COMPARISON OF SWAMP FOREST AND *PHRAGMITES AUSTRALIS* COMMUNITIES AT MENTOR MARSH, MENTOR, OHIO

A Thesis

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By

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ABSTRACT

Two intermixed plant communities within a single wetland were studied. The plant community of Mentor Marsh changed over a period of years beginning in the late 1950's from an ash-elm-maple swamp forest to a wetland dominated by *Phragmites australis* (Cav.) Trin. ex Steudel. Causes cited for the dieback of the forest include salt intrusion from a salt fill near the marsh, influence of nutrient runoff from the upland community, and initially higher water levels in the marsh. The area studied contains a mixture of swamp forest and *P. australis*-dominated communities. Canopy cover was examined as a factor limiting the dominance of *P. australis* within the marsh. It was found that canopy openness below 7% posed a limitation to the dominance of *P. australis* where a continuous tree canopy was present. *P. australis* was also shown to reduce diversity at sites were it dominated, and canopy openness did not fully explain this reduction in diversity. Canopy cover, disturbance history, and other environmental factors play a role in the community composition and diversity. Possible factors to consider in restoring the marsh are discussed.

KEYWORDS: *Phragmites australis*, invasive species, canopy cover, Mentor Marsh

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CHAPTER 1

INTRODUCTION

Mentor Marsh is an example of a marsh damaged by human actions. The marsh occupies an abandoned ancient channel of the Grand River which now empties into Lake Erie at Fairport Harbor. In 1959, the elm-ash-maple forest at Mentor Marsh began dying, likely due to a combination of a salt influx from a salt waste fill on Black Brook Creek and higher than normal water levels. By the late 1970's the die-off area exceeded 225 acres. The die-off of the swamp forest left a window open for the invasion of the salt-tolerant species common reed, *Phragmites australis* (Cav.) Trin. ex Steud. In the 20 years after the first salt entered the marsh, *P.australis* spread throughout the marsh, significantly changing the ecology of the preserve. In 1980, Black Brook was re-routed around the salt fill. This remediation lowered salt levels and improved water quality in the marsh, but the swamp forest vegetation never fully recovered. Most of the marsh is now dominated by *Phragmites australis.* In addition, the marsh has been significantly impacted by the effects of enhanced eutrophication from *Phragmites* as dead culms accumulate and decompose, which has also affected the biodiversity of the flora in the marsh. There is currently some evidence to suggest the swamp forest may be beginning to recover and expand in places. The questions of this study seek to address the dynamic of vegetative change at the interface of the swamp forest and the *P.australis* stands.

Phragmites australis is known to be expanding rapidly in the Great Lakes region, but this expansion is occurring primarily in association with herbaceous, emergent marshes, not swamp forests. The situation at Mentor Marsh offers a unique opportunity to study the successional dynamics at the interface of an apparently expanding swamp forest and an extensive and well-established *P. australis* stand. While the impact of a woody canopy on understory herbaceous species has been examined in previous studies, the effect shade from woody species on *P.australis*, an open canopy species, has not been studied. Also, the amount known about methods for restoration varies with wetland type and location and very little is known about the restoration of forested wetlands as woody species have longer regeneration times than herbaceous species (Kusler and Kentula, 1990b). Study of the effect of woody vegetation on *P.australis* has practical applications to the restoration of the swamp forest at Mentor Marsh as well as expanding what is known about shading in wetlands in general and effects of tree shading on *P.australis* in particular.

HYPOTHESES

1. The flora of swamp forest and *P. australis*-dominated stands will differ significantly.
2. Shade from swamp forest canopies will inhibit the growth of *P. australis*.
3. *P. australis* at Mentor Marsh will be associated with low plant species diversity compared to other Lake Erie marshes not dominated by *P. australis*.

CHAPTER 2

LITERATURE REVIEW

2.1 Life history and ecology of *P. australis*

Phragmites australis (Cav.) Trin. ex Steudel (henceforth *P.australis*) is commonly called common reed, giant reed, and giant reedgrass. It is an emergent aquatic grass and a member of the *Poaceae* Family. While there are no recognized subspecies, varieties, or forms, there can be considerable genetic variety among clones (Koppitz, 1999). *P.australis* is found on every continent except Antarctica, and in the United States it has become the dominant plant species in many marshes and disturbed wetlands around the Great Lakes, the East coast, and the Mississippi River Delta (Tucker, 1990)

Phragmites australis reaches two to four meters in height. It is a perennial species that leaves dry, dead culms standing in the winter. These culms fall after about two seasons, forming a peat layer on the soil surface. The peat also forms a barrier to light reaching the soil surface. The soil remains cooler during the spring, and receives less light all year around (Meyerson et al., 2000). This makes the interior of a *P.australis* stand an especially inhospitable place for other plants to germinate.

Common reed rhizomes, actually horizontal stems, produce new buds every several inches along their length. *Phragmites australis* rhizomes can form an extensive network, crossing water and open ground. Rhizome depths have been reported up to 100cm (Fiala, 1976). Roots grow to around 100cm in depth, allowing *P.australis* to reach very low-lying ground water (Cross, 1989). The Raukiaer system classifies *P. australis* as a cryptophyte.

Common reed occurs very commonly in alkaline and brackish wetlands (Haslam, 1970). *P.australis* tolerates these conditions rather than requiring them for growth. But, *P.australis* generally becomes more dominant under alkaline and brackish conditions, than it does in freshwater conditions because other species intolerant of brackish, alkaline, or acidic waters generally out compete *P.australis* in freshwater. Maximum salinity tolerances have been reported as 12ppt to 40ppt (Hocking et. al., 1983). *P.australis* prefers level ground in freshwater marshes, oxbow lakes, backwater areas of rivers and streams, and irrigation ditches. Although it does withstand flooding, *P.australis* doesn't do well in permanently standing water. It does well in sites with high water tables or seasonally flooded sites with not more than 50cm water. *Phragmites australis* has a low tolerance for current and wave action, which can break its culms and impede bud formation in the rhizomes (Haslam, 1970).

Phragmites australis can persist in most soil textures from fine clays to sandy loams, although it prefers firm mineral clays. It is tolerant of alkaline conditions and has been reported on soils with pH from 6.4 to 8.1 (Shay & Shay, 1986). It generally occurs in regions with annual precipitation from 3.1 to 24.1 dm, annual temperatures of 6.6 to 26.6 degrees C, and pH from 4.8 to 8.2 (Duke, 1978).

Phragmites australis typically grows in closed, monodominant stands, sometimes associated with cattail, bulrush, and arrowhead (*Sagittaria* spp.) in wetter habitats. It grows with white-top grass (*Scholochloa festucacea* (Willd.) Link), thistle (*Circium* spp) sedges (*Carex* spp.), dock (*Rumex* spp.) northern reedgrass (*Calamagrostis inexpansa* Gray), reed canarygrass (*Phalaris arundinacea* L.) and American mannagrass (*Glyceria grandis* S. Watson) in drier habitats. In general *P. australis* is found in association with plants from genera including: *Spartina, Carex, Nymphaea, Typha, Glyceria, Junus, Myrica, Triglochin, Calamogrostis, Galium, and Phalaris* (Howard et al., 1978.)

Phragmites australis generally flowers and sets seed between July and September. Great quantities of seed are dispersed between November and January (in the Northeast); however most of these seeds are not viable (Tucker, 1990), and those that are short lived and do no occur in the seed banks (van der Valk and Davis, 1978). Seeds are dispersed generally by wind, but may also be transported by water and birds such as the red-winged blackbird that nests in the reeds (Haslam, 1972).

Phragmites australis reproduces principally through vegetative means. Natural germination is uncommon, and successful seeding establishment is rare. Rhizomes can be up to 13m in length. Reported annual rhizome lateral spread averages include 40cm in Wisconsin and one to two meters in Europe (Haslam, 1973, Curtis 1959). Newly opened sites may be colonized by seed or by rhizome fragments carried to the area by humans in soils and on machinery during construction or naturally in floodwaters.

Phragmites australis begins growing in late spring, usually after the last frost. Shoots emerge over a period of one to three months. Large buds formed the previous fall emerge first, smaller buds emerge later in the season. Shoots are sensitive to frost: if killed, one to three side shoots develop from the frosted shoot (Haslam, 1969). Following emergence, stems grow rapidly, up to four cm per day. Foliage remains green until frost in fall; thereafter it turns brittle and pale yellow and is shed.

Clonal integration, or the rhizome connection between *Phragmites* clones, may also help *P. australis* grow in otherwise unfavorable conditions. Amsberry et al. (2000), observed *P. australis* in western Atlantic salt marshes expanding from their historic site at the terrestrial border of the marsh into lower elevations of the marsh. They found that *P. australis* in a more physically restrictive site did not survive without clonal integration with a *P. australis* stand in a more benign site. The clonal nature of *P. australis* enables it to grow in otherwise restrictive environments.

2.2 History and Spread of *P. australis* in North America

While there is still debate around the geographic origins of *P.australis*, botanical manuals typically treat it as native to North America (Kearney and Peebles, 1951; Gleason and Cronquist, 1991; Munz and Keck, 1963; Seymour, 1969; Long and Lakela, 1971). The recent expansion of *P. australis* to form mono-dominant stands in some wetlands lead to some speculation as to whether or not it is native to North America. But, two separate sources have dated the presence of *P. australis* to well before European contact with North America. Niering and Warren (1977) found *Phragmites* remains in 3000-year old peat cores from tidal marshes in Connecticut. *Phragmite*s remains were also found at an archaeological investigation of Anasazi sites in Colorado dating from

600 to 900 A.D. Various author have dated the presence of *P.australis* in North America from between 2000 and 4000 years ago (Chambers et al., 1999).

Phragmites australis abundance has increased greatly in many areas of the north-central and north eastern United States during the 1900's (Marks et al., 1994, Stalter and Baden, 1994; Buck, 1995; Rice and Stevenson, 1996; Chambers et al., 1999). This recent invasiveness has led to an inquiry into whether there exists a non-native invasive genotype and a native non-invasive genotype, with no conclusive answers (Tucker, 1990; Marks et al. 1994; Pellegrin and Hauber, 1998; Chambers et al., 1999, Koppitz, 1999; Meyerson et al., 2000). Another possible explanation for the expansion of *P.australis* is human-caused disturbances to the environment such as human alteration of the hydrologic cycle, saltwater intrusion, mechanical disturbance, pollution, coastal development as well as eutrophication and increased salinity (Chamber et al., 1999, Meyerson et al., 2000).

Historically, *P.australis* occurred in the upper border of brackish tidal marshes in mixed associations (Orson, 1999). There is evidence from peat core analysis that the nature of the plant community associated with *P.australis* has also changed with its recent expansion. Current-day *P.australis* stands tend to be monodominant with less diverse associations than occurred historically (Orson, 1999). Possible explanations include marsh disturbance and a new genotype (Orson, 1999).

In some parts of the world, decline of *P.australis* is a concern. In parts of coastal Louisiana, managers fear *P. australis* may be declining due to increasing saltwater intrusion into its brackish marsh habitat. Throughout the western U.S. there is some concern over decreases in common reed habitat and numbers. In Texas, invasion of *P.*

australis habitat by the alien grass *Arundo donax* L. is causing it to decline (Poole, pers. comm. 1985 cited in Marks 1993). The decline of *P. australis* in Europe, where it is still used for thatch, has been a concern for years. Habitat destruction and manipulation of hydrologic regimes by humans, grazing, sedimentation, and decreased water quality (eutrophication) are all cited as factors in its decline (Ostendorp, 1989).

Because of its low value as waterfowl habitat and its tendency to lower the diversity of sites where it is dominant, *P. australis* is not desired everywhere it grows. Common reed can be controlled by aerial applications of herbicides when plants are actively growing (Cross et al., 1989). The most effective herbicides to date are amithrole, dalapon, and glyphosate (Cross et al., 1989). Mechanical control includes disking or plowing, crushing, mowing, and dredging. On sites that become dry during the summer, mowing mid summer greatly reduces *P.australis* (Ward, 1942). But, this method is ineffective on sites that remain moist, and all cuttings must be removed to prevent their sprouting and forming stolons (Osterbrock 1984). At the Delta Marsh in Manitoba, Canada, shortgrass-sedge-thistle meadow replaced a stand of *P. australis* after three successive years of summer mowing (Ward, 1942). Grazing, while able to impact the abundance of stands, cannot be used in waterfowl management areas because the level of grazing necessary to control stands negatively impacts other desirable plant species (Cross et al., 1989).

2.3 Effects of *P.australis* invasion on plant communities

Phragmites australis tends to lower plant species diversity in freshwater wetlands. Several explanations have been put forth to explain this general, although not universal effect. At the soil surface, *P.australis* stands accumulate dead culms which shade the soil, lowering temperature and potentially limiting light to germinating species (Meyerson et al., 2000). The height of *P.australis* stems and their dense growth contributes further to the effect of shade at the soil surface and to lower air temperatures within *P. australis* stands (Meyerson et al., 2000). Spring thaw may be delayed by lowered light levels within *P. australis* stands due to accumulated biomass, slowing the decomposition of organic material and further deterring the establishment of non-*P.australis* species (Meyerson et al., 2000). *Phragmites australis* invasion has been correspondingly correlated with lowered plant species diversity in general (Meyerson et al., 2000). *Phragmites australis* has been reported to grow in monospecific stands where diversity is zero or very low (Keller, 2000, Meyerson et al., 2000). Even where other species are present, they may survive only as scattered pockets of sterile individuals, unable to sustain themselves (Meyerson et al., 2000). When *P.australis* is cleared, diversity generally increases as seeds in the seedbank have light to germinate (Galinato and van der Valk, 1987).

This effect is seen much less in tidal coastal wetlands, as they naturally tend to have a low level of diversity (Meyerson et al., 2000). But, according to Stalter and Baden (1994), *P.australis* expansion in costal wetlands does sometimes, although not always, alter wetland structure and function including nutrient cycling, and wildlife utilization

(Chambers et al., 1999). Specifically, biotically available nitrogen is generally lower in *P.australis* dominated sites, and use by migrating waterfowl is altered, with a reduction in waders and marsh specialists (Chambers et al., 1999).

Phragmites australis does provide functions such as shore stabilization, nutrient retention, sediment trapping, and rapid vegetative cover (Chamber et al., 1999). These benefits and its economic value for roof thatching and cattle feed explain concern over its decline in Europe.

Environmental factors that have been reported to favor *P.australis* dominance include disturbance (i.e. an open canopy), clear ground, and slight salinity (Chambers et al., 1999, Meyerson et al., 2000). A salinity of between 5-10ppt seems to support *P.australis* germination (Chambers et al., 1999). In some systems, salt water intrusion creates a brackish environment, killing off the freshwater species and leaving an opening for *P.australis* to invade (Chambers et al., 1999, Fineran, 2003). Other possible factors include high soil organic matter, hydroperiod, and water level (Lenssen et al.,1999) High nitrogen seems to favor *P.australis* dominance in North America, allowing it to compete more effectively for light (Chambers et al., 1999).

Natural limits to *P.australis* growth include mechanical disturbance such as tides, sulfide effects, depth of flooding, high salinities, competition by some other species, herbivory and reduced light (Hellings and Gallagher, 1992, Chambers et al.,1998, Lissner et al., 1999, Meyerson et al. 2000, Chambers et al., 1999). Of the factors listed above, depth of flooding, light reduction and competition are seen in non-tidal freshwater wetlands in North America. Lissner et al., (1999) found that cloud cover corresponded with a loss of net photosynthetic CO_2 uptake in *P.australis*, possibly lowering its salt tolerance and productivity. In fact, the ratio of realized to potential sun hours may override even temperature as an environmental determinant of *P.australis* production. Shading may also affect germination of *P.australis.* Ekstam, 1995, examined the effect of artificial shading on plots of *P.australis.* He found a reduction in mean shoot density in the shaded verses unshaded plots in one of two treatment years.

2.4 Influence of canopy cover on understory plant community composition

The effect of light reduction by woody canopy cover on herbaceous freshwater wetland understory has not been well studied, and the question of the influence of canopy cover on understory plant composition has been addressed most extensively in forest ecology. Canopy cover is driven by factors such as floristic composition, plant structure, age of stand, stand density, nitrogen and soil moisture (Thomas et al., 1999). It in turn influences abiotic factors such as temperature, elevation, soil nitrogen, rainfall and biotic factors such as floristic composition and diversity. Canopy cover has also been linked to degrees of succession in forests. In general, canopy cover increase with forest age. However, in mature and old growth forests substantial gaps in canopy cover may occur due to tree mortality, reducing overall canopy cover.

Degree of canopy cover modifies the microclimate under the canopy (Geiger, 1965). Canopy cover is correlated to lower available solar radiation, lower daytime temperatures (on sunny days), higher humidity, and lower wind speed under the canopy (Geiger, 1965). All these factors potentially affect germination and growing conditions under the canopy and hence plant community composition. Differences in understory microclimate influence understory composition, wildlife habitat, and biogeochemical processes (Grimmond et al., 2000).

Canopy cover has been shown to correlate significantly with measures of diversity as well as with understory biomass and composition (Gonzalez-Hernandez et al. 1998; McLachlan & Bazely 2001; Brosofske et al. 2001; Battles et al.; 2001) While studies have reported increased species richness with decreased canopy cover (Van Dyke et al, 2001; Ferris et al., 2000; Bone et al., 1997) this conclusion is not universal. Thompson et al., (2002) found that historic land use was also a factor, with higher canopy cover and higher species richness being related to less historical disturbance. Other factors that affect understory species richness include type of disturbance (thinning, clear-cutting, soil contamination, fire, mining, etc.) distance from contiguous forest, patch size, and soil properties (pH, plant available soil nitrogen content, organic matter, soil moisture and texture.)

Canopy cover and light availability have been studied in the context of ecosystem invasibility. Hutchison and Vankat, (1997), found forest invasibility by Amur honeysuckle (Lonicera maackii (Rupr.) Herder) increased with high light levels and proximity to a seed source. As invasive species become established, they alter the composition and dominance of the canopy vegetation. Holmes and Cowling (1997) reported a decrease in cover, richness and frequency of indigenous fynbos vegetation in Cape Peninsula, South Africa with degree of invasion by the alien invasive species *Acacia saligna* (Labill) Wendl. Standish et al. (2001) saw a similar effect in podocarp/broad-leaved forest remnants in New Zealand. There, *Tradescantia fluminensis* Vell., an invasive weed, reduced native woody seeding abundance through competitive shading, limiting forest regeneration. The canopy cover of woody species can limit the success of invasive species and can in turn be limited by them.

CHAPTER 3

SITE DESCRIPTION, METHODS, AND TERMINOLOGY

3.1. Site Description

This study was carried out at the Mentor Marsh during the growing season of 2001. Mentor Marsh is located on the southern shore of Lake Erie between the cities of Mentor and Fairport Harbor in Lake County, approximately 50 km east of downtown Cleveland, Ohio (41°45"00' N and 81°17"30'W) (Fig. 1). Average annual precipitation is 895 mm (35.26 inches), most of which occurs as winter snows or spring rainfall. About ten percent of this moisture arrives as lake-effect snow (ca 1,000mm snow(39.8 inches) or 85 mm moisture(3.3 inches)). Average winter temperature averages -1°C (30°F), and summer temperatures average 21°C (70°F) (USDA,NRCS, 1991).

The Marsh occupies an abandoned stretch of the Grand River approximately 8 km long (5 miles). The River abandoned this stretch when it broke through to Lake Erie at the present-day Fairport Harbor. This occurred approximately 4,000 BP (Fineran, 2003). The substrate of the Marsh is Carlisle Muck overlying post-glacial till deposits. The Marsh differs from typical Lake Erie marshes in that it is not a coastal marsh (open to the Lake). It occupies the old Grand River basin and is connected to the Lake only at its eastern end at Fairport Harbor and at its western end at the ancient confluence of the Grand River and the Lake and Mentor Lagoons. Between these two points, the Marsh is separated from the Lake by the Mentor Headlands, a prominent elevational feature. The marsh bottom is approximately 200 m above sea level and is currently approximately 7 m above Lake Erie water level (Whipple, 1999). Its southern shore rises abruptly from the marsh basin to adjacent uplands, now largely developed.

The area of the Mentor Marsh is approximately 351 ha (868 acres) and is almost totally dominated by *Phragmites australis* (common or giant reed). This makes it the largest marsh within the Lake Erie basin. Prior to 1959 the central part of the Marsh was dominated by elm, ash, maple swamp forest, but starting in that year salt pollution from various industrial sources, killed most of the trees. Remnant stands of swamp forest survived along the south shore, probably owing to fresh-water inflows along that shore. The die-off of the trees opened an invasion window for *P.australis,* which now dominates the former swamp forest area. There is some indication that some remnant swamp forest stands are beginning to expand (James Bissel, Cleveland Museum of Natural History, personal communication).

3.2 Methods

Vegetation Sampling

Four sampling sites on the south side of the marsh were selected for analysis because they were representative of the variation in vegetation types arrayed along this shore. Vegetation was sampled three times within these four sites to capture temporal variation in the floras of the sites. The first sampling was carried out in May and is referred to as the spring sample. The second sampling occurred in August to coincide with peak standing crop of herbaceous species in the Marsh. This is called the summer sample. The final sampling was carried out in October and is called the fall survey. This survey was done primarily to coincide with the taking of canopy photographs while the trees had no leaves (see below). The summer sampling was used for all the analysis.

A base-line approximately 125 m long was established running approximately east and west on the shore, parallel to the Marsh in each sampling site (Figure 2). Site #1 (transects 1 and 2) was dominated by a broad band of swamp forest that transitioned to *P. australis* at its northern edge, sites #2 and #3 (transects 3-6) were mixtures of trees, shrubs and *P. australis* dominance, and Site #4 was a solid *P. australis* stand starting at the shoreline.

Each base line was divided in half and one transect starting point was randomly selected (random numbers table) in each half. Transects were run perpendicular to this line, roughly northward, into the Marsh. To minimize the chances of overlapping transects, no transect starting points were selected within 10 m of the baseline center point. To sample the herbaceous vegetation, 1 X 1-m quadrats were established at 10-m intervals along each transect. The first quadrat on each transect was established on the upland side of the marsh boundary. Transects terminated when the substrate became too dangerous for researchers (Figs. 3-7, Chapter 4). The length of transects varied: 1 and 2 were 120m, 3 and 4 were 70m, and 5 through 8 were 40m. Shrubs were sampled within 5 X 5-m quadrats, and trees were sampled within 10 X 10-m quadrats. These were established at 30-m intervals along the transects beginning on the upland slope. Within each quadrat all plant species were identified according to Gleason and Cronquist (1991).

Stem density of all shrub species and tree samplings (dbh <3-cm and more than 80 cm tall) was recorded in each 5 X 5 quadrat. For trees trunk density and dbh was recorded for each species in the 10 X 10-m quadrats.

Biomass samples

P.australis biomass was sampled during the summer sampling period from selected quadrats lying within *P.australis* stands. Where stands were wide enough that more than one quadrat fell within the stand, samples were collected from two quadrats in an attempt to capture biomass variability within the stand; the quadrat nearest the edge of the stand and the quadrat nearest the center of the stand were sampled. In the largest stands as many as three quadrats were sampled. In each quadrat sampled, 3-5 ramets were harvested and returned to the laboratory for analysis. The plant parts were dried in paper bags at 93°C (200*f*F) for 14 days and weighed to the nearest gram. *P.aus*tralis biomass/m^2 was determined by multiplying the mean weight by the number of stems per quadrat.

Canopy Analysis

Canopy digital photographs were taken during full leaf-out (August). Photographs were taken with a Nikon CoolPix 990 camera with a 183 degree fisheye lens. Two photographs were taken on each date in the center of each 1 X 1-m quadrat at 1.3 and 2.6-m above the substrate. The former was to determine shade levels within the herbaceous canopy, and the latter was meant to sample shading above the herbaceous canopy. Where the herbaceous canopy exceeded 2.6-m in height, most importantly *P. australis*, photographs were taken at 4.0-m. To achieve the desired height, the camera was mounded on the end of a series of1.3-m, interlocking PVC pipes, 4-cm in diameter.

Each canopy photograph was analyzed by using the computer program SCANOPY (Regent Instruments Copyright (c) 1998-2003 by Regent Instruments Inc.). Summer light parameter values were averaged for the tree dominated sites and for combined *P.australis*-dominated and ecotone sites, and compared using a two-tailed t-test (α=0.05). Values from 2.6-m photos were used in the swamp forest zone because they captured the overstory canopy. But, in the *P. australis*/ecotone zone, *P. australis* often reached heights greater than 2.6 m. In an attempt to capture canopy coverage above the tops of the *Phragmites* ramets in these areas, the 4-m photographs were used. Unfortunately, even at this height, shade from very tall *P. australis* ramets was captured in the photographs, confounding the results. The impact of the overstory is reported as "openness" which is the fraction of sky unobstructed by vegetation in the region above the lens.

Linear regression (Moore and McCabe, 1998) was used to assess the relationship between summer light variables at 1.3 and 2.6 or 4.0 m and measures of *P. australis* dominance, tree dominance, and species composition. These relationships were examined in the *P. australis* stands, in the swamp forest, and in the overall data set.

Analyses of Vegetation Zones

Three vegetative zones were identified in this study: the swamp forest community dominated by tree species, the *Phragmites* community dominated by

P.australis, and the ecotonal zones dominated by a mixture of trees, shrubs, and *P. australis.* The distribution of sites among the three vegetation types is illustrated in Table 1 and the *P.australis* density is listed in Table 2. The similarity of the three vegetation zones were assessed using the Jaccard's Index of Similarity (Magurran, 1988). Jaccard's Index compares pairs of sites or zones, e.g. swamp forest to ecotone, swamp forest to *P. australis*-dominated sites, *and P. australis*-dominated sites to ecotone.

$$Cj = j / (a + b - J)$$

Where:

j = number of species common to both zones

a = the number of species found in zone A

b = the number of species found in zone B.

For further analyses, the *P. australis* and ecotonal areas were combined and compared to the swamp forest. Average *P. australis* ramet density and biomass/m^2, tree trunk density/m2, species richness, Shannon's Index and Simpson's Index were compared between these two zones using a two-sample t-test (α=0.05).

Diversity

Three diversity indices were used in this study:

Species Richness (S): the total number of species found in a community. It is dependent on sample size and intensity (Magurran, 1988).

Shannon's Index (H):

$$H' = -\sum p_i \ln p_i$$

Where:

P_i = the proportional abundance of the ith species.

The value of this index usually ranges between 1.5 and 3.5 and only rarely passes 4.5 (Magurran 1998). H'= 0 when there is only one species in the sample and increases as the species become more evenly distributed. H' is a measure of the average degree of uncertainty in predicting what species a randomly selected individual will belong to. As the number of species present increases and the evenness of distribution of individuals among the species increases, the uncertainty increases (Ludwig and Reynolds, 1998).

Simpson's Index (D)

$$D = \sum[\{ni9ni-1)\} / \{N (N-1)\}]$$

Where:

Ni = the number if individuals in the ith species and N = the total number of individuals.

Simpson's index varies from 0 to 1 and is the probability that any two individuals drawn randomly from the population are the same species. If the probability is high, the diversity of the community is low (Ludwig and Reynolds 1998.) As diversity increases, D decreases. For this study, Simpson's index is expressed as 1/D so that as diversity increases, the value of the index increases.

Diversity indices should be interpreted with caution. The same diversity index can result from various combinations of species richness and proportional abundance. If one community had low species richness and a high evenness while another had a high number of species and with low evenness, they could have the same diversity index. The homogeneity and size of the area sampled could also affect the diversity index value (Ludwig and Reynolds, 1998).

3.3 Terminology

Wetland Indicator Status

The National List of Vascular Plant Species That Occur in Wetlands (Reed 1988) was used to identify the wetland indicator category for each species. The indicator category is an estimate of the probability that the species occurs in wetlands verses non-wetlands in the region. The status of the species in the Northeast region was used for the purpose of this study. If the species was included in the list but no status was assigned for the Northeast region, the status of the plant's national indicator range was used. The indicator categories are as follows:

- OBL= Obligate Wetland species which occur almost always (estimated probability >99%) under natural wetland conditions in wetlands.
- FACW= Facultative species which are equally likely to occur in wetlands or non-wetlands (estimated probability 67%-99%)
- FAC = Facultative species that are equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%)
- FACU = facultative upland species that are usually found in non-wetlands (estimated probability 67%-99%), but occasionally are found in wetlands (estimated probability 1%-33%)

- UPL = Obligate upland species found in wetlands in another region, but under natural conditions, almost always found in non-wetlands (estimated probability >99%) in the region specified.
- NL= not listed in Reed (1988).

Guilds

Guilds are assemblages of different plant species that are found growing in the same or similar habitat types. They are, therefore, assumed to have similar habitat tolerances. The guild categories used in this study have been adapted from Galatowitsch and van der Valk (1996). WM = wet meadow species, SDE= shallow and deep water species, SFA= submerged and floating aquatic species, WSVT = woody shrub, vine, and tree species, MWU=moist wood understory, and WM/MWU = widespread understory plants.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Vegetation of the Study Site

Three vegetation zones were identified in the study site: Swamp forest, *P. australis*-dominated zones, and ecotonal areas. Fifty-five species of vascular plants were found in these zones, 52 of which were identifiable to species (Table 3). Forty-five identifiable species were found in the swamp forest zones, 21 were found in areas dominated by *P. australis*, and 13 identifiable species were found in ecotonal areas. Sixty-three percent (33) of the species were native to North America, 31 percent were widespread species of unknown origin, and only three species (5%) were introduced.

Sixty-two percent of the species were either obligate or facultative wetland species according to the National List of Plant Species that Occur in Wetlands (Reed, 1988). Twenty-one percent were facultative species that occur equally in uplands and wetlands, and only 18 percent were classified as facultative upland species (See Chapter 3 for definitions of wetland indicator species. All three vegetation zones were dominated by obligate or facultative wetland species (Table 8): 62 percent of the swamp forest species, 71 percent of the species in the *P. australis*-dominated zones, and 69 percent of the species occupying the ecotone. The boundary of the Mentor Marsh on its southern side is abrupt, transitioning from a steep, north-facing slope directly into relatively flat and low-lying swamp forest. Therefore, it is not surprising that wetland indicator species would dominate the site.

The swamp forest had a rich plant guild structure: 51 percent woody species (WSVT), 16 percent herbaceous species typical of swamp forest understories in this region (MWU), and 22 percent comprising species found both in the forest understory and in wet meadows. The remaining species belonged to the wet meadow guild (WM, 4%) or to the shallow and deep water emergent guild (SDE). This diversity of guilds probably reflects the complex mosaic of water depths found in the swamp forest. Ecotonal zones also had diverse guild structures, probably for the same reason. The study area was dominated before 1959 by dense swamp forest, so it is not surprising that the WSVT guild remains important on these sites. If water depth decline in the Marsh in the future, this forest will probably reestablish itself from remnant individuals and stands and from seed sources in the seed bank and in the existing swamp forest and the adjacent upland forests just to the south of the marsh boundary.

Interestingly, WSVT were the most common guild in all three zones, most notably the *P. australis*-dominated areas (Table 9). Two-thirds of the species found in quadrats dominated by *P. australis* belonged to the woody shrub, vine, and tree guild (WSVT), whereas just more than half of the species in the swamp forest and ecotone belonged to this woody guild. While the WSVT guild extends across all three zones, there is a shift from predominantly tree species in the swamp forest to predominantly shrub species in the ecotone and *P. australis*-dominated sites. This reflects the general increase in water depth from the shore toward the center of the marsh. Many of these shrub species can tolerate standing water for extended periods of time.

No submersed or floating-leaved aquatic species (SFA guild) were found in the swamp forest, probably because of the shade cast by the forest canopy and the relative shallowness of the water. Spirodela and Lemna were found only in the ecotonal and *P. australis*-dominated areas.

Species composition varied considerably among the three zones. Jaccard's index of similarity reveals that the species composition of the swamp forest and ecotonal areas had only a 22 percent overlap in species, while the overlap between the swamp forest and *P. australis*-dominated areas was only 20 percent. The *P. australis*-dominated sites were most similar to the ecotonal areas, but still overlapped only by 35 percent. This illustrates the significant shift in species that can occur when a swamp forest is converted to an emergent macrophyte marsh as occurred in the Mentor Marsh as a result of salt pollution of the Marsh beginning in 1959. In addition to the change in species composition that occurred when *P. australis* replaced the swamp forest, there was an actual decline in species richness from 47 in the swamp forest to 21 in the shallow *P. australis* stands sampled in this study. Had samples been possible in the deeper water areas now dominated by *P. australis*, the decline in species richness would likely have been greater.

The swamp forest flora at Mentor Marsh is depauperated compared to that found by Gara (1995) in Culberson Woods, a mature swamp forest in southern Ohio. Gara found 155 plant species at Culberson Woods, compared to the 45 species found in the swamp forest or the 55 species found in all three zones at Mentor Marsh. This difference might be attributable to generally drier conditions in Culberson Woods that allow more upland species to enter the flora, especially in dry years. Culberson Woods has only a few cm of water at the surface in the spring; the remainder of the year, no standing water exists and the soil can become dry by late summer.

In contrast, the flora of the study sites at Mentor Marsh compare favorably with the floras of other Lake Eire marshes, most of which are dominated by herbaceous species. Welch (2001), Bhardwaj (1997), Hoosein (2001), Thiet (1998) and Mauer (1995) found between 41 and 88 species in their studies of shoreline wetlands in the Sandusky Bay area. Because species richness is dependent on sample size, species richness estimated in this study may be underestimated somewhat. Unconsolidated bottom sediments made sampling in the central open marsh treacherous or even dangerous. This substrate condition was noted by surveyors as early as 1874 (Blunt, 1874). More recently fire fighters battling reed fires in the marsh found that they could not proceed very far into the marsh from the shore because they encountered patches that were "like quicksand" (Fineran, 2003).

4.2 Impact of forest canopy shading on the distribution, density, and biomass of *Phragmites australis* ramets.

Transects 1 and 2 passed from the wetland edge through a broad band of swamp forest and abruptly into a dense *Phragmites* stand (Figure 1). The swamp forest provided an even, intact canopy below 7 percent openness over the first 9 quadrats on both transects, and *P. australis* was not present until the canopy opened above 7 percent in quadrat 10. Quadrat 10 lies in a transition zone about 10 m wide where some tree canopy is still present but *P. australis* has been able to establish in low numbers (< 5 ramets/m^2). Quadrats 11 and 12 occupied a dense *P. australis* stand with ramet densities reaching 50-60/m^2.

The closed forest canopy ended between quadrats 9 and 10 and tree cover was totally absent above quadrats 11 and 12. The decline in openness above quadrats 11 and 12 (Fig. 1) reflects shade cast by the *P. australis* itself. The tallest *Phragmites* ramets at Mentor Marsh often top the 4-m. pole upon which the canopy camera was situated. Further, the hemispheric lens of the camera does pick up objects low on the horizon. Data from Transects 1 and 2 clearly suggest that P. australis is intolerant of shade cast by an intact forest canopy (Figure 2).

Transect 3 (Figure 3) passes through an area of swamp forest with a less even canopy than was found along transects 1 and 2. The forest canopy thickens and thins in bands, with *P. australis* occupying areas of lower canopy cover. Quadrat 2 occupied a narrow band of dense swamp forest near the edge of the marsh with a forest canopy openness of less than 6 percent, *and P. australis* was not present. The forest canopy opened above 7 percent in quadrat 3 and reached nearly 8 percent above quadrat 4. Two *P. australis* ramets were found in quadrat 3 and 16 occurred in quadrat 4. The tree canopy closed again over quadrats 5 and 6 dropping openness below 7 percent and eliminating *P. australis*. When canopy openness opened again to >7 percent in quadrat 7, *P. australis* appeared once more.

As was found in transects 1 and 2, seven percent openness seems to be critical for he appearance of *P. australis*. But, *while P. australis* was found in dense stands of 50+ ramets/m^2 at canopy openness above 7 percent in transects 1 and 2, it never exceeded 16 ramets/m^2 along transect 3. Once the tree canopy opened on transects 1 and 2, *P. australis* formed a full, contiguous stand. This never occurred along transect 3. In transects 1 and 2, the tree canopy ended between quadrats 9 and 10, and much of the cover measured beyond that point was self-shading by the 4+ m *P. australis* ramets. Though the tree canopy thinned above quadrats 3, 4, and 7 on transect 3, it did not disappear and continued to suppress *P.australis* growth, keeping stem density below 20/m^2. Therefore, while a tree canopy with more than 7 percent openness is adequate for the establishment of *P.australis*, it is not sufficient for the formation of dense *P.australis* stands. The latter seems to occur only when the forest canopy is eliminated or at least greatly disbursed.

Transect 4 passes through a band of dense forest canopy that thins in a canopy gap above quadrat 3 (Fig. 4). At quadrat 4, the transect enters the ecotonal zone which is dominated by shrubs and *P. australis..* Canopy openness is below 7 in the dense forest but rises to more than ten percent in the gap above quadrat 3. But, *Phragmites* did not occur in this opening. Instead, the understory was made up of herbaceous species commonly found on swamp forest floors. Phragmites comes in densely in quadrats 4, 5 and 6 with ramet numbers ranging between 35 and 45/m^2. Canopy cover in these quadrats is imposed by a few trees, many shrubs and *P. australis.* Whatever the source of shade in these quadrats it did not eliminate or even greatly suppress *P. australis* growth. At quadrat 7, canopy openness declined slightly but remained well above 7 percent. The steep decline in *P. australis* density in quadrat 7 was most likely caused by the deeper water encountered at this quadrat. *Phragmites australis* is known to do poorly in water deeper than 50 cm (Haslam, 1970). The transect terminated at quadrat 7 owing to the unconsolidated substrate conditions mentioned above.

While *P. australis* density increased from quadrats 4 to 6, *P. australis* biomass declined. This decline continued in quadrat 7. This decline is probably a reflection of worsening abiotic conditions, most probably increasing water depth. The duration of flooding is longer in deeper areas than it is in shallower areas. The increased duration of flooding along the water depth gradient between quadrats 4 and 7 is also the likely cause of the replacement of the swamp forest by ecotonal species and *P. australis* and the opening of the tree canopy in this zone.

Transect 5 passes through a relatively open band of swamp forest at quadrat 2 before passing into a zone best described as a mosaic of dense *P. australis*, patches of shrub and scattered tree clumps. Only a few *P. australis* ramets were found in quadrat 2 even though canopy openness was relatively high (ca 9%). In quadrat 3, however, *P. australis* dominated with ramet numbers/m^2 surpassing 100. The decline in openness at quadrat 3 reflects shade cast by the *P. australis* ramets which were more than 4 m tall at this site and by nearby trees and shrubs. At quadrat 4, *P. australis* ramet density declined and woody shrub cover increased (27 stems/m^2). The decline in *P. australis* density at quadrat 4 was likely caused by deeper water, as was suggested above for similar declines at the deeper end of transect 4, and by competition with the shrubs. The increase in openness at this site was likely caused by the decline of *P. australis* density, a decline that was not made up by the increase in shrub density. Unfortunately, 10 X 10 m and 5 X 5 m tree and shrub quadrats were not taken on this transect beyond quadrat 2, so no definitive statements can be made about the relative importance of tree and shrub cover in quadrats 3 and 4 as compared to the impact of *P.australis* cover. This transect was terminated at quadrat 4 owing to worsening substrate conditions.

Transects 6, 7, and 8 were entirely in mature *P. australis* stands. Openness is above 7 percent in all three quadrats on each transect, and *P. australis* increases from about 25 ramets/m^2 to more than 60 ramets/m^2 in quadrats 3 and 4. Again, sampling had to be curtailed at quadrat 3 on these transects owing to dangerous substrate conditions. The cover recorded during sampling reflects the tops of the tall *P. australis* plants.

One hypothesis of this study was that there would be a level of overstory shading under which *P. australis* would not be able to compete successfully, a level at which *P. australis* could compete but not thrive, and a level at which it could flourish. Evidence presented here (Figs. 1-5) suggests that *P. australis* is unable to compete under conditions where the overstory canopy openness is less than 7 percent. There is a negative relationship *between P.australis* density and tree density and dbh (p<.05) (Table 8). This relationship also holds for overstory shading; as shading increases, *P. australis* density decreases (p<.05). Finally, as might be expected, overstory shading is positively correlated with tree numbers (p<.05). Therefore, while individual sites may vary greatly, in general, the presence of trees and the shade they cast is negatively correlated with the health and vigor of *P. australis.*

Unfortunately, the fact that canopy photographs taken in areas dominated by *P. australis* and/or shrubs were shot at a maximum elevation of 4 m which, in many cases, was below the canopy tops of the shrubs and *P. australis.* Therefore, we were not able to separate overstory shading from shade cast by tall *P. australis* ramets and/or shrubs. Therefore, all we can say with confidence is that *P. australis* does not grow under overstory canopies with less than 7 percent openness and that *P. australis* thrives when there is no overstory canopy. We are unable to address intermediate conditions of openness between 7 and nearly 100 percent.

Discussion

The literature on forest canopy openness and its impact on understory plants is sparse, and no work has been done on the impact of tree canopy shade on wetland macrophytes. One study of upland forests in Wisconsin (Brosofke et al) found canopy openness values of 3.6 percent in mature hardwood forests and 4.8 percent in young hardwood forests. These data were obtained with the use of a densitometer which gives results comparable to those obtained from digital canopy photographs such as ours at Mentor Marsh (Englund et al, 2000). Swamp forest canopy openness at Mentor Marsh averaged 6.0-6.3 percent, slightly higher than was found in the Wisconsin upland forests, but still less than the 7.0 percent required by *P. australis*.

Overstory openness or shading is one of many factors possibly affecting *P. australis* survival and growth at Mentor Marsh. Hydrology, water and soil salinity and nitrogen levels, proximate environment, and disturbance history have also been shown to influence the establishment and expansion of invasive species such as *P. australis* (Chambers et al., 1999, Meyerson et al., 2000; Amsberry, 2000). Ecosystem invasability, the likeliness that an ecosystem will become dominated by one species that has not historically dominated in that system, has been explained in terms of several factors, including whether the system is an extreme or fertile environment and how prone the system is to natural disturbance (Bart and Hartman, 2000). At Mentor Marsh, the die off of the dominant swamp forest community in the 1960's and its replacement almost entirely by *P. australis*, has been attributed to a combination of high marsh water levels and severe salinization caused by salt leaking into the marsh from upland land fills or blowing onto trees from salt storage piles at a near-by salt plant (Keefe, 1974, Whipple, 1999, Fineran 2003). The present-day swamp forest stands at Mentor Marsh are remnants of the previous dominant forest. There is some indication that these refugial stands may be expanding, owing to lower water levels and a dilution of the salt in the soil and water. How successful this expansion will be in light of the dominance of *P. australis* on former forested sites is unknown. But evidence from this study suggest that if new trees can become established on the fringe of the present-day *P. australis* stands, the giant reed will not be able to survive. The long-term effect of such competition could be reestablishment of swamp forest in areas suitable for tree growth.

4.3 Impacts of Phragmites australis canopy shading on understory species diversity.

Twenty plant species were found growing in quadrats dominated by dense *P. australis*. This is fewer species than were found in all zones at some other Lake Erie marshes where species numbers ranged from 41 to 88 species. Whether the low numbers of species found within the *P. australis* stands at Mentor Marsh may be attributable to the presence of the giant reed is not certain. Nor is the causal mechanism that might be operating if *P. anstralis* has indeed reduced plant species diversity on this site. Results from this study do indicate, however, that shade levels at an elevation of 1.3 m within *P.australis* stands were slightly negatively related to species density (species/m^2) (p=.095, r^2%=14.68). This suggests that *P.australis* does have a negative impact on understory species diversity and supports the hypothesis that *P. australis* shading is at least partly responsible for this negative impact.

Discussion

Meyerson (2000) reported total species richness within two non-*P.australis* dominated marshes in Connecticut between 20 and 30 species, and in *P.australis* dominated marshes 9 to 10 species. As noted above, several studies on Lake Erie wetlands have documented total species richness between 41 and 88 species, significantly more than was found in the stands in this study (Welch (2001), Bhardwaj (1997), Hoosein (2001), Thiet (1998) and Mauer,1995). This might suggest that the species richness found in *P. australis* stands in this study has been reduced by the presence of *P. australis*. But, the highest species diversity found in those other Lake Erie wetland studies was the 88 species that Welch (2001) found in a diked wetland dominated by *P. australis*. Welch's site included a wide diversity of habitat types ranging from semi-permanent pools to near-upland conditions on sand piles in the center of the wetland. While *P. australis* dominated most of this wetland, it was less dominant on the sand piles and was largely absent from the standing pools. This may explain the greater diversity found on his site as compared to what was found in this study at Mentor Marsh.

While canopy shade from the dominant *P. australis* could be one constraint limiting species richness on the *P. australis* sites, other factors may also be playing a role. This *P.australis* stand developed over the past four decades on a site contaminated with salt. It is possible that the low species diversity on the site reflects the fact that most freshwater wetland species have low tolerance for saline conditions, lower than does *P.*

australis (Shay and Shay, 1986; Hocking et. al., 1983). And Maclachlen and Bazley (2001) cited time since disturbance and distance from contiguous forest as factors than can influence overall species diversity and the number of rare species on disturbed sites. Even if shading by *P. australis* is the driving force limiting understory diversity, its effect might be indirect through the cooling of the substrate which could constrain germination in some species.

CHAPTER 5

CONCLUSIONS

The swamp forest and *P.australis* stand provide very different understory environments. *P.australis* does not provide more canopy cover, being about equal to swamp forest at 1.3m, and less at 2.6 meters and above. However, diversity is significantly lower in those sites. This is likely due to the different substrate of *P. australis* stands. Its dense growth and deep litter fall contrast with the relatively open understory and lack of a litter mat in the swamp forest. These factors may affect understory species germination rates. Additionally, *P. australis* can tolerate and thrive in conditions that may be stressful for other species, including deeper water and moderately high salinity.

Competition for light between trees and *P. australis* is one of the fundamental factors limiting the expansion of *P.australis* into areas dominated by mature trees. From examining the openness data, the level of shading that correlates with tree dominance is around 93% canopy closure. The tree dominated sites were on average 94% shaded; the *P.australis* stands were generally below 93% shaded by trees. Where *P.australis* is found at lower levels of shading, the stands themselves are likely contributing to the level of shade and are often bordered by areas of greater openness. Deciduous, flooding-tolerant trees seem to compete with *P. australis*, such that the two are nearly mutually exclusive. Shade-tolerant tree species such as sugar maple (*Acer saccharum* Marsh) typically grow up under a closed canopy and should be able to mature under the less dense *P.australis* canopy unless constrained by other factors such as root competition.

In some sites dominated by *P. australis* no other species were present. At less dense sites, various species grew within the stands, including shrubs and scattered trees. Trees seemed to favor raised ground with less standing water, although some shrub-dominated sites were quite wet in summer and fall. In terms of guilds, woody, shrubby and vine species dominated the *P.australis* sites as well as the swamp forest sites and in the ecotone. The tree dominated sites and ecotone sites showed a bias towards facultative wetland species, reflecting the moderate inundation level of those sites. The *P.australis* dominated sites had an even distribution of obligate, facultative wetland, and facultative species, reflecting the ability of *P.australis* to persist in very wet sites and drier sites. Most of the obligate species found in the *P.australis* dominated sites were submerged or floating aquatics and shallow or deep water emergent species. In contrast, those in the ecotone and tree dominated sites tended to be wet meadow or moist woods understory species.

P. australis is a pioneer species that thrives on open soils after a disturbance. One course of succession would predict that *P.australis*, as a shade-intolerant ruderal, would be eventually replaced by longer-lived, slow-growing shade-tolerant trees as they over top the stands and shade them out. But, other factors may be shaping the course of succession in the marsh. Areas of the *P. australis* stand have caught fire, through lightening and from human causes. On May 9, 1982, approximately 100-150 acres of marsh burned in the eastern part of the preserve. Another fire took approximately 350 acres on May 11, 1992 in what was known as the "Mother's Day Fire," and approximately 60-90 acres of the preserve burned between August 1 and 13, 1998, and (ODNR, 1994).

This kind of disruption is not something a wetland tree species is adapted to handle, and the burning of the *P.australis* stands may be perpetuating their dominance by damaging or destroying woody species growing in the stands. Silver maple has a low fire tolerance that varies with growing conditions, and both elm and sugar maple are not typically dominant in areas that burn frequently (Merz, 1978, Daubenmire, 1949, Kittredge, 1934). Woody species recover much more slowly from fire than does *P. australis*, and frequent enough burns could continue to set back the course of succession to swamp forest. Also, while chloride levels have decreased in the marsh overall, there is still some question of whether or not areas of the marsh still have unusually high salinity (Whipple, 1999). Such contamination would strongly favor the dominance of *P.australis* in those areas.

The swamp forest is a mix of shade tolerant *Acer saccharum* intermediate tolerant species such as American elm (*Ulmus Americana* L.), and shade intolerant species such as sugar maple (*Acer saccharinum* L.). Typically, sugar maple and elm will be able to form a mature community. Silver maple, however, is generally a fast growing, early succession species that is tolerant of flooding (Johnson, 1983). The most common tree species in the *P.australis* stands was silver maple. This reflects the stands history of disturbance, and perhaps the presence of silver maple trees indicates the beginning of forest regeneration.

Restoration efforts are under way at the marsh. They involve understanding the hydrology of the marsh and how the vegetation has altered and minimizing chemical contamination to the marsh through the re-routing of Blackbrook creek. More extensive efforts may be needed to promote the regeneration of the pre-disturbance swamp forest vegetation. Possible areas of interest include more details of the marsh hydrology and the abiotic conditions in the *P. australis* stands and swamp forest. Some areas of the marsh seen to be intermediate between an intact swamp forest and a solid *P.australis* stand. Monitoring of the vegetation in these areas over time might provide insight in to the swamp's natural pace of regeneration. It is likely, however, that the areas dominated by *P.australis* will not return to swamp forest in the near future without human intervention. One possible course of action would be investigating conditions necessary for planted trees or shrubs to survive and expand in areas that are now *P.australis* stands. This would require adequate investigation of such factors as hydrology and soil and water chemistry in the swamp forest and *P. australis* stands. Other methods of *P.australis* control including: mowing, burning, burying, and pesticides used in connection with tree plantings, could favor the restoration of the swamp forest. In addition, investigation of the seed bank in the *P.australis* stands may determine if planting would be necessary or if the removal of *P.australis* and alteration of other abiotic factors would be sufficient to allow for regeneration of the swamp forest.

Also of interest is the question of whether the swamp forest is expanding, dying back, or basically stable in area. The expansion, dieback, or stabilization of the

P.australis stands in the marsh as a whole is also relevant to the ecology of this unique site.

Finally, a comment on the use of canopy analysis within *P. australis* stands: Canopy analysis was designed to be used in forests where the canopy is far from the camera lens and the leaf size relatively small compared to the field of view. *P. australis* stands grow much more densely and leaf out relatively near the ground. The canopy of *P. australis* may by unsuited to this type of analysis. Other possible sources of error in the use of canopy photography include the necessity of a uniform cloud cover in the photographs and a consistent degree of illumination between photographs.

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APPENDIX A

FIGURES

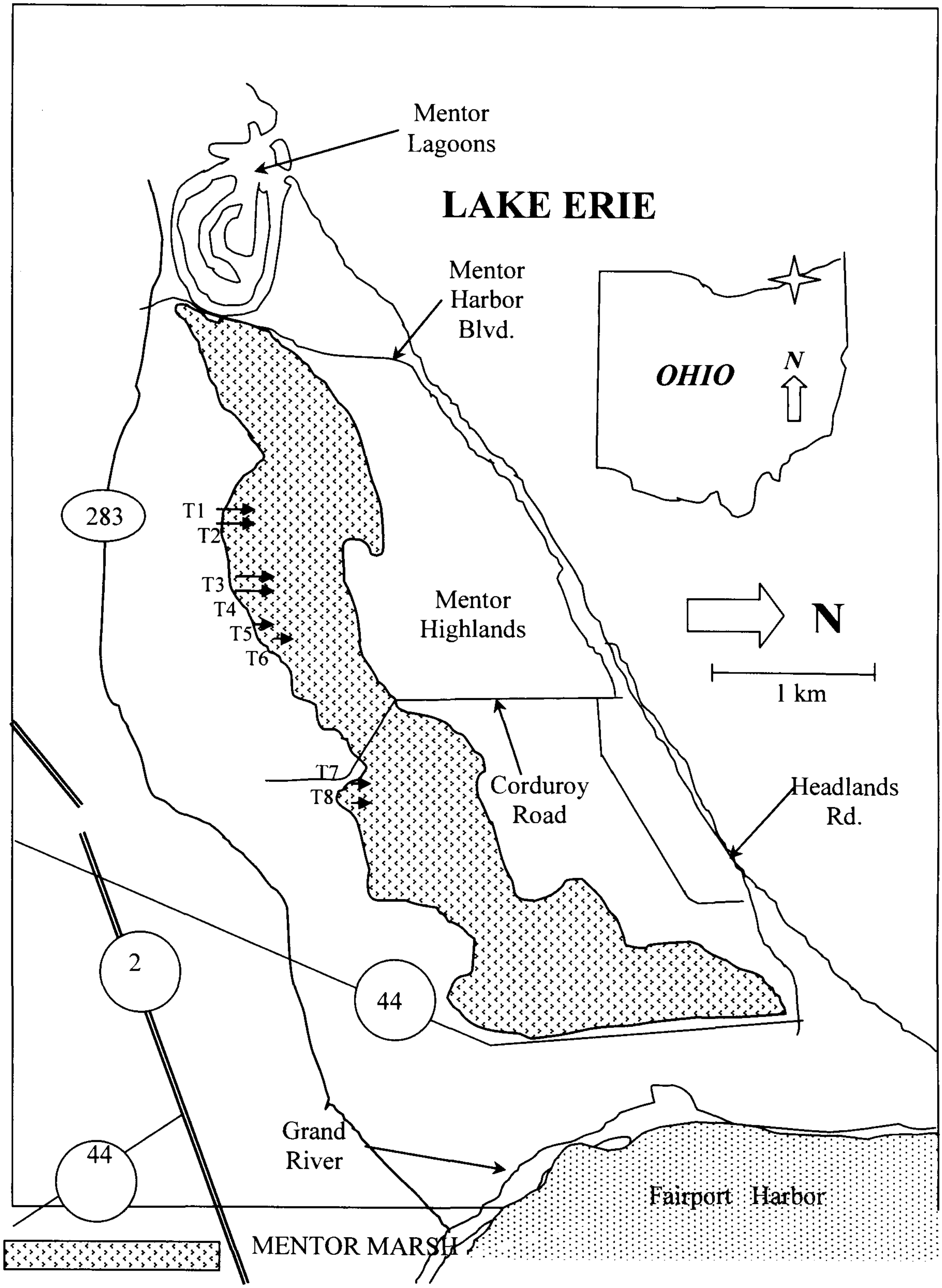

Figure 1. Mentor Marsh. Lake County, Ohio, USA. (41°45"00' N and 81°17"30'W).

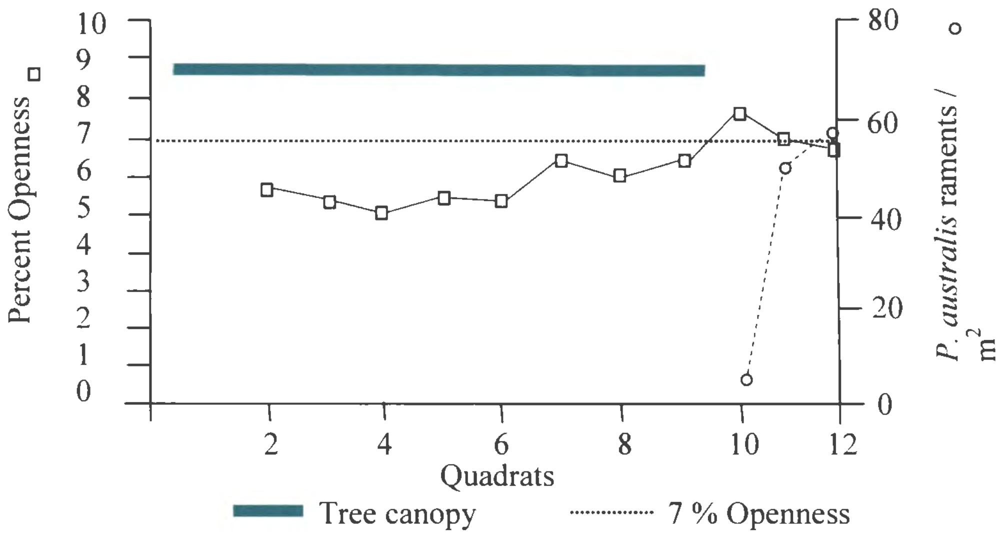

Figure 2. Canopy openness and *P. australis* ramet density along transects 1 and 2. Both transects passed through swamp forest before passing into an open *P. australis* stand between quadrats 9 and 10.

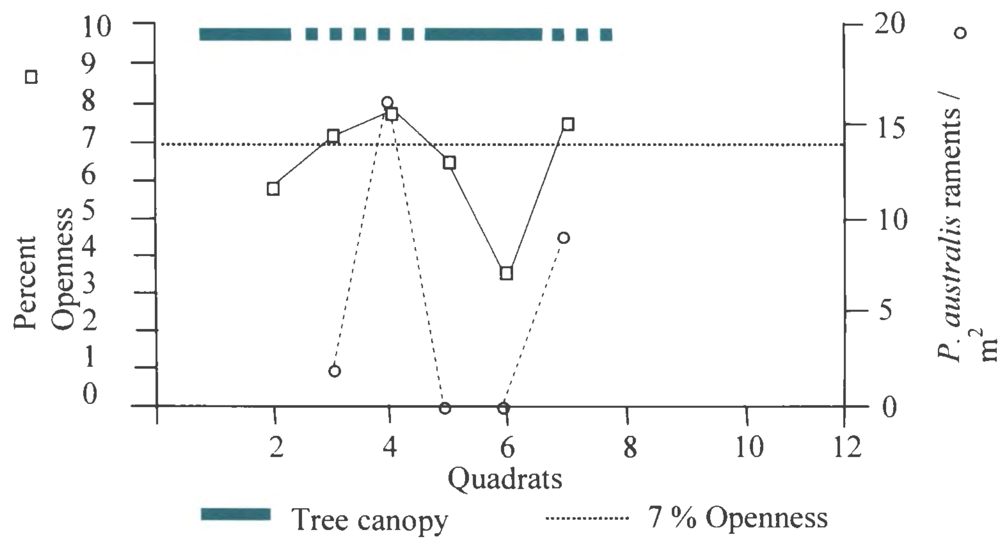

Figure 3. Canopy openness and *P. australis* ramet density along transect 3 which passed through a fairly open area of swamp forest.

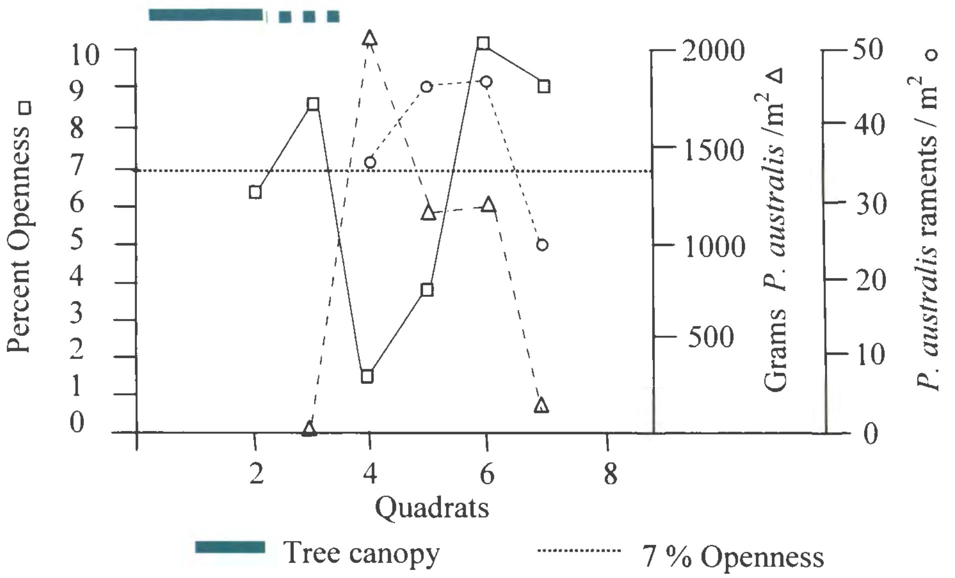

Figure 4. Transect 4 passes through a band of dense forest which thins in a canopy gap at quadrat 3. It then enters the ecotone zone made up of a mixture of shrubs and *P. australis*.

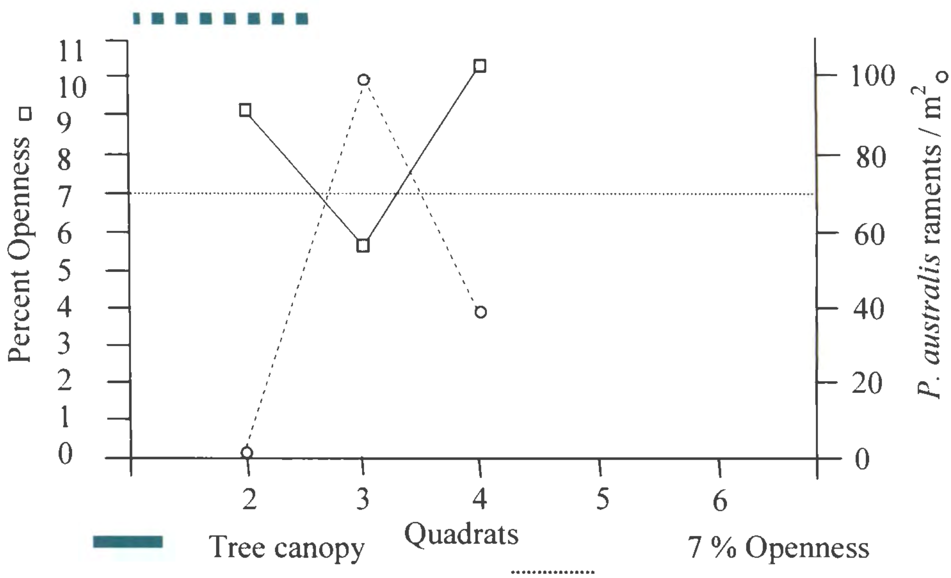

Figure 5. Transect 5 passed through an open band of swamp forest before passing into a zone that includes dense *P.australis*, patches of shrubs and scattered trees.

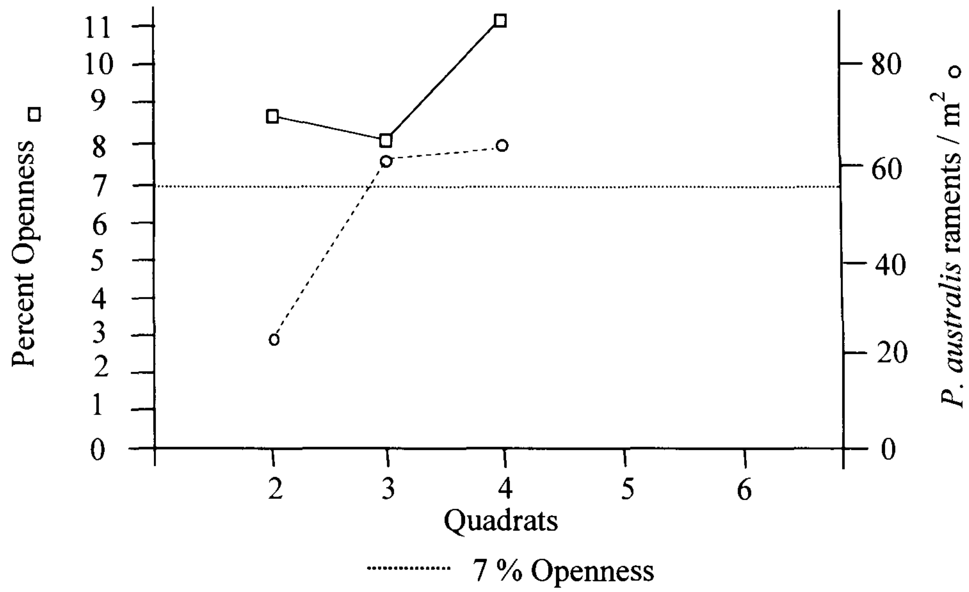

Figure 6. Transects 6, 7, and 8 lie entirely in mature stands of *P. australis*.

Fig. 7: Canopy photo at transect 1 quadrat 3, 2.6m, within the swamp forest. Openness is 5.57.

Fig 8: Canopy photo at transect 7 quadrat 4, 4m, within a *P.australis* stand. Upland forest is present on the horizon. Openness is 9.96.

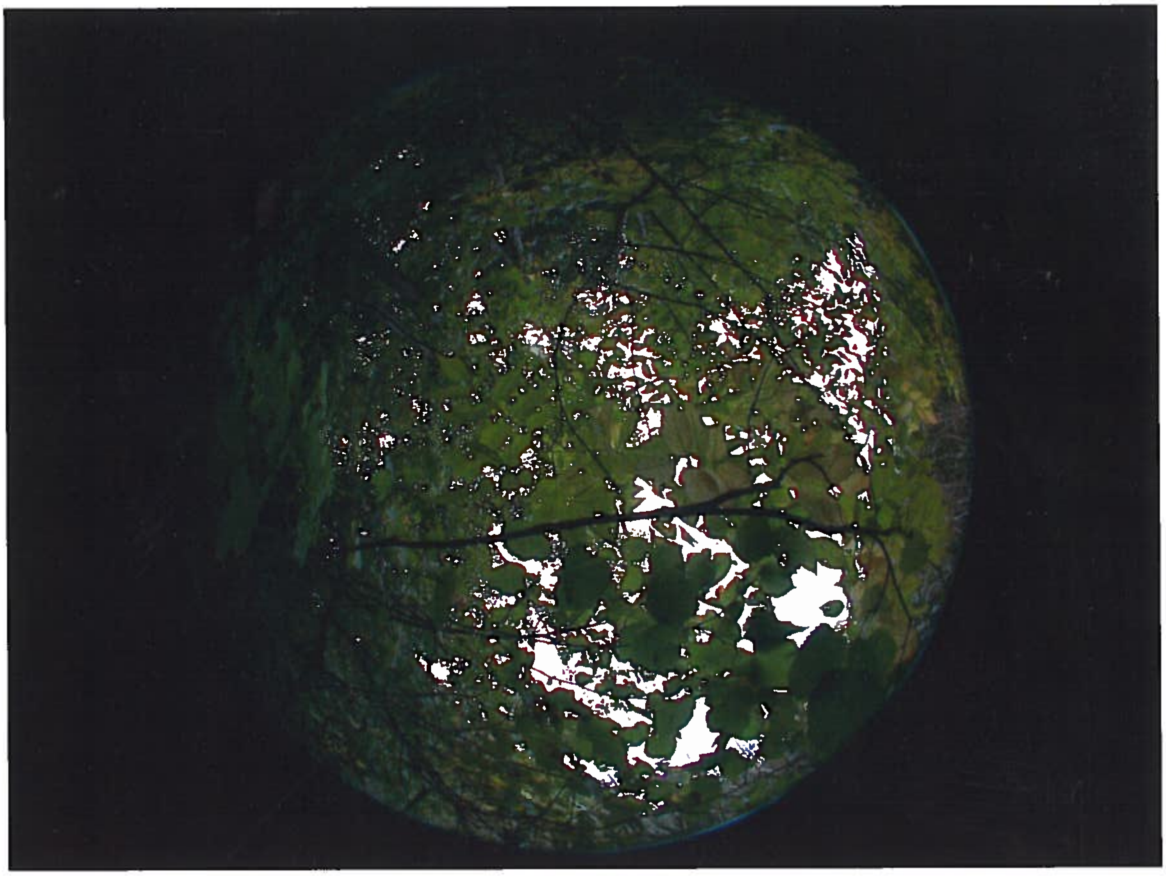

Fig 9: Canopy photo at transect 7 quadrat 2, 2.6m, ecotone. Proximity of the leaves to the camera may be reducing perceived openness. Openness is 6.07

Fig 10: Canopy photo at transect 4 quadrat 4, 4m. Shrubs and *P.australis* are present. Cloud cover may be reducing perceived openness. Openness is 1.5

Fig 11: Canopy photo at transect 4 quadrat 7, 2.6m. Mix of shrubs and *P.australis*. Openness is 8.98

APPENDIX B

TABLES

	Transects							
Quadrats	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2	SF	SF	SF	SF	SF	E	E	Pa
3	SF	SF	SF	SF	Pa	Pa	Pa	Pa
4	SF	SF	P	Pa	Pa	Pa	Pa	Pa
5	SF	SF	SF	Pa				
6	SF	SF	SF	Pa				
7	SF	SF	SF	E				
8	SF	SF						
9	SF	SF						
10	SF	SF						
11	Pa	Pa						
12	E	Pa						

Table 1. Tree dominated (SF), *P.australis* dominated (Pa), and ecotone (E) quadrats All Quadrat 1 sites were in the uplands and thus removed from the study.

Quadrats	Transects															
	T1		T2		T3		T4		T5		T6		T7		T8	
	Ramets	g/m	Ramets	g/m	Ramets	g/m	Ramets	g/m	Ramets	g/m	Ramets	g/m	Ramets	g/m	Ramets	g/m
Q1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q2	0	0	0	0	0	0	0	0	3	55	19	706	15	315	37	1058
Q3	0	0	0	0	2	10	0	0	100	3716	100	3716	47	987	38	1086
Q4	0	0	0	0	16	200	35	1773	40	1486	55	1486	88	1848	53	1515
Q5	0	0	0	0	0	0	45	1166								
Q6	0	0	0	0	0	0	46	1192								
Q7	0	0	0	0	9	171	26	132								
Q8	0	0	0	0												
Q9	0	0	0	0												
Q10	0	0	8	11												
Q11	39	636	60	1812												
Q12	25	500	92	2778												

Table 2: Total *P.australis* stems and biomass (g/m^2) by quadrat..

Species	*SF*	*Eco*	*P.a.*	*Wetland Indicator Status*	*Guild*	*Origin*
Acer saccharinum L.	X	X	X	FACW	WSVT	W
Acer saccharum Marshall.	X			FACU	WSVT	N
Arisaema triphyllum (L.) Schott	X			FACW-	MWU	N
Aster lateriflorus (L.) Britt.	X			FACW-	WM/MWU	N
Aster spp.	X					
Caltha palustris L	X		X	OBL	WM/MWU	N
Carex lavivaginata (Kükenth.) Mackenzie	X			OBL	MWU	N
Carex spp.	X					
Celtis occidentalis L.			X	FACU	WSVT	N
Circaea lutetiana L.	X			FACU	MWU	N
Claytonia virginaiam L.	X			FACU	WM/MWU	N
Cornus amomum Miller	X		X	FACW+	WSVT	N
Cornus sericea L.	X		X	FACW	WSVT	W
Cornus stolonifera Michx.	X			FACW	WSVT	N
Crategus coccinea L.	X			NL	WSVT	N
Crategus crus-galli L.	X		X	FAC	WSVT	N
Equisetum arvense L.	X			FAC	WM/MWU	N
Fagus grandifolia Ehrh.	X			FAC+	WSVT	N
Fraxinus americana L.	X			FACU	WSVT	N
Fraxinus nigra Marshall.	X			FACW+	WSVT	W
Fraxinus pennsylvanica var. *subintergerrina* (Vahl) Fern.	X			FACW	WSVT	N

Continued

Table 3. Herbaceous and Woody Species found in the swamp forest (SF), ecotone (Eco), and *Phragmites* stands (P.a.). Swamp forest is defined as fewer than 10 *P. australis* ramets/m^2. The *Phragmites* stand contains >30 ramets/m^2. The ecotone has 10-29 ramets of *P. australis*/m^2. Identification and Origins information follows Gleason and Cronquist (1991). For Origins, N=native to North America, I=introduced, W=widespread, origins uncertain. Wetland indicator status follows Reed (1988). OBL = Obligate wetland species which occur almost always (estimated probability >99%) under natural wetland conditions. FACW = Species that are usually found in wetlands (estimated probablility 67%-99%), but occasionally are found in uplands. FAC = Species which are equally likely to occur in wetlands or non-wetlands (estimated probability 67%-99%), FACU = Species that are usually found in uplands (estimated probablility 67%-99%), but occasionally are found in wetlands. NL= not listed in Reed (1988). Guilds are adapted from Galatowitch and van der Valk (1996). WM = wet meadow species, SDE = shallow and deep water species, SFA = submersed and floating aquatic species, MWU = moist wood understory species, and WSVT = woody shrub, vine, and tree species.

Table 3 continued

Geum rivale L.	X			OBL	WM/MWU	N
Glyceria striata (Lam.) Hitchc.	X			OBL	WM	N
Ilex verticillata (L.) A. Gray.	X	X	X	FACW+	WSVT	W
Impatiens capensis Meerb.	X	X	X	FACW	WM/MWU	N
Lemna minor L.		X	X	OBL	SFA	W
Lindera benzoin (L.) Blume	X	X	X	FACW-	WSVT	N
Maianthemum canadense Desf.	X			FAC	MWU	N
Nyssa sylvatica Marshall.	X			FAC	WSVT	W
Onoclea sensibilis L.	X			FACW	WM/MWU	W
Osmunda cinnamonea L.	X		X	FACW	MWU	W
Osmunda regalis L.	X		X	OBL	WM/MWU	W
Parthenocissus quinquefolia (L.)Planchon.	X	X	X	FAC-	WSVT	N
Phragmites australis (Cav.) Trin. ex Steud.	X	X	X	FACW+	SDE	W
Pilea pumila Gray	X			FACW	WM/MWU	N
Polygonum arifolium L.	X	X		OBL	WM	N
Polygonum punctatum Ell.	X			OBL	SDE	W
Quercus rubra L.	X			FACU	WSVT	N
Ranunculus hispidus Michx.		X		FAC	WM	N
Ranunculus spp.		X				
Ranunculus recurvatus Poir.	X			FACW	MWU	N
Rhamnus frugula L.	X			FAC+	WSVT	I
Rosa multiflora Thunb.			X	FACU	WSVT	I
Rosa palustris Marshall			X	OBL	WSVT	N
Sagittaria latifolia Willd.	X		X	OBL	SDE	W
Saururus cernuus L.	X			OBL	WM/MWU	N
Solanum dulcamara L.	X		X	FAC	WSVT	W
Spirodela polyrhiza (L.) Schleiden			X	OBL**	SFA	W
Symplocarpus foetidus (L.) Nutt.	X	X		OBL	MWU	N
Tilia americana L.	X			FACU	WSVT	W
Toxicodendron radicans (L.) Kuntze	X	X	X	FAC+	WSVT	W
Ulmus americana L.	X	X	X	FACW-	WSVT	N
Viburnum dentatum var. *lucidum* Aiton.	X	X		FAC	WSVT	I
Vitis riparia Michx	X			FACW+	WSVT	N
Total number of species = 55*	47	14	21			

* Only taxa identified to species are included.in calculations.
** Not listed in Reed but is clearly a floating species.

	P. australis Stands		*Ecotone Sotes*		*Swamp Forest*	
	#	%	#	%	#	%
Obligate wet;amd species (OBL)	6	29	3	23	10	22
Facultative wetland species (FACW)	9	43	6	46	18	40
Facultative species (FAC)	4	19	4	31	10	22
Facultative upland species (FACU)	2	9	0	0	6	14
Obligate upland species (OBLU)	0	0	0	0	0	0
Not Listed in Reed (1988) NL	0	0	0	0	1	2

Table 4. Distribution of wetland indicator designations among *P. australis*, ecotone, and swamp forest habitats.

	P. australis Stands		*Ecotone Sites*		*Swamp Forest*	
	#	%	#	%	#	%
WSVT (woody shrubs, vines & trees)	14	67	7	53	23	51
MWU (moist woods understory)	1	4	1	8	7	16
WM/MWU	3	15	1	8	10	22
WM (wet meadow)			2	15	2	4
SDE (shallow- and deep-water emergents)	2	10	1	8	3	7
SFA (submersed and floating-leaved species)	1	4	1	8		

Table 5. Distribution of wetland plant species guilds among *P. australis*, ecotone, and swamp forest habitats.

		P. australis stem density/m²		*P. australis biomass (g/m²)*	
		r^2%	p-value	r^2%	p-value
All Quadrats	Trees / $10m^2$	68.4	0	49.7	0.003
	2.6- or 4.0-m Openness	14.8	0.008	9.8	0.034
Swamp Forest	1.3-m Openness	0.04	0.888	0.97	0.632
	2.6-m Openness	37.42	0.001*	13.12	0.069**
P. australis Dominance	1.3-m Openess	25.01	0.025*	11.02	0.153
	2.6-m Openness	3.46	0.432	2.88	0.474

* = Significant at 0.05 ** = Significant at 0.10

Table 6. Regression analysis comparing *P. australis* dominance measures (stem density/m^2 and biomass/m^2) and tree dominance (number of trees/100-m^2, average tree circumference/100-m^2, total tree circumferance/100-m^2, and tree canopy openness. All relationships shown are negative except for 2.6-m or 4.0-m openness and 2.6-m openness compared to *P. australis* biomass, which are positive.

APPENDIX C
DATA

Transect	Quadrat	Height	Openness 1.3m	Openness 2.6m	Openness 4m	Live P.australis Biomass	Dead P.australis Biomass
1	1	1.3	5.82	4.88		0	0
1	2	1.3	5.92	5.78		0	0
1	3	1.3	5.7	5.51		0	0
1	4	1.3	5.57	5.32		0	0
1	5	1.3	4.46	5.05		0	0
1	6	1.3	5.17	5.73		0	0
1	7	1.3	6.93	6.68		0	0
1	8	1.3	7.36	6.84		0	0
1	9	1.3	6.88	6.62		0	0
1	10	1.3	6.47	5.92		0	0
1	11	1.3	4.83	7.34	8.58	130.4	505.3
1	12	1.3	5.82	6.95	3.85	80	420
2	1	1.3	6.78	6.64		0	0
2	2	1.3	5.98	5.8		0	0
2	3	1.3	4.57	5.15		0	0
2	4	1.3	4.77	4.87		0	0
2	5	1.3	6.16	5.88		0	0
2	6	1.3	5.21	5.01		0	0
2	7	1.3	7.01	6.16		0	0
2	8	1.3	5.24	5.37		0	0
2	9	1.3	6.39	6.26		0	0
2	10	1.3	6.61	9.55		9.331	1.333
2	11	1.3	5.85	4.51	5.56	604	1208
2	12	1.3	5.25	8.14	9.43	966.4	1812
3	1	1.3	4.11	15.13		0	0
3	2	1.3	6.19	5.85		0	0
3	3	1.3	7.65	7.23		0	10.2
3	4	1.3	9.07	7.94		87.5	112.5
3	5	1.3	8.04	6.43		0	0
3	6	1.3	5.15	3.38		0	0
3	7	1.3	4.71	7.53		95	76

Transect	Quadrat	Height	Openness 1.3m	Openness 2.6m	Openness 4m	Live P.australis Biomass	Dead P.australis Biomass
4	1	1.3	5.66	4.36		0	0
4	2	1.3	5.12	6.4		0	0
4	3	1.3	6.18	8.64		0	0
4	4	1.3	6.7	4.51	1.47	607.992	1165.318
4	5	1.3	5.67	5.15	3.82	699.732	466.488
4	6	1.3	6.43	6.43	10.28	544.236	647.9
4	7	1.3	6.37	8.97		107.1	25.5
5	1	1.3	6.69	7.27		0	0
5	2	1.3	8.22	9.1		54.999	0
5	3	1.3	5.97	4.47	5.58	1709.636	2006.964
5	4	1.3	6.87	9.22	10.33	743.32	743.32
6	1	1.3	6.32	6.22		0	0
6	2	1.3	6.65	13.76	4.04	408.826	297.328
6	3	1.3	4.8	10.66	9.97	1783.968	1932.632
6	4	1.3	8.53	6.21	12.25	321.328	1887.802
7	1	1.3	7.17	7.35		0	0
7	2	1.3	9.11	6.01		231	84
7	3	1.3	5.15	9.83	5.47	231	756
7	4	1.3	4.99	6.1	9.88	504	1344
8	1	1.3	5.87	6.16		0	0
8	2	1.3	9.95	16.16		543.4	514.8
8	3	1.3	5.54	6.05	9.21	1086.8	0
8	4	1.3	4.57	5.85	10.9	1201.2	314.6

Transect	Quadrat	Height	Live P.australis stems/m2	Dead P.australis stems/m2	Total P.australis stems/m2	Total P.australis Biomass
1	1	1.3	0	0	0	0
1	2	1.3	0	0	0	0
1	3	1.3	0	0	0	0
1	4	1.3	0	0	0	0
1	5	1.3	0	0	0	0
1	6	1.3	0	0	0	0
1	7	1.3	0	0	0	0
1	8	1.3	0	0	0	0
1	9	1.3	0	0	0	0
1	10	1.3	0	0	0	0
1	11	1.3	39	8	31	635.7
1	12	1.3	25	4	21	500
2	1	1.3	0	0	0	0
2	2	1.3	0	0	0	0
2	3	1.3	0	0	0	0
2	4	1.3	0	0	0	0
2	5	1.3	0	0	0	0
2	6	1.3	0	0	0	0
2	7	1.3	0	0	0	0
2	8	1.3	0	0	0	0
2	9	1.3	0	0	0	0
2	10	1.3	8	7	1	10.664
2	11	1.3	60	20	40	1812
2	12	1.3	92	32	60	2778.4
3	1	1.3	0	0	0	0
3	2	1.3	0	0	0	0
3	3	1.3	2	0	2	10.2
3	4	1.3	16	7	9	200
3	5	1.3	0	0	0	0
3	6	1.3	0	0	0	0
3	7	1.3	9	5	4	171
4	1	1.3	0	0	0	0
4	2	1.3	0	0	0	0
4	3	1.3	0	0	0	0
4	4	1.3	35	12	23	1773.31
4	5	1.3	45	27	18	1166.22
4	6	1.3	46	21	25	1192.136
4	7	1.3	26	21	5	132.6
5	1	1.3	0	0	0	0
5	2	1.3	3	3	0	54.999
5	3	1.3	100	46	54	3716.6
5	4	1.3	40	20	20	1486.64
6	1	1.3	0	0	0	0

Transect	Quadrat	Height	Live P.australis stems/m2	Dead P.australis stems/m2	Total P.australis stems/m2	Total P.australis Biomass
6	2	1.3	19	11	8	706.154
6	3	1.3	100	48	52	3716.6
6	4	1.3	55	8	47	2209.13
7	1	1.3	0	0	0	0
7	2	1.3	15	11	4	315
7	3	1.3	47	11	36	987
7	4	1.3	88	24	64	1848
8	1	1.3	0	0	0	0
8	2	1.3	37	19	18	1058.2
8	3	1.3	38	38	0	1086.8
8	4	1.3	53	42	11	1515.8

Herbaceous Species
Summer 8/02

Quadrat	Species	Common	Number of stems
T1Q1	Maianthemum canadense Desf.	Canadian Mayflower	1
T1Q2	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	2
	Lindera benzoin (L.) Blume	Spicebush seedling	1
T1Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	6
	Pilea pumila Gray	Clearweed	5
	Onoclea sensibilis L.	Sensitive Fern	4
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	1
T1Q4	Osmunda cinnamonea?	Cinnamon Fern	3
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	7
	Acer saccharinum	Maple saplings?	2
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
T1Q5	Osmunda regalis L.	Royal Fern	3
	Acer saccharinum	Maple saplings?	15
	Aster lateriflorus	Aster?	1
	Osmunda cinnamonea	Cinnamon Fern	2
	Carex lavi-vaginata (rosea)		19
T1Q6	Osmunda cinnamonea?	Cinnamon Fern	1
	Acer saccharinum	Maple saplings?	12
	Cornus stolonifera	Woody seedlings	2
	Maianthemum canadense Desf.	Canadian Mayflower	1
T1Q7	Osmunda cinnamonea	Cinnamon Fern	2
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	6
	Acer saccharinum	Maple saplings?	9
	Maianthemum canadense Desf.	Canadian Mayflower	2
	Impatiens capensis Meerb.	Spotted Jewelweed	1
T1Q8	Onoclea sensibilis L.	Sensitive Fern	1
	Acer saccharinum	Maple saplings?	3
	Rhamnus frugula L.		2
T1Q9	Osmunda cinnamonea	Cinnamon Fern	2
	Onoclea sensibilis L.	Sensitive Fern	1
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	1
T1Q10	Osmunda cinnamonea	Cinnamon Fern	2
	Acer saccharinum	Maple saplings?	13
	Maianthemum canadense Desf.	Canadian Mayflower	2
	Rhamnus frugula L.	Buckthorn	23
	Ilex verticillata L. (Gray)		13
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Pilea pumila Gray	Clearweed	1
	Solanum dulcamara	Bittersweet Nightshade	1
T1Q11	Osmunda regalis L.	Royal Fern	1
	Acer saccharinum	Maple saplings?	37

	Phragmites australis	Common reed	8
T1Q12	Phragmites australis	Common reed	4
	Ilex verticillata L. (Gray)		5
T2Q1	Viburnum acerifolium L.		1
T2Q2	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	5
	Onoclea sensibilis L.	Sensitive Fern	1
	Saururus cernuus L.	Lizard's Tail	2
	Equisetum arvense	Field Horsetail	2
	Glyceria striata	Fowl-Meadow Manna Grass	93
	Lindera benzoin (L.) Blume	Spicebush seedling	9
	Pilea pumila Gray	Clearweed	22
	Aster lateriflorus		1
T2Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	5
	Osmunda cinnamonea?	Cinnamon Fern	2
	Acer saccharinum	Maple saplings?	11
T2Q4	Maianthemum canadense Desf.	Canadian Mayflower	1
	Pilea pumila Gray	Clearweed	4
T2Q5	None		0
T2Q6	Osmunda cinnamonea?	Cinnamon Fern	3
	Impatiens capensis Meerb.	Spotted Jewelweed	1
	Acer saccharinum	Maple seedlings?	3
	Crategus crusgali		2
T2Q7	Pilea pumila Gray	Clearweed	1
	Acer saccharinum	Maple saplings?	28
T2Q8	Osmunda cinnamonea?	Cinnamon Fern	2
	Acer saccharinum	Maple saplings?	9
	Crategus coccinea		6
	Maianthemum canadense Desf.	Canadian Mayflower	4
	Polygonum arifolium L.	Tearthumb	1
	Carex (rosea)		2
T2Q9	None		0
T2Q10	Phragmites australis	Common reed	7
	Vitis riparia	River Grapevine	1
	Acer saccharinum	Maple saplings?	8
	Carex lavi-vaginata (rosea)		37
T2Q11	Phragmites australis	Common reed	20
	Osmunda regalis L.	Royal Fern	1
	Acer saccharinum	Maple saplings?	2
T2Q12	Phragmites australis	Common reed	32
	Ilex verticillata L. (Gray)		1
T3Q1	Toxicodendron radicans (L.) Kuntze	Poison Ivy	13
	Equisetum arvense	Field Horsetail	6
	Cornus stolonifera		7
	Viburnum spp. (recognitum/dentatum)		2
	Acer spp.	Maple saplings?	5
	Rosa multiflora Murray	Mulitflora rose	3

T3Q2	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Fraxinus pennsylvanica var. integerrima	Green Ash	1
T3Q3	Impatiens capensis Meerb.	Spotted Jewelweed	8
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	2
	Pilea pumila Gray	Clearweed	5
	Phragmites australis	Common reed	2
	Cornus stolonifera		1
	Glyceria striata	Fowl-Meadow Manna Grass	176
T3Q4	Impatiens capensis Meerb.	Spotted Jewelweed	30
	Phragmites australis	Common reed	7
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	3
	Polygonum arifolium L.	Tearthumb	1
	Toxicodendron radicans (L.) Kuntze	Poison Ivy	1
	Ranunculus hispidis		1
	Acer spp.	Maple saplings?	1
	Lindera benzoin (L.) Blume	Spicebush seedling	1
T3Q5	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	3
	Viburnum molle Michx.		1
T3Q6	Osmunda regalis L.	Royal Fern	3
	Osmunda cinnamonea?	Cinnamon Fern	1
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Caltha palustris L	Marsh Marigold	5
	Impatiens capensis Meerb.	Spotted Jewelweed	1
T3Q7	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Impatiens capensis Meerb.	Spotted Jewelweed	4
	Osmunda regalis L.	Royal Fern	4
	Acer spp.	Maple saplings?	8
	Pilea pumila Gray	Clearweed	1
	Claytonia virginaiam L.		3
	Phragmites australis	Common reed	5
T4Q1	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	9
	Onoclea sensibilis L.	Sensitive Fern	11
	Rosa multiflora Murray	Mulitflora rose	1
T4Q2	Equisetum arvense	Field Horsetail	10
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	4
	Circea lutetiana	Enchanter's Nightshade	6
	Claytonia virginaiam L.		1
	Lindera benzoin (L.) Blume	Spicebush seedling	2
T4Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	3
	Circaea lutetiana L.	Enchanter's Nightshade	34
	Equisetum arvense	Field Horsetail	19
	Geum rivale L.	Water Avens	8
	Ranunculus recurvatus Poir.		4
	Arisaema triphyllum (L.) Schott	Jack-in-the-Pulpit	1
	Acer spp.	Maple saplings?	1

	Polygonum punctatum		
T4Q4	Phragmites australis	Common reed	12
	Impatiens capensis Meerb.	Spotted Jewelweed	4
	Caltha palustris L		8
	Solanum dulcamara	Bittersweet Nightshade	1
	Phragmites australis		27
	Osmunda cinnamonea?	Cinnamon Fern	3
T4Q5	Phragmites australis	Common reed	21
T4Q6	Impatiens capensis Meerb.	Spotted Jewelweed	1
	Phragmites australis	Common reed	21
	Ranunculus spp. (celeratus)		17
T4Q7	Cornus stolonifera		11
	Viburnum acerifolium L.	Maple-leaved viburnum	4
T5Q1	Onoclea sensibilis L.	Sensitive Fern	3
	Impatiens capensis Meerb.	Spotted Jewelweed	5
T5Q2	Phragmites australis	Common reed	3
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	8
	Sagittaria latifolia	Broad-leaved Arrowhead	1
	Phragmites australis	Common reed	46
T5Q3	Caltha palustris		15
	Crategus crusgali		11
	Osmunda regalis		14
T5Q4	Impatiens capensis Meerb.	Spotted Jewelweed	3
	Acer spp.	Maple saplings?	1
	Phragmites australis	Common reed	20
T6Q1	none		
T6Q2	Solanum dulcamara	Bittersweet Nightshade	2
	Sagittaria latifolia	Broad-leaved Arrowhead	1
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper	1
	Phragmites australis	Common reed	11
T6Q3	Phragmites australis	Common reed	48
	Impatiens capensis Meerb.	Spotted Jewelweed	1
T6Q4	Phragmites australis		8
T7Q1	none		
T7Q2	Phragmites australis	Common reed	11
	Phragmites australis	Common reed	4
	Impatiens capensis Meerb.	Spotted Jewelweed	1
T7Q3	Phragmites australis	Common reed	11
	Phragmites australis	Common reed	36
T7Q4	Phragmites australis	Common reed	24
	Phragmites australis	Common reed	64
T8Q1	Crategus crusgali		3
T8Q2	Impatiens capensis Meerb.	Spotted Jewelweed	4
	Phragmites australis	Common reed	19
	Phragmites australis	Common reed	18
T8Q3	Phragmites australis	Common reed	38

	Phragmites australis	Common reed	
T8Q4	Phragmites australis	Common reed	42
	Phragmites australis	Common reed	11

Fall 10/02 Herbaceous Species

Quadrat	Species	Commom	Number
T1Q1	None		
T1Q2	None		
T1Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	3
	Pilea pumila	Clearweed	2
	Onoclea sensibilis	Sensitive Fern	2
	shrubby saping, 3 lanceolate leaves		1
T1Q4	Parthenocissus quinquefolia	Virginia creeper	1
T1Q5		aster?	1
	Carex lavi-vaginata (rosea)		20
		Moss	20%
T1Q6	Carex		4
	rosette species		1
	Woody sapling		2
		Moss	30%
		Fragile fern	2
	Ranunculus?		20
T1Q7	Osmunda cinnamonea	Cinnamon fern	1
	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	4
		Moss	25%
T1Q8	seedling w/ one leaf		1
T1Q9	Osmunda cinnamonea	Cinnamon fern	1
		seedling like Q8	
	Parthenocissus quinquefolia	Virginia Creeper	1
		Moss	5%
T1Q10		Fragile fern	7
		Maple sapling	4
		shrubby seedling	1
		seedlings	10
		woody seedling	1
		voucher	6
		Maple sapling	15
T1Q11	Phragmites australis	Commom reed	10 live
	Phragmites australis	Commom reed	18 dead
T1Q12	Phragmites australis	Commom reed	18 dead
	Pilea pumila	Clearweed	1
T2Q1	fuzzy trilobed		1
T2Q2	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	12
	Onoclea sensibilis	Sensitive Fern	2
	Saururus cernuus L.	Lizard's Tail	2
	Glyceria striata	Fowl-Meadow Manna grass	30
	lanceolate serrate possinly Avens		1
	fuzzy hearbaceous species(voucher)		3

		wispy barnyard grass	30	
		Aster	1	
		basal rosette of leaves T1Q6		
T2Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	6	
T2Q4	None			
T2Q5	Carex	larger than rosea	13	
	fuzzy leaved; possibly shruby		4	
T2Q6	Osmunda cinnomonea	Cinnamon fern	2	
		Aster	1	
	Osmunda regalis	Royal fern	1	
T2Q7		Fragile fern	2	
	Carex (rosea)		14	
		Moss	35%	
T2Q8	None			
T2Q9	Carex		3	
T2Q10	Phragmites australis	Commom reed	2	live
	Phragmites australis	Commom reed	0	dead
	Carex		76	
T2Q11	Phragmites australis	Commom reed	26	live
	Phragmites australis	Commom reed	76	dead
T2Q12	Phragmites australis	Commom reed	15	live
	Phragmites australis	Commom reed	8	dead
T3Q1		saplings	8	
		Goosberry?	5	
Quadrat	Species	Commom	Number	Notes
		Aster	5	
T3Q2	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1	
		Cornus sapling	2	
T3Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	7	
	Pilea pumila	Clearweed	1	
	Phragmites australis	Commom reed	1	live
	Phragmites australis	Commom reed	3	dead
	Glyceria striata	Fowl-Meadow Manna grass	251	
T3Q4	Phragmites australis	Commom reed	12	dead
	Symplocarpus foetidus (L.) Nutt.	skunk cabbage	22	
		Cornus seedling	5	
T3Q5		Cornus seedling	4	
	Rosa multiflora	Multiflora rose	1	
	Symplocarpus foetidus (L.) Nutt.	skunk cabbage	24	
T3Q6	Phragmites australis		1	live
	Osmunda cinnamonea	Cinnamon fern	2	dead
	Symplocarpus foetidus (L.) Nutt.	skunk cabbage	5	
	Impatiens capensis	spotted jewelweed	1	
		Moss	20%	
		Cornus sapling	1	
T3Q7	Impatiens capensis Meerb.	Spotted Jewelweed	2	

	Viburnum		1
		Cornus	1
		Aster	2
	Phragmites australis	Commom reed	1 live
	Phragmites australis	Commom reed	7 dead
T4Q1	Rosa multiflora Murray	Mulitflora rose	1
T4Q2	None		
T4Q3	Symplocarpus foetidus (L.) Nutt.	Skunk Cabbage	1
	Equisetum arvense	Field Horsetail	2
	Geum rivale L.	Water Avens	3
	unidentified Z		7
	Unidentified Y		6
T4Q4	Phragmites australis	Commom reed	10 live
	Phragmites australis	Commom reed	23 dead
	Osmunda regalis	Royal Fern	2
	unidentified		2
	Solanum dulcamara	Bittersweet Nightshade	1
T4Q5	Phragmites australis	Commom reed	10 live
	Phragmites australis	Commom reed	18 dead
		Lemna	5%
T4Q6	Phragmites australis	Commom reed	10 live
	Phragmites australis	Commom reed	47 dead
T4Q7	Phragmites australis	Commom reed	8 live
	Phragmites australis	Commom reed	2 dead
	Ranunculus?		13
	Lemna minor		100%
T5Q1	none		
T5Q2	Onoclea sensibilis L.	Sensitive Fern	2
	Impatiens capensis Meerb.	Spotted Jewelweed	1
	Phragmites australis	Commom reed	3 live
	Phragmites australis	Commom reed	2 dead
		sapling from t1Q10	1
T5Q3	Sagittaria latifolia	Broad-leaved Arrowhead	1
	Phragmites australis	Commom reed	27 live
	Phragmites australis	Commom reed	28 dead
		voucher	3
T5Q4	Lemna minor	Lessor duckweed	sparse
		voucher T5Q3	2
	Phragmites australis	Commom reed	12 live
	Phragmites australis	Commom reed	14 dead
T6Q1	none		
T6Q2	Sagittaria latifolia	Broad-leaved Arrowhead	2
	Phragmites australis	Commom reed	11 live
	Phragmites australis	Commom reed	14 dead
	Lemna minor	Lessor duckweed	sparse
T6Q3	Phragmites australis	Commom reed	32 live;

	Phragmites australis	Commom reed	44 dead
	Lemna minor	Lessor duckweed	90%
T6Q4	Phragmites australis	Commom reed	8 live
	Phragmites australis	Commom reed	49 dead
	Lemna minor	Lessor duckweed	90%
T7Q1	none		
T7Q2	Phragmites australis	Commom reed	10 live
	Phragmites australis	Commom reed	5 dead
T7Q3	Phragmites australis	Commom reed	8 live
	Phragmites australis	Commom reed	43 dead
T7Q4	Phragmites australis	Commom reed	30 live
	Phragmites australis	Commom reed	32 dead
T8Q1	none		
T8Q2	Phragmites australis	Commom reed	16 live
	Phragmites australis	Commom reed	8 dead
T8Q3	Phragmites australis	Commom reed	24 live
	Phragmites australis	Commom reed	4 dead
T8Q4	Phragmites australis	Commom reed	25 live
	Phragmites australis	Commom reed	26 dead

Shrubs, Aug. 02

Quadrat	Latin name	Common name
T1Q1	Acer saccharum Marshall.	Sugar maple
	Rosa multiflora Thunb.	Multiflora Rose
	Fraxinus americana L.	White Ash
T1Q4	Parthenocissus quinquefolia (L.) Planchon.	Virgina Creeper
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Nyssa sylvatica Marshall.	Black gum
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
T1Q7	Acer saccharinum L.	Silver Maple
T1Q10	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Cornus amomum Miller	Silky Dogwood
	Ilex verticillata (L.) A. Gray.	Winter holly
		Voucher 13
T1Q12	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Parthenocissus quinquefolia (L.) Planchon.	Virginia creeper
	Solanum dulcamara L.	Bittersweet Nightshade
T2Q12	Ilex verticillata (L.) A. Gray.	Winter holly
	Rosa multiflora Thunb.	Multiflora Rose
	Cornus amomum Miller	Silky Dogwood
T2Q10	Viburnum dentatum var. lucidum Aiton.	Arrowwood
T2Q7	Ulmus americana L.	Elm?
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Acer saccharum Marshall.	Sugar Maple
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Acer saccharinum L.	Silver Maple
T2Q4	Ulmus americana L.	Elm?
		Alder?/Voucher 16
	Lindera benzoin (L.) Blume.	Spicebush
	Parthenocissus quinquefolia (L.) Planchon.	Virginia creeper
	Tilia americana L.	Basswood
		Elm?/16
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
T2Q1	Acer saccharum Marshall.	Sugar Maple
Quadrat	Latin name	Common name
	Populus deltoides Marshall.	Cottonwood
T3Q4	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Ulmus americana L.	American Elm
T3Q7	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Solanum dulcamara L.	Bittersweet Nightshade
		Voucher 19
T4Q1	Ulmus americana L.	Elm?
	Tulipa sylvestris L.	Tulip
	Lindera benzoin (L.) Blume.	Spicebush
	Rosa multiflora Thunb.	Multiflora Rose

	Lonicera japonica Thunb.	Japenese honeysuckle
	Fraxinus spp. L.	Ash
T4Q2	Lindera benzoin (L.) Blume.	Spicebush
	Cornus sericea L.	Red-osier Dogwood
	Fraxinus spp. L.	Ash (Voucher 2)
	Fagus grandifolia Ehrh.	Beech
T4Q4	Toxicodendron radicans (L.) Kuntze	Poison ivy
	Solanum dulcamara L.	Bittersweet Nightshade
	Cornus sericea L.	Red-osier Dogwood
	Celtis occidentalis L.	N. Hackberry
		Cornus
T4Q6	Solanum dulcamara L.	Bittersweet Nightshade
T5Q1	Ulmus americana L.	Elm?/Voucher 5
	Viburnum dentatum var. lucidum Aiton.	Arrowwood
	Nyssa sylvatica Marshall.	Black Gum
		Hickory /oddly pinnate voucher 8
T5Q4	Rosa palustris Marshall.	Swamp Rose
	Lindera benzoin (L.) Blume.	Spicebush
	Acer saccharinum L.	Silver Maple
	Cornus sericea L.	Red-osier Dogwood
T6Q1	Acer saccharum Marshall.	Sugar Maple
T6Q4	Solanum dulcamara L.	Bittersweet Nightshade
	Celtis occidentalis L.	Blueberry tree (Hackberry)
	Ulmus americana L.	Elm
	Parthenocissus quinquefolia (L.) Planchon.	Virginia Creeper
Quadrat	Latin name	Common name
T7 Q1	Acer saccharum Marshall.	Sugar Maple
T7Q4		N/A
T8Q1	Ulmus americana L.	Elm?
	Acer saccharum Marshall.	Sugar Maple
T8Q4		N/A

Trees

Quadrats	Latin Name	Common name	Quantity
T8Q1	Acer saccharum Marshall.	Sugar Maple	13
T1Q1	Acer saccharum Marshall.	Maple	6
		Voucher 5	4
	Ulmus americana L.	Elm?	3
T1Q4	Fraxinus nigra Marshall.	Black Ash	5
	Fagus grandifolia Ehrh.	Beeech	2
T1Q7	Acer saccharinum L.	Silver Maple	13
T1Q10	Acer saccharinum L.	Silver Maple	6
	Fraxinus spp. L.	Ash?	3
T1Q12	Acer saccharinum L.	Maple	4
T2Q12	Acer saccharum Marshall.	Sugar Maple/Voucher 14	1
	Acer saccharinum L.	Silver Maple	3
T2Q10	Acer saccharum Marshall.	Sugar Maple	4
T2Q7	Ulmus americana L.	Elm?	5
	Acer saccharum Marshall.	Sugar Maple	8
	Acer saccharinum L.	Silver Maple	1
T2Q4	Ulmus americana L.	American Elm	6
	Acer saccharinum L.	Silver Maple	4
	Quercus rubra L.	Red Oak	1
	Acer saccharum Marshall.	Sugar Maple	1
	Tilia americana L.	Basswood	3
T2Q1	Acer saccharum Marshall.	Sugar Maple	8
T3Q4		Voucher 18	4
	Fraxinus spp. L.	Ash	5
		Voucher 8	1
T3Q7		No trees	
T4Q1	Ulmus americana L.	Elm?	9
	Tulipa sylvestris L.	Tulip	1
T4Q2	Fraxinus spp.	Ash (Voucher 2)	2
	Fraxinus americana L.	White Ash	1
T4Q4	Acer saccharinum L.	Silver Maple	2
	Fraxinus spp. L.	Ash	2
Quadrats	Latin Name	Common name	Quantity
	Acer saccharum Marshall.	Sugar Maple	2
T4Q6		No trees	
T5Q1	Quercus rubra L.	Red Oak	1
		Voucher 5/Elm?	3
	Acer saccharum Marshall.	Sugar Maple	1
T5Q4	Acer saccharinum L.	Silver Maple	1
T6Q1	Acer saccharum Marshall.	Sugar Maple	4
	Quercus rubra L.	Red Oak	2
		Voucher 11	1
		Voucher 5	2

T6Q4		No trees	
T7Q1	Acer saccharum Marshall.	Sugar Maple	10
	Tilia americana L.	Basswood	4
		Voucher 1	2
		Voucher 2	2
	Quercus rubra L.	Red Oak	1
	Viburnum lentago L.		3
	Tilia americana L.	Basswood	4
	Fraxinus spp. L.	Ash	1