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Vegetation of the Ulao Swamp, A Disturbed Hardwood-Conifer Swamp in Southeastern Wisconsin

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Abstract: Ulao Swamp (Grafton, Wisconsin) is a 185-hectare wetland, which was a confer/hardwood swamp before European settlement. Post-settlement disturbances include logging, drainage, flooding, cultivation, grazing, non-metallic mining, and development in the watershed. As a result of these disturbances, very little of the presettlement-type mixed hardwood and cedar/tamarack conifer swamp vegetation currently remains in the wetland. Historically the northern quarter of the wetland had surface drainage to the north, and the southern three-quarters drained to the south. Between 1980 and 1985 a north-south ditch was constructed causing water from the northern quarter of the wetland to drain southward, dramatically increasing water levels in the central portions of the wetland. This dramatic increase in water levels has caused high mortality of the hardwood trees that were established in the central and southern portions of the swamp. Severe flooding continues in some portions of the wetland.

During the 2000 and 2001 field seasons, the vegetation of the Ulao Swamp was quantitatively sampled to describe current conditions and serve as baseline data for evaluating future change in the vegetation. Using ordination and classification analysis, six vegetation cover types were recognized in the swamp: cattail marsh, reed canary grass, sedge/shrub, flooded maple forest, open ash forest, and closed ash forest. The distribution of these six types was mapped, and their species composition was described.

The closed ash forest vegetation type was found to most resemble the likely pre-flooding plant community of those portions of the Ulao Swamp that are at slightly higher elevations. The lower elevations of the swamp now have cattail marsh, sedge/shrub, and flooded maple forest vegetation types, and these were dominated by silver maple forest, rather than green and black ash, before they were flooded. The flooded maple forest, sedge/shrub, and cattail vegetation types appear to have been the most severely affected by flooding, with the sedge/shrub and cattail communities having been flooded for sufficiently long to have nearly lost their forest canopies. The presence and densities of standing dead trees and tree stumps, and analysis of aerial photographs, indicates that nearly all of the Ulao Swamp was a closed canopy swamp forest before flooding began in the early 1980's.

We conclude that restoration of a native swamp forest community to the Ulao Swamp would be greatly hastened by closure of the ditch that breaches the drainage divide in the northern portions of the swamp.

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INTRODUCTION

Lying just north of the tension zone (Curtis 1959), Ulao Swamp is placed in the northern hardwoods floristic province. Original land surveys conducted between 1835 and 1836 showed that the presettlement upland vegetation of Ozaukee County, Wisconsin was almost entirely beech/maple forest, and the wetlands were predominately a combination of hardwood and conifer swamp forest (United States Public Land Survey 1836, Finley 1976, SEWRPC 1997). Lowland hardwood forests consisting of black ash *(Fraxinus nigra)*, green ash *(Fraxinus pennsylvanica)*, American elm *(Ulmus americana)*, willow species *(Salix spp.)*, red maple *(Acer rubrum)*, and silver maple *(Acer saccharinum)* were found throughout southeastern Wisconsin. Conifer swamps, characterized by white cedar *(Thuja occidentalis)* and tamarack *(Larix laricina)* in addition to the swamp hardwoods, were concentrated in Ozaukee and Washington counties.

Curtis (1959) treated these conifer swamps in southern Wisconsin as relic outliers of the northern Wisconsin forest, and did not include them in his statewide study of homogeneous stands. Previous studies of the vegetation of mixed conifer and hardwood swamps in southeastern Wisconsin have described river flood plains and mesic sites (Dietz 1950, Ware 1955), disturbance in bog communities (Farley 1974, Luebke 1976), a conifer swamp (Reinartz 1985, 1986), and identification and inventory of natural areas (Brumm 1977, Swartz 1977). Only a small number of conifer swamps remain in southeastern Wisconsin; most of this vegetation type has been lost to disturbance.

Descriptions of vegetation provide baseline data that allow long-term field studies of community composition and dynamics, both of which remain poorly understood. The initial baseline description provides a static view of plant community composition and structure; follow-up studies indicate the direction and amount of change in the community over an ecological time scale. Descriptions of vegetation can also be used to compare altered communities with relatively undisturbed reference sites (Brinson and Rheinhardt 1996; Brown 1999; Ehrenfeld 1983; Kentula, et. al.1993; Rheinhardt, et. al. 1999; and White and Walker 1997). Within the past 20 years, large portions of the Ulao Swamp have been severely disturbed by flooding as the result of a ditch constructed between 1980 and 1985 (SEWRPC Aerial Photos). Description of the current condition of vegetation in the swamp, 1) will document the plant communities that have resulted from this flooding, 2) will allow prediction of succession in plant communities in response to this flooding, and 3) will be important information in the event that a restoration of the pre-ditch hydrology and vegetation is planned.

This study describes the vegetation and some aspects of the physical environment of Ulao Swamp, a disturbed wetland located in Grafton, Wisconsin. The objectives of this study were to: 1) assemble information from historical records on the vegetation characteristics of Ulao Swamp over time, 2) describe the condition and composition of the existing vegetation, 3) develop a flora of the swamp, 4) provide a description of the woody sapling and seedling composition to enable a crude prediction of the course of succession, 5) identify the presence, location, and density of invasive species to provide data useful for management, and 6) create a baseline Geographic Information System (GIS) for the swamp and surrounding watershed. This information will be useful to current efforts to plan the restoration of swamp forest in the wetland.

DESCRIPTION OF THE STUDY SITE

Ulao Swamp is located in Ozaukee County, Wisconsin, 2 km (1.26 miles) southwest of Port Washington and a little more than 1 km (0.63 miles) west of the Lake Michigan shoreline (43° 21' N. 87° 56' W.). The 185-hectare (457 acre) wetland is primarily privately owned with parcels ranging from 1.2 to 32.4 hectares (3 to 80 acres) in size. The shape of Ulao Swamp is long and narrow, averaging 0.42 km (0.26 miles) in width and approximately 3.18 km (2 miles) in length. The wetland boundaries were defined to reflect the approximate limits of jurisdictional wetland (Fig. 1).

Ulao Swamp may occupy the site of a narrow glacial outwash plain, formed 12,000 to 16,000 years ago by stalled glacial action (Mickelson and Syverson 1997). The local water table is very near the soil surface at 211 to 215 m (692 to 705 feet) above sea level in this relatively flat lowland forest (Fig. 2). The wetland receives substantial groundwater discharge, which is evidenced by numerous springs along the western boundary. In addition to evapotranspiration, hydrologic outflows include groundwater recharge in the eastern and most northern portions of the swamp, as well as nearly permanent surface outflow from a ditch that flows from the south end of the swamp (BRAA 1998, Northern Environmental Technologies 1997) (Fig. 5). Soils of Ulao Swamp include the very poorly drained organic substrate of the Houghton-Adrian-Palms-Ogden association (Parker, et. al.1970) (Fig. 3).

Since Ulao Swamp extends across section lines, it was described and mapped in the original land surveyor notes (Burt 1835). In 1835, the wetland vegetation was recorded as a mixture of black ash, American beech (*Fagus grandifolia*), white cedar, birch (*Betula spp.)*, tamarack, and white ash (*Fraxinus americana*). According to Curtis (1959), these forest types are slowly invaded by white cedar, which once established, prevents further regeneration of shade intolerant species. Gradually, the forest becomes dominated by white cedar, almost to the total exclusion of all other species. The upland forest surrounding Ulao Swamp consisted of American beech, sugar maple (*Acer saccharum*), white ash, birch, bur oak (*Quercus macrocarpa*), shagbark hickory (*Carya ovata*), American elm, and ironwood (*Carpinus caroliniana*).

Since the Government Land Survey nearly 170 years ago, the Ulao Swamp vegetation has been converted to a mosaic of degraded hardwood swamp (snags and damaged trees) and herbaceous marsh (cattail, grasses, and sedge). Active and fallow agricultural fields, commercial development, and private homes have largely replaced the presettlement beech-maple forest surrounding the swamp.

METHODS

We established 82 sampling units at intervals of 100 m along 16 east-west transects across Ulao Swamp (Fig. 4). Fourteen transects were at a fixed distance (20 m) north or south of quarter section lines in order to utilize property boundaries as references for relocation of the transects, but to avoid the disturbance often associated with immediate property boundaries. Two transects were placed in the center of longer east-west exten-

FIG. 1. Location and boundaries of the Ulao Swamp, Ozaukee County, Wisconsin

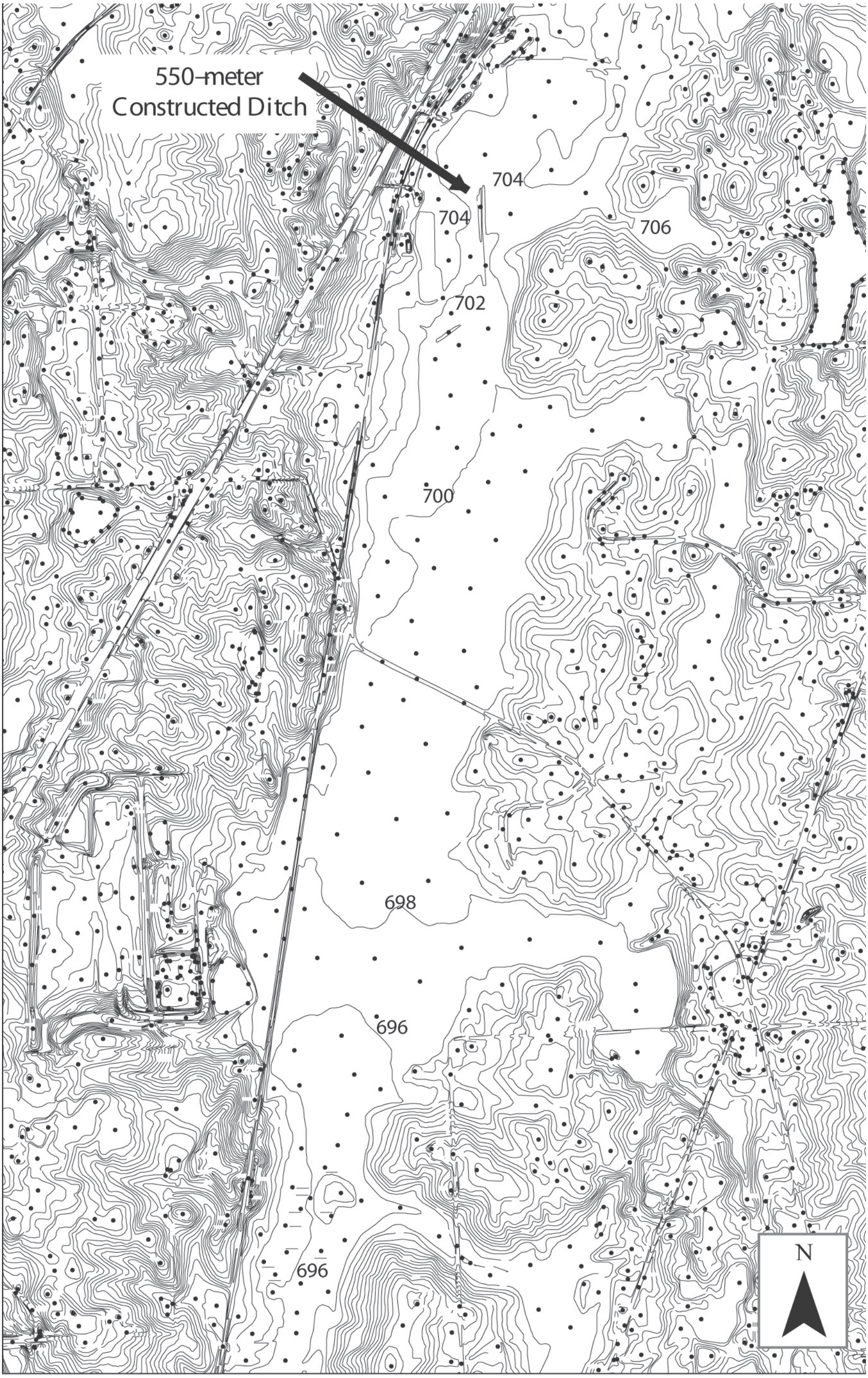


FIG. 2. Topography (2 foot contours) of Ulao Swamp.

sions of the swamp (Fig. 4). No sampling was conducted in approximately 30 hectares of the northwest portion of the wetland, where we were refused access (Fig. 8), however, the 1990 Wisconsin Department of Natural Resources Managed Forest Law Management Plan for that area was located to provide a description of the vegetation. Transects were established by using a compass, while sampling unit spacing was set using a disposable string distance measurer. A 10-foot section of 1.5-inch diameter PVC pipe was used to mark the center of each sampling unit. A Garmin 12XL@ global positioning system (GPS) was used to record the UTM coordinates of 21 sampling units, from which all remaining units can be easily relocated.

Vegetation sampling was conducted between 5 June and 4 August 2001. Since the vegetation could only be sampled once during the growing season in this study, the transects were sampled according to a schedule that minimized any spatial bias associated with change in cover or ability to identify early and late blooming herbaceous species over the growing season.

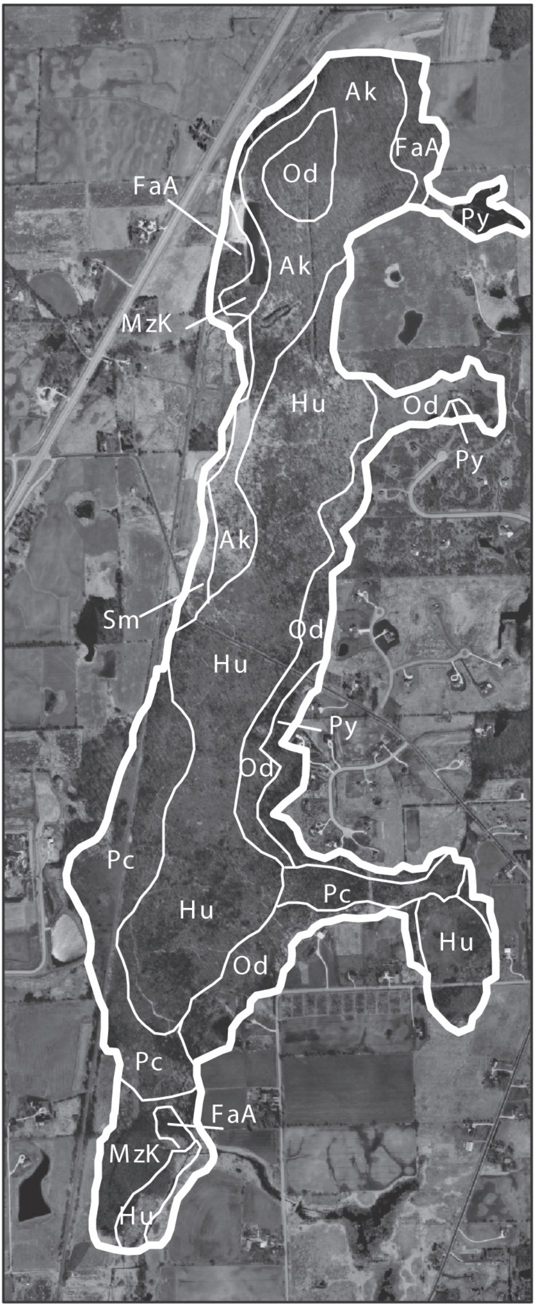
A 100 m^2 circular quadrat was centered at each sampling unit (Hapner Hewitt 2002). Within these 100 m^2 circular quadrats, the species, condition (A = undamaged, > half the tree crown intact; B = damaged, < half the tree crown intact; C = dead), and diameter at breast height (DBH) of all trees of at least 2.5 cm DBH was recorded. Trees with DBH between 2.5 cm and 10 cm are traditionally placed in the sapling size class. However, we collected a large amount of data on saplings to predict succession in the Ulao Swamp. The number of stumps with diameters of 30 cm or greater was also recorded in this 100 m^2 quadrat.

A 10 m line-intercept shrub sample line was centered in the 11.3 m diameter, large circular quadrat and oriented in a cardinal east-west direction. We recorded the aerial intercept of each species of shrub along this 10 m line to provide a direct estimate of shrub and woody vine cover.

To record the presence, abundance, and density of tree seedlings and estimate the cover of herbaceous plants, we placed square, 0.25 m^2 quadrats at the eastern and western perimeters of the 100 m^2 quadrats. Cover of each herbaceous plant species was recorded on the following scale: 0 = absent, 1 = 0 to 5%, 2 = 5 to 25%, 3 = 26 to 50%, 4 = 51 to 75%, 5 = 76 to 100%. Cover data was converted to the cover class midpoint (i.e., 2.5, 15, 38, 66, 88) for analysis. Tree and shrub seedlings (DBH < 2.5 cm) were identified to species and counted in these 0.25 m^2 quadrats (Hapner Hewitt 2002).

Identification of the cattails *(Typha latifolia, T. angustifolia*, and *T. x glauca)* to species was difficult because they have similar appearances in the field and often grow together. The cover of all cattail was recorded as one taxonomic group (*Typha spp.*). Likewise, due to extreme hybridization, all hawthorn species were recorded as *Crataegus spp.* Dead ash, maple, and elm were only identified to genus and assigned three separate species numbers due to the difficulty of distinguishing between congeneric species when the trees are dead. Cover of duckweed *(Lemna minor)* (a non-rooted vascular plant) was estimated according to the methods used for rooted herbs, but was counted as open space when estimating area not covered by herbaceous plants, from which total herbaceous cover was calculated.

Standard summaries of the vegetation were calculated using ArcView 3.2™. Tree and sapling species importance values (IV) were calculated by totaling relative dominance (as ex-



Ak – Adrian Mucky Peat
FaA – Fabius Loam
Hu – Houghton Mucky Peat
MzK – Mussey Loam
Od – Ogden Mucky Peat
Pc – Palms Mucky Peat
Py – Poygan Silty Clay Loam
Sm – Sebewa Silt Loam

FIG. 3. Soils of Ulao Swamp. Modified from Parker, Kurer, and Steingraeber, 1970.

FIG. 4. Location of 82 vegetation sample units in Ulao Swamp classified by TWINSPAN vegetation types.

pressed by basal area), relative density, and relative frequency. Using the methods described by Host et al. (1993) and Kirkman et al. (2000), an importance percentage (IP) of each herbaceous species was calculated by multiplying the mean cover of that species by its frequency.

A flora of the swamp was compiled by recording all species encountered during fieldwork regardless of whether or not they were found in a sample unit (App. D). Nomenclature followed Gleason and Cronquist (1991). Voucher specimens were deposited in the University of Wisconsin-Milwaukee Field Station Herbarium.

We recorded densiometer readings at three locations in each sampling unit to estimate total tree canopy cover. Only cover of the tree canopy was estimated using the densiometer. We also recorded maximum surface water depth in each 100 m^2 quadrat to the nearest centimeter and surface water pH was measured at five locations throughout the swamp. Aerial photographs captured in 1937, 1956, 1963, 1967, 1970, 1975, 1980, 1985, 1990, 1995, and 2000 were compared to note large scale changes in the wetland vegetation over time.

Two more recent natural area assessments have also been conducted in the study site (Brumm 1977, SEWRPC 1997). Quantitative tree data collected in approximately eight hectares during 1976 (Brumm 1977) were compared with our 2001 tree data collected in the same area of Ulao Swamp (Hapner Hewitt 2002) (Fig. 5).

DATA ANALYSIS

We used two-way indicator species analysis (TWINSPAN), a divisive classification technique (Hill 1979b), to determine similar assemblages of plant species. TWINSPAN default settings (5 pseudospecies cut levels, % coverage, maximum number of individuals per division = 5, maximum level of divisions = 6, minimum size of group divided = 5) were used. Detrended correspondence analysis (DECORANA, Hill 1979a) was used to ordinate the data from the original 82 sampling units and to group the samples by the similarity of their vegetation. The analysis was run on the default setting (26 segments, no down-weighting rare species, axes rescaled four times). The first and second axes of the DECORANA ordinations of species in quadrat space (to explore relationships among species based on their co-occurrences in the samples) and quadrats in species space (to examine relationships between vegetation sample units based on plant species composition) were graphed.

Thirty-two species were included in the TWINSPAN and DECORANA analysis; trees with an IV of greater than 7.0, shrubs with a minimum frequency of 0.1, and herbs with an IP of 0.9 and higher (Table 2). Relative tree basal area, shrub percent cover, and herbaceous percent cover values were used for the analysis. Tree basal area was converted to a relative scale of 0-100 by dividing 100 by the maximum total basal area measured for a single species in the 82 sampling quadrats and then multiplying that constant by the total basal area of each species in each quadrat. This method converted tree basal areas to a scale of 0-100 to enable their inclusion in the multivariate analysis along with the shrub and herbaceous percent cover data.

The 82 sampling units were classified and mapped according to the six TWINSPAN and DECORANA groups. Using the TWINSPAN-derived classification of vegetation types and visual interpretation of black and white 1:2,400 scale orthophotographs captured in spring, 2000 (SEWRPC, 2000), the boundaries of vegetation types in the Ulao

Swamp were mapped. The 30 hectare area in the northwestern part of the swamp that we were unable to sample was mapped according to information from the orthophotographs and the WDNR MFL plan for the area. Harvested Forest (1% of study site area) was added as a vegetation type for the newly cleared portion of the northern swamp, and Wet Meadow and Reed Canary Grass (*Phalaris arundinacea*) were added as vegetation types to include significant areas of the southern swamp (1% and 2% respectively) that were not adequately represented in the vegetation sampling data. Sampling unit 82 was included within the boundaries of the Reed Canary Grass community. Approximately 1% of the wetland has been converted to ponds, which are hydrologically within the Ulao Swamp.

Richness was estimated for each vegetation type as the total number of species occurring in all sampling units assigned to each community. We calculated community diversity utilizing the Shannon-Wiener diversity index (Shannon and Weaver 1948).

The Wisconsin Floristic Quality Assessment (WFQA) (Bernthal 2003) was also used to provide a current measure of floristic quality or integrity of the study site. The WFQA assigned native plants a coefficient of conservatism (C value) ranging from 0-10, a relative scale expressing the extent to which the species requires undisturbed native plant communities for its growth. The mean C value is multiplied by the square root of the number of native species to calculate a Floristic Quality Index (FQI) that reflects the extent to which a tract of land supports conservative native plants.

Utilizing ArcView 3.2™ software, Jill Hapner developed a Geographic Information System (GIS) for the swamp and surrounding watershed. Existing and newly created digital files were referenced to the Wisconsin State Plane Coordinate System, South Zone, North American Datum of 1927 (Table 1). ArcView™ files have been deposited, and are available by request from the Ulao Creek Partnership, Ozaukee County Planning, Resources, and Land Management Department, and the University of Wisconsin-Milwaukee Field Station.

RESULTS

Disturbances and Hydrology

Tree species recorded in the swamp before settlement included black ash, American beech, white cedar, birch, and tamarack. The surrounding upland forest was dominated by American beech, sugar maple, and white ash (the latter not usually differentiated from green ash in the U.S. Public Land Survey). Local Native Americans most probably used the swamp for hunting and gathering food (WDNR 1976). Native American settlements were often concentrated around the perimeter of wetlands similar to the Ulao Swamp (Bezella 1992).

Prior to ditch construction, the Ulao Swamp probably had no well-defined stream channel within its boundaries, or had a defined channel only in the southernmost part of the swamp where the surface water drainage from the swamp would have concentrated into a defined outlet. Burt (1835; State of Wisconsin, 1848) drew and mapped a stream channel no farther north than one mile south of the present southern boundary of the Ulao Swamp. We hypothesize that before ditch construction, surface water flow in the swamp was diffuse and meandering through the forested wetland hummock structure of the relatively flat wetland system. The first land patents were issued in 1837, and by 1848 the swamp was parceled between 28 landowners (BLM 2001). As lumbering

Table 1. Existing and developed* digital spatial data sets used as inputs to the GIS.

Data Layer	Scale / resolution	Source
B/W Orthophotography	1:2,400 / 1 ft. pixel	SEWRPC
Soil Survey	1:15,840	OCLIO
Topography	1:2,400 / 2 ft. contours	OCLIO
Watershed Boundaries	1:2,400	WDNR
Presettlement Vegetation	1:2,400	FLEL
Swamp Boundary*	1:2,400 / 1 ft. pixel	JAH
Vegetation Sampling Units*	1:2,400 / 1 ft. pixel	JAH
Vegetation Types*	1:2,400 / 1 ft. pixel	JAH

SEWRPC - Southeastern Regional Planning Commission, Waukesha, WI.
OCLIO - Ozaukee County Land Information Office, Port Washington, WI.
FLEL - Forest Landscape Ecology Lab, University of Wisconsin, Madison, WI.
WDNR -Wisconsin Department of Natural Resources, Madison, WI.
JAH - Jill A. Hapner, University of Wisconsin-Field Station, Saukville, WI.

and farming became important economic activities, the swamp was cleared and partially drained (WDNR 1976). Both white cedar and tamarack are highly resistant to decay and tamarack was used extensively for structural timbers. Also at this time, wood-burning steamers began replacing sailing ships on Lake Michigan. American beech was favored for fuel (Burns and Honkala 1990), and wood for steamers was hauled on roads constructed around and through the swamp to Port Ulao (Town of Grafton 2001). By 1853, the ships no longer used wood for fuel and Port Ulao was closed soon after (Wisconsin Historical Society 2001). Railroad construction along the western boundary of the swamp may have further depleted the population of beech, which was commonly used for railroad ties. Any remaining tamaracks in the swamp would have been further decimated by a severe outbreak of the larch sawfly (*Pristophera ericksonii*), which spread through southeastern Wisconsin between 1900 and 1910 (Curtis 1959, Graham 1956).

Following the extensive tree harvesting, a ditch system was constructed in an attempt to drain the swamp for agricultural and grazing practices. According to the United States Department of Agriculture, no drainage district was created for the area, suggesting that ditch construction in the swamp was an uncoordinated and unsynchronized effort (D. Russell, personal communication, October 4, 2001). Nonetheless, the ditch system appears to have been reasonably effective, substantially lowering water levels while it was maintained.

Comparison of historical air photographs captured from 1937–1980 reveals a gradual decrease in agricultural and grazing practices in and around Ulao Swamp over that time period. Successional changes in these abandoned old fields resulted in small patches of forest, shrub-carr, wet meadow, and cattail marsh. Selective harvesting was isolated to small areas of the lowland forest.

Our interpretation of historical aerial photographs suggests that the Ulao Swamp has undergone severe hydrologic modification since 1980, which has resulted in flooding of large portions of the wetland. Between 1980 and 1985, a 550 m-long internal ditch was constructed in the northern portion of the swamp. This ditch effectively breached an internal drainage divide within the swamp (Fig. 5). The northern portion of the swamp was formerly in the Sauk Creek sub-watershed, which drained to the northeast to Lake Michigan. This northern portion of the swamp is at a higher elevation than the swamp to the south (Fig. 2), and may have a substantial amount of groundwater discharge. The ditch constructed in the early 1980's reversed the flow direction, and caused the northern portion of the swamp to drain to the south across the former sub-watershed divide (Fig. 5). It is possible that over the same time period the former drainage to the north for this part of the wetland was obstructed by development and alteration of the drainageway contours, although we have not fully analyzed this hydrologic setting. It is apparent on aerial photographs that severe flooding of the swamp south of the ditch (evidenced by standing water and damage to the forest canopy) began shortly after construction of the ditch. Examination of aerial photographs of the area south of the ditch and north of Ulao Parkway shows notable changes in canopy architecture between 1980 and 1985. Over the following 5 years, examination of the imagery suggests a reduction in tree canopy with identifiable flow channels and standing water south of the ditch. By between 1990 and 1995 the former swamp forest shifts toward a spectral signature indicative of cattail marsh. By spring of 2000, the former dense lowland forest north of Ulao Parkway, sampled by Brumm in 1976, was converted to cattail marsh (Fig. 5).

Compounding this severe flooding due to construction of a new internal ditch in the wetland, the artificial ditch system constructed much earlier at the southern end of the wetland was undoubtedly losing effectiveness over the same period. Over time with a lack of ditch maintenance, gradual obstruction by fallen trees, natural processes of sedimentation, and growth of vegetation substantially reduced the effectiveness of the southern ditch at draining water from the swamp into Ulao Creek. For several years during the 1980's, Wisconsin Electric Power Company routed flow from an artesian well directly into the southwestern part of the swamp (N. Cutright, personal communication, October 16, 2001), which may have also increased water levels. Increased surface water runoff from impervious surface associated with an increase in residential development may have also contributed to higher water levels in the swamp. The combined effects of hydrologic alterations causing flooding in the Ulao Swamp have resulted in severe damage or death of the vast majority of mature hardwood forest trees in the wetland. A flooding-damaged swamp is the current general state of most of the Ulao Swamp.

In January of 2001, approximately 2 hectares of ash, cedar, yellow birch, silver maple, and additional unspecified tree species on the northern lowland forest boundary was clear-cut (J. Peltier, personal communication, October 17, 2003). The Adrian peat substrate was then harvested, and the underlying sand was mined. A pond has been constructed in the resulting depression.

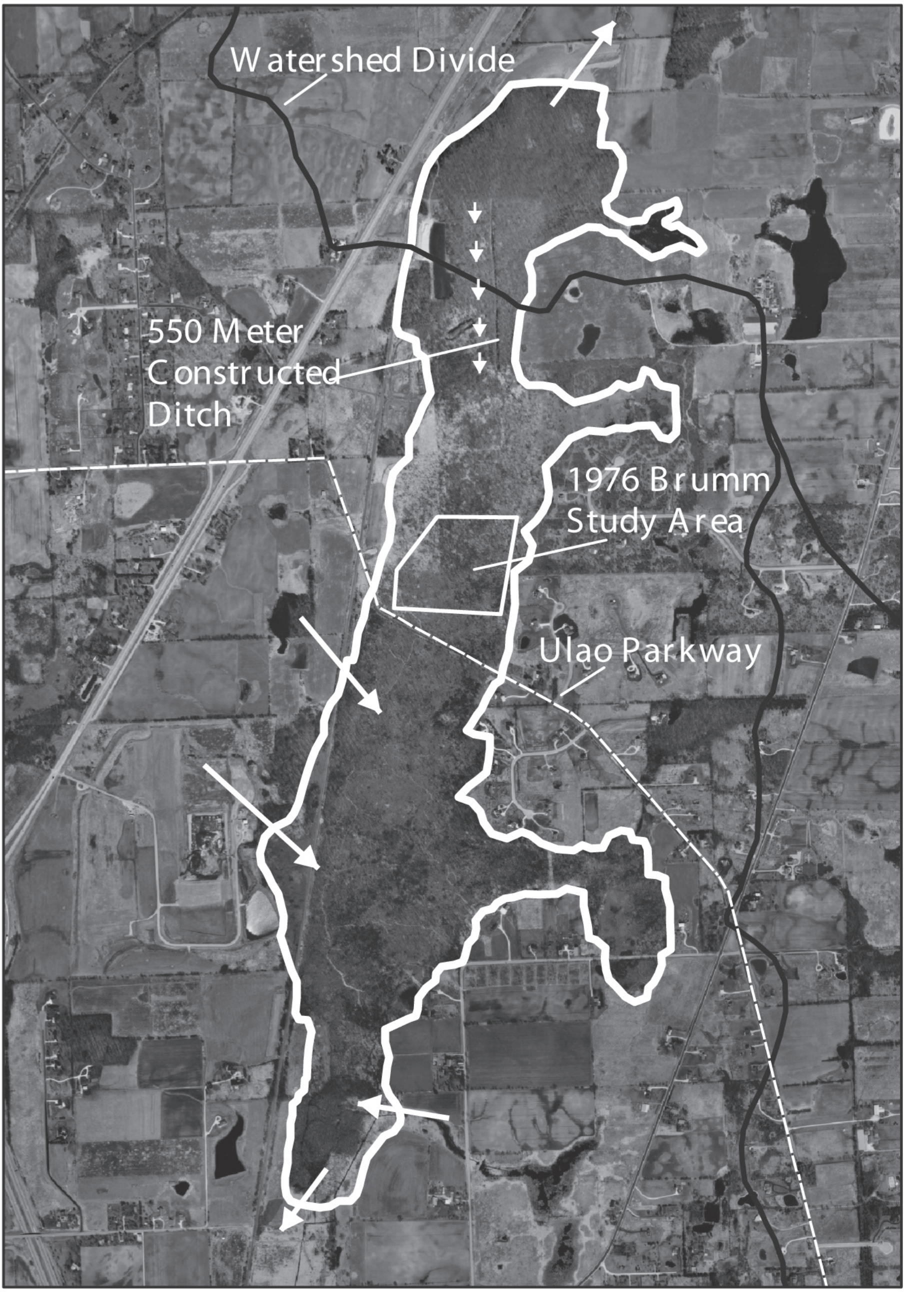


FIG. 5. Location of watershed boundaries and direction of groundwater flow into, and surface flow from, the Ulao Swamp. The ditch that was constructed in the early 1980's to breach the watershed divide, and the direction of flow in that ditch, is shown. The Brumm (1977) data collection site is identified.

PRESENT VEGETATION OF ULAO SWAMP

Flora and Environment

Two hundred twenty-two vascular plant species were identified and collected in Ulao Swamp during this study (App. D). The wetland flora includes 24 tree, 36 shrub and woody vine, and 162 herbaceous species; 90% are native to Wisconsin. Leading families are *Asteraceae, Cyperaceae,* and *Poaceae.* Tamarack and Balsam fir (*Abies balsamea*) have been recently planted in parts of the lowland forest; tamarack is a reintroduction, but it is very unlikely that balsam fir was present in the pre-settlement flora. Summary statistics describing the general vegetation and environment of Ulao Swamp are presented in Table 3. Tree canopy coverage in individual sample units varied from completely open to 99% cover, as estimated by measurements with a densiometer. Depth of surface water varied from 0 to 100 cm. Average pH measured in Ulao Swamp was 6.65 (neutral to slightly acidic) (Hapner Hewitt 2002).

Invasive Species in the flora

Two herbaceous species, reed canary grass and garlic mustard (*Alliaria petiolata*) and three shrub species, common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*R. frangula*), and Tartarian honeysuckle (*Lonicera tatarica*), considered invasive in our region, were recorded in sampling units. Reed canary grass was located in 19 sample units, while common buckthorn was found in 14, mostly at the margins of the wetland. Glossy buckthorn, Tartarian honeysuckle, and garlic mustard were each identified at only 2 sample units (Hapner Hewitt 2002).

Vegetation Types

A TWINSPAN analysis using the 32 most common plant species (Table 2) resulted in the classification of five vegetation types. A sixth type was created for sampling unit 82, which was a near monoculture of reed canary grass, and did not fit well into any of the other vegetation types (Fig. 6). The five plant communities separated using TWINSPAN were named according to the species that formed their dominant structure and the extent of their apparent flooding damage, and were described individually (Table 3, Appendices A, B, and C). Sampling unit 82, dominated by reed canary grass, was not summarized due to a lack of replication of this type.

Closed Ash Forest, Open Ash Forest, Cattail Marsh, Sedge/Shrub, and Flooded Maple Forest vegetation types separated by TWINSPAN were also apparent as distinct clusters in a DECORANA ordination (Fig. 7a). DECORANA plots multidimensional data into 2-dimensional space. The distance between two plots may be interpreted as a measure of similarity/dissimilarity based on the composition of their vegetation (Fig. 7a). In a similar way, two species often occurring in the same sample plots will plot close together in an ordination of species in sample space (Fig. 7b).

Using DECORANA, the ordination of species in sample space (Fig. 7b) is oriented and dimensioned identically to the ordination of samples in species space (Fig. 7a).

TABLE 2. The most common plant species found in Ulao Swamp and their Importance Values (5 tree species), and Frequencies (27 herbaceous and shrub species) in five plant communities. These are the species included in the TWINSPAN and DECORANA analyses used to define vegetation types. Species codes are those used in Figure 7b.

		Vegetation Type (Importance Value or Frequency)				
Trees	Code	Closed Ash Forest	Open Ash Forest	Cattail Marsh	Sedge/ Shrub	Flooded Maple Forest
Acer saccharinum	Ace	4.2	44.6	190.6	170.5	145.9
Fraxinus nigra	FNi	72.8	52.1	60.8	38.3	64.3
Fraxinus pennsylvannica	FPe	110.8	107.5	11.1	82.2	60.1
Tilia americana	Til	21.6	10.0	0	0	0.0
Ulmus americana	Ulm	42.1	58.0	11.4	9.1	18.9
Shrubs						
Alnus incana	Aln	0	0.105	0	0	0.471
Cornus sericea	Cor	0	0.579	0.150	0.692	0.294
Ilex verticillata	Ile	0.083	0.158	0.100	0.077	0.059
Parthenocissus vitaceae	Par	0.583	0.632	0.100	0	0
Rhamnus cathartica	Rha	0.583	0.211	0	0	0
Ribes americanum	Rib	0.333	0.421	0.100	0.154	0
Herbs						
Aster lateriflorus	Ast	0.167	0.105	0	0.077	0
Calamagrostis canadensis	CCa	0.083	0.053	0.075	0.308	0.167
Calla palustris	Cal	0.083	0	0.050	0.115	0.111
Carex comosa	CCo	0	0	0.100	0.038	0.250
Carex lacustris	CLa	0	0.421	0.550	0.808	0.029
Carex stricta	CSt	0	0.105	0.175	0.038	0
Cicuta bulbifera	Cic	0.042	0.026	0.150	0.077	0.139
Equisetum arvense	Equ	0	0.447	0.025	0.077	0
Geum canadense	Geu	0.250	0.053	0.025	0	0
Impatiens capensis	Imp	0.667	0.684	0.400	0.500	0.111
Leersia oryzoides	Lee	0.042	0.184	0	0.077	0.083
Lemna minor	Lem	0.042	0.105	0.575	0.731	0.765
Lysimachia thyrsiflora	Lys	0.042	0.026	0.450	0.115	0
Onoclea sensibilis	Ono	0.042	0.211	0.125	0.192	0.056
Phalaris arundinaceae	Pha	0.083	0.184	0.100	0	0.235
Pilea pumila	Pil	0.125	0.105	0.250	0.192	0.278
Rubus pubescens	Rub	0.042	0.158	0.025	0.038	0
Solanum dulcamara	Sol	0.125	0.158	0.400	0.346	0.306
Sparganium eurycarpum	Spa	0	0	0	0.154	0.056
Symplocarpus foetidus	Sym	0.208	0.395	0.075	0	0.029
Typha spp.	Typ	0	0.237	0.750	0.192	0.206

TABLE 3. Summary of vegetation and environmental conditions for the five major plant communities identified in the Ulao Swamp

							Averages of Sample Units									
Vegetation Type	Number of sample units	% of Swamp Area	Species Richness	Diversity Index (H)	Mean Coefficient of Conservatism	Floristic Quality Index	Tree Canopy Cover (%)	Density of all trees (# / ha)	Density of all saplings (# / ha)	Basal Area of all trees (m2/ha)	Percent of trees damaged	Percent of standing trees dead	Denity of stumps / hectare	Cover of all shrubs (%)	Cover of all herbs (%)	Maximum water depth (cm)
Closed Ash Forest	12	22	72	3.99	4.63	36.5	91.4	867	725	38.4	23.1	2.8	58.3	36.7	74.8	0.0
Open Ash Forest	19	25	90	4.12	4.89	44.0	58.8	500	1147	19.0	29.8	10.4	78.9	28.8	85.4	8.6
Flooded Maple Forest	17	15	48	3.49	4.91	32.2	29.4	318	672	14.0	57.4	23.9	88.2	15.2	58.1	61.4
Sedge/Shrub	13	13	56	3.67	5.00	36.7	33.6	285	354	12.1	62.2	14.0	92.3	22.8	89.6	29.0
Cattail Marsh	20	19	62	3.72	4.92	36.8	19.6	150	445	6.1	46.7	33.3	75.0	6.5	71.1	25.6
Entire Ulao Swamp	82	94	137	4.26	4.78	53.0	50.3	456	721	19.2	40.5	15.9	76.6	23.1	76.2	21.3
Flora of Entire Swamp			223		4.80	67.7										

FIG. 6. TWINSPAN classification of 82 vegetation sampling units into six vegetation types. Species in parentheses were identified by TWINSPAN as primary indicators of each dichotomy.

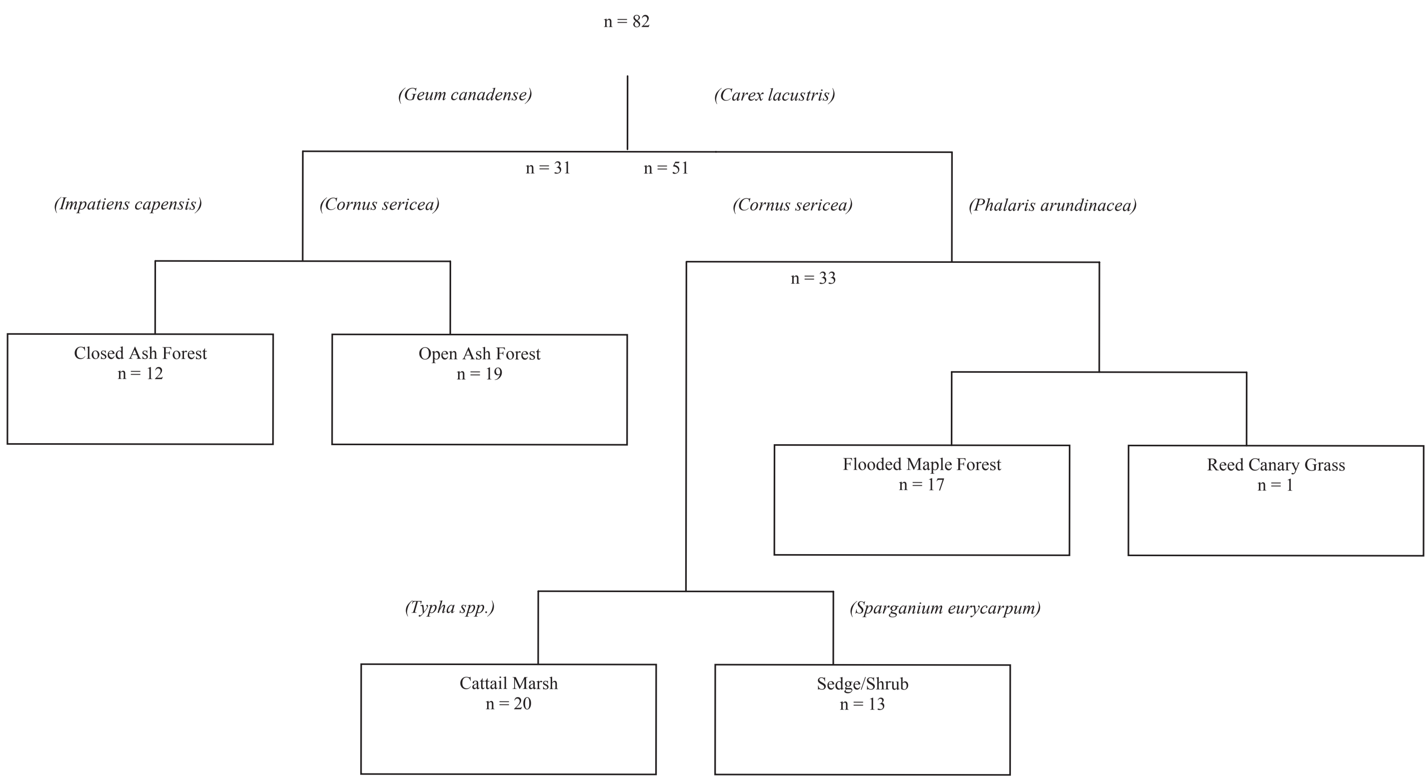
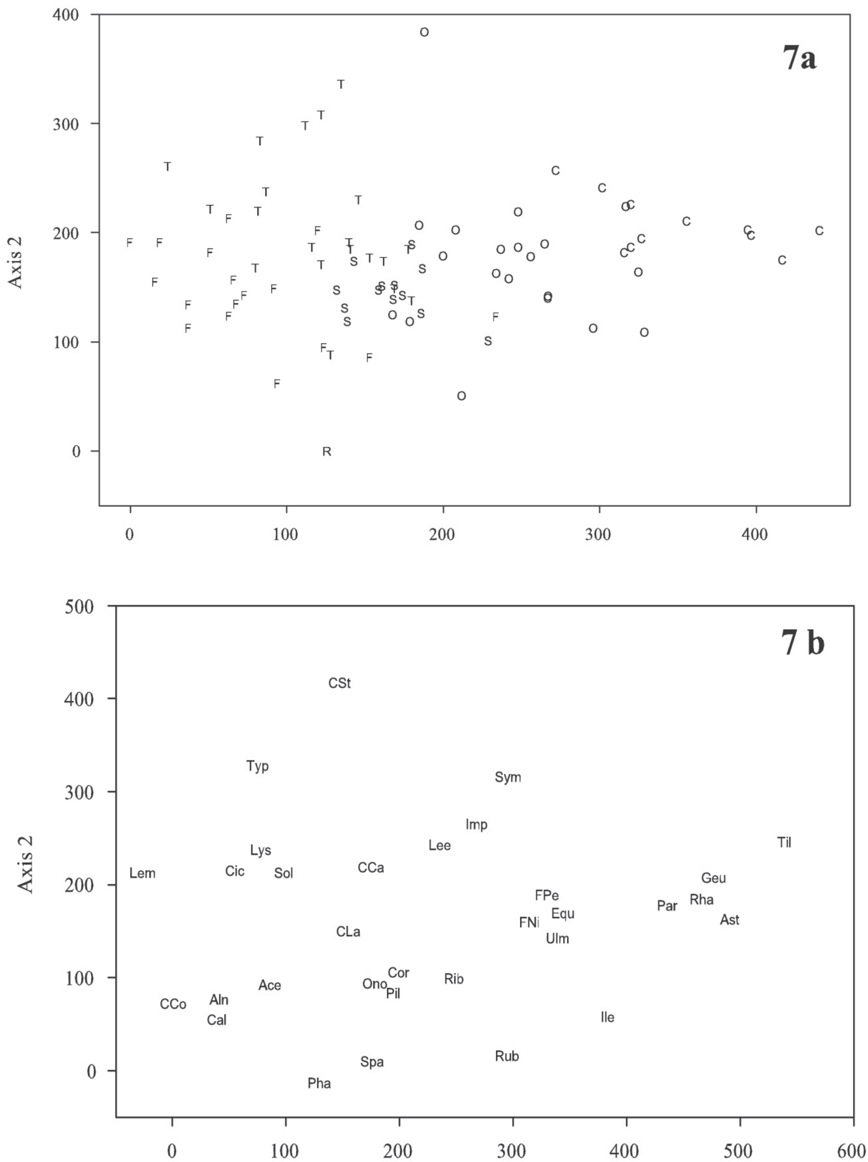


FIG. 7. DECORANA ordination (axis 1 eigenvalue = 0.611, length of gradient = 0.02 standard deviations; axis 2 eigenvalue = 0.430, length of gradient = 0.75 standard deviations).

a. Ordination of 82 vegetation sampling units. The five TWINSPAN groups are indicated: C = Closed Ash Forest, O = Open Ash Forest, F = Flooded Maple Forest, S = Sedge/Shrub, T = Cattail Marsh, and R = Reed canary grass.

b. Ordination of 32 plant species included in the ordination. Three letter codes identify species and are keyed in Table 1.



Therefore, those species that, for example, plot to the right on Axis 1 in Figure 7b are the species that are most common in the Closed Ash Forest (Fig.7a).

Closed Ash Forest

The Closed Ash Forest (CAF) vegetation type occupies 22% (39.9 ha) of the Ulao Swamp. CAF is found primarily at the northern end, and in small patches mostly at the margins of the swamp (Fig. 8). During our study, no surface water above the soil was found in any sample unit in the CAF (Table 3). There is a good spatial correlation between the CAF vegetation type and soil surface elevations above 702' in the northern parts of the swamp (Figs. 2 and 8). CAF also appears to occupy some of the higher elevations in the southern part of the swamp, although the correlation is not as clear. The tree stratum of the CAF has been less damaged by flooding than any other community in the swamp. The density of living trees in CAF (867 trees/ha, Table 3) is almost 75% higher than the density in Open Ash Forest, the community with the next highest living tree density. CAF had by far the highest canopy cover (91%) of any vegetation type in the Ulao Swamp (Table 3) and over twice the total tree basal area per hectare of the next most forested community, Open Ash Forest (Table 3). Only 2.8% of the standing trees were dead in the CAF, compared to 10.4% in the Open Ash Forest and 23.9% in the Flooded Maple Forest. The density of tree stumps over 30 cm in diameter (fallen dead trees) was lower in the CAF than in any other vegetation type in the swamp (Table 3). The percent of trees with damaged crowns was also lowest in the CAF.

Green ash (*Fraxinus pennsylvanica*) and black ash (*F. nigra*) made up 68% of the tree, and 54% of the sapling size classes. American elm (*Ulmus americana*) comprised another 12% of the trees and 15% of the saplings (App. A1). A very high percentage of the green ash in both size classes had damaged crowns, while black ash exhibited much lower levels of flooding damage. Black ash appears to be substantially more resistant to flooding than green ash not only in the CAF, but in all five plant communities in the swamp (App. A). Black ash is also reproducing better than green ash in the CAF; while green ash had higher density in the CAF tree size class, there was a higher density of black ash than green ash saplings. In contrast to the Open Ash and Flooded Maple vegetation types, the maples are an unimportant component of the Closed Ash Forest (App. A1).

CAF has the highest shrub cover (37%) of any plant community in the swamp (App. B), although 15% of this cover was a small tree, hawthorn (*Crataegus* spp.), which we sampled with the shrub stratum since it does not reach the stature of the primary tree canopy. Hawthorn and the non-native invasive, common buckthorn (*Rhamnus cathartica*), comprise 24% of the total shrub cover, and reach their highest cover in the CAF. Red osier dogwood (*Cornus sericea*), which is one of the most dominant shrubs in the other four plant communities, did not occur in our CAF samples.

The most dominant herbaceous species in the CAF are jewelweed (*Impatiens capensis*), skunk cabbage (*Symplocarpus foetidus*), white avens (*Geum canadense*), and goblet aster (*Aster lateriflorus*) (App. C). Among the species that reach a higher cover in CAF than in any other vegetation type are jewelweed, white avens, goblet aster, stinging nettle (*Urtica dioica*), and yellow avens (*Geum aleppicum*). Sedges (*Carex* spp.), which are dominant in the herbaceous layer of all other community types (App. C), are conspicuously absent from the CAF. The invasive reed canary grass (*Phalaris arundinacea*) has substantially lower cover in CAF than it does in the Open Ash or Flooded Maple Forests, most likely because of reed canary grass' intolerance of the more heavily shaded conditions in CAF.

Open Ash Forest

The Open Ash Forest (OAF) plant community occupies 25% (45.6 ha) of Ulao Swamp. OAF is found in a large area just north of where Ulao Parkway crosses the swamp; south of Ulao Parkway it is confined almost entirely to the western half of the wetland (Fig. 8). The average maximum water depth in our OAF sample units was 8.6 cm (Table 3), and Open Ash Forest appears to be consistently located at slightly lower soil elevations that Closed Ash Forest (Figs. 2 and 8). OAF has a tree density and total basal area lower than the Closed Ash Forest and higher than Flooded Maple Forest (Table 3). Total canopy cover of the OAF (59%) is the second highest of the vegetation types in Ulao Swamp, but is less than two-thirds that of the Closed Ash Forest (Table 3).

A higher proportion of standing trees are dead in the OAF than in CAF, and there were 79 stumps/ha in the OAF. We counted only stumps 30 cm or greater in diameter. If we assume that the average DBH of the trees that left these stumps was 40 cm, these 79 stumps/ha would represent a basal area of over 99,000 cm^2/ha. The total of the basal area of these dead fallen trees, the 25,000 cm^2/ha of dead standing trees, and the living trees of the OAF, is 314,000 cm^2/ha, nearly as high as the living tree community in the Closed Ash Forest. This examination of the tree stratum suggests that the existing Closed Ash Forest in the swamp may be very similar to the condition of the Open Ash Forest before it was damaged by flooding. While the percentage of living green ash that have damaged crowns is about the same in the two ash forest types, a much higher proportion of black ash (29%) have damaged crowns in the OAF than in the CAF (4%).

Like in the Closed Ash Forest, green ash, black ash, and American elm make up most of the tree community in the OAF, comprising a combined 79% of the tree density and 68% of the basal area (App. A2). However, in contrast to the CAF, silver maple (*Acer saccharinum*) is an important subdominant in the Open Ash Forest, making up over 10% of the trees and 22% of the total basal area. The Closed Ash Forest and OAF have the highest richness of tree species in the swamp with 12 and 9 species of trees of at least sapling size respectively (Hapner Hewitt 2002). The density of saplings in OAF (1,147/ha) is by far the highest of any plant community in the wetland (Table 3). Green ash makes up a higher proportion of the sapling stand than it does of the tree size class, but all of the dominant trees appear to be reproducing well in the OAF (App. A2).

Open Ash Forest has the highest species richness, diversity, and Floristic Quality Index of any plant community in the Ulao Swamp (Table 3). Average shrub cover is high in the OAF (29%) and there are more species of shrubs present than in any other community (App. B). Over half of the total shrub cover is made up by red osier dogwood (*Cornus sericea*), speckled alder (*Alnus incana*), and winterberry (*Ilex verticillata*), although only winterberry and some other minor species reach their highest frequency and cover in the OAF (App. B).

The OAF has by far the richest herbaceous flora of the swamp (71 species) (App. C). Lake sedge (*Carex lacustris*) and skunk cabbage (*Symplocarpus foetidus*) make up 29% of the total herbaceous cover, and there are six other species that have an average cover of over 5%, jewelweed (*Impatiens capensis*), reed canary grass (*Phalaris arundinacea*), seedlings of red-osier dogwood (*Cornus sericea*), sensitive fern (*Onoclea sensibilis*), common horsetail (*Equisetum arvense*), and tussock sedge (*Carex stricta*) (App. C). Skunk cabbage, sensitive fern, common horsetail, and several other species reach their highest frequencies and covers in the Open Ash Forest.

Flooded Maple Forest

The Flooded Maple Forest (FMF) vegetation type covers nearly 15% (28.5 ha) of Ulao Swamp (Fig. 8). FMF is found in both the northern and southern lobes of the swamp that extend to the east, and in an area just south of Ulao Parkway. The Flooded Maple plant community seems to be closely associated with Cattail Marsh, being almost always adjacent to, or imbedded in, areas dominated by cattail. Flooded Maple is found at relatively low elevations and where surface drainage appears to be poor, and appears to be the plant community currently most severely affected by flooding in the Ulao Swamp. The average maximum depth of water in sample units was 61cm, over twice as deep as in any other vegetation type (Table 3). The percent of trees dead or damaged by flooding, and the density of stumps were all the highest, or among the highest (with Sedge/Shrub and Cattail Mash) of the plant communities in the swamp.

Density and basal area of all trees are higher in FMF than they are in Cattail Marsh and Sedge/Shrub communities (Table 3). While the density of living trees is only 12% higher in FMF than it is in Sedge/Shrub, there are nearly twice as many saplings, and the density and basal area of dead standing trees is twice as high in FMF as in Sedge/Shrub. As in the Open Ash Forest, the combined basal area per hectare of living trees, dead standing trees, and stumps (assuming 40 cm average DBH) is over 300,000 cm^2/ha, which is nearly as high as the Closed Ash community. The FMF was clearly a closed canopy swamp forest community that has now been reduced to less than 30% canopy by flooding.

Unlike the ash forest types, but similar to the Cattail and Sedge/Shrub communities, silver maple (*Acer saccharinum*) is by far the most dominant tree species (App. A3). Black and green ash are also important in the FMF making up 40% of the trees, and red maple (*Acer rubrum*) reaches its highest importance in FMF although it only appeared in one sample unit at high density. Silver maple, black and green ash, American elm, and red maple are all important components of the sapling community, but a higher density of dead saplings (159/ha) than in any other community suggests that tree mortality due to flooding continues to be severe in the FMF (App. A3).

Shrub cover is relatively low in FMF, and over 75% of that cover is speckled alder (*Alnus incana)* a species that can tolerate high water levels and flooded conditions (App. B). Alder reaches its peak frequency and cover in the FMF. The Flooded Maple community has the lowest species richness, lowest diversity, and lowest Floristic Quality Index in the swamp (Table 3). The cover of all herbaceous plants is less than 60% because of the extensive amount of flooding over the soil surface (App. C). Duckweed (*Lemna minor*) covers this stagnant standing water and reaches a total cover of 38%. The only rooted herbaceous species that reach over 5% cover are reed canary grass (*Phalaris arundinacea*) and the sedge

(*Carex comosa)*, each reaching their peak frequency and density in FMF. Due to the extreme flooding of this area, duckweed was recorded in 77% of the sampling units (App. C).

Sedge/Shrub

Approximately 13% (24.6 ha) of Ulao Swamp has the Sedge/Shrub (S/S) vegetation type (Fig. 8). Sedge/Shrub is confined entirely to the eastern portions of the swamp and is most often adjacent to Flooded Maple and Cattail communities. These three communities seem to form the group most severely affected by flooding, and they have much greater maximum water depths than do either of the ash forest vegetation types (Table 3). In these three communities (Flooded Maple, Sedge/Shrub, and Cattail), tree canopy cover is low, density of living trees is low, and basal area of living trees is low; while the percent of living trees that are damaged and the percent of standing trees that are dead are high, and the density of stumps is high (Table 3). The overall condition of all three of these vegetation types can be summarized by the phrase "severe flooding damage". The percent of trees that are damaged and stump density are higher in Sedge/Shrub than in any other community in the swamp.

Silver maple (*Acer saccharinum*) is the most important tree and sapling species in all three of these severely damaged vegetation types (Appendices A3, A4, and A5), especially in the Sedge/Shrub where silver maples comprise 62% of all living trees and 67% of standing dead trees. The composition of the sapling stratum is more diverse, with a nearly even mix of silver maple, green, and black ash (App. A4). The density of saplings is lower in the Sedge/Shrub than in any other community. A physical sense of a density of 354 saplings/ha can be obtained by imagining this density arranged on a uniform grid; with a uniform arrangement there would be a spacing of 5.3 m between all of the saplings. This is well below a sapling density that would regenerate a typical forest structure when the original canopy has been mostly lost.

In addition to the severely damaged (largely missing) tree canopy, the Sedge/Shrub community is characterized by a heavy dominance of just two species, red-osier dogwood and lake sedge. Red-osier dogwood (*Cornus sericea*) makes up almost 90% of the shrub cover in Sedge/Shrub, was found in almost 70% of all the sample units, and covered 21% of all the ground surface (App. B). No single species of shrub reaches more than 12% cover in any other plant community. Similarly the herbaceous stratum is heavily dominated by lake sedge (*Carex lacustris*), which was found in 81% of all quadrats and had an average cover of 31% (App. C). No single herbaceous species obtains more than 20% cover in any other plant community. Jewelweed (*Impatiens capensis*), red-osier dogwood (*Cornus sericea*) seedlings, Canada bluejoint grass (*Calamagrostis canadensis*), and giant bur-reed (*Sparganium eurycarpum*) all have over 5% cover in Sedge/Shrub, and all but jewelweed reach their peak importance in this plant community.

Cattail Marsh

Cattail marsh (CM) comprises approximately 19% (34.3 ha) of Ulao Swamp (Fig. 8). It is found in a large contiguous area at the center of the swamp, both north and south of Ulao Parkway (Fig. 8). The Cattail Marsh has the appearance of being the community that has been the longest flooded, or most thoroughly converted by flooding from a forested to an herbaceous community. Tree canopy cover is less than 20%, and tree density and basal area are by far the lowest of any community in the swamp (Table 3). The average maximum water depth in sample units (26 cm) is less than that of the Flooded Maple Forest (61 cm), but this difference may be misleading, since the deep hollows between hummocks have largely been filled in with a dense mat of cattail.

Silver maple makes up 60% of the trees that are present (App. A5), however the total living tree density of only 150/ha gives an average spacing between living trees of over 8 m. One-third of all standing trees are dead. Unlike the other communities where the total basal area of living and all recorded dead trees is approximately 300,000 cm^2/ha, it is only 191,000 cm^2/ha in the CM. This may be because the trees have been dead for a longer period of time and a portion of the stumps were no longer apparent. Tree reproduction in the CM appears to be better than in the Sedge/Shrub community with 445 live saplings/ha, and only 10% of the standing saplings dead, however this is still a low density for forest reproduction, having an average spacing between saplings of 4.7 m.

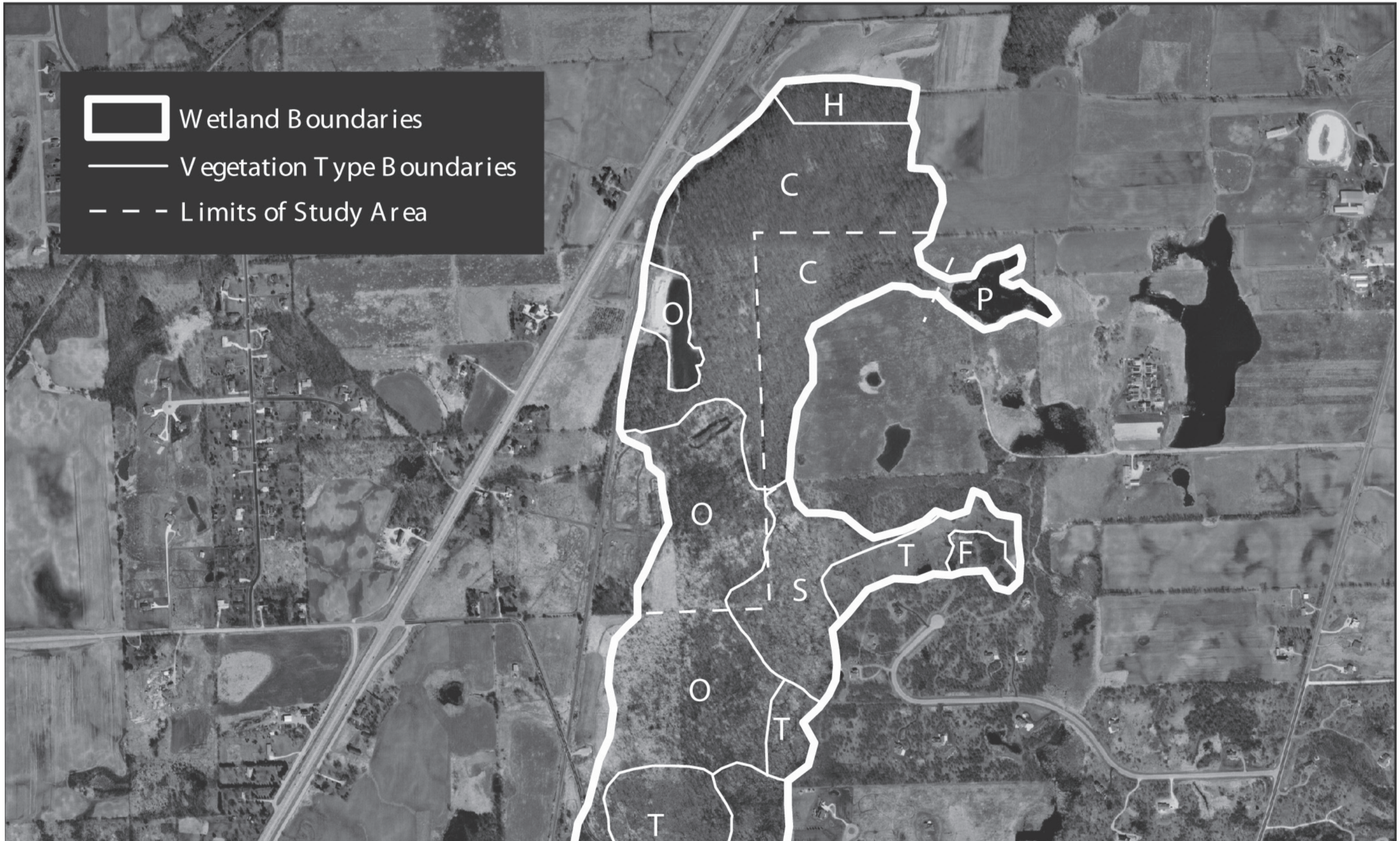
Cattail Marsh has by far the lowest shrub cover of any community in Ulao Swamp (6.5%), with red-osier dogwood (*Cornus sericea*) being the only important shrub species (App. B). Cattail (*Typha* spp.), which does not reach an average cover of over 4.4% in any other plant community, covers 20% of the ground surface in the CM. Lake sedge (*Carex lacustris*), reed canary grass (*Phalaris arundinacea*), bittersweet nightshade (*Solanum dulcamara*), tufted loosestrife (*Lysimachia thyrsiflora*), and tussock sedge (*Carex stricta*) all reach over 5% cover in Cattail Marsh (App. C). Bittersweet nightshade, tufted loosestrife, and tussock sedge reach their highest covers in the CM. The aquatic plant, pickerel weed (*Pontederia cordata*), was only observed in the Cattail Marsh plant community.

Comparison of 1976 and 2001 Forest Samples

Brumm (1977) quantitatively described a sample of trees greater than 30 cm DBH in a small part of the swamp north of Ulao Parkway (the area of our sample units 22 through 29, Fig. 5). We summarized our data for only those sample units, and only for trees at least 30 cm DBH, for comparison with the data collected in 1976 (Table 4). Brumm apparently did not distinguish between silver maple and red maple. Assuming that his maples were silver maple (the only maple species that we found in these sample units), the density of living silver maples has decreased at the same time that the basal area/ha has increased over this 25-year period (Table 4). The average diameter at breast height (DBH) of the maples that he sampled in 1976 was 33.5 cm; the average DBH in 2001 was 41.4 cm. An 8 cm growth in diameter of silver maples over a 25-year period is a relatively slow growth rate for the species. The reduction in maple density over this 25-year period suggests that there has been a loss of trees, as opposed to any new recruitment to the tree size class. The majority of the silver maple trees that we sampled in this area were recorded as damaged. We did not find any black or green ash over 30 cm DBH (present at a combined density of 77 trees/ha in the Brumm sample) in this part of the swamp in 2001.

The combined estimated basal area of living and dead-standing trees, and the trees that caused the stumps in our sample is 334,000 cm^2/ha, substantially higher than the 154,000 cm^2/ha recorded by Brumm. We clearly did not sample the same sample units that Brumm used in 1976, and much of this difference may be due to a different set of

FIG. 8. Map of the plant communities of Ulao Swamp: C = Closed Ash Forest, F = Flooded Maple Forest, H = Harvested, O = Open Ash Forest, P = Pond, R = Reed Canary Grass, S = Sedge/Shrub, T = Cattail Marsh, W = Wet Meadow.



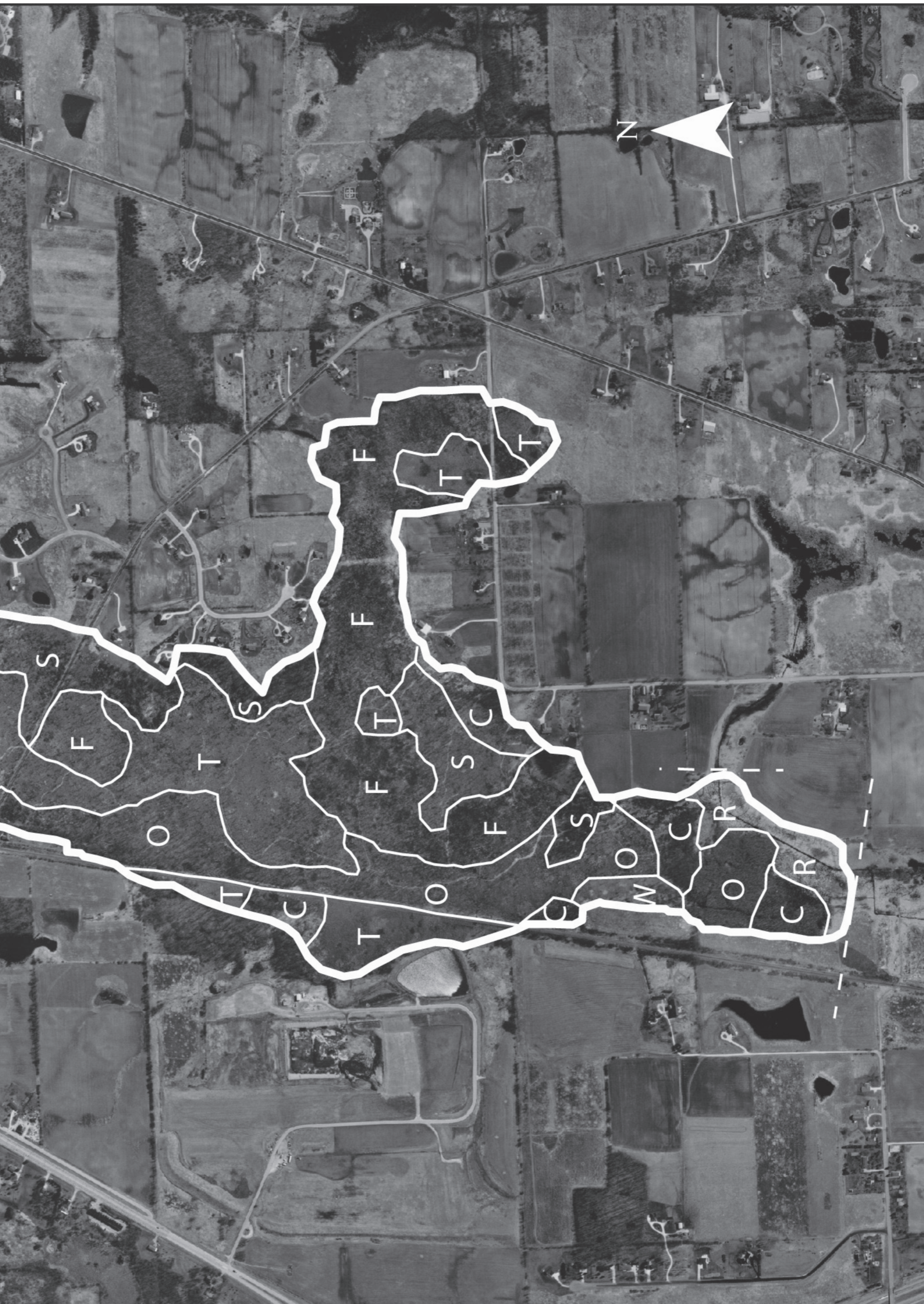

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TABLE 4. 25 years of change in the forest of Ulao Swamp. 1976 data were collected by Brumm (1977) and are compared to eight 2001sampling units located in the same area of the wetland.

	Dens. (#/ha)	BA (cm^2/ha)	Rel. Freq. (%)	Rel. Dens. (%)	Rel. Dom. (%)	IV
1976 Trees > 30 cm DBH						
Acer rubrum - saccharinum	97.1	85,658	37.1	47.5	55.7	140.3
Fraxinus nigra	63.9	38,814	34.3	31.3	25.2	90.8
Betula alleghaniensis	4.6	12,711	17.1	13.7	8.3	39.1
Fraxinus pennsylvannica	12.8	16,307	8.6	6.3	10.6	25.5
Quercus bicolor	2.6	178	2.9	1.2	0.1	4.1
Totals	181.0	153,668				
2001 Trees > 30 cm DBH						
Acer saccharinum	87.5	117,399	80.0	87.5	86.8	254.3
Quercus bicolor	12.5	17,888	20.0	12.5	13.2	45.7
Totals	100.0	135,287				
Dead ash	12.5	10,237				
Stumps > 30cm diameter	150.0					

sample units. In general, a comparison of the data sets suggests that there has been a degradation of the swamp forest, and a loss of some dominant species over this 25-year period.

Discussion

Before European settlement of the area, Ulao Swamp was a mixed conifer/hardwood swamp forest, probably very similar in composition to the conifer swamp of the Cedarburg Bog, Ozaukee County, Wisconsin (Reinartz 1985, 1986). These swamps were southern outliers of the forests Curtis (1959) described as "northern wet, and wet-mesic forests". Over time the dominant vegetation of Ulao Swamp was converted from conifer to hardwood swamp, probably as the result of logging of the tamarack and cedar, an outbreak of larch sawfly in the early 1900's, and the greater sensitivity of the conifers (especially tamarack) than some hardwoods to hydrologic changes. As recently as the early 1980's the wetland was entirely forested, mostly with a hardwood swamp of ashes and maples. This recent forested condition of the wetland is evident from our sample of dead standing trees and tree stumps in the wetland, interpretation of aerial photography, and the recollections of area residents. The present composition and condition of the vegetation in the Ulao Swamp is the result of extensive flooding of large portions of the wetland over the past 20 years.

The recent flooding of Ulao Swamp was primarily caused by a 550 m-long internal ditch, which was constructed in the northern portion of the swamp between 1980 and

1985. The northern one-quarter of the swamp formerly drained to the northeast to Lake Michigan. This new ditch caused the northern portion of the swamp to drain to the south across what was previously a sub-watershed divide within the wetland (Fig. 5). The former drainage to the north for the northern part of the wetland may also have been obstructed by development and alteration of the drainageway contours. This northern portion of the swamp is at a higher elevation than the swamp to the south (Fig. 2), and may have a substantial amount of groundwater discharge. The new ditch discharged additional surface flow to the center of the swamp, which had no surface outlet other than at the far southern end of the wetland. The resulting hydrologic alteration caused severe flooding in the central and southern portions of the wetland. It is apparent on aerial photographs that severe flooding of the swamp south of the ditch (evidenced by standing water and damage to the forest canopy, Fig. 8) began in 1985, shortly after construction of the ditch. Over the same time period, lack of maintenance of the artificial ditch at the southern end of the wetland may have reduced its effectiveness, further exacerbating the flooding.

There are currently five major plant communities that we identified in the Ulao Swamp. All of these except the Closed Ash Forest are successional or disturbance communities that have developed in response to the severe flooding. It is not surprising that the Closed Ash Forest of Ulao Swamp is confined to the northern portion of the wetland that was drained (as opposed to flooded) by the ditch constructed in the early 1980's, and to a few marginal areas of the wetland where ground elevations are relatively high. These are the only parts of the wetland that have not been substantially impacted by flooding. Differences among the remaining four plant communities in the swamp seem to be primarily a response to varying intensities, and perhaps durations, of flooding.

Mapping the vegetation types in Ulao Swamp was difficult due to the mosaic nature of the vegetation, and gradual transitions from one type to another. Decisions on where to map the exact location of community boundaries was difficult, and in some cases somewhat arbitrary (Fig. 8). For example, there are several sampling units in the large area of Open Ash Forest north of Ulao Parkway that were all classified by TWINSPAN as Open Ash Forest (Fig. 4), yet the 2000 aerial photograph revealed a distinct north/south boundary distinguishing the eastern and western parts of this area (Figs. 4 and 8). A review of the field data explained the contrast in spectral signatures as a difference in tree density, but not in species composition. All the sampling units were therefore mapped as Open Ash Forest. There are actually few relatively large areas of homogeneous vegetation in the swamp, but rather the vegetation is distributed in a mosaic of smaller patches differing in composition. This mosaic pattern of vegetation on a smaller scale than is typical in undisturbed plant communities is probably due to, 1) subtle, small-scale, differences in intensity of flooding, and 2) the fact that recent disturbance has caused shifts in plant assemblages, combining components from different native communities; and these assemblages are at this time far from stable communities. The plant communities of Ulao Swamp are still in a state of rapid flux due to the recent nature of the flooding disturbance. White (1965) found mapping shrub carr associations difficult because they characteristically occur as widely scattered, small aerial units. This was also the case in Ulao Swamp (Figs. 4 and 8).

The canopy structure (dominance by green ash, black ash, and American elm) of the Open Ash Forest vegetation type appears to have been very similar to Closed Ash Forest, but nearly half of the tree density and canopy has been removed as the result of flooding. This removal of the canopy has allowed colonization by a much greater diversity of shrubs and herbs than is found in the more intensely shaded Closed Ash Forest. The Open Ash Forest has the greatest number of both shrub and herbaceous species of any community in the wetland, because it has the combined presence of those species normally found in forested communities and those found in more open wet meadows and shrub carr. Many of the species typically found in northern conifer swamps are still found in the Closed and Open Ash Forests of the Ulao Swamp (e.g. *Carex disperma, Maianthemum canadense, Mitella nuda, Rubus pubescens*, *Smilacina trifolia,* App. D), but in very low numbers because of the extensive disturbance to the plant communities. Skunk cabbage (*Symplocarpus foetidus*), often found in groundwater seepage areas (Eggers and Reed 1997), occurred most frequently along the west boundary of Ulao Swamp where groundwater springs and seeps are reportedly located (BRAA 1998, Northern Environmental Technologies 1997).

Based on a summary of living and dead trees, the density and basal area of trees in the Flooded Maple Forest appears to have been similar to the ash forests before flooding, but the dominant tree species are silver and red maple as opposed to green and black ash. The tree populations of the most severely flooded communities of the swamp (Flooded Maple Forest, Sedge/Shrub, and Cattail Marsh) are all dominated by maple, which tolerates wider hydrologic regimes than ash (Burns and Honkala 1990). Curtis (1959) and Brumm (1977) observed that silver maple replaces ash after disturbance in lowland forests. It appears that the maple forest was found at slightly lower elevations and in wetter areas than the ash forests in the Ulao Swamp. The maple forest has therefore suffered much more severe effects of flooding than the ash forest, and has its tree canopy reduced to just 29% cover, with nearly 60% of all living trees showing severe damage from flooding. The Flooded Maple Forest vegetation type has very low species diversity and a low Floristic Quality Index, because it has lost most herbaceous species typical of a forest understory. The composition of the herbaceous community suggests that the Flooded Maple Forest is rapidly converting to a combination of cattail marsh, reed canarygrass, and sedge/wet meadow. There is still substantial tree reproduction in the Flooded Maple Forest, but continued flooding will probably prevent these saplings from reaching the tree size class.

The Flooded Maple Forest, having the highest percentage of damaged adult trees and saplings, appears to be the community that has been most recently damaged by flooding. Most of the live trees arise from several centimeters of surface water, which is present throughout the growing season. There has been very little colonization of stumps, hummocks, and logs by species requiring dryer microhabitats, as was commonly observed in the Cattail Marsh and Sedge/Shrub vegetation types. The poor herbaceous flora and high cover of reed canary grass cover in the Flooded Maple Forest seem to indicate a relatively early response to flooding. Tree mortality will probably continue if the water levels remain high. In contrast, the Cattail Marsh and Sedge/Shrub vegetation types have fewer standing dead trees than the Flooded Maple Forest, and appear to have had some time to acclimate to the flooding.

Twenty-five years ago Brumm (1977) collected tree data in 20 sampling units throughout a 20-acre (8.1 ha) area in Ulao Swamp (Fig. 5, Table 4). According to his data, silver maple dominated the community, with black ash, yellow birch *(Betula alleghaniensis),* and green ash also well represented. Brumm stated that the lowland forests of Ozaukee County resembled those of presettlement with two notable exceptions: 1) black ash dominance had been replaced by red and silver maple, and 2) elm had been eliminated from most of the stands by Dutch Elm Disease. Brumm gave the Ulao Lowland Forest a natural area rank of NA-2 (Natural Area of regional significance with native biotic communities and a limited amount of disturbance) and described it as: "A large lowland hardwoods dominated by red and silver maple and black ash, up to 30" DBH. Dense canopy in center opens up to north and south. Several old fence lines present. Several edges grazed. Scattered small areas of cut stumps". Twenty-five years later the plant community has been seriously degraded, live tree density in the sample area has been decreased by 45%, with the remainder of the former population represented by snags and stumps (Table 4). Maple and swamp white oak persist in Brumm's study area, but ash and birch species have disappeared. Fifty percent of the maple trees in the Brumm study area of Ulao Swamp are currently damaged.

The Sedge/Shrub and Cattail Marsh vegetation types are both open plant communities, however aerial photography and the presence of standing dead trees and stumps attest to the fact that these were forested less than 25 years ago. The almost complete conversion of these areas from forest to herbaceous and shrub carr wetland plant communities suggests that they may have been the first in the wetland to experience the effects of flooding. The vegetation in these open communities is very patchy; the composite description of the units sampled does not provide an adequate picture of the true nature of this vegetation. For example, there are patches of diverse native sedge meadow community, and other patches that are very heavily dominated by cattail. There is still reproduction of silver maple, black ash, and green ash in these open communities, but the present density of saplings is too low to rapidly generate a natural forest stand, and it is likely that with continued flooding few of these saplings will survive to the tree size class.

Only 59% of the live tree population in Ulao Swamp has more than 50% of its canopy intact (defined as undamaged). Sixteen percent of all standing trees are dead. In the maples and elms, larger trees were more severely affected by flooding, so the mean diameter of undamaged trees is less than that of damaged and dead trees. The presence of healthy saplings and seedlings of black ash, green ash, silver maple, and American elm throughout the Ulao Swamp indicate the potential for succession back to a southern wet-mesic forest composition, if the flooded conditions would be eliminated in the swamp. However, many of these healthy tree saplings are currently growing in flooded areas on top of hummocks formed by large roots and dead fallen trees, which may provide an unstable and only temporary substrate for growth (Harmon et al. 1986). The average diameters of undamaged, damaged, and dead black and green ash in the Ulao Swamp are nearly the same. This suggests that the ashes may suffer damage from high water levels at small diameters (mean DBH of damaged and dead ash trees = 10.4 cm), and although ash sapling density is high, the ashes may not survive and become dominant in the overstory of the currently flooded swamp.

The persistence of a large number of native herbaceous species in Ulao Swamp may be attributed to microhabitat created by varying canopy cover and pronounced microtopography of the flooded lowland forest. Logs emerging from the water are the only sites in some areas of the flooded lowland forest on which the native wetland species that were part of the pre-flooding community can survive (Harmon et al. 1986). As described by Ehrenfeld (1993), microtopographic features can originate from woody debris around which sediments, organic matter, and dense mats of roots develop. Mosses rapidly colonize logs and tree stumps, and fine roots grow between the surface of the dead wood and moss. Microtopography is created in the wetland from these woody structures that become covered with mosses and then are colonized by new tree, shrub, and herb species. Prolonged flooding in Ulao Swamp has contributed to a high frequency of tree tip-ups and blow-downs, which has accentuated the microtopographic relief of the forest floor.

In the absence of fire, the natural potential "climax" plant community of Ulao Swamp remains a forested wetland (swamp) (interpretation of plant communities in Curtis 1959). Restoration of a natural hydrologic regime to Ulao Swamp (cessation of the ongoing flooding) would result in a relatively rapid transition to Southern Wet and Wet-mesic Forest (Curtis 1959), although complete recovery of mature examples of these community types would take several decades. We would not expect the tamarack and white cedar populations of the presettlement vegetation to re-establish naturally. Neither tamarack nor cedar remains viable in the litter or soil seed banks (Burns and Honkala 1990). There are currently no nearby populations of tamarack for colonization; white cedar is present in small numbers in the northern portion of the swamp (not accessed by our study) but this area continues to be logged and disturbed. Tamarack and cedar could be successfully planted in the wetland to restore seed sources for long-term restoration of their populations, if the present flooding disturbance was eliminated. Most of the other normal components of swamp communities are still present in the wetland. The herbaceous plants typical of open wetland vegetation would gradually diminish because they would not tolerate the increasing shade caused by development of a woody plant canopy.

Without restoration of natural hydrology (closure and restoration of the internal ditch that has caused flooding) the Ulao Swamp would still be expected to return to forested plant communities, however this succession to forest is likely to take a very long time. Some, or all, of the disturbance communities in the wetland still appear to be undergoing a transition to open marsh and wet meadow vegetation. Although some production of sapling-sized trees continues to occur, these are at low densities, and there is little evidence that these saplings are able to grow to tree size under the current flooded conditions. Those areas that are converted from forest to open habitat are susceptible to establishment of reed canarygrass (currently having substantial cover in both the Flooded Maple Forest and Cattail Marsh communities), which is very aggressive, and once dominant is able to resist invasion by trees for long periods (Thompson 1995). Many areas of the swamp are currently so severely flooded that build up of a higher level of peat or muck will be required to form a substrate firm enough for successful tree growth. Cattail marshes have the highest rates of biomass production of our wetland plant communities, and build substrate by producing undecomposed biomass and detritus at very high rates. It is interesting that although the sapling density in the Cattail Marsh community in Ulao Swamp is low, these saplings have a lower percentage mortality than saplings in any other vegetation type. This suggests that the areas dominated by cattail marsh may have begun the soil building and stabilization process that will be required for succession back to forest. The conversion of large parts of the swamp to cattail and high productivity communities, and subsequent succession back to swamp forest after accumulation of soil, is likely to take a very long time.

Several residents in the Ulao Swamp area would like to restore Ulao Swamp to a healthy, native swamp forest. Our analysis indicates that closure of the 550 m ditch at the north end of Ulao Swamp is an essential first step to restore the Ulao Swamp. Closure of this ditch would restore natural hydrology and eliminate the still ongoing flooding of the wetland.

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APPENDIX A. Composition of the tree stratum of the five vegetation types of Ulao Swamp. For each vegetation type, only species that occurred in more than one sample unit are listed. **Freq,** Frequency in the number of 100 m^2 circular quadrats sampled. **Den**, Density (trees/ha). **BA**, Basal Area (cm^2/ha). **% Dam**, Percent of trees that were damaged (less than half of crown intact). **IV,** Importance Value (the sum of relative frequency, density and dominance values).

Appendix A1.

Closed Ash Forest (N = 12 quadrats)

	Living					**Dead**			
Trees (> 10 cm DBH)	Freq	Den trees/ha	BA cm^2/ha	% Dam	IV	Freq	Den trees/ha	BA cm^2/ha	IV
Fraxinus pennsylvanica	0.667	400.0	150,900	43.8	110.8				
Fraxinus nigra	0.833	191.7	80,000	4.3	72.8				
Dead ash						0.166	16.7	10,018	217.9
Ulmus americana	0.583	100.0	38,500	16.7	42.1	0	0	0	0
Quercus bicolor	0.250	41.7	42,600	0	25.2	0	0	0	0
Tilia americana	0.167	66.7	29,800	0	21.6	0	0	0	0
Betula alleghaniensis	0.167	25.0	8,300	0	10.9	0.083	8.3	1,824	82.0
Totals		866.7	383,600	23.1			25.0	11,842	
Saplings (2.5 - 10 cm DBH)									
Fraxinus pennsylvanica	0.417	175.0	5,100	85.7	62.8				
Fraxinus nigra	0.417	216.7	8,300	26.9	83.5				
Dead ash						0.417	100.0	2,925	227.5
Ulmus americana	0.417	108.3	3,100	7.7	44.6	0	0	0	0
Quercus bicolor	0.167	16.7	900	0	12.6	0	0	0	0
Tilia americana	0.250	25.0	700	0	15.6	0	0	0	0
Betula alleghaniensis	0.167	16.7	400	0	10.1	0.083	8.3	55	20.8
Acer saccharum	0.167	50.0	600	16.7	15.8				
Acer negundo	0.500	50.0	900	16.7	29.5	0.083	8.3	358	29.6
Totals		725.0	21,650	32.2			125.0	3,437	

Appendix A2.

Open Ash Forest (N = 19 quadrats)

	Living					Dead			
		Den	BA				Den	BA	
Trees (> 10 cm DBH)	Freq	trees/ha	cm^2/ha	% Dam	IV	Freq	trees/ha	cm^2/ha	IV
Fraxinus pennsylvanica	0.737	184.2	78,800	45.7	107.5				
Dead ash						0.421	47.4	20,523	244.9
Ulmus americana	0.579	100.0	28,600	10.5	58.0				
Fraxinus nigra	0.474	110.5	21,300	28.6	52.1				
Acer saccharinum	0.316	52.6	41,100	30.0	44.6				
Quercus bicolor	0.105	10.5	11,500	0	12.4	0	0	0	0
Betula alleghaniensis	0.158	15.8	4,300	33.3	11.7	0	0	0	0
Tilia americana	0.105	21.1	3,100	0	10.0	0	0	0	0
Totals		500.0	190,000	29.8			58.0	24,688	
Saplings (2.5 - 10 cm DBH)									
Fraxinus pennsylvanica	0.684	589.5	13,200	33.0	129.3				
Dead ash						0.368	78.9	2,325	257.4
Ulmus americana	0.421	163.2	4,300	0	49.6				
Fraxinus nigra	0.579	263.2	8,000	28.0	78.2				
Acer saccharinum	0.158	94.7	4,000	33.3	29.4				
Tilia americana	0.105	26.3	600	0	9.7	0	0	0	0
Totals		1,147.4	30,200	25.6			89.5	2,542	

Appendix A3.

Flooded Maple Forest (N = 17 quadrats)

	Living					Dead			
		Den	BA				Den	BA	
Trees (> 10 cm DBH)	Freq	trees/ha	cm^2/ha	% Dam	IV	Freq	trees/ha	cm^2/ha	IV
Acer saccharinum	0.588	141.0	88,050	50.0	145.9				
Dead maple						0.235	29.4	27,600	115.8
Fraxinus nigra	0.353	82.4	21,400	50.0	64.3				
Fraxinus pennsylvanica	0.353	64.7	23,200	91.0	60.1				
Dead ash						0.353	52.9	16,300	131.9
Ulmus americana	0.176	17.6	2,470	0	18.9				
Betula papyrifera	0	0	0	0	0	0.118	11.8	4,920	37.1
Totals		318.0	140,000	57.4			100.0	49,600	
Saplings (2.5 - 10 cm DBH)									
Acer saccharinum	0.471	271.0	6,550	37.0	106.2				
Dead maple						0.235	35.3	1,190	73.9
Fraxinus nigra	0.529	118.0	2,640	35.0	60.5				
Fraxinus pennsylvanica	0.471	153.0	3,390	69.2	67.9				
Dead ash						0.471	100.0	2,670	172.3
Ulmus americana	0.235	35.3	829	16.7	22.1				
Dead elm						0.176	23.5	910	53.8
Acer rubrum	0.235	82.4	1,650	0	34.5				
Totals		672.0	15,300	37.7			159.0	4,770	

Appendix A4.

Sedge/Shrub (N = 13 quadrats)

	Living					Dead			
		Den	BA				Den	BA	
Trees (> 10 cm DBH)	Freq	trees/ha	cm^2/ha	% Dam	IV	Freq	trees/ha	cm^2/ha	IV
Acer saccharinum	0.538	176.9	84,000	52.2	170.5				
Dead maple						0.231	30.8	15,071	180.2
Fraxinus pennsylvanica	0.462	69.2	30,000	88.9	82.2				
Dead ash						0.154	15.4	13,042	119.7
Fraxinus nigra	0.308	30.8	6,400	75.0	38.3				
Totals		284.6	120,500	62.2			46.2	28,113	
Saplings (2.5 - 10 cm DBH)									
Acer saccharinum	0.538	130.8	3,500	29.4	111.0				
Dead maple						0.308	53.8	1,712	157.7
Fraxinus pennsylvanica	0.308	84.6	2,100	63.7	67.4				
Dead ash						0.385	46.2	1,167	142.3
Fraxinus nigra	0.538	100.0	2,700	15.4	94.2				
Totals		353.9	8,800	30.4			100.0	2,879	

Appendix A5.

Cattail Marsh (N = 20 quadrats)

	Living					Dead			
Trees (> 10 cm DBH)	Freq	Den trees/ha	BA cm^2/ha	% Dam	IV	Freq	Den trees/ha	BA cm^2/ha	IV
Acer saccharinum	0.350	90.0	49,400	38.9	190.6				
Dead maple						0.250	35.0	19,858	158.5
Fraxinus nigra	0.150	40.0	7,800	50.0	60.8				
Dead ash						0.200	40.0	15,354	141.3
Totals		150.0	61,300	46.7			75.0	35,212	
Saplings (2.5 - 10 cm DBH)									
Acer saccharinum	0.400	205.0	5,700	12.2	124.9				
Dead maple						0.100	10.0	347	85.6
Fraxinus nigra	0.350	80.0	1,800	18.8	57.6				
Dead ash						0.200	25.0	708	185.0
Ulmus americana	0.250	45.0	1,400	11.1	39.3				
Totals		445.0	11,050	21.3			40.0	1,084	

APPENDIX B. Frequency of occurrence and mean percent cover of shrubs and woody vines in five plant communities. Frequency is the proportion of 10 m line intercept samples on which the species was found. Only species found in more than one sample are listed.

Species	Closed Ash		Open Ash		Flood Maple		Sedge/Shrub		Cattail	
	Freq N=12	Cover (%)	Freq N=19	Cover (%)	Freq N=17	Cover (%)	Freq N=13	Cover (%)	Freq N=20	Cover (%)
Alnus incana			0.11	3.63	0.47	12.00				
Cornus racemosa	0.08	4.33	0.11	1.42						
Cornus sericea			0.58	11.32	0.29	2.00	0.69	21.38	0.15	5.00
Crataegus spp.	0.33	15.00	0.05	2.16						
Ilex verticillata	0.08	0.75	0.16	3.52	0.06	0.06	0.08	1.46	0.10	0.55
Lonicera tatarica	0.08	0.75	0.05	0.26						
Parthenocissus vitaceae	0.58	5.00	0.63	3.21					0.10	0.30
Prunus virginiana	0.08	4.08								
Rhamnus cathartica	0.58	8.50	0.21	1.63						
Rhamnus frangula			0.11	0.53						
Ribes americanum	0.33	0.83	0.42	2.11			0.15	0.54	0.10	0.55
Rosa palustrus			0.05	0.05	0.12	1.12	0.08	0.38		
Rubus idaeus	0.08	1.92	0.26	1.32						
Salix petiolaris			0.05	0.05			0.08	0.77		
Spirea alba					0.06	0.30			0.10	1.10
Viburnum lentago			0.11	0.63						
Viburnum trilobum	0.08	0.33							0.05	0.20
Total		41.82		32.84		15.78		24.53		7.75
Average total shrub cover (%)		36.67		28.79		15.18		22.77		6.45

APPENDIX C. Frequency of occurrence and mean percent cover of herbaceous species and woody plant seedlings in five plant communities. Frequency is the proportion of 0.25 m^2 quadrats in which the species was found. Only species found in more than one quadrat are listed. *, Woody plants, for which seedlings were recorded. Bolded numbers indicate the community in which the species achieves its greatest abundance.

	Closed Ash		Open Ash		Flood Maple		Sedge/Shrub		Cattail			
Species	Freq N=24	Cover (%)	Freq N=38	Cover (%)	Freq N=34	Cover (%)	Freq N=26	Cover (%)	Freq N=40	Cover (%)	Mean Freq	Mean Cover
Carex lacustris			0.42	14.80	0.28	5.35	**0.81**	**30.87**	0.55	16.50	0.41	13.50
Impatiens capensis	**0.67**	**20.10**	0.68	7.70	0.11	0.28	0.50	8.08	0.40	4.63	0.47	8.16
Typha spp.			0.24	4.41	0.22	3.61	0.19	3.75	**0.75**	**20.00**	0.28	6.35
Symplocarpus foetidus	0.21	9.06	**0.40**	**13.88**					0.08	2.25	0.14	5.04
Phalaris arundinacea	0.08	1.66	0.18	6.91	**0.28**	**11.46**			0.10	5.06	0.13	5.02
*Cornus sericea**			0.24	6.51	0.06	0.83	**0.39**	**10.19**	0.10	2.00	0.16	3.91
Solanum dulcamara	0.13	0.31	0.16	1.05	0.31	2.50	0.35	3.27	**0.40**	**5.25**	0.27	2.48
Onoclea sensibilis			**0.21**	**5.26**	0.06	0.14	0.19	2.40	0.13	4.25	0.12	2.41
Carex stricta			0.11	5.33					**0.18**	**5.81**	0.06	2.23
Calamagrostis canadensis	0.08	0.21	0.05	1.71	0.17	0.76	**0.31**	**7.17**	0.08	0.19	0.14	2.01
Carex comosa					**0.25**	**7.50**			0.10	1.19	0.07	1.74
Pilea pumila	0.13	0.83	0.11	0.92	**0.28**	**2.36**	0.19	2.31	0.25	1.25	0.19	1.53
Sparganium eurycarpum					0.06	0.83	**0.15**	**6.35**			0.04	1.44
Geum canadense	**0.25**	**5.10**	0.05	1.97							0.06	1.41
Equisetum arvense			**0.45**	**6.84**			0.08	0.19			0.10	1.41
Cicuta maculata	0.13	2.29	**0.11**	**3.98**							0.05	1.25
Calla palustris	0.08	0.21			**0.11**	**2.99**	0.12	2.12	0.05	0.75	0.07	1.21
Lysimachia thyrsiflora			0.05	0.13			0.12	0.29	**0.45**	**5.63**	0.12	1.21
Aster lateriflorus	**0.17**	**5.00**	0.11	0.26			0.08	0.67			0.07	1.19
*Parthenocissus vitacea**	0.17	2.50	**0.29**	**3.29**					0.05	0.13	0.10	1.18
*Rubus idaeus**	0.13	1.35	**0.16**	**3.88**							0.06	1.05
Solidago gigantea	0.17	1.46	**0.24**	**3.16**					0.08	0.50	0.10	1.02

Appendix C. Continued

Species	Closed Ash Freq N=24	Closed Ash Cover (%)	Open Ash Freq N=38	Open Ash Cover (%)	Flood Maple Freq N=34	Flood Maple Cover (%)	Sedge/Shrub Freq N=26	Sedge/Shrub Cover (%)	Cattail Freq N=40	Cattail Cover (%)	Mean Freq	Mean Cover
Leersia oryzoides			**0.18**	**3.36**	0.08	1.53	0.08	0.19			0.07	1.02
*Acer saccharinum**			0.16	0.39	0.11	1.60	**0.31**	**2.12**	0.20	0.50	0.16	0.92
*Ribes americanum**			**0.21**	**3.95**					0.10	0.25	0.06	0.84
Viola sororia	0.29	1.77	**0.26**	**2.24**			0.08	0.19			0.13	0.84
Trillium flexipes	**0.25**	**2.60**	0.05	1.38							0.06	0.80
Sium suave			0.05	0.46	0.22	0.49	**0.19**	**1.92**	0.13	0.94	0.12	0.76
Urtica dioica	**0.08**	**3.75**									0.02	0.75
Geum aleppicum	**0.25**	**3.13**									0.05	0.63
Geranium maculatum	**0.13**	**1.77**	0.13	1.32							0.05	0.62
Cicuta bulbifera					0.14	0.69	**0.08**	**2.02**	0.15	0.38	0.07	0.62
Rubus pubescens			**0.16**	**2.89**							0.03	0.58
Polygonum arifolium			0.05	0.46	0.06	0.49	0.08	0.19	**0.01**	**1.75**	0.04	0.58
*Fraxinus pennsylvanica**	0.08	0.73	0.05	0.13					**0.05**	**1.88**	0.04	0.55
Glyceria striata	**0.08**	**1.67**	0.11	0.26			0.08	0.67			0.05	0.52
*Fraxinus nigra**	**0.21**	**1.56**	0.11	0.92							0.06	0.50
Rumex orbiculatus							**0.08**	**2.02**	0.05	0.44	0.03	0.49
Alliaria petiolata	**0.08**	**2.19**									0.02	0.44
Iris virginica					**0.14**	**2.01**					0.03	0.40
Lysimachia ciliata			**0.08**	**1.12**					0.08	0.81	0.03	0.39
Arisaema triphyllum	**0.13**	**1.35**	0.08	0.53							0.04	0.38
Solidago canadensis	**0.08**	**0.73**	0.05	0.46			0.08	0.67			0.04	0.37
Mentha arvensis			**0.05**	**1.63**							0.01	0.33
Caltha palustris	**0.13**	**0.83**					0.08	0.67	0.05	0.13	0.05	0.33
Aster puniceus			**0.05**	**1.38**							0.01	0.28
Pontederia cordata									**0.05**	**1.31**	0.01	0.26

Appendix C. Continued

Species	Closed Ash Freq N=24	Closed Ash Cover (%)	Open Ash Freq N=38	Open Ash Cover (%)	Flood Maple Freq N=34	Flood Maple Cover (%)	Sedge/Shrub Freq N=26	Sedge/Shrub Cover (%)	Cattail Freq N=40	Cattail Cover (%)	Mean Freq	Mean Cover
*Cornus racemosa**	**0.08**	**1.25**									0.02	0.25
*Alnus incana**					**0.08**	**1.25**					0.02	0.25
Aster lanceolatus			**0.16**	**1.05**			0.08	0.19			0.05	0.25
Amphicarpaea bracteata			**0.11**	**1.18**							0.02	0.24
Eupatorium maculatum							**0.08**	**0.67**	0.08	0.50	0.03	0.23
Carex vulpinoidea			**0.08**	**0.86**							0.02	0.17
Dryopteris carthusiana	**0.13**	**0.83**									0.03	0.17
Lycopus uniflorus			0.05	0.13			**0.08**	**0.67**			0.03	0.16
*Rhamnus cathartica**	**0.21**	**0.52**	0.08	0.20							0.06	0.14
Scirpus microcarpus			**0.08**	**0.53**							0.02	0.11
Carex bebbii			**0.05**	**0.46**							0.01	0.09
Equisetum sylvaticum			**0.05**	**0.46**							0.01	0.09
Polygonum amphibium			**0.05**	**0.46**							0.01	0.09
Sonchus arvensis			**0.05**	**0.46**							0.01	0.09
Bidens comosa									**0.05**	**0.44**	0.01	0.09
Glyceria grandis					**0.08**	**0.21**	0.08	0.19			0.03	0.08
Bidens connata			**0.08**	**0.20**			0.08	0.19			0.03	0.08
Mitella nuda			**0.08**	**0.20**	0.06	0.14					0.03	0.07
Solidago patula			**0.08**	**0.20**							0.02	0.04
Eupatorium perfoliatum									**0.08**	**0.19**	0.02	0.04
Poa palustris			**0.05**	**0.13**							0.01	0.03
Lemna minor (duckweed)			0.11	0.26	**0.75**	**35.56**	0.73	6.92	0.58	10.19	0.43	10.59
Total (Without duckweed)		74.76		121.39		47.02		90.23		84.87		83.65
Average total herb cover (%)		74.79		85.39		58.09		89.62		71.06		75.79

APPENDIX D. Vascular plants observed in Ulao Swamp. Introduced species are bolded.
LH, Life History: A = annual, B = biennial, P = perennial.
W.I.S., Wetland Indicator Status: OBL = obligate; FACW = facultative wetland; FAC = facultative; FACU = facultative upland; UPL = obligate upland; positive (+) and negative (-) signs indicate a frequency towards wetter and dryer ends of the categories respectively.
C, coefficient of conservatism value ranging from 0-10 (Bernthal 2003).
Vegetation Type, vegetation type in which the species occurred: C = Closed Ash Forest, F = Flooded Maple Forest, O = Open Ash Forest, S = Sedge/Shrub, and T = Cattail Marsh.

Species	Common name	LH	W.I.S.	C	Vegetation Type
Abies balsamea	**Balsam fir**	P	FACW	5	
Acer negundo	Boxelder	P	FACW-	0	C
Acer rubrum	Red maple	P	FAC	3	C, F, T
Acer saccharinum	Silver maple	P	FACW	2	C, F, O, S, T
Acer saccharum	Sugar maple	P	FACU	5	C
Acer spicatum	Mountain maple	P	FACU	6	
Acorus calamus	**Sweet Flag**	P	OBL		
Agrimonia gryposepala	Common agrimony	P	FACU+	2	T
Agrostis gigantea	**Redtop**	P	FACW		
Alisma subcordatum	Southern water-plantain	P	OBL	3	F
Alliaria petiolata	**Garlic-mustard**	B	FAC		C
Alnus incana	Speckled alder	P	OBL	4	F, O
Amelanchier arborea	Downey serviceberry	P	FACU	6	
Amphicarpaea bracteata	Hog peanut	A	FAC	5	C, O, S, T
Aralia nudicaulis	Wild sarsaparilla	P	FACU	6	
Arisaema triphyllum	Jack-in-the-pulpit	P	FACW-	5	C, O
Asclepias incarnata	Swamp milkweed	P	OBL	5	F
Asclepias syriaca	Common milkweed	P		1	
Aster firmus	Shining aster	P	FACW+	6	O
Aster furcatus	Forked aster	P		8	
Aster lanceolatus	White field aster	P	FACW	4	O, S, T
Aster lateriflorus	Calico aster	P	FACW-	3	C, O, S
Aster prenanthoides	Zigzag aster	P	FAC	9	
Aster puniceus	Purple-stemmed aster	P	OBL	5	O
Athyrium filix-femina	Lady fern	P	FAC	5	
Barbarea vulgaris	**Yellow rocket**	P	FAC		
Berberis thunbergii	**Japanese barberry**	P	FACU-		
Betula alleghaniensis	Yellow birch	P	FAC	7	C, O, S, T

Species	Common name	LH	W.I.S.	C	Vegetation Type
Betula papyrifera	White or Paper birch	P	FACU+	3	F, O
Bidens comosa	Strawstem beggar-ticks	P	FACW	5	C, S. T
Bidens connata	Purple-stmd beggar-ticks	A	OBL	6	C, F, O, S, T
Bidens frondosa	Devil's beggar-ticks	A	FACW	1	S, T
Boehmeria cylindrica	False nettle	P	OBL	6	
Bromus sp.		P			O, T
Calamagrostis canadensis	Bluejoint grass	P	OBL	5	C, F, O, S, T
Calla palustris	Water arum	P	OBL	9	C, F, S, T
Caltha palustris	Marsh marigold	P	OBL	6	C, F, O, S, T
Cardamine rhomboidea	Spring cress	P	OBL	6	
Carex alopecoidea	Sedge	P	FACW+	5	
Carex bebbii	Sedge	P	OBL	4	O
Carex blanda	Sedge	P	FAC	3	
Carex bromoides	Sedge	P	FACW+	8	O
Carex brunnescens	Sedge	P	FACW	7	T
Carex comosa	Sedge	P	OBL	5	F, S, T
Carex cristatella	Sedge	P	FACW+	4	C
Carex disperma	Sedge	P	OBL	10	
Carex gracillima	Sedge	P	FACU	5	O
Carex granularis	Sedge	P	FACW+	3	C, O
Carex hystericina	Sedge	P	OBL	3	
Carex intumescens	Sedge	P	FACW+	5	C, F, O
Carex lacustris	Sedge	P	OBL	6	F, O, S, T
Carex lasiocarpa	Sedge	P	OBL	9	
Carex pseudocyperus	Sedge	P	OBL	8	F
Carex retrorsa	Sedge	P	OBL	6	
Carex stipata	Sedge	P	OBL	2	O
Carex stricta	Sedge	P	OBL	7	O, S, T
Carex vulpinoidea	Sedge	P	OBL	2	F, O
Carpinus caroliniana	Musclewood	P	FAC	6	C, O
Carya ovata	Shagbark hickory	P	FACU	5	
Chelone glabra	White turtlehead	P	OBL	7	
Cicuta bulbifera	Bulb-brng. wtr. hemlock	P	OBL	7	C, F, S, T
Cicuta maculata	Common water hemlock	P	OBL	6	C, O, S
Cinna arundinacea	Common woodreed	P	FACW	5	F
Circaea lutetiana	Enchanter's nightshade	P	FACU	2	C
Cirsium muticum	Swamp thistle	B	OBL	8	
Cornus racemosa	Gray dogwood	P	FACW-	2	C, O
Cornus sericea	Red osier dogwood	P	FACW	3	C, F, O, S, T

Species	Common name	LH	W.I.S.	C	Vegetation Type
Crataegus spp.	Hawthorne	P			C
Daucus carota	**Wild carrot**	B			C
Dryopteris carthusiana	Toothed wood fern	P	FACW-	7	C, O, T
Echinocystis lobata	Wild cucumber	A	FACW-	2	
Elymus hystrix	Bottlebrush grass	P		6	
Elymus virginicus	Virginia wild rye	P	FACW-	6	C, O
Epilobium coloratum	Eastern willow herb	P	OBL	3	
Epilobium leptophyllum	Marsh willow herb	P	OBL	8	
Epipactis helleborine	**Broadleaf helleborine**	P			
Equisetum arvense	Common horsetail	P	FAC	1	O, S, T
Equisetum sylvaticum	Woodland horsetail	A	FACW	7	O
Erigeron philadelphicus	Philadelphia daisy	B	FACW	2	T
Erigeron strigosus	Rough fleabane	P	FAC-	2	
Eupatorium maculatum	Spotted joe-pye weed	P	OBL	4	O, S, T
Eupatorium perfoliatum	Boneset	P	FACW+	6	S, T
Eupatorium rugosum	White snakeroot	P	FACU	1	
Euthamia graminifolia	Flat-topped goldenrod	P	FAC	4	
Fagus grandifolia	American beech	P	FACU	8	
Fragaria virginiana	Wild strawberry	P	FAC-	1	C, O
Fraxinus nigra	Black ash	P	FACW+	8	C, F, O, S, T
Fraxinus pennsylvanica	Green ash	P	FACW	2	C, F, O, S, T
Galium trifidum	Bedstraw	P	FACW+	6	
Galium triflorum	Sweet-scented bedstraw	P	FACU+	5	S
Geranium maculatum	Wild geranium	P	FACU	4	C, O
Geum aleppicum	Yellow avens	P	FAC+	3	C, O
Geum canadense	White avens	P	FAC	2	C, O, T
Geum rivale	Water avens	P	OBL	8	C
Glechoma hederacea	**Gill-over-the-ground**	P	FACU		C
Glyceria grandis	American mannagrass	P	OBL	6	F, O, S
Glyceria striata	Fowl mannagrass	P	OBL	4	C, O, S
Hamamelis virginiana	Witch hazel	P	FACU	7	
Helenium autumnale	Common sneezeweed	P	FACW+	4	
Heracleum lanatum	Cow parsnip	P	FACW	3	
Hydrophyllum virginianum	Eastern water leaf	P	FACW-	4	
Hypericum punctatum	Spotted St. John's Wort	P	FAC+	4	
Ilex verticillata	Winterberry	P	FACW+	7	C, F, O, S, T
Impatiens capensis	Jewelweed	A	FACW	2	C, F, O, S, T
Iris virginica	Southern blue flag	P	OBL	5	F, S, T
Juncus tenuis	Path-rush	P	FAC	1	

Species	Common name	LH	W.I.S.	C	Vegetation Type
Juniperus communis	Common juniper	P		3	
Laportea canadensis	Nettle	P	FACW	4	O
Larix laricina	Tamarack	P	FACW	8	
Leersia oryzoides	Rice cut grass	P	OBL	3	C, F, O, S
Lemna minor	Lesser duckweed	P	OBL	4	C, F, O, S, T
Lilium michiganense	Michigan lily	P	FAC+	6	
Lonicera morrowii	**Morrow honeysuckle**	P	NI		
Lonicera tatarica	**Tartarian honeysuckle**	P	FACU		C, O
Lycopus americanus	Am. water-horehound	P	OBL	4	
Lycopus uniflorus	Bugleweed	P	OBL	4	O, S
Lycopus virginicus	Virginia water-horehound	P	OBL	8	O
Lysimachia ciliata	Fringed loosestrife	P	FACW	5	O, T
Lysimachia thyrsiflora	Swamp loosestrife	P	OBL	7	C, F, O, S, T
Lythrum salicaria	**Purple loosestrife**	P	OBL		
Maianthemum canadense	Canada mayflower	P	FAC	5	F, T
Matteuccia struthiopteris	Ostrich fern	P	FACW	5	
Mentha arvensis	Field mint	P	FACW	3	F, O, S
Mimulus ringens	Monkey-flower	P	OBL	6	
Mitella nuda	Naked mitrewort	P	FACW	9	C, F, O, S, T
Monarda fistulosa	Wild bergamot	P	FACU	3	
Muhlenbergia mexicana	Wirestem muhly	P	FACW	4	S
Onoclea sensibilis	Sensitive fern	P	FACW	5	C, F, O, S, T
Osmorhiza claytonii	Bland sweet cicely	P	FACU-	5	
Osmunda cinnamomea	Cinnamon fern	P	FACW	7	
Ostrya virginiana	Hop-hornbeam	P	FACU-	5	C
Parthenocissus vitacea	Grape woodbine	P	FACU	4	C, O, S, T
Pedicularis lanceolata	Swamp lousewort	P	FACW+	8	
Phalaris arundinacea	**Reed canary grass**	P	FACW+		C, F, O, T
Phleum pratense	**Timothy**	P	FACU		
Pilea pumila	Clearweed	A	FACW	3	C, F, O, S, T
Poa alsodes	Bluegrass	P	FACW-	5	O
Poa palustris	Fowl meadow grass	P	FACW+	5	C, F, O
Poa saltuensis	Bluegrass	P		7	C, S
Podophyllum peltatum	May-apple	P	FACU	4	C
Polygonum amphibium	Water smartweed	P	OBL	5	O
Polygonum arifolium	Halberd-leaved tearthumb	A	OBL	7	F, O, S, T
Polygonum caespitosum	**Smartweed**	P	UPL		
Polymnia canadensis	Pale-flowered leaf cup	P		7	
Pontederia cordata	Pickerel-weed	P	OBL	8	O, S, T

Species	Common name	LH	W.I.S.	C	Vegetation Type
Populus deltoides	Cottonwood	P	FAC+	2	
Populus tremuloides	Quaking aspen	P	FAC	2	
Potentilla anserina	Silver-weed	P	FACW+	4	
Potentilla norvegica	Strawberry weed	A	FAC	0	O
Potentilla recta	**Sulphur cinquefoil**	P			
Potentilla simplex	Old-field five-fingers	P	FACU-	2	
Prunella vulgaris	Self heal	P	FAC	1	T
Prunus americana	Wild plum	P	UPL	3	
Prunus serotina	Wild black cherry	P	FACU	3	
Prunus virginiana	Choke cherry	P	FAC-	3	C, S
Quercus bicolor	Swamp white oak	P	FACW+	7	C, O
Quercus rubra	Northern red oak	P	FACU	5	
Ranunculus flabellaris	Yellow buttercup	P	OBL	8	
Ranunculus hispidus	Hispid buttercup	P	FAC	6	
Ranunculus recurvatus	Hooked buttercup	P	FACW	5	C
Ranunculus sceleratus	Cursed crowfoot	P	OBL	3	F
Rhamnus cathartica	**Common buckthorn**	P	FACU		C, O, T
Rhamnus frangula	**Glossy buckthorn**	P	FAC+		O
Ribes americanum	Wild black current	P	FACW	4	C, O, S, T
Ribes cynosbati	Dogberry	P		3	C
Rosa blanda	Smooth rose	P	FACU	4	T
Rosa palustris	Swamp rose	P	OBL	7	F, O, S, T
Rubus idaeus	Red raspberry	P	FACW-	3	C, O
Rubus occidentalis	Black raspberry	P		2	
Rubus parviflorus	Thimbleberry	P	FACU+	7	C
Rubus pubescens	Dwarf raspberry	P	FACW+	7	C, O, S, T
Rumex orbiculatus	Great water dock	P	OBL	8	O, S, T
Sagittaria latifolia	Common arrowhead	P	OBL	3	
Salix amygdaloides	Peach leaf willow	P	FACW	4	
Salix bebbiana	Bebb's willow	P	FACW+	7	
Salix eriocephala	Diamond willow	P	FACW+	4	
Salix exigua	Sandbar willow	P	OBL	2	
Salix nigra	Black willow	P	OBL	4	
Salix pedicellaris	Bog willow	P	OBL	8	
Salix petiolaris	Slender willow	P	FACW+	6	O, S
Sanguinaria canadensis	Bloodroot	P	FACU-	6	
Saxifraga pensylvanica	Swamp saxifrage	P	OBL	7	C, O
Scirpus atrovirens	Black bulrush	P	OBL	3	
Scirpus cyperinus	Woolgrass	P	OBL	4	

Species	Common name	LH	W.I.S.	C	Vegetation Type
Scirpus microcarpus	Bulrush	P	OBL	6	O
Scirpus validus	Softstem bulrush	P	OBL	4	
Scutellaria galericulata	Marsh skullcap	P	OBL	5	S
Scutellaria lateriflora	Mad dog skullcap	P	OBL	5	
Sicyos angulatus	Bur-cucumber	A	FACW-	5	
Sium suave	Water parsnip	P	OBL	5	F, O, S, T
Smilacina trifolia	False Solomon's seal	P	OBL	10	O, F
Solanum dulcamara	**Bittersweet nightshade**	P	FAC		C, F, O, S, T
Solidago canadensis	Canada goldenrod	P	FACU	1	C, O, S, T
Solidago gigantea	Smooth goldenrod	P	FACW	3	C, O, T
Solidago patula	Rough-leaved goldenrod	P	OBL	8	O, S
Sonchus arvensis	**Perennial sow-thistle**	P	FAC-		O
Sparganium eurycarpum	Giant bur-reed	P	OBL	5	F, S
Sphenopholis intermedia	Wedge grass	A/P	FAC	7	O
Spiraea alba	Meadowsweet	P	FACW+	4	F, T
Stachys palustris	Hedge-nettle	P	OBL	5	O
Symplocarpus foetidus	Skunk cabbage	P	OBL	8	C, F, O, T
Taraxacum officinale	**Common dandelion**	P	FACU		
Thalictrum dasycarpum	Purple meadow-rue	P	FACW-	4	C, T
Thelypteris palustris	Marsh fern	P	FACW+	7	T
Thuja occidentalis	Northern white cedar	P	FACW	9	
Tilia americana	Basswood	P	FACU	5	C, F, O
Toxicodendron radicans	Common poison-ivy	P	FAC+	4	
Triadenum fraseri	Marsh St. John's wort	P	OBL	8	T
Trillium flexipes	Bent trillium	P	FAC-	7	C, O
Typha sp.	Cattail	P	OBL		F, O, S, T
Ulmus americana	White or American elm	P	FACW-	3	C, F, O, S, T
Ulmus rubra	Slippery or red elm	P	FAC	4	O
Urtica dioica	Stinging nettle	P	FAC+	1	C
Verbena hastata	Common vervain	P	FACW+	3	
Verbena urticifolia	White vervain	A/P	FAC+	2	
Veronica scutellata	Narrow-leaved speedwell	P	OBL	5	T
Viburnum dentatum	**Arrow-wood**	P	FACW-		F
Viburnum lentago	Nannyberry	P	FAC+	4	O
Viburnum opulus	High-bush cranberry	P	FACW		C, O, T
Viburnum rafinesquianum	Downey arrow-wood	P		7	
Viola sororia	Dooryard violet	P	FACU	3	C, F, O, S, T
Vitis riparia	River-bank grape	P	FACW-	2	