Potential Indicators for Assessing Biological Integrity of Forested, Depressional Wetlands in Southern Michigan

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Introduction

Report Organization

During 1999 and 2000 an effort was made to locate and sample conifer and hardwood swamps in southern Michigan. This report summarizes the results of vegetation sampling at 9 conifer and 7 hardwood forested wetlands. Included as an appendix in this report are the results of surveys for the tamarack tree cricket (*Oecanthus laricis*), a rare species that inhabits tamarack (*Larix laricina*) (Appendix A) and results from the first year of hydrologic monitoring at the six conifer swamps we sampled in 1999 (Appendix B).

Forested Wetland Community Types

Forested wetlands occur throughout Lower Michigan and account for much of the remaining forested lands in the region. Several types of forested wetlands occur in southern Michigan and are distinguished by their landscape context and species composition. Some of the largest remaining tracks of forested wetlands occur along the floodplains of the large rivers that flow through the area such as the Grand River, Kalamazoo River, St. Joseph River, and Maple River. The southern floodplain forest community type is typically dominated by hardwood species such as red ash, silver maple, red maple, and sycamore. Other types of forested wetlands occur in isolated, ice-block depressions, and within glacial outwash channels. Though these systems, especially those in outwash channels, may be associated with small streams, they are not strongly influenced by large river processes such as flowing floodwaters, deposition, and ice scour. This report focuses on the forested wetlands occurring in depressions and glacial outwash channels that are not directly influenced by large river systems. For the purposes of this report we refer to these wetlands as forested, depressional wetlands.

Several types of forested, depressional wetlands occur in southern Michigan and can be relatively easily distinguished by their overstory composition, general soil type (e.g., mineral or organic soil), and soil pH. Two types of conifer-dominated swamps occur in southern Michigan and though both typically occur on deep organic soils, they differ substantially in their soil pH and species composition. Hardwood-dominated, forested, depressional wetlands may occur on either mineral or organic soil and are easily distinguished from conifer swamps by their overstory composition.

Conifer swamps in southern Michigan may be dominated by black spruce (*Picea mariana*), tamarack, or white cedar (*Thuja occidentalis*) and may also contain low numbers of other conifers such as white pine (*Pinus strobus*), red cedar (*Juniperus virginiana*) and jack pine (*Pinus banksiana*). Typically, black spruce is restricted to sites with a low soil pH (e.g., 4.0 - 4.5) or high acidity. Conifer swamps dominated by black spruce are often referred to as black spruce bogs and are classified as a poor conifer swamp community (MNFI 1989). In fact, poor conifer swamps are hydrologically very similar to bogs as both community types are considered to be ombrotrophic wetlands that are isolated from groundwater by very deep organic soils. Southern Michigan poor conifer swamps typically occur in isolated depressions on deep (>3 m) organic peat and muck soil. In the absence of black spruce, these acidic sites may be dominated by tamarack, which also usually occurs as part of the overstory within the black spruce-dominated sites.

It is likely that the poor conifer swamps present today in southern Michigan were once open bogs, that overtime, were colonized by black spruce and/or tamarack (Curtis 1959). In fact, poor conifer swamps are also sometimes referred to as treed bogs (Kudray 1999). The process of colonization of open bog by black spruce and tamarack may have been hastened by the suppression of fire following settlement. In the absence of fire, successional processes in these ecosystems have continued with hardwood species such as silver maple and red maple colonizing these sites. The outer edges of many southern Michigan poor conifer swamps are dominated by silver maple (*Acer saccharinum*) and/or red maple (*Acer saccharum*) and contain numerous dead, standing black spruce and tamarack. Both tamarack and black spruce are light demanding species and are not capable of remaining viable or successfully regenerating under the dense shade of a hardwood-dominated canopy.

Because both tamarack and black spruce are spire shaped, they allow sunlight to reach the sub-canopy and forest floor. Consequently, the shrub layer in southern Michigan poor conifer swamps is extremely well developed. Smooth highbush blueberry

(*Vaccinium corymbosum*) typically dominates the shrub layer along with black chokeberry (*Aronia prunifolia*) and winterberry (*Ilex verticillata*). The ground layer of southern Michigan's poor conifer swamps is dominated by sphagnum mosses with Virginia chain fern (*Woodwardia virginica*), pink lady's slipper (*Cypripedium acaule*), starflower (*Trientalis borealis*) and Canada mayflower (*Maianthemum canadensis*) also commonly occurring.

Another type of conifer swamp common to southern Michigan and also dominated by tamarack is the rich conifer swamp. This community type may also be referred to as a relict conifer swamp (MNFI 1989). Rich conifer swamp is distinguished from poor conifer swamp by the high soil pH (e.g., 7.0 – 8.0), or alkalinity. Rich conifer swamps typically occur in glacial outwash channels rather than as isolated depressions. The dominant tree species in southern Michigan's rich conifer swamps is typically tamarack, although white cedar, white pine, and red cedar may also be present. Further north, in mid and northern Lower Michigan and throughout the Upper Peninsula, rich conifer swamps are dominated by white cedar. Unlike poor conifer swamp mentioned above, the hydrology of rich conifer swamp is greatly influenced by groundwater.

Because the underlying glacial till of these ecosystems is high in calcium and magnesium, the groundwater that maintains these systems is high in alkalinity. Hydrologically, rich conifer swamp is very similar to prairie fen, as both community types are dependent on mineral rich, alkaline groundwater seeps. The strong influence of alkaline, mineral-rich groundwater on the vegetation of both prairie fen and rich conifer swamp in southern Michigan put these communities into a class of wetlands known as minerotrophic wetlands. The soil profiles of both communities are also very similar with both typically containing a thick layer of marl, a gray-colored, calcium carbonate precipitate. Because of their similar landscape context, hydrology, and soils, prairie fen and rich conifer swamp share many of the same species and thus rich conifer swamps are sometimes referred to as treed fens (Kudray and Gale 1997).

Similar to the processes responsible for conversion of open bog to poor conifer swamp, it is likely that many of the rich conifer swamps occurring in southern Michigan were once open prairie fen, that overtime, were colonized by tamarack as a result of fire suppression following European settlement. In the absence of fire, successional processes have continued, with red maple invading rich conifer swamp. It is common to find dead, standing and fallen tamaracks under the broad canopy of red maple in many of southern Michigan's hardwood-dominated, forested wetlands. Because tamarack requires high levels of sunlight to reach maturity and remain healthy, it does not successfully regenerate or remain viable in the heavily shaded conditions produced by invading hardwood species such as red maple.

In the past, ecological processes such as fire, beaver-induced flooding, and insect outbreaks probably kept the boundary between rich conifer swamp and prairie fen, and poor conifer swamp and open bog, in continuous flux within the southern Michigan landscape. In the absence of both fire and beaver-induced flooding, and possibly because of a reduction in insect outbreaks due to fragmentation (e.g., larch sawfly), many once open wetlands are now dominated by woody species. In addition, the exclusion of fire, particularly from the Interlobate region of southern Michigan, has allowed red maple to invade oak forests and consequently, spread into the adjacent conifer-dominated wetlands. Fire suppression in the uplands, particularly in the Interlobate region, may be especially responsible for the invasion of red maple into the conifer swamps of southern Michigan. The increase in red maple abundance in northeastern North America following European settlement is well documented (Abrams 1998).

Because of the high level of light that penetrates the spire-shaped tamarack canopy, southern Michigan's rich conifer swamps support a very dense and diverse shrub layer. Species that dominate the shrub layer of most rich conifer swamps in southern Michigan include winterberry, smooth highbush blueberry, poison sumac (*Toxicodendron vernix*), gray dogwood (*Cornus foemina*), and silky dogwood (*Cornus amomum*). The ground-layer vegetation is composed of a heterogeneous mixture of shade tolerant and light-demanding wetland species. Microtopography is extremely varied with large tamarack root masses elevated above both open and shaded, muck-lined pools. Tree tip-up mounds are also abundant and add to the community's complex microtopography and structure. The tamarack root masses typically support species such as Canada mayflower, sedge (*Carex leptalea*), dwarf raspberry (*Rubus pubescens*), and violet (*Viola* sp.), while the adjacent pools harbor species such as spotted touch-me not (*Impatiens capensis*), water hemlock, (*Cicuta bulbifera*), and tall swamp-marigold (*Bidens coronatus*).

The hardwood-dominated depressional wetlands in southern Michigan are referred to as a southern swamp community. Southern swamp is typically dominated by hardwoods such as black ash (*Fraxinus nigra*), red ash (*Fraxinus pensylvanica*), yellow birch (*Betula alleghaniensis*), American elm (*Ulmus americana*), red maple and silver maple. Southern swamp typically occurs on mineral soils but may also be found on deep organic soils where hardwoods have invaded conifer swamps. It is found in depressions and channels of ground moraines, on glacial lake plains, and in depressions of glacial outwash associated with end moraines (MNFI 1989). More information is needed to determine if species composition, hydrology, or soil differences among different hardwood-dominated, forested wetland types are great enough to warrant the recognition of several different hardwood swamp community types. A better understanding of southern swamp is especially important for achieving conservation objectives that strive to protect the most intact examples of this community type.

If there are several very different and distinct hardwood swamp community types, as is the case for conifer-dominated wetlands, it will be difficult to recognize high quality examples of each type without a clear understanding of the communities. For example, even the most pristine poor conifer swamp may have less plant diversity than a disturbed rich conifer swamp. If all conifer-dominated wetlands were treated as the same community type, the poor conifer swamps would likely be considered lower quality than the inherently, species-rich, rich conifer swamps. This example serves to highlight the importance of having a thorough knowledge of forested wetland types so that the highest quality examples of each can receive the greatest amount of protection. Hardwood-dominated, forested, depressional wetlands may require further study to determine if the southern swamp community type is composed of several distinct community types.

Objectives

The objectives of this study were to identify high quality examples of southern Michigan forested, depressional wetlands and to determine biological factors that may be measured to assess a site's overall quality. In particular, we conducted vegetation and soil sampling in both conifer-dominated and hardwood-dominated, forested, depressional wetlands and used the information to derive a set of ecological factors that could be measured to determine the quality of a particular site. It is expected that this information will be used by the Michigan Department of Environmental Quality in their assessment of forested wetlands during the wetland permitting process.

Methods

In all, 16 forested, depressional wetlands were chosen for sampling. Sites were chosen to represent a range of conditions. Six tamarack swamps were sampled between June 3 - July 2, 1999, and 3 between June 15 - July 14, 2000. Seven hardwood-dominated wetlands were sampled between August 18 - September 3, 1999. Conifer swamp sites occurred within 3 sub-subsections including the Jackson Interlobate, Battlecreek Outwash Plain, and Cassopolis Ice-Contact Ridges (Figure 1) (Albert 1995). Hardwood sites occurred within the same sub-subsections as well as the Lansing Tillplain.

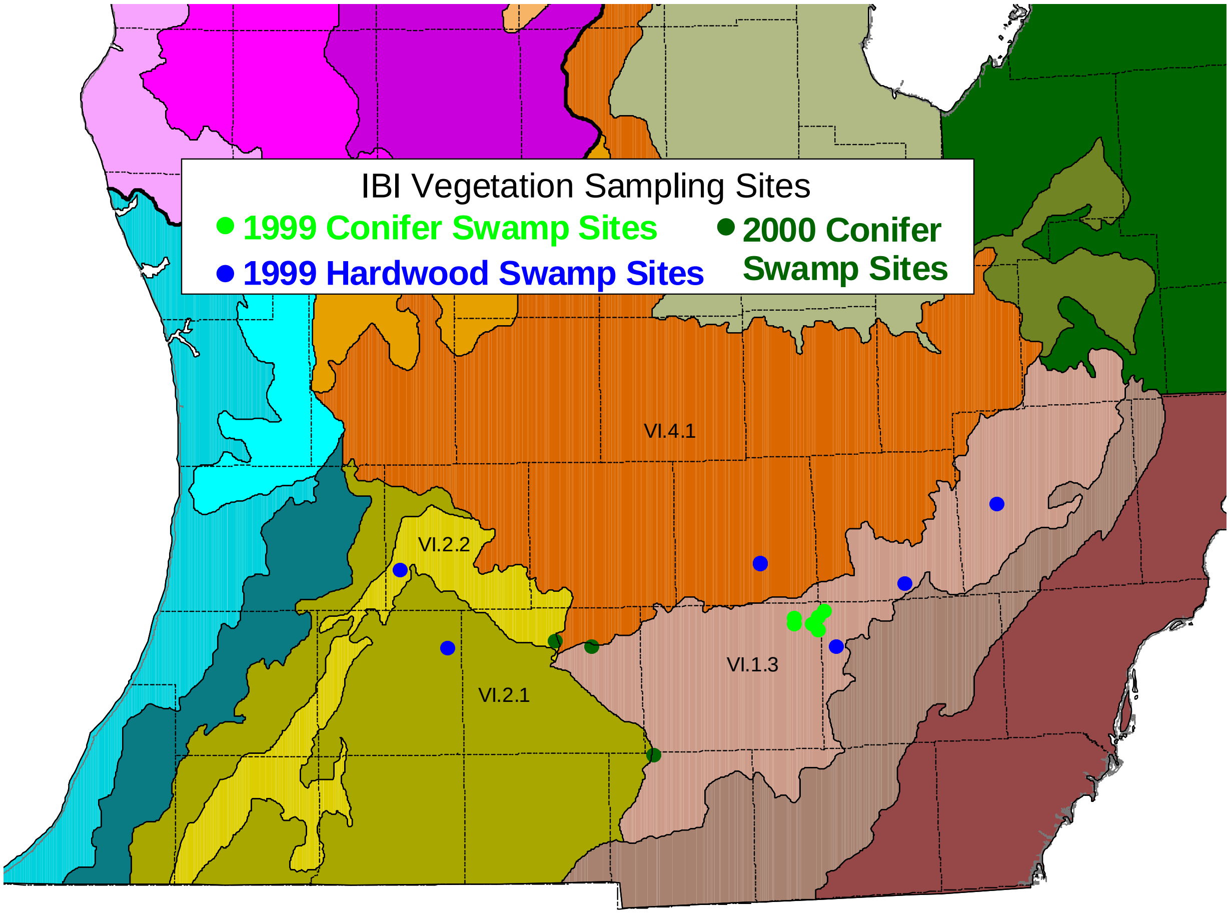


Figure 1. Sampling sites by sub-subsection. Sub-subsections are as follows: VI.1.3, Jackson Interlobate; VI.2.1, Battle Creek Outwash Plain; VI.2.2, Cassopolis Ice-Contact Ridges; VI.4.1, Lansing Tillplain (Albert 1995).

1999 Methods

Sampling occurred along transects placed parallel to the hydrologic gradient. All transects were randomly located within the wetland. Using a random start, sample plots were systematically placed along transects at 15 m intervals. At each sample location, a ground-layer plot and shrub-layer line intercept were nested within a larger (100-m^2) tree plot. The ground layer was sampled by recording species presence within .25m^2 plots.

Shrub layer sampling utilized a 5-m line intercept placed perpendicular to the transect. Cover for each species was estimated by reading the intercept cover to the nearest decimeter directly from the measuring tape (White 1965). All shrub species $\geq$.5 m in height, and tree and vine species between .5 m and 2 m in height were included in the shrub-layer samples.

Tree sampling utilized 100-m^2 circular plots. The diameter at breast height (dbh) was recorded in centimeters for all tree species greater than 2 m in height and at least 1 cm in diameter. Tree species frequently referred to as shrubs such as Juneberry (*Amelanchier arborea*), hornbeam (*Carpinus caroliniana*), and nannyberry (*Viburnum lentago*) were counted as trees when they met the size criteria.

Because of the small size of the Fort Custer site (e.g., < 1/6 ha, or 57 m x 34 m) we were forced to modify our sampling methods. At this site we ran one line transect, lengthwise (e.g., 57 m), across the site and sampled ground layer plots every 5 m on alternate sides of the transect line. Shrub line intercepts were placed perpendicular to the transect and were also placed on alternate sides of the transect every 5 m. Tree sampling utilized a single 10 m wide belt transect (e.g., 57 m x 10 m).

While plot sampling we also recorded the presence of species that did not occur within one of the sample plots. However, no exhaustive meander surveys were conducted.

Soil type, pH, texture, and organic-matter depth were recorded along a transect at each of the sites.

Hydrology was monitored by Dave Merkey, as part of his doctoral research at the University of Michigan, at the six conifer sites sampled in 1999 (e.g., M52, Leeke, Portage, Huttenlocker, Waterloo, and Harr) (Appendix B). A ground water monitoring well was placed at each site. Hydrologic monitoring included recording monthly water levels, alkalinity, and conductivity.

Analysis

The percent frequency of each species occurring within the ground layer was calculated and a percent site frequency was derived based on species presence within all sites. Using the ground-layer plot data, the mean number of species per ground-layer plot was calculated and a Species Richness Index (SRI) was derived for the ground layer at each site (Bowles et al. 2001). To characterize the shrub layer, the cover of each species within each 5-m intercept was summed to derive a total cover value for each species and site. A species and site percent cover was calculated by dividing their total cover values by the total length of all intercepts at a site and multiplying by 100. The percent frequencies of each shrub layer species was calculated based on its occurrence along the line intercepts. An importance value was also derived for each species within the shrub layer at the conifer swamp sites by summing their relative cover and relative frequency values. For the tree layer, tree density (trees/ha), relative density, cover (basal area m^2/ha), relative cover, percent frequency and percent relative frequency were calculated for each tree species at each site. An importance value was also calculated for each tree species at each site by summing the relative density, relative cover, and relative frequency for each species.

A univariate analysis of variance (ANOVA), using plots within sites as replicates, was performed to compare site differences in the number of species per ground-layer plot, number of shrub-layer species per line intercept, shrub-layer intercept cover, tree-plot density, and tree-plot cover at all conifer swamps sampled in 1999. All significant results were followed by a Tukey's post-hoc test to determine the source of significant site differences.

A Floristic Quality Index (FQI) (Wilhelm and Masters 1999) was derived for each site using the species lists that included all species occurring within a sample plot as well as species observed outside of our plots.

To compare the sites sampled duing 1999 a cluster diagram was constructed in PC-ORD version 4.0 (McCune and Mefford 1999) using a cluster flexible beta value of -.5. The data set for the cluster analysis utilized species lists derived from species presence within plots and included only species occurring in least 3 sites.

2000 Methods

In June and July of 2000 we sampled 3 tamarack-dominated swamps in southwest Michigan. The methods used in vegetation and soil sampling differed little from those used during the previous year. We did, however, attempt to expedite the vegetation sampling by using fewer sample plots, and by not recording the presence of shrub/tree species such as Juneberry, nannyberry, and hornbeam within the tree layer plots. Consistent with our 1999 sampling methods, these species were recorded as part of the shrub layer sampling when encountered. Soil samples for the 2000 field season consisted of a single soil core taken along a vegetation sampling transect.

Vegetation data analysis included calculating ground-layer species frequencies and mean plot species richness, shrub-layer species percent cover and percent total cover, FQI and SRI values, site species richness, and examining our tree-layer data for evidence of tamarack regeneration.

Site Descriptions

Conifer Swamp Site Descriptions

M52, Washtenaw County (T1S, R3E section 7)
This 80+-acre wetland may be one of the largest contiguous tamarack-dominated wetlands remaining in southern MI. A headwater stream emanates from the wetland. While a small portion of the wetland lies within the Waterloo Recreation Area, the majority of the wetland is owned by 3 private landowners, 2 of which gave MNFI staff permission to enter the swamp. Row crops border the north end of the wetland. Scattered residential housing occurs in the uplands south of the site. Small patches of prairie fen and sedge meadow occur along both the north and south edges of the wetland. The eastern portion of the wetland contains a leatherleaf bog with stunted tamaracks. Our sampling concentrated on the thick tamarack swamp located in the north-central portion of the wetland and was adjacent to a small patch of prairie fen along the wetland's perimeter. The site was chosen for sampling because of its extensive size.

Leeke, Jackson County (T1S, R2E section 13)
This 40-acre tamarack swamp occurs adjacent to Leeke Lake within an extensive wetland complex at the Waterloo State Recreation Area. Sedge meadow and cattail marsh surround the swamp on the other three sides. The site is within 1 mile of the M52 swamp. It was chosen for sampling because of its large size, and relatively intact landscape context and condition.

Portage, Jackson County (T1S, R2E section 20)
The site is part of an extensive wetland complex within the Waterloo State Recreation Area. The tamarack swamp is approximately 40 acres in size and is bordered by several residential homes to the north. One of the homeowners granted us permission to access the site through his property. The swamp borders a small, unnamed lake and cattail marsh to the south. A headwater stream originates from the tamarack swamp and flows into the lake. The site was chosen for sampling because of its large size and relatively intact landscape context and condition.

Harr, Jackson County (T1S, R2E section 23)
The tamarack swamp at Harr Road is approximately 5 acres in size and is bordered by several acres of reed-canary-grass marsh to the west and north and an extensive cattail marsh to the south and west. A thin band of shrubby sedge meadow along its south edge separates the island of tamarack from cattail marsh. The site is within the Waterloo Recreation Area. The tamarack swamp at this site was chosen for sampling because of its small size and because it is surrounded by invasive graminoid species.

Waterloo, Jackson County (T1S, R2E section 25)
This swamp is within the Waterloo State Recreation Area and borders a farm, road, upland forest, and old field. The site grades into an expansive cattail marsh to the east and north. The site appears permanently flooded by several feet of standing water, possibly as a result of artificial damming caused by the road along the south border of the wetland. The site was chosen because it contained numerous dead, standing tamaracks and it appeared degraded.

Huttenlocker, Jackson County (T1S, R2E section 17)
The tamarack swamp borders row crop agriculture to the north and south. The west edge of the swamp borders a reed-canary-grass marsh along Huttenlocker Rd. We chose to sample this site because of the site's close proximity to the Huttenlocker Rd., row crop agriculture, and the presence of reed canary grass, an invasive species. Although the immediate area surrounding our sampling locations appeared impacted, the site is actually part of an extensive tamarack swamp that also contains a small lake surrounded by a bog with stunted tamaracks.

J Ave., Calhoun County (T2S, R5W section 3)
J Ave. is a 55-acre tamarack-dominated swamp that differs significantly in appearance from the other conifer swamps because sphagnum mosses dominate its ground layer. A small lake occurs near the center of the swamp. The site is surrounded by row crop agriculture. A short, narrow wetland corridor links this site with a larger wetland complex to the north. Although the site differs significantly from the other conifer-dominated wetlands we sampled, it was chosen for sampling so that our methods could be tested in this type of conifer swamp.

Ionia, Eaton County (T1S, R6W section 34)
This 50-acre tamarack-dominated site is part of a large wetland complex (e.g., approx. 120 acres) that is surrounded by agriculture. A small headwater stream emanates from the wetland and flows through the tamarack swamp. It was chosen for sampling because of its large size.

Fish Lake, Cass County (T5S, R13W section 5)
The 40-acre tamarack swamp at the Fish Lake site is part of a large wetland complex (e.g., approx. 130

acres) that borders the north side of Fish Lake. The tamarack swamp is located in the northern portion of the wetland complex. A headwater stream emanates from the tamarack swamp. The site is bordered by agriculture. It was chosen for sampling because of its large size.

Hardwood Swamp Site Descriptions

Barry, Barry County (T2N, R10W section 33)
This site is a hardwood-dominated swamp forest within the Barry State Game Area. The forested wetland borders a steep, ice-contact ridge that supports an oak-hickory forest. The forested wetland borders a large wet meadow dominated by cut-grass (*Leersia oryzoides*). A tamarack swamp occurs a short distance (e.g., < 1 mile) south of the site. Several groundwater monitoring wells were placed in the wetland by MSU. This site was chosen for sampling because it was being studied by MSU researchers.

Dansville Pool, Ingham County (T2N, R1E section 33)
Located within the Dansville State Game Area this large, forested vernal pool is underlain by fine silt and clay. A narrow shrub zone occurs where the wetland meets an upland pine plantation. Further from the upland, in the center of the pool are numerous, large dead-standing and fallen hardwoods. This site borders Dansville Swamp (see below). This was one of the sites in which MSU researchers had placed groundwater monitoring wells. It was chosen for sampling because it was being studied by MSU researchers.

Dansville Swamp, Ingham County (T2N, R1E section 33)
This site is a hardwood-dominated swamp containing several large widely scattered tamaracks as well as many dead-standing and fallen tamaracks. The site borders Dansville Pool (see above) and is also located within the Dansville State Game Area. It was chosen for sampling because of its relatively intact condition and landscape context.

Fort Custer, Kalamazoo County (T2S, R9W section 3)
This site occurs within in Fort Custer State Park and consists of a small (e.g., 57 m x 34 m), forested vernal pool located approximately 40 m from a road and surrounded by an old field. The vernal pool is underlain by clay and ringed by poison ivy and red-ash seedlings. Adjacent to the vernal pool are the typical assemblage of old field, invasive species including autumn olive (*Elaeagnus umbellata*), European buckthorn (*Rhamnus cathartica*), honeysuckle (*Lonicera morrowii*), and Kentucky bluegrass (*Poa compressa, Poa pratensis*). The exotic purple loosestrife (*Lythrum salicaria*) occurs within a small depression in the old field, 10 m south of the forested vernal pool. Old plow lines or possibly ruts from a tracked-vehicle are present in the old field adjacent the vernal pool. A monitoring well was placed at this site by MSU researchers. The site was chosen for sampling because it was being studied by MSU researchers.

Geology Center, Jackson County (T2S, R3E section 9)
This site is located at the Geology Center in the Waterloo Recreation Area. It occurs within an area of former ice-contact and is bordered by steep-sided hills supporting oak forest. Several upland islands of American beech occur within the wetland. The swamp forest occupies a depression between two lakes, Cedar Lake and a small, unnamed lake. Tamaracks surround portions of both lakes and a bog containing stunted tamaracks borders the eastern bay of Cedar Lake. This bog grades into the hardwood swamp forest where we sampled. Like Dansville Swamp discussed above, a few widely scattered, large tamaracks occur within the hardwood-dominated swamp as well as numerous dead-standing and fallen tamaracks. An MSU monitoring well was placed at this site. This site was chosen because of its relatively intact landscape context and condition.

Haven Hill, Oakland County (T3N, R8E section 19)
The Haven Hill site occurs within the Haven Hill Natural Area in Highland State Recreation Area. The hardwood-dominated wetland is adjacent to ice-contact moraines supporting beech-sugar maple forest. North of the site and separated by upland forest, are large tracks of tamarack-dominated wetlands. The site was chosen for sampling because of its relatively intact condition and landscape context.

Rose Lake, Shiawassee County (T1E, R5N section 21)
This site occurs within the Rose Lake State Game Area and consists of a small (less than 1 acre) hardwood-dominated forested wetland adjacent to a road intersection. Residential housing occurs across the road from the site. Several groundwater monitoring wells were placed in the wetland by MSU researchers. The site was chosen for sampling because it was being studied by MSU researchers.

Results and Discussion

A cluster analysis of all sites sampled in 1999 was performed in PC-ORD version 4.0 (McCune and Mefford) and separated the 13 sites into two groups, corresponding to conifer and hardwood swamp (Figure 2). This division between conifer and hardwood sites was used throughout the data analysis. Further divisions within each group separated the hardwood sites into two distinct groups, which correspond to sites occurring on organic soil and having high species richness (B, DS, GC, HH), and mineral soil sites (DP, RL, FC) which have low species richness. The analysis also separted the conifer swamp sites into two groups, the three sites we had originally chosen to sample as examples of intact rich conifer swamp (LE, M52, P) and the sites chosen to represent impacted rich conifer swamps (HR, HT, WL).

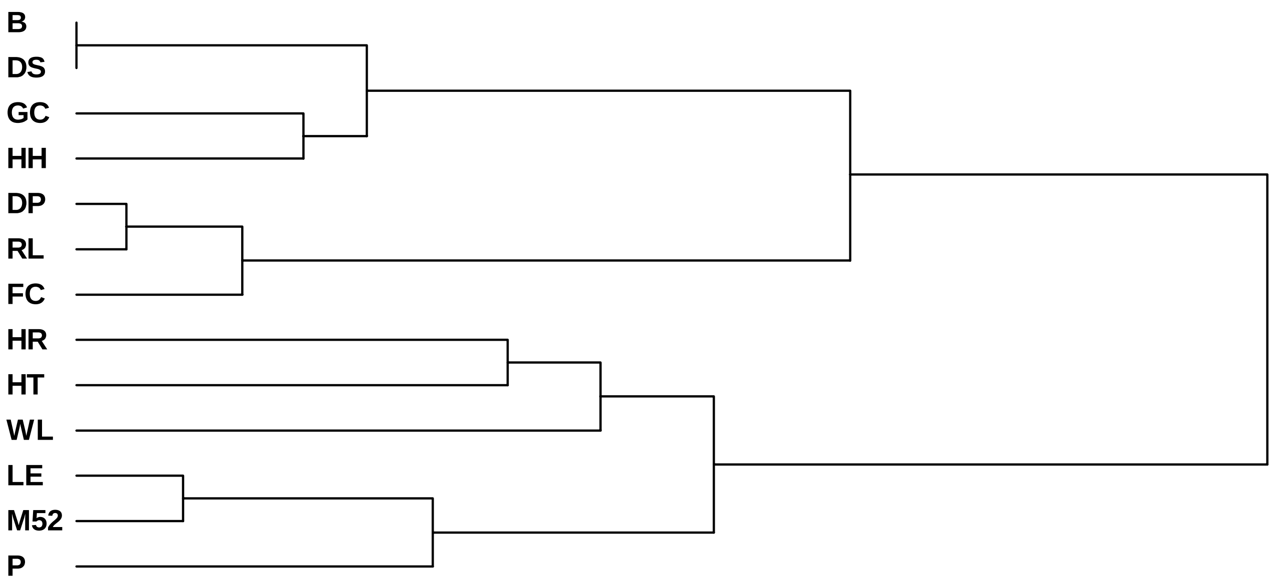


Figure 2. Cluster diagram for all sites. Analysis was performed in PC-ORD version 4.0 (McCune and Mefford 1999). Site abbreviations are as follows: B, Barry; DS, Dansville Swamp; GC, Geology Center; HH, Haven Hill; DP, Dansville Pool; RL, Rose Lake; FC, Fort Custer; HR, Harr; HT, Huttenlocker; WL, Waterloo; LE, Leeke; M52, M52; P, Portage.

Conifer Swamp Results

1999 Results

Overall Species Composition

A total of 126 species occurred in our conifer swamp sample plots (Appendix 1). The most species-rich sites were M52 and Portage with 86 and 82 species, respectively. By comparison, Harr and Waterloo had relatively low species richness with 35 and 44 species, respectively. Leeke and Huttenlocker with 63 and 60 species, respectively, had an intermediate level of species richness. The difference between species-rich and species-poor sites is further increased when additional species observed outside of the plots are added to the site species lists (Appendix 1). Fifteen species occurred within our samples at all sites. Species which were sampled exclusively at all four species-rich sites (e.g., M52, Portage, Leeke, and Huttenlocker) include the following 5 species, bog birch (*Betula pumila*), blue-joint grass (*Calamagrostis canadensis*), canada mayflower (*Maianthemum canadense*), swamp goldenrod (Solidago patula), and riverbank grape (*Vitis riparia*). While all species occurring at Harr Road were found in at least one of the species-rich sites, Waterloo contained four species not found in the any other sites.

The FQI values at Portage (49.7) and M52 (48.9) were nearly double those of Waterloo (29.7) and Harr (24.5) and (Appendix 1). Leeke (37.3) and Huttenlocker (35.6) also had much lower FQI values than Portage and M52.

Ground Layer

Eight species occurred in ground plots at all sites including smooth swamp aster (*Aster firmus*), false nettle (*Boehmeria cylindrica*), bitter cress (*Cardamine* sp.), winterberry (*Ilex verticillata*), spotted touch-me-not (*Impatiens capensis*), cut grass (*Leersia oryzoides*), tufted loosestrife *(Lysimachia thyrsiflora*), and skunk cabbage (*Symplocarpus foetidus*) (Appendix 2). Species found to occur exclusively in ground plots at all four species rich sites include blue-joint grass (*Calamagrostis canadensis*), tamarack, Canada mayflower, swamp goldenrod, and poison ivy (*Toxicodendron radicans*). An additional 59 species occurred exclusively in ground plots at 3 or fewer of the species-rich sites.

Ground layer species richness was lowest at Harr and Waterloo, where species richness was nearly half that of the other sites (Appendix 2). The mean number of species per ground layer plot differed significantly among sites (ANOVA: F = 7.641; df = 5, 89; P = 0.00) with Harr (7.1) having significantly fewer species per plot than all sites except Waterloo (8.4) (Figure 3). In contrast, M52 (13.9) had significantly higher mean plot species richness than all sites except Portage (12.4) and Huttenlocker (11.7).

Diversity indices typically incorporate measures of both species richness and species evenness. Evenness in ground-layer species distribution is partially reflected for a given site in its mean number of species per ground-layer per plot. The SRI uses both the total number of species occurring within plots and the mean plot species richness to derive a single value for a site (Bowles et al. 2000). The SRI values show that Portage (25.2), M52 (22.8), Huttenlocker (19.8), and Leeke (18.8), also have much greater ground-layer species diversity than Waterloo (12.5), and Harr (10.0).

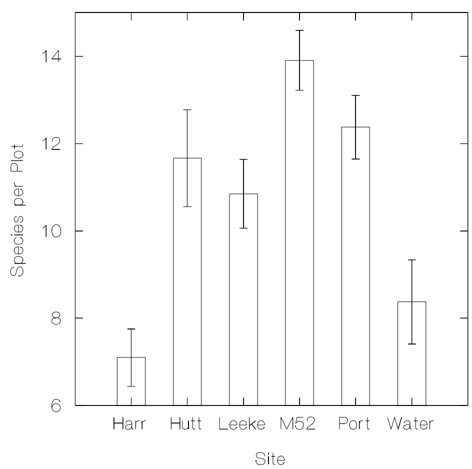


Figure 3. Mean number of ground-layer species per plot for conifer swamp sites. Site abbreviations are as follows: Hutt, Huttenlocker; Port, Portage; Water, Waterloo.

Shrub Layer

A total of 37 species occurred within our shrub-layer samples, and with the exception of one species, bittersweet nightshade (*Solanum dulcamara*), an herbaceous vine, all were native species. Species common to all sites include silky dogwood (*Cornus amomum*), gray dogwood (*Cornus foemina*), winterberry (*Ilex verticillata*), poison sumac (*Toxicodendron vernix*), and smooth highbush blueberry (*Vaccinium corymbosum*). These 5 species also composed the majority of the shrub cover at most sites (Appendix 3). Only two species, bog birch and riverbank grape, occurred within in the shrub layer of all four species-rich sites. An additional 17 native shrubs were sampled as part of the shrub layer at 3 or fewer of the most species-rich sites (Table 1). Bittersweet nightshade was the only exotic species occurring within our shrub-layer samples, however, the highly invasive, exotic shrub, glossy buckthorn (*Rhamnus frangula*) was observed outside of our plots at both Leeke and M52.

Table 1. Native shrub species occurring within the shrub layer at 3 or fewer of the most species-rich sites.

Scientific Name	Common Name
Aronia prunifolia	black chokeberry
Cornus alternifolia	alternate-leaved dogwood
Juniperus communis	ground juniper
Lindera benzoin	spicebush
Lonicera oblongifolia	swamp fly honeysuckle
Nemopanthus mucronata	mountain holly
Potentilla fruticosa	shrubby cinquefoil
Rhamnus alnifolia	alder-leaved buckthorn
Ribes americanum	wild black currant
Rubus occidentalis	black raspberry
Salix bebbiana	bebb's willow
Salix candida	sage willow
Salix discolor	pussy willow
Salix serissima	autumn willow
Sambucus canadensis	elderberry
Spiraea alba	meadowsweet
Viburnum lentago	nannyberry

With total shrub-layer percent cover ranging between 76% and 133%, it is clear that a very dense and diverse shrub layer characterized all sites (Appendix 3). The four sites with the greatest overall species richness also had the highest shrub-layer percent cover (M52, 132.7%; Leeke, 116.7%; Huttenlocker, 95.7%; and Portage 90.5%). The mean shrub-layer intercept cover differed significantly among sites (ANOVA: $F = 4.14$; $df = 5, 89$; $P < 0.01$) with M52 having significantly higher shrub-layer intercept cover than Harr, Portage and Waterloo (Figure 4).

A difference in the total numbers of species encountered within the shrub layer was also evident (Appendix 3). For example, at both M52 and Little Portage Lake, 28 species were present in the shrub layer, while between 9 to 15 species were observed in other sites. The mean number of species per 5-m line intercept varied significantly among sites (ANOVA: $F= 15.0$; df 5, 89; $P < 0.001$), with M52 having significantly greater mean line-intercept diversity than all other sites (Figure 5).

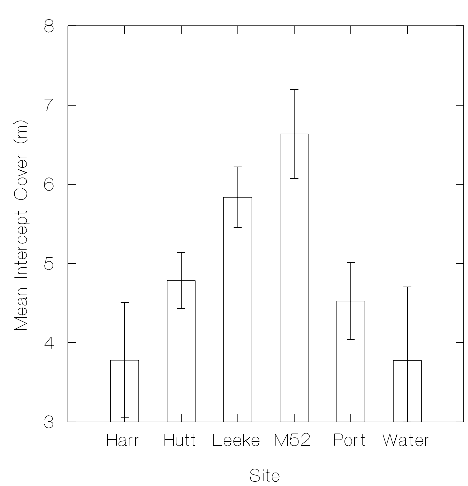


Figure 4. Shrub-layer mean intercept percent cover for conifer swamp sites.

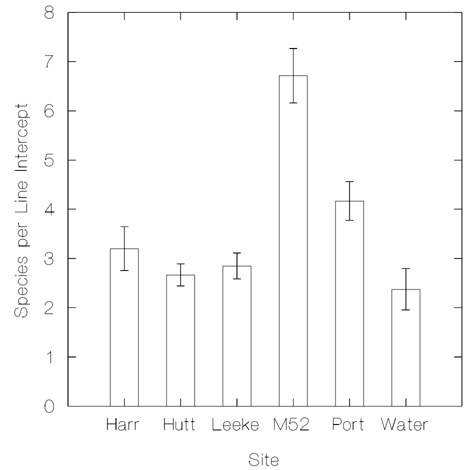


Figure 5. Mean number of shrub species per line intercept for conifer swamp sites.

Tree Layer

Thirteen species occurred within the tree layer at the conifer swamp sites including several species sometimes referred to as shrubs, such as Juneberry, hornbeam, and nannyberry (Appendix 4). Only three species occurred within the tree plots at all sites, red maple, tamarack and American elm (Appendix 4). All sites contained between 7 to 10 tree species except Harr, where only 3 species occurred within our plots.

Mean tree plot density varied significantly among sites (ANOVA: F =8.2; df = 5, 88; $P < 0.001$), with Waterloo having a significantly higher mean plot density than all other sites (157.8 trees/ha vs. 22.4 to 90.2 trees/ha) (Figure 6). However, total tree density was higher at Portage (2,073.9 trees/ha) and M52 (1,776.2 trees/ha) than at Waterloo (1,262.5 trees/ha) (Appendix 4). Tamarack was the most abundant species at all sites except Waterloo, where only one living tamarack occurred within our plots, and at Portage, where elm had a greater density (1,060.9 trees/ha for elm vs. 565.2 trees/ha for tamarack) (Appendix 4). While mature and dead, standing tamaracks were widely scattered throughout Waterloo, yellow birch (337.5 trees/ha) and black ash (250.0 trees/ha) were the most abundant tree species. Although this site is dominated by hardwoods today, it is included here as an example an impacted conifer swamp.

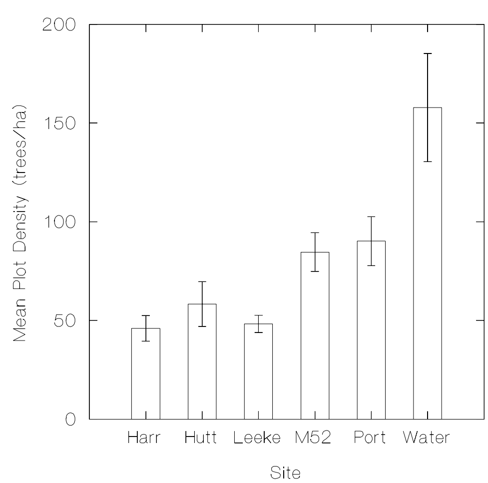


Figure 6. Mean tree-plot density for conifer swamp sites.

Mean tree-plot cover varied significantly among sites (ANOVA: $F = 8.2$; $df = 5, 88$; $P < 0.001$) with Harr and Waterloo having significantly higher mean plot covers than all other sites (Figure 7). However, total tree cover was shown to be greatest at Portage (21.0 m^2/ha vs. 11.8 to 16.6 m^2/ha for all other sites) (Appendix 4). Tamarack had the highest cover of all tree species at all sites except Waterloo and Huttenlocker. In fact, at Harr, Leeke, and M52, tamarack cover was greater than all other trees species combined, and at Portage, tamarack cover was nearly equal to that of all other species combined (48.2 % relative cover) (Appendix 4). At Waterloo, tree cover was dominated by black ash (6.4 m^2/ha), swamp white oak (*Quercus bicolor*) (1.8 m^2/ha), and yellow birch (1.6 m^2/ha). At Huttenlocker, American elm (5.0 m2/ha) had a higher cover than both red maple (3.3 m^2/ha) and tamarack (3.1 m^2/ha).

Red maple and tamarack were the species with the highest plot frequencies at most sites indicating that these species were widely distributed throughout most sites. For example, the frequency of tamarack was greater than 90% at M52 (100%), Portage (100%), Leeke (95%), and Harr (90%) (Appendix 4). Red maple frequency was also very high at most sites, especially at M52 (100%), Portage (87%), Huttenlocker (83.3%) and Leeke (80%).

Tamarack dominated Harr, Leeke, and M52 as indicated by its high importance value at these sites (235.3, 155.7, and 151.6, respectively) (Appendix 4). Tamarack also had a high importance value at Portage (104.2), where American elm (108.1) ranked slightly higher because of its prevalence in the smaller dbh size classes (Figure 9). American elm had the highest importance value (120.3) at Huttenlocker as well. Lastly, at Waterloo, black ash had the highest importance value (80.9).

Clear distinctions in tree species composition among size classes were observed. Most sites had a similar pattern with the smallest size classes dominated by hardwoods and upper size classes by tamarack. For example, at Leeke, M52, and Portage, red maple and American elm dominate the smallest size classes while tamarack dominates the middle and large size classes (Figure 9). A similar pattern occurs at Huttenlocker where red maple and American elm dominate both the small and mid size classes, but tamarack abundance is nearly equal to red maple and American elm within the upper size classes. At Harr, tamarack also dominated the upper size classes, but in the mid size classes, red maple and tamarack were equally abundant. Only one tree, an American elm, occurred within the small size classes at Harr. Waterloo, which was dominated by hardwoods, had only one tamarack (28cm dbh) within our sample. This site's smaller size classes were dominated by yellow birch, while black ash dominated the upper size classes.

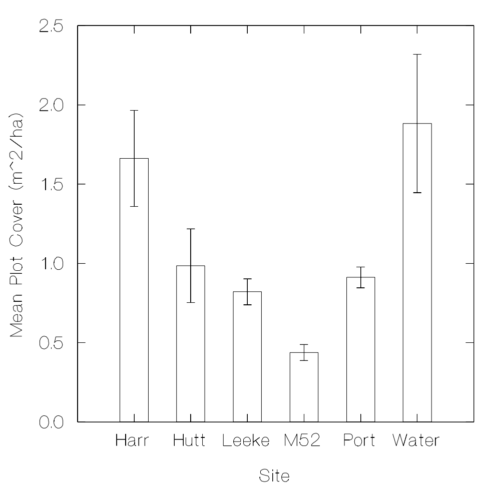


Figure 7. Mean tree-plot cover for conifer swamp sites.

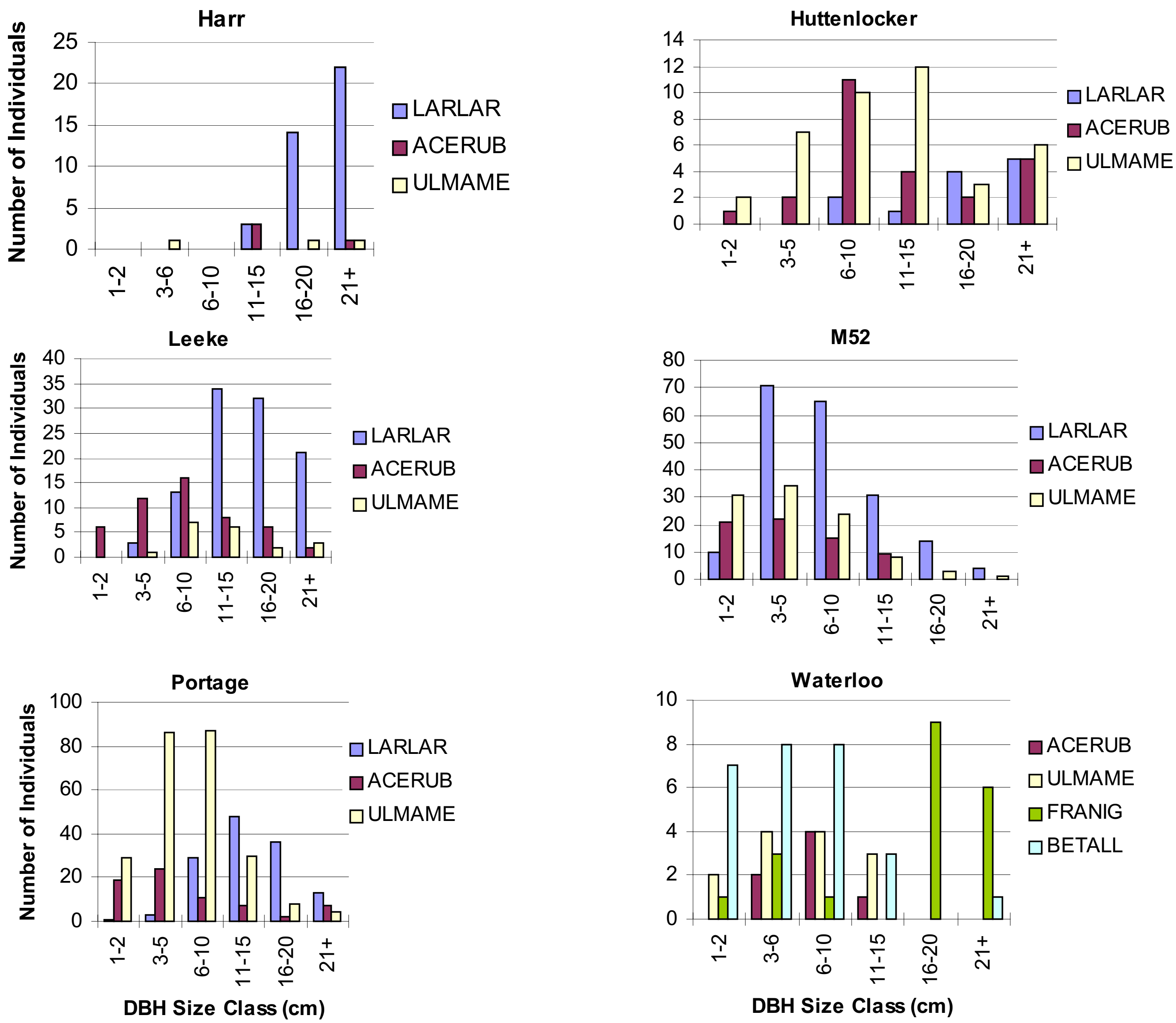


Figure 8. Tree size class distributions for conifer swamp sites. Species abbreviations are as follows: ACERUB, red maple; LARLAR, tamarack; ULMAME, American elm; and BETALL, Betula alleghaniensis.

Invasive Species

Five invasive species were observed during sampling. Reed canary-grass (*Phalaris arundinacea*), an aggressive, invasive grass species, was present in 70% of the ground plots at Harr and also occurred in plots at Huttenlocker (42%) and Portage (4%) (Appendix 2). The high frequency of reed canary grass at Harr may be negatively impacting ground-layer species diversity, as the site had fewer ground-layer species than any other site sampled. It also had a significantly lower mean number of species per plot (7.1) than all other sites except Waterloo (Figure 4). Reed (*Phragmites australis*), another invasive grass species, did not occur within any ground plots but was observed to be abundant in portions of M52 and Portage (Appendix 1). The exotic vine, bittersweet nightshade was present in 60% of the ground plots at Harr and occurred in one plot at Leeke (Appendix 2). It was also present in 50% of the shrub-layer line intercepts at Harr and in 16.7% of the Portage shrub-layer line intercepts (Appendix 3). Glossy buckthorn (*Rhamnus frangula*), an aggressive, exotic shrub, was observed occasionally in the M52 and Leeke shrub layers and was present in one ground plot at M52. Though not present in any ground plot, the invasive, exotic purple loosestrife (*Lythrum salicaria*) was observed occasionally at M52, and was abundant within the sedge meadow bordering Leeke. Lastly, narrow-leaved cattail (*Typha angustifolia*) was found in one ground-layer plot at Huttenlocker.

Soils

The substrate at all sites consists of muck and fibric peat (Appendix 5). Marl was encountered at all sites except Harr. However, it is possible that Harr may also contain marl at a depth deeper than our soil auger was able to reach (e.g., greater than 13'). Soil pH was alkaline (8.0) at the surface of all sites except Harr where it was neutral (7.0). Soil pH at a depth of 8" was also alkaline (8.0) at all sites except Huttenlocker, where it was slightly alkaline (7.5), and at Harr where it was neutral. Woody debris was abundant throughout the soil profiles of all sites.

Hydrology

Hydrologic monitoring appears to indicate that all conifer-swamp sites sampled in 1999 are supported by groundwater (Appendix B). However, M52, Waterloo, and Portage had more consistent water levels throughout the year, indicating that hydrology at these sites was especially influenced by groundwater. In contrast, surface water also plays an important role in the hydrologic regime of Leeke, Huttenlocker, and Harr. Conductivity and alkalinity monitoring also indicate that the hydrology of all the conifer swamp sites is strongly influenced by groundwater (Appendix B).

The results from the soils and hydrology data indicate that all of the sites sampled in 1999 may be considered rich conifer swamps.

2000 Results

In 2000 we sampled two tamarack-dominated rich conifer swamps and one tamarack-dominated poor conifer swamp. The two tamarack swamp types differed greatly in their soil pH and species richness. For example, soil pH measured 8.0 at the rich conifer swamp sites, Fish Lake and Ionia, while it measured only 4.5 at J Ave., the poor conifer swamp site. Species richness was also considerably higher at the rich conifer swamp sites (e.g., Fish Lake 52 species, and Ionia 39 species) than at the poor-conifer-swamp site (e.g., J Ave 11 species).

Because all of the sites we sampled in 1999 were rich conifer swamps, comparisons with the 1999 vegetation sampling results should be restricted to the Ionia and Fish Lake sites. The rich-conifer-swamp sites we sampled in 2000 had a high a mean number of species per ground-layer plot, high SRI values, and mid level FQI and site species richness values when compared to the sites sampled in 1999 (Table 2). While overall shrub cover at all 2000 sites was very high (e.g., 112-131 % cover), shrub-layer species richness was relatively low, especially and at J. Ave., as compared with our 1999 shrub-layer samples (Table 2). Our sampling data indicates that tamarack regeneration (e.g. presence of both seedlings and samplings) is not occurring within any of the sites we sampled in 2000 (Table 2).

Conifer Swamp Discussion

All of the sites we chose to sample were dominated by tamarack except Waterloo, where mature and dead-standing tamaracks were scattered throughout the site. This site had much higher water levels than the other sites (Appendix B) and appeared to be permanently flooded as a result of a dam created by a road. Species richness differed greatly among sites and was closely tied with shrub-layer percent cover. Sites with the highest shrub-layer percent cover also had high species richness. The sites with the greatest species richness also had the highest FQI values, indicating that these sites contained many species typically found in relatively intact natural areas. In addition to comparisons of total numbers of species, how species are distributed across a site is also an important component of diversity. For example, while large areas of a site may be dominated by a single species, the site may also contain smaller, species-rich patches that account for much of the site's overall species richness. Comparisons of site species richness can be enhanced by also examining the mean plot species richness. Our sample data indicates that sites with a high mean number of species per ground-layer plot also had the highest SRI and FQI values, and greatest overall species richness, as well as the highest shrub-layer percent cover (Table 2).

All of the sites we sampled were either dominated by tamarack or the species was prevalent throughout the site. However, comparisons of tree species abundance within dbh size classes show a lack of tamarack recruitment into the tree layer (Figure 8). At most sites the smaller size classes were consistently dominated by hardwoods such as red maple and American elm, or yellow birch and were accompanied by a lack of tamarack recruitment in the lower size classes. In addition, the frequency of red maple, which was greater than 80% at the four most species-rich sites, also indicates that red maple, in particular, is poised for a future position as a canopy dominant. Because of the large, shade-producing canopy of broad-leaved deciduous hardwoods like red maple, tamarack is at a distinct disadvantage when they co-occur. It is common to find dead-standing tamarack in red maple-dominated swamps in southern Michigan. The transition from conifer to hardwood dominance likely results in lower plant species richness for the site and may also negatively impacts animal species that rely on tamarack and/or high amounts of shrub cover. Shrub-layer cover and species richness declines significantly when the canopy dominance shifts from conifer to hardwood. Because the fruit of many shrubs found within tamarack-dominated swamps matures during late summer, it provides an important food resource to migratory birds as well as winter resident species. With the exception of smooth highbush blueberry, the shrub species that occurred at all sites and which had the greatest percent site frequencies were all species whose fruit matures in late summer such as silky dogwood, gray dogwood, winterberry, and poison sumac. In time, the smaller red maples at these sites will begin to occupy the canopy and shrub-layer cover and species richness is likely to decline along with late summer fruit production and the abundance of species that rely on this resource.

Indicators of Biological Integrity for Tamarack-Dominateed Rich Conifer Swamps

This study suggests that there may be several biological indicators for assessing quality in tamarack-dominated, southern Michigan, rich conifer swamps (Table 2). 1) **Plant species richness** appears to be a good indicator for assessing quality. The higher quality sites had more than 60 species and several sites had more than 80 species. 2) **The Floristic Quality Index** may also be a useful tool for assessing the quality of a tamarack-dominated rich conifer swamp. Several of our sites had FQI values near 50 with the lower quality sites scoring near 30. 3) A **diverse and relatively evenly distributed ground flora** may also be a reliable indicator of quality. We used the mean number of species per plot to assess species diversity in the ground flora and found that a mean of 11 or more species per .25m^2 plot may be a good indicator of quality. 4) The **SRI**, which incorporates the mean number of species per ground layer per plot, may also be a reliable indicator of quality.

With total shrub-layer cover in all sites at 75% or greater, the shrub layer appears to be a major component of southern Michigan tamarack-dominated wetlands. 5) In particular, a **total shrub-layer cover** of 90% or higher appears be a good indicator of quality for the sites we sampled (Table 2). It is important to note that the shrub layer was entirely dominated by native species. 6) Another attribute of the **shrub layer** is **species richness**. Sites with at least 15 species within their shrub layers also had the highest overall species richness and FQI values (Table 2). It is interesting to note that the site with the most species-rich shrub layer, M52, also contained the most diverse ground flora (Table 2 and Appendices 2 and 3). This observation is consistent with a study of shrub-carr in southern Wisconsin that found shrub-dominated communities to have high species richness because both light demanding and shade tolerant ground layer species are able to thrive under a heterogeneous shrub layer (White 1965).

7) **Tamarack regeneration** is also an important attribute to consider in assessing quality for southern Michigan tamarack-dominated wetlands. Typically, tree species regeneration is thought to be occurring if a species is present in both the ground layer as seedlings and shrub layer as saplings (e.g., .5 m – 2 m in height). While tamarack seedlings occurred within the ground-layer plots of four sites, the shrub-layer samples revealed tamarack saplings to be present at only two sites, M52 and Portage (Table 2). The tree-layer samples also revealed a similar trend with tamarack occurring in the lowest dbh size class (e.g., 1 cm – 2 cm) at only M52 and Portage as well (Table 2 and Figure 8). These two sites also have high values for the other potential indicators of quality mentioned above.

Table 2. Indicators of biological integrity for southern Michigan rich conifer swamps.

Site	Species Richness (from plot samples)	FQI	SRI	Mean number of Species per ground plot	Total Shrub Layer % Cover	Shrub Layer Species Richness	Mean number of Species per Shrub Layer Line Intercept	Tamarack seedlings present in Ground Layer Samples	Tamarack present in Shrub Layer Samples	Tamarack present in lowest DBH size class
1999 Sites										
Harr	35.0	24.5	11.0	7.1	75.6	12	3.2	No	no	no
Huttenlocker	60.0	35.6	20.8	11.7	95.7	9	2.7	**Yes**	no	no
Leeke	63.0	37.3	19.6	10.9	**116.7**	15	2.9	**Yes**	no	no
M52	**82.0**	**49.7**	**23.7**	**12.4**	**132.7**	**28**	**6.7**	**Yes**	**yes**	**yes**
Portage	**86.0**	**48.9**	**26.9**	**13.9**	90.5	**28**	**4.2**	**Yes**	**yes**	**yes**
Waterloo	44.0	29.7	13.8	8.4	75.5	10	2.4	No	no	no
2000 Sites										
Fish Lake	52.0	41.4	**25.7**	**15.0**	**131.1**	8	3	No	no	no
Ionia	39.0	35.8	**24.3**	**15.3**	**138.0**	6	**4.2**	**Yes**	no	no
J Ave.	11.0	28.0	5.3	5.1	112.8	3	2.5	**Yes**	no	no

8) The **prevalence of invasive species** at a site may also be helpful in assessing its quality. In particular, the presence of reed canary grass at two sites (e.g., Harr and Huttenlocker) seems to have contributed to low species richness. Because reed canary grass forms extensive clonal mats, it has the potential to significantly alter community structure and negatively impact species richness. Another invasive species, bittersweet nightshade, which occurred in both shrub layer and ground layer samples, may have also contributed to lower species richness at one site (e.g., Harr). However, this species is usually a minor component of cover and thus may be a less reliable indicator of degradation than reed canary grass. The species with the greatest potential to negatively impact the quality of these sites in the future is glossy buckthorn. This aggressive shrub species has completely colonized similar habitats in southern Michigan, northern Indiana, northeastern Illinois, and southeastern Wisconsin, altering community structure and negatively impacting species richness. It was observed as a very minor component of the shrub layer at two of the most species-rich sites, M52 and Leeke. Without management to control the species, it is likely to increase in abundance and has the potential to dominate these sites in the future.

9) **Red maple cover**. Another species with the potential to alter community structure and negatively impact species richness at these sites in the future is red maple. As stated above, because of the dense shade produced by large red maple trees, tamarack, as well as many shrub, forb, grass, and sedge species will likely be lost from these sites if red maple comes to assume a dominant position within the canopy. The tree-size distribution information we collected reveals that future red maple dominance at many of these sites appears likely (Figure 8). The hardwood-swamp sampling data demonstrates that these hardwood-dominated communities have fewer shrub, forb, grass, and sedge species than the rich-conifer-swamp sites.

While the presence of certain invasive species may indicate degradation, it is more difficult to suggest individual species that may indicate a condition of high quality. The closest attempt at using species presence to assess a site's condition is the Floristic Quality Assessment and this method requires a comprehensive plant species list. More than 86 species occurred exclusively in the four most species-rich sites. With more survey work it may be possible to identify particular species from this list that are reliable indictors of high quality, rich conifer swamps in southern Michigan.

The inclusion of a poor conifer swamp (e.g., J Ave.) in our year 2000 sampling was very useful for understanding the importance of developing indicators that are based on data from specific community types. For example, even though the J Avenue site appeared relatively intact and was very similar to other southern Michigan poor conifer swamps, it had less than one third as many species as the lowest quality rich conifer swamp sites (e.g., Harr and Waterloo). Consequently, both its FQI and SRI scores, and shrub-layer species richness appeared very low when compared with the other 8 conifer-dominated wetlands sampled during 1999 and 2000 (Table 2). This suggests that even the most pristine and intact poor conifer swamp is unlikely to have the same level of species richness and diversity as a low quality, rich conifer swamp. Therefore, it will be necessary to collect data specific to poor conifer swamps if meaningful diversity and species-richness measures are to be developed for this community type. To more accurately assess the quality of the J Avenue site will require comparisons with other poor conifer swamps.

Hardwood Swamp Results

Overall Species Composition

A total of 94 species occurred within the hardwood swamp sample plots (Appendix 6). An additional 19 species were noted outside of the plots, bringing the total species count for all sites to 113 species. The most species-rich sites were Barry and Geology Center, each with 48 species occurring within our plots. Dansville Swamp (44) and Haven Hill (43) also had high species richness. Rose Lake (29) and Dansville Pool (25) had relatively low species richness. Fort Custer, a small, forested vernal pool, had the lowest species richness with only 5 species occurring within our plots. Only two species occurred within plots at all sites, red maple and American elm. An additional four species were sampled at all sites except Fort Custer, these include false nettle, black ash, spotted touch-me-me-not, and violet. Only four species occurred exclusively the four most species-rich sites (e.g., Barry, Geology Center, Dansville Swamp, and Haven Hill), hornbeam, Canada mayflower, wood reedgrass (*Cinna arundinacea*), and rough goldenrod (*Solidago rugosa*). Conversely, only one species, the invasive reed canary grass, was sampled exclusively at the sites with the lowest species richness, Rose Lake and Dansville Pool.

The FQI values were also highest at the four species-rich sites with values near 30 (Dansville Swamp, 31.5; Haven Hill, 30.7; Geology Center, 30.4; Barry, 28.3), while the other three sites had values near 20 or less (Dansville Pool. 20.6; Rose Lake, 20.4; Fort Custer, 4.5) (Appendix 6).

Ground Layer

A total of 81 species occurred within the ground-layer plots (Appendix 7). Similar numbers of species were sampled at Barry (38), Geology Center (36), Haven Hill (36), and Dansville Swamp (35), while Rose Lake (21), Dansville Pool (19), and Fort Custer (2) had far less species richness. Red maple was the only species to occur in ground-layer plots at all sites. Three species, Canada mayflower, rough goldenrod and wood reedgrass were found exclusively at all four species-rich sites (e.g., Barry, Dansville Swamp, Geology Center, and Haven Hill). The only species to occur exclusively at sites with low species richness (e.g., Rose Lake and Dansville Pool) was reed canary grass.

Ground-layer species richness can also be measured by comparing the mean number of species per ground-layer plot. Considerable variation in mean plot species richness among sites was observed (Figure 9) (Appendix 7). The Haven Hill and Barry sites had the highest mean-plot species richness with 8.7 and 8.1 species per plot respectively. Dansville Swamp (6.4) and Geology Center (6.0) had an intermediate numbers of species per plot. The lowest ground-layer species richness was seen at Dansville Pool (4.3), Rose Lake (4.2), and Fort Custer (0.2). The SRI values followed a similar trend (Appendix 6).

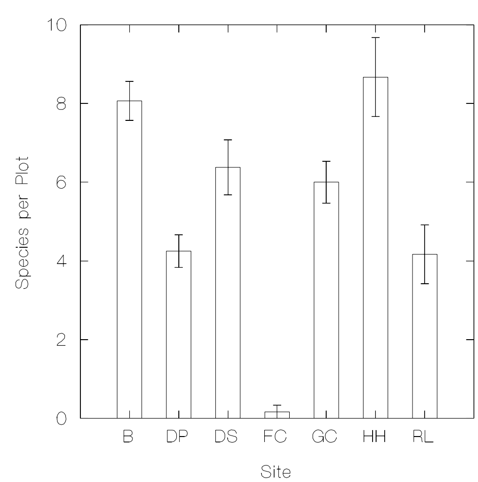


Figure 9. Mean ground-layer plot species richness for hardwood swamp sites.

Shrub Layer

Shrub layer cover was also highest at the four species rich-sites (e.g., Barry, Dansville Swamp, Geology Center, and Haven Hill) (Appendix 8). However, all sites had relatively little shrub cover when compared with the conifer swamp sites (e.g., 21.3% - 1.0% cover for hardwood swamp sites vs. 132.7% - 75.5% cover for conifer swamp sites) (Appendices 8 and 3). Winterberry was found in the most number of sites (5), and hornbeam was the only species to occur exclusively in all four species rich sites. The two sites that contained a remnant population of tamarack (e.g., Dansville Swamp and Geology Center) had the greatest diversity of species within the shrub layer, 11 and 8 species, respectively. The mean number of species per shrub-layer line intercept was also highest at these sites (Figure 10).

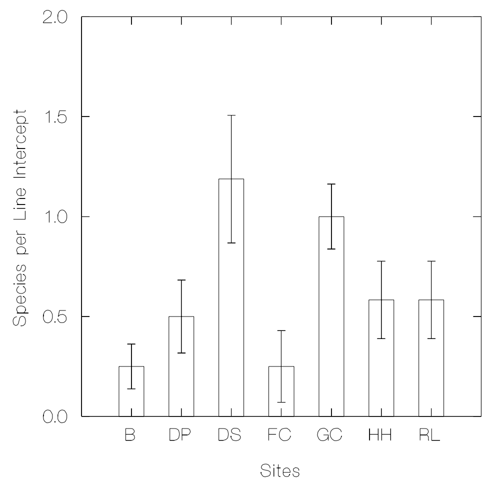


Figure 10. Mean number of species per shrub layer line intercept for hardwood swamp sites.

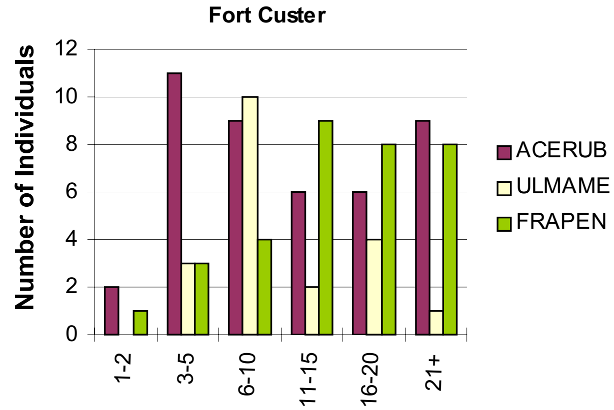
Tree Layer

Tree layer samples contained 17 species with red maple and American elm being the only species to occur in plots at all sites (Appendix 9). Black ash was also very common, occurring in all sites except Fort Custer. Red ash and basswood (*Tilia americana*) were also frequently encountered occurring at 5 out of 7 sites. Haven Hill had the greatest total tree density (3991.7 trees/ha) with more than twice as many trees per hectare as any other site (Appendix 9). The most abundant species at Haven Hill were black ash (1150.0 trees/ha), American elm (1066.7 trees/ha), and yellow birch (833.3 trees/ha). Black ash was also the most abundant species at the Geology Center (545.0 trees/ha) and Barry (437.5 trees/ha). The lowest tree density was observed at Dansville Pool (318.8 trees/ha) where red maple accounted for 77% (243.8 trees/ha) of all trees sampled. Red maple was also the most abundant species observed at Fort Custer (754.4 trees/ha) and was very abundant at Rose Lake (558.3 trees/ha) as well.

Total tree cover was greatest at Fort Custer (45 m^2/ha) and Barry (40.6 m^2/ha) and lowest at Dansville Pool (14.2 m^2/ha). Red maple had the greatest cover of any species at all sites except Haven Hill. In fact, at four sites red maple occupied more cover than all other species combined (e.g., percent relative cover of red maple: Dansville Pool 99.0%, Rose Lake 91.5%, Barry 53.2%, and Dansville Swamp 52.5 %) (Appendix 9). While red maple (38%) had the highest percent relative cover at the Geology Center, black ash (26.7%) and yellow birch (17.5%) also contributed substantially to cover. Similarly, at Dansville Swamp, where red maple also dominated cover (52.5%), the percent relative cover of both yellow birch (21%) and American elm (19%) was substantial (Appendix 9).

Red maple was the only species with high plot frequencies at all sites (Appendix 9). However, other species such as yellow birch, black ash, and American elm were also widely distributed throughout most sites. Importance values were relatively balanced among several species (e.g., red maple, yellow birch, black ash, and American elm) at all sites except Dansville Pool and Rose Lake, where red maple dominated the tree layer (Appendix 9).

Comparisons of tree species abundance by dbh size class can help reveal successional trends among sites. Several sites such as Haven Hill, Geology Center, and Dansville Swamp, had high tree densities in the lower size classes with fewer individuals in the upper size classes (Figure 11). This pattern is exemplified most clearly at Haven Hill by the distribution of American elm, a species that typically succumbs to disease before reaching maturity. Future canopy dominants at these sites may be drawn from the species that are most abundant in lower size classes today. For example, while red maple presently dominates the upper size classes at Barry, black ash, which is more abundant in the lower size classes may dominate the canopy in the future. Similarly, at Dansville Swamp, red maple also dominates the largest size class but yellow birch is much more abundant in the lower size classes.



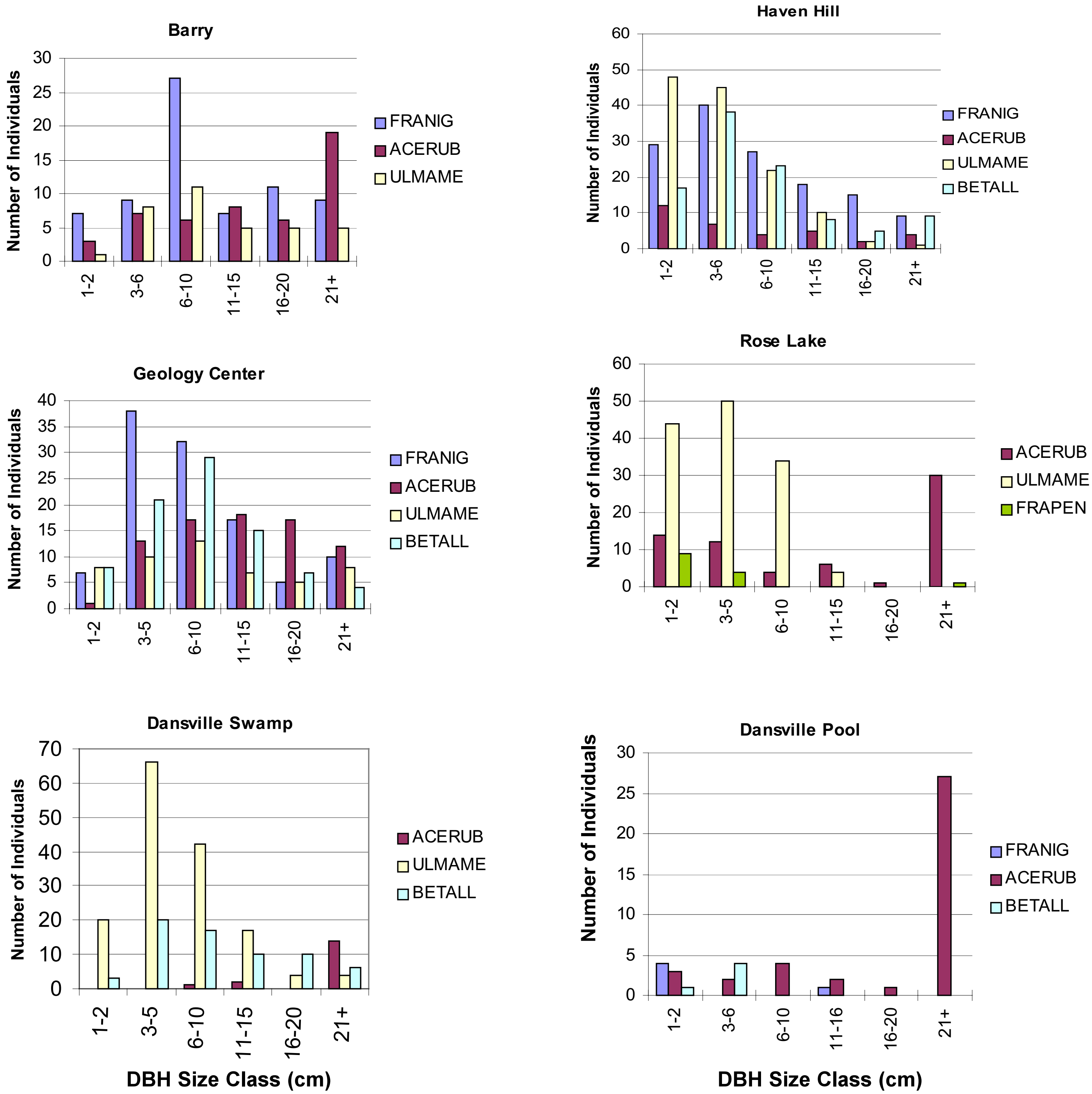


Figure 11. Tree size class distributions for hardwood swamp sites. Species abbreviations are as follows: FRANIG, black ash; BETALL, yellow birch; ACERUB, red maple; and ULMAME, American elm.

Soils

Substrate composition differed greatly among sites (Appendix 5). Similar to all of the conifer-dominated swamps we examined, the substrate at four of the hardwood-dominated sites (e.g., Barry, Dansville Swamp, Geology Center, and Haven Hill) consisted of deep organics. In contrast, Dansville Pool, Fort Custer, and Rose Lake occurred on mineral soil. Three of the organic-soil sites, Barry, Dansville Swamp and Haven Hill, also contained a layer of marl, as did nearly all of the rich conifer swamps we sampled. It is possible that a layer of marl may also be present at the Geology Center at a depth deeper than we were able to sample (e.g., greater than 13'). Woody debris was common in the soil profiles of all the organic soil sites. The soil pH ranged from neutral (7.0) to alkaline (8.0) for both the organic and mineral soil sites.

Hardwood Swamp Discussion

While the hardwood-dominated sites we sampled differed considerably in species composition and species richness, their substrate composition and size differed greatly as well. For example, Rose Lake, Dansville Pool, and Fort Custer all occurred on different types of mineral soil while Barry, Dansville Swamp, Geology Center, and Haven Hill occurred on deep organics. The Rose Lake site was located adjacent to a road intersection and the Fort Custer site occupied a small depression in an old field, while all other sites occur in a less disturbed context. Fort Custer and Rose Lake are also much smaller than all other sites. Drawing conclusions about quality from comparisons among such different types of ecosystems is difficult and may be clouded by lack of replication among some types. The Fort Custer site, in particular, would best be studied in context with other small, forested vernal pools. At the Geology Center and Dansville Swamp the presence of widely scattered tamaracks in the tree layers, as well as the presence of dead-standing and downed tamaracks, suggests that these sites have recently undergone a transition from conifer to hardwood domination. Both sites also occurred on deep organic soils and supported a diverse shrub layer similar to the conifer-dominated sites we sampled. Barry and Haven Hill, which also occur on deep organic soils and contained a layer of marl within their soil profiles, similar to the most of the tamarack-dominated wetlands we studied, may have also recently been conifer-dominated. Although tamarack-dominated wetlands occur within less than a mile of these sites, we did not record the presence of tamarack at either Barry or Haven Hill.

Indicators of Biological Integrity for Hardwood Swamps

Factors that may indicate quality for the sites we studied include: floristic measures such as the 1) **total number of species sampled**, 2) **shrub-layer species richness**, and 3) **FQI value**; diversity measures such as the 4) **number of species per ground-layer plot**, 5) **SRI** and 6) **shrub-layer line intercept species richness**; and structural measures such as the amount of 7) **shrub-layer cover** (Table 3). In addition, 8) **certain species** may also **suggest a condition of degradation** or high quality. For example, the presence of reed canary grass, which occurred exclusively at the sites with the lowest species richness, may suggest that a site is degraded. While the presence of hornbeam, wood reedgrass, Canada mayflower, and rough goldenrod, which occurred exclusively at the most species-rich sites, may indicate that a site is in relatively good condition.

Table 3. Indicators of biological integrity for southern Michigan hardwood swamps.

Site	Species Richness (from plot samples)	FQI	SRI	Mean number of Species per .25m^2 ground plot	Total Shrub Cover	Shrub-Layer Species Richness	Mean number of Species per Shrub-Layer Line Intercept
Barry	**48.0**	**28.3**	**12.7**	**8.1**	**17.5**	3.0	0.3
Dansville Pool	25.0	20.6	5.4	4.3	6.6	6.0	0.5
Dansville Swamp	**44.0**	**31.5**	**9.8**	**6.4**	**16.6**	**11.0**	**1.2**
Fort Custer	5.0	4.5	0.1	0.2	1.0	2.0	0.3
Geology Center	**48.0**	**30.4**	**9.3**	**6.0**	**21.3**	**8.0**	**1.0**
Haven Hill	**36.0**	**30.7**	**13.5**	**8.7**	12.3	4.0	0.6
Rose Lake	21.0	20.4	5.5	4.2	9.0	4.0	0.6

Conclusion

We concluded that two very different types of tamarack-dominated conifer swamp occur in southern Michigan, rich conifer swamp and poor conifer swamp. Rich conifer swamps are minerotrophic, groundwater influenced, forested wetlands that occur on alkaline, organic soils. In contrast, poor conifer swamps are ombrotrophic, rain and surface water fed, forested wetlands that occur on acidic, organic soils. Our work concentrated primarily on rich conifer swamps with vegetation sampling occurring in 8 rich conifer swamps and 1 poor conifer swamp. Because these community types differ greatly in their species composition and inherent level of plant species diversity, it is not possible to use the species richness and diversity scores developed by studying rich conifer swamp sites for judging the quality of southern Michigan's poor conifer swamps. Drawing conclusions about the quality of poor conifer swamps in southern Michigan will require further study.

Measures of quality for rich conifer swamp derived from the 8 wetlands we sampled include: floristic diversity measures such as overall-site species richness, FQI, and shrub-layer species richness; measures of ground-layer diversity such as mean-plot species richness and SRI; and structural components such as shrub-layer percent cover, and evidence of tamarack regeneration.

The findings of this study indicate that reed canary grass, an invasive grass species, has the potential to negatively impact plant species richness in both rich conifer swamps and hardwood swamps.

Red maple may also be a species that contributes to a lowering of species richness in conifer-dominated sites. This was evident in the difference between the high level of species richness observed in the rich conifer swamp sites and the much lower number of species recorded from the hardwood swamps that contained a remnant tamarack population. As red maple assumes canopy dominance within a previously conifer-dominated site, sunlight infiltration into the shrub and ground layers is reduced and likely results in the extirpation of many, shade intolerant species. Comparisons of species richness and shrub-layer cover between the most species-rich rich conifer swamp and hardwood swamp sites may serve to illustrate theses changes (Figures 12 and 13). Many of the shrub species that appear to be adversely impacted by the lower light levels are prolific, fall, fruit producers and so the conversion of a conifer-dominated site to a hardwood swamp may also negatively impact many animal species that rely on this fruit during fall migration and winter.

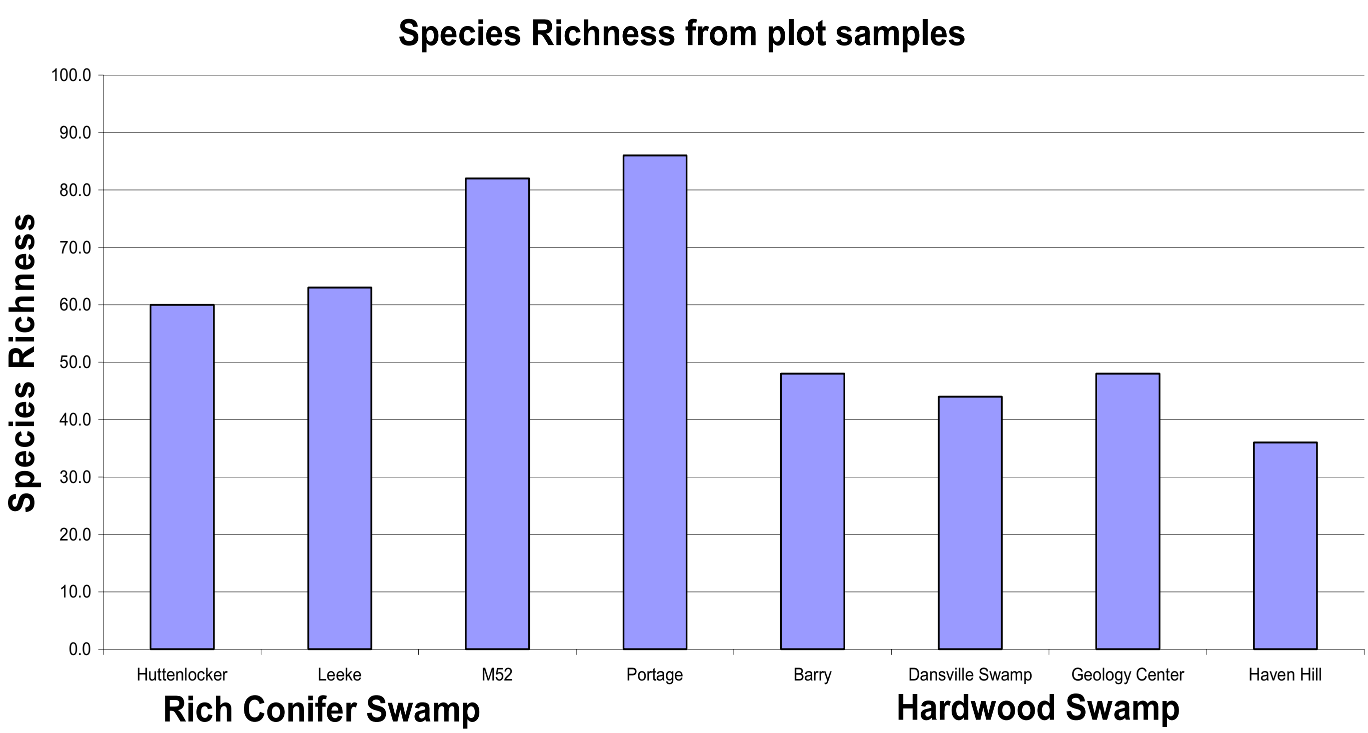


Figure 12. Species richness comparison between the most species-rich rich conifer swamp and hardwood swamp sites. Note that the four hardwood swamp sites occur on deep organic soils.

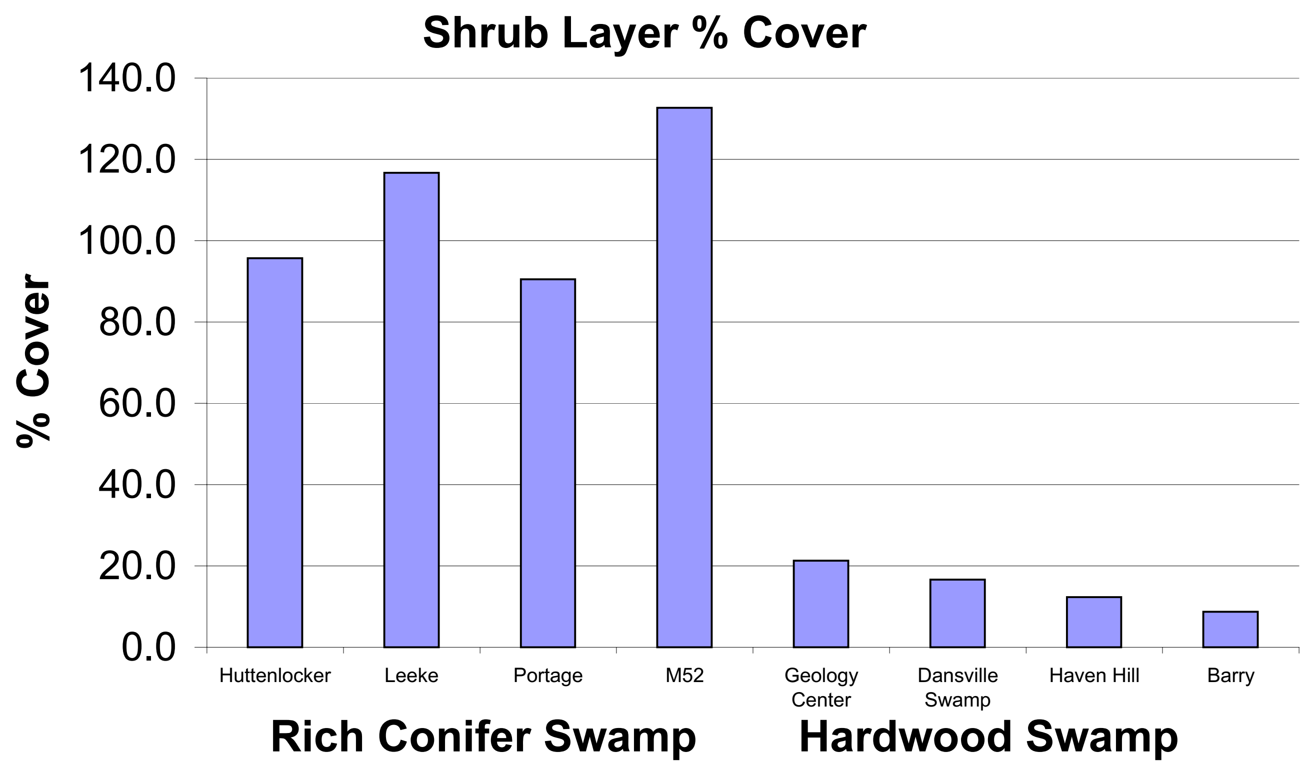


Figure 13. Shrub-layer percent cover comparison between the most species-rich rich conifer swamp and hardwood swamp sites. Note that the four hardwood swamp sites occur on deep organic soils.

Several types of hardwood swamps were also identified although more survey work is needed to further elucidate the types and their characteristic species. Hardwood swamps occurred on both mineral soils and deep organic soils (>13' in depth). The four sites that occurred on organic soil appeared to have much greater diversity than the 3 mineral soil sites. Because of the small sample size (e.g., 3 and 4 sites of each type), we are hesitant to draw firm conclusions from our data. However, measures that may suggest high quality conditions for hardwood swamp include: floristic measures such as overall-site species richness, shrub-layer species richness and FQI; ground layer measures such as the mean number of species per plot and SRI; and structural components such as shrub-layer cover. Hardwood swamps on organic soil may be inherently more species rich than mineral soil sites, however, more survey work is needed before this conclusion can be fully supported. The organic-soil, hardwood sites may also have recently undergone a conversion from conifer to hardwood domination.

A structural component that we did not measure, but that may prove to correlate well with high species richness is microtopography. From casual observations, high microtopographic variation appeared to foster high levels of species richness. Other studies where microtopography has been measured support this hypothesis (Golet et al. 1993, Vivian-Smith 1995, Kudray 1999). Microtopography is also a factor that may be easily measured, and unlike plant identification, learning to reliably measure microtopography is likely to require only several hours or a day of training, rather than several years.

Although it is likely that certain animal species are closely associated with high quality examples of rich and poor conifer swamps, our surveys for the tamarack tree cricket suggest that this species is not a particularly good indicator of biological integrity for these conifer-dominated community types (Appendix A).

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Appendicies 1-9

Appendix 1. Plant species observed at conifer swamp sites. "1" indicates the species occurred within a sample plot. "+" indicates the species occurred at the site but not within a sample plot. Percent site frequency is based on speciesoccurrences within plots. The total number of species and Floristic Quality Index is given at the bottom of the table for each site.

			Sites						
SCIENTIFIC NAME	**COMMON NAME**	**Life form**	**Harr**	**Hutten-Locker**	**Leeke**	**M52**	**Portage**	**Waterloo**	**% Site Frequency**
Acer rubrum	RED MAPLE	N Tree	1	1	1	1	1	1	100
Aster firmus	SMOOTH SWAMP ASTER	N Forb	1	1	1	1	1	1	100
Boehmeria cylindrica	FALSE NETTLE	N Forb	1	1	1	1	1	1	100
Cardamine sp.	BITTER CRESS	N Forb	1	1	1	1	1	1	100
Cornus amomum	SILKY or PALE DOGWOOD	N Shrub	1	1	1	1	1	1	100
Cornus foemina	GRAY DOGWOOD	N Shrub	1	1	1	1	1	1	100
Ilex verticillata	WINTERBERRY	N Shrub	1	1	1	1	1	1	100
Impatiens capensis	SPOTTED TOUCH-ME-NOT	N Forb	1	1	1	1	1	1	100
Larix laricina	TAMARACK	N Tree	1	1	1	1	1	1	100
Leersia oryzoides	CUT GRASS	N Grass	1	1	1	1	1	1	100
Lysimachia thyrsiflora	TUFTED LOOSESTRIFE	N Forb	1	1	1	1	1	1	100
Symplocarpus foetidus	SKUNK-CABBAGE	N Forb	1	1	1	1	1	1	100
Toxicodendron vernix	POISON SUMAC	N Shrub	1	1	1	1	1	1	100
Ulmus americana	AMERICAN ELM	N Tree	1	1	1	1	1	1	100
Vaccinium corymbosum	SMOOTH HIGHBUSH BLUEBERRY	N Shrub	1	1	1	1	1	1	100
Carex leptalea	SEDGE	N Sedge	1	1	1	1	1	0	83
Corylus americana	HAZELNUT	N Shrub	1	1	1	1	1	0	83
Equisetum fluviatile	WATER HORSETAIL	N Fern	0	1	1	1	1	1	83
Glyceria striata	FOWL MANNA GRASS	N Grass	1	1	1	1	1	0	83
Lycopus uniflorus	NORTHERN BUGLE WEED	N Forb	1	1	1	1	1	0	83
Onoclea sensibilis	SENSITIVE FERN	N Fern	1	1	0	1	1	1	83
Parthenocissus quinquefolia	VIRGINIA CREEPER	N Vine	1	1	1	1	1	0	83
Ribes hirtellum	SWAMP GOOSEBERRY	N Shrub	1	0	1	1	1	1	83
Rosa palustris	SWAMP ROSE	N Shrub	1	0	1	1	1	1	83
Rubus pubescens	DWARF RASPBERRY	N Forb	1	1	1	1	1	0	83
Thelypteris palustris	MARSH FERN	N Fern	0	1	1	1	1	1	83
Toxicodendron radicans	POISON-IVY	N Vine	1	1	1	1	1	0	83
Viburnum lentago	NANNYBERRY	N Shrub	0	1	1	1	1	1	83
Viola spp.	VIOLET	N Forb	1	1	1	1	1	0	83
Amelanchier sp. (arborea)	JUNEBERRY	N Tree	+	0	1	1	1	1	67

Table continues

Appendix 1 continued

			Sites						
SCIENTIFIC NAME	COMMON NAME	Life form	Harr	Hutten-Locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Betula alleghaniensis	YELLOW BIRCH	N Tree	0	1	1	+	1	1	67
Betula pumila	BOG BIRCH	N Shrub	0	1	1	1	1	0	67
Calamagrostis canadensis	BLUE-JOINT GRASS	N Grass	0	1	1	1	1	+	67
Carex alata	WINGED SEDGE	N Sedge	1	1	1	0	1	0	67
Cicuta bulbifera	WATER HEMLOCK	N Forb	+	0	1	1	1	1	67
Maianthemum canadense	CANADA MAYFLOWER	N Forb	0	1	1	1	1	0	67
Quercus bicolor	SWAMP WHITE OAK	N Tree	0	0	1	1	1	1	67
Rubus strigosus	WILD RED RASPBERRY	N Shrub	1	0	0	1	1	1	67
Solidago patula	SWAMP GOLDENROD	N Forb	0	1	1	1	1	0	67
Vitis riparia	RIVERBANK GRAPE	N Vine	0	1	1	1	1	0	67
Aronia prunifolia	BLACK CHOKEBERRY	N Shrub	0	0	1	1	1	0	50
Aster lanceolatus	EASTERN LINED ASTER	N Forb	0	1	0	1	0	1	50
Bidens cernuus	NODDING BUR-MARIGOLD	N Forb	0	0	1	1	+	1	50
Bidens coronatus	TALL SWAMP-MARIGOLD	N Forb	0	1	0	1	1	0	50
Caltha palustris	MARSH-MARIGOLD	N Forb	0	+	1	1	1	0	50
Campanula aparinoides	MARSH BELLFLOWER	N Forb	0	1	0	1	1	0	50
Carex comosa	SEDGE	N Sedge	1	+	+	1	+	1	50
Carex hystericina	SEDGE	N Sedge	0	1	0	1	1	0	50
Carex lacustris	SEDGE	N Sedge	0	0	0	1	1	1	50
Carex stricta	SEDGE	N Sedge	0	1	0	1	0	1	50
Dryopteris carthusiana	SPINULOSE WOODFERN	N Fern	1	1	1	0	+	+	50
Fraxinus nigra	BLACK ASH	N Tree	0	0	0	1	1	1	50
Galium asprellum	ROUGH BEDSTRAW	N Forb	0	1	0	0	1	1	50
Galium labradoricum	BOG BEDSTRAW	N Forb	0	1	0	1	1	0	50
Galium tinctorium	STIFF BEDSTRAW	N Forb	1	0	1	+	0	1	50
Lemna minor	SMALL DUCKWEED	N Forb	0	0	1	1	0	1	50
Osmunda regalis	ROYAL FERN	N Fern	1	0	1	0	1	0	50
Phalaris arundinacea	REED CANARY GRASS	N Grass	1	1	0	0	1	0	50
Pilea pumila	CLEARWEED	N Forb	0	0	1	1	0	1	50
Populus tremuloides	QUAKING ASPEN	N Tree	0	1	0	1	1	0	50
Sagittaria latifolia	COMMON ARROWHEAD	N Forb	0	0	1	1	0	1	50
Scutellaria lateriflora	MAD-DOG SKULLCAP	N Forb	0	1	1	1	0	0	50
Senecio aureus	GOLDEN RAGWORT	N Forb	0	1	1	0	1	0	50
SOLANUM DULCAMARA	BITTERSWEET NIGHTSHADE	A Vine	1	0	1	0	1	0	50

Table continues

Appendix 1 continued

SCIENTIFIC NAME	COMMON NAME	Life form	Sites: Harr	Hutten-Locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Solidago rugosa	ROUGH GOLDENROD	N Forb	0	1	1	1	+	+	50
TARAXACUM OFFICINALE	COMMON DANDELION	A Forb	0	1	1	1	0	0	50
Trientalis borealis	STARFLOWER	N Forb	0	+	1	1	1	0	50
Amphicarpaea bracteata	HOG-PEANUT	N Forb	0	1	0	+	0	1	33
Carex disperma	SEDGE	N Sedge	0	0	0	1	1	0	33
Carex lasiocarpa	SEDGE	N Sedge	0	0	0	1	1	0	33
Carex pseudo-cyperus	SEDGE	N Sedge	0	0	1	1	0	0	33
Carex radiata	SEDGE	N Sedge	0	0	0	1	1	0	33
Carex stipata	SEDGE	N Sedge	1	0	0	0	1	0	33
Carpinus caroliniana	BLUE-BEECH	N Tree	0	0	0	0	1	1	33
Cirsium muticum	SWAMP-THISTLE	N Forb	0	0	0	1	1	0	33
Epilobium leptophyllum	FEN WILLOW-HERB	N Forb	0	0	0	0	1	1	33
Eupatorium maculatum	JOE-PYE WEED	N Forb	+	1	0	+	1	+	33
Galium triflorum	FRAGRANT BEDSTRAW	N Forb	0	0	1	1	0	0	33
Lindera benzoin	SPICEBUSH	N Shrub	0	0	1	0	1	0	33
Lonicera oblongifolia	SWAMP FLY HONEYSUCKLE	N Shrub	0	0	1	1	0	0	33
Mitella diphylla	BISHOP'S CAP	N Forb	0	0	0	1	1	0	33
Poa sp. (palustris)	FOWL MEADOW GRASS	N Grass	0	1	0	0	1	0	33
Poaceae spp.	Grass spp.	N Grass	0	0	0	0	1	1	33
Potentilla palustris	MARSH CINQUEFOIL	N Forb	0	0	0	1	1	0	33
Rubus occidentalis	BLACK RASPBERRY	N Shrub	0	0	1	1	0	0	33
Rumex orbiculatus	GREAT WATER DOCK	N Forb	0	0	1	+	1	+	33
Salix bebbiana	BEBB'S or BEAKED WILLOW	N Shrub	0	+	0	1	1	0	33
Salix candida	SAGE or HOARY WILLOW	N Shrub	0	0	0	1	1	0	33
Salix discolor	PUSSY WILLOW	N Shrub	0	0	0	1	1	0	33
Salix serissima	AUTUMN WILLOW	N Shrub	0	0	0	1	1	0	33
Scutellaria galericulata	COMMON SKULLCAP	N Forb	+	1	+	1	0	0	33
Solidago gigantea	LATE GOLDENROD	N Forb	0	0	1	1	0	0	33
Sphagnum spp.	SPHAGNUM MOSS	N Moss	0	0	+	1	1	+	33
Allium canadense	WILD GARLIC	N Forb	0	0	0	0	1	0	17
Aster borealis	NORTHERN BOG-ASTER	N Forb	0	0	0	1	0	0	17
Carex gracillima	SEDGE	N Sedge	0	0	1	0	0	0	17
Carex interior	SEDGE	N Sedge	0	0	0	0	1	0	17
Carex prairea	SEDGE	N Sedge	0	1	0	0	0	0	17

Table continues

Appendix 1 continued

SCIENTIFIC NAME	COMMON NAME	Life form	Sites Harr	Hutten- Locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Carex sp.	SEDGE	N Sedge	0	0	1	0	0	0	17
Carex sterilis	SEDGE	N Sedge	0	1	0	0	0	0	17
Carex trisperma	SEDGE	N Sedge	0	0	0	0	1	0	17
Cornus alternifolia	ALTERNATE-LEAVED DOGWOOD	N Tree	0	0	0	0	1	0	17
Decodon verticillatus	SWAMP LOOSESTRIFE	N Shrub	0	0	1	0	0	0	17
Eleocharis spp.	SPIKE-RUSH	N Sedge	0	0	0	1	0	0	17
Euonymus obovata	RUNNING STRAWBERRY BUSH	N Shrub	0	0	0	0	0	1	17
Eupatorium perfoliatum	COMMON BONESET	N Forb	+	1	0	+	+	0	17
Galium boreale	NORTHERN BEDSTRAW	N Forb	0	0	0	1	0	0	17
Juniperus communis	COMMON or GROUND JUNIPER	N Shrub	0	0	+	1	0	0	17
Nemopanthus mucronata	MOUNTAIN HOLLY	N Shrub	0	0	0	1	0	0	17
Osmorhiza claytonii	HAIRY SWEET-CICELY	N Forb	0	1	0	0	0	0	17
Polygonatum pubescens	DOWNY SOLOMON SEAL	N Forb	0	0	0	0	1	0	17
Polygonum scandens	FALSE BUCKWHEAT	N Vine	0	1	0	0	0	0	17
Potentilla fruticosa	SHRUBBY CINQUEFOIL	N Shrub	0	0	0	1	0	0	17
Prunus serotina	WILD BLACK CHERRY	N Tree	0	1	0	+	0	0	17
Pyrola asarifolia	PINK PYROLA	N Forb	0	0	0	0	1	0	17
Quercus rubra	RED OAK	N Tree	0	1	0	0	0	0	17
Rhamnus alnifolia	ALDER-LEAVED BUCKTHORN	N Shrub	0	+	0	1	+	0	17
Ribes americanum	WILD BLACK CURRANT	N Shrub	0	0	0	0	1	0	17
Salix nigra	BLACK WILLOW	N Tree	0	0	0	0	0	1	17
Salix pedicellaris	BOG WILLOW	N Shrub	0	0	0	1	+	0	17
Sambucus canadensis	ELDERBERRY	N Shrub	0	0	0	0	1	0	17
Spiraea alba	MEADOWSWEET	N Shrub	0	0	0	1	0	0	17
TYPHA ANGUSTIFOLIA	NARROW-LEAVED CAT-TAIL	A Forb	0	1	0	0	0	0	17
Typha latifolia	BROAD-LEAVED CAT-TAIL	N Forb	0	0	0	+	0	1	17
Vaccinium oxycoccos	SMALL CRANBERRY	N Shrub	0	0	0	1	0	0	17
Zizia aurea	GOLDEN ALEXANDERS	N Forb	0	0	0	1	0	0	17
Achillea millefolium	YARROW	N Forb	0	+	0	0	0	0	+
Alnus rugosa	SPECKLED ALDER	N Shrub	0	0	0	0	+	0	+
Arisaema triphyllum	JACK-IN-THE-PULPIT	N Forb	0	0	+	0	+	0	+
Asclepias incarnata	SWAMP MILKWEED	N Forb	+	+	0	+	+	0	+
Bromus ciliatus	FRINGED BROME	N Grass	0	+	0	0	0	0	+
Calopogon tuberosus	GRASS-PINK	N Forb	0	0	0	+	0	0	+

Table continues

Appendix 1 continued

			Sites						
SCIENTIFIC NAME	**COMMON NAME**	**Life form**	**Harr**	**Hutten-Locker**	**Leeke**	**M52**	**Portage**	**Waterloo**	**% Site Frequency**
Carex aquatilis	SEDGE	N Sedge	0	0	0	0	+	0	+
Carex aurea	SEDGE	N Sedge	0	0	+	0	0	0	+
Carex crinita	SEDGE	N Sedge	0	0	0	+	0	0	+
Chamaedaphne calyculata	LEATHERLEAF	N Shrub	0	0	0	+	0	0	+
Cinna arundinacea	WOOD REEDGRASS	N Grass	0	0	0	0	+	0	+
Clematis virginiana	VIRGIN'S BOWER	N Vine	0	0	0	+	+	0	+
Cuscuta sp.	DODDER	N Forb	0	0	0	0	+	0	+
Cypripedium acaule	PINK LADY'S-SLIPPER	N Forb	0	0	0	+	+	0	+
Cypripedium reginae	SHOWY LADY-SLIPPER	N Forb	0	0	0	0	+	0	+
Drosera rotundifolia	ROUND-LEAVED SUNDEW	N Forb	0	0	0	+	+	0	+
Dryopteris cristata	CRESTED SHIELD FERN	N Fern	0	0	+	+	+	0	+
Epilobium ciliatum	WILLOW-HERB	N Forb	0	0	0	0	0	+	+
Eriophorum sp.	COTTON-GRASS	N Sedge	0	0	0	+	0	0	+
Euthamia graminifolia	GRASS-LEAVED GOLDENROD	N Forb	0	0	0	+	0	0	+
Geum canadense	WHITE AVENS	N Forb	0	0	0	0	+	0	+
Geum rivale	PURPLE AVENS	N Forb	0	0	+	0	0	0	+
Iris virginica	SOUTHERN BLUE FLAG	N Forb	0	0	0	0	+	0	+
Juncus canadensis	CANADIAN RUSH	N Forb	0	0	0	+	0	0	+
Juniperus virginiana	RED-CEDAR	N Tree	0	0	0	0	+	0	+
LYTHRUM SALICARIA	PURPLE LOOSESTRIFE	A Forb	0	0	0	+	0	0	+
Menyanthes trifoliata	BUCKBEAN	N Forb	0	0	+	+	+	0	+
Osmunda cinnamomea	CINNAMON FERN	N Fern	0	+	0	+	+	0	+
Pedicularis lanceolata	SWAMP-BETONY	N Forb	0	+	0	0	0	0	+
Phragmites australis	REED	N Grass	0	0	0	+	+	0	+
Platanthera hyperborea	TALL NORTHERN BOG ORCHID	N Forb	0	0	0	0	+	0	+
RHAMNUS FRANGULA	GLOSSY BUCKTHORN	A Shrub	0	0	+	+	0	0	+
Sarracenia purpurea	PITCHER-PLANT	N Forb	0	0	0	+	+	0	+
Sparganium sp.	BUR-REED	N Forb	0	0	0	0	0	+	+
Total number of species observed in sample plots			**35**	**60**	**63**	**86**	**82**	**44**	**126**
Total number of species observed both in and out of sample plots			**41**	**70**	**73**	**111**	**108**	**52**	**160**
Floristic Quality Index			**24.5**	**35.6**	**37.3**	**48.9**	**49.7**	**29.7**	

Appendix 2. Percent frequency of ground layer species at conifer swamp sites based on occurrences within .25m^2 plots. Percent site frequencies are given for all species occurring in at least one plot.

SCIENTIFIC NAME	COMMON NAME	Sites: Harr	Hutten-locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Impatiens capensis	SPOTTED TOUCH-ME-NOT	90.0	33.3	85.0	4.8	70.8	50.0	100.0
Boehmeria cylindrica	FALSE NETTLE	80.0	16.7	35.0	4.8	12.5	12.5	100.0
Cardamine sp.	BITTER CRESS	50.0	16.7	85.0	23.8	37.5	37.5	100.0
Lysimachia thyrsiflora	TUFTED LOOSESTRIFE	30.0	8.3	35.0	38.1	33.3	12.5	100.0
Leersia oryzoides	CUT GRASS	20.0	25.0	60.0	38.1	54.2	25.0	100.0
Symplocarpus foetidus	SKUNK-CABBAGE	20.0	50.0	25.0	47.6	37.5	25.0	100.0
Ilex verticillata	WINTERBERRY	10.0	41.7	15.0	28.6	8.3	12.5	100.0
Aster firmus	SMOOTH SWAMP ASTER	10.0	33.3	25.0	57.1	50.0	25.0	100.0
Onoclea sensibilis	SENSITIVE FERN	40.0	33.3	0.0	9.5	29.2	12.5	83.3
Viola spp.	VIOLET	30.0	33.3	65.0	57.1	54.2	0.0	83.3
Carex leptalea	SEDGE	20.0	33.3	30.0	47.6	41.7	0.0	83.3
Glyceria striata	FOWL MANNA GRASS	20.0	41.7	20.0	23.8	20.8	0.0	83.3
Lycopus uniflorus	NORTHERN BUGLE WEED	20.0	41.7	30.0	61.9	25.0	0.0	83.3
Rosa palustris	SWAMP ROSE	20.0	0.0	5.0	4.8	8.3	12.5	83.3
Parthenocissus quinquefolia	VIRGINIA CREEPER	10.0	41.7	30.0	19.0	25.0	0.0	83.3
Rubus pubescens	DWARF RASPBERRY	10.0	75.0	55.0	81.0	66.7	0.0	83.3
Equisetum fluviatile	WATER HORSETAIL	0.0	16.7	10.0	61.9	12.5	12.5	83.3
Thelypteris palustris	MARSH FERN	0.0	41.7	10.0	76.2	41.7	12.5	83.3
Cornus foemina	GRAY DOGWOOD	0.0	8.3	15.0	4.8	8.3	25.0	83.3
Cornus amomum	SILKY or PALE DOGWOOD	10.0	0.0	5.0	19.0	4.2	0.0	66.7
Carex alata	SEDGE	10.0	8.3	5.0	0.0	8.3	0.0	66.7
Calamagrostis canadensis	BLUE-JOINT GRASS	0.0	8.3	15.0	19.0	4.2	0.0	66.7
Larix laricina	TAMARACK	0.0	8.3	40.0	4.8	37.5	0.0	66.7
Maianthemum canadense interius	CANADA MAYFLOWER	0.0	58.3	10.0	76.2	37.5	0.0	66.7
Solidago patula	SWAMP GOLDENROD	0.0	41.7	20.0	47.6	66.7	0.0	66.7
Toxicodendron radicans	POISON-IVY	0.0	16.7	35.0	23.8	16.7	0.0	66.7
Acer rubrum	RED MAPLE	0.0	16.7	20.0	0.0	8.3	12.5	66.7
Ulmus americana	WHITE or AMERICAN ELM	0.0	16.7	10.0	4.8	0.0	25.0	66.7
Cicuta bulbifera	WATER HEMLOCK	0.0	0.0	5.0	9.5	4.2	37.5	66.7
Phalaris arundinacea	REED CANARY GRASS	70.0	41.7	0.0	0.0	4.2	0.0	50.0
Galium tinctorium	STIFF BEDSTRAW	20.0	0.0	10.0	0.0	0.0	25.0	50.0

Table continues

Appendix 2 continued

		Sites						
SCIENTIFIC NAME	**COMMON NAME**	**Harr**	**Hutten-locker**	**Leeke**	**M52**	**Portage**	**Waterloo**	**% Site Frequency**
Dryopteris carthusiana	SPINULOSE WOODFERN	10.0	8.3	5.0	0.0	0.0	0.0	50.0
Osmunda regalis	ROYAL FERN	10.0	0.0	5.0	0.0	4.2	0.0	50.0
Carex comosa	SEDGE	10.0	0.0	0.0	4.8	0.0	12.5	50.0
Bidens coronatus	TALL SWAMP-MARIGOLD	0.0	25.0	0.0	42.9	62.5	0.0	50.0
Caltha palustris	MARSH-MARIGOLD; COWSLIP	0.0	0.0	30.0	14.3	16.7	0.0	50.0
Campanula aparinoides	MARSH BELLFLOWER	0.0	8.3	0.0	19.0	4.2	0.0	50.0
Carex hystericina	SEDGE	0.0	25.0	0.0	4.8	4.2	0.0	50.0
Galium labradoricum	BOG BEDSTRAW	0.0	8.3	0.0	9.5	8.3	0.0	50.0
Scutellaria lateriflora	MAD-DOG SKULLCAP	0.0	8.3	20.0	14.3	0.0	0.0	50.0
Senecio aureus	GOLDEN RAGWORT	0.0	58.3	15.0	0.0	12.5	0.0	50.0
Solidago rugosa	ROUGH GOLDENROD	0.0	41.7	5.0	28.6	0.0	0.0	50.0
TARAXACUM OFFICINALE	COMMON DANDELION	0.0	8.3	10.0	4.8	0.0	0.0	50.0
Trientalis borealis	STARFLOWER	0.0	0.0	5.0	52.4	25.0	0.0	50.0
Aster lanceolatus	EASTERN LINED ASTER	0.0	8.3	0.0	4.8	0.0	12.5	50.0
Carex stricta	SEDGE	0.0	25.0	0.0	14.3	0.0	12.5	50.0
Galium asprellum	ROUGH BEDSTRAW	0.0	25.0	0.0	0.0	29.2	12.5	50.0
Bidens cernuus	NODDING BUR-MARIGOLD	0.0	0.0	55.0	28.6	0.0	25.0	50.0
Sagittaria latifolia	COMMON ARROWHEAD	0.0	0.0	5.0	19.0	0.0	37.5	50.0
Pilea pumila	CLEARWEED	0.0	0.0	35.0	4.8	0.0	62.5	50.0
Lemna minor	SMALL DUCKWEED	0.0	0.0	5.0	14.3	0.0	75.0	50.0
Carex lacustris	SEDGE	0.0	0.0	0.0	4.8	8.3	100.0	50.0
SOLANUM DULCAMARA	BITTERSWEET NIGHTSHADE	60.0	0.0	5.0	0.0	0.0	0.0	33.3
Carex stipata	SEDGE	20.0	0.0	0.0	0.0	8.3	0.0	33.3
Betula pumila	BOG BIRCH	0.0	0.0	0.0	4.8	4.2	0.0	33.3
Cirsium muticum	SWAMP-THISTLE	0.0	0.0	0.0	9.5	4.2	0.0	33.3
Carex disperma	SEDGE	0.0	0.0	0.0	4.8	16.7	0.0	33.3
Carex lasiocarpa	SEDGE	0.0	0.0	0.0	14.3	4.2	0.0	33.3
Carex pseudo-cyperus	SEDGE	0.0	0.0	5.0	9.5	0.0	0.0	33.3
Carex radiata	SEDGE	0.0	0.0	0.0	9.5	20.8	0.0	33.3
Eupatorium maculatum	JOE-PYE WEED	0.0	8.3	0.0	0.0	4.2	0.0	33.3
Galium triflorum	FRAGRANT BEDSTRAW	0.0	0.0	10.0	14.3	0.0	0.0	33.3
Lonicera oblongifolia	SWAMP FLY HONEYSUCKLE	0.0	0.0	10.0	4.8	0.0	0.0	33.3
Mitella diphylla	BISHOP'S CAP	0.0	0.0	0.0	19.0	16.7	0.0	33.3
Poa palustris	FOWL MEADOW GRASS	0.0	33.3	0.0	0.0	41.7	0.0	33.3

Table continues

Appendix 2 continued

SCIENTIFIC NAME	COMMON NAME	Sites Harr	Hutten- locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Potentilla palustris	MARSH CINQUEFOIL	0.0	0.0	0.0	9.5	8.3	0.0	33.3
Quercus bicolor	SWAMP WHITE OAK	0.0	0.0	5.0	0.0	4.2	0.0	33.3
Ribes hirtellum	SWAMP GOOSEBERRY	0.0	0.0	15.0	4.8	0.0	0.0	33.3
Rumex orbiculatus	GREAT WATER DOCK	0.0	0.0	5.0	0.0	8.3	0.0	33.3
Scutellaria galericulata	COMMON SKULLCAP	0.0	8.3	0.0	4.8	0.0	0.0	33.3
Solidago gigantea	LATE GOLDENROD	0.0	0.0	5.0	4.8	0.0	0.0	33.3
Sphagnum spp.	SPHAGNUM MOSS	0.0	0.0	0.0	14.3	16.7	0.0	33.3
Vaccinium corymbosum	SMOOTH HIGHBUSH BLUEBERRY	0.0	0.0	0.0	9.5	8.3	0.0	33.3
Amphicarpaea bracteata	HOG-PEANUT	0.0	8.3	0.0	0.0	0.0	12.5	33.3
Epilobium leptophyllum	FEN WILLOW-HERB	0.0	0.0	0.0	0.0	4.2	12.5	33.3
Poaceae spp.	GRASS	0.0	0.0	0.0	0.0	4.2	50.0	33.3
Rubus strigosus	WILD RED RASPBERRY	10.0	0.0	0.0	0.0	0.0	0.0	16.7
Allium canadense	WILD GARLIC	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Aster borealis	NORTHERN BOG-ASTER	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Betula alleghaniensis	YELLOW BIRCH	0.0	0.0	0.0	0.0	8.3	0.0	16.7
Osmorhiza claytonii	HAIRY SWEET-CICELY	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Carex sp.	SEDGE	0.0	0.0	5.0	0.0	0.0	0.0	16.7
Cornus alternifolia	ALTERNATE-LEAVED DOGWOOD	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Carex gracillima	SEDGE	0.0	0.0	5.0	0.0	0.0	0.0	16.7
Carex interior	SEDGE	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Carex prairea	SEDGE	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Carex sterilis	SEDGE	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Carex trisperma	SEDGE	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Decodon verticillatus	SWAMP LOOSESTRIFE	0.0	0.0	5.0	0.0	0.0	0.0	16.7
Eleocharis spp.	SPIKE-RUSH	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Eupatorium perfoliatum	COMMON BONESET	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Galium boreale	NORTHERN BEDSTRAW	0.0	0.0	0.0	19.0	0.0	0.0	16.7
Juniperus communis	COMMON JUNIPER	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Lindera benzoin	SPICEBUSH	0.0	0.0	0.0	0.0	8.3	0.0	16.7
Polygonatum pubescens	DOWNY SOLOMON SEAL	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Polygonum scandens	FALSE BUCKWHEAT	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Pyrola asarifolia	PINK PYROLA	0.0	0.0	0.0	0.0	8.3	0.0	16.7
Rhamnus alnifolia	ALDER-LEAVED BUCKTHORN	0.0	0.0	0.0	9.5	0.0	0.0	16.7
RHAMNUS FRANGULA	GLOSSY BUCKTHORN	0.0	0.0	0.0	4.8	0.0	0.0	16.7

Table continues

Appendix 2 continued

SCIENTIFIC NAME	COMMON NAME	Sites: Harr	Hutten-locker	Leeke	M52	Portage	Waterloo	% Site Frequency
Rubus occidentalis	BLACK RASPBERRY	0.0	0.0	5.0	0.0	0.0	0.0	16.7
Salix bebbiana	BEBB'S or BEAKED WILLOW	0.0	0.0	0.0	0.0	4.2	0.0	16.7
Salix pedicellaris	BOG WILLOW	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Sambucus canadensis	ELDERBERRY	0.0	0.0	0.0	0.0	8.3	0.0	16.7
TYPHA ANGUSTIFOLIA	NARROW-LEAVED CAT-TAIL	0.0	8.3	0.0	0.0	0.0	0.0	16.7
Vaccinium oxycoccos	SMALL CRANBERRY	0.0	0.0	0.0	9.5	0.0	0.0	16.7
Vitis riparia	RIVERBANK GRAPE	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Zizia aurea	GOLDEN ALEXANDERS	0.0	0.0	0.0	4.8	0.0	0.0	16.7
Euonymus obovata	RUNNING STRAWBERRY BUSH	0.0	0.0	0.0	0.0	0.0	12.5	16.7
Typha latifolia	BROAD-LEAVED CAT-TAIL	0.0	0.0	0.0	0.0	0.0	25.0	16.7
Total Frequency		**710.0**	**1166.7**	**1085.0**	**1390.5**	**1237.5**	**837.5**	
Number of spp/site (109 total species)		**26.0**	**49.0**	**53.0**	**69.0**	**65.0**	**31.0**	**109.0**
Mean number of species per plot		**7.1**	**11.7**	**10.9**	**13.9**	**12.4**	**8.4**	
Species Richness Index (SRI)		**11.0**	**20.8**	**19.6**	**23.7**	**26.9**	**13.8**	
Number of ground layer plots		**10.0**	**12.0**	**20.0**	**21.0**	**24.0**	**8.0**	

Appendix 3**.** Shrub layer species percent cover (C) and percent frequency (F) for conifer swamp sites. Percent site frequencies are based on occurrences within shrub layer line intercepts. Importance values (IV) are a sum of a species' relative cover and relative frequency values.

		Sites													
		Harr		**Hutten-locker**		**Leeke**		**M52**		**Portage**		**Watterloo**			
SCIENTIFIC NAME	**COMMON NAME**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**% Site Frequency**	**IV**
Ilex verticillata	WINTERBERRY	17.4	60.0	26.8	41.7	79.9	95.0	44.2	90.5	16.3	45.8	18.0	37.5	100.0	40.4
Toxicodendron vernix	POISON SUMAC	24.6	70.0	25.7	75.0	15.2	65.0	7.6	61.9	20.2	70.8	5.3	37.5	100.0	22.7
Cornus foemina	GRAY DOGWOOD	10.6	20.0	29.8	66.7	5.6	25.0	10.2	38.1	5.2	25.0	14.5	25.0	100.0	18.8
Cornus amomum	SILKY DOGWOOD	5.2	40.0	7.3	25.0	0.4	5.0	14.6	76.2	4.3	25.0	18.3	50.0	100.0	14.4
Vaccinium corymbosum	SMOOTH HIGHBUSH BLUEBERRY	1.0	10.0	0.7	16.7	2.7	15.0	13.0	66.7	18.4	66.7	6.5	12.5	100.0	13.1
Rosa palustris	SWAMP ROSE	1.0	10.0	-	-	1.9	10.0	10.5	47.6	2.0	12.5	3.5	12.5	83.3	8.1
Corylus americana	HAZELNUT	6.8	20.0	1.3	8.3	4.5	10.0	1.9	9.5	0.2	4.2	-	-	83.3	7.4
Ribes hirtellum	SWAMP GOOSEBERRY	0.2	10.0	-	-	0.6	15.0	2.8	42.9	0.2	4.2	0.5	12.5	83.3	5.6
Vitis riparia	RIVERBANK GRAPE	-	-	2.5	8.3	3.4	15.0	0.1	4.8	0.2	4.2	-	-	66.7	5.0
Betula pumila	BOG BIRCH	-	-	0.8	8.3	0.1	5.0	1.8	33.3	1.3	12.5	-	-	66.7	4.6
Rubus strigosus	WILD RED RASPBERRY	2.0	10.0	-	-	-	-	0.4	4.8	0.1	4.2	1.0	12.5	66.7	4.5
Ulmus americana	AMERICAN ELM	0.4	10.0	-	-	0.1	5.0	2.3	33.3	0.2	8.3	-	-	66.7	4.4
Aronia prunifolia	BLACK CHOKEBERRY	-	-	-	-	1.0	5.0	8.6	33.3	2.1	8.3	-	-	50.0	4.9
Viburnum lentago	NANNYBERRY	-	-	-	-	0.7	5.0	-	-	3.1	12.5	1.3	12.5	50.0	3.8
Amelanchier arborea	JUNEBERRY	-	-	-	-	0.4	5.0	0.2	4.8	0.8	4.2	-	-	50.0	3.2
Parthenocissus quinquefolia	VIRGINIA CREEPER	-	-	0.7	16.7	-	-	0.6	9.5	0.2	8.3	-	-	50.0	3.2
Lindera benzoin	SPICEBUSH	-	-	-	-	0.2	5.0	-	-	7.0	33.3	-	-	33.3	3.2
SOLANUM DULCAMARA	BITTERSWEET NIGHTSHADE	5.0	50.0	-	-	-	-	-	-	2.2	16.7	-	-	33.3	3.2
Salix discolor	PUSSY WILLOW	-	-	-	-	-	-	3.3	28.6	0.8	4.2	-	-	33.3	2.7
Salix bebbiana	BEBB'S	-	-	-	-	-	-	2.5	4.8	0.7	8.3	-	-	33.3	2.5
Acer rubrum	RED MAPLE	-	-	-	-	-	-	0.9	19.0	1.8	4.2	-	-	33.3	2.4
Salix serissima	AUTUMN WILLOW	-	-	-	-	-	-	0.9	4.8	1.4	8.3	-	-	33.3	2.3
Larix laricina	TAMARACK	-	-	-	-	-	-	1.0	9.5	0.3	4.2	-	-	33.3	2.2
Salix candida	SAGE WILLOW	-	-	-	-	-	-	0.4	4.8	0.1	4.2	-	-	33.3	2.0
Carpinus caroliniana	HORNBEAM	-	-	-	-	-	-	-	-	-	-	6.8	25.0	16.7	2.1
Rhamnus alnifolia	ALDER-LEAVED BUCKTHORN	-	-	-	-	-	-	2.6	9.5	-	-	-	-	16.7	1.4
Toxicodendron radicans	POISON-IVY	1.4	10.0	-	-	-	-	-	-	-	-	-	-	16.7	1.2
Juniperus communis	COMMON JUNIPER	-	-	-	-	-	-	1.3	9.5	-	-	-	-	16.7	1.2
Cornus alternifolia	ALTERNATE-LEAVED DOGWOOD	-	-	-	-	-	-	-	-	0.7	4.2	-	-	16.7	1.1
Sambucus canadensis	ELDERBERRY	-	-	-	-	-	-	-	-	0.7	4.2	-	-	16.7	1.1
Nemopanthus mucronata	MOUNTAIN HOLLY	-	-	-	-	-	-	0.5714	4.7619	-	-	-	-	16.7	1.1
Lonicera oblongifolia	SWAMP FLY HONEYSUCKLE	-	-	-	-	-	-	0.3	4.8	-	-	-	-	16.7	1.0
Betula alleghaniensis	YELLOW BIRCH	-	-	-	-	-	-	-	-	0.3	4.2	-	-	16.7	1.0
Potentilla fruticosa	SHRUBBY CINQUEFOIL	-	-	-	-	-	-	0.2	4.8	-	-	-	-	16.7	1.0
Rubus occidentalis	BLACK RASPBERRY	-	-	-	-	-	-	0.0952	4.7619	-	-	-	-	16.7	1.0
Spiraea alba	MEADOWSWEET	-	-	-	-	-	-	0.1	4.8	-	-	-	-	16.7	1.0
Ribes americanum	WILD BLACK CURRANT	-	-	-	-	-	-	-	-	0.1	4.2	-	-	16.7	1.0
Total % Cover and % Frquency		**75.6**	**320.0**	**95.7**	**266.7**	**116.7**	**285.0**	**132.7**	**671.4**	**90.5**	**416.7**	**75.5**	**237.5**		
Total number of species (total = 37 species)		**12**		**9**		**15**		**28**		**28**		**10**			
Number of line-intercept segments		**10**		**12**		**20**		**21**		**24**		**8**			

Appendix 4. Tree layer summary table for conifer swamp sites. Importance values (IV) are a sum of a species' relative density, relative cover, and relative frequency values. The number of plots for each site is indicated in parentheses.

Site	SCIENTIFIC NAME	COMMON NAME	Total	Density (trees/ha)	% Relative Density	Cover (m2/ha)	% Relative Cover	% Frequency	% Relative Frequency	IV
Harr (n=10)										
	Larix laricina	TAMARACK	39	390.0	84.8	15.0	90.5	90.0	60.0	235.3
	Acer rubrum	RED MAPLE	4	40.0	8.7	0.9	5.6	30.0	20.0	34.3
	Ulmus americana	AMERICAN ELM	3	30.0	6.5	0.6	3.9	30.0	20.0	30.4
	Total		**46**	**460.0**	**100.0**	**16.6**	**100.0**	**150.0**	**100.0**	**300.0**
Huttenlocker (n=12)										
	Ulmus americana	AMERICAN ELM	40	333.3	47.6	5.0	42.4	83.3	30.3	120.3
	Acer rubrum	RED MAPLE	25	208.3	29.8	3.3	28.3	83.3	30.3	88.3
	Larix laricina	TAMARACK	12	100.0	14.3	3.1	26.3	58.3	21.2	61.8
	Betula alleghaniensis	YELLOW BIRCH	2	16.7	2.4	0.0	0.4	8.3	3.0	5.8
	Prunus serotina	WILD BLACK CHERRY	2	16.7	2.4	0.0	0.1	16.7	6.1	8.6
	Populus tremuloides	QUAKING ASPEN	1	8.3	1.2	0.1	0.6	8.3	3.0	4.8
	Quercus rubra	RED OAK	1	8.3	1.2	0.2	1.8	8.3	3.0	6.0
	Viburnum lentago	NANNYBERRY	1	8.3	1.2	0.0	0.2	8.3	3.0	4.4
	Total		**84**	**700.0**	**100.0**	**11.8**	**100.0**	**275.0**	**100.0**	**300.0**
Leeke (n=20)										
	Larix laricina	TAMARACK	103	515.0	53.4	11.7	71.2	95.0	31.1	155.7
	Acer rubrum	RED MAPLE	50	250.0	25.9	2.7	16.3	80.0	26.2	68.5
	Ulmus americana	AMERICAN ELM	19	95.0	9.8	1.4	8.4	50.0	16.4	34.7
	Quercus bicolor	SWAMP WHITE OAK	15	75.0	7.8	0.6	3.7	55.0	18.0	29.5
	Viburnum lentago	NANNYBERRY	3	15.0	1.6	0.0	0.2	15.0	4.9	6.7
	Betula alleghaniensis	YELLOW BIRCH	2	10.0	1.0	0.0	0.2	5.0	1.6	2.9
	Amelanchier arborea	JUNEBERRY	1	5.0	0.5	0.0	0.0	5.0	1.6	2.2
	Total		**193**	**965.0**	**100.0**	**16.4**	**100.0**	**305.0**	**100.0**	**300.0**
M52 (n=21)										
	Larix laricina	TAMARACK	195	928.6	52.3	6.2	68.0	100.0	31.3	151.6
	Ulmus americana	AMERICAN ELM	101	481.0	27.1	1.9	20.4	76.2	23.9	71.3
	Acer rubrum	RED MAPLE	67	319.0	18.0	1.0	11.0	100.0	31.3	60.3
	Quercus bicolor	SWAMP WHITE OAK	5	23.8	1.3	0.0	0.3	19.0	6.0	7.6

Table continues

Appendix 4 continued

Site	SCIENTIFIC NAME	COMMON NAME	Total	Density (trees/ha)	% Relative Density	Cover (m2/ha)	% Relative Cover	% Frequency	% Relative Frequency	IV
	Fraxinus nigra	BLACK ASH	2	9.5	0.5	0.0	0.1	9.5	3.0	3.6
	Amelanchier arborea	JUNEBERRY	1	4.8	0.3	0.0	0.0	4.8	1.5	1.8
	Populus tremuloides	QUAKING ASPEN	1	4.8	0.3	0.0	0.0	4.8	1.5	1.8
	Viburnum lentago	NANNYBERRY	1	4.8	0.3	0.0	0.2	4.8	1.5	2.0
	Total		**373**	**1776.2**	**100.0**	**9.2**	**100.0**	**319.0**	**100.0**	**300.0**
Portage (n=23)										
	Ulmus americana	AMERICAN ELM	244	1060.9	51.2	6.2	29.4	95.7	27.5	108.1
	Larix laricina	TAMARACK	130	565.2	27.3	10.1	48.2	100.0	28.7	104.2
	Acer rubrum	RED MAPLE	70	304.3	14.7	3.5	16.5	87.0	25.0	56.2
	Betula alleghaniensis	YELLOW BIRCH	15	65.2	3.1	0.7	3.4	26.1	7.5	14.1
	Carpinus caroliniana	HORNBEAM	9	39.1	1.9	0.2	0.8	13.0	3.7	6.5
	Viburnum lentago	NANNYBERRY	6	26.1	1.3	0.0	0.1	13.0	3.7	5.1
	Populus tremuloides	QUAKING ASPEN	1	4.3	0.2	0.3	1.5	4.3	1.2	2.9
	Fraxinus nigra	BLACK ASH	1	4.3	0.2	0.0	0.0	4.3	1.2	1.5
	Amelanchier arborea	JUNEBERRY	1	4.3	0.2	0.0	0.0	4.3	1.2	1.5
	Total		**477**	**2073.9**	**100.0**	**21.0**	**100.0**	**347.8**	**100.0**	**300.0**
Waterloo (n=8)										
	Betula alleghaniensis	YELLOW BIRCH	27	337.5	26.7	1.6	10.8	62.5	13.2	50.7
	Fraxinus nigra	BLACK ASH	20	250.0	19.8	6.4	42.7	87.5	18.4	80.9
	Carpinus caroliniana	HORNBEAM	14	175.0	13.9	0.2	1.2	50.0	10.5	25.6
	Ulmus americana	AMERICAN ELM	13	162.5	12.9	0.7	4.6	87.5	18.4	35.9
	Viburnum lentago	NANNYBERRY	12	150.0	11.9	0.2	1.3	50.0	10.5	23.8
	Acer rubrum	RED MAPLE	7	87.5	6.9	0.5	3.5	50.0	10.5	21.0
	Quercus bicolor	SWAMP WHITE OAK	5	62.5	5.0	1.8	12.3	50.0	10.5	27.7
	Amelanchier arborea	JUNEBERRY	1	12.5	1.0	0.0	0.1	12.5	2.6	3.7
	Larix laricina	TAMARACK	1	12.5	1.0	0.8	5.1	12.5	2.6	8.7
	Salix nigra	BLACK WILLOW	1	12.5	1.0	2.8	18.3	12.5	2.6	21.9
	Total		**101**	**1262.5**	**100.0**	**15.1**	**100.0**	**475.0**	**100.0**	**300.0**

Appendix 5. Soil sampling results.

Site	General Description	Marl (depth)	pH at surface	pH at 8" depth
Harr	muck and fibric peat to 13' +	no	7.0	7.0
Huttenlocker	muck and fibric peat to 13' +, near edges of wetland encountered silty, gleyed clay at 9'	yes (7' - 13')	8.0	7.5
Leeke	muck and fibric peat to 13' +	yes (11' - 13')	8.0	8.0
M52	muck and fibric peat to 13' +	yes (9.5' - 13')	8.0	8.0
Portage	muck and fibric peat to 13' +	yes (12' - 13')	8.0	8.0
Waterloo	muck and fibric peat over marl to 7', edges of wetland contain muck over gleyed clay and gleyed, fine sand to 4'	yes (6.5' - 7')	8.0	8.0

Site	General Description	Marl (depth)	pH at Surface	pH at 8" depth
Barry	muck and fibric peat over marl to 12.5'	yes (6' - 12.5')	8.0	8.0
Dansville Pool	gleyed clay over mottled sand to 3.5' +	no	7.0	7.0
Dansville Swamp	muck and fibric peat over marl to 13'	yes (12' - 13')	7.0	7.0
Fort Custer	gleyed clay to 3.5' +	no	8.0	8.0
Geology Center	muck and fibric peat to 13' +	no	7.0	8.0
Haven Hill	muck and fibric peat over marl to 10.5' +	yes (8.5' - 10.5')	8.0	8.0
Rose Lake	gleyed clay mixed with mottled and gleyed fine sand and silt to 4.5'	no	8.0	8.0

Appendix 6. Plant species observed at hardwood swamp sites. "1" indicates the species occurred within a sample plot. "+" indicates the species occurred at the site but not within a sample plot. Percent site frequency is based on species occurrences within plots. The total number of species and Floristic Quality Index is given at the bottom of the table for each site.

			Sites							
SCIENTIFIC NAME	**COMMON NAME**	**PHYSIOG.**	**Barry**	**Dansville Pool**	**Dansville Swamp**	**Fort Custer**	**Geology Center**	**Haven Hill**	**Rose Lake**	**Site % Frequency**
Acer rubrum	RED MAPLE	N Tree	1	1	1	1	1	1	1	100.0
Ulmus americana	AMERICAN ELM	N Tree	1	1	1	1	1	1	1	100.0
Boehmeria cylindrica	FALSE NETTLE	N Forb	1	1	1	-	1	1	1	85.7
Fraxinus nigra	BLACK ASH	N Tree	1	1	1	-	1	1	1	85.7
Impatiens capensis	SPOTTED TOUCH-ME-NOT	N Forb	1	1	1	-	1	1	1	85.7
Viola spp.	VIOLET	N Forb	1	1	1	-	1	1	1	85.7
Fraxinus pennsylvanica	RED ASH	N Tree	1	-	-	1	1	1	1	71.4
Glyceria striata	FOWL MANNA GRASS	N Grass	1	-	1	-	1	1	1	71.4
Ilex verticillata	WINTERBERRY	N Shrub	1	1	1	-	1	1	+	71.4
Parthenocissus quinquefolia	VIRGINIA CREEPER	N Vine	1	-	1	-	1	1	1	71.4
Pilea pumila	CLEARWEED	N Forb	1	1	1	-	1	1	-	71.4
Rubus pubescens	DWARF RASPBERRY	N Forb	1	-	1	-	1	1	1	71.4
Scutellaria lateriflora	MAD-DOG SKULLCAP	N Forb	-	1	1	-	1	1	1	71.4
Symplocarpus foetidus	SKUNK-CABBAGE	N Forb	1	1	1	-	1	-	1	71.4
Tilia americana	LINDEN; BASSWOOD	N Tree	1	-	1	-	1	1	1	71.4
Toxicodendron radicans	POISON-IVY	N Vine	1	-	1	-	1	1	1	71.4
Betula alleghaniensis	YELLOW BIRCH	N Tree	-	1	1	-	1	1	-	57.1
Bidens cernuus	NODDING BUR-MARIGOLD	N Forb	-	1	-	-	1	1	1	57.1
Carpinus caroliniana	HORNBEAM	N Tree	1	-	1	-	1	1	-	57.1
Carex spp.	SEDGE	N Sedge	1	1	1	-	1	-	-	57.1
Cinna arundinacea	WOOD REEDGRASS	N Grass	1	-	1	-	1	1	-	57.1
Cornus foemina	GRAY DOGWOOD	N Shrub	1	-	1	1	1	-	-	57.1
Dryopteris carthusiana	SPINULOSE WOODFERN	N Fern	1	1	1	-	+	+	1	57.1
Leersia oryzoides	CUT GRASS	N Grass	1	1	-	-	1	-	1	57.1
Lycopus uniflorus	NORTHERN BUGLE WEED	N Forb	-	1	1	-	1	-	1	57.1
Maianthemum canadense	CANADA MAYFLOWER	N Forb	1	-	1	-	1	1	-	57.1
Osmunda cinnamomea	CINNAMON FERN	N Fern	1	1	1	-	1	-	-	57.1
Solidago rugosa	ROUGH GOLDENROD	N Forb	1	-	1	-	1	1	-	57.1
Arisaema triphyllum	JACK-IN-THE-PULPIT	N Forb	1	-	1	-	-	1	-	42.9
Aster lanceolatus	EASTERN LINED ASTER	N Forb	1	-	-	-	-	1	1	42.9
Carex lacustris	SEDGE	N Sedge	-	1	-	-	1	-	1	42.9
Fagus grandifolia	AMERICAN BEECH	N Tree	1	-	-	-	1	1	-	42.9
Galium triflorum	FRAGRANT BEDSTRAW	N Forb	1	-	1	-	-	1	-	42.9
Lindera benzoin	SPICEBUSH	N Shrub	1	-	+	-	-	1	1	42.9

Table continues

Appendix 6 continued

SCIENTIFIC NAME	COMMON NAME	PHYSIOG.	Sites: Barry	Dansville Pool	Dansville Swamp	Fort Custer	Geology Center	Haven Hill	Rose Lake	Site % Frequency
Prunus virginiana	CHOKE CHERRY	N Shrub	1	-	-	-	-	1	1	42.9
Quercus bicolor	SWAMP WHITE OAK	N Tree	1	-	1	-	1	-	-	42.9
Rosa palustris	SWAMP ROSE	N Shrub	-	1	1	-	1	-	-	42.9
Sambucus canadensis	ELDERBERRY	N Shrub	-	1	1	-	1	-	-	42.9
Viburnum lentago	NANNYBERRY	N Shrub	1	-	1	-	1	-	-	42.9
Aralia nudicaulis	WILD SARSAPARILLA	N Forb	-	-	1	-	-	1	-	28.6
Aster lateriflorus	SIDE-FLOWERING ASTER	N Forb	-	-	1	-	+	1	-	28.6
Cicuta maculata	WATER HEMLOCK	N Forb	-	-	-	-	-	1	1	28.6
Cuscuta gronovii	COMMON DODDER	N Forb	1	1	-	-	-	-	-	28.6
Carex stipata	SEDGE	N Sedge	-	-	-	-	1	1	-	28.6
Equisetum arvense	FIELD HORSETAIL	N Fern	-	-	-	-	1	1	-	28.6
Laportea canadensis	WOOD NETTLE	N Forb	1	-	-	-	-	1	-	28.6
Lysimachia thyrsiflora	TUFTED LOOSESTRIFE	N Forb	-	1	-	-	1	-	-	28.6
Mitella diphylla	BISHOP'S CAP	N Forb	-	-	-	-	1	1	-	28.6
Osmunda regalis	ROYAL FERN	N Fern	+	-	+	-	1	1	-	28.6
Phalaris arundinacea	REED CANARY GRASS	N Grass	-	1	-	-	-	-	1	28.6
Polygonum arifolium	TEAR-THUMB	N Forb	-	+	-	-	1	1	-	28.6
Prunus serotina	WILD BLACK CHERRY	N Tree	1	-	-	-	-	-	1	28.6
Quercus rubra	RED OAK	N Tree	-	-	-	-	1	1	-	28.6
Rubus occidentalis	BLACK RASPBERRY	N Shrub	1	-	-	-	-	+	1	28.6
Toxicodendron vernix	POISON SUMAC	N Shrub	1	-	-	-	1	-	-	28.6
Vaccinium corymbosum	SMOOTH HIGHBUSH BLUEBERRY	N Shrub	-	-	1	-	1	-	-	28.6
Zanthoxylum americanum	PRICKLY-ASH	N Shrub	1	-	1	-	-	-	-	28.6
Osmorhiza longistylis	SMOOTH SWEET-CICELY	N Forb	1	-	-	-	-	-	-	14.3
Amelanchier arborea	JUNEBERRY	N Tree	-	-	-	-	1	-	-	14.3
Athyrium filix-femina	LADY FERN	N Fern	1	-	-	-	-	-	-	14.3
Caltha palustris	MARSH-MARIGOLD	N Forb	-	-	-	-	-	1	-	14.3
Cardamine sp.	BITTER CRESS	N Forb	-	-	-	-	1	-	-	14.3
Cirsium muticum	SWAMP-THISTLE	N Forb	-	-	1	-	-	-	-	14.3
Coptis trifolia	GOLDTHREAD	N Forb	-	-	1	-	-	-	-	14.3
Cornus alternifolia	ALTERNATE-LEAVED DOGWOOD	N Tree	-	-	-	-	-	1	-	14.3
Corylus americana	HAZELNUT	N Shrub	+	-	1	-	+	-	-	14.3
Cryptotaenia canadensis	HONEWORT	N Forb	1	-	-	-	-	-	-	14.3
Carex diandra	SEDGE	N Sedge	-	-	-	-	-	-	1	14.3
Carex gracillima	SEDGE	N Sedge	1	-	-	-	-	-	-	14.3
Carex leptalea	SEDGE	N Sedge	-	-	1	-	-	-	-	14.3
Carex radiata	SEDGE	N Sedge	-	-	-	-	-	1	-	14.3
Carex stricta	SEDGE	N Sedge	-	-	-	-	-	-	1	14.3
Dioscorea villosa	WILD YAM	N Vine	1	-	-	-	-	-	-	14.3
Dryopteris cristata	CRESTED SHIELD FERN	N Fern	-	-	1	-	-	+	-	14.3
ELAEAGNUS UMBELLATA	AUTUMN-OLIVE	A Tree	-	-	-	-	-	-	1	14.3
Euonymus obovata	RUNNING STRAWBERRY BUSH	N Shrub	-	-	-	-	-	1	-	14.3

Table continues

Appendix 6 continued

SCIENTIFIC NAME	COMMON NAME	PHYSIOG.	Sites Barry	Dansville Pool	Dansville Swamp	Fort Custer	Geology Center	Haven Hill	Rose Lake	Site % Frequency
Galium tinctorium	STIFF BEDSTRAW	N Forb	-	1	-	-	-	-	-	14.3
Geum canadense	WHITE AVENS	N Forb	1	-	-	-	-	-	-	14.3
Liriodendron tulipifera	TULIP TREE	N Tree	-	-	-	-	1	+	-	14.3
Lycopus americanus	COMMON WATER HOREHOUND	N Forb	-	-	-	-	+	1	-	14.3
Lycopodium annotinum	STIFF CLUBMOSS	N Fern	-	-	1	-	-	-	-	14.3
Poaceae spp	GRASS	N Grass	-	-	-	-	1	-	-	14.3
Podophyllum peltatum	MAY APPLE	N Forb	1	-	-	-	-	-	-	14.3
Polygonum hydropiperoides	WATER-PEPPER	N Forb	1	-	-	-	-	-	-	14.3
Polygonatum pubescens	DOWNY SOLOMON SEAL	N Forb	-	-	1	-	-	+	-	14.3
Polygonum sagittatum	ARROW-LEAVED TEAR-THUMB	N Forb	1	-	-	-	-	-	-	14.3
Polygonum virginianum	JUMPSEED	N Forb	1	-	-	-	-	-	-	14.3
Populus deltoides	COTTONWOOD	N Tree	-	-	-	1	-	-	-	14.3
Ribes americanum	WILD BLACK CURRANT	N Shrub	-	-	-	-	-	1	-	14.3
Senecio aureus	GOLDEN RAGWORT	N Forb	+	-	1	-	-	-	-	14.3
SOLANUM DULCAMARA	BITTERSWEET NIGHTSHADE	A Vine	-	-	-	-	1	-	-	14.3
Solidago patula	SWAMP GOLDENROD	N Forb	-	-	+	-	1	-	-	14.3
Trientalis borealis	STARFLOWER	N Forb	-	-	1	-	-	-	-	14.3
Urtica dioica	NETTLE	N Forb	-	1	-	-	-	-	-	14.3
Apios americana	GROUNDNUT	N Forb	-	-	-	-	-	+	-	+
Aralia racemosa	SPIKENARD	N Forb	-	-	-	-	-	-	+	+
Aronia prunifolia	BLACK CHOKEBERRY	N Shrub	-	-	+	-	-	-	-	+
Aster firmus	SMOOTH SWAMP ASTER	N Forb	-	-	-	-	+	-	-	+
Aster umbellatus	TALL FLAT-TOP WHITE ASTER	N Forb	-	-	+	-	-	-	+	+
Bidens coronatus	TALL SWAMP-MARIGOLD	N Forb	-	+	-	-	-	-	-	+
Chelone glabra	TURTLEHEAD	N Forb	-	-	-	-	-	+	-	+
Carex intumescens	SEDGE	N Sedge	-	-	-	-	-	+	-	+
Epilobium ciliatum	WILLOW-HERB	N Forb	-	+	-	-	-	-	-	+
Eupatorium perfoliatum	COMMON BONESET	N Forb	-	+	-	-	-	-	+	+
Eupatorium rugosum	WHITE SNAKEROOT	N Forb	+	-	-	-	-	-	-	+
Hystrix patula	BOTTLEBRUSH GRASS	N Grass	+	-	-	-	-	-	-	+
Larix laricina	TAMARACK	N Tree	-	-	+	-	+	-	-	+
Onoclea sensibilis	SENSITIVE FERN	N Fern	+	-	-	-	+	+	-	+
Phragmites australis	REED	N Grass	+	-	-	-	-	-	-	+
Pinus strobus	WHITE PINE	N Tree	+	-	-	-	-	-	-	+
RHAMNUS FRANGULA	GLOSSY BUCKTHORN	A Shrub	-	-	-	-	-	-	+	+
Sphagnum spp.	SPHAGNUM MOSS	N Moss	-	-	-	-	+	-	-	+
Viburnum opulus	EUROPEAN HIGHBUSH CRANBERRY	A Shrub	-	-	-	-	-	-	+	+
Total number of species observed within all plots			**48**	**25**	**44**	**5**	**48**	**43**	**29**	
Total number of species observed both in and out of plots			**56**	**29**	**50**	**5**	**56**	**52**	**35**	
Floristic Quality Index			**28.3**	**20.6**	**31.5**	**4.5**	**30.4**	**30.7**	**20.4**	

Appendix 7. Percent frequency of ground layer species at hardwood swamp sites based on occurrences within .25m^2 plots. Percent site frequencies are given for all species occurring in at least one plot.

		Sites							
SCIENTIFIC NAME	COMMON NAME	Barry	Dansville Pool	Dansville Swamp	Fort Custer	Geology Center	Haven Hill	Rose Lake	% Site Frequency
Acer rubrum	RED MAPLE	12.5	56.3	25.0	8.3	25.0	25.0	33.3	100.0
Boehmeria cylindrica	FALSE NETTLE	43.8	31.3	37.5	0.0	40.0	33.3	25.0	85.7
Impatiens capensis	SPOTTED TOUCH-ME-NOT	25.0	62.5	31.3	0.0	60.0	33.3	16.7	85.7
Viola spp.	VIOLET	62.5	6.3	50.0	0.0	35.0	50.0	16.7	85.7
Glyceria striata	FOWL MANNA GRASS	37.5	0.0	12.5	0.0	5.0	8.3	41.7	71.4
Parthenocissus quinquefolia	VIRGINIA CREEPER	31.3	0.0	37.5	0.0	10.0	25.0	8.3	71.4
Pilea pumila	CLEARWEED	68.8	56.3	6.3	0.0	40.0	66.7	0.0	71.4
Rubus pubescens	DWARF RASPBERRY	18.8	0.0	50.0	0.0	20.0	33.3	8.3	71.4
Scutellaria lateriflora	MAD-DOG SKULLCAP	0.0	6.3	18.8	0.0	35.0	8.3	25.0	71.4
Symplocarpus foetidus	SKUNK-CABBAGE	25.0	6.3	37.5	0.0	20.0	0.0	8.3	71.4
Toxicodendron radicans	POISON-IVY	18.8	0.0	6.3	0.0	15.0	8.3	8.3	71.4
Ulmus americana	WHITE or AMERICAN ELM	31.3	0.0	25.0	0.0	35.0	25.0	16.7	71.4
Bidens cernuus	NODDING BUR-MARIGOLD	0.0	50.0	0.0	0.0	30.0	33.3	41.7	57.1
Carex spp.	SEDGE	6.3	6.3	6.3	0.0	5.0	0.0	0.0	57.1
Cinna arundinacea	WOOD REEDGRASS	12.5	0.0	6.3	0.0	10.0	66.7	0.0	57.1
Dryopteris carthusiana	SPINULOSE WOODFERN	12.5	6.3	43.8	0.0	0.0	0.0	8.3	57.1
Leersia oryzoides	CUT GRASS	37.5	62.5	0.0	0.0	15.0	0.0	16.7	57.1
Lycopus uniflorus	NORTHERN BUGLE WEED	0.0	12.5	6.3	0.0	10.0	0.0	16.7	57.1
Maianthemum canadense	CANADA MAYFLOWER	18.8	0.0	62.5	0.0	30.0	25.0	0.0	57.1
Osmunda cinnamomea	CINNAMON FERN	18.8	6.3	18.8	0.0	5.0	0.0	0.0	57.1
Solidago rugosa	ROUGH GOLDENROD	18.8	0.0	12.5	0.0	5.0	8.3	0.0	57.1
Arisaema triphyllum	JACK-IN-THE-PULPIT	6.3	0.0	31.3	0.0	0.0	16.7	0.0	42.9
Aster lanceolatus	EASTERN LINED ASTER	6.3	0.0	0.0	0.0	0.0	41.7	25.0	42.9
Carex lacustris	SEDGE	0.0	12.5	0.0	0.0	15.0	0.0	33.3	42.9
Fraxinus nigra	BLACK ASH	6.3	0.0	0.0	0.0	5.0	33.3	0.0	42.9
Galium triflorum	FRAGRANT BEDSTRAW	31.3	0.0	6.3	0.0	0.0	25.0	0.0	42.9
Ilex verticillata	WINTERBERRY	0.0	0.0	6.3	0.0	10.0	8.3	0.0	42.9
Aralia nudicaulis	WILD SARSAPARILLA	0.0	0.0	6.3	0.0	0.0	16.7	0.0	28.6
Aster lateriflorus	SIDE-FLOWERING ASTER	0.0	0.0	12.5	0.0	0.0	16.7	0.0	28.6
Carex stipata	SEDGE	0.0	0.0	0.0	0.0	5.0	16.7	0.0	28.6
Cicuta maculata	WATER HEMLOCK	0.0	0.0	0.0	0.0	0.0	8.3	16.7	28.6
Cornus foemina	GRAY DOGWOOD	12.5	0.0	6.3	0.0	0.0	0.0	0.0	28.6
Cuscuta gronovii	COMMON DODDER	6.3	6.3	0.0	0.0	0.0	0.0	0.0	28.6
Equisetum arvense	COMMON or FIELD HORSETAIL	0.0	0.0	0.0	0.0	5.0	25.0	0.0	28.6
Laportea canadensis	WOOD NETTLE	81.3	0.0	0.0	0.0	0.0	8.3	0.0	28.6
Lysimachia thyrsiflora	TUFTED LOOSESTRIFE	0.0	18.8	0.0	0.0	5.0	0.0	0.0	28.6

Table continues

Appendix 7 continued

		Sites							
SCIENTIFIC NAME	COMMON NAME	Barry	Dansville Pool	Dansville Swamp	Fort Custer	Geology Center	Haven Hill	Rose Lake	% Site Frequency
Mitella diphylla	BISHOP'S CAP	0.0	0.0	0.0	0.0	10.0	25.0	0.0	28.6
Osmunda regalis	ROYAL FERN	0.0	0.0	0.0	0.0	20.0	8.3	0.0	28.6
Phalaris arundinacea	REED CANARY GRASS	0.0	6.3	0.0	0.0	0.0	0.0	33.3	28.6
Polygonum arifolium	TEAR-THUMB	0.0	0.0	0.0	0.0	15.0	41.7	0.0	28.6
Rosa palustris	SWAMP ROSE	0.0	0.0	6.3	0.0	5.0	0.0	0.0	28.6
Athyrium filix-femina	LADY FERN	12.5	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Betula alleghaniensis	YELLOW BIRCH	0.0	0.0	0.0	0.0	0.0	25.0	0.0	14.3
Caltha palustris	MARSH-MARIGOLD	0.0	0.0	0.0	0.0	0.0	41.7	0.0	14.3
Cardamine sp.	BITTER CRESS	0.0	0.0	0.0	0.0	10.0	0.0	0.0	14.3
Carex diandra	SEDGE	0.0	0.0	0.0	0.0	0.0	0.0	8.3	14.3
Carex gracillima	SEDGE	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Carex leptalea	SEDGE	0.0	0.0	12.5	0.0	0.0	0.0	0.0	14.3
Carex radiata	SEDGE	0.0	0.0	0.0	0.0	0.0	25.0	0.0	14.3
Carex stricta	SEDGE	0.0	0.0	0.0	0.0	0.0	0.0	8.3	14.3
Carpinus caroliniana	HORNBEAM	0.0	0.0	0.0	0.0	5.0	0.0	0.0	14.3
Cirsium muticum	SWAMP-THISTLE	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Coptis trifolia	GOLDTHREAD	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Cornus alternifolia	ALTERNATE-LEAVED DOGWOOD	0.0	0.0	0.0	0.0	0.0	8.3	0.0	14.3
Cryptotaenia canadensis	HONEWORT	12.5	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Dioscorea villosa	WILD YAM	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Dryopteris cristata	CRESTED SHIELD FERN	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Euonymus obovata	RUNNING STRAWBERRY BUSH	0.0	0.0	0.0	0.0	0.0	8.3	0.0	14.3
Fraxinus pennsylvanica	RED ASH	0.0	0.0	0.0	8.3	0.0	0.0	0.0	14.3
Galium tinctorium	STIFF BEDSTRAW	0.0	6.3	0.0	0.0	0.0	0.0	0.0	14.3
Geum canadense	WHITE AVENS	31.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Lindera benzoin	SPICEBUSH	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Lycopodium annotinum	STIFF CLUBMOSS	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Lycopus americanus	COMMON WATER HOREHOUND	0.0	0.0	0.0	0.0	0.0	8.3	0.0	14.3
Osmorhiza longistylis	SMOOTH SWEET-CICELY	12.5	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Poaceae spp.	GRASS	0.0	0.0	0.0	0.0	5.0	0.0	0.0	14.3
Podophyllum peltatum	MAY APPLE	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Polygonatum pubescens	DOWNY SOLOMON SEAL	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Polygonum hydropiperoides	WATER-PEPPER	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Polygonum sagittatum	ARROW-LEAVED TEAR-THUMB	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Polygonum virginianum	JUMPSEED	25.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Quercus bicolor	SWAMP WHITE OAK	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
Ribes americanum	WILD BLACK CURRANT	0.0	0.0	0.0	0.0	0.0	8.3	0.0	14.3
Rubus occidentalis	BLACK RASPBERRY	12.5	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Sambucus canadensis	ELDERBERRY	0.0	0.0	0.0	0.0	5.0	0.0	0.0	14.3

Table continues

Appendix 7 continued

		Sites							
SCIENTIFIC NAME	**COMMON NAME**	**Barry**	**Dansville Pool**	**Dansville Swamp**	**Fort Custer**	**Geology Center**	**Haven Hill**	**Rose Lake**	**% Site Frequency**
Senecio aureus	GOLDEN RAGWORT	0.0	0.0	6.3	0.0	0.0	0.0	0.0	14.3
SOLANUM DULCAMARA	BITTERSWEET NIGHTSHADE	0.0	0.0	0.0	0.0	5.0	0.0	0.0	14.3
Solidago patula	SWAMP GOLDENROD	0.0	0.0	0.0	0.0	25.0	0.0	0.0	14.3
Toxicodendron vernix	POISON SUMAC	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Trientalis borealis	STARFLOWER	0.0	0.0	12.5	0.0	0.0	0.0	0.0	14.3
Urtica dioica	NETTLE	0.0	6.3	0.0	0.0	0.0	0.0	0.0	14.3
Zanthoxylum americanum	PRICKLY-ASH	6.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3
Number of species/site (81 total species)		**38.0**	**19.0**	**35.0**	**2.0**	**36.0**	**36.0**	**21.0**	**81.0**
Mean number of species per plot		**8.1**	**4.3**	**6.4**	**0.2**	**6.0**	**8.7**	**4.2**	
Species Richness Index (SRI)		**12.7**	**5.4**	**9.8**	**0.1**	**9.3**	**13.5**	**5.5**	
Number of ground layer plots		**16.0**	**16.0**	**16.0**	**12.0**	**20.0**	**12.0**	**12.0**	

Appendix 8. Shrub layer species percent cover (C) and percent frequency (F) for hardwood swamp sites. Percent site frequencies are based on occurrences within shrub layer line intercepts.

		Sites														
		Barry		Dansville Pool		Dansville Swamp		Fort Custer		Geology Center		Haven Hill		Rose Lake		% Site Frequency
SCIENTIFIC NAME	**COMMON NAME**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	
Ilex verticillata	WINTERBERRY	2.8	6.3	3.5	12.5	4.0	37.5	-	-	12.4	45.0	1.8	16.7	-	-	71.4
Carpinus caroliniana	HORNBEAM	2.5	6.3	-	-	1.5	6.3	-	-	4.2	10.0	9.3	25.0	-	-	57.1
Ulmus americana	AMERICAN ELM	-	-	0.9	12.5	0.1	6.3	-	-	-	-	0.5	8.3	2.0	25.0	57.1
Fraxinus nigra	BLACK ASH	-	-	0.9	6.3	0.9	6.3	-	-	0.1	5.0	-	-	-	-	42.9
Lindera benzoin	SPICEBUSH	3.5	12.5	-	-	-	-	-	-	-	-	0.7	8.3	3.2	8.3	42.9
Cornus foemina	GRAY DOGWOOD	-	-	-	-	-	-	0.2	8.3	0.5	5.0	-	-	-	-	28.6
Acer rubrum	RED MAPLE	-	-	0.3	6.3	0.4	6.3	-	-	-	-	-	-	-	-	28.6
Fraxinus pennsylvanica	RED ASH	-	-	-	-	-	-	0.8	16.7	-	-	-	-	0.3	8.3	28.6
Quercus bicolor	SWAMP WHITE OAK	-	-	-	-	1.9	12.5	-	-	0.2	5.0	-	-	-	-	28.6
Sambucus canadensis	ELDERBERRY	-	-	0.4	6.3	0.9	6.3	-	-	-	-	-	-	-	-	28.6
Vaccinium corymbosum	SMOOTH HIGHBUSH BLUEBERRY	-	-	-	-	1.0	12.5	-	-	2.0	20.0	-	-	-	-	28.6
Betula alleghaniensis	YELLOW BIRCH	-	-	-	-	0.8	6.3	-	-	-	-	-	-	-	-	14.3
Corylus americana	HAZELNUT	-	-	-	-	3.6	12.5	-	-	-	-	-	-	-	-	14.3
Rosa palustris	SWAMP ROSE	-	-	0.8	6.3	-	-	-	-	-	-	-	-	-	-	14.3
Rubus occidentalis	BLACK RASPBERRY	-	-	-	-	-	-	-	-	-	-	-	-	3.5	16.7	14.3
Toxicodendron vernix	POISON SUMAC	-	-	-	-	-	-	-	-	1.5	5.0	-	-	-	-	14.3
Viburnum lentago	NANNYBERRY	-	-	-	-	-	-	-	-	0.4	5.0	-	-	-	-	14.3
Zanthoxylum americanum	PRICKLY-ASH	-	-	-	-	1.6	6.3	-	-	-	-	-	-	-	-	14.3
Total Site % Cover and % Frequency		**17.5**	**50.0**	**6.6**	**50.0**	**16.6**	**118.8**	**1.0**	**25.0**	**21.3**	**100.0**	**12.3**	**58.3**	**9.0**	**58.3**	**557.1**
Total # of species per site (18 in total)		**3.0**		**6.0**		**11.0**		**2.0**		**8.0**		**4.0**		**4.0**		**18.0**
Number of line-intercept segments		**16.0**		**16.0**		**16.0**		**12.0**		**20.0**		**12.0**		**12.0**		

Appendix 9. Tree layer summary table for hardwood swamp sites. Species at each site are sorted by their cover values. Importance values (IV) are a sum of a species' relative density, relative cover, and relative frequency values (when available). "n.a." indicates not available (see methods). The number of plots for each site is indicated in parentheses.

Site	SCIENTIFIC NAME	COMMON NAME	Total	Density (trees/ha)	% Relative Density	Cover (m2/ha)	% Relative Cover	% Frequency	% Relative Frequency	IV
Barry (n=16)										
	Acer rubrum	RED MAPLE	49	306.3	25.8	21.6	53.2	75.0	24.5	103.5
	Fraxinus nigra	BLACK ASH	70	437.5	36.8	5.5	13.5	56.3	18.4	68.7
	Ulmus americana	AMERICAN ELM	35	218.8	18.4	4.5	11.0	56.3	18.4	47.8
	Tilia americana	BASSWOOD	3	18.8	1.6	3.0	7.4	12.5	4.1	13.0
	Prunus serotina	WILD BLACK CHERRY	12	75.0	6.3	2.3	5.7	37.5	12.2	24.3
	Quercus bicolor	SWAMP WHITE OAK	3	18.8	1.6	2.2	5.4	18.8	6.1	13.1
	Fraxinus pennsylvanica	RED ASH	3	18.8	1.6	0.9	2.1	12.5	4.1	7.8
	Carpinus caroliniana	HORNBEAM	12	75.0	6.3	0.6	1.6	18.8	6.1	14.0
	Fagus grandifolia	AMERICAN BEECH	1	6.3	0.5	0.0	0.1	6.3	2.0	2.6
	Prunus virginiana	CHOKE CHERRY	1	6.3	0.5	0.0	0.0	6.3	2.0	2.6
	Viburnum lentago	NANNYBERRY	1	6.3	0.5	0.0	0.0	6.3	2.0	2.6
	Total		**190**	**1187.5**	**100.0**	**40.6**	**100.0**	**306.3**	**100.0**	**300.0**
Dansville Pool (n=16)										
	Acer rubrum	RED MAPLE	39	243.8	76.5	14.0	99.0	62.5	52.6	228.1
	Fraxinus nigra	BLACK ASH	5	31.3	9.8	0.1	0.7	18.8	15.8	26.3
	Betula alleghaniensis	YELLOW BIRCH	5	31.3	9.8	0.0	0.2	25.0	21.1	31.0
	Ulmus americana	AMERICAN ELM	2	12.5	3.9	0.0	0.1	12.5	10.5	14.6
	Total		**51**	**318.8**	**100.0**	**14.2**	**100.0**	**118.8**	**100.0**	**300.0**
Dansville Swamp (n=16)										
	Acer rubrum	RED MAPLE	17	106.3	6.1	13.2	52.5	62.5	15.6	74.2
	Betula alleghaniensis	YELLOW BIRCH	66	412.5	23.7	5.3	21.1	93.8	23.4	68.2
	Ulmus americana	AMERICAN ELM	153	956.3	55.0	4.8	19.0	100.0	25.0	99.1
	Fraxinus nigra	BLACK ASH	11	68.8	4.0	0.8	3.1	50.0	12.5	19.5
	Tilia americana	BASSWOOD	8	50.0	2.9	0.6	2.3	25.0	6.3	11.4
	Quercus bicolor	SWAMP WHITE OAK	6	37.5	2.2	0.4	1.5	31.3	7.8	11.5
	Carpinus caroliniana	HORNBEAM	16	100.0	5.8	0.1	0.4	31.3	7.8	14.0

Table continues

Site	SCIENTIFIC NAME	COMMON NAME	Total	Density (trees/ha)	% Relative Density	Cover (m2/ha)	% Relative Cover	% Frequency	% Relative Frequency	IV
	Viburnum lentago	NANNYBERRY	1	6.3	0.4	0.0	0.1	6.3	1.6	2.0
	Total		**278**	**1737.5**	**100.0**	**25.2**	**100.0**	**400.0**	**100.0**	**300.0**
Fort Custer (belt transect, see methods)										
	Acer rubrum	RED MAPLE	43	754.4	44.3	20.3	44.8	n.a.	n.a.	89.1
	Fraxinus pennsylvanica	RED ASH	33	578.9	34.0	13.2	29.2	n.a.	n.a.	63.2
	Populus deltoides	COTTONWOOD	1	17.5	1.0	8.0	17.6	n.a.	n.a.	18.6
	Ulmus americana	AMERICAN ELM	20	350.9	20.6	3.8	8.5	n.a.	n.a.	29.1
	Total		**97**	**1701.8**	**100.0**	**45.3**	**100.0**	n.a.	n.a.	**200.0**
Geology Center (n=20)										
	Acer rubrum	RED MAPLE	78	390.0	21.0	9.5	38.2	95.0	19.0	78.3
	Fraxinus nigra	BLACK ASH	109	545.0	29.4	6.6	26.7	90.0	18.0	74.1
	Betula alleghaniensis	YELLOW BIRCH	84	420.0	22.6	4.3	17.5	90.0	18.0	58.2
	Ulmus americana	AMERICAN ELM	52	260.0	14.0	3.2	12.9	85.0	17.0	43.9
	Fraxinus pennsylvanica	RED ASH	15	75.0	4.0	0.7	2.8	45.0	9.0	15.8
	Carpinus caroliniana	HORNBEAM	17	85.0	4.6	0.2	0.7	40.0	8.0	13.2
	Tilia americana	BASSWOOD	1	5.0	0.3	0.1	0.6	5.0	1.0	1.8
	Liriodendron tulipifera	TULIP TREE	3	15.0	0.8	0.1	0.4	10.0	2.0	3.2
	Fagus grandifolia	AMERICAN BEECH	4	20.0	1.1	0.0	0.1	10.0	2.0	3.2
	Viburnum lentago	NANNYBERRY	3	15.0	0.8	0.0	0.1	10.0	2.0	2.9
	Amelanchier arborea	JUNEBERRY	3	15.0	0.8	0.0	0.0	10.0	2.0	2.9
	Quercus rubra	RED OAK	2	10.0	0.5	0.0	0.0	10.0	2.0	2.6
	Total		**371**	**1855.0**	**100.0**	**24.8**	**100.0**	**500.0**	**100.0**	**300.0**
Haven Hill (n=12)										
	Fraxinus nigra	BLACK ASH	138	1150.0	28.8	11.2	38.2	100.0	15.6	82.6
	Betula alleghaniensis	YELLOW BIRCH	100	833.3	20.9	8.7	29.9	100.0	15.6	66.4
	Acer rubrum	RED MAPLE	34	283.3	7.1	4.0	13.8	91.7	14.3	35.2
	Ulmus americana	AMERICAN ELM	128	1066.7	26.7	3.1	10.5	100.0	15.6	52.8
	Tilia americana	BASSWOOD	16	133.3	3.3	1.0	3.4	58.3	9.1	15.8
	Carpinus caroliniana	HORNBEAM	50	416.7	10.4	0.9	3.0	100.0	15.6	29.0
	Fraxinus pennsylvanica	RED ASH	10	83.3	2.1	0.3	1.1	66.7	10.4	13.6
	Quercus rubra	RED OAK	1	8.3	0.2	0.0	0.1	8.3	1.3	1.6

Table continues

Appendix 9 continued

Site	SCIENTIFIC NAME	COMMON NAME	Total	Density (trees/ha)	% Relative Density	Cover (m2/ha)	% Relative Cover	% Frequency	% Relative Frequency	IV
	Prunus virginiana	CHOKE CHERRY	1	8.3	0.2	0.0	0.0	8.3	1.3	1.5
	Fagus grandifolia	AMERICAN BEECH	1	8.3	0.2	0.0	0.0	8.3	1.3	1.5
	Total		**479**	**3991.7**	**100.0**	**29.3**	**100.0**	**641.7**	**100.0**	**300.0**
Rose Lake (n=12)										
	Acer rubrum	RED MAPLE	67	558.3	30.3	33.5	91.5	100.0	32.4	154.3
	Ulmus americana	AMERICAN ELM	132	1100.0	59.7	2.2	6.1	100.0	32.4	98.2
	Fraxinus pennsylvanica	RED ASH	14	116.7	6.3	0.8	2.1	58.3	18.9	27.4
	Prunus virginiana	CHOKE CHERRY	4	33.3	1.8	0.0	0.1	16.7	5.4	7.3
	Fraxinus nigra	BLACK ASH	1	8.3	0.5	0.0	0.1	8.3	2.7	3.2
	Prunus serotina	WILD BLACK CHERRY	1	8.3	0.5	0.0	0.1	8.3	2.7	3.2
	Tilia americana	BASSWOOD	1	8.3	0.5	0.0	0.1	8.3	2.7	3.2
	ELAEAGNUS UMBELLATA	AUTUMN-OLIVE	1	8.3	0.5	0.0	0.0	8.3	2.7	3.2
	Total		**221**	**1841.7**	**100.0**	**36.6**	**100.0**	**308.3**	**100.0**	**300.0**

Appendix A

Assessing the use of Tamarack Tree Cricket (*Oecanthus laricis* T.J. Walker), a rare species, as an Indicator of Biological Integrity

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Michigan DNR

MICHIGAN STATE UNIVERSITY EXTENSION

Michigan Natural Features Inventory

Introduction

Surveys for the tamarack tree cricket (*Oecanthus laricis*), a species of special concern in Michigan, were conducted to help assess whether its presence could be used as an indicator of biological integrity in southern Michigan. Because of its perceived rarity, having previously been recorded from only eight locations worldwide, our efforts also aimed at trying to better assess the tamarack tree cricket's habitat requirements, range, and conservation status. The tamarack tree cricket has been collected on tamarack from six sites in southeastern MI and from eastern hemlock (*Tsuga canadensis*) at two sites in northeastern Ohio. Because the species is thought to deposit its eggs only in the wood of tamarack, it may be completely dependent on the tree during a portion of its life cycle. Prior to our surveys the species was thought to be restricted to the upper portions of small, open grown tamaracks (Cantrall 1943). Adult tamarack tree cricket's can be found on tamaracks during August and September.

Methods

Tamarack tree cricket surveys were conducted at a total of 54 sites in 22 counties and included the six conifer swamp sites where our vegetation sampling occurred in 1999 (Table 1). Surveys were conducted from mid August to mid September during 1999 and 2000. A variety of natural communities were surveyed including tamarack-dominated, rich conifer swamp and poor conifer swamp, as well as bog and prairie fen. Survey methods included sweeping and beating the tamarack trees with sweep nets and collecting several specimens from each site where they occurred. Specimens were then keyed to species and later verified by Dr. Roger Bland of Central Michigan University.

Results

The tamarack tree cricket was recorded from 32 sites in 16 counties including all sites where detailed vegetation sampling was conducted except for Waterloo (Tables 1 and Figure 1). The results of our surveys have extended the known range of the species in Michigan from southeast MI to south central and southwestern lower MI. The species was found to occur in a variety of natural communities including both tamarack-dominated rich conifer swamps and poor conifer swamps, as well as in prairie fen, and bog. It occurred in both small, highly disturbed sites as well as large, intact wetland complexes.

Discussion

The tamarack tree cricket is probably not a reliable indicator of high quality conditions for conifer swamp in southern Michigan. Though the species appears to be restricted to tamarack, it was found in a wide variety of natural communities and conditions, occurring in both large, intact natural communities as well as small, isolated patches of tamarack adjacent to roads and drainage ditches. Further sampling may show higher tamarack tree cricket population densities in high quality conifer swamps and the long-term viability of the species may depend on these sites.

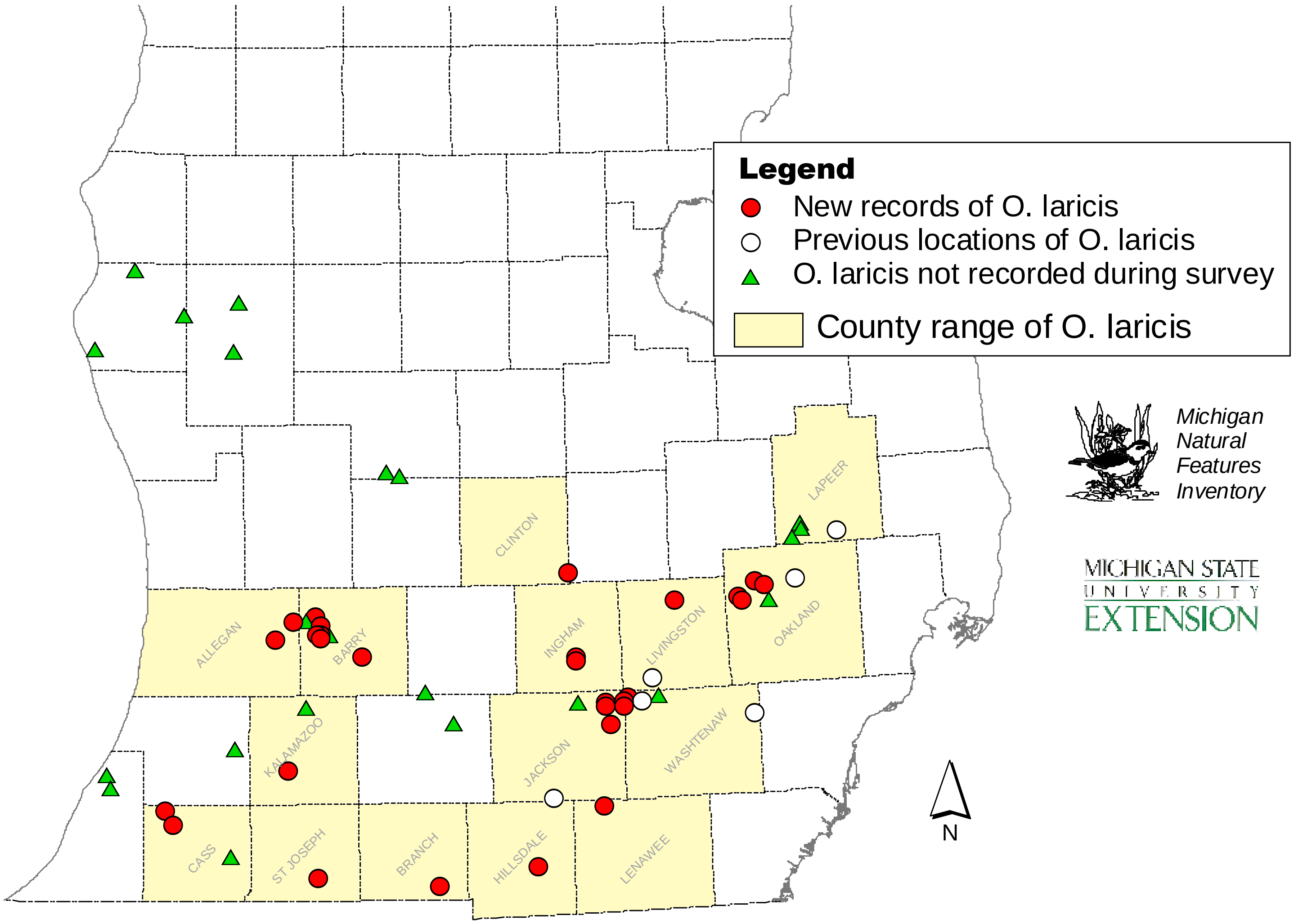
It is possible that with more survey work the known range of the species may continue to expand to include mid MI as well as northern Indiana.

Acknowledgements

Funding for this project was provided by a grant from the US Environmental Protection Agency and the Michigan Department of Environmental Quality. Matching funds were provided by The Nature Conservancy and Michigan Department of Natural Resources. Several MNFI zoologists participated in field sampling including Jeff Cooper, Daria Hyde, Yu Man Lee, and Mat Smar. Dennis Albert and Mary Rabe, MNFI Program Managers, provided guidance on the project.

Table 1. Tamarack tree cricket survey sites and results. * indicates a previously known sites, four of which were not re-surveyed. ** indicates 1999, rich conifer swamp vegetation sampling site.

Survey Site	County	Township	Range	Section	Tree Cricket Occurrence
Ebersole Center Fen	Allegan	03N	11W	11	yes
Otis Lake Bog	Barry	03N	09W	30	no
Barry State Game Area (S. of Hall Lake)	Barry	03N	10W	27	yes
Shaw Lake Fen	Barry	03N	10W	03	yes
Turner Creek Fen	Barry	03N	10W	14	yes
Yankee Springs Deep Lake Fen	Barry	03N	10W	26	yes
Yankee Springs Fen (southeast)	Barry	03N	10W	35	yes
Barry State Game Area (Bowen Mills Rd. West)	Barry	03N	10W	08	no
Sarett Nature Center	Berrien	03S	18W	34	no
Blue Creek	Berrien	04S	18W	14	no
Quimby Road Fen (Catey Tract)	Branch	08S	06W	01	yes
Quimby Road Fen (Woodward Tract)	Branch	08S	06W	01	yes
Van Sickle/Walker tracts	Calhoun	02S	05W	03	no
Cook Lake/Rudy Road Complex-Hassle Tract	Cass	05S	15W	30	yes
Priest Lake Fen	Cass	05S	16W	11	yes
T.K. Lawless County Park	Cass	06S	13W	32	no
Rose Lake SGA-Clark Road	Clinton	05N	01W	24	yes
Kuzera Site	Eaton	01N	06W	34	no
Lost Nation State Game Area Fen	Hillsdale	07S	02W	15	yes
Dansville SGA-Hewes Lake Tamarack Swamp	Ingham	02N	01E	32	yes
Dansville SGA-Meridian Road Tamarack Swamp	Ingham	02N	01E	29	yes
Waterloo **	Jackson	01S	01E	17	no
Harr **	Jackson	01S	02E	24	yes
Huttenlocker **	Jackson	01S	02E	17	yes
Leeke Lake **	Jackson	01S	02E	13	yes
Portage **	Jackson	01S	02E	20	yes
Glenn Road/Mt. Hope Road Tamarack Savanna	Jackson	02S	02E	09	yes
Liberty Fen *	Jackson	04S	01W	32	pre-1998 record, not re-surveyed
Springbrook Fen (North of C-Avenue)	Kalamazoo	01S	10W	18	no
Gordneck SGA-Little Sugarloaf Lake	Kalamazoo	03N	11W	31	yes
Bishop Bog/Schrier Park	Kalamazoo	03S	11W	28	yes
Metamora-Hadley State Recreation Area N	Lapeer	06N	09E	12	no
Metamora-Hadley State Recreation Area SW	Lapeer	06N	09E	13	no
Ortonville State Recreation Area	Lapeer	06N	09E	27	no
Seven Ponds Nature Center *	Lapeer	06N	11E	20	yes, reconfirmed 1989 record
Onsted State Game Area	Lenawee	05S	02E	07	yes
George Reserve *	Livingston	01N	04E	19	pre-1998 record, not re-surveyed
Oak Grove State Game Area	Livingston	04N	05E	30	yes
Flat River SGA-Clear Lake	Montcalm	09N	07W	35	no
Flat River SGA-Miller Road	Montcalm	09N	07W	29	no
Alley Lake Bog	Newaygo	13N	13W	11	no
Richmond Lake Bog	Newaygo	15N	13W	13	no
Proud Lake State Recreation Area	Oakland	02N	08W	20	yes
Milford *	Oakland	02S	07E	02	pre-1998 record, not re-surveyed
Buckhorn Lake South	Oakland	04N	07E	34	yes
Buckhorrn Lake Road Tamarack Savanna	Oakland	04N	07E	28	yes
Dilley Road Tamarack Savanna	Oakland	04N	08E	16	yes
Long Lake Tamarack Savanna	Oakland	04N	08E	07	yes
Indian Springs	Oakland	04N	08E	34	no
Independence Oaks County Park *	Oakland	04N	09E	10	pre-1998 record, not re-surveyed
Arthur Bog	Oceana	13N	18W	10	no
Fairchild Lake	Oceana	15N	15W	36	no
Jefferson Bog	Oceana	16N	16W	07	no
Thompson Lake-Frohriep Tract	St. Joseph	07S	10W	28	yes
Lime Lake	Van Buren	02S	13W	33	no
Snyder Lake Fen *	Washtenaw	01S	03E	15	yes, reconfirmed 1995 record
M-52 **	Washtenaw	01S	03E	07	yes
Hankard Road Fen	Washtenaw	01S	04E	08	no



Known Distribution of *Oecanthus laricis* in Michigan

Appendix B

Dominant Water Sources of Six Conifer Swamps of Southeastern Michigan

Submitted to:
The Michigan Natural Features Inventory (MNFI)

By David H. Merkey M.L.A.
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May 8, 2001

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Introduction

This report explains the development and on-going progress of a wetland classification and assessment method being developed for the southeastern section of the Lower Peninsula of Michigan. A total of 59 wetlands are being monitored for this study. Six of these sites have undergone vegetation sampling by the Michigan Natural Features Inventory to determine which metrics might be useful in the development of a vegetation-based Index of Biological Integrity for conifer swamps of southeastern Michigan. Only results from these six sites and their relationship within the broader range of monitored wetlands will be discussed in detail in the Results and Discussion section.

Project Background: The main objective of the Clean Water Act (CWA) is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Early efforts at controlling chemical and physical pollutants, through the use of discharge and chemical monitoring standards, has proven to be very successful. The chemical and physical quality of the Nation's waters, though not completely restored, is much improved. However, as more information about the health of biological communities has become available, it is obvious that severe impairments are still being found, particularly, but not limited to, the Nation's wetlands. In an effort to restore and maintain the biological integrity of the Nation's wetlands, the U.S. E.P.A. Wetlands Division has been working with state, tribal, and other federal agencies to develop a reliable system of wetland biological assessment techniques (http://www.epa.gov/ceisweb1/ceishome/atlas/bioindicators/biodocs/biolcont.htm).

Though well intentioned, early attempts to develop wetland assessment and monitoring techniques (biological or otherwise) have failed to provide resource managers with comparable, timely, or cost effective information. One reason for this failure is the fact that assessment methods were designed to be done on a case-by-case basis. Assessments were to be carried out "wetland-by-wetland", typically as part of a dredge and fill permit application, to assess the functions or values of a specific wetland. These methods often required the collection of detailed, time consuming, and expensive field-data for each wetland. Information concerning the wetland's surrounding landscape context, the inherent differences in wetland types across a landscape, the relative abundance of that wetland type in the area, or the ability to successfully mitigate that wetland type in order to maintain landscape diversity are often not taken into consideration (Brinson 1993, 1996; Bedford 1996; Cowardin et al. 1979; Hollands 1987; Kusler 1998a; Magee 1998; Smith et al. 1995). This lack of understanding of the characteristic differences in wetland classes and functions has led to an overall loss in wetland structural and biological diversity at the landscape-scale (Brinson 1996; Bedford 1996). Furthermore, if biological or functional assessments were done on a number of wetlands in an area, no methodologies were in place in ensure that accurate, ecologically sound comparisons could take place between wetland types.

Biological wetland assessment methods, which do not take into account a wetland's physical and landscape context, fail to provide resource managers with several pieces of important information.

- Hydrologic context. Not only do wetland functions and values largely depend upon the broader hydrologic context of the wetland, so do biological communities. Understanding the relationship a wetland has with the local water table, surrounding uplands, lakes, rivers, or other wetlands, is not only important when interpreting hydrologic functions of a wetland, these factors also form the context through which a biological assemblage is shaped and must, therefore, be viewed. Without understanding a biological community within the hydrologic conditions which helped bring it to be, resource managers cannot fully integrate management of a particular wetland into regional water planning, storm water or floodplain management, or other water planning issues without risk of altering or damaging existing flora and fauna (Gosselink 1978; Kusler 1998a; Novinski 1979; O'Brien and Motts 1980). In addition to the short-term or site-scale changes wetland hydrology has on flora and fauna, the effect of long-term, water level fluctuations on vegetation dynamics in wetlands has been well documented (for prairie marshes, see van der Valk (1978); for inland lakes in the Great Lakes region, see Keddy and Reznicek (1982); and for Great Lakes marshes associated with lakes with regulated and non-regulated water levels, see Wilcox (1995). Each of these studies found that species diversity and seed bank maintenance were directly linked to periodic, long-term, naturally occurring water level fluctuations. One of the main strengths of biological assessments is the ability to monitor changes in wetland biota over time. The ability to predict which wetlands are subject to natural, long-term water level fluctuations, as opposed to man-made fluctuations or alterations, increases the power and efficiency of bioassessment projects.

- Comparative wetland information. Biological assessment methods which do not take into account the physical context of a wetland, can not provide resource managers with comprehensive and comparative information for all wetlands across a region. Assessments are usually carried out on only a handful of wetlands within an area, an area that may actually contain several hundred wetlands and dozens of wetland types. Assessment of all types of wetlands within a region is needed to properly select sites for acquisition, scientific study, restoration, mitigation, or other uses (Kusler 1998a). This requires a cost-effective method to classify wetlands across the landscape and identify those most likely to be useful for sampling and as reference wetlands. Current case-by-case wetlands classification and assessments can not provide such information.
- Ecological/Habitat context. At some point in their life cycle, most wildlife require a variety of habitat types for feeding, breeding, cover, etc. Biological assessments, done without context, only provide small pieces of the overall habitat puzzle. The ability to cost-effectively determine wetland type and diversity, at the landscape or regional level, can be a powerful tool for land managers trying to maintain wildlife diversities within their jurisdiction.

The final product of this landscape-level study will be the demonstration of a GIS-based, HGM wetland classification method which will allow land managers to quickly and efficiently assess the potential functions and biological communities of specific types of wetlands across large areas (*Sub-subsections* following Albert, et al. 1986, 1994). (Albert divides the Lower Peninsula of Michigan into 2 Sections, a northern lake-affected Section and a southern Section that contains 6 Subsections. The 3 Sub-subsections used in this study range in size from 1600 to 2500 square miles.) Characteristics and potential functions will be predicted for any depressional or headwater wetland within the sub-subsection for which the model has been calibrated. This will allow resource managers to:

- make comparisons of biologically assessed wetlands through classification by the physical processes which help bring biological assemblages to be.
- more efficiently allocate resources used during permitting and planning processes by eliminating the need for detailed site analyses in wetlands where the model has proven to have good predictability.
- assess the abundance or rarity of wetland types within a given area.
- better assess the role individual wetlands play in providing wildlife habitat.
- understand the role existing and future (constructed) wetlands play in water management goals.
- develop goals and guidelines for wetland restoration, creation, and mitigation efforts.

Due to a myriad of regulations at the local level encouraging development, permitting the use of wetland areas is one of the few tools available to state resource managers to limit development of natural areas. Headwater areas once far removed from urban centers are now threatened with development (http://www.semcog.org). A recent ruling by the Supreme Court effectively states that isolated wetlands are not protected under Section 404(a) of the Clean Water Act (http://www.supremecourtus.gov/opinions/00pdf/99-1178.pdf). This means that state and local management agencies are in need of new methods of protecting these systems. Understanding the biological and physical functions of headwater and depressional wetlands is critical to their protection. It is with these reasons that headwater and depressional wetlands are the focus of this effort (as opposed to other types of wetlands).

Researchers and resource managers across the country have been using either biological assessment methods or the Hydrogeomorphic assessment method to assess the health and/or functional capacity of their regional wetlands. Each method was originally designed to suit different purposes and obtain different types of information, different pieces of the wetland puzzle. A combination of the two methodologies promises to be extremely useful in understanding the overall ecological processes and patterns present in various types of wetlands across the landscape. The HGM classification sets up a framework from which to view and compare biological measurements. Measuring the biota provides a direct and comparable metric of the health of various wetland systems, thus providing a more complete picture of wetland ecosystems for resource managers. Efforts to merge the 2 assessment methodologies have not been attempted at a large scale in the glaciated Midwest. Southeastern Michigan, with its variety of glacial landscapes and wetland types, proves to be an excellent location to research such possibilities.

Materials and Methods

Field Sampling:

Hydrology: Field sampling for the larger study consists of hydrologic measurements, analysis of water chemistry and vegetation sampling. Hydrologic measures are obtained using either a surface water gauge or a monitoring well for measuring water levels below the soil surface, depending on the type of wetland being monitored. All measurements are made in reference to a local datum (i.e. the substrate surface at the sample point). For surface water gauges, water levels are simply read in centimeters off the gauge itself. For measuring water levels in monitoring wells, a metal ruler is inserted down the well until contact with the water table is established. Monitoring wells have been constructed in accordance to U.S. Army Corps of Engineers WRP Technical Note HY-IA-3.1, "Installing Monitoring Wells/Piezometers in Wetlands". Measurements are taken once per month throughout the year. Measurements are recorded in a waterproof field book at the time of measurement and transferred to an electronic database monthly.
Chemistry: Analysis of water chemistry includes: temperature, alkalinity, conductivity and pH. Temperature is the only water quality parameter measured in the field. Temperature is measured using a shielded thermometer inserted down the monitoring well after the water level has been measured and at rooting depth (6" below the soil surface). It has been shown that mean August water temperatures can be used as a reliable measure of groundwater inputs in Michigan streams (Wehrly 1998). It is not know, at this time, whether some measure of water or subsurface temperature can also be used as a meaningful indicator of groundwater inputs to wetlands. Water samples are collected in 250 ml, Nalgene sample bottles and returned to the lab for analysis at the end of the day. Water from the monitoring wells is obtained using a plastic bailer inserted down the well. Two well-waters are removed and discarded prior to obtaining the third well-water on which chemical analysis is run. This ensures that water from the subsurface is analyzed, not water which may have entered the well from some other source or which has been modified by its contact with the atmosphere. Surface water samples are taken near the top of the water column to minimize inclusion of sediments with the sample. Chemistry samples are kept on ice while in the field and analyzed the same day as collected.

Lab Procedures: Conductivity and alkalinity measures will be used to determine the relative proportion of groundwater in the waters of each wetland. Though not ideal measures of groundwater content, due to anthropogenic contamination of many surface and ground waters of southeastern Michigan from the seasonal addition of road salt and biological production of alkalinity, these metrics have proved reasonable and cost effective for studying groundwater loading of Michigan rivers (Seelbach, et. al. 1997). pH will also be recorded but will only be used as an indication that the instrumentation is working properly. Due to the large amounts of carbonate in the underlying glacial deposits of southeastern Michigan, most surface waters in the area exhibit pH values in the neutral range. A small number of wetlands register pHs below neutral, indicating precipitation or surface water inputs, but these waters also have correspondingly low alkalinity and conductivity as well.

Classification and Model Development: Wetlands will be classified using GIS-derived, landscape-level data and an existing HGM classification method developed for the glaciated Northeast and Midwest (Magee 1998). HGM classification will also be done, at each site, in the field. Vegetation and chemical data will be used to validate assumptions made from the methodology concerning cover type (for GIS derived data) and the relative amounts of groundwater/surface water inputs to each wetland. Classification outcomes using each method will be plotted against each other to determine the success of HGM classification from the GIS compared to traditional site-level classification. Attempts at automating the classification procedure with the GIS will be explored. This will be done in order to facilitate the classification of groups of wetlands across the landscape instead of classifying individual wetlands one at a time. Wetland classes where the model has reasonable predictability will then be assigned potential functions based on assumptions made in the HGM literature.

Preliminary model development has already begun using data collected in the first year of the study. Principal components analysis will be used to determine which variables from the landscape-level and site-level data are most useful in classifying wetland types. Discriminant analysis and logistic regression will be explored for use in classifying wetland types. Multiple linear regression models have been used to explain and predict hydrologic characteristics of Michigan streams such as: spring and summer discharge frequencies, summer water temperatures, nutrient yields, and fish species composition from landscape-level, catchment data (Kleiman 1995; Wehrly 1998; Zorn in press; Wiley and Seelbach 1998). This methodology will also be explored for predicting continuous variables in wetlands such as: seasonal and annual water table fluctuations, inundation, and depth to fluctuation ratio of each wetland. Relationships between these continuous variables (which also affect species composition) and HGM classes will also be examined in an attempt to validate assumed hydrologic functions.

Hydrologic and chemical data from the second and third years will be incorporated into the models as they are collected. This will reduce error rates expected to be found using only the first year of data due, in part, to temporal (>1 year) variation in regional climate and the hydrologic cycle of wetlands. Once data collection from the second and third years is completed, a final set of models will be developed, and final error rates and correlations calculated.

As these efforts are newly underway, results from the above statistical analysis are not included in this preliminary report but have been included in this introduction to explain the future direction of this research and provide context for results to date. Results and Discussion will be based on pattern analysis only, by visually comparing the chemical and hydrological results from the 6 MNFI sites to each other and the other 53 sites under study.

Results and Discussion

To determine the dominant source of water of each of the MNFI studied wetlands the following data were explored: water level fluctuation throughout the year, water chemistry, landscape position, and ground water loading as predicted by the Darcy map. (For more information on the use and development of the Darcy map, see http://rivers.snre.umich.edu/mri/darcy/index.htm.) Indicators that ground water is the dominant source of water to the wetland would be: stable water levels throughout the year, high alkalinity and conductivity, prediction of ground water discharge within the wetland by the Darcy map, and a landscape position that is low lying in an area of coarse glacial deposits such as in an outwash channel (Seelbach and Wiley 1997, Seelbach, et. al. 1997). The 6 MNFI sites exhibit most, if not all of these characteristics.

An analysis of the hydrographs of the 6 MNFI sites (Figure 1) shows that there was some variation in the amount and timing of water level fluctuations between sites throughout the year, particularly in respect to the draught taking place in S.E. Michigan during the Fall and Winter of 1999 – 2000. The conifer swamps at Huttenlocker Road and Leeke Lake underwent a deep drawdown in water levels during the drought. Harr Road, too, exhibited lower water levels than were later measured after the drought began to break in Spring (April – May). These variations however are very slight when compared to the degree of water level fluctuation at many of the other wetlands in the larger study (see Figure 2).

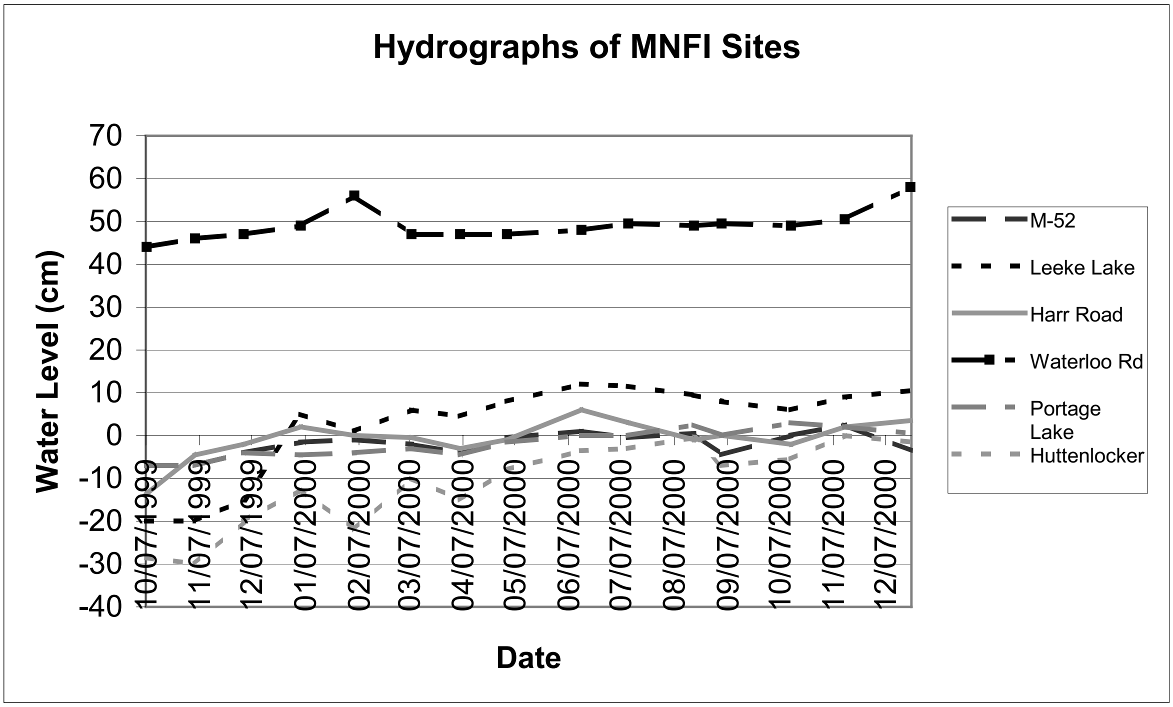

Figure 1: Hydrographs of the 6 MNFI sites. This graph shows the hydrographs of the 6 MNFI sites for the period October, 1999 through January, 2001. A severe drought was taking place in S.E. Michigan during the Fall and Winter of 1999 – 2000. By February, 2000, the drought was starting to break and water levels were rebounding. Note that wetlands at M-52, Waterloo Road and Portage Lake exhibited very little change in water level in respect to the drought. While the wetlands at Leeke Lake, Huttenlocker Road, and Harr Road had lower water levels during the drought than after the drought ended.

Figure 2 is a plot of the MNFI sites illustrating their variability in water level fluctuation and mean depth in relation to all the other sites in the larger study. The covariance measure, in the y axis, is the natural log of the standard deviation of monthly water level measurements divided by the mean depth. This was used instead of a simple standard deviation or variance measure, since it incorporates the affect depth has on water level fluctuation. There is a weak linear relationship between the 2 measures. Wetlands with standing water do not fluctuate as greatly as wetlands with predominantly subsurface water. Presumably, this is due to the volume of water taken up by wetland sediments. An equal volume of water will occupy a larger vertical space in the presence of soil as opposed to standing water. Wetlands with higher covariance values, exhibit greater water level fluctuations throughout the year than wetlands with lower covariance values (note the negative scale of the plot).

All of the MNFI sites are on the lower portion of the covariance measure, indicating stable water levels relative to the other wetlands in the larger study. Note that Huttenlocker (D) and Harr Road (F) exhibited greater fluctuation in water levels throughout the year as was also noted in the hydrographs in Figure 1. Leeke Lake (E) does not show as great a level of fluctuation as the others since water levels were very stable once they rebounded after the Winter drought. Waterloo Road (A) is deeper than the rest of the MNFI sites. It is the only one of the 6 sites that doesn't have a hummock texture to the substrate but is almost completely inundated. Waterloo Road also does not have a deep, organic soil at the location of the monitoring well as the other 5 sites do, but instead has a mineral clay soil near the wetland surface.

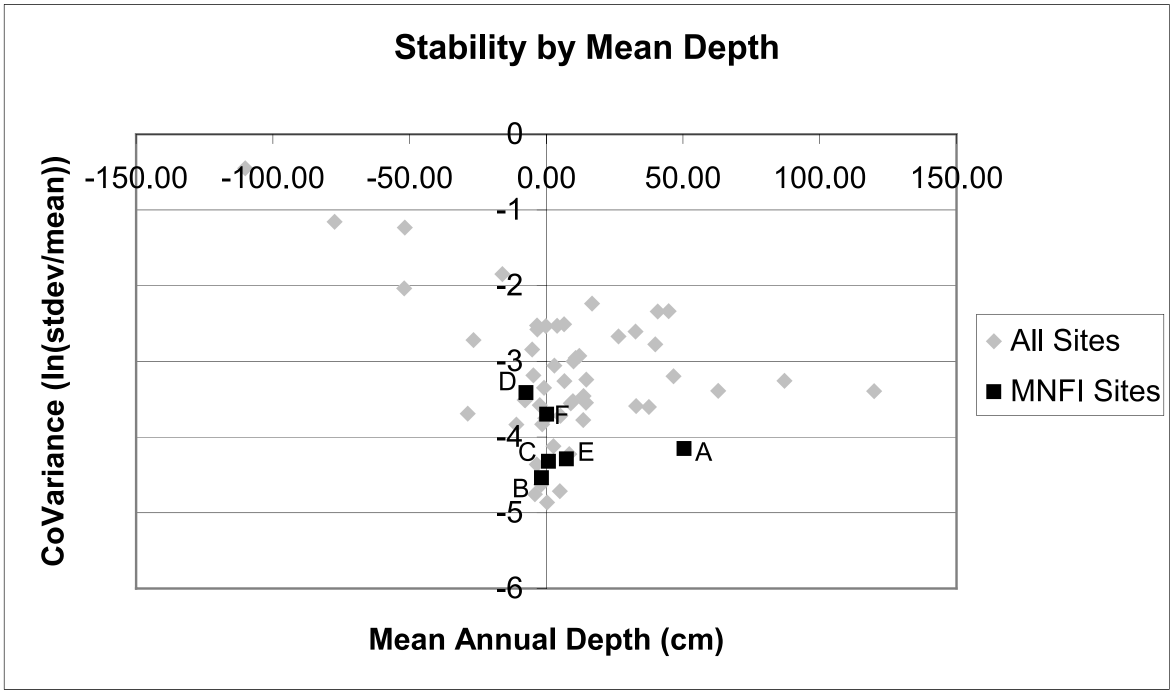

Figure 2: Stability of Mean Water Depth. Wetland A is Waterloo Road, B is M-52, C Portage Lake, D Huttenlocker, E Leeke Lake, and F Harr Road. Plot values are calculated from January 2000 – January 2001 and do not fully take into account the affect the drought had on Leeke Lake, Huttenlocker Road, or Harr Road. In some cases, measurements did not start until January 2000 for some study sites in the larger study. In the interest of comparability, only time periods where a complete set of data is available were used in making this plot.

Table 1 lists the mean annual alkalinity (mg CaCO3/ L) and conductivity (uS) for each of the MNFI study sites. Also included in the table, for comparison, are mean, maximum, and minimum values for each measure for all the sites in the larger study. The MNFI sites are all near or above the overall mean for alkalinity and clustered around the mean for conductivity.

Figure 3 is a plot of mean annual conductivity and alkalinity for all sites and the MNFI sites. This graph allows the relative amounts of groundwater in a particular wetland to be inferred. The farther out on the graph a wetland lies indicates that groundwater is a larger and larger percentage of the wetland water. Due to the constraints, outlined in the Methods and Materials section of this paper, these measures should not be used by themselves to indicate the relative amount of groundwater present in the wetland. They can, however, be used in conjunction with water level stability and the Darcy map to infer the relative abundance or dominance of ground water found within a wetland. In Table 3, the MNFI sites are all clustered together in the middle to upper portion of the graph, further indicating that ground water is a dominant source of water to each of these wetlands when compared to all wetlands in the larger study. Note that Waterloo Road, which is one of the more stable sites from a water level fluctuation standpoint, also has the highest conductivity and alkalinity values. M-52, also very stable, has high conductivity and alkalinity values indicating a strong influence of ground water on the wetland's hydrology. Leeke Lake, though shown as relatively stable on Table 2, had very low water levels during the Winter drought and rebounded quickly once the drought was over. This, coupled with lower chemistry values, compared to the other MNFI sites, indicates that though ground water is still very important in the hydrology of this wetland, it may be getting less groundwater than the other 5 sites.

Table 1: Mean alkalinity (mg CaCO3/L) and conductivity (uS) for each of the MNFI sites. Maximum, minimum, and mean values for all sites in the larger study are given for comparison.

MNFI Site	Alkalinity	Conductivity
M-52	293.375	649.25
Leeke Lake	221.5	524.5
Harr Road	280.875	589.875
Waterloo Rd	394	708.5
Portage Lake	248	515.5
Huttenlocker	306	716.5
All Sites		
Maximum	683.9	1250
Minimum	3.4	61.4
Average	257	662

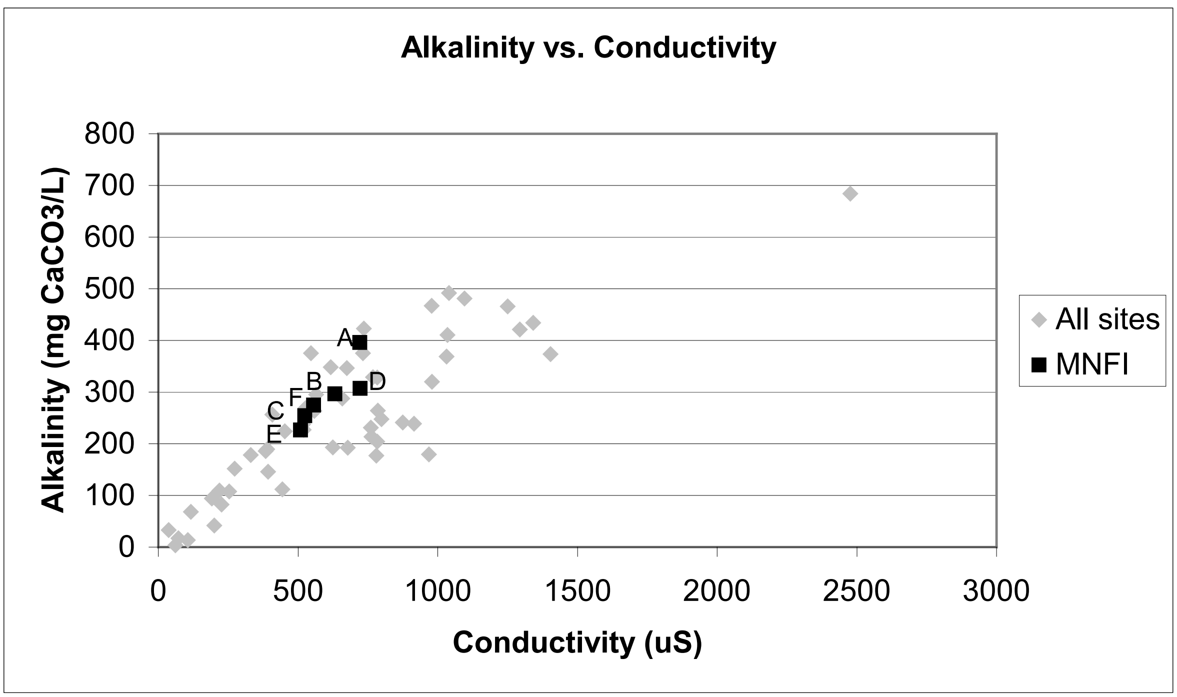

Figure 3: Alkalinity vs. conductivity for each of the MNFI sites and all sites within the larger study. As in Figure 2, wetland A is Waterloo Road, B is M-52, C Portage Lake, D Huttenlocker, E Leeke Lake, and F Harr Road.

The Darcy maps for each of the MNFI sites are given the Appendix. The maps are colored to indicate the number of standard deviations a particular cell is away from the mean with respect to predicted ground water discharge velocity. Blue areas have little to no ground water being delivered to them. Red indicated areas where ground water is predicted to discharge to a wetland or surface water body, the darker the red, the greater the velocity of ground water discharge at that point. Three sites (M-52, Portage Lake, and Waterloo Road) all show areas of groundwater discharge close to their borders (due to constraints in reproducing these maps in a document, it can not be seen that these wetlands also have red cells, or areas of ground water discharge within them). The other sites (Harr Road, Huttenlocker, and Leeke Lake) have no red cells around their border or within them. (The few red cells around the Huttenlocker wetland are on the downstream side of the wetland and do not significantly influence water inputs to the sample point.)

Discussion

Waterloo Road. The combination of very stable water levels throughout the year and during the Winter drought, high conductivity and alkalinity, and predicted ground water discharge points within and around the wetland indicate the hydrology of the Waterloo Road site is dominated by groundwater. (The Waterloo Road site is inundated to a greater depth than any of the other MNFI sites. Caution should be used when comparing vegetation data from this site to the other sampled conifer swamps as the difference in depth alone will account for some of the variation in plant species.)

M-52. The M-52 site also exhibited very little fluctuation in water table throughout the year or with respect to the Winter drought. High conductivity and alkalinity, and predicted ground water discharge points within and around the wetland again indicate that ground water is the dominant source of water to the M-52 swamp.

Portage Lake. The Portage Lake site also exhibited very little fluctuation in the water table throughout the year or during the Winter drought and had high alkalinity and conductivity values. As with the Waterloo Road and M-52, the Darcy map predicts ground water discharge points within and around the wetland boundary. Portage Lake too, is dominated by groundwater.

Leeke Lake. Though the conifer swamp at Leeke Lake had relatively stable water levels once the drought of last winter was over, it did respond to the drought with a significant water level draw down. Though the chemistry measures were lower for this site than for any of the other MNFI sites, they are still moderately high compared to the rest of the wetlands in the larger study. The Darcy map does not indicate ground water discharge of any significant velocity around or within this wetland. However, the Darcy map is just that, a prediction of velocity. The position of the Leeke Lake wetland within a large wetland complex, in a coarse textured glacial fluvial channel indicates that this wetland, though not receiving inputs of ground water at velocity, is in contact with the local ground water table.

Harr Road. Water level fluctuations at the Harr Road wetland, though larger than some of the other MNFI sites, were still relatively small when compared to wetlands in the larger study. The Harr Road site also had relatively high conductivity and alkalinity measurements. As with the Leeke Lake wetland, no ground water inputs of significant velocity were predicted using the Darcy map but its similar landscape position within a large wetland complex in a glacial fluvial channel indicates that this wetland, too, is potentially in contact with the local water table and receives a significant portion of its water from groundwater.

Huttenlocker Road. The wetland at Huttenlocker Road experienced the largest water table fluctuations of any of the MNFI sites, both with respect to last winter's drought and throughout the year. However, compared to wetlands in the larger study, these fluctuations are still not extremely large. Although there is also no significant, predicted ground water discharge within or around this site, the conductivity and alkalinity are quite high. Ground water is still a significant source of water to the Huttenlocker Road site, though probably to a lesser degree than some of the other MNFI sites.

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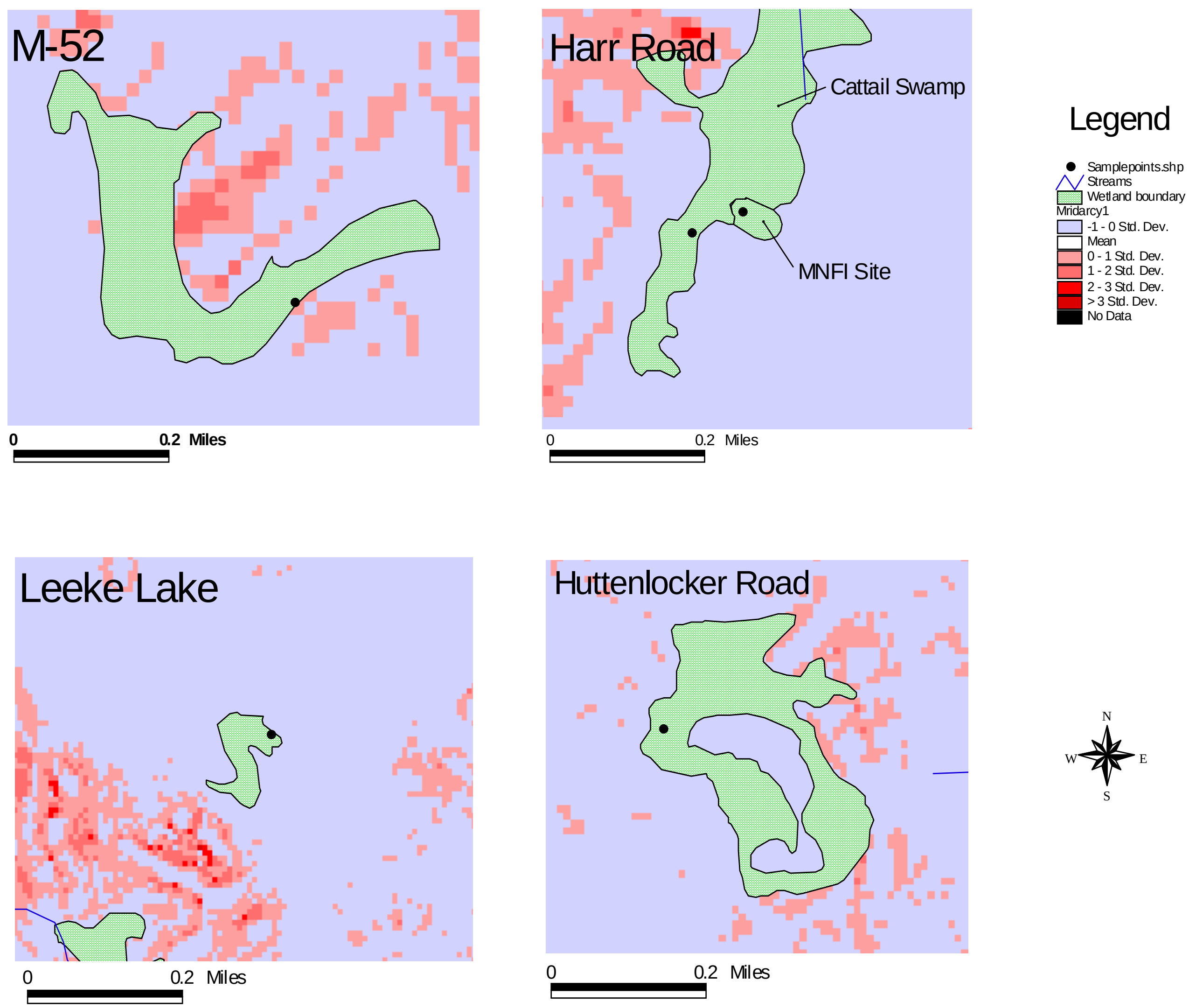
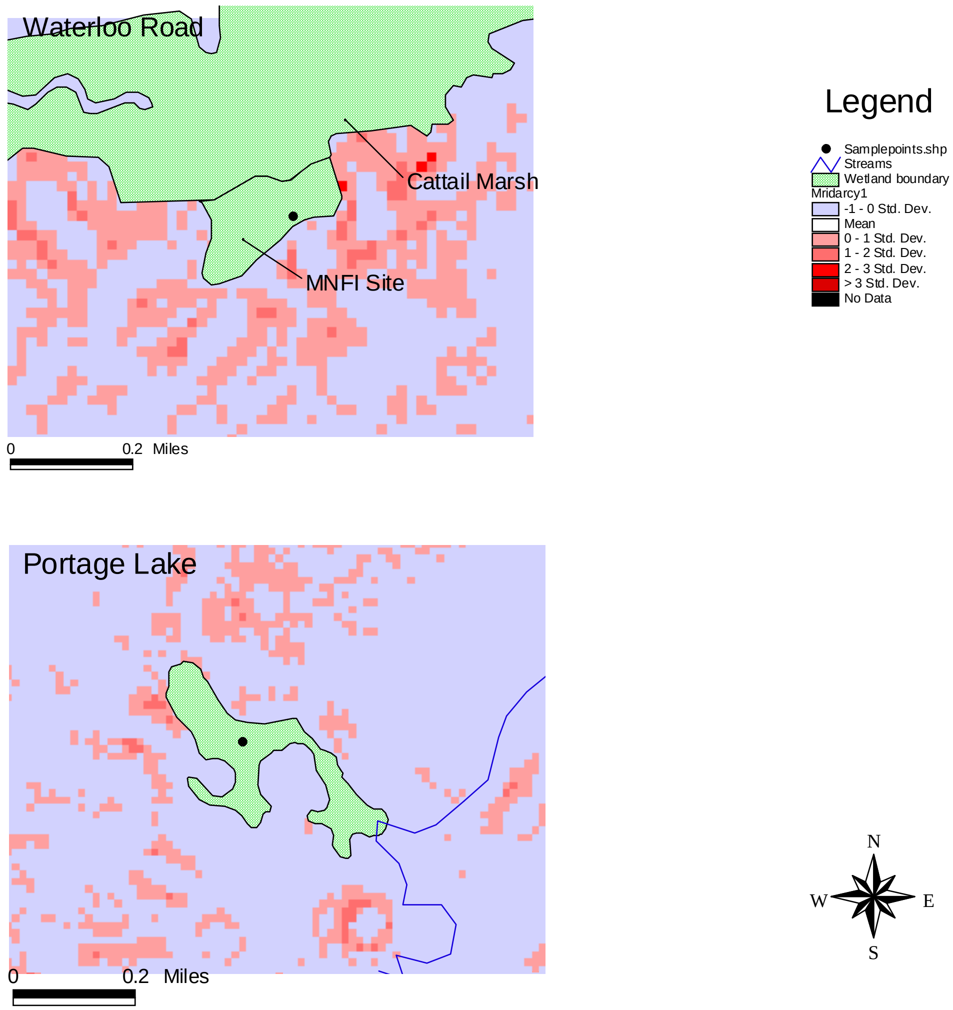
Appendix: Darcy Maps for the MNFI Sites




Waterloo Road
Cattail Marsh
MNFI Site
0
0.2 Miles
Portage Lake
0
0.2 Miles
Legend
Samplepoints.shp
Streams
Wetland boundary
Mridarcy1
-1 - 0 Std. Dev.
Mean
0 - 1 Std. Dev.
1 - 2 Std. Dev.
2 - 3 Std. Dev.
> 3 Std. Dev.
No Data
N
W
E
S