and 14 in section 3.8 “Correlations Between Root Concentration and Organic Carbon”, data suggests that there is an inverse relationship between Hg_T root concentration and sediment organic carbon content. That is, in locations where organic carbon content was low, an increase in root concentration was observed. This relationship may occur due to varying amounts of Hg that is available for root uptake. At sites where there is a higher percentage of sediment organic carbon, there may be a higher percentage of Hg that is bound to the organic fraction of the sediment. This could be verified by analyzing the sediments for Hg speciation to determine the percentage of organic Hg.

Organic carbon may only be one part of the Hg fractions not available for plant uptake. Fletcher, 2003, analyzed Patroon Reservoir sediment core sections by sequential chemical extraction to determine the fractions of Hg present. The speciation data (located in Appendix D) shows most Hg in the elemental form (66 to 92%) with the next largest fraction being organic (humic and fulvic acids, 1 to 21%). However, a significant amount of Hg also exists in Fe and Mn oxides (3 to 21%), with lesser amounts in sulfidic, residual, and exchangeable fractions (0 to 4%). The same may be true of the sediments where aquatic plants are found. Tessier et al, 1979, lists various fractions where trace metals can partition in sediment. Metals may be bound to carbonates, Fe and Mn oxides, organic matter, residual primary and secondary minerals, or be exchangeable through several fractions (clays, Fe and Mn oxides, humic acids). Therefore, Hg speciation through sequential extraction may be more revealing as to existing fractions of Hg than organic carbon analysis alone.

4.6 Excluder, Indicator, or Accumulator?

When root concentration is compared to the concentration in the next successive tissue (rhizome, or in the case of *sedge*, stem), root concentration almost always has a larger concentration. The exception was the spring concentration of *iris* at Lake Myosotis in which the root concentration was similar to the rhizome concentration (root: 10.8 ng/g vs. rhizome: 11.6 ng/g). Based on the Hg_T data from roots and rhizomes, it is clear that *common reed*, *cattail*, *iris*, and *sedge* all function as excluders in the presence of Hg at sediment concentrations the same or similar to those found at the Huyck Preserve, and the Patroon Creek watershed. Even though root concentration was highest for *common reed* at North Branch, rhizome concentration remained much lower indicating a restriction of mercury translocation through plant tissues. True to the excluder strategy, concentrations in other tissues may change if sediment concentration were to increase to a critical level causing unrestricted metal transport (Windham et al, 2003).

4.7 Remaining Questions and Recommendations

Efficacy in extraction of Hg

Root concentration varied widely between location and species/genera, and when compared to the rest of the plant, almost always contained the highest Hg concentration.

Therefore, the root may be the most pertinent indicator of Hg extraction. Of the four speciesexamined in this study, most often *common reed* accumulated the highest amount of mercury.

Root concentration varied by location, but not always by sediment concentration. While overall, *common reed* had much higher root concentrations within the Patroon watershed, Hg concentrations in the roots of *cattail* at Bryan Swamp were similar to, but slightly higher than concentrations in the roots of *common reed* (a 6 ng/g difference on average).

Root plaques

While root plaques frequently contain Fe and Mn, and may inhibit, but not prevent the uptake of these metals into plants (Batty et al, 2002), it is not known if they act similarly on Hg. Mercury was not detected on plaque samples that underwent SEM microprobe analysis, but Hg was detected on root tissues that had root plaque. Residue in sample digestion tubes indicate that some or all of the root plaque was not digested with the root material.

Of the samples containing root plaque (spring sample, Patroon; summer and fall samples, Tivoli), total mercury in the Patroon sample was the highest of all three measurements for *common reed* root at Patroon (121 vs. 75 and 105 ng/g) while Hg_T in the Tivoli root plaque samples were both the highest and lowest of all three measurements (70 and 107 vs. 102 ng/g). Since fractions of trace metals can become bound to Fe and Mn oxides (Tessier et al, 1979) root plaque could potentially be an adheration site for Hg. However, more samples and evaluation would be needed to reach a definitive conclusion.

Hg speciation

Speciation on Patroon Reservoir sediment cores by Fletcher, 2003, revealed Hg existing in several species. While the amount of Hg_T in the sediments at Patroon Reservoir and North Branch are similar, the roots of *common reed* contained significantly more Hg_T at North Branch. This may indicate the presence of more Hg in forms that are available for plant uptake and less Hg that is bound to the organic, or other fractions of the sediment. While organic carbon sediment values seem to support this, partitioning of Hg and other trace metals can be affected by differing environmental conditions (Tessier et al, 1979). Therefore, analysis of Hg speciation would help to determine if this hypothesis is valid.

Differences in atmospheric deposition

There is still the remaining question of the portion of leaf concentration that can be attributed to atmospheric deposition versus transloction of Hg through a macrophyte's vascular system. Tyler and Olsson, 2006, demonstrated that Hg aerosols can accumulate on leaf surfaces and account for a percentage of the total concentration of the leaf tissue. No clear conclusions on atmospheric deposition can be made with the data available here. An additional study would need at least one group of macrophyte samples where leaves were not exposed to atmospheric deposition. This is an interesting issue and may warrant further investigation.

5. CONCLUSIONS

Sediment total mercury concentrations from five sites in Albany County, NY ranged from 54 to 483 ng/g and sediment organic carbon content ranged from 1.63 to 7.05%. Macrophyte tissue concentrations ranged from below detection to 354 ng/g (*common reed* root, North Branch, fall sample). The North Branch tributary had the highest mean sediment concentration (483 ng/g) followed by Patroon Reservoir (356 ng/g). Lake Myosotis had the lowest mean sediment concentration (54 ng/g) followed by Tivoli Pond (56 ng/g) and Bryan Swamp (59 ng/g).

As noted in the work of others (e.g. Windham et al, 2003), strong Hg partitioning was observed between plant tissues in all species. The highest concentrations were found in roots, with lesser concentrations in rhizome and stem tissue. Leaf tissue often had higher concentrations than rhizome and stem tissue, likely due to intake of atmospheric Hg through stomatal pores (Millenholen et al, 2006).

Hg partitioning was also noticed between sediment and root tissues in that at most sites, root concentration appeared to be independent of sediment concentration. However, the two sites with the highest Hg sediment concentrations, had markedly different root concentrations. Coquery and Welbourn, 1995, suggested that a fraction of Hg can become bound to organic material in the sediment, limiting the bioavailability of Hg to the plant. Sediment organic carbon analysis showed an inverse relationship between organic carbon content and root concentration. Besides elemental and organic fractions, sediment Hg can become bound to carbonates, Fe and Mn oxides, residual primary and secondary minerals, or become exchangeable through several fractions (clays, Fe and Mn oxides, humic acids) (Tessier et al, 1979). Therefore, analysis through sequential chemical extraction may be a better indicator of Hg available for plant uptake than Hg_T.

Root plaques were observed on *common reed* roots from Patroon Reservoir (spring sample) and from Tivoli Pond (summer and fall samples). While the sample from Patroon had the highest root Hg_T value for *common reed* at that site, the other samples had both the highest and lowest root values for *common reed* at Tivoli. While root plaques may be an important adheration site for Hg, not enough data exists to draw a definitive conclusion.

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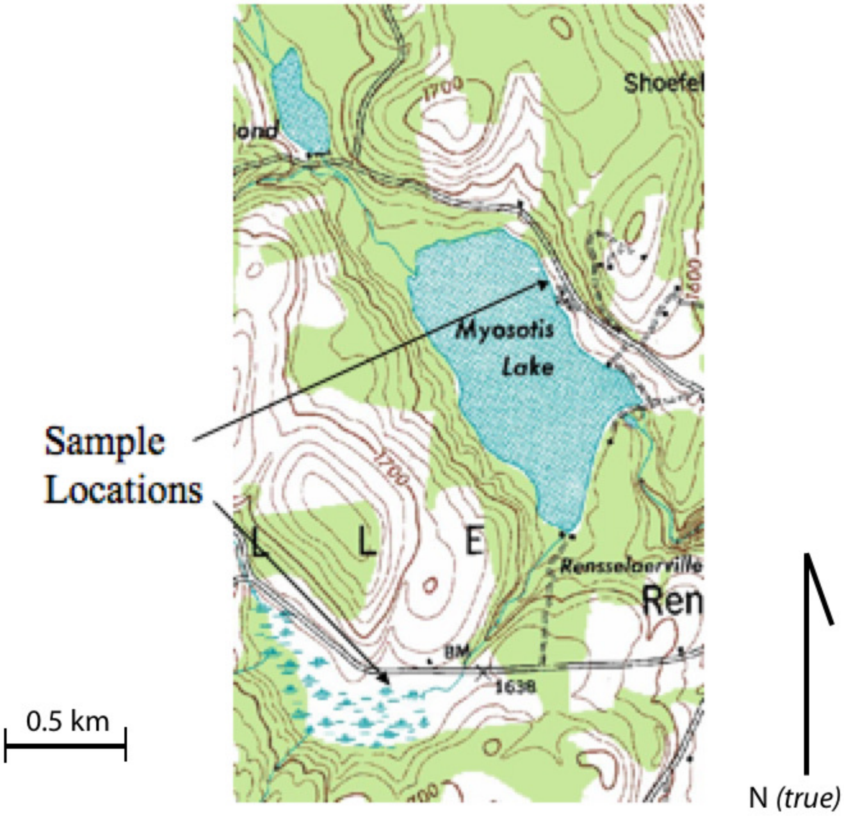
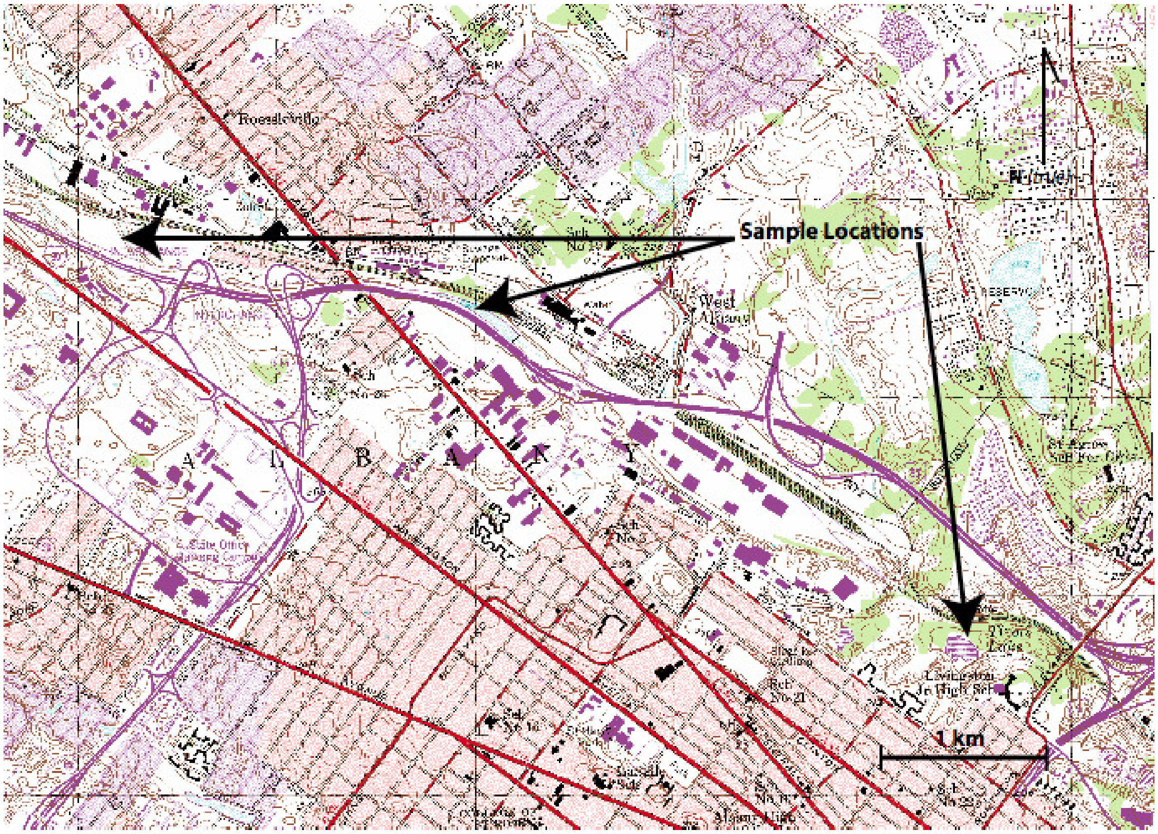
7. APPENDICES

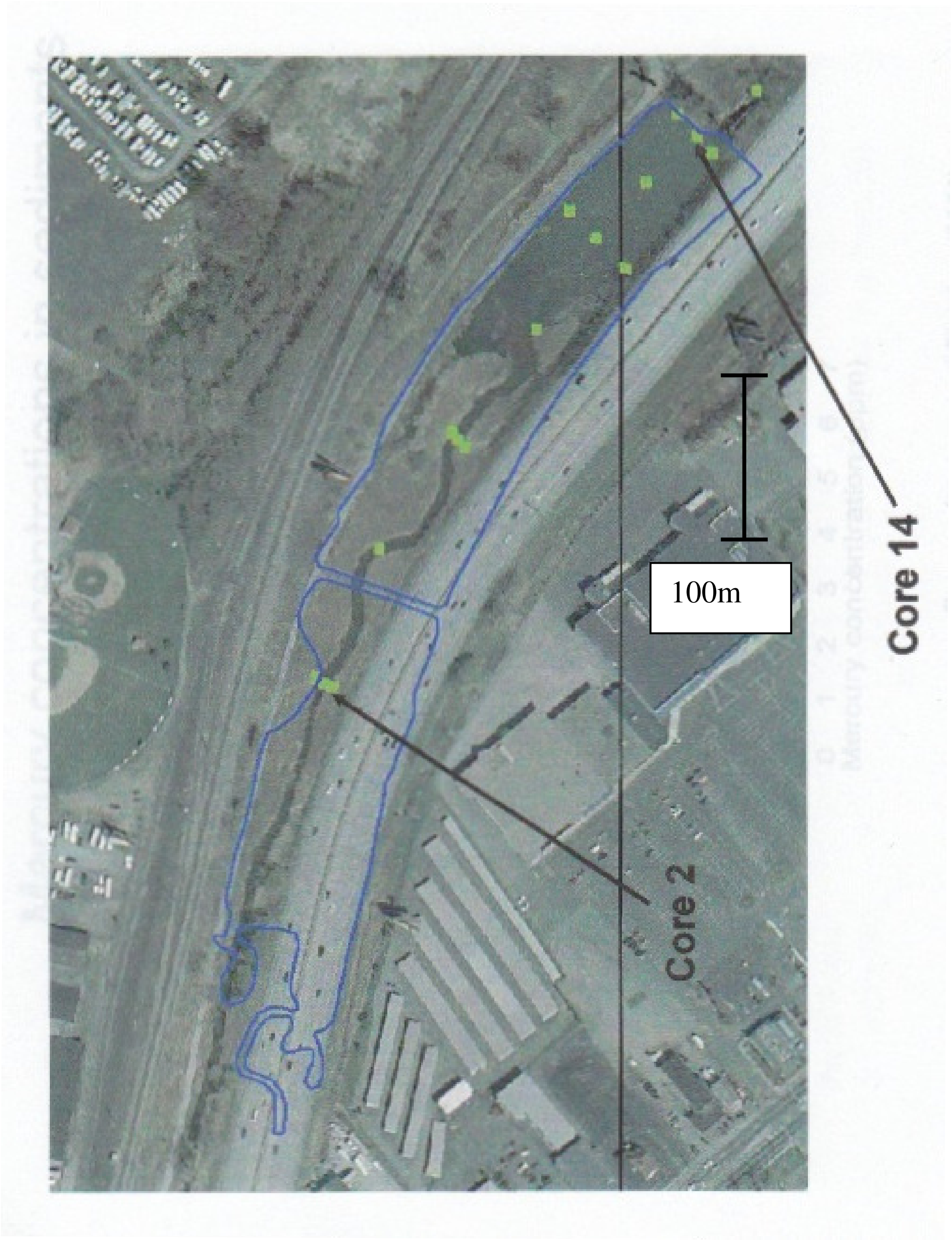
Appendix A. Topographic Map of the Huyck Preserve Showing Sampling Locations
Source: USGS 7.5 Minute Quadrangle, Rensselaerville, NY, 1946.



Appendix B. Topographic Map of the Patroon Watershed Showing Sampling Locations
Source: USGS 7.5 Minute Quadrangle, Albany, NY, 1980.

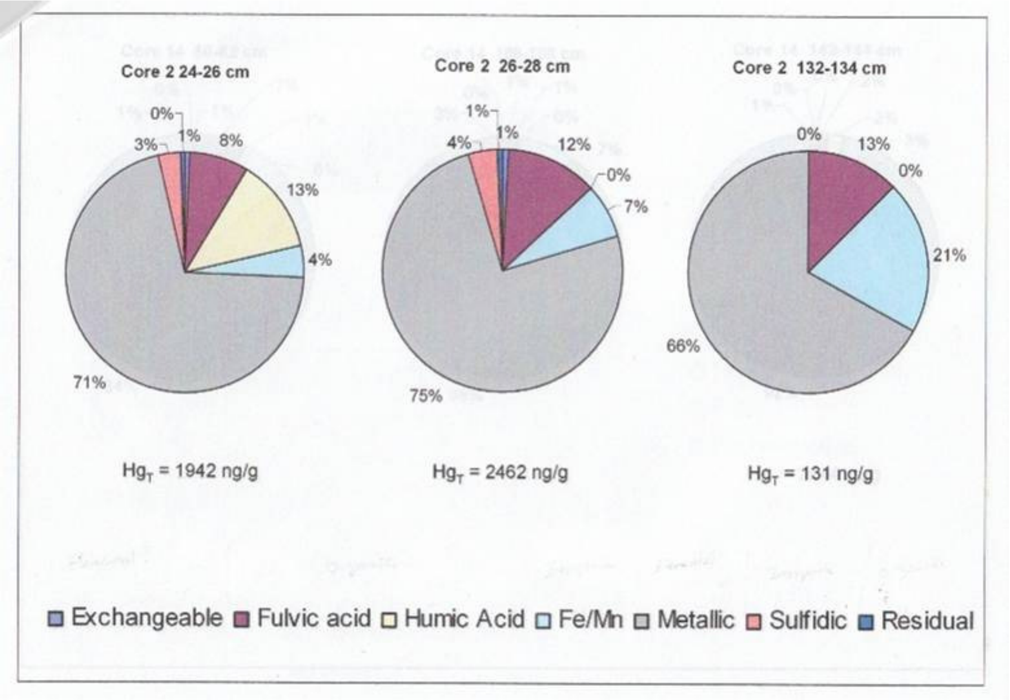


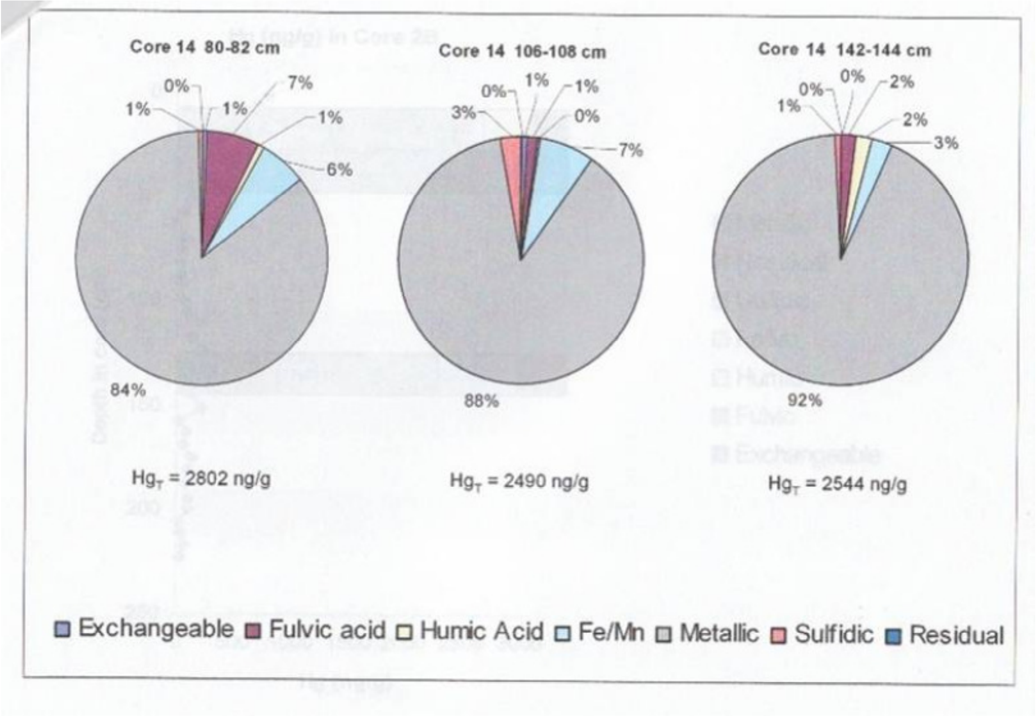
Appendix C. Map of Patroon Reservoir Showing Core Locations
Source: Fletcher, 2003.



Appendix D. Hg speciation data from Patroon Reservoir cores

Source: Fletcher, 2003.





Appendix E. Site descriptions for sample sites at the Edmund Niles Huyck Preserve and Patroon Creek Watershed

Bryan Swamp: Lat: 42° 30’ 50”, Long: 74° 9’ 15” The site is along the south side of Albany County Route 353, approximately 1.5 km west-southwest of the Village of Rensselaerville, along the northern edge of the swamp.

Lake Myosotis: Lat: 42° 30’ 50”, Long: 74° 8’ 40” From the west side of Pond Hill Road, 750m northwest of the Village of Rensselaerville, the site is reachable from the trail from the residential swimming area southeast to Lake Myosotis dam at Ten Mile Creek. The site is approximately 10m northwest of the dam along the east shore of Lake Myosotis.

North Branch Tributary: Lat: 42° 41’ 30”, Long: 73° 48’ 45” From the power substation at Yardboro Avenue in Albany, the site is along a dirt vehicle trail, approximately 300m northwest of the substation. The site is on the southside of the railroad tracks, and the north side of the tributary.

Patroon Reservoir: Lat: 42° 41’ 15”, Long: 73° 47’ 30” The site is accessible from the gated access road along northeast side of Central Avenue, across from Yardboro Avenue. The site is on the sediment delta on the west side of the reservoir.

Tivoli Pond: Lat: 42° 40’ 10”, Long: 73° 45’ 45” Site access is from the northwest side of Northern Boulevard near the northeast side of the Livingston Middle School. A trail leads into the Tivoli Preserve. The site is located along the northeast side of the pond.

Appendix F. Hg$_T$ data and quality control data for all samples

Spring 2007 Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg$_T$ (ppb)	Analysis Date
052507-14	Bryan	Cattail	Root	41900	42	80907
052507-15	Bryan	Cattail	Rhizome	7750	8	80907
052507-13	Bryan	Cattail	Stem	4230	4	80907
052507-12	Bryan	Cattail	Leaf	10100	10	80907
052507-7	Bryan	Common Reed	Root	31800	32	80907
052507-8	Bryan	Common Reed	Rhizome	13800	14	80907
052507-6	Bryan	Common Reed	Stem	8100	8	80907
052507-5	Bryan	Common Reed	Leaf	32100	32	80907
052507-4	Bryan	Sedge	Root	47000	47	80907
n/a	Bryan	Sedge	Stem		n/a	
052507-2	Bryan	Sedge	Leaf	32300	32	80907
052507-10	Bryan	Iris	Root	16500	17	80907
052507-11	Bryan	Iris	Rhizome	13800	14	80907
052507-9	Bryan	Iris	Leaf	25600	26	80907
052507-3	Bryan	Sedge	Sediment	49700	50	80907
052507-1	Bryan	Sediment Sediment	Core Composite	35600	36	80907
061407-1	Myosotis	Cattail	Root	23600	24	80907
061407-2	Myosotis	Cattail	Rhizome	2450	2	80907
061407-5	Myosotis	Cattail	Stem	1130	1	80907
061407-4	Myosotis	Cattail	Leaf	5960	6	80907
061407-12	Myosotis	Sedge	Root	40400	40	11008
061407-7	Myosotis	Sedge	Stem	4930	5	80907
061407-6	Myosotis	Sedge	Leaf	7890	8	80907
061407-8	Myosotis	Sedge	Seed Pod	5920	6	80907
061407-11	Myosotis	Iris	Root	10800	11	80907
061407-10	Myosotis	Iris	Rhizome	11600	12	80907
061407-9	Myosotis	Iris	Leaf	6560	7	80907
061407-13	Myosotis	Cattail	Sediment	26800	27	80907
061407-3	Myosotis	Sedge	Sediment	28700	29	80907
061407-14	Myosotis	Iris Sediment	Sediment Composite	69200	69	80907

Spring 2007

Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg_T (ppb)	Analysis Date
071107-1	Patroon	Old Reed	Stem	7850	8	11108
071107-2	Patroon	Common Reed	Root	121000	121	11108
071107-3	Patroon	Common Reed	Rhizome	53600	54	11108
071107-4	Patroon	Common Reed	Stem	4820	5	11108
071107-5	Patroon	Common Reed	Leaf	12600	13	11108
071107-6	Patroon	Cattail	Root	52600	53	11108
071107-7	Patroon	Cattail	Rhizome	13300	13	11108
071107-8	Patroon	Cattail	Stem	5310	5	11108
071107-13	Patroon	Cattail	Leaf	7220	7	11108
071107-9	Patroon	Iris	Root	19600	20	11108
071107-10	Patroon	Iris	Rhizome	12300	12	11108
071107-11	Patroon	Iris	stem/stalk	8200	8	11108
071107-12	Patroon	Iris	Leaf	11400	11	11108
071107-19	Patroon	Sediment	Delta	218000	218	22808
071107-20	Patroon	Sediment	NW Shore	665000	665	22808
060107-9	Tivoli	Old Reed	Root	70400	70	80907
060107-11	Tivoli	Old Reed	Rhizome	16300	16	80907
060107-1	Tivoli	Old Reed	Stem	2860	3	80907
060107-10	Tivoli	Old Reed	Sediment	67800	68	80907
060107-15	Tivoli	Common Reed	Root	102000	102	80907
060107-16	Tivoli	Common Reed	Rhizome	5070	5	80907
060107-3	Tivoli	Common Reed	Stem	7170	7	80907
060107-2	Tivoli	Common Reed	Leaf	12500	13	80907
060107-17	Tivoli	Common Reed	Sediment	104000	104	80907
060107-12	Tivoli	Cattail	Root	85200	85	80907
060107-13	Tivoli	Cattail	Rhizome	12400	12	80907
060107-4	Tivoli	Cattail	Stem	5860	6	80907
060107-5	Tivoli	Cattail	Leaf	8310	8	80907
060107-14	Tivoli	Cattail	Sediment	14600	15	80907
060107-7	Tivoli	Sedge	Root	65400	65	80907
	Tivoli	Sedge	Stem			
060107-6	Tivoli	Sedge	Leaf	18400	18	80907
060107-8	Tivoli	Sedge	Sediment	41000	41	80907
	Tivoli	Sediment	Composite			
071107-14	North	Common Reed	Root	240000	240	11108
071107-15	North	Common Reed	Rhizome	17200	17	11108
071107-16	North	Common Reed	Stem	13900	14	11108
071107-17	North	Common Reed	Leaf	24400	24	11108
071107-18	North	Sediment	Sediment	421000	421	80907

Summer 2007

Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg_T (ppb)	Analysis Date
082307-6	Bryan	Common Reed	Root	33300	33	11008
082307-7	Bryan	Common Reed	Rhizome	3870	4	11008
082307-8	Bryan	Common Reed	Stem	6650	7	11008
082307-9	Bryan	Common Reed	Leaf	6250	6	11008
082307-10	Bryan	Common Reed	flower	4430	4	11008
082307-2	Bryan	Cattail	Root	39700	40	11008
082307-3	Bryan	Cattail	Rhizome	7350	7	11008
082307-4	Bryan	Cattail	Stem	9180	9	11008
082307-5	Bryan	Cattail	Leaf	5050	5	11008
082307-11	Bryan	Cattail	flower	5300	5	11008
082307-12	Bryan	Sedge	Root	30600	31	11008
082307-13	Bryan	Sedge	Leaf	15100	15	11008
082307-14	Bryan	Sedge	Stem	11800	12	11008
082307-15	Bryan	Iris	Root	13500	14	11008
082307-16	Bryan	Iris	Rhizome	6080	6	11008
082307-17	Bryan	Iris	Leaf	7350	7	11008
082307-1	Bryan	Sediment	Composite	77600	78	22808
082607-1	Myosotis	Cattail	Root	22000	22	11008
082607-2	Myosotis	Cattail	Rhizome	1990	2	11008
082607-3	Myosotis	Cattail	Stem	3900	4	11008
082607-4	Myosotis	Cattail	Leaf	2300	2	11008
082607-5	Myosotis	Cattail	flower	2570	3	11008
082607-6	Myosotis	Sedge	Root	29000	29	11008
082607-7	Myosotis	Sedge	Stem	8720	9	11008
082607-8	Myosotis	Sedge	Leaf	7640	8	11008
082607-9	Myosotis	Iris	Root	15900	16	11008
082607-10	Myosotis	Iris	Rhizome	4000	4	11008
082607-11	Myosotis	Iris	Leaf	6630	7	11008
082607-12	Myosotis	Sediment		47300	47	22808
091107-1	Patroon	Common Reed	Root	74700	75	21408
091107-2	Patroon	Common Reed	Rhizome	10700	11	21408
091107-3	Patroon	Common Reed	Stem	6940	7	21408
091107-4	Patroon	Common Reed	Leaf	19400	19	21408
091107-5	Patroon	Common Reed	Flower	21500	22	21408
091107-6	Patroon	Cattail	Root	46500	47	21408
091107-7	Patroon	Cattail	Rhizome	6510	7	21408
091107-8	Patroon	Cattail	Stem	6650	7	21408
091107-9	Patroon	Cattail	Leaf	10800	11	21408
091107-10	Patroon	Iris	Root	54500	55	21408
091107-11	Patroon	Iris	Rhizome	5800	6	21408
091107-12	Patroon	Iris	Leaf	11800	12	21408
091107-13	Patroon	Sediment	Delta	264000	264	22808

Summer 2007

Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg (ppb)	Analysis Date
092407-1	Tivoli	Common Reed	Root	70200	70	21408
092407-2	Tivoli	Common Reed	Rhizome	4570	5	21408
092407-3	Tivoli	Common Reed	Stem	6130	6	21408
092407-4	Tivoli	Common Reed	Leaf	22100	22	21408
092407-5	Tivoli	Sedge	Root	42700	43	21408
092407-6	Tivoli	Sedge	Stem	34100	34	21408
092407-7	Tivoli	Sedge	Leaf	28800	29	21408
092407-8	Tivoli	Cattail	Root	57400	57	21408
092407-9	Tivoli	Cattail	Rhizome	5390	5	21408
092407-10	Tivoli	Cattail	Stem	5730	6	21408
092407-11	Tivoli	Cattail	Leaf	20100	20	21408
092407-12	Tivoli	Sediment		57300	57	22808
091807-1	North	Common Reed	Root	333000	333	21408
091807-2	North	Common Reed	Rhizome	17700	18	21408
091807-3	North	Common Reed	Stem	10000	10	21408
091807-4	North	Common Reed	Leaf	24600	25	21408
091807-5	North	Sediment		567000	567	22808

Fall 2007

Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg (ppb)	Analysis Date
110207-1	Bryan	Common Reed	Root	22900	23	21408
110207-2	Bryan	Common Reed	Rhizome	6170	6	21408
110207-3	Bryan	Common Reed	Stem	7020	7	21408
110207-4	Bryan	Common Reed	Leaf	15500	16	21408
110207-5	Bryan	Cattail	Root	26300	26	21408
110207-6	Bryan	Cattail	Rhizome	13300	13	21408
110207-7	Bryan	Cattail	Stem	4250	4	21408
110207-8	Bryan	Cattail	Leaf	16300	16	21408
110207-9	Bryan	Sedge	Root	17500	18	21408
110207-10	Bryan	Sedge	Stem	11400	11	21408
110207-11	Bryan	Sedge	Leaf	24000	24	21408
110207-12	Bryan	Iris	Root	15100	15	21408
110207-13	Bryan	Iris	Rhizome	5620	6	21408
110207-14	Bryan	Iris	Leaf	8590	9	21408
110207-15	Bryan	Sediment	Composite	57100	57	22808
110507-1	Myosotis	Cattail	Root	25200	25	21408
110507-2	Myosotis	Cattail	Rhizome	3670	4	21408
110507-3	Myosotis	Cattail	Stem	3850	4	21408
110507-4	Myosotis	Cattail	Leaf	10400	10	21408
110507-5	Myosotis	Sedge	Root	24500	25	21408
110507-6	Myosotis	Sedge	Stem	19700	20	21408
110507-7	Myosotis	Sedge	Leaf	17200	17	21408
110507-8	Myosotis	Iris	Root	21500	22	21408
110507-9	Myosotis	Iris	Rhizome	9940	10	21408
110507-10	Myosotis	Iris	Leaf	10400	10	22808
110507-11	Myosotis	Sediment		68600	69	22808

Fall 2007 Sample ID	Location	Species	Section	Sample Conc. (ppt)	Hg (ppb)	Analysis Date
111207-13	Patroon	Common Reed	Root	105000	105	22808
111207-14	Patroon	Common Reed	Rhizome	3130	3	22808
111207-15	Patroon	Common Reed	Stem	3680	4	22808
111207-16	Patroon	Common Reed	Leaf	21700	22	22808
111207-17	Patroon	Cattail	Root	61900	62	22808
111207-18	Patroon	Cattail	Rhizome	10700	11	22808
111207-19	Patroon	Cattail	Stem	128	0	22808
111207-20	Patroon	Cattail	Leaf	14300	14	22808
111207-21	Patroon	Iris	Root	55700	56	22808
111207-22	Patroon	Iris	Rhizome	9590	10	22808
111207-23	Patroon	Iris	Leaf	10000	10	22808
111207-24	Patroon	Sediment	Delta	587000	587	22808
111207-1	Tivoli	Common Reed	Root	107000	107	22808
111207-2	Tivoli	Common Reed	Rhizome	9710	10	22808
111207-3	Tivoli	Common Reed	Stem	7550	8	22808
111207-4	Tivoli	Common Reed	Leaf	18100	18	22808
111207-5	Tivoli	Cattail	Root	53400	53	22808
111207-6	Tivoli	Cattail	Rhizome	3990	4	22808
111207-7	Tivoli	Cattail	Stem	2230	2	22808
111207-8	Tivoli	Cattail	Leaf	14900	15	22808
111207-9	Tivoli	Sedge	Root	34700	35	22808
111207-10	Tivoli	Sedge	Stem	6040	6	22808
111207-11	Tivoli	Sedge	Leaf	24100	24	22808
111207-12	Tivoli	Sediment	Composite	53100	53	22808
111207-25	North	Common Reed	Root	354000	354	22808
111207-26	North	Common Reed	Rhizome	8400	8	22808
111207-27	North	Common Reed	Stem	5190	5	22808
111207-28	North	Common Reed	Leaf	33200	33	22808
111207-29	North	Sediment	Composite	462000	462	22808

Duplicates & Spikes

Sample ID	052507-9	060107-6	060107-17	082307-16	082607-3
sample (ng/g)	25.6	18.4	104	6.08	3.9
duplicate (ng/g)	25.4	19	125	6.64	5.3
spike (ng/g)	196	196	296	174	164
mean	25.5	18.7	114.5	6.36	4.6
stdev	0.14	0.42	14.85	0.40	0.99
%RSD	0.6%	2.3%	13.0%	6.2%	21.5%
% recovery	85.3%	88.7%	90.8%	83.8%	79.7%

Sample ID	061807-4	071107-1	082607-20	092407-1	110207-9
sample (ng/g)	6.45	7.9	19.9	70.2	17.5
duplicate (ng/g)	6.58	5.2	19.4	63.9	17.6
spike (ng/g)	191	217	243	284	232
mean	6.515	6.55	19.65	67.05	17.55
stdev	0.09	1.91	0.35	4.45	0.07
%RSD	1.4%	29.1%	1.8%	6.6%	0.4%
% recovery	92.2%	105.2%	111.7%	108.5%	107.2%

Sample ID	111207-5	111207-21	111207-12
sample (ng/g)	53.4	55.7	53.1
duplicate (ng/g)	52.2	56	63.8
spike (ng/g)	313	302	300
mean	52.8	55.85	58.45
stdev	0.85	0.21	7.57
%RSD	1.6%	0.4%	12.9%
% recovery	130.1%	123.1%	120.8%

NIST #1573a (Tomato Leaves)

Analysis Date	*8/9/07-1*	*8/9/07-2*	8/9/07-3	8/9/07-4	1/10/08-1
analysis (ng/g)	*25.4*	*26.9*	27.7	23.5	*31.3*
certified (ng/g)	34	34	34	34	34
cert. error	4	4	4	4	4
difference	9	7	6	11	3
bias	25.3%	20.9%	18.5%	30.9%	7.9%
% recovery	*74.7*	*79.1*	81.5	69.1	*92.1*

Analysis Date	1/10/08-2	1/10/08-3	1/10/08-4	1/10/08-5
analysis (ng/g)	*28.9*	29.6	26.8	26.2
certified (ng/g)	34	34	34	34
cert. error	4	4	4	4
difference	5	4	7	8
bias	15.0%	12.9%	21.2%	22.9%
% recovery	*85.0*	87.1	78.8	77.1

NIST #1573a (Tomato Leaves)

Analysis Date	1/10/08-6	1/10/08-7	1/11/08-1	1/11/08-2	1/11/08-3
analysis (ng/g)	29.9	30.1	*33.3*	*34.5*	33.1
certified (ng/g)	34	34	34	34	34
cert. error	4	4	4	4	4
difference	4	4	1	-1	1
bias	12.1%	11.5%	2.1%	-1.5%	2.6%
% recovery	87.9	88.5	*97.9*	*101.5*	97.4

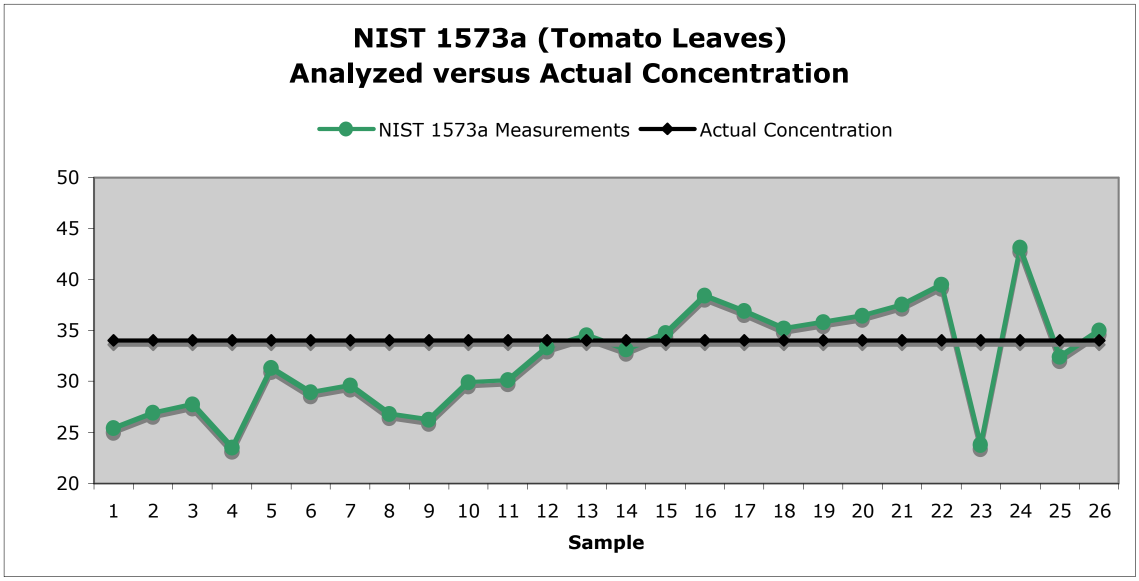
Analysis Date	2/14/08-1	2/14/08-2	2/14/08-3	2/14/08-4	2/14/08-5
analysis (ng/g)	*34.7*	*38.4*	36.9	35.2	35.8
certified (ng/g)	34	34	34	34	34
cert. error	4	4	4	4	4
difference	1	4	3	1	2
bias	2.1%	12.9%	8.5%	3.5%	5.3%
% recovery	*102.1*	*112.9*	108.5	103.5	105.3

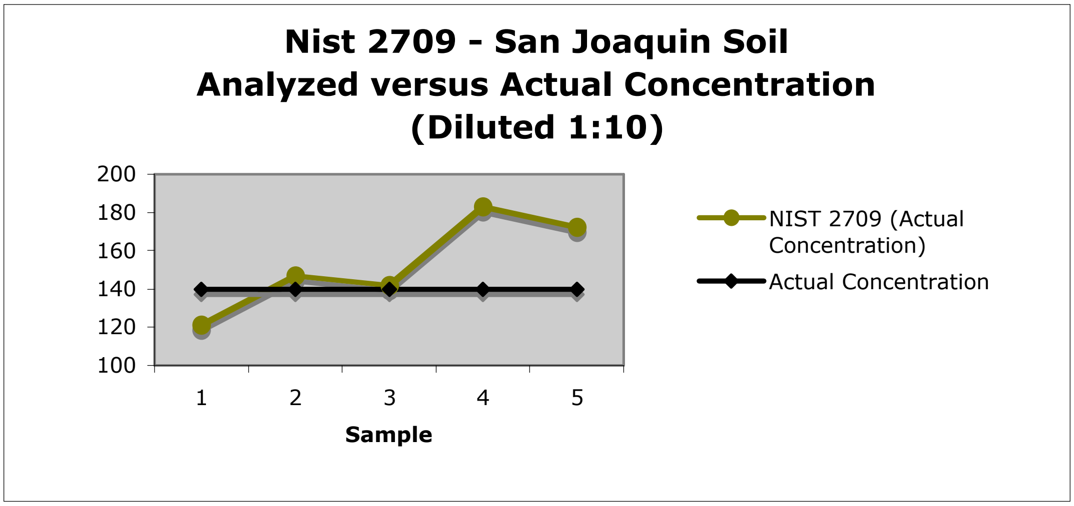
Analysis Date	2/14/08-6	2/28/08-1	2/28/08-2	2/28/08-3	2/28/08-4
analysis (ng/g)	36.4	*37.5*	*39.5*	23.8	43.1
certified (ng/g)	34	34	34	34	34
cert. error	4	4	4	4	4
difference	2	4	6	-10	9
bias	7.1%	10.3%	16.2%	-30.0%	26.8%
% recovery	107.1	*110.3*	*116.2*	70.0	126.8

Analysis Date	2/28/08-5	2/28/08-6
analysis (ng/g)	32.4	35.0
certified (ng/g)	34	34
cert. error	4	4
difference	-2	1
bias	-4.7%	2.9%
% recovery	95.3	102.9

NIST 2709 (San Joaquin Soil) Diultuon Factor of 10 used

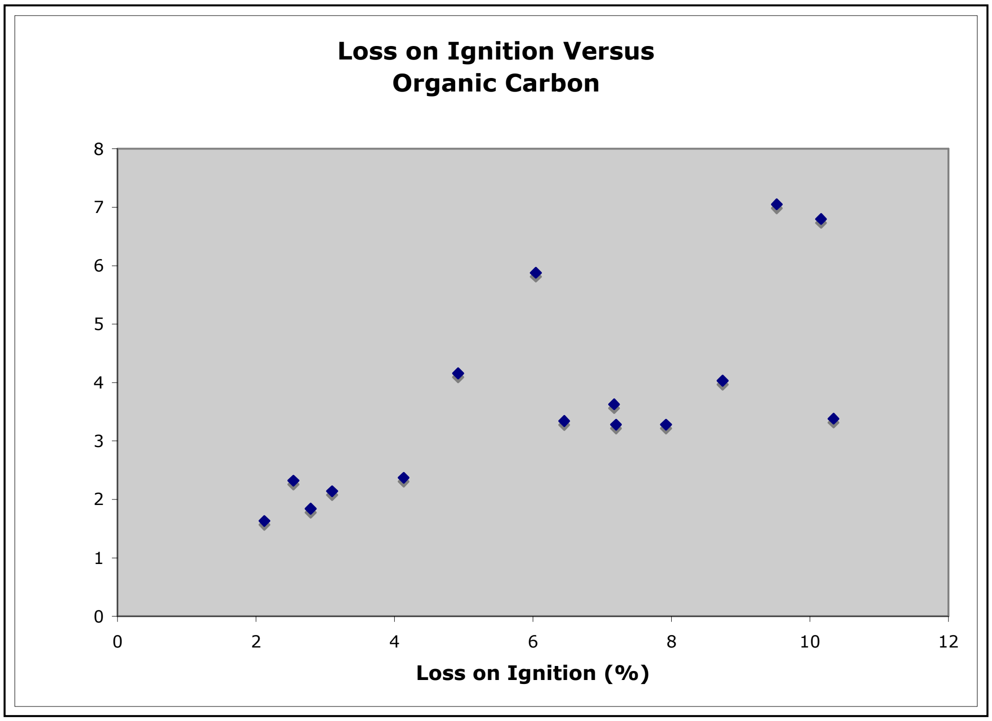
Analysis Date	8/9/07-1	1/10/08-1	1/10/08-2	2/28/08-1	2/28/08-2
analysis (ng/g)	*121*	*147*	*142*	*183*	*172*
certified (ng/g)	140	140	140	140	140
cert. error	80	4	80	4	4
difference	19	-7	-2	43	32
bias	13.6%	-5.0%	-1.4%	30.7%	22.9%
% recovery	*86.4*	*105.0*	*101.4*	*130.7*	*122.9*


NIST 1573a (Tomato Leaves)
Analyzed versus Actual Concentration
NIST 1573a Measurements
Actual Concentration
50
45
40
35
30
25
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
Sample

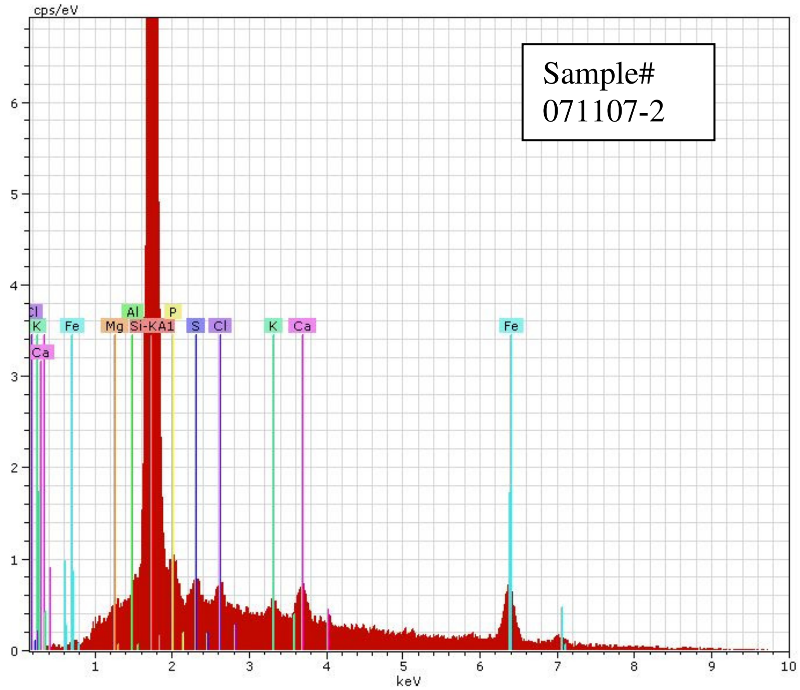

Nist 2709 - San Joaquin Soil
Analyzed versus Actual Concentration
(Diluted 1:10)
200
180
160
140
120
100
1
2
3
4
5
Sample
NIST 2709 (Actual Concentration)
Actual Concentration

Appendix G. Results of Loss on Ignition (LOI) and organic carbon by coulometry on sediment samples. The scatter plot shows a comparison of these two methods.

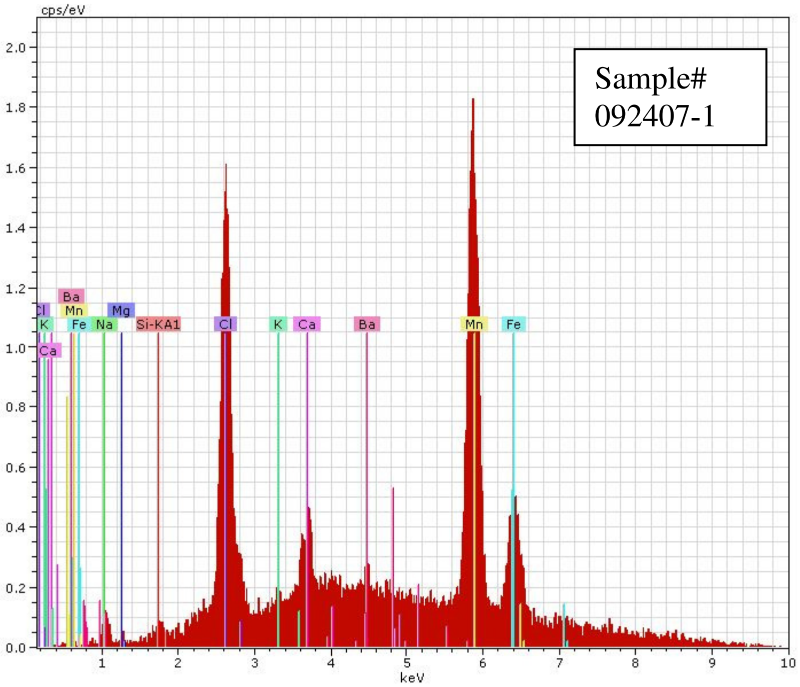
Site	Season	LOI %	Coulometry %
Bryan	Spring	6.04	5.88
	Summer	7.92	3.28
	Fall	7.2	3.28
Myosotis	Spring	10.2	6.8
	Summer	8.74	4.03
	Fall	10.34	3.38
Tivoli	Spring	7.17	3.63
	Summer	6.45	3.34
	Fall	4.13	2.37
Patroon	Spring	2.54	2.32
	Summer	4.92	4.16
	Fall	9.52	7.05
North Branch	Spring	3.1	2.14
	Summer	2.79	1.84
	Fall	2.12	1.63



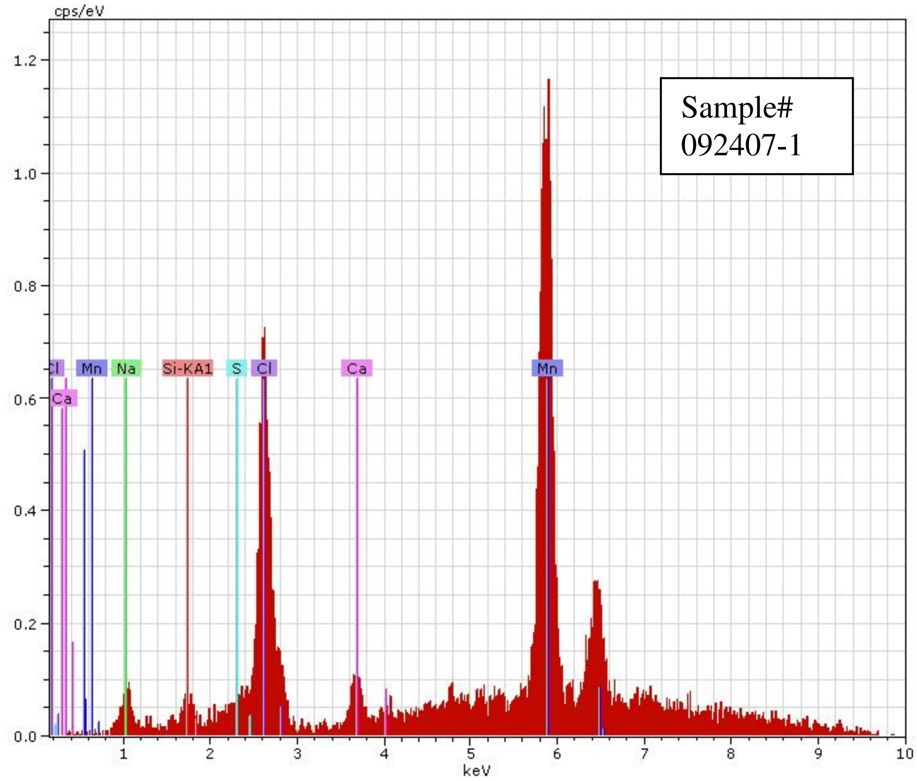
Appendix H. Composition of root plaques identified by SEM microprobe.



SEM microprobe analysis of root plaque from sample 071107-2, common reed root from Patroon Reservoir.



SEM microprobe analysis of root plaque from sample 092407-1, common reed root from Tivoli Pond.



SEM microprobe analysis of root plaque from sample 092407-1, common reed root from Tivoli Pond.

Appendix I. Wet and dry weights, and percent water for plant and sediment samples. (Summer and Fall only. Wet and dry weights were not collected for Spring samples.)

Bryan Swamp 8/23/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
082307-1	Sediment	Sedx (comp)	23.76	11.35	52.23%
082307-2	Cattail	root	20.18	1.62	91.97%
082307-3	Cattail	rhizome	14.09	2.74	80.55%
082307-4	Cattail	stem	27.38	4.89	82.14%
082307-5	Cattail	leaf	15.42	4.03	73.87%
082307-6	Common Reed	root	13.08	1.27	90.29%
082307-7	Common Reed	rhizome	7.68	3.07	60.03%
082307-8	Common Reed	stem	16.12	8.48	47.39%
082307-9	Common Reed	leaf	8.72	3.66	58.03%
082307-10	Common Reed	flower	8.08	2.62	67.57%
082307-11	Cattail	flower	25.83	11.51	55.44%
082307-12	Sedge	root	4.65	0.54	88.39%
082307-13	Sedge	leaf	7.25	1.41	80.55%
082307-14	Sedge	stem	4.99	0.52	89.58%
082307-15	Iris	root	4.76	0.79	83.40%
082307-16	Iris	rhizome	22.97	6.76	70.57%
082307-17	Iris	leaf	10.37	7.32	29.41%

Lake Myosotis 8/26/07

Sample ID		Description	Wet Wt (g)	Dry Wt (g)	% Water
082607-1	Cattail	root	13.93	1.6	88.51%
082607-2	Cattail	rhizome	19.81	5.29	73.30%
082607-3	Cattail	stem	37	8.95	75.81%
082607-4	Cattail	leaf	10.18	3.01	70.43%
082607-5	Cattail	flower	40.39	14.25	64.72%
082607-6	Sedge	root	18.04	2.84	84.26%
082607-7	Sedge	stem	4.56	1.04	77.19%
082607-8	Sedge	leaf	8.33	1.96	76.47%
082607-9	Iris	root	6.22	1.24	80.06%
082627-10	Iris	rhizome	5.32	1.89	64.47%
082607-11	Iris	leaf	12.02	2.75	77.12%
082607-12	Sediment		69.73	34.09	51.11%

Patroon Reservoir 9/11/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
091107-1	Common reed	root	16.7	1.3	92.22%
091107-2	Common reed	rhizome	18.4	4.3	76.63%
091107-3	Common reed	stem	8.1	2.7	66.67%
091107-4	Common reed	leaf	10.3	4.4	57.28%
091107-5	Common reed	flower	3.1	1.1	64.52%
091107-6	Cattail	root	30.6	1.8	94.12%
091107-7	Cattail	rhizome	22.7	4.7	79.30%
091107-8	Cattail	stem	29.2	4.9	83.22%
091107-9	Cattail	leaf	14.3	3.3	76.92%
091107-10	Iris	root	21.6	3.3	84.72%
091107-11	Iris	rhizome	25.9	6.1	76.45%
091107-12	Iris	stem	25	3	88.00%
091107-13	Sediment		37.3	19.2	48.53%

North Branch 9/18/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
091807-1	Common reed	root	5.6	0.8	85.71%
091807-2	Common reed	rhizome	15.5	6.2	60.00%
091807-3	Common reed	stem	13.2	6.9	47.73%
091807-4	Common reed	leaf	5.1	2.3	54.90%
091807-5	Common reed	sediment	72.7	53.5	26.41%

Tivoli Pond 9/24/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
092407-1	Common reed	root	8.7	1.2	86.21%
092407-2	Common reed	rhizome	9.1	3.3	63.74%
092407-3	Common reed	stem	23.2	10.8	53.45%
092407-4	Common reed	leaf	9.3	4.2	54.84%
092407-5	Sedge	root	19.4	3.1	84.02%
092407-6	Sedge	stem	4.4	0.7	84.09%
092407-7	Sedge	leaf	2.3	0.5	78.26%
092407-8	Cattail	root	9.9	0.4	95.96%
092407-9	Cattail	rhizome	17.9	2.4	86.59%
092407-10	Cattail	stem	19.5	2.7	86.15%
092407-11	Cattail	leaf	6	1.6	73.33%
092407-12	Sediment		35.4	19.8	44.07%

Bryan Swamp 11/2/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
110207-1	Common reed	root	5.36	0.91	83.02%
110207-2	Common reed	rhizome	17.89	8.02	55.17%
110207-3	Common reed	stem	14.83	9.14	38.37%
110207-4	Common reed	leaf	8.39	5.4	35.64%
110207-5	Cattail	root	22.89	1.73	92.44%
110207-6	Cattail	rhizome	16.72	4.06	75.72%
110207-7	Cattail	stem	23.6	4.37	81.48%
110207-8	Cattail	leaf	15.73	4.79	69.55%
110207-9	Sedge	root	11.72	1.82	84.47%
110207-10	Sedge	stem	13.52	4.05	70.04%
110207-11	Sedge	leaf	11.01	2.6	76.39%
110207-12	Iris	root	4.33	0.81	81.29%
110207-13	Iris	rhizome	14.05	4.07	71.03%
110207-14	Iris	stem	11.37	2.63	76.87%
110207-15	Sediment		48.09	20.06	58.29%

Lake Myosotis 11/5/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
110507-1	Cattail	root	5.06	0.76	84.98%
110507-2	Cattail	rhizome	27.46	9.01	67.19%
110507-3	Cattail	stem	12.13	5.8	52.18%
110507-4	Cattail	leaf	13.04	3.21	75.38%
110507-5	Sedge	root	5.6	0.95	83.04%
110507-6	Sedge	stem	7.23	1.89	73.86%
110507-7	Sedge	leaf	3.12	1.5	51.92%
110507-8	Iris	root	6.21	1.31	78.90%
110507-9	Iris	rhizome	9.09	3.75	58.75%
110507-10	Iris	stem	5.58	1.57	71.86%
110507-11	Sediment		67.11	31.84	52.56%

Tivoli Pond 11/12/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
111207-1	Common reed	root	9.5	1	89.47%
111207-2	Common reed	rhizome	6.5	1.7	73.85%
111207-3	Common reed	stem	9	6.3	30.00%
111207-4	Common reed	leaf	7	4.9	30.00%
111207-5	Cattail	root	14.7	1.1	92.52%
111207-6	Cattail	rhizome	12.7	3.8	70.08%
111207-7	Cattail	stem	8.3	2.1	74.70%
111207-8	Cattail	leaf	7.2	2.1	70.83%
111207-9	Sedge	root	13.6	1.2	91.18%
111207-10	Sedge	rhizome	12.8	2.7	78.91%
111207-11	Sedge	stem	10.7	2.7	74.77%
111207-12	Sediment		n/a	n/a	

Patroon Reservoir 11/12/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
111207-13	Common reed	root	8.2	0.6	92.68%
111207-14	Common reed	rhizome	12.5	3	76.00%
111207-15	Common reed	stem	5.1	2.3	54.90%
111207-16	Common reed	leaf	3.2	1.6	50.00%
111207-17	Cattail	root	19.6	1	94.90%
111207-18	Cattail	rhizome	10.6	1.7	83.96%
111207-19	Cattail	stem	8.7	1.9	78.16%
111207-20	Cattail	leaf	8.6	1.8	79.07%
111207-21	Iris	root	12.9	1.4	89.15%
111207-22	Iris	rhizome	11.8	2.9	75.42%
111207-23	Iris	stem	11.5	1.6	86.09%
111207-24	Sediment		n/a	n/a	

North Branch 11/12/07

Sample ID	Species	Section	Wet Wt (g)	Dry Wt (g)	% Water
111207-25	Common reed	root	3.3	0.3	90.91%
111207-26	Common reed	rhizome	8.4	2.5	70.24%
111207-27	Common reed	stem	8.5	5	41.18%
111207-28	Common reed	leaf	3	2.3	23.33%
111207-29	Sediment		n/a	n/a	

Appendix J. Descriptions of sediment samples.

Spring 2007

Sample ID# 052507-1, Bryan Swamp, 5 to 10 cm sediment core.
Tan to light brown, fine grained, apparent high clay content.

Sample ID# 052507-3, Bryan Swamp, sediment from sedge extraction point.
Medium brown, fine grained.

Sample ID# 060107-8, Tivoli Pond, sediment from sedge extraction point.
Medium to dark brown, fine grained, slightly sandy.

Sample ID# 060107-10, Tivoli Pond, sediment from old common reed extraction point.
Medium to dark brown, fine grained, slightly sandy.

Sample ID# 060107-14, Tivoli Pond, sediment from cattail extraction point.
Medium brown, very fine grained, some clay, slightly sandy.

Sample ID# 060107-17, Tivoli Pond, sediment from common reed extraction point.
Medium brown, very fine grained, some clay, slightly sandy.

Sample ID# 061407-3, Lake Myosotis, sediment from sedge extraction point.
Medium gray to medium brown, fine grained, some clay.

Sample ID# 061407-13, Lake Myosotis, sediment from cattail extraction point.
Medium gray to medium brown, fine grained, some clay.

Sample ID# 061407-14, Lake Myosotis, sediment from iris extraction point.
Medium gray to dark brown, fine grained, some clay.

Sample ID# 071107-18, North Branch, sediment from common reed extraction point.
Medium gray to medium brown, sandy.

Sample ID# 071107-19, Patroon Reservoir, sediment from sediment delta.
Dark brown, very fine grained, strong organic scent.

Sample ID# 071107-20, Patroon Reservoir, sediment from northwest shore.
Dark brown to black, very fine grained, some clay.

Summer 2007

Sample ID# 082307-1, Bryan Swamp, composite sediment sample.
Light to medium brown, fine to very fine grained, some clay.

Sample ID# 082607-12, Lake Myosotis, composite sediment sample.
Medium brown, fine grained, slightly sandy.

Sample ID# 091107-13, Patroon Reservoir, composite sediment sample.
Very dark brown, fine grained, slightly sandy, strong organic scent.

Sample ID# 091807-5, North Branch, composite sediment sample.
Medium brown, fine grained, slightly sandy.

Sample ID# 092407-12, Tivoli Pond, composite sediment sample.
Medium brown, fine grained, slightly sandy, some clay.

Fall, 2007

Sample ID# 110207-15, Bryan Swamp, composite sediment sample.
Light to medium brown, fine grained, some clay.

Sample ID# 110507-11, Lake Myosotis, composite sediment sample.
Medium brown, fine grained.

Sample ID# 111207-12, Tivoli Pond, composite sediment sample.
Light to medium brown, fine grained, some clay.

Sample ID# 111207-24, Patroon Reservoir, composite sediment sample.
Very dark brown, fine grained, slightly sandy, strong organic scent.

Sample ID# 111207-29, North Branch, composite sediment sample.
Medium brown, fine grained, slightly sandy.