Softwood Swamps of Vermont: Distribution, Ecology, Classification, and Some Sites of Ecological Significance

Black Spruce Swamp, illustration by Libby Davidson

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for

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BACKGROUND

Softwood swamps are dominated by coniferous trees, including spruce, hemlock, fir, cedar, pine, and tamarack. Because of the typically dense canopy formed by these needle-leaved trees and the abundant moisture from the saturated soils, the ground level of most softwood swamps is shady and cool. On a hot summer day it is not uncommon to find the interior of a softwood swamp to be 10 to 15 degrees cooler than the surrounding uplands. But the cool and moist conditions also mean that softwood swamps may host large swarms of mosquitoes.

Softwood swamps are typically very different from the upland forests that surround them in terms of the species of trees, shrubs, and herbs, the types of soil, and the hydrology. There are also many differences between individual softwood swamps, although these differences may be more subtle than between the sharply contrasting upland forests and swamps. Understanding these differences is part of the natural community concept and provides us with a strong tool for deciphering the complexity of the landscape around us.

A natural community is an interacting assemblage of plants, animals, and other organisms, their physical environment, and the natural processes that affect them. What makes natural communities such a useful ecological concept is that there is a pattern to their distribution. These assemblages of plants, animals, and other organisms found in natural communities repeat across the landscape wherever certain environmental conditions (climate, soil, and water) are found. This makes it possible for us to identify and describe *natural community types*, which are based on composite descriptions summarizing the characteristics of all known examples of a natural community type that have been studied.

There are currently over 80 natural community types recognized in Vermont by the Natural Heritage Information Project (formerly Nongame and Natural Heritage Program) of Vermont Fish and Wildlife Department. These include common types such as Northern Hardwood Forest and Alder Swamp, as well as rare community types such as Pitch Pine-Oak-Heath Rocky Summit and Red Maple-Black Gum Swamp. For much more detail about natural communities in Vermont, please refer to the book *Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont*.[1]

The natural community types that are recognized in Vermont by the Natural Heritage Information Project (NHIP) are the result of many years of observation and study by NHIP staff and by many biologists, ecologists, and naturalists around the state and the region. NHIP has been tracking natural communities since its inception in 1984, but 20 years prior to this time many important natural communities around the state were identified by Dr. Hubert Vogelmann in his two reports on Natural Areas in Vermont (1964 and 1969).

Improving our understanding of the distribution of natural community types across the landscape gives us insight into the staggering complexity of the diversity of life and the natural world

[1] E.H. Thompson and E.R. Sorenson. 2005. Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont. Published by The Nature Conservancy and Vermont Department of Fish and Wildlife, distributed by University Press of New England. Available at book stores.

around us. Natural communities are receiving considerable attention in recent years due to their importance as a planning tool for protecting biological diversity. It is readily acknowledged that it is impractical to develop specific plans to conserve each of the many thousands of species occurring in Vermont, especially those species that we know little about. However, it is likely that we can conserve most of these species by conserving multiple examples of all natural community types in relatively natural landscapes and by representing the full variation of each natural community type across its geographic range. Inventories such as this one are important for understanding that variation within a natural community type. In order to be successful, this type of conservation planning will also need to identify species that are not well conserved by this natural community net, and we must provide specific protections for them. Examples include animals that range over wide areas and species that are rare or at the edge of their range. Also, it is critical that the natural community classification be as detailed as possible and that it be consistent among states and across regions.

Toward this latter goal, the NHIP is working with ecologists from neighboring states and NatureServe (see www.NatureServe.org) to refine regional and national classifications of natural community types. This inventory of Vermont's softwood swamps contributes to this classification work.

INTRODUCTION

This statewide inventory focuses on swamps (forested wetlands) that are dominated by red spruce (*Picea rubens*), black spruce (*Picea mariana*), hemlock (*Tsuga canadensis*), balsam fir (*Abies balsamea*), white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), and tamarack (*Larix laricina*) – all species of trees with needle-leaved, evergreen leaves (tamarack is an exception as it has needle-leaved, deciduous leaves). These wetlands are generally referred to as softwood swamps.

Cedar swamp, dominated by northern white cedar (*Thuja occidentalis*), is another type of softwood swamp. Cedar swamps are not addressed in this inventory project, as they were studied separately (see Sorenson et al. 1998b).

Forested wetlands are the dominant wetland type in Vermont, as determined by the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) (Tiner, 1987). The National Wetlands Inventory project identified approximately 220,000 acres of palustrine wetlands[2] in Vermont, of which more than half (120,000 acres) are forested wetlands. Of these forested wetlands, nearly half (53,543 acres) are needle-leaved evergreen, a category that includes all of the swamps dominated by needle-leaved evergreen (NWI code PFO4) and needle-leaved deciduous (tamarack; NWI code PFO2), as well as mixed swamp types dominated by needle-leaved evergreen trees (PFO4/1and PFO4/2). These broadly defined wetland types include organic and mineral soil swamps.

[2] Palustrine wetlands include swamps, marshes, bogs, and fens. In contrast, riverine wetlands are all those associated with streams and rivers and lacustrine wetlands are deepwater wetlands associated with lakes and ponds.

The ecological value of softwood swamps has long been recognized. They are known to provide a number of important wetland functions, including storage of floodwaters, surface water quality protection, shoreline stabilization, wildlife habitat, and rare, threatened, and endangered species habitat. Taken together, the natural community types that are included within the broad softwood swamp class represent habitat for many plant and animal species and are an important component of biological diversity in Vermont.

For this current study, softwood swamps are broadly defined as being dominated by softwood or needle-leaved trees (primarily spruces, fir, hemlock, pine, and tamarack). Cedar swamps are also a type of softwood swamp, but are not included in this study. Swamps that have a mixed canopy of softwoods and hardwoods (maples, ashes, birches, and elms) are also included in the study, as long as the softwood species are dominant.

IMPORTANT SOFTWOOD TREES OF SOFTWOOD SWAMPS

Although the focus of this project is the study of softwood swamp natural communities – the interacting assemblage of plants, animals, their physical environment, and the natural processes that affect them – it is also useful to consider the ecologies of the dominant species in these swamps, namely the trees. The following species notes are based on information primarily from Silvics of North America (Burns and Honkala 1990).

Red Spruce (*Picea rubens*): A northeastern species, ranging from the Maritime Provinces, New York, and northern New England, south along the Appalachian Mountains to North Carolina. In Vermont, red spruce is most common above 1,500 feet elevation, extending up to subalpine forests. It grows in a cool, moist climate, on soils that are typically acidic and range from shallow tills in uplands to deep organic soils in wetlands. Red spruce is very shade tolerant and may live to 400 years.

Black Spruce (*Picea mariana*): A boreal species, extending from Labrador to Alaska north to tree line, and south to Minnesota, Pennsylvania, and Connecticut. In Vermont, black spruce is most common in the Northeastern Highlands biophysical region. It grows in a cold climate with generally less precipitation than red spruce and tolerates less fertile conditions. Soils are usually deep, saturated organics but also include upland sands, coarse tills, and shallow-to-bedrock settings. Black spruce occurs in cool wetland basins and in krummholz forests near timber line. Black spruce is shade tolerant, but less so than balsam fir and northern white cedar, two common competitors. Old black spruce trees commonly reach 200 years, but some have been known to reach 280 years.

Eastern Hemlock (*Tsuga canadensis*): This species occurs from northern Minnesota to Nova Scotia, and south in a broad band along the Appalachian Mountains to northern Georgia and Alabama. In Vermont, hemlock generally grows below 1,800 feet elevation and is more common in the southern and warmer regions of the state. It grows most frequently on moist soils, but is also found on poor, shallow-to-bedrock settings and in swamps with organic soils. Hemlock is considered the most shade tolerant tree species in our region and may be suppressed in the understory for as long as 200 years. It may live to 600 years or more.

Balsam Fir (*Abies balsamea*): A boreal species, extending from Labrador and Newfoundland west to northwestern Alberta and south to northern Minnesota, central Pennsylvania, and Connecticut, with outlying populations in the mountains of Virginia and West Virginia. Balsam fir grows in cool, moist climates with abundant precipitation. Soils vary from deep, saturated organics to glacial till with an organic surface horizon, but best growth is on slightly acidic to circum-neutral soils with abundant mineral enrichment. In Vermont, balsam fir is most abundant in the Green Mountains and the Northeastern Highlands, either at higher elevations (including krummholz forest) or in cool depressions. Balsam fir is very shade tolerant but short-lived, with a maximum age of about 200 years.

Eastern White Pine (*Pinus strobus*): This species ranges from Newfoundland west across southern Canada to southeastern Manitoba, south to southern Minnesota and Pennsylvania and continuing south along the Appalachian Mountains to Georgia and South Carolina. White pine grows in a variety of soils as an early-successional species but is most likely to persist on very well drained to excessively drained soils. It also persists in some wetlands. White pine is intermediate in shade tolerance and reaches a maximum age of about 450 years. In Vermont, it is most common in the Southern Vermont Piedmont and Champlain Valley.

Pitch Pine (*Pinus rigida*): This species extends from central Maine to New York and Ontario, and south in a broad band along the Appalachian Mountains to northern Georgia and South Carolina. It grows in poor, infertile soils, ranging from dry sandy and rocky sites to saturated peatland soils. In Vermont, pitch pine grows in the warmer regions on rocky outcrops, postglacial sand deposits in the Champlain and Connecticut River Valleys, and in Maquam Bog. Many pitch pines, especially to our south, are dependant on fire to open the seed cones and to promote a seed bed that is optimal for germination. Pitch pine is shade intolerant and may reach ages ranging from 200 to 350 years.

Tamarack (*Larix laricina*): This species has a broad distribution, ranging from Newfoundland and Labrador west along the northern limit of trees to Yukon Territory, and south to British Columbia, northern Illinois, and New Jersey. There is a large disjunct population in central Alaska. Tamarack grows on a variety of soils but is most common on wet organic soils such as Sphagnum and woody peat. In Vermont, it is most common in acidic wetlands in the northeast, but also occurs frequently in calcareous wetlands, particularly in the Vermont Valley but also the Champlain Valley. Tamarack is very shade intolerant and generally does not reach ages over 150 to 180 years.

PURPOSE

This inventory project was undertaken to investigate the distribution, quality, and variability of softwood swamps across Vermont. The ecological information collected during the study was used to refine the classification of softwood swamp natural community types and to identify some of the best examples of each community type in Vermont. Information about significant wetlands that were identified has been, or will be, provided to landowners, along with recommendations for management. This information will also be used to identify significant or threatened wetlands that warrant further conservation measures by the State of Vermont or by private conservation organizations.

The specific objectives of this project were to:

- Identify the extent, distribution, and variability of softwood swamps in Vermont;
- Document vegetation composition, forest structure, and soil characteristics of softwood swamps,
- Refine the natural community classification of softwood swamp communities in Vermont based on data collection and analysis;
- Identify some of the best remaining examples of these natural community types;
- Notify landowners of the ecological significance of these wetland natural communities on their properties and provide them with management recommendations;
- Inform government and conservation planners of the significance of identified softwood swamps;
- Document rare plant species associated with these natural communities; and
- Identify characteristic animals, especially breeding birds and amphibians, associated with each of these natural communities.

METHODS

The methods used in this inventory of softwood swamp communities are similar in most regards to previous natural community inventories conducted by NHIP (Thompson and Popp, 1995; Lapin, 1988; Sorenson et al., 1998a; Sorenson et al., 1998b; Sorenson et al., 2004; and Sorenson and Popp, 2006). The inventory is divided into four stages: 1) landscape analysis, 2) landowner identification and contact, 3) field inventory, and 4) data compilation, analysis, and reporting. In addition to the traditional NHIP field inventory methods, a breeding bird survey and an amphibian survey were undertaken. Methods for these aspects of the study are described in the field inventory section below.

LANDSCAPE ANALYSIS

The purpose of the landscape analysis phase of the project was to identify particular swamps that were to be the focus for later, detailed field investigation. For several of the past statewide inventories of rare to uncommon community types conducted by NHIP (fens, clayplain forests, floodplain forests, cedar swamps, and limestone bluff cedar-pine forests) the goal has been to

identify all or most examples of the community type in the state and then select the best examples for further detailed study. As a broad class, however, softwood swamps are too common for that approach – there are more than 53,000 acres of softwood swamp mapped in over 4,800 polygons by the National Wetlands Inventory in Vermont. Consequently, the approach for this project was somewhat different than past projects in that there was a need to sort out a very large number of potential study sites into a reasonable number that could be studied over a three year period and that represent the variability of softwood swamps across Vermont. In this sense, this project was most similar to the NHIP study of hardwood swamps (Sorenson et al., 2004).

The first step of landscape analysis was to review all existing information on softwood swamps contained in the NHIP Biotics database. This database contains over 6,200 records of rare plants, animals, and exemplary natural communities in Vermont, including records of 41 softwood swamps that had been visited and documented prior to the beginning of this study. These 41 softwood swamps included examples of Black Spruce Swamp (13), Black Spruce Woodland Bog (4), Calcareous Red Maple-Tamarack Swamp (6), Hemlock Swamp (6), and Spruce-Fir-Tamarack Swamp (12). A subset of these 41 swamps was selected for further field investigation based on whether they were high quality examples of particular community types, whether they were a rare community type, or whether additional quantitative or qualitative information was needed from the swamp. The NHIP database includes an additional 99 records of Northern White Cedar Swamp and 29 records of Red Maple-Northern White Cedar Swamp that had been visited during a previous inventory project. Because these two cedar-dominated softwood swamp community types had been studied previously (Sorenson et al., 1998b), they were not included in the current softwood swamp inventory project.

The second step of landscape analysis, and the main source of information on identifying potential new softwood swamps for study, was review of the National Wetlands Inventory maps for Vermont. Paper NWI maps on a U.S.G.S. topographic base map were checked for all areas of the state except for a few mountainous areas where few wetlands occur. Digital versions of these maps were reviewed for all areas of Vermont. All swamps on the NWI maps typed as Palustrine Forested Needle-leaved Evergreen (PFO4) and Palustrine Forested Needle-leaved Deciduous (PFO2) were evaluated for study. In addition, mixed conifer swamps that were typed as being dominated by needle-leaved evergreen or deciduous trees (PFO4/1 and PFO2/1) were also evaluated. Aerial photographs, especially the 1992-1994 set of color infrared photos (1:40,000) were viewed under a stereoscope for portions of the state where more information about a particular swamp or surrounding landscape was needed. The digital black and white orthophotos (1:5,000, 1995-1999) were available for the entire state and provided more current information about the swamps. Several general criteria were used to select swamps for further evaluation. Swamps were selected from all eight biophysical regions of the state. An attempt was made to select swamps to represent many topographic positions and many types of soil, surficial deposits, and bedrock. In general, larger wetlands were selected over smaller wetlands in a given area. And finally, swamps in relatively undisturbed landscapes were selected over those in highly developed, fragmented, or heavily logged landscapes. Since only a subset of the state's softwood swamps could be studied in detail for this project, the intent of this selection process was to represent the diversity of Vermont's softwood swamps as study sites. Each selected site was assigned a priority rank of "high", "medium", or "low" based on its apparent

condition and representation of a softwood swamp type or biophysical region. Each site was also assigned a code based on the town in which it is located and a consecutive numbering system.

Knowledgeable individuals, such as wildlife biologists, foresters, soil scientists, and naturalists were consulted for additional information and leads on other swamps that should be investigated.

Aerial reconnaissance in a small airplane was the final means for obtaining information for the landscape analysis. Prior to the flights, softwood swamps selected from the preceding steps were plotted on 1:100,000 topographic base maps to be used for navigation and reference during the flights. The "high" and "medium" priority swamps were mapped in different colors from the "low" priority swamps and all swamps were labeled with the codes, so that in-flight notes could be taken efficiently. Aerial reconnaissance was carried out primarily during April and May, before leaf-out and when standing water in the swamps was more readily visible. Reconnaissance information gathered included swamp type(s) present, condition of the swamp, and updated priority ranking for the swamp. This information was recorded on a small tape recorder and later transcribed onto the master list. Oblique color print photographs were taken of most sites and later annotated with the swamp code or name.

The primary product of the landscape analysis was a softwood swamp GIS shapefile containing all the identified swamps with their priority rank for further study. The attribute table of this shapefile included the site code, the polygon codes for those swamps with multiple softwood swamp locations at a site, the site name, the priority rank, source of information about the swamp, swamp size, and comments on the swamp based on some significant aspect of the landscape analysis.

LANDOWNER IDENTIFICATION AND CONTACT

It is the policy of Vermont Fish and Wildlife Department that privately owned sites will be visited only if specific permission from landowners has been obtained. In order to accomplish this, town clerks were contacted to identify landowners whose property included high and medium priority sites. These landowners were then contacted by a letter that explained the purpose of the inventory and asked for permission to visit their property. Landowners were provided return-stamped postcards for responding. Follow-up telephone calls were made to many landowners who did not respond and to landowners who indicated that they wanted more information about the project.

FIELD INVENTORY

Field inventory was conducted in 2003 through 2006. Field methods consisted of both general observation of the site and quantitative vegetation sampling. Site observation entailed reconnoitering the swamp, developing a species list of vascular plants and bryophytes, periodically sampling organic soil depth with fiberglass chimney-sweep pole extensions, periodically sampling pH and conductivity of surface water with pocket meters, and noting characteristics of microtopography, hydrology (e.g., active seeps, flowing water), and vegetation patterns, including forest structure and tree diameter. In this way a general picture of the site was obtained and the variations and gradients present were observed. In smaller swamps, such reconnaissance may have covered much of the site, whereas in larger swamps a reconnaissance transect, the placement of which was based on aerial photo interpretation, was often used in an

attempt to expeditiously observe a great deal of the natural variation in the wetland. In some instances, permission was only available for a portion of the swamp and, therefore, site visits were restricted to these areas.

Quantitative Vegetation Sampling and Other Plot Data

Vegetation sampling followed standard methodology used by NHIP. Most plots were 400 square meters (20m x 20m). Plots were located in areas of mature, representative vegetation. Both vegetative and biophysical data were collected. For each plot, vegetation cover was estimated by species by stratum for the following layers: emergent trees (T1), tree canopy (T2), small trees (T3), tall shrubs (S1), short shrubs (S2), herbaceous (H), and non-vascular (N). Species lists were constructed by stratum and percent cover was estimated for each species. Additionally for trees, diameters at breast height (dbh) for stems greater than 3.9 inches (10cm) were recorded. Unknown mosses and liverworts were collected and later identified, and voucher specimens will be deposited in the Pringle Herbarium at the University of Vermont. Two or more average-sized trees were cored to estimate stand age; most cores were read in the field and a subsample of the cores were further prepared and read again under a microscope. Biophysical data included soil profile description, depth of organic soil, degree of decomposition of organic soil layers by the von Post method, characterization of soil drainage and soil moisture regime, and description of microtopography. The pH and conductivity of surface water was measured with field meters either in wet hollows or small holes dug in the swamp surface. Field meters were standardized each field day using three pH buffers (4.0, 7.0, and 10.0) and conductivity standard solution (447μS).

Taxonomy and nomenclature for vascular plants follows *Flora of North America* for published volumes, and *Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (Gleason and Cronquist, 1991). Bryophyte taxonomy follows Anderson, Crum, and Buck (1990) for mosses, except for Sphagnaceae, which follows Anderson (1990). Liverwort taxonomy follows Stotler and Crandall-Stotler (1977).

Breeding Bird Survey

A breeding bird survey was conducted in six of the softwood swamps. The sampling protocol followed that used by the Vermont Center for Ecostudies in their Forest Bird Monitoring Program. Two to five listening stations were established at each of the six sites. The first station was established 100 meters into the community, and subsequent stations were located at 200-meter intervals. Care was taken that no station was less than 100 meters from the edge of the community type. Because of the small size of the communities that were sampled and concern about including birds from adjacent communities, there were fewer than the five recommended listening stations at some of the swamps. Breeding bird surveys were conducted at Atwater Bay Hemlock Swamp, Castle Meadow Wetlands, Guildhall Swamp, Peacham Bog, Halnon Brook Swamp, and Mill Brook Swamp.

Breeding bird surveys occurred in 2004 and 2005. Each site was sampled twice during the breeding season - once during the first ten days of June and again seven to ten days later. In all cases both samples at a site were conducted by the same individual. All individuals conducting the sampling were skilled in identifying birds by song. The survey began at dawn or very soon thereafter and entailed an observer listening at each station for a total of ten minutes before

proceeding to the next station. Species were identified visually and by their song and data was recorded on special field sheets.

The data were evaluated to estimate the number of breeding individuals of each species at each site on a per listening station basis. For each listening station the number of breeding individuals was based on the type of observation. The following observations were tallied as two individuals: a singing male and any observation of a pair, family group, or nest. Alternatively, a calling individual and any visual observation (male or female) was tallied as a single individual. The number used was the higher of the two sampling times for each species. Once the number of individuals of every species was determined for all listening stations at the site, this total was divided by the number of listening stations. This provides a measure of the average number of individuals per listening station that allows direct comparison among the six sites. It also results in presentation of fractions of birds for most sites.

Amphibian and Reptile Survey

An amphibian and reptile survey was conducted in five softwood swamps. Each site was visited during the spring of 2003 and four of the sites were revisited during the summer of 2003. Visits were spread out temporally within the warm season (June-September) to attempt to detect a range of species that are not necessarily observable at the same time of year. For larger swamps, a different portion was surveyed on each visit. Surveys were conducted in Atwater Bay Hemlock Swamp, Tinmouth Channel WMA, Calais Town Forest Spruce-Fir-Tamarack Swamp, Lanesboro Kettle Swamp, and Vernon Town Forest Swamp.

Effort was focused primarily on areas of habitat interface, such as the swamp margins and larger pools within the swamp. Methods included searching for egg masses in open water, turning over logs and other cover materials, sweeping pools with a dip-net to find larvae, and listening for frog calls. Nearby portions of adjacent uplands were also searched in order to detect species that are seasonal users of swamps that may not be present within a swamp at the time of the survey. No quantitative methods were employed, as the focus of this survey was to detect presence/absence of as many species as possible. Recorded data included location of observations (within swamp or adjacent to swamp; under rock; in pool, etc.), detection of breeding, number of individuals observed for each species, and confidence level of identification.

Tree Age Measurements

In most study plots, one to three trees were cored using an increment borer. Trees chosen for coring were medium to large-sized canopy trees with no obvious external signs of interior rotting. When available, older looking trees, inside or outside of plots, were cored in order to get some idea of maximum age at a site. Furthermore, some trees were cored in different areas of a site that contained obviously different age class trees. Trees were cored at breast height and read in the field in most cases, although some cores that were difficult to read were brought back from the field, sanded, and read under a microscope. Tree ages and rates of growth were helpful in better understanding the history of natural and human disturbance at individual swamps. This information is included in site reports.

DATA COMPILATION, ANALYSIS, AND REPORTING

Information from the field inventory was compiled in site reports (see site reports organized by county and town in Appendix A) and in the manual (Geographic Manual File) and computerized (Biotics) databases of the Natural Heritage Information Project. This information includes rank of the quality or ecological integrity of each site (A through D) compared to others in the state, information on any rare plants present, observations of wildlife use, and brief management guidelines to protect the natural community and species. In addition, the quantitative and qualitative vegetation and environmental data from 75 plots was entered into a Microsoft Access database and then converted to Microsoft Excel spreadsheets for analysis.

A map of wetland natural communities was made for each site that was visited during this inventory and also for those sites that were visited by NHIP staff prior to this inventory and included in the NHIP database. Natural community maps were made using ArcMap 9.2 based on information in ecologists' field notes and field maps, digital topographic maps, digital NWI layers, and digital orthophotos. Attributes included for each polygon in this ArcMap shapefile included site name, site code, natural community type, acreage, and field ecologist's name. A separate point theme was developed based on this wetland natural community polygon theme. In this theme, a point was created at the center of each wetland polygon that represented a softwood swamp natural community type.

Multivariate analyses techniques were used to help in identifying patterns in the vegetation and environmental data that were collected in the softwood swamp plots. Plot data collected from previous EPA-funded swamp inventories (cedar swamps and hardwood swamps) was also analyzed to improve our understanding of the similarities and differences among all Vermont swamp types. These techniques included classification of the plots using Two-way Indicator Species Analysis (TWINSPAN) and ordination of the data using Detrended Correspondence Analysis (DCA). These methods were developed by M.O. Hill at Cornell University (1979a and b) and analyses were run using the software package PC-ORD, version 5.10 (McCune and Mefford, 2006).

TWINSPAN was used to cluster or group swamp plots by similarity of the vegetation assemblages. TWINSPAN simultaneously classifies species and plots and displays both on a two-way table. In this two-way table, plots that are most similar based on their vegetation are grouped together. Vegetation species lists were edited to remove species that only occurred in one plot prior to analysis with TWINSPAN, as these rare species can introduce noise into the analysis.

Detrended Correspondence Analysis (DCA) was used in order to further explore the similarities and differences among swamp plots and to investigate relationships between plant communities and certain environmental variables. DCA ordinates species and sample plots using reciprocal averaging. The resulting graphs or ordinations of plots help to show similarities and differences between plots or groups of plots. Environmental parameters can be analyzed along with the plot ordinations to help elucidate the ecological basis behind plot groupings and the axes of the graphs.

Copies of this report and appropriate individual site reports are provided to landowners whose property was visited and contained a softwood swamp of state or local significance. Copies of the full report with all site reports are also provided to all regional planning commissions, the Vermont Wetlands Office (Agency of Natural Resources), District Offices of the Agency of Natural Resources, the Vermont office of the U.S. Army Corps of Engineers, the Vermont Chapter of The Nature Conservancy, the Vermont Land Trust, and the U.S. Environmental Protection Agency.

RESULTS AND DISCUSSION

ABUNDANCE AND DISTRIBUTION OF SOFTWOOD SWAMPS IN VERMONT

The U.S. Fish and Wildlife Service's National Wetlands Inventory has produced the most comprehensive maps available of wetlands distribution in Vermont. The digital versions of these maps can be used and analyzed with geographic information systems. All Palustrine Forested Needle-leaved Evergreen (PFO4) and Palustrine Forested Needle-leaved Deciduous (PFO2) swamps identified on the NWI maps for Vermont, as well as all mixed conifer swamps, including those typed as Palustrine Needle-leaved Evergreen/Broad-leaved Deciduous (PFO4/1) or Needle-leaved Deciduous/Broad-leaved Deciduous (PFO2/1), were analyzed to provide information on the general abundance and distribution of softwood swamps in Vermont. The distribution of these broad classes of NWI-mapped wetlands was sorted by the eight biophysical regions of Vermont and the descriptive statistics for these data are shown in Table 1. The locations of the eight biophysical regions are shown in Figure 1.

Based on these NWI maps, it is not possible to separate northern white cedar-dominated swamps from other softwood swamp types. So although cedar swamps were not part of this softwood swamp inventory, they are included in this NWI analysis. Another note is that beaver continue to alter softwood swamps and other wetland types and so the acreage of softwood swamps listed in Table 1 are likely higher than what actually occurs.

There are several conclusions that can be made from the information presented in Table 1. On the statewide scale, PFO4 wetlands occupy only 0.9 percent of the landscape and have a mean size of 11 acres, with the largest swamp being 1,589 acres (this is Cornwall Swamp, a Red Maple-Northern White Cedar Swamp). The Northeastern Highlands (17,383 acres) and the Champlain Valley (17,002 acres) contain substantially more area of PFO4 wetland, larger mean swamp size (16.7 and 16.9 acres, respectively), and higher percentages of PFO4 wetland in the landscape (3.2 % and 1.4%, respectively) than other biophysical regions. Both of these biophysical regions have areas of large flat basins where wetlands are abundant. Although there are similarities in the abundance and size distribution of softwood swamp between these two biophysical regions, there is a significant difference in the types of wetlands present. Spruce-fir swamps dominate in the cold and generally acidic Northeastern Highlands, whereas northern white cedar and hemlock swamps are more common in the warm and generally limy Champlain Valley. The much lower percentage of PFO4 wetlands and smaller average swamp size occurring in most of the other biophysical regions is likely the result of the hilly topography and lack of large flat basins.

In sharp contrast, tamarack-dominated swamps (PFO2) are a minor component of wetlands in all biophysical regions of the state, except the Vermont Valley, where PFO2 wetlands occupy 0.4 percent of the region. Calcareous Red Maple-Tamarack Swamps are characteristic of the Vermont Valley, which is underlain by calcium-rich bedrock.

Table 1. Descriptive statistics on the acreages of all Palustrine Needle-leaved Evergreen (PFO4) and Palustrine Needle-leaved Deciduous (PFO2) NWI wetland polygons for the State of Vermont and the eight biophysical regions in Vermont.

Biophysical Region ➡	Champlain Valley	Northeast Highlands	Northern Green Mountains	Northern Vermont Piedmont	Southern Green Mountains	Southern Vermont Piedmont	Taconic Mountains	Vermont Valley	**State of Vermont**
Size of Region (acres)	1,205,867	537,912	1,156,498	1,118,641	922,529	642,757	422,040	146,677	**6,152,921**
Mean PFO4 size (acres)	16.9	16.7	7.1	9.9	4.1	3.2	9.5	9.2	**11.0**
Standard Deviation PFO4	60.7	36.5	12.7	21.3	5.0	3.9	17.1	13.0	**33.7**
Range PFO4 size (acres)	1,589.2	482.0	130.1	409.7	57.4	38.7	154.4	80.5	**1,589.2**
Maximum PFO4 size (acres)	1,589.2	482.0	130.3	409.7	57.5	38.7	154.8	81.2	**1,589.2**
Total PFO4 acreage	17,002.4	17,382.6	4,664.6	12,700.7	3,363.2	827.0	1,410.3	785.8	**58,136.5**
Number of PFO4 Polygons	1,006	1,042	654	1,287	814	258	148	85	**5,294**
Percent PFO4 by Region	1.4	3.2	0.4	1.1	0.4	0.1	0.3	0.5	**0.9**
Mean PFO2 size (acres)	6.1	8.9	3.9	4.8	2.5	2.4	6.7	5.6	**5.4**
Standard Deviation PFO2	7.7	19.3	3.7	6.6	2.2	1.2	8.3	7.2	**8.6**
Range PFO2 size (acres)	44.0	109.8	18.7	51.4	11.7	3.0	49.8	55.1	**110.5**
Maximum PFO2 size (acres)	44.2	110.7	19.1	51.8	12.1	3.8	50.5	55.7	**110.8**
Total PFO2 acreage	200.9	329.4	113.1	614.7	94.2	14.3	301.2	595.9	**2,263.6**
Number of PFO2 Polygons	33	37	29	129	38	6	45	106	**423**
Percent PFO2 by Region	0.01	0.06	0.01	0.05	0.01	0.002	0.07	0.4	**0.04**

DISTRIBUTION OF STUDY SITES

As part of this inventory, a total of 64 softwood swamp sites were visited. At these 64 sites, 184 distinct softwood swamp areas (polygons) were identified, classified to natural community type, and mapped. In addition to these sites that were visited as part of this inventory, an additional 103 softwood swamp sites were visited in prior years by NHIP staff and the information contained in the NHIP database was reviewed, community types assignments revised, and quality ranks were re-evaluated based on the new ranking specification. Figure 1 shows the locations of these 64 softwood swamp sites visited as part of this inventory and the additional 103 swamps that were visited prior to this inventory project.

Study sites were identified and visited in all eight biophysical regions. However, the greatest concentration of sites was in the Northeastern Highlands where softwood swamps are abundant, especially those dominated by spruce and fir. The concentration of previously visited softwood swamps in this region is also the result of detailed natural community mapping work conducted on the former Champion Paper lands in this area (Lapin and Engstrom 2002). Although northern white cedar swamps are abundant in the Champlain Valley, there are relatively few spruce and fir swamps.

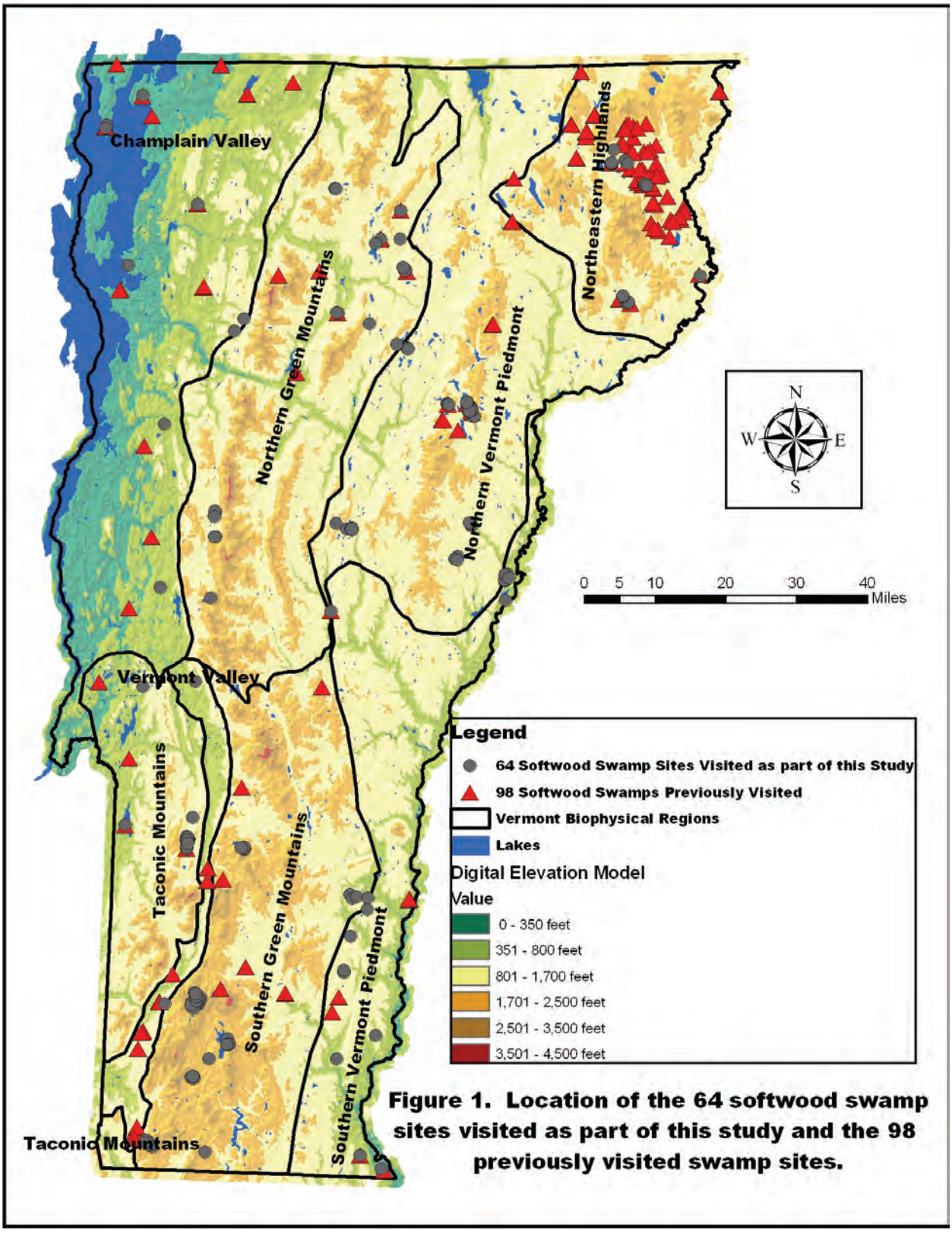


Figure 1. Location of the 64 softwood swamp sites visited as part of this study and the 98 previously visited swamp sites.

Site reports are provided in Appendix A for the 65 sites visited during this project that were considered to be of state significance. Each site report provides a summary of the significant species and natural community types at the site, a general description of the softwood swamps present, general comments about the site, management guidelines, and a map showing the location of the site. The management guidelines are Natural Heritage Information Project recommendations for landowners on protecting or enhancing the quality of the natural community or associated rare species. Many of the maps show the location of softwood swamps occurring on private property. Permission of the landowners should be obtained before visiting these properties.

PLOT DATA ANALYSIS

Plot data analysis is the primary basis for classifying Vermont's natural community types recognized by NHIP. NHIP typically collects plot data for each inventory project and analyzes this data to aid in classifying the range of community types covered for a particular study. This has been the case for NHIP's past work on inventories covering rich fens (Thompson and Popp 1995), floodplain forests (Sorenson et al. 1998a), cedar swamps (Sorenson et al. 1998b), clayplain forests (Lapin 1998), and hardwood swamps (Sorenson et al. 2004). This is the first time that plot data from multiple inventories has been combined and analyzed to provide a broader perspective on natural community classification.

Plot data was compiled from previous cedar swamp and hardwood swamp studies and combined with current plot data collected in softwood swamps. The resulting data set included 225 plots. Only two plots were eliminated from the analyses as it was determined by visual inspection of the vegetation data and preliminary multivariate analyses that these plots represented natural community types other than forested swamp types.

The resulting data set included 592 species identified in 223 plots. This includes 461 species of vascular plants and 131 species of bryophytes (mosses and liverworts). The percent cover of each woody species occurring in a plot was summed for all strata in which it occurred (three tree strata and two shrub strata) and this data was used in the analyses. For both the classification (TWINSPAN) and ordination (DCA) portions of the analyses, those species occurring in only one or two of the plots were deleted as these rare species can cause noise in the analyses. The resulting reduced dataset for all types of swamps sampled included 223 plots and 395 species.

The first step in classifying the 223 vegetation plots into community types was to use Two-Way Indicator Species Analysis (TWINSPAN). The two-way ordered table resulting from this TWINSPAN identified eight main types of swamps that appeared to be ecologically meaningful. The full TWINSPAN table is too large to be included in this report, but is available from NHIP upon request.[3] The eight TWINSPAN categories identified in the analysis are briefly described in Table 2, based on the dominant species present, species indicative of particular environmental conditions, and interpretation of what the environmental settings appear to be for each category.

[3] Please contact Eric Sorenson, Natural Heritage Information Project, Vermont Fish and Wildlife Department, (802) 241-3714 or eric.sorenson@state.vt.us

Table 2. The eight TWINSPAN categories for the 223 swamp vegetation plots with the dominant and indicator species listed for each and comments on environmental setting.

TWINSPAN Category	Dominant and Indicator Species	Comments on Environmental Setting Based on Species	Number of Plots in this Category
1	red maple, silver maple, green ash, black ash, winterberry, sensitive fern, false nettle, water parsnip, rice cut-grass, few mosses	hardwood swamps flooding during the growing season	31
2	red maple, black ash, hemlock, white pine, tamarack, yellow birch, red oak seedlings, highbush blueberry, dwarf blackberry, spicebush, sensitive fern, cinnamon fern, marsh fern, foam flower, swamp saxifrage, *Thuidium delicatulum*	mixed swamps with mineral-rich seepage water in warmer climates	53
3	balsam fir, black ash, hemlock, red maple, yellow birch, red spruce, dwarf blackberry, Canada honeysuckle, cinnamon fern, sensitive fern, foamflower, common wood-sorrel, *Thuidium delicatulum*, *Hylocomnium splendens*	mixed swamps with mineral-rich seepage water in cooler climates	29
4	northern white cedar, balsam fir, black ash, red maple, dwarf blackberry, red-osier dogwood, Canada honeysuckle, alder-leaved buckthorn, Canada yew, naked miterwort, goldthread, common wood-sorrel, *Hylocomnium splendens*, *Rhytidiadelphus triquetrus*, *Sphagnum warnstorfii*	cedar swamps with mineral-rich seepage water	62
5	red spruce, balsam fir, mountain holly, northern wild raisin, velvet-leaf blueberry, three-seeded sedge, cinnamon fern, goldthread, *Bazzania trilobata*, *Sphagnum girgensohnii*, *S. magellanicum*	red spruce and fir swamps in cool, acidic settings	14
6	red maple, white pine, black gum, hemlock, yellow birch, highbush blueberry, mountain holly, winterberry, red oak seedlings, cinnamon fern, goldthread, *Sphagnum centrale*, *S. angustifolium*, *S. magellanicum*, *S. girgensohnii*	hardwood and hemlock swamps in warm, acidic settings	10
7	black spruce, tamarack, balsam fir, red maple, mountain holly, northern wild raisin, sheep laurel, velvet-leaf blueberry, Labrador tea, three-seeded sedge, bunchberry, snowberry, cinnamon fern, *S. girgensohnii*, *S. magellanicum*, *S. angustifolium*, *Pleurozium schreberi*	black spruce and tamarack swamps in cool, acid settings	19
8	black spruce, tamarack, white pine, red maple, black huckleberry, leatherleaf, highbush blueberry, Labrador tea, mountain holly, three-seeded sedge, *Sphagnum subtile*, *S. magellanicum*	conifer swamps with huckleberry in acidic settings; possible fire history	5

Most of these eight TWINSPAN categories are broader than current natural community type concepts. However, the broadly defined types of swamps identified in these eight categories provide a useful insight into variations in vegetation. Category 1 is the only strictly hardwood swamp type and the species listed indicate its association with seasonal flooding. Categories 2 and 3 are mixed hardwood and softwood swamps with species indicative of mineral-rich groundwater seepage. These two categories seem to be most clearly distinguished from one another by warm and cool climate species, reflecting their geographic distribution. Category 4 is closely linked to Northern White Cedar Swamps and Red Maple-Northern White Cedar Swamps. Categories 5, 7, and 8 are all acidic conifer swamps dominated by spruce and fir, with the more northern black spruce swamps contained in categories 7 and 8. Category 6 is primarily hardwood swamps in acidic settings, with several species indicating a more temperate climate. Huckleberry is an important defining species of category 8 and may also indicate a fire history at these swamps.

The second step in classifying the 223 plots was to ordinate the vegetation data using Detrended Correspondence Analysis (DCA). In DCA, the primary data matrix is the relative abundance (percent cover) of all plant species for each of the 223 plots. A secondary matrix of quantitative and categorical environmental, vegetation structure, and procedural variables associated with each plot was included in the analysis in order to elucidate patterns between these variables and the distribution of swamp plots in the resulting DCA graph. Seventeen environmental variables were included in the analysis and are listed in Table 3. In addition, the eight TWINSPAN categories were included in the secondary matrix as a categorical variable so that the results of the TWINSPAN could be compared with the DCA. Surface water pH and conductivity were measured in many of these plots, but since this data was not collected in all plots these variables were not included in this DCA. Figure 2 shows the DCA graph of the 223 plots, with each plot coded to its TWINSPAN category, and vectors showing the most important environmental and structural variables that were measured.

Table 3. Environmental variables included in the Detrended Correspondence Analysis of 223 swamp plots.

Environmental Variable Name	**Variable Type**	**Description of Environmental Variable**
Surveyor	Categorical	Surveyor that completed the plot; a basic quality control method
Inventory Type	Categorical	NHIP inventory categories includes cedar swamps, hardwood swamps, and softwood swamps
Slope	Quantitative	Most swamps surfaces are nearly level; a slope would indicate water movement
Elevation	Quantitative	Elevation of the plot is related to climate
Depth of Organic Matter Class	Categorical	Organic soil depth assigned to one of five categories
Depth of Organic Matter Minimum	Quantitative	Minimum observed depth or organic soil observed in the plot by soil probing
Cover Estimate T1	Quantitative	Percent cover estimate of the emergent tree stratum
Cover Estimate T2	Quantitative	Percent cover estimate of the main canopy tree stratum
Cover Estimate T3	Quantitative	Percent cover estimate of the subcanopy tree stratum
Cover Estimate S1	Quantitative	Percent cover estimate of the tall shrub stratum
Cover Estimate S2	Quantitative	Percent cover estimate of the short shrub stratum
Cover Estimate H	Quantitative	Percent cover estimate of the herb stratum
Cover Estimate N	Quantitative	Percent cover estimate of the bryophyte (non-vascular) stratum
Total Canopy Cover Estimate	Quantitative	Percent cover estimate of the total tree canopy cover
Soil Drainage Class	Categorical	Drainage classes of somewhat poorly drained to very poorly drained are defined by the NRCS
Swamp Latitude	Quantitative	Latitude of the town in which the swamp occurs
Swamp Longitude	Quantitative	Longitude of the town in which the swamp occurs
TWINSPAN Category	Categorical	Categories 1-8 as described in Table 2

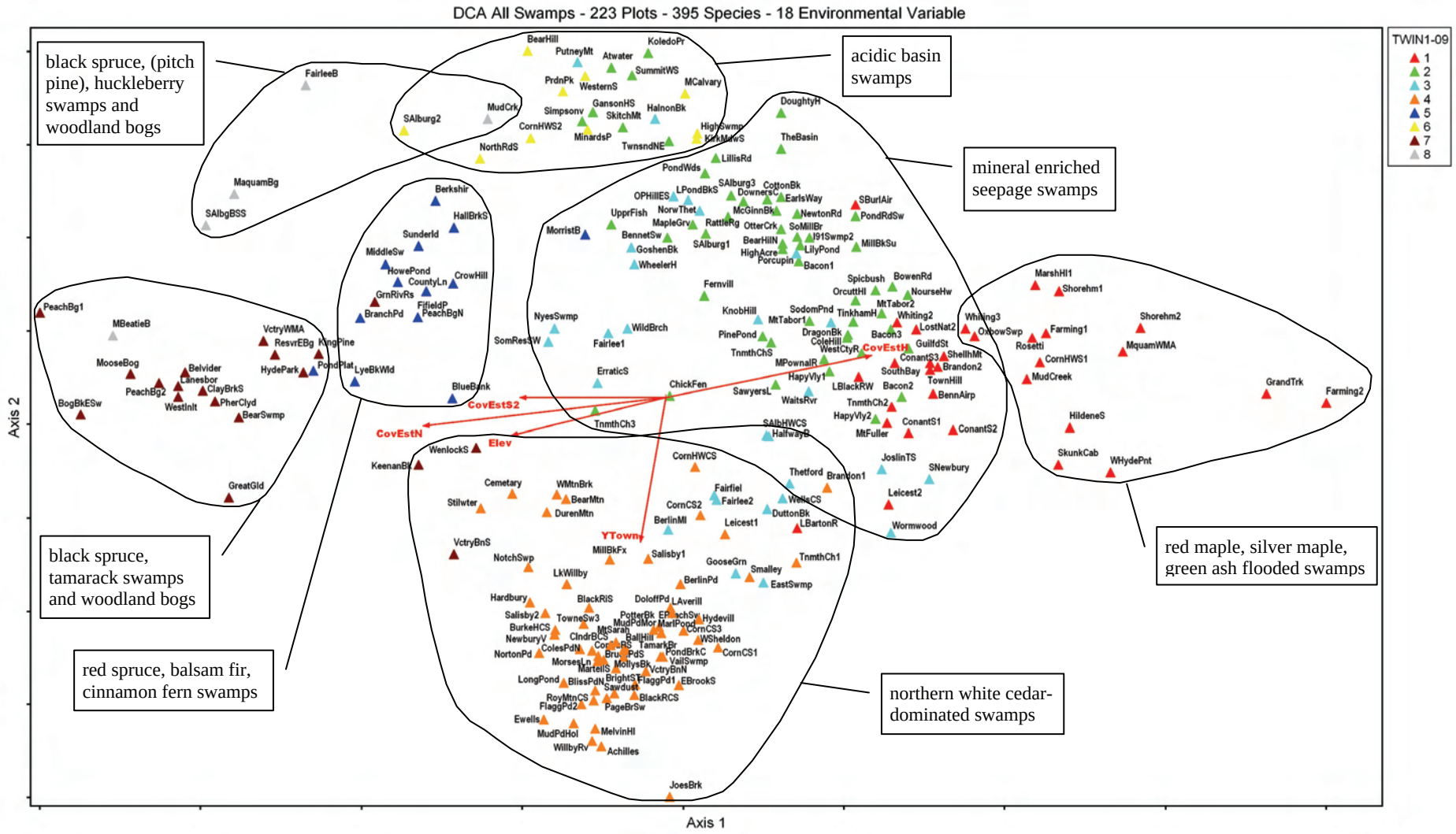


Figure 2. Detrended Correspondence Analysis graph of 223 swamp plots color coded to the eight TWINSPAN categories and showing vectors for four important environmental variables ("CovEstN" is bryophyte strata percent cover; "CovEstS2" is short shrub strata percent cover, "Elev" is plot elevation, and "YTown" is latitude of the town in which the plot occurs). The hand-drawn polygons identify broad categories of swamp types.

Figure 2 also includes hand-drawn polygons that identify broad categories of similar swamp types. These polygons are based on interpretation of the DCA ordination, the eight TWINSPAN categories, and review of the species composition and environmental characteristics of the swamps included (especially those plots graphed on the margins of groupings).

Unlike TWINSPAN that forces separation of the plots into groups based on species composition, DCA portrays the similarities and differences between plots by their relative position in the ordination (graph). In this respect, the DCA ordination is a much better reflection of what occurs in nature – there is a continuum in variation between natural communities. This continuum in variation is evident in the DCA ordination by the plots that are graphed at the margin of a cluster of plots from one TWINSPAN category and that are intermixed with plots of other TWINSPAN categories.

The swamps dominated by northern white cedar (*Thuja occidentalis*) form one of the tightest clusters of plots in the ordination. To the upper right, this cluster merges with mineral-enriched seepage swamps containing less cedar and more red maple (*Acer rubrum*) and black ash (*Fraxinus nigra*). To the upper left, this cluster includes several plots with black spruce (*Picea mariana*) as a co-dominant with cedar (WenlockS, KeenanBk, and VictoryS). Axis 2 of the ordination is negatively correlated (r^2=0.22) with latitude – this makes sense as most cedar swamps are in the northern half of Vermont. Three clusters of acidic, black spruce and red spruce swamps are located on the left side of the ordination. Axis 1 of the ordination is negatively correlated with total bryophyte cover (r^2=0.38) and has weaker negative correlations with total short shrub cover (r^2=0.23) and elevation (r^2=0.24). These acidic spruce swamps typically have a carpet of *Sphagnum* moss, an abundance of low ericaceous shrubs, and many occur in the higher elevations of the Southern Green Mountain and the Northeast Highlands biophysical regions. At the top of the ordination is a small cluster of acidic swamps, mostly occurring in small basins, dominated by red maple (*Acer rubrum*), white pine (*Pinus strobus*), black gum (*Nyssa sylvatica*), or hemlock (*Tsuga canadensis*) and several species of *Sphagnum*. These are mostly swamps of southern Vermont or warm climate areas. This cluster of acidic swamps is a mixture of three TWINSPAN categories (2, 3, and 6). On the far right of the ordination is a cluster of hardwood swamps dominated by red maple, silver maple (*Acer saccharinum*), and/or green ash (*Fraxinus pennsylvanica*), many of which are associated with Lake Champlain or larger rivers and experience seasonal flooding. Axis 1 is positively correlated (r^2=0.32) with the total cover of the herb stratum. These seasonally flooded swamps typically have an abundance of ferns and other herbs, but very low abundance of bryophytes. In the center of the ordination is a large cluster of plots from swamps that have mineral enrichment, either as a result of groundwater seepage input to the swamp or vegetation contact with underlying enriched mineral soils, such as the clays of the Champlain Valley.

All of the groupings in the ordination can be easily classified as primarily hardwood or softwood swamps except this large central group of enriched swamps and the top group of acidic basin swamps. Although we tend to focus on tree species when classifying swamps and other forested natural communities, this points out how other species may be better indicators of critical environmental factors driving the formation of the community. In this case, the presence of species that are strong indicators of mineral enrichment, even if they occur in low abundance, are a better reflection of the environmental conditions than the dominant trees. Examples of species

indicative of mineral enrichment include foam flower (*Tiarella cordifolia*), sensitive fern (*Onoclea sensibilis*), swamp saxifrage (*Saxifraga pensylvanica*), inland sedge (*Carex interior*), orange jewelweed (*Impatiens capensis*), water avens (*Geum rivale*), delicate-stemmed sedge (*Carex leptalea*), Jack-in-the-pulpit (*Arisaema triphyllum*), alder-leaved buckthorn (*Rhamnus alnifolia*), dwarf blackberry (*Rubus pubescens*), black ash, and the mosses *Thuidium delicatulum, Climaceum dendroides*, and *Rhytidiadelphus triquetrus*. The lack of these indicator species and the abundance of several species of *Sphagnum* (*S. girgensohnii, S. magellanicum,* and *S. angustifolium*) are important in defining the acidic basin swamps. The dominant trees in the plots from both the enriched swamp and acidic basin swamp groups are red maple, hemlock, white pine, yellow birch (*Betula alleghaniensis*), and balsam fir (*Abies balsamea*), all of which are mostly indifferent to the degree of mineral enrichment.

Even with this understanding that dominant tree species may not be the best reflection of underlying environmental conditions, it is still useful to distinguish between softwood and hardwood swamps, even if just for practical reasons. A classification of swamp natural communities based primarily on herb and moss indicators of mineral enrichment would be of little use to most people. However, a classification that uses trees as a primary separator and herb and moss indicator species as a secondary separator is likely to be useful to more people. This decision on classification approach will result in identification of more swamp natural community types, but hopefully will also result in a classification that is more widely used.

From the full swamp data set of 223 plots, 73 plots from softwood swamps were selected for further multivariate analyses. These plots were primarily those obtained during field work for the softwood swamp inventory project, but several plots from the hardwood swamp inventory that had more than 50 percent cover of softwood tree species were also included. Plots from Northern White Cedar Swamps and Red Maple-Northern White Cedar Swamps were not included. Species occurring in only one or two of the plots were deleted from the softwood swamp dataset for the analyses. The resulting reduced dataset for softwood swamps included 73 plots and 223 species.

The two-way ordered table resulting from this TWINSPAN produces eight groups or categories of swamps at the third level of division. Category 1 consisted of only two swamps and was determined to be very similar to Category 2, so these two categories are treated as one. Therefore, seven types of softwood swamps were identified that appeared to be ecologically meaningful. The full TWINSPAN table is too large to be included in this report, but is available from NHIP upon request. The seven TWINSPAN categories identified in the analysis are briefly described in Table 4, based on the dominant species present, species indicative of particular environmental conditions, and interpretation of what the environmental settings appear to be for each category.

These seven TWINSPAN categories are a strong basis for classifying and describing the natural community types described below. At the broadest scale, these groupings separate swamps into those with species indicative of mineral-rich seepage water (categories 1-3) from those with species indicative of acidic, mineral-poor water (categories 4-8). At the natural community scale, tree species, indicators of mineral-rich seepage water, and *Sphagnum* species associated with forested swamp and acidic peatlands are useful in characterizing the categories.

Table 4. The eight TWINSPAN categories for the 73 softwood swamp vegetation plots with the dominant and indicator species listed for each and comments on environmental setting.

TWINSPAN Category	Dominant and Indicator Species	Comments on Environmental Setting and Dominant Species	Number of Plots in this Category
1 and 2	tamarack, red maple, black ash, white pine, alder-leaved buckthorn, red-osier dogwood, dwarf blackberry, rough-leaved goldenrod, lakeshore sedge, inland sedge, *Thuidium delicatulum, Sphagnum warnstorfii, Pleurozium schreberi*	tamarack open canopy swamps with mineral-rich seepage water	7
3	hemlock, balsam fir, black ash, red maple, Canada honeysuckle, dwarf blackberry, foam flower, water avens, golden saxifrage, sensitive fern, orange jewelweed, swamp saxifrage, fowl mannagrass, cinnamon fern, *Thuidium delicatulum, Rhytidiadelphus triquetrus, Hylocomnium splendens*	hemlock and/or balsam fir swamps with mineral-rich seepage water	15
4	hemlock, red spruce, red maple, yellow birch, winterberry holly, cinnamon fern, three-seeded sedge, *Sphagnum girgensohnii, S. centrale, S. palustre, S. angustifolium, Bazzania trilobata*	hemlock swamps with *Sphagnum* and acidic, mineral-poor water	19
5	red spruce, balsam fir, red maple, northern wild raisin, mountain holly, common pinkster flower, creeping snowberry, cinnamon fern, three-seeded sedge, goldthread, wild sarsaparilla, *Sphagnum girgensohnii, S. fallax, S. magellanicum, Bazzania trilobata*	red spruce, cinnamon fern, and *Sphagnum* swamps with acidic, mineral-poor water	9
6	balsam fir, red spruce, black spruce, tamarack, red maple, yellow birch, mountain holly, northern wild raisin, sheep laurel, Labrador tea, black chokeberry, creeping snowberry, three-seeded sedge, cinnamon fern, bunchberry, *Sphagnum magellanicum, S. fallax, S. girgensohnii, Bazzania trilobata, Pleurozium schreberi*	tamarack, spruce, fir, and *Sphagnum* swamps with acidic, mineral-poor water	5
7	black spruce, tamarack, balsam fir, red maple, mountain holly, northern wild raisin, velvet-leaf blueberry, sheep laurel, bog laurel, Labrador tea, leatherleaf, rhodora, creeping snowberry, three-seeded sedge, cinnamon fern, bunchberry, *Sphagnum magellanicum, S. angustifolium, S. girgensohnii, Pleurozium schreberi, Dicranum polysetum*	black spruce swamps and woodland bogs with peatland shrubs and *Sphagnum* and acidic, mineral-poor water	14
8	black spruce, tamarack, red maple, white pine, grey birch, black huckleberry, highbush blueberry, leatherleaf, *Sphagnum magellanicum, S. centrale, S. subtile*	black spruce (and pitch pine) open canopy peatlands with black huckleberry	4

The softwood swamp dataset of 73 plots was also analyzed using DCA. A secondary matrix of environmental variables was included in the analysis in order to elucidate patterns between these variables and the distribution of swamp plots in the resulting DCA graph. Seventeen environmental variables were included in the analysis and are listed in Table 3. In addition, the eight TWINSPAN categories derived from the 73-plot analysis were included in the secondary matrix as a categorical variable so that the results of the TWINSPAN could be compared with the DCA. Surface water pH and conductivity were measured in many of these plots, but since this data was not collected in all plots these variables were not included in this DCA. Figure 3 shows the DCA graph of the 73 plots, with each plot coded to its TWINSPAN category, and vectors showing the most important environmental and structural variables that were measured.

Hand drawn polygons on the DCA ordination identify clusters of plots that are classified to a particular natural community type. These natural community polygons are based on several factors, including the TWINSPAN categories, the graphed location of plots relative to each other, and evaluation of each plot based on professional judgment. Although some of the natural community clusters correspond closely with the TWINSPAN categories (Calcareous Red Maple-Tamarack Swamp, Black Spruce Swamp, Black Spruce Woodland Bog, and Spruce-Fir-Tamarack Swamp), other clusters include plots classified to multiple TWINSPAN categories (Hemlock-Balsam Fir-Black Ash Seepage Swamp and Red Spruce-Cinnamon Fern Swamp). The concentration of plots graphed in the lower left quadrant of the ordination shows the overall similarity of these community types and demonstrates that there is a continuum in variation of species composition. Although the Hemlock-Sphagnum Acidic Basin Swamp is not clearly distinguished as a separate type based on the TWINSPAN or the DCA, we have chosen to recognize it based on its acidic character and observed lack of species associated with mineral enrichment.

The DCA clearly separates the acidic, mineral-poor, black spruce swamps and bogs on the right side of the ordination from the mineral-rich seepage swamps on the left side of the ordination. The correlations of environmental variables with the first two axes of the ordination further clarify the separation of plots. The percent cover of short shrubs is positively correlated (r^2=.466) with axis 1. Short shrubs, especially heaths, are abundant and characteristic of Black Spruce Woodland Bog, Pitch Pine Woodland Bog, and Black Spruce Swamp. These communities also have abundant bryophyte cover which is also positively correlated (r^2=.308) with axis 1. Seepage swamps typically have abundant and diverse herbaceous plant cover and this variable is negatively correlated (r^2=.466) with axis 1. Although pH and conductivity were not measured at all 73 softwood swamp plots, a separate DCA was run on a 64 plot subset of the softwood swamps for which pH and conductivity were measured. This 64-plot ordination was very similar to the 73 plot ordination in terms of the distribution of plots in the graph. There was a strong negative correlation (r^2=.585) between pH and axis 1, meaning that plots on the left side of the graph generally had a higher pH. This corresponds well with the concepts of Calcareous Red Maple-Tamarack Swamp and Hemlock-Balsam Fir-Black Ash Swamp, both of which have mineral-rich groundwater seepage and pH that ranges from near 5.0 to 8.2.

There were no strong correlations between any of the environmental variables that were measured and axis 2 of the ordination. However, there are some distinct similarities in species composition in the plots and communities found at the top of the ordination. Most of these plots include tamarack, white pine, and highbush blueberry (*Vaccinium corymbosum*) in relatively high abundance. This combination of species is characteristic of the warm-climate peatlands in which the plots at the top portion of the ordination were taken.

An interesting result of both the TWINSPAN and the DCA is the strong role that black huckleberry (*Gaylussacia baccata*) apparently played. TWINSPAN category 8 is the only category in which this species is abundant and the plots with this species are all grouped in the upper right corner of the ordination. Abundant huckleberry is commonly associated with a history of fires in a natural community. Repeated fires are known to have occurred at Maquam Bog (Strimbeck 1988) and are suggested based on the vegetation at the Mud Creek Red Maple-White Pine Huckleberry Swamp (Lapin 2003 site visit, see report in Appendix A).

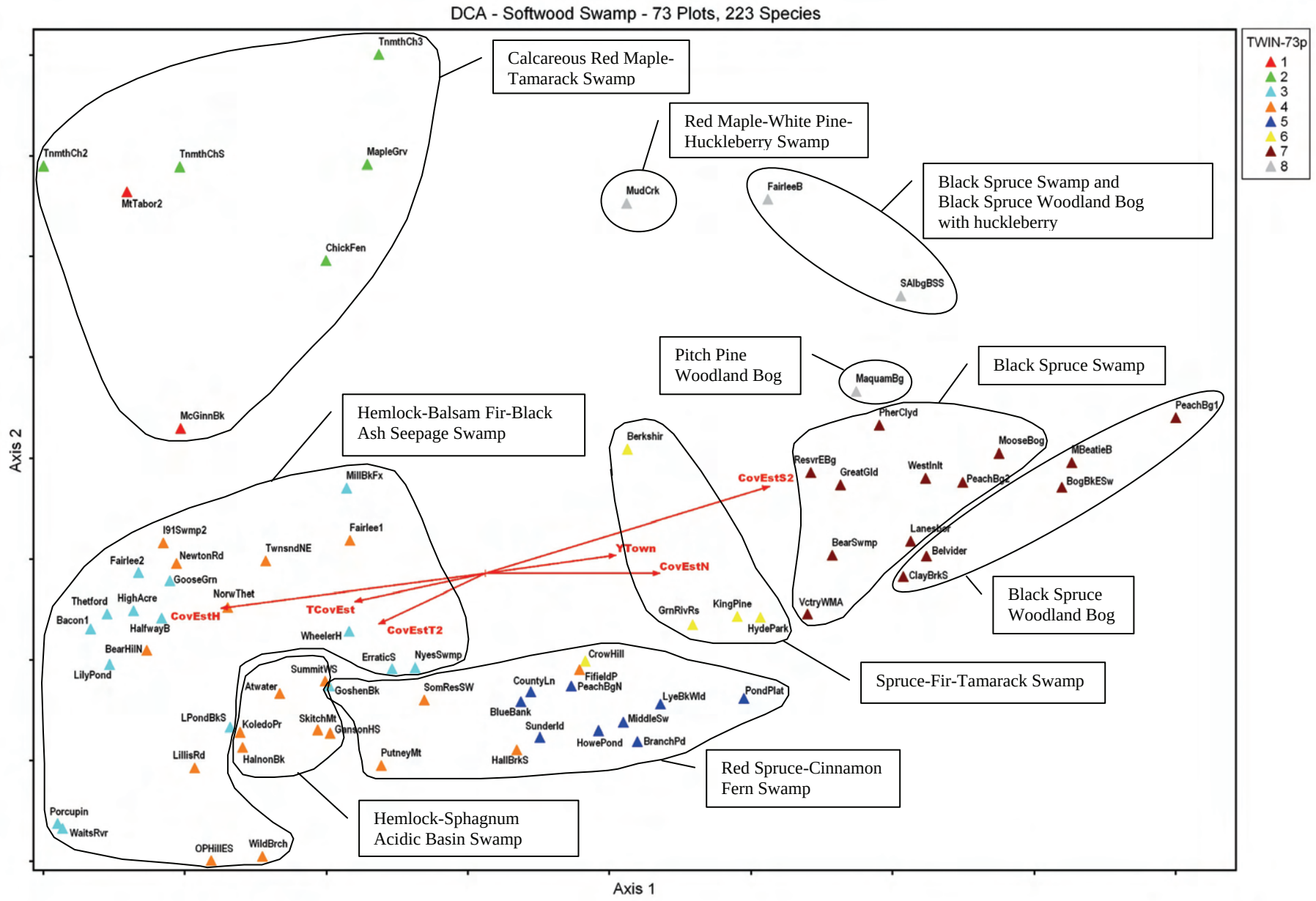


Figure 3. Detrended Correspondence Analysis graph of 73 softwood swamp plots color coded to the eight TWINSPAN categories and showing vectors for six important environmental variables (see Table 3 for explanations of these variable; "YTown" is latitude of the town in which the plot occurs). The hand-drawn polygons identify natural community types.

DESCRIPTIONS OF NATURAL COMMUNITY TYPES

As a result of this statewide softwood swamp inventory and data analyses, NHIP will now recognize seven types of softwood swamps, not including those dominated by northern white cedar. These seven community types are described below. The most significant change in the types that will be recognized and tracked by NHIP is that the former Hemlock Swamp will now be split into two natural community types: Hemlock-Sphagnum Acidic Basin Swamp and Hemlock-Balsam Fir-Black Ash Seepage Swamp. In addition, the former Red Spruce-Hardwood Swamp variant of Spruce-Fir-Tamarack Swamp will now be recognized as a separate community type: Red Spruce-Cinnamon Fern Swamp. The following descriptions are taken in part from Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont (Thompson and Sorenson, 2005), although they have also been revised to incorporate new information from this study. Calcareous Red Maple-Tamarack Swamp (which may be dominated by tamarack) and Red Maple-White Pine Huckleberry Swamp (which may be dominated by white pine) are also described here, even though they were the subject of the hardwood swamp inventory and their descriptions have not changed significantly since that study (Sorenson et al., 2004). Descriptions of Northern White Cedar Swamp and Red Maple-Northern White Cedar Swamp are not included here. The National Vegetation Classification name for the association is given in italics after each natural community name (NatureServe 2009).

Hemlock-Sphagnum Acidic Basin Swamp
S2 rank – rare

(New type – replaces Hemlock Swamp, in part)
Tsuga canadensis - Betula alleghaniensis / Ilex verticillata / Sphagnum spp. Forest (CEGL006226)

Hemlock-Sphagnum Acidic Basin Swamps typically occur in small bedrock basins and are fed by small watersheds. They occur in warmer climatic settings in Vermont, including the Taconic Mountains, Connecticut River Valley, Vermont Valley, and likely the Champlain Valley. They generally occur at low elevations (mean elevation 752 feet, range 370-1,280 feet, n=5). They generally have deep peat accumulations (mean depth of 12.1 feet, range 0.4-16.0 feet, n=5) of poorly decomposed *Sphagnum* with common wood pieces. The organic soils are consistently saturated, but there is little standing water in the hollows. Water at or near the peat surface is acidic (pH ranges from 4.1-4.7, mean pH of 4.3, n=4), and receives little mineral enrichment from surface water runoff (mean conductivity of 60 µS, range 50-90 µS, n=4).

Hemlock (*Tsuga canadensis*) dominates the canopy of these swamps, creating a densely-shaded forest floor. Other canopy trees that vary in their abundance include red spruce (*Picea rubens*), red maple (*Acer rubrum*),

yellow birch (*Betula alleghaniensis*), and white pine (*Pinus strobus*). Balsam fir (*Abies balsamea*), a northern species associated with more mineral enrichment, is typically lacking from Hemlock-Sphagnum Acidic Basin Swamps. The shrub layers are sparse and generally dominated by hemlock regeneration. Winterberry holly (*Ilex verticillata*) is present in low abundance as a tall shrub and low sweet blueberry (*Vaccinium angustifolium*) is occasional as a short shrub. Cinnamon fern (*Osmunda cinnamomea*) forms dense stands (25 to 60 percent cover) across the hummocks. Three-seeded sedge (*Carex trisperma*) is common. Boreal herbs are scattered across the mossy hummocks and hollows, including goldthread (*Coptis trifolia*), bluebead lily (*Clintonia borealis*), starflower (*Trientalis borealis*), and Canada mayflower (*Maianthemum canadense*). Other herbs include common water-horehound (*Lycopus uniflorus*), wild sarsaparilla (*Aralia nudicaulis*), and partridge berry (*Mitchella repens*). The bryophyte cover ranges from 50 to 90 percent and is strongly dominated by *Sphagnum* moss, primarily *Sphagnum centrale* and *Sphagnum girgensohnii*. Other bryophytes include *Hypnum imponens*, pincushion moss (*Leucobryum glaucum*), and the liverwort *Bazzania trilobata*. Hemlock-Sphagnum Acidic Basin Swamps have low species richness. The average number of species in five 400 square meter plots was 30, with a range of 20 to 37 species.

Hemlock-Sphagnum Acidic Basin Swamps are similar to Red Maple-Sphagnum Acidic Basin Swamps, with the dominance of canopy species being the primary distinguishing factor. The relationship between these community types needs additional study. Land use history might play a role in the canopy composition of these two natural community types. Hemlock-Sphagnum Acidic Basin Swamps are easily distinguished from Hemlock-Balsam Fir-Black Ash Seepage Swamps by the lack of seepage indicators in Hemlock-Sphagnum Acidic Basin Swamps and the relatively low species richness in these swamps.

Hemlock-Balsam Fir-Black Ash Seepage Swamp
S3 rank – uncommon
(New type – replaces Hemlock-Hardwood Swamp variant of Hemlock Swamp)
Betula alleghaniensis - Acer rubrum - (Tsuga canadensis, Abies balsamea) / Osmunda cinnamomea Forest (CEGL006380)

Hemlock-Balsam Fir-Black Ash Seepage Swamps are widely distributed in Vermont, but are most common at lower elevations (mean of 898 feet, range 360-1,600 feet, n=19) in areas with bedrock or till that has moderate to high available calcium. The distinctive feature of these swamps is that they receive ground water discharge from seeps or springs; therefore, the surface and near surface waters in these swamps have relatively high concentrations of dissolved minerals. It is common to find springs and cool, slowly moving seepage waters at their margins. Because of this constant source of ground water seepage, Hemlock-Balsam Fir-Black Ash Seepage Swamps typically form the headwaters of perennial streams. The water chemistry of these swamps is variable, with pH ranging from 4.8 to 8.2 (mean pH of 5.4, n=15) and conductivity ranging from 10 to 460 µS (mean of 81 µS, n=15). This surface water variability reflects the variability in underlying bedrock and till composition. There is also considerable variability in soils in these seepage swamps, with organic soil depth ranging from zero to 16.0 feet (mean 6.9 feet, n=19).

Hemlock-Balsam Fir-Black Ash Seepage Swamps are rich in species, with an average of 60 species recorded in nineteen 400 square meter plots (range of 36 to 85 species per plot). Typically, hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*) are co-dominants in the canopy layer of these conifer swamps, but swamps with only hemlock occur in warmer regions and swamps with only balsam fir occur in cooler regions. Black ash (*Fraxinus nigra*) is a characteristic species of seepage swamps and it may approach co-dominance with hemlock and fir. Other canopy species include yellow birch (*Betula alleghaniensis*), red maple (*Acer rubrum*), red spruce (*Picea rubens*), and white pine (*Pinus strobus*).

The shrub layers are generally sparse. Winterberry holly (*Ilex verticillata*) is typically present in low abundance and Canada honeysuckle (*Lonicera canadensis*) occurs in many swamps. In cooler settings, mountain holly (*Nemopanthus mucronata*) and velvet-leaf blueberry (*Vaccinium myrtilloides*) may be present. In warmer settings, spicebush (*Lindera benzoin*), highbush blueberry (*Vaccinium corymbosum*), or poison sumac (*Toxicodendron vernix*) may be present. Shrubs indicative of the mineral-enriched surface waters occur in some swamps and include alder-leaved buckthorn (*Rhamnus alnifolia*), red-osier dogwood (*Cornus sericea*), and poison ivy (*Toxicodendron radicans*).

Dwarf blackberry (*Rubus pubescens*) is a common low shrub. The herb layer is diverse. Cinnamon fern (*Osmunda cinnamomea*) is dominant in many swamps, but it is the abundance of seepage indicator species that is characteristic of these swamps. These species include water avens (*Geum rivale*), delicate-stemmed sedge (*Carex leptalea*), inland sedge (*Carex interior*), golden saxifrage (*Chrysosplenium americanum*), swamp saxifrage (*Saxifraga pensylvanica*), foam flower (*Tiarella cordifolia*), orange jewelweed (*Impatiens capensis*), and sensitive fern (*Onoclea sensibilis*). Some combination of these species is present in all swamps. Other herbs include three-seeded sedge (*Carex trisperma*), wild sarsaparilla (*Aralia nudicaulis*), goldthread (*Coptis trifolia*), marsh fern (*Thelypteris palustris*), starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), bluebead lily (*Clintonia borealis*), and crested wood fern (*Dryopteris cristata*). Bryophyte cover varies from zero to 90 percent in these seepage swamps, with an average of 50 percent cover. Common fern moss (*Thuidium delicatulum*) is one of the most characteristic mosses and may cover up to 35 percent of the moist ground. Other bryophytes that are also indicative of ground water seepage and that may be present include *Rhytidiadelphus triquetrus*, *Hylocomnium splendens*, *Sphagnum squarrosum*, *Sphagnum teres*, *Sphagnum warnstorfii*, and the liverwort *Trichocolea tomentella*. Other bryophytes include *Sphagnum angustifolium*, *Sphagnum centrale*, *Sphagnum palustre*, and *Sphagnum girgensohnii*.

Red Spruce-Cinnamon Fern Swamp
S3 rank – uncommon
(New type – replaces Red Spruce-Hardwood Swamp variant of Spruce-Fir-Tamarack Swamp)
Picea rubens - Acer rubrum / Nemopanthus mucronatus Forest (CEGL006198)

These swamps occur in small bedrock and till basins or may be part of large wetland complexes. They have moderately deep peat accumulations (mean depth of 6.8 feet, range 0.25-15.7 feet, n=15) and are acidic (pH ranges from 3.5 to 5.9, mean pH of 4.1, n=14) and poor in dissolved minerals (mean conductivity of 38, range of 20-60µS, n=14). They are typically not associated with flow-through streams, but they may contain headwaters or small, seasonal streams. Red Spruce-Cinnamon Fern Swamps are most common on the plateau of the Southern Green Mountains, where they typically occur as part of large wetland complexes. They also occur in the Northern Green Mountains and in both the Northern and Southern Vermont Piedmont; they are not found in the coldest basins or in the warmest valleys. They occur at moderate to high elevations in the state (mean elevation 2,080 feet, range 807-2,660 feet, n=15).

Red Spruce-Cinnamon Fern Swamps are dominated by red spruce (*Picea rubens*), with lesser amounts of balsam fir (*Abies balsamea*) and red maple (*Acer rubrum*). Other trees that may be present in low abundance include yellow birch (*Betula alleghaniensis*), paper birch (*Betula papyrifera*), and white pine (*Pinus strobus*). Total canopy cover is typically about 70 percent. Tamarack (*Larix laricina*) and black spruce (*Picea mariana*), which are characteristic of Spruce-Fir-Tamarack Swamp, are typically absent from Red Spruce-Cinnamon Fern Swamps. The tall shrub layer is well developed and dominated by mountain holly (*Nemopanthus mucronata*) and northern wild raisin (*Viburnum cassinoides*), although common pinkster flower (*Rhododendron prinophyllum*) and winterberry (*Ilex verticillata*) may also be common. Low shrubs include velvet-leaf blueberry (*Vaccinium myrtilloides*), low sweet blueberry (*Vaccinium angustifolium*), sheep laurel (*Kalmia angustifolia*), and black chokeberry (*Aronia melanocarpa*). Creeping snowberry (*Gaultheria hispidula*) and dwarf blackberry (*Rubus pubescens*) are common on hummocks in the swamps. Three-seeded sedge (*Carex trisperma*) and cinnamon fern (*Osmunda cinnamomea*) are the dominant herbs across hummocks and hollows. Other herbs include wild sarsaparilla (*Aralia nudicaulis*), goldthread (*Coptis trifolia*), bluebead lily (*Clintonia borealis*), dewdrop (*Dalibarda repens*), common wood-sorrel (*Oxalis acetosella*), and evergreen woodfern (*Dryopteris intermedia*). There are usually some

species present that are indicative of mineral enrichment, such as slender mannagrass (*Glyceria melicaria*), fowl mannagrass (*Glyceria striata*), drooping woodreed (*Cinna latifolia*), or white turtlehead (*Chelone glabra*). Bryophyte cover is typically greater than 80 percent and is dominated by *Sphagnum fallax* and *Sphagnum girgensohnii*, with *Sphagnum angustifolium*, *Sphagnum magellanicum*, *Bazzania trilobata*, and *Pleurozium schreberi*. Red Spruce-Cinnamon Fern Swamps have relatively low species richness, with an average of 38 species recorded in fifteen 400 meter square plots (range of 25 to 65 species).

Spruce-Fir-Tamarack Swamp
S3 rank – uncommon
Picea rubens - Abies balsamea / Gaultheria hispidula / Osmunda cinnamomea / Sphagnum spp. Forest (CEGL006312)

Spruce-Fir-Tamarack Swamps are one of Vermont's boreal swamp types, occurring in the colder regions of the state. These swamps are typically found in topographic basins that have little surface water movement. They may occur in isolation from other wetland types or as part of wetland complexes, typically with Black Spruce Swamps, Black Spruce Woodland Bogs, and Dwarf Shrub Bogs or Poor Fens. Spruce-Fir-Tamarack Swamps have organic peat soils that are generally saturated throughout the year. For eight swamps sampled, the peat depth ranged from 1.0 to 14.8 feet, with an average depth of 5.7 feet. These swamps are acidic (pH range of 3.7 to 5.0, mean pH of 4.0, n=8), but may receive some mineral enrichment from surface water runoff or from groundwater seepage near the swamp margin (mean conductivity of 56 µS, range 30-80 µS, n=8).

The interiors of Spruce-Fir-Tamarack Swamps have a distinct structure. The straight, vertical trunks of red spruce (*Picea rubens*), black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), and tamarack (*Larix laricina*) dominate the relatively closed canopy. There is a well-developed tall shrub layer of mountain holly (*Nemopanthus mucronata*) and northern wild raisin (*Viburnum cassinoides*), and a sparse low shrub layer that consistently includes sheep laurel (*Kalmia angustifolia*), and commonly includes Labrador tea (*Ledum groenlandicum*), bog laurel (*Kalmia polifolia*), low sweet blueberry (*Vaccinium angustifolium*), and velvet-leaf blueberry (*Vaccinium myrtilloides*). Cinnamon fern (*Osmunda cinnamomea*) and three-seeded sedge (*Carex trisperma*) are both abundant herbs, along with the suite of boreal herbs in less abundance, including bluebead lily (*Clintonia borealis*), bunchberry (*Cornus canadensis*), goldthread (*Coptis trifolia*), Canada mayflower (*Maianthemum canadense*),

starflower (*Trientalis borealis*), and creeping snowberry (*Gaultheria hispidula*). The low hummocks and shallow hollows are carpeted by mosses, including several species of Sphagnum (*Sphagnum girgensohnii, S. angustifolium, S. fallax,* and *S. magellanicum*), the windswept moss (*Dicranum polysetum*), and the ubiquitous moss of the north, Schreber's moss (*Pleurozium schreberi*). Other species that may be present in varying abundance include the trees red maple (*Acer rubrum*) and yellow birch (*Betula alleghaniensis*); the shrubs black chokeberry (*Aronia melanocarpa*), American mountain ash (*Sorbus americana*), leatherleaf (*Chamaedaphne calyculata*), rhodora (*Rhododendron canadense*), and wintergreen (*Gaultheria procumbens*); and the herbs tussock sedge (*Carex stricta*) and pitcher plant (*Sarracenia purpurea*).

Species richness is relatively low in the acidic, boreal Spruce-Fir-Tamarack Swamps, with an average of only 31 species recorded in eight 400 meter square plots (range of 26-34 species per plot).

Spruce-Fir-Tamarack Swamps have many similarities with Red Spruce-Cinnamon Fern Swamps. A combination of factors is best used to distinguish between these two types. Tamarack is characteristic of Spruce-Fir-Tamarack Swamps, and black spruce is commonly present. Spruce-Fir-Tamarack Swamps typically have more boggy conditions, with Labrador tea, bog laurel, leatherleaf, rhodora, and occasionally pitcher plant. Total cover by Sphagnum moss tends to be higher in Spruce-Fir-Tamarack Swamps, with greater abundance of the boggy species *Sphagnum magellanicum* and *Sphagnum capillifolium*. It is unusual to find herbs indicative of mineral enrichment in Spruce-Fir-Tamarack Swamps, although these are more common in Red Spruce-Cinnamon Fern Swamps.

Black Spruce Swamp
S2 rank – rare
Picea mariana - (Larix laricina) / Ledum groenlandicum / Sphagnum spp. Forest (CEGL005271)

Black Spruce Swamps are dark and shady. They occur in the coldest regions of Vermont, commonly in topographic depressions that receive cold air drainage. They occupy large and small basins with impeded surface water movement. This community is often considered transitional between Black Spruce Woodland Bog and Spruce-Fir-Tamarack Swamp, and it may occur in association with either or both of these communities. Black Spruce Swamps typically have deep organic soils (mean depth of 9.0 feet, range of 4.1 to 15.7 feet, n=8) of partially decomposed *Sphagnum* and wood fragments. This peat is saturated throughout the year, but there is typically little standing water in the hollows. Black Spruce Swamps are one of the most acidic swamp types (mean pH of 3.8, range 3.5-4.5, n=8) and are generally found in areas of the state with acidic bedrock or in basins that have developed peat of sufficient depth to isolate the surface of the swamp from any significant mineral enrichment from ground or surface waters.

Black spruce (*Picea mariana*) dominates the canopy of these swamps. The canopy varies substantially in the degree of closure from swamp to swamp, with the boggier examples having open canopies and grading into Black Spruce Woodland Bog. Tamarack (*Larix laricina*) is commonly mixed in the canopy and may be substantially taller than the black spruce. Other trees that may be present in low abundance are balsam fir (*Abies balsamea*), red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). Black spruce may also be common in the tall

shrub layer, along with northern wild raisin (*Viburnum cassinoides*) and mountain holly (*Nemopanthus mucronata*). Low shrubs can be abundant and include black spruce, velvet-leaf blueberry (*Vaccinium myrtilloides*), Labrador tea (*Ledum groenlandicum*), bog laurel (*Kalmia polifolia*), sheep laurel (*Kalmia angustifolia*), low sweet blueberry (*Vaccinium angustifolium*), black chokeberry (*Aronia melanocarpa*), and rhodora (*Rhododendron canadense*). Creeping snowberry (*Gaultheria hispidula*) is usually abundant on the mossy hummocks. The presence of black huckleberry (*Gaylussacia baccata*) in some swamps may indicate that these swamps have burned in the past. The herb layer is often sparse, with the fine-leaved, three-seeded sedge (*Carex trisperma*) as the most abundant species. Other species include cinnamon fern (*Osmunda cinnamomea*), bunchberry (*Cornus canadensis*), goldthread (*Coptis trifolia*), bluebead lily (*Clintonia borealis*), dewdrop (*Dalibarda repens*), Virginia cotton-grass (*Eriophorum virginicum*), three-leaved Solomon's seal (*Smilacina trifolia*), pitcher plant (*Sarracenia purpurea*), and pink ladyslipper (*Cypripedium acaule*). Mosses form a nearly complete cover over the low hummocks and moist hollows. *Sphagnum angustifolium* and *Sphagnum magellanicum* are typically the most abundant species, with lesser amounts of *Sphagnum girgensohnii, S. fallax,* and *S. capillifolium.* Schreber's moss (*Pleurozium schreberi*) is also common and knight's plume (*Ptilium crista-castrensis*) is often present.

There is low species richness in Black Spruce Swamps, with an average of 28 species recorded in eight 400 square meter plots (range of 26 to 32 species).

Black Spruce Woodland Bog
S2 rank – rare
Picea mariana / Ledum groenlandicum / Carex trisperma / Sphagnum spp. Forest (CEGL002485) (typical of Northern Appalachian ecoregion); *Picea mariana / (Vaccinium corymbosum, Gaylussacia baccata) / Sphagnum* spp. Woodland (CEGL006098) (typical of Lower New England ecoregion)

Black Spruce Woodland Bogs are acidic, nutrient and mineral-poor peatlands with open canopies of black spruce (*Picea mariana*). They occur in the colder regions of the state or in depressions that receive cold air drainage. Black Spruce Woodland Bogs are common in the extensive peatlands across the boreal region to our north. In Vermont, Black Spruce Woodland Bogs are transitional between Black Spruce Swamps and Dwarf Shrub Bogs and often occur in association with one or both of these communities. Like Dwarf Shrub Bogs, Black Spruce Woodland Bogs occur in kettlehole basins and as part of larger peatland systems. The poorly decomposed

Sphagnum and woody peat is deep (mean of 10.6 feet, range 5.9 to 15.7 feet, n=4) and are saturated throughout the year. Hummocks and hollows are well developed, but there is seldom any standing water in the mossy, moist hollows. Water near the peat surface is acidic (mean pH of 3.8; range 3.6-4.6, n=3).

This woodland natural community has scattered, stunted black spruce trees that are generally less than 30 feet tall and form an open canopy of 25 to 60 percent cover. Stunted tamarack (*Larix laricina*) trees are generally present in low abundance. Black spruce is usually the dominant tall shrub, although mountain holly (*Nemopanthus mucronata*) may also be common. Other tall shrubs include northern wild raisin (*Viburnum cassinoides*), and in warmer settings, highbush blueberry (*Vaccinium corymbosum*). The low shrub layer is dense and typically includes black spruce, leatherleaf (*Chamaedaphne calyculata*), Labrador tea (*Ledum groenlandicum*), sheep laurel (*Kalmia angustifolia*), and bog laurel (*Kalmia polifolia*). Other shrubs include velvet-leaf blueberry (*Vaccinium myrtilloides*), low sweet blueberry (*Vaccinium angustifolium*), rhodora (*Rhododendron canadense*), creeping snowberry (*Gaultheria hispidula*), small cranberry (*Vaccinium oxycoccus*), and black huckleberry (*Gaylussacia baccata*). The herb layer is sparse and species-poor. Three-seeded sedge (*Carex trisperma*) is the most common species. Others include goldthread (*Coptis trifolia*), bunchberry (*Cornus canadensis*), pitcher plant (*Sarracenia purpurea*), hare's-tail cottongrass (*Eriophorum vaginatum*), Virginia cotton-grass (*Eriophorum virginicum*), three-leaved false Solomon's seal (*Smilacina trifolia*), and poor sedge (*Carex paupercula*). Raised hummocks and moist hollows are all carpeted by Sphagnum moss, with the typical species zonation from hummock top to hollow being *Sphagnum fuscum, Sphagnum capillifolium, Sphagnum magellanicum,* and *Sphagnum angustifolium*. Other common bryophytes include Schreber's moss (*Pleurozium schreberi*), *Dicranum undulatum*, and *Sphagnum subtile*. There is low species richness in Black Spruce Woodland Bogs, with an average of only 24 species recorded in four 400 meter square plots (range of 19 to 29 species per plot).

Pitch Pine Woodland Bog
S1 rank – very rare
Pinus rigida / Chamaedaphne calyculata / Sphagnum spp. Woodland (CEGL006194)

Only one example of this community is known in Vermont, although examples of the community type are documented from Pennsylvania and New Jersey, north to Maine. Maquam

Bog is an 890-acre open peatland located near the mouth of the Missisquoi River on Lake Champlain. Pitch Pine Woodland Bog is only one of several natural communities occurring at Maquam Bog, with the majority of the peatland best classified as Dwarf Shrub Bog. Pitch Pine occurs in groves that are scattered across the open peatland surface. This peatland has a slightly raised center and a surface of irregular hummocks and hollows. Peat depths vary from 2.5 feet to nearly 8 feet, and the peat is generally fibrous and woody at the surface and grades to muck at the base. The peatland water is acidic, with pH ranging from 3.6 to 4.5. Beneath the peat are deltaic sand and silt deposits, reflecting an earlier course of the Missisquoi River.

The ecology and vegetation patterns of Maquam Bog have been related to past fires and flooding (Strimbeck 1988). Fires have repeatedly burned across the surface of the peatland, and lake levels have been shown to inundate the peatland every other year on average. Strimbeck hypothesized that periodic fires reduce the cover of tall shrubs, exclude fire intolerant species, and promote reproduction and maintenance of pitch pine in the peatland. Lake level fluctuations may be related to gradients in pH and nutrients in the peatland, thereby influencing plant species distribution.

The Pitch Pine Woodland Bog at Maquam Bog is characterized by an open canopy of pitch pine (*Pinus rigida*), typically less than 60 percent cover. Gray birch (*Betula populifolia*) is abundant in some areas, and there are scattered, stunted trees of black spruce (*Picea mariana*) and red maple (*Acer rubrum*). The abundance of red maple in some areas of the open peatland may be related to absence of fire. Tall shrubs typically cover less than 15 percent of the woodland bog, but their distribution is patchy. The most abundant species are highbush blueberry (*Vaccinium corymbosum*), mountain holly (*Nemopanthus mucronata*), northern wild raisin (*Viburnum cassinoides*), red maple, and gray birch. Both the open portions of Maquam Bog and the Pitch Pine Woodland Bog are dominated by low shrubs. Rhodora (*Rhododendron canadense*) is especially abundant and a sea of pink flowers adorns the bog in late May to early June. Other abundant low shrubs include leatherleaf (*Chamaedaphne calyculata*), black huckleberry (*Gaylussacia baccata*), black chokeberry (*Aronia melanocarpa*), sheep laurel (*Kalmia angustifolia*), bog laurel (*Kalmia polifolia*), Labrador tea (*Ledum groenlandicum*), and sweet gale (*Myrica gale*). Both small cranberry (*Vaccinium oxycoccus*) and large cranberry (*Vaccinium macrocarpon*) are common. Sedges are abundant in some areas and include hare's-tail cottongrass (*Eriophorum vaginatum*), few-seeded sedge (*Carex oligosperma*), and Virginia cotton-grass (*Eriophorum virginicum*). Three-leaved

false Solomon's seal (*Smilacina trifolia*), the rare Virginia chain fern (*Woodwardia virginica*), and cinnamon fern (*Osmunda cinnamomea*) are also locally common. Several species of Sphagnum carpet the hummocks and hollows under the low shrubs and open canopy of pitch pine, including *Sphagnum fuscum, Sphagnum magellanicum*, *Sphagnum capillifolium*, and *Sphagnum angustifolium, Sphagnum fallax*, and the haircap moss *Polytrichum strictum*.

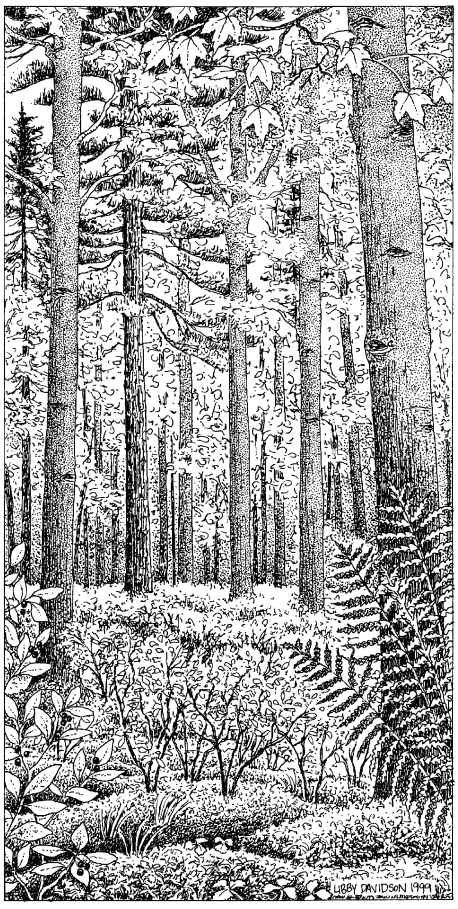
Calcareous Red Maple-Tamarack Swamp
S2 rank – rare
Fraxinus nigra - Acer rubrum - (*Larix laricina*) / *Rhamnus alnifolia* Saturated Forest (CEGL006009)

Calcareous Red Maple-Tamarack Swamps are a rare forested wetland type associated with calcium-rich groundwater seepage. They are closely related to Red Maple-Black Ash Seepage Swamps, although they also share characteristics with open fen communities. Most examples are considered hardwood swamps. This community occurs primarily in the Vermont Valley, with examples also in the Champlain Valley, Southern Green Mountains, and Northern Vermont Piedmont. They are closely associated with calcium-rich bedrock types, such as limestone, dolomite, and marble. As with the more common seepage swamp type, Calcareous Red Maple-Tamarack Swamps occur along the margins of streams and in poorly drained depressions, which often form stream headwaters. Organic soils are permanently saturated, resulting in substantial accumulations of peat. Surface waters have circumneutral to slightly basic pH (7.2-7.6, 4 samples) and generally high conductivity (50-1,300µS, 3 samples). Microtopography is variable, ranging from flat, open fenny areas to well-developed hummocks and hollows. Calcareous Red Maple-Tamarack Swamps may be the only wetland community type present in small basins or they may occur as part of large wetland complexes, intergrading with other wetland types such as Red Maple-Black Ash Seepage Swamp, Northern White Cedar Swamps, and Rich and Intermediate Fens.

Red maple (*Acer rubrum*) and tamarack (*Larix laricina*) are the most abundant trees in a canopy that ranges from very open over the fenny areas to nearly closed. Other trees include black ash (*Fraxinus nigra*), yellow birch (*Betula alleghaniensis*), and white pine (*Pinus strobus*). Characteristic shrubs that reflect the mineral-rich groundwater include alder-leaved buckthorn (*Rhamnus alnifolia*), shrubby cinquefoil (*Potentilla fruticosa*), red-osier dogwood (*Cornus sericea*), and poison sumac (*Toxicodendron vernix*). Other shrubs include highbush blueberry (*Vaccinium corymbosum*), northern arrowwood (*Viburnum dentatum*), dwarf blackberry (*Rubus pubescens*), and poison ivy (*Toxicodendron radicans*). The herbaceous layer is rich in species, a

feature common to many calcareous wetland types. Characteristic species include water avens (*Geum rivale*), rough-leaved goldenrod (*Solidago patula*), yellow sedge (*Carex flava*), inland sedge (*Carex interior*), lakeshore sedge (*Carex lacustris*), delicate-stemmed sedge (*Carex leptalea*), and marsh marigold (*Caltha palustris*). Ferns are very abundant at some sites, especially royal fern (*Osmunda regalis*), cinnamon fern (*Osmunda cinnamomea*), and sensitive fern (*Onoclea sensibilis*. Bryophytes include several species typically associated with fens, such as *Calliergonella cuspidata*, *Sphagnum warnstorfii*, *Campylium stellatum*, and the rare *Meesia triquetra*. *Sphagnum centrale* may form nearly complete cover on the tops of some hummocks. Successional trends in this community type are poorly understood. Tamarack is very shade intolerant and would not be expected to persist unless there is a regular disturbance that keeps the canopy open. Open canopy areas may be maintained by persistent groundwater discharge as in fens, or the openings could be the result of past land use history.

Red Maple-White Pine-Huckleberry Swamp
S2 rank – rare



This rare and narrowly defined community type is also closely related to the more common Red Maple-Sphagnum Acidic Basin Swamp. Most examples are considered hardwood swamps. Red Maple-White Pine-Huckleberry Swamps are currently only known from four locations in the Champlain Valley. In all of these examples the Red Maple-White Pine-Huckleberry Swamp community is part of a larger forested wetland complex with deep organic soils – the average organic soil depth at two sites was 10.8 feet. The examples of this community type are found in the central portion of the larger wetland complexes in which they occur. The Red Maple-White Pine-Huckleberry Swamp communities appear to be on slightly raised portions of the wetland surface relative to adjacent wetland communities, although this should be confirmed by surveying. Surface water is acidic (pH range from 3.3-4.0 based on three samples) and low in dissolved minerals (conductivity of 70µS at one site), indicating that there is little influence of groundwater at the surface of these wetlands. Hummocks are low (generally less than 10 inches) and the hollows do not contain standing water, although the soils appear to be permanently saturated.

The canopy is co-dominated by red maple (*Acer rubrum*) and white pine (*Pinus strobus*), which together form a tall, closed canopy. Black spruce (*Picea mariana*) occurs as a small tree and tall shrub, along with regeneration of the canopy trees. Tall-shrub cover is sparse and includes winterberry holly (*Ilex verticillata*), highbush blueberry (*Vaccinium corymbosum*), mountain holly (*Nemopanthus mucronatus*), and northern wild raisin (*Viburnum cassinoides*). A

characteristic feature of these swamps is the dense cover of black huckleberry (*Gaylussacia baccata*) in the short shrub stratum. Other short shrubs include black chokeberry (*Aronia melanocarpa*), Labrador tea (*Ledum groenlandicum*), sheep laurel (*Kalmia angustifolia*), and low sweet blueberry (*Vaccinium angustifolium*). Tall cinnamon fern (*Osmunda cinnamomea*) and low, creeping goldthread (*Coptis trifolia*) are the most abundant herbs. Others include starflower (*Trientalis borealis*), bluebead lily (*Clintonia borealis*), wild sarsaparilla (*Aralia nudicaulis*), Canada mayflower (*Maianthemum canadense*), and pink lady's slipper (*Cypripedium acaule*). The low hummocks and moist hollows are completely moss-covered, with *Sphagnum magellanicum* and *Sphagnum capillifolium* on hummocks and *Sphagnum centrale* and *Sphagnum angustifolium* in hollows. Other bryophytes include Schreber's moss (*Pleurozium schreberi*), *Bazzania trilobata*, and *Sphagnum fimbriatum*.

Additional study of these swamps is needed to explain their vegetative differences from other acidic basin swamps. The Cornwall Swamp, South Alburg Swamp, and Mud Creek WMA examples all have relatively young forests (trees are 80 to 100 years old), although the trees are large and have grown relatively fast. This tree age and size, the low hummocks, and the dominance of black huckleberry may indicate that the surfaces of these swamps burned in the past. However, evidence of past fires has not been noted.

Wet Sand-Over-Clay Forest
S2 rank – rare

Wet Sand-Over-Clay Forest is one of the four natural community types that make up the clayplain forest ecosystem of the Champlain Valley. The clayplain forest ecosystem dominated the post-glacial lake and marine plain of the Champlain Valley prior to European settlement. These fertile, stone-free soils have been prized for agricultural uses, and the majority of the clayplain forest has been cleared. Consequently, all four of the clayplain forest natural community types are rare in Vermont. Clayplain forests have been described in detail by Lapin (1998, 2003).

Wet Sand-Over-Clay Forest occurs on broad flats in the Champlain Valley, but is usually associated with the sandy deposits along larger rivers. These sandy deposits are of glaciolacustrine or glaciofluvial origin and have a high water table for at least part of the growing season. The soils either have a sandy layer over clay (this includes Swanton, Whately, and Enosburg soils) or have deep sand deposits with a high water table (this includes Scarboro, Au Gres, Searsport, and Wareham soils). This is a wetland natural community type, although some examples may have no standing water or saturated surface soils at some time during the year. The depth of surface organic layer varies with the hydrology of each site, with sites with permanent saturation having deeper organic layers. On the drier sites, surface organic layers may be only an inch or two thick. The forest canopy is mostly closed and is dominated by either red maple (*Acer rubrum*) or hemlock (*Tsuga canadensis*) (hemlock variant). Other trees that vary in abundance include green ash (*Fraxinus pennsylvanica*), swamp white oak (*Quercus bicolor*), white pine (*Pinus strobus*), bur oak (*Quercus macrocarpa*), shagbark hickory (*Carya ovata*), white oak (*Quercus alba*), silver maple (*Acer saccharinum*), and yellow birch (*Betula alleghaniensis*). Black ash may be present, but is typically not abundant. Black gum (*Nyssa sylvatica*) occurs at several of the known examples. Shrubs include winterberry holly (*Ilex verticillata*), highbush blueberry (*Vaccinium corymbosum*), witch hazel (*Hamamelis virginiana*),

musclewood (*Carpinus caroliniana*), and dwarf blackberry (*Rubus pubescens*). Hummocks are low and poorly developed and hollows may be very large and contain standing water in the spring. Herbaceous cover is less under canopies dominated by hemlock. In the hollows, ferns are common, including cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Onoclea sensibilis*), royal fern (*Osmunda regalis*), and marsh fern (*Thelypteris palustris*). Sedges include long sedge (*Carex folliculata*), common hop sedge (*Carex lupulina*), Tuckerman's sedge (*Carex tuckermanii*), long-hair sedge (*Carex crinita*), and bladder sedge (*Carex intumescens*). Other common herbs include fowl mannagrass (*Glyceria striata*), blue flag (*Iris versicolor*), drooping

woodreed (*Cinna latifolia*), and spotted water-hemlock (*Cicuta maculata*). The low hummocks support species that cannot withstand the seasonal flooding that occurs in the hollows, including wild sarsaparilla (*Aralia nudicaulis*), goldthread (*Coptis trifolia*), Canada mayflower (*Maianthemum canadense*), and low abundance of bryophytes (*Sphagnum centrale, Sphagnum girgensohnii, Bazzania trilobata,* and *Leucobryum glaucum*).

SUMMARY OF NATURAL COMMUNITY TYPE CHARACTERISTICS

Table 5 provides a summary of the characteristics of the seven softwood swamp community types that were the focus of this study. The distinctions between the swamp types can be made based both on vegetation and environmental characteristics. The primary environmental variables are mineral enrichment and climate. Hemlock-Balsam Fir-Black Ash Seepage Swamps (and Calcareous Red Maple-Tamarack Swamps, not included in the table) have mineral-enriched water that is reflected in higher pH and conductivity. Other swamp types have little mineral enrichment and have more acidic waters. Black Spruce Woodland Bogs, Black Spruce Swamps, and Spruce-Fir-Tamarack Swamps occur in the coldest regions of Vermont. Distinctions between the softwood swamp types based on vegetation reflect both species composition and community vegetation structure. The dominant trees present in the canopy are often the most easily observed distinction between types. However, the presence or absence of shrub, herbaceous, and bryophyte species that are indicators of mineral enrichment is also a very important factor. Community structure varies from open woodland canopies (less than 60 percent cover) of stunted trees in Black Spruce Woodland Bogs and Pitch Pine Woodland Bogs, to tall mostly closed canopies in the other swamp types. Hemlock-Balsam Fir-Black Ash Seepage Swamps (and other seepage swamps) have both a high percent cover a rich species composition of herbaceous species, whereas Black Spruce Woodland Bogs, Black Spruce Swamps, and Spruce-Fir-Tamarack Swamps have low herbaceous cover and diversity, but high percent cover of dwarf shrubs (mostly in the heath family) and *Sphagnum* species. Figure 4 shows the distribution of softwood swamps classified to natural community type for sites visited during this inventory and for sites identified during previous inventory work but that have been reclassified based on the results of this study.

Table 5. A comparison of the distribution, environmental variables, and vegetation of softwood swamp types. For those factors based on data collected in this study, mean, range, and number of samples (n) are provided. Qualitative descriptions are based on interpretation of the study data and professional judgment.

Community Type	Biophysical Regions (A)	Elevation (feet) mean: range:	Size (acres) mean: range:	Hydrology/ Enrichment	Soils	pH mean: range:	Conductivity (µS) mean: range:	Characteristic Trees / Shrubs	Characteristic Herbs / Bryophytes
Hemlock-Sphagnum Acidic Basin Swamp	SVP, TM, VV, and likely CV	752 370-1,280 n=5	7.3 0.8-22.3 n=9	permanently saturated but no standing water; little mineral enrichment	deep, poorly decomposed peat; mean depth: 12 ft	4.3 4.1-4.7 n=4	60 50-90 n=4	hemlock, with some red spruce, red maple, or white pine; winterberry and low sweet blueberry sparse	cinnamon fern, with three-seeded sedge common; boreal herbs; *Sphagnum centrale* and *S. girgensohnii*
Hemlock-Balsam Fir-Black Ash Seepage Swamp	all	898 360-1,600 n=19	10.4 0.8-59.6 n=58	permanently saturated; pools common; enrichment from groundwater seeps at swamp margins	variable; well decomposed organics from 0 to 16 feet	5.4 4.8-8.2 n=15	81 10-460 n=15	hemlock and/or balsam fir, with black ash; also yellow birch, red spruce, red maple, white pine; alder-leaved buckthorn, red-osier dogwood, dwarf blackberry	cinnamon fern, with water avens, golden saxifrage, interior sedge, foam flower, swamp saxifrage; *Thuidium delicatulum, Sphagnum squarrosum, Rhytidiadelphus triquetrus*
Red Spruce-Cinnamon Fern Swamp	SGM mostly, also NGM, NVP, SVP	2,080 807-2,660 n=15	6.7 0.5-57.5 n=70	permanently saturated but little standing water; little mineral enrichment	poorly decomposed peat; mean depth: 6.8 ft	4.1 3.5-5.9 n=14	38 20-60 n=14	red spruce, with balsam fir and red maple; mountain holly and wild raisin abundant; blueberries, sheep laurel, creeping snowberry	three-seeded sedge and cinnamon fern, with goldthread, wild sarsaparilla, common wood-sorrel, slender mannagrass; *Sphagnum fallax, S. girgensohnii*
Spruce-Fir-Tamarack Swamp	NEH mostly also NGM, NVP, SGM, northern CV	1,322 885-2,640 n=9	18.5 2.0-257.5 n=132	permanently saturated but little standing water; little mineral enrichment	poorly decomposed peat; mean depth: 5.7 ft	4.0 3.7-5.0 n=8	56 30-80 n=8	red spruce, black spruce, balsam fir, tamarack; mountain holly and wild raisin abundant, with sheep laurel, Labrador tea, bog laurel, creeping snowberry	cinnamon fern and three-seeded sedge; bunchberry, goldthread, starflower; *Sphagnum fallax, S. girgensohnii, Pleurozium schreberi*
Black Spruce Swamp	NEH mostly also NGM, NVP, SGM, northern CV	1,416 100-2,620 n=9	14.3 0.6-123.4 n=108	permanently saturated but little standing water; very little mineral enrichment	poorly decomposed peat; mean depth: 9.0 ft	3.8 3.5-4.5 n=8	56 20-100 n=7	black spruce, with tamarack and some red maple, balsam fir, paper birch; mountain holly, wild raisin, Labrador tea, velvet-leaf blueberry, bog laurel, creeping snowberry	Sparse herbs include three-seeded sedge, cinnamon fern, bunchberry, goldthread, bluebead lily, dewdrop, pitcher plant; *Sphagnum angustifolium, S. magellanicum, Pleurozium schreberi*
Black Spruce Woodland Bog	NEH, NVP, SVP, SGM, NGM, northern CV	1,544 1,100-2,620 n=5	6.7 0.3-87.8 n=46	permanently saturated but little standing water; very little mineral enrichment	poorly decomposed peat; mean depth: 10.6 ft	3.8 3.6-4.6 n=3	82 60-105 n=3	stunted black spruce and tamarack in open canopy; leatherleaf, Labrador tea, sheep and bog laurel, creeping snowberry, small cranberry	Sparse herbs include three-seeded sedge, goldthread, bunchberry, pitcher plant, hare's-tail cotton-grass; *Sphagnum fuscum, S. capillifolium, S. magellanicum*
Pitch Pine Woodland Bog	northern CV	100 n=1	144.4 n=1	permanently saturated but no standing water; very little mineral enrichment	poorly decomposed peat 2.5-8.0 feet deep	3.9 n=1	60 n=1	open canopy of pitch pine with gray birch, black spruce; rhodora, leatherleaf, black huckleberry, bog and sheep laurel, both cranberries	hare's-tail cottongrass, three-seeded sedge, three-leaved false Solomon's seal, Virginia chain fern; Sphagnum fuscum, S. fallax, S. magellanicum, S. capillifolium

(A): CV=Champlain Valley, TM=Taconic Mountains, VV=Vermont Valley, NGM=Northern Green Mountains, SGM=Southern Green Mountains, NVP=Northern Vermont Piedmont, SVP=Southern Vermont Piedmont, NEH=Northeastern Highlands

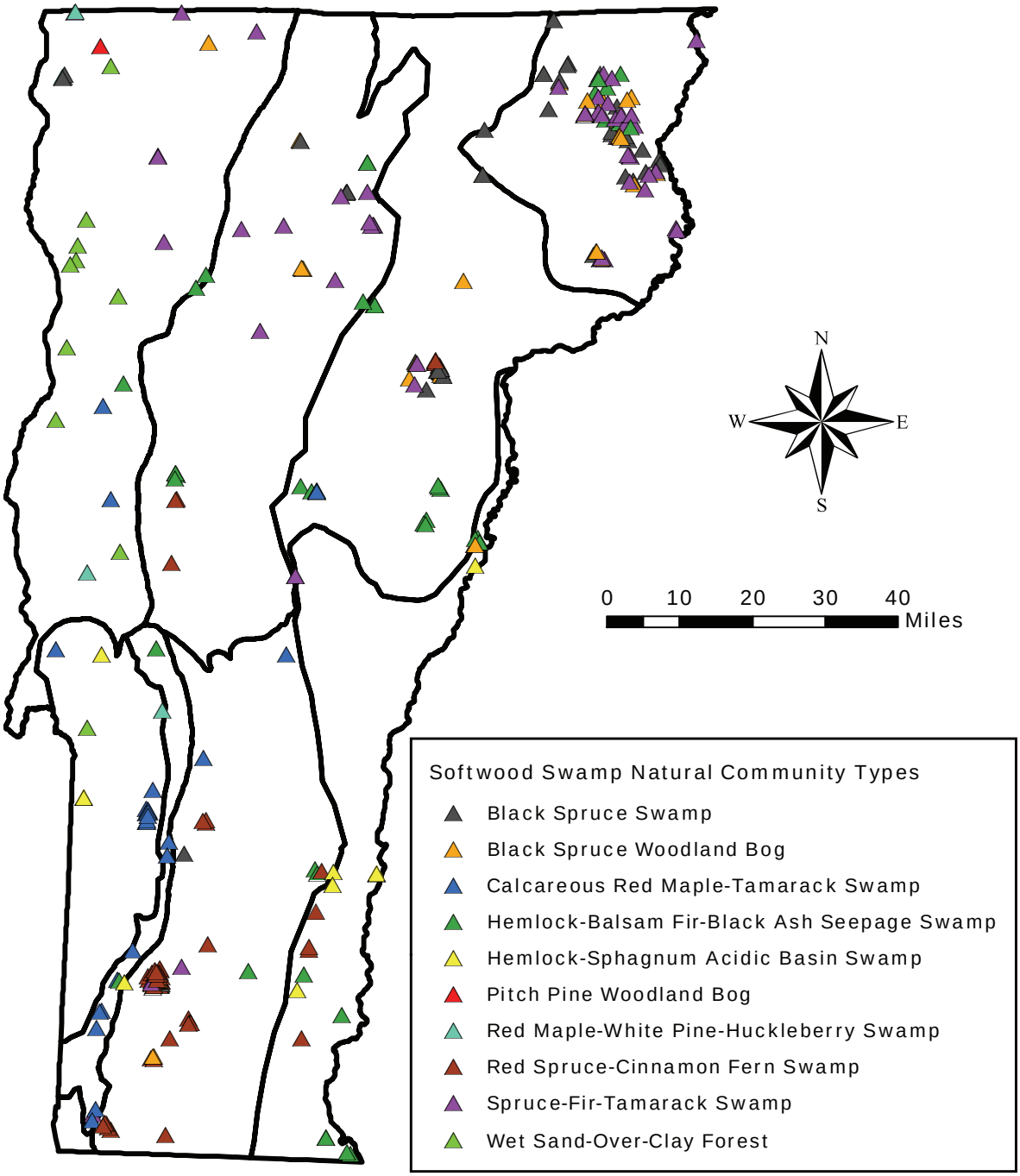


Figure 4. Location of softwood swamp visited during this study and during previous inventories; all classified to natural community type.

RELATIVE RARITY OF VERMONT'S SOFTWOOD SWAMP COMMUNITY TYPES

The various types of softwood swamps in Vermont have very different distributions across the landscape and vary in their relative abundance. Understanding and documenting the relative rarity of natural community types has long been a function of the Natural Heritage Information Project and has important implications for setting conservation priorities. Understanding the reasons why a particular natural community type is rare can also be very helpful in developing conservation strategies. Community rarity may be a natural condition or it may be the result of human activity. Rarity is also a function of the area in which one looks for a natural community.

Black Spruce Swamp and Black Spruce Woodland Bog are community types that are rare in Vermont because this community type reaches the southern edge of its range in northern New England, New York, and the Great Lakes states. Although these community types are considered rare in Vermont and adjacent states, similar natural communities are much more common to our north, where they may form extensive stands in boreal regions.

Hemlock-Sphagnum Acidic Basin Swamp is a rare community type in Vermont because it is found only in physical settings where several environmental conditions occur together. These small swamps occur almost entirely in areas of acidic bedrock, in topographic settings that include a poorly-drained depression fed by a small watershed, and located in a warm to moderately climatic region where hemlock grows.

Wet Sand-Over-Clay Forest is one of the four natural community types of the clayplain forest ecosystem. Although this ecosystem and component natural communities were widespread prior to European settlement in the Champlain Valley and other areas of glacial lake plains, all of these natural community types are now rare in Vermont because they have mostly been converted to agricultural land and other developed uses.

The community classification system itself can also be a factor in the relative rarity of natural community types. If a community type is too broadly defined, many examples will fit the definition, and the type will be considered widespread and common. In contrast, if a community type is too narrowly defined, very few examples will fit the definition, and the type will be considered rare unnecessarily. The important balance in this process is to identify community types that are distinct and recognizable, that repeat across the landscape, and that have significance for conserving biological diversity or making management decisions. NHIP will continue to update community classification and rarity ranking as new inventories are completed. The rarity ranks for all softwood swamp community types, including cedar swamps, are provided in Table 6.

Table 6. Relative rarity of Vermont softwood swamp natural community types.

Natural Community Type	Rarity Rank
Hemlock-Sphagnum Acidic Basin Swamp	S2 (new type)
Hemlock-Balsam Fir-Black Ash Seepage Swamp	S3 (new type)
Red Spruce-Cinnamon Fern Swamp	S3 (new type)
Spruce-Fir-Tamarack Swamp	S3
Black Spruce Swamp	S2
Black Spruce Woodland Bog	S2
Pitch Pine Woodland Bog	S1
Northern White Cedar Swamp	S3
Calcareous Red Maple-Tamarack Swamp	S2 (typically a hardwood swamp)
Red Maple-White Pine-Huckleberry Swamp	S2 (typically a hardwood swamp)
Wet Sand-Over-Clay Forest (hemlock variant)	S2

S1: **very rare** in the state, generally with fewer than five high quality occurrences
S2: **rare** in the state, occurring at a small number of sites or occupying a small total area in the state
S3: high quality examples are **uncommon** in the state, but not rare; the community is restricted in distribution for reasons of climate, geology, soils, or other physical factors, or many examples have been severely altered
S4: **widespread** in the state, but the number of high quality examples is low or the total acreage occupied by the community type is relatively small
S5: **common** and widespread in the state, with high quality examples easily found

RANKING OF INDIVIDUAL SOFTWOOD SWAMPS

The Natural Heritage Information Project has developed criteria for ranking individual occurrences of each natural community type. The previously existing ranking specifications for softwood swamp types were reviewed as a result of this inventory project and they were rewritten. The new ranking specifications for each swamp type consider three factors associated with the ecological integrity and quality of each softwood swamp example: size of the swamp, the current condition of the swamp, and the condition of the landscape surrounding the swamp. Each of these factors is ranked independently and assigned appropriate weighting, and then the ranks are combined to create an overall rank for the swamp. Large size, condition reflecting minimal human disturbance, and surrounding landscape with intact natural communities and minimal fragmentation are all factors that contribute to a high rank. In general, the higher the rank, the more likely it is that the community will be viable over long time periods and the higher its conservation value. However, lower ranked natural communities may have high conservation value for other reasons, such as rare species occurrences or important wildlife habitat. Also, in highly developed areas of the state, such as the Champlain Valley, there may be no highly-ranked examples of some natural community types due to the fragmented landscape. In cases like this, the best remaining examples likely have the highest conservation value. The importance of size as a ranking factor for softwood swamps was down-weighted because size varies considerably from one biophysical region to another and recognizing geographic difference among the swamps was considered much more important than recognizing only large swamps as having the highest conservation value. Current condition and landscape quality were both weighted equally.

Sites are ranked on a scale of A to D, with A-ranked sites being the highest quality. All A, B, and C ranked examples of very rare (S1) and rare (S2) natural community types (see Table 6) are considered to be of statewide significance. Similarly, all A- and B-ranked examples of

uncommon (S3) and widespread (S4) community types and all A-ranked examples of common (S5) natural community types are considered to be of statewide significance. Other swamps that do not meet these ranking criteria may still have many important wetland functions and be of high local significance. Quality ranks are provided along with all site reports in Appendix A. The ranking specifications for softwood swamps are available upon request.

NATURAL DISTURBANCE IN SOFTWOOD SWAMPS

The predominant form of natural disturbance in softwood swamps is most likely wind. Hurricanes may affect swamps and blow down many trees at once, but the frequency of this type of disturbance is rare and the low topographic position and short stature of the swamp trees relative to the adjacent uplands may provide some protection. The primary effect of wind in softwood swamps is to blow down individual trees and open small canopy gaps. This small-scale disturbance is evident in almost every swamp that has been visited. Swamp trees generally have very shallow root systems due to the saturated soil conditions and consequently are more susceptible to blow-down than adjacent trees in the uplands that have deeper root systems. There are three major effects of these blow-downs on swamp ecology. When trees tip over they pull up soil with their roots and effectively mix the soils in the swamp. In swamps with shallow organic soils, these tip-ups can bring mineral soil to the surface and increase dissolved mineral and nutrient availability to plants. Tip-ups are also the primary process by which the swamp microtopography of hummocks and hollows is formed. Wet hollows and raised hummocks provide a diversity of microhabitats that would not be found in swamps lacking microtopography. Canopy gaps also provide increased light to the swamp floor and opportunity for growth of suppressed seedlings and saplings and sun-loving herbs.

Beaver are ubiquitous in Vermont and are a significant form of natural disturbance in softwood swamps and other wetland types. Although beaver were extirpated from Vermont by 1850 (Thompson, 1853), they were reintroduced in 1921, and are now abundant in every major watershed. Almost any swamp that is associated with a stream or that forms the headwater of a stream is susceptible to beaver activity. Among softwood swamp natural community types, those that are associated with streams or with groundwater seepage (Hemlock-Balsam Fir-Black Ash Seepage Swamp and Calcareous Red Maple-Tamarack Swamp) are more likely to affected by beaver activity than those found in small, isolated basins (such as Hemlock-Sphagnum Acidic Basin Swamp). Beaver activity was noted by the authors in 33 of the 88 wetland complexes described in the detailed site reports (Appendix A).

Beavers' affect on softwood swamps is dramatic. The damming of a stream and the creation of an impoundment generally kills all trees and most shrubs within the impounded area and the upslope area in which the water table is significantly raised. An impoundment that only lasts a season may not kill all of the herbaceous vegetation and bryophytes, but most impoundments are maintained for many years. Beaver will remain at a site as long as there is a supply of young hardwood trees or alder for food near the impoundment. Following abandonment, an impoundment may persist for years before the dam fails and the beaver pond drains. The resulting mud flats are quickly colonized by annuals, then perennials, and eventually woody plants. Important wildlife habitat is created by all phases of this beaver impoundment cycle, from standing dead trees for birds and insects, to the pond itself for fish and waterfowl, to mud

flats for shorebirds, to emergent marsh and shrub swamp for many species of birds and small mammals. Although beaver are clearly part of the natural disturbance cycle in softwood swamps, there may be situations for which management of the beaver at a particular swamp is advisable, such as the presence of rare plant species or an old-growth swamp forest. The presence of a road or culvert may also promote beaver activity in an area where it may otherwise not occur, and beaver management in these areas may also be necessary. Ideally, this would entail the installation of a beaver baffle which controls the impoundment water level while allowing the resident beavers to remain.

RARE AND UNCOMMON PLANT SPECIES

A total of 29 species of rare or uncommon plants were documented to occur in the nine different softwood swamp natural community types (Table 7). Although an impressive number, this is less than the 36 species documented from hardwood swamps in the state (Sorenson et al. 2004). These 29 species occur at a total of 69 sites, so a number of the species occur at multiple sites. Once again this does not compare with hardwood swamps where there was a total of 150 sites with rare or uncommon species. Of the nine softwood swamp types, Hemlock-Balsam Fir-Black Ash Seepage Swamp has the greatest number of rare or uncommon species with ten different species represented. This is followed by Black Spruce Bog and Black Spruce Swamp, both of which have seven rare or uncommon species. All of the other softwood types have five or fewer. Hemlock-Balsam Fir-Black Ash Seepage Swamps also has the greatest number of sites with rare or uncommon species: 19. This is followed by Black Spruce Swamp with 13 and Red Spruce-Cinnamon Fern Swamp with 11. All of the other types have eight or fewer sites. It is not surprising that the Hemlock-Balsam Fir-Black Ash Seepage Swamp has the greatest number of rare species as they are typically the most species rich of the softwood types due to the often calcareous nature of the groundwater seepage. They are also one of the more common types. Some community types, such as Calcareous Red Maple-Tamarack Swamp and the Hemlock variant of the Wet Sand-over-Clay Forest were not the focus of this inventory, so few examples of these types were visited.

Seven of the ten rare or uncommon species that occur in Hemlock-Balsam Fir-Black Ash Seepage Swamp were found only in this community type during this inventory – these species do occur in other wetland community types in Vermont, just not other softwood swamp types. Two of the three uncommon species that occur in Calcareous Red Maple-Tamarack Swamp and the one rare species in Red Maple-White Pine-Huckleberry Swamp were found only in these community types during this inventory. A total of 19 of the 29 rare or uncommon species occur in only a single swamp type whereas the remainder are broader in their tolerance and occur in multiple types. While eight of these species occur in only two softwood swamp types, two are more widespread. Massachusetts fern (*Thelypteris simulata*) occurs in four different swamp types while mountain fly-honeysuckle (*Lonicera villosa*) occurs in three different types.

Six of the 29 uncommon or rare species are legally protected as threatened or endangered on the Vermont Endangered Species List. Northeastern bulrush (*Scirpus ancistrochaetus*) is the only species considered endangered in Vermont and it is also listed as federally endangered under the Endangered Species Act. The remaining five species are listed as threatened in Vermont. All of these species occur at only a single site, except for the lily-leaved twayblade (*Liparis lilifolia*)

Table 7. Rare and uncommon plants of softwood swamp natural communities in Vermont.

Species Common Name	Scientific Name	State Status	Frequency
Black Spruce Swamp			
Dwarf mistletoe	*Arceuthobium pusillum*	Rare	3 Swamps
Bog Aster	*Aster nemoralis* (*Oclemena nemoralis*)	Rare	1 Swamp
Bog sedge	*Carex exilis*	Rare	1 Swamp
Mountain fly-honeysuckle	*Lonicera villosa*	Uncommon	1 Swamp
Shining rose	*Rosa nitida*	Rare	1 Swamp
Moose dung moss	*Splachnum ampullaceum*	Uncommon	5 Swamps
Mountain cranberry	*Vaccinium vitis-idaea*	Rare	1 Swamp
Black Spruce Woodland Bog			
Dwarf mistletoe	*Arceuthobium pusillum*	Rare	1 Swamp
Bog sedge	*Carex exilis*	Rare	1 Swamp
Mountain fly-honeysuckle	*Lonicera villosa*	Uncommon	1 Swamp
White-fringed orchid	*Platanthera blephariglottis*	Rare	2 Swamps
Rose pogonia	*Pogonia ophioglossoides*	Uncommon	1 Swamp
Moose dung moss	*Splachnum ampullaceum*	Uncommon	1 Swamp
Mountain cranberry	*Vaccinium vitis-idaea*	Very Rare	1 Swamp
Calcareous Red Maple-Tamarack Swamp			
Showy lady's-slipper	*Cypripedium reginae*	Uncommon	1 Swamp
Hoary willow	*Salix candida*	Uncommon	1 Swamp
Roughleaf goldenrod	*Solidago patula*	Uncommon	1 Swamp
Hemlock-Sphagnum Acidic Basin Swamp			
Folliculate sedge	*Carex folliculata*	Uncommon	1 Swamp
Lily-leaved twayblade	*Liparis lilifolia*	Very Rare/Threatened	1 Swamp
Loesel's twayblade	*Liparis loeselii*	Uncommon	1 Swamp
Maleberry	*Lyonia ligustrina*	Uncommon	1 Swamp
Massachusetts fern	*Thelypteris simulata*	Rare	1 Swamp
Wet Sand-over-Clay Forest (Hemlock variant)			
False cyperus	*Carex pseudocyperus*	Uncommon	1 Swamp
Lily-leaved twayblade	*Liparis lilifolia*	Very Rare/Threatened	1 Swamp
Pinxter-flower	*Rhododendron periclymenoides*	Very Rare	1 Swamp
Massachusetts fern	*Thelypteris simulata*	Rare	1 Swamp
Hemlock-Balsam Fir-Black Ash Seepage Swamp			
Swamp thistle	*Cirsium muticum*	Uncommon	3 Swamps
Small yellow lady's-slipper	*Cypripedium parviflorum var. makasin*	Uncommon	2 Swamps
Showy lady's-slipper	*Cypripedium reginae*	Uncommon	3 Swamps

A moss	*Helodium blandowii*	Uncommon	4 Swamps
Spicebush	*Lindera benzoin*	Uncommon	2 Swamps
Sweet fly-honeysuckle	*Lonicera oblongifolia*	Rare	1 Swamp
Maleberry	*Lyonia ligustrina*	Uncommon	1 Swamp
White adder's-mouth	*Malaxis brachypoda* (*Malaxis monophyllos* var. *brachypoda*)	Rare/Threatened	1 Swamp
Sweet coltsfoot	*Petasites frigidus* var. *palmatus*	Rare/Threatened	1 Swamp
Massachusetts fern	*Thelypteris simulata*	Rare	1 Swamp
Red Maple-White Pine-Huckleberry Swamp			
Virginia chain-fern	*Woodwardia virginica*	Very Rare/Threatened	1 Swamp
Red Spruce-Cinnamon Fern Swamp			
Folliculate sedge	*Carex folliculata*	Uncommon	4 Swamps
Eastern Jacob's ladder	*Polemonium vanbruntiae*	Rare/Threatened	1 Swamp
Pinkster flower	*Rhododendron periclymenoides*	Very Rare	2 Swamps
Northeastern bulrush	*Scirpus ancistrochaetus*	Rare/Endangered (VT&Federal)	1 Swamp
Massachusetts fern	*Thelypteris simulata*	Rare	3 Swamps
Spruce-Fir-Tamarack Swamp			
Mountain fly-honeysuckle	*Lonicera villosa*	Uncommon	4 Swamps
Moose dung moss	*Splachnum ampullaceum*	Uncommon	1 Swamp

which occurs at two sites. Aside from the legal status in the state, the ecological status of the rare and uncommon species is as follows: three of the species are considered to be very rare (S1) in the state, 12 are considered to be rare (S2) in the state, and the remaining 14 are uncommon (S3) in the state. As a result of this inventory the status of mountain cranberry (*Vaccinium vitis-idaea)*, sweet coltsfoot (*Petasites frigidus* var. *palmatus)*, and white fringed orchid (*Platanthera blephariglottis*) was changed from S1 to S2 because they were found to be less rare than previously thought. One species, bog aster (*Aster nemoralis)*, was changed from S2/S3 to S2 because it did not show up at many additional sites as had been expected. The most significant plant result was the presumed rediscovery of the pinxter-flower (*Rhododendron periclymenoides*) at four sites. This species was known only historically in the state, and had been last observed here in 1965. However, since all specimens observed were vegetative, definitive identification is still pending.

Since essentially all of these sites are National Wetlands Inventory-mapped wetlands, they are regulated by the state under the Vermont Wetland Rules and hence are not easily developed or converted to other uses. This is in addition to the obvious physical constraints of activities in most of these swamps. In addition, the general lack of invasive, exotic species in softwood swamps minimizes the threat to rare and uncommon plants from this source. So in general, most of these rare species documented from softwood swamps in the state are secure at least for the near future. While logging is an allowed use in these swamps under the Vermont Wetland Rules, and may even benefit some of the rare species under certain circumstances, we urge caution if

and when timber is harvested near rare species. Because of the concern of introducing invasive exotic species into the swamp or altering swamp hydrology, we recommend that any logging occur in winter under frozen soil conditions and that heavy equipment be kept out of the swamps as much as possible. In many softwood swamps the organic soils do not freeze, especially those with ground water seepage. Except as warranted for certain species that may require additional sunlight to flower or regenerate, we recommend that at least 75 percent of the swamp canopy cover be retained to maintain the naturally shady swamp floor.

RARE AND UNCOMMON ANIMAL SPECIES

Although by no means a complete inventory, rare and uncommon animals were noted from a few different sources. These include information in the Natural Heritage Information Project database, chance encounters while conducting the swamp inventories, and observations during the breeding bird surveys. A total of eleven different animal species were documented (Table 8). These species were noted at 25 sites among five different softwood swamp natural community types. As with rare and uncommon plants the Hemlock-Balsam Fir-Black Ash Seepage Swamp had the greatest number of rare or uncommon animal species present with six. This was closely followed by Black Spruce Woodland Bog with five species, and Spruce-Fir-Tamarack Swamp and Black Spruce Swamp, both with four. The four rare or uncommon species that were documented in Black Spruce Swamps occurred at a total of eight sites, giving this type the greatest representation of rare and uncommon animals. This was closely followed by Hemlock-Balsam Fir-Black Ash Seepage Swamp with a total of six sites and Black Spruce Woodland Bog and Spruce-Fir-Tamarack Swamp, both with five sites with rare or uncommon animals.

Two of the animal species are considerably more ubiquitous than any of the others. These are the Black-backed Woodpecker and the Gray Jay. Both of these species were noted at six different sites, all in the Northeastern Highlands biophysical region. For both species these six sites were spread across four different community types, an indication of the broad habitat tolerance for both of these species. Spruce Grouse, the only documented animal that is legally listed in the state as endangered, occurred at three sites representing two different swamp types. Both the Bay-breasted Warbler and the Rusty Blackbird were noted at two sites of different types. The remaining six species were noted at only a single site each.

Management for these rare and uncommon animals would vary widely depending upon the species. For the salamanders it would entail avoiding the creation of ruts by restricting heavy equipment use in the swamp and maintaining a forest cover around breeding pools and foraging habitat. For the three most abundant bird species it would vary from Gray Jay which has broad tolerance as long as there is extensive coniferous forest cover, to the more specialized requirements of Black-back Woodpecker and Spruce Grouse. The Black-back requires dead and dying conifers (especially black spruce) for its breeding, whereas spruce grouse requires extensive dense stands of spruce, generally black spruce, in the colder, wetter portions of the state. We have a unique opportunity to provide for these rare and uncommon animals since most of the sites from which they were documented are in public ownership, mostly on the Conte Refuge, West Mountain WMA, or Wenlock WMA, all in the Northeastern Highlands.

Table 8. Rare and uncommon animals of softwood swamp natural communities in Vermont.

Species Common Name	Scientific Name	State Status	Frequency
Black Spruce Swamp			
Black-backed Woodpecker	*Picoides arcticus*	Uncommon	3 Swamps
Gray Jay	*Perisoreus canadensis*	Rare	2 Swamps
Great Blue Heron Rookery	*Ardea herodias*	Uncommon	1 Swamp
Spruce Grouse	*Falcipennis canadensis*	Very Rare - Endangered	2 Swamps
Black Spruce Woodland Bog			
Arctic jutta (a butterfly)	*Oeneis jutta*	Rare	1 Swamp
Black-backed Woodpecker	*Picoides arcticus*	Uncommon	1 Swamp
Four-toed Salamander	*Hemidactylium scutatum*	Rare	1 Swamp
Gray Jay	*Perisoreus canadensis*	Rare	1 Swamp
Palm Warbler	*Dendroica palmarum*	Very Rare	1 Swamp
Hemlock-Balsam Fir-Black Ash Seepage Swamp			
Bay-breasted Warbler	*Dendroica castanea*	Very Rare	1 Swamp
Black-backed Woodpecker	*Picoides arcticus*	Uncommon	1 Swamp
Gray Jay	*Perisoreus canadensis*	Rare	1 Swamp
Rusty Blackbird	*Euphagus carolinus*	Uncommon	1 Swamp
Spruce Grouse	*Falcipennis canadensis*	Very Rare - Endangered	1 Swamp
Wood Turtle	*Clemmys insculpta*	Uncommon	1 Swamp
Hemlock-Sphagnum Acidic Basin Swamp			
Jefferson salamander	*Ambystoma jeffersonianum*	Rare	1 Swamp
Spruce Fir Tamarack Swamp			
Gray Jay	*Perisoreus canadensis*	Rare	2 Swamps
Bay-breasted Warbler	*Dendroica castanea*	Very Rare	1 Swamp
Black-backed Woodpecker	*Picoides arcticus*	Uncommon	1 Swamp
Rusty Blackbird	*Euphagus carolinus*	Uncommon	1 Swamp

INVASIVE AND EXOTIC PLANT SPECIES

Searches were not conducted specifically for the presence of invasive exotic plants during this inventory. However, part of the assessment of the current condition of each swamp is whether there are invasive exotic species present, so when they were encountered, their presence was noted, especially if they were abundant and likely to be a threat to the natural community or rare species that was being documented. The good news is that the threat from invasive plants is generally low in softwood swamps. Both the number of swamps affected and the number of invasive species encountered is considerably less than in hardwood swamps. The five types of hardwood swamps had a total of nine invasive or potentially invasive plants and four naturalized, exotic plant species represented (Sorenson et al. 2004). Softwood swamps in contrast had only two invasive species on the Noxious Weed Quarantine List (6 V.S.A., Chapter 84, Pest Survey)

and three naturalized, exotic plant species documented (Table 9). These species occurred at ten sites spread over eight different swamps. The only site with multiple species is the Waits River Swamp which is a Hemlock-Balsam Fir-Black Ash Seepage type. Interestingly, all three of the naturalized, exotic plant species occurred in this swamp. This is perhaps not too surprising in that the swamp itself is rather narrow and bordered on one side by the Waits River and on the other by agricultural fields, both conduits for invasive species.

Of the two species on the Vermont Noxious Weed Quarantine list, glossy buckthorn (*Frangula alnus*) is by far the most common, occurring in six different swamps spread over three different types. This species thrives in more nutrient rich conditions so it is no surprise that it occurs most frequently in the Hemlock-Balsam Fir-Black Ash Seepage type. What is perhaps surprising is that this highly invasive species does not occur in more of the softwood swamps of this type. The only other species on the state quarantine list is the related common buckthorn (*Rhamnus cathartica*). This highly invasive species was encountered at only a single swamp of the Spruce-Fir-Tamarack type.

Although they are not presently a big problem in softwood swamps in Vermont, we should not become complacent about invasive, exotic plants in this class of wetlands. Care should be exercised if timber harvesting is undertaken so that invasive species are not introduced or if already present, that they are not spread by this or other activities. Although there is not strong evidence at present, the Hemlock-Balsam Fir-Black Ash Seepage type seems to be most prone to the introduction and spread of invasive exotic species. This is because they are typically more nutrient rich and in warmer settings than the other types. Thesesettings are also generally in the more developed areas of the state, and so the swamps are more likely to have edge bordering other more impacted habitats. Special care should be taken when implementing any activities in this community type.

Table 9. Invasive and exotic plants of softwood swamps in Vermont.

Species Common Name	Scientific Name	State Status	Frequency
Hemlock-Balsam Fir-Black Ash Seepage Swamp			
Common nightshade	*Solanum dulcamara*	Naturalized	1 Swamp
Glossy buckthorn	*Frangula alnus*	Quarantine	3 Swamps
Heal-all	*Prunella vulgaris*	Naturalized	1 Swamp
Moneywort	*Lysimachia nummularia*	Naturalized	1 Swamp
Red Spruce-Cinnamon Fern Swamp			
Glossy buckthorn	*Frangula alnus*	Quarantine	2 Swamps
Spruce-Fir-Tamarack Swamp			
Common buckthorn	*Rhamnus cathartica*	Quarantine	1 Swamp
Glossy buckthorn	*Frangula alnus*	Quarantine	1 Swamp

BREEDING BIRD SURVEY

A total of 47 bird species were identified during the surveys and presumed to be nesting at the six softwood swamps that were surveyed (Table 10). The locations of the six sites are shown in Figure 5. They are widely distributed throughout the state and represent five of the eight biophysical regions. Furthermore, each of the swamps surveyed represents a different type of softwood swamp.

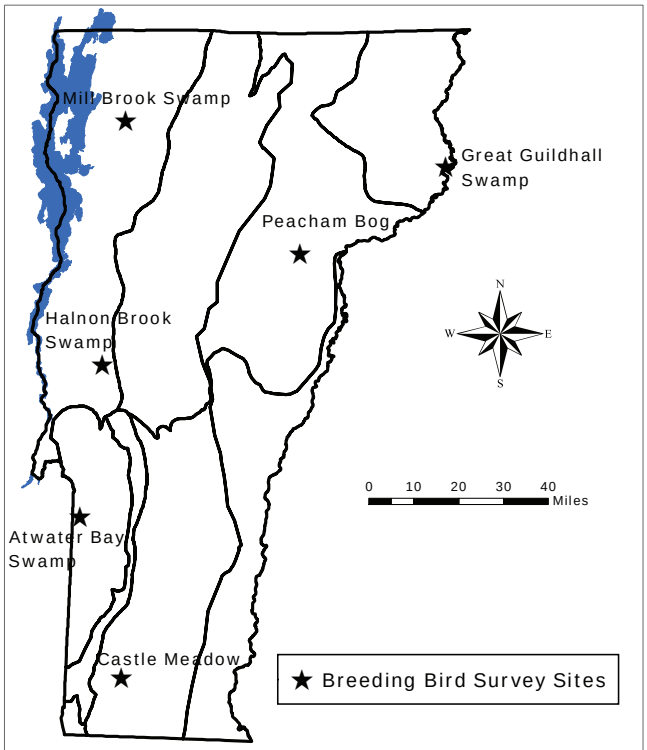


Figure 5. Location of the six softwood swamps where breeding bird surveys were conducted. Biophysical region boundaries are shown.

Nineteen species occurred in at least half the sites (three or more) while only two species occurred at all six sites. Only two rare species, the black-backed woodpecker and palm warbler, were noted in the Black Spruce Woodland Bog at Peacham Bog. Black-backed woodpecker is a species of special concern in Vermont.

The 19 species that were identified to be breeding in at least half the sites might be considered to be reasonable indicators of good quality softwood swamps. It should be noted that while good quality softwood swamps might be expected to harbor many of these 19 species, most are not restricted to softwood swamps for breeding. A good example is the northern waterthrush which occurred at all six softwood swamps, but was also found to breed at all six hardwood swamps (Sorenson, et al. 2004), as well as each of the three cedar swamps and hardwood-cedar swamps (Sorenson, et. al. 1998) that were previously surveyed. Bluejay, the other species found at all six softwood sites, is generally cosmopolitan and breeds in a broad range of habitats. The three species that occurred at five of the six swamps also occupy broader habitats. The Nashville warbler and white-throated sparrow breed primarily in coniferous woods, both upland and wetland, and both species were predictably scarce in hardwood swamps. The common yellowthroat prefers shrubby openings in wetlands, and it was the most common species encountered breeding in hardwood swamps. Of the four species breeding at four of the sites only Canada warbler shows some fidelity to softwood swamps. This species occurred in only two hardwood swamps, and the one where it was most abundant had a high percentage of hemlock in the canopy. The other three species, black-capped chickadee, veery, and hermit thrush, are more ubiquitous and were also found in most of the hardwood and cedar swamps that were previously surveyed. Of the ten species that were breeding at three of the sites, only magnolia warbler, yellow-rumped warbler, golden-crowned kinglet, and red-breasted nuthatch display fidelity to coniferous woods, but these may be either wetland or upland.

As would be expected, the species occurring at five or six sites generally had the highest average number of individuals per listening station. However, there were two notable exceptions:

Lincoln sparrow and tufted titmouse. Both of these species were found breeding in only one swamp, but still had a relatively high average number of individuals per station because they were very abundant at the single site. The Lincoln sparrow is a bird of bogs and shrubby openings at higher elevations and was observed only in the Black Spruce Woodland Bog at Peacham Bog. Conversely, the tufted titmouse prefers warmer, lower elevations and was found only in the Hemlock-Sphagnum Acidic Basin Swamp at Atwater Bay in the Taconic Mountains.

It is hard to determine fidelity to the type of softwood swamp since only six sites were sampled and each of these was a different softwood type. Some clear species differences are apparent when contrasting softwoods swamps with hardwood, cedar, or mixed hardwood-cedar types. Of the species occurring at four or more softwood swamps, Canada warbler, Nashville warbler, and white-throated sparrow were all found in low numbers in hardwood swamps while Nashville warbler and common yellowthroat also occurred in low numbers in cedar and hardwood-cedar swamps. Conversely, of the birds breeding in four or more of the hardwood swamps, red-eyed vireo, hairy woodpecker, and eastern wood pewee were absent or in low numbers in softwood swamps. For birds breeding in four or more cedar or hardwood-cedar types, American crow, black and white warbler, and dark-eyed junco were all absent from softwood swamps.

Despite the difference in softwood swamp types, size of the swamps, and location within different biophysical regions, there are no obvious differences among the breeding bird populations at the six sites. The number of species ranged from a high of 20 in the very large Hemlock-Balsam Fir-Black Ash Seepage Swamp at Mill Brook to a low of 14 in the Black Spruce Woodland Bog at Peacham Bog. The number of individuals per listening station ranged from 21.6 at the Mill Brook Swamp to a low of 15.6 in the Great Guildhall Spruce-Fir-Tamarack Swamp. Although breeding birds may show a preference for conifers over hardwoods or wet conditions over drier ones, it is probably safe to assume that typically they are not selecting nesting habitat based upon the actual species composition of the swamp canopy.

Table 10. Average number of birds per species per listening station for six softwood swamps.

Site Name	Atwater Bay Swamp	Castle Meadow	Great Guildhall Swamp	Halnon Brook Swamp	Mill Brook Swamp	Peacham Bog	Avg. # of Individuals per Listening Station	Frequency
Number of Listening Stations	**4**	**4**	**5**	**5**	**5**	**5**		
Softwood Swamp Type	Hemlock-Sphagnum Acidic Basin	Red Spruce-Cinnamon Fern Swamp	Spruce-Fir-Tamarack Swamp	Wet Sand-over-Clay (Hemlock)	Hemlock-Balsam Fir-Black Ash Seepage Swp	Black Spruce Woodland Bog		
Species								
Northern Waterthrush	2.5	0.5	1.2	0.4	1.2	1.2	**1.14**	**6**
Blue Jay	1.75	0.25	0.8	1.2	2.4	0.2	**1.11**	**6**
Nashville Warbler		1.5	2	0.8	3.6	2.4	**1.79**	**5**
White-throated Sparrow		2.5	1.4	0.4	2.4	2.8	**1.61**	**5**
Common Yellowthroat	0.5		0.8	1.2	0.4	3.6	**1.14**	**5**
Black-capped Chickadee	2.25		1.6	2.4	1.4		**1.29**	**4**
Hermit Thrush			2	2.8	1.6	0.4	**1.21**	**4**
Canada Warbler	1	1.5			1.8	0.8	**0.82**	**4**
Veery	1.5	0.5		1	0.8		**0.61**	**4**
Ovenbird		1		2	1.2		**0.71**	**3**
Winter Wren	1	1			1.6		**0.57**	**3**
Magnolia Warbler		1.5	0.8		0.8		**0.50**	**3**
Red-breast Nuthatch			0.4	0.4	2		**0.50**	**3**
Yellow-rumped Warbler		1.5	0.8	0.8			**0.50**	**3**
American Robin	0.5			0.8	1.4		**0.46**	**3**
Golden-crown Kinglet	1	1.5	0.6				**0.46**	**3**
Blue-headed Vireo	1		0.8	0.8			**0.43**	**3**
Great Crested Flycatcher	1			0.8	0.8		**0.43**	**3**
Brown Creeper	0.5			0.2	0.8		**0.25**	**3**
Blackburnian Warbler	1	2					**0.43**	**2**
Yellow-bellied Flycatcher		1	0.8				**0.29**	**2**
Red-eyed Vireo	0.5	1					**0.21**	**2**
American Crow			0.4		0.4		**0.14**	**2**
Black-throated Blue Warbler		0.5	0.4				**0.14**	**2**
Lincoln Sparrow						3.2	**0.57**	**1**
Tufted Titmouse	2						**0.29**	**1**
Least Flycatcher						1.2	**0.21**	**1**
Cedar Waxwing						1	**0.18**	**1**
Eastern Wood Pewee	1						**0.14**	**1**
Hairy Woodpecker					0.8		**0.14**	**1**
Scarlet Tanager	1						**0.14**	**1**
Black and White Warbler					0.4		**0.07**	**1**
Black-throated Green Warbler			0.4				**0.07**	**1**
Dark-eyed Junco		0.5					**0.07**	**1**
Northern Parula			0.4				**0.07**	**1**
Olive-sided Flycatcher						0.4	**0.07**	**1**
Palm Warbler						0.4	**0.07**	**1**
Purple Finch			0.4				**0.07**	**1**
Red-bellied Woodpecker	0.5						**0.07**	**1**
Swainson's Thrush		0.5					**0.07**	**1**
White-breasted Nuthatch						0.4	**0.07**	**1**
Willow Flycatcher					0.4		**0.07**	**1**
Wood Thrush		0.5					**0.07**	**1**
Black-backed Woodpecker						0.2	**0.04**	**1**
Downy Woodpecker		0.25					**0.04**	**1**
Ruffed Grouse				0.2			**0.04**	**1**
Yellow-bellied Sapsucker	0.25						**0.04**	**1**
Number of Individuals per Listening Station	**16.5**	**14.75**	**10.6**	**13.4**	**16.6**	**11.6**		
Total Number of Bird Species	**19**	**19**	**18**	**16**	**20**	**14**		

AMPHIBIAN AND REPTILE SURVEY

A total of eight amphibian species were observed at the five softwood swamp sites visited during this study (Table 11). This is a low number of species compared to what was observed in the inventory of hardwood swamps (Sorenson, 2004). The low number of species and individuals observed at most swamps is likely because these softwood swamps have little standing water suitable for amphibian breeding. The exceptions are Vernon Town Swamp that includes part of an impounded stream and Atwater Bay Swamp, where the hemlock swamp is bordered by a wet red maple swamp with many pools. It is these specific pool habitats that seem to be more important for amphibians than the type of softwood swamp present.

All of the amphibian species observed are common, other than Jefferson's salamander, which is a rare species (S2) of Special Concern. A single Jefferson's salamander was found under a rock in the upland forest adjacent to Atwater Bay Swamp and is expected to use the pools on the swamp margin for breeding.

Table 11. Amphibian species observed in the five softwood swamp survey sites. "X" indicates that the species was observed in the swamp and "(X)" indicates that the species was observed in the adjacent uplands but is expected to use the swamp. Towns in which the swamps are located are indicated in bold type.

	Softwood Swamp Site				
	Calais Town Forest **Calais**	Lanesboro Kettle Swamp **Marshfield**	Vernon Town Forest Swamp **Vernon**	Atwater Bay Swamp **Wells**	Tinmouth Channel WMA **Tinmouth**
Natural Community Type	Spruce-Fir-Tamarack Swamp	Black Spruce Swamp	Red Maple-Black Gum Swp (hemlock dom.)	Hemlock-Sphagnum Acidic Basin Swamp	Calcareous Red Maple-Tamarack Swamp
Species					
Wood Frog				X	
Green Frog			X		
Spring Peeper			(X)	(X)	X
Spotted Salamander	X			X	
Eastern Newt			(X)	X	
Redback Salamander	(X)		(X)	X	
Two-lined Salamander				X	X
Jefferson's Salamander				(X)	
Total Species	**2**	**0**	**4**	**7**	**2**

THREATS TO SOFTWOOD SWAMPS

There are numerous threats to softwood swamps in Vermont. These threats can be separated into three main categories, in order of increasing severity: 1) temporary impairment of the condition of the swamp or its associated upland buffer; 2) permanent alteration and impairment of the swamp condition; and 3) wetland loss due to filling, draining, or clearing. Logging of softwood swamps and their adjacent upland buffer zones are in most cases temporary alterations of the swamp ecology. Removal of overstory trees may change the species composition of the swamp forest, promoting early successional species. Other temporary changes include alteration of organic soil accumulation by removal of woody debris, changing tree tip-up dynamics that create hummocks and hollows, and altering wildlife habitat for amphibians and other groups. Cutting in the upland buffer zone can change surface runoff characteristics and alter wildlife habitat values. Permanent swamp alteration may be associated with heavy logging equipment entering wetlands when soils are not frozen and creating ruts or compaction of organic soils that change wetland hydrology. Similarly, logging may introduce invasive exotic plant species that are very difficult to control and may proliferate in the swamp. Wetland hydrology can also be altered by changes in surface and ground water flow associated with development in adjacent upland forests. Changes in the quantity of runoff reaching softwood swamps may be especially significant for those that occur in small watersheds, such and Hemlock-Sphagnum Acidic Basin Swamp. Changes in water quality, such as may occur from introduction of storm water from developments, may be especially significant for softwood swamps that are associated with mineral-enriched ground water seepage, such as Hemlock-Balsam Fir-Black Ash Seepage Swamp. Both changes in hydrology and introduction of exotic plant species are usually permanent alterations and can be associated with most activities that open swamp canopy cover or alter swamp hydrology. Permanent loss of softwood swamps is most often associated with development, which results in wetland filling or draining.

Most softwood swamps are considered Class Two wetlands under the Vermont Wetland Rules and are therefore protected from activities that alter their functions and values.[4]

It is clear that the threats are not equal to all softwood swamp community types. The uncommon swamp types are under less threat than rarer types. Basin swamps may be very susceptible to small alterations in surface water runoff characteristics, whereas seepage swamps are more likely to be altered by changes in ground water characteristics that can occur at some distance from the swamp.

There are other sources of threat to softwood swamps and other ecological systems that may have profound but still uncertain effects. Global climate change has the potential to alter water budgets in wetlands which can change the rates of organic soil accumulation. Regional warming may have the greatest effect on wetland communities that are at the edge of their range, such as Black Spruce Swamps. Finally, introduction and spread of invasive pests, such as emerald ash borer (*Agrilus planipennis*) and hemlock woolly adelgid (*Adelges tsugae*) are likely to dramatically alter the species composition of some swamp types.

[4] For information on the Vermont Wetland Rules and wetland protection, contact the Wetlands Office, Vermont Department of Environmental Conservation, 802-241-3770, http://www.anr.state.vt.us/dec/waterq/wetlands.htm

CONCLUSIONS

Softwood swamps, when considered as a broad class of wetlands, are common across Vermont. However, when evaluated more closely, there is considerable variation in the vegetation, hydrology, soils, nutrient enrichment, and distribution of these forested wetlands. Each of the softwood swamp natural community types identified in this report (and cedar swamp types that were studied earlier) has its own set of component species and environmental conditions. Understanding the distribution and relative rarity of each natural community type and the rare species and threats associated with each type helps us to set conservation priorities to protect all species of plants and wildlife associated with these communities. Although softwood swamps occupy only approximately one percent of the Vermont land area, it is significant to note that 404 plant species (vascular plants and bryophytes) have been documented in just the plots taken in these swamps for this study (excluding cedar swamps). This represents approximately 15 percent of the total number of vascular plant species (2,000) and bryophytes (626) known to occur in Vermont.

The objectives of this inventory have been to identify the distribution and variability of softwood swamps in Vermont, to refine the community classification, to document rare plants and some of the characteristic animals, to notify landowners of the significance of swamps that they own, and to identify some of the best examples of softwood swamp communities in Vermont. The project has completed these objectives. However, it is important to note, that given the widespread distribution of softwood swamps in Vermont, this study has been far from a complete inventory. It is expected that many more state-significant examples of all softwood swamp community types will be documented with further inventory, although it is likely that more of the common types will be found than of the rare types. This emphasizes the importance of continued inventory throughout the state.

Natural community-based inventory provides quantitative information on vegetation and environmental characteristics of the communities studied. This information is critical to refining the community classification for Vermont. For previous natural community inventories, the quantitative data has been analyzed in order to revise only the community types that are the subject of the particular study. A new and useful approach used in this project was to include quantitative plot data from the previous cedar swamp and hardwood swamp studies, along with the data collected for this softwood swamp study in order to provide a more "seamless" classification of all forested swamp types.

RECOMMENDATIONS FOR CONSERVATION

As most softwood swamps are privately owned, the long term conservation of the biological diversity occurring in softwood swamps will depend primarily on the continued good stewardship provided by private landowners. By continuing to learn about the ecology, hydrology, soils, plants, animals, and history of human use of swamps, landowners can better gauge the effects that nearby land uses will have on the swamps and plan accordingly. Landowners are encouraged to call the Natural Heritage Information Project, the Vermont Wetlands Office, and district Wildlife Biologists with questions about particular swamps and their management.

Almost all softwood swamps in Vermont have been altered by human activities. Swamps that are subject to only natural disturbance processes, especially wind, develop and mature differently than those that are actively managed by people. These swamps that mature under natural ecological processes provide a critical baseline for our understanding of the ecology and natural variability of softwood swamps. Although careful logging is definitely compatible with maintaining many softwood swamps, it is very

important that there be high quality examples (large size and unfragmented landscape) of all softwood swamp community types that are not logged or otherwise actively managed, but instead are allowed to mature. It is a conservation goal to conserve representative examples of all softwood swamp community types in all biophysical regions in which they occur and to allow these swamps to mature under natural ecological processes, with minimal human disturbance. Whenever possible, these representative examples should be conserved in unfragmented landscapes. Many of these representative examples can be conserved on public lands, although cooperation with interested private landowners is also be critical to conservation success.

We have little information on how softwood swamps and other natural communities change over time in response to natural or anthropogenic environmental changes. Global climate change is expected to result is changes in temperature, quantity and timing of precipitation, and intensity of storms in the Northeastern United States (Union of Concerned Scientists 2006). These factors and others are likely to alter hydrology, species composition, and structure of softwood swamps. In order to better understand these potential alterations over time, it is recommended that permanent plots be established and monitored in high quality examples of softwood swamps and all other natural community types.

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