VERMONT WETLANDS BIOASSESSMENT PROGRAM
An Evaluation of the Chemical, Physical, and Biological Characteristics of Seasonal Pools and Northern White Cedar Swamps

Final Report

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and
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Nongame and Natural Heritage Program

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The full report can be found at http://www.anr.state.vt.us/dec/waterq/bassvernal.htm

Table of Contents

List of Figures

List of Tables

INTRODUCTION AND BACKGROUND

The Vermont Department of Environmental Conservation (VTDEC) has been assessing the biological integrity of lakes, rivers, and streams throughout Vermont since the early 1970's. Primary target communities have been aquatic macrophytes, aquatic macroinvertebrates, and fish. In certain instances, the VTDEC has applied theoretical considerations regarding the impact of ecosystem disturbance to ecological integrity to develop biocriteria for select biological communities. Biological criteria are currently being implemented for wadeable streams and are under development for other types of rivers and ponded waters.

Prior to 1997, VTDEC conducted limited wetland bioassessments. Those earlier studies were conducted on palustrine and permanently flooded open-water wetlands. VTDEC began to seriously consider the applicability of wetlands bioassessments in 1997 and 1998 with the sampling of various wetland types including seasonal pools, small beaver ponds, wetland streams, and cedar swamps. The efforts were concentrated on qualitative collection techniques simply to determine presence/absence of aquatic macroinvertebrates. Twenty-six wetlands were sampled. This preliminary undertaking set the stage for Vermont's participation in the Vermont Wetlands Bioassessment Project of 1999 and 2000.

The natural community classification system developed by the Vermont Fisha nd Wildlife's Nongame and Natural Heritage Program (VT NNHP) and the Vermont Chapter of The Nature Conservancy identifies 40 wetland and 40 upland community types in the state (Thompson and Sorenson 2000). These community types are assemblages of plants and animals that are found recurring across the landscape under similar environmental conditions. The Vermont natural community classification system is linked directly to a national classification system developed by The Nature Conservancy, NatureServe, and other state Natural Heritage Programs. This national classification system has now been adopted by the Federal Geographic Data Committee as the framework for an information and classification standard to be used by all federal agencies (FGDC 1997). The VT NNHP maintains an extensive database containing information collected from wetland and upland natural communities over the past 20 years of inventory work.

VT NNHP has developed criteria to rank occurrences of all natural communities based on size, naturalness, and ecological integrity of the community, and whether it occurs in a landscape where natural processes can take place. The VTDEC has worked extensively on the development of biological criteria for wadeable streams and lakes using various biological assemblages from those environments, with emphasis on aquatic macroinvertebrate and fish assemblages. In addition, VTDEC has been involved in recent efforts to develop a classification system, based on biological assemblage attributes, for running and ponded surface waters. This cooperative effort between The Nature Conservancy, VT NNHP, VTDEC, and others focused attention on the differences and similarities between the biocriteria and the community classification approaches to biological assessment and ranking of biological attributes and integrity. While the two approaches have been independently developed and are based on different goals and objectives, there were many similarities between the approaches and the combined effort was reflective of the strengths provided by each program.

As part of a New England-wide effort to develop and implement biological assessment and monitoring programs for wetlands, the VTDEC and the VT NNHP, with funding from the United States Environmental Protection Agency (USEPA), initiated a three year collaboration in 1999 to develop methods for the classification and bioassessment of two very different wetland types: seasonal pools (vernal and autumnal) and northern white cedar swamps. These two wetland types were selected for study for distinct reasons.

Seasonal pools were selected due to an interest in expanding our understanding of the community characteristics of this wetland type and because improved assessment methods would aid in the protection of seasonal pools during the regulatory review process. Seasonal pools are typically small, isolated depressional wetlands with no permanent inlet or outlet. Because the main source of water is often rain and snowfall, most seasonal pools have standing water in the spring (vernal pools), but are dry by early to midsummer. Some pools may refill with water in the fall (autumnal pools). Seasonal pools are often overlooked in regulatory site evaluations, as they may be dry and therefore difficult to identify during much of the year. Nevertheless, these ephemeral pools provide critical habitat for several amphibians and many invertebrate species. Several New England states, conservation commissions, and non-profit organizations have developed volunteer-based programs to locate seasonal pools and identify particular "obligate" species associated with them (Calhoun 1997, Colburn 1997, and Tappan 1997). However, there has been little effort toward developing standardized methods for quantitatively sampling water chemistry or biota, especially macroinvertebrates, or community classification (with exception of Cutko 1997) in seasonal pools. Such quantitative techniques are necessary to determine the natural variability associated with seasonal pools, critical information when evaluating the effects of anthropogenic impacts to these wetlands.

Cedar swamps were selected because they represent a very different wetland type (saturated wetland forest) for which little biological assessment work has been conducted and because a recently completed statewide inventory of northern white cedar swamps in Vermont (Sorenson et al. 1998) provided the background data on natural community classification based on plants. Northern white cedar swamps present a different challenge for aquatic-based biological assessments in that they contain very little standing water at any time of the year. In these wetlands, truly aquatic organisms may be scarce or non-existent; therefore, focus must be shifted to more terrestrial plant and animal assemblages. As part of this assessment, we evaluated vegetation and breeding bird data that the VT NNHP gathered in previous state-wide inventories of cedar swamps, augmented these with new data using previously established protocols. We also assessed the feasibility of sampling aquatic macroinvertebrates.

In addition, the collaborators explored the feasibility of using the characterization data from both wetland types to assess the effects of disturbance on the ecological integrity of the wetlands. The reference condition model for biological criteria development was developed from the data collected.

PROJECT GOALS

The overall goal of this project has been to combine the expertise of the VT NNHP with its background in natural community classification tand he VTDEC with its background in biocriteria development as promoted by USEPA water programs to: **1) gather and assess chemical, physical, and biological characteristics of seasonal pools and northern white cedar swamps; 2) evaluate assessment methods; and 3) evaluate the feasibility of utilizing these data to develop an ecologically-based classification of reference condition seasonal pools and determine the effects of disturbance on the ecological integrity of seasonal pools and northern white cedar swamps.**

In order to address these goals, the collaborators conducted chemical, physical, and biological assessments of 28 seasonal pools and 74 northern white cedar swamps within a range of minimally disturbed (reference) and disturbed conditions. Characterization assessments included measures of aquatic macroinvertebrates, amphibians, algae, vascular plants and bryophytes, soils, birds, and landscape condition. This report presents the results of these assessments with analysis and discussion relevant to the overall goals of the project. In the interests of clarity and organization, the two wetland types will be reported separately.

PART 1 – SEASONAL POOLS

PROJECT DESCRIPTION AND OVERVIEW

The overall goal of this phase of the project has been to investigate the establishment of a framework from which to assess the ecological condition of seasonal pools in Vermont in a manner consistent with the Vermont Water Quality Standards. Seasonal pools were assessed in order to :1) develop and evaluate standardized protocols for sampling of aquatic macroinvertebrates, vegetation, water quality, and other biological and physical characteristics of seasonal pools; 2) assess the natural variability in the biological, chemical, and physical make-up of undisturbed, reference condition seasonal pools; 3) assess the biological, chemical, and physical make-up of disturbed seasonal pools; 4) assess the feasibility of classifying minimally disturbed pools according to biological and/or physical characteristics; and 5) assess the effects of disturbance on ecological integrity and identify biological metrics that reflect ecological integrity.

A total of twenty-eight seasonal pools were assessed during the years 1999 and 2000. The assessed pools included those representative of reference (minimally disturbed) conditions as well as those representing a range of disturbance. Of those twenty-eight pools, five were assessed in both years in order to evaluate annual variability. Pools were selected to represent most of the biophysical regions of Vermont as well as a range of disturbance type and intensity. Biological communities assessed included aquatic macroinvertebrates, algae, vegetation, and amphibians. Water chemistry included earth metals, major anions, color, pH, alkalinity, aluminum, and specific conductance. A number of ecological observations were made at each pool, including: pool size; pool depth; in-pool habitat characteristics; and forest type and condition surrounding each pool. All pools were visited a minimum of twice to assess amphibians and aquatic macroinvertebrates (early and late spring), with additional later visits between August and November as necessary to characterize physical and vegetative parameters. Data were analyzed in a variety of ways in an effort to identify ecological indicators of reference condition classification or disturbance gradients.

Regulatory Protection of Seasonal Pools in Vermont

State

The Vermont Wetland Rules (Vermont Water Resources Board, 2001) provide administrative jurisdiction to VTDEC over certain types of wetlands, specifically those deemed “significant” and shown on Vermont Significant Wetland Inventory maps derived from National Wetland Inventory maps. Most seasonal pools are not identified on the Vermont Significant Wetland Inventory maps and therefore are not initially protected by the Rules. However, since the Vermont Wetland Rules are based on the protection of wetland functions and values and most seasonal pools provide important amphibian habitat, seasonal pools can be protected under the Wetland Rules through the petition process.

Seasonal pools are protected as “waters of the State” under the Vermont Water Quality Standards (Vermont Water Resources Board, adopted June 10, 1999). The Vermont Water Quality Standards (VWQS) authorize protection of water quality as well as existing and designated uses of seasonal pools. The VWQS authorize the VTDEC to “establish and apply numeric biological indices to determine whether there is full support of aquatic biota and aquatic habitat uses. These numeric biological indices shall be derived from measures of the biological integrity of the reference condition for different water body types."

In addition to the Vermont Wetland Rules and the VWQS, permit applications for land development reviewed under Vermont's Act 250 land development law are reviewed by the VTDEC wetlands office and Fish and Wildlife Department staff and recommendations related to a number of review criteria are made to the District Environmental Commissions and the Environmental Board to protect wetlands when appropriate. Review criteria include water pollution, groundwater, streams, shorelines, sediment and erosion control, storm and floodwater control, rare and irreplaceable natural areas, wildlife habitat, recreation, and aesthetics. Evaluation of these criteria may be conducted independently of Federal Clean Water Act or VWQS authorities.

Local

Several Vermont statutes provide authorization for Vermont towns and cities to protect wetlands at the local level. This can be accomplished through the Town's municipal plan, zoning, and subdivision regulations, shoreland protection bylaws, health ordinances, and flood hazard regulations.

Federal

Section 404 of the Clean Water Act establishes programs to regulate the discharge of dredged and fill material, excavation, and mechanized land clearing in waters of the United States, which includes seasonal pools. The USEPA and the United States Army Corps of Engineers administer the program jointly, with assistance from the United States Fish and Wildlife Service and the Vermont Agency of Natural Resources. Federal wetland permits are not valid in Vermont without first obtaining a State of Vermont Section 401 Water Quality Certification from the VTDEC Wetlands Office. Under Section 401 of the Clean Water Act, all federal permits are reviewed by state programs to assure compliance with state water quality standards. Vernal pools are considered "special aquatic sites" under the Vermont General Permit and all proposed disturbances to vernal pools need to be reviewed as Category B projects.

METHODS

Site Selection

The VTDEC and VTNNHP sampled 28 seasonal pools for water chemistry, vegetation, aquatic macroinvertebrates, and amphibians from 1999-2000 (see **Table 1**). An effort was made to select seasonal pools across a range of geographical locations and elevations within the state. Seasonal pools include pools commonly referred to as vernal, temporary, intermittent, ephemeral, or autumnal. See **Figure 1** for the distribution of pools throughout Vermont's biophysical regions. For this study, a seasonal pool was defined by the following criteria:

- no permanent inlets or outlets
- standing water for at least two months of the year, and
- dries out for some portion of each year with average rainfall.

Candidate sites were solicited from a wide range of sources, including landowners, foresters, naturalists, state and federal natural resources programs, environmental education organizations, and interested individuals. Candidate sites were mapped, ownership determined, and access permission secured, and then visited and evaluated. The 28 pools were selected from the list of candidates. Consideration was given to statewide geographical distribution, accessibility, availability of historical information and knowledge, as well as factors below related to reference and disturbed condition. It was not possible to determine definitively at the time of site selection whether each of the 28 pools would meet the criteria listed above, and in fact, some pools were later determined to be permanent, not seasonal pools.

Reference Pools

Initial selection of reference quality seasonal pools was based on the pool being surrounded by a continuous forested buffer of at least 150 m width and having no other obvious impairments from human activity. A buffer width of 150 m approaches the 164.3 m buffer proposed by Semlitsch (1998) to encompass 95% of the ambystomid salamander population associated with a pool or pond. The initial selection of reference quality seasonal pools was based largely on professional judgment. A more formal ranking of seasonal pools disturbance type and severity was conducted as a step during data analysis. This ranking process is described in the Additional Site Information section.

Disturbed Pools

In addition to selection of reference quality seasonal pools, pools were also selected with varying degrees of disturbance from human activities. An effort was made to select pools disturbed by a variety of activities and with varying degrees of disturbance severity. For example, seasonal pools were selected that had been disturbed by adjacent logging, road construction, development, and agriculture and that were expected to have alterations in their hydrologic regime or water quality. Selection of these disturbed sites was based on the professional judgment of the investigators and information obtained from others who were more familiar with the individual seasonal pools. Ranking of the seasonal pool disturbance type and severity was not a part of the initial selection process but was conducted as a step during data analysis. This ranking process is described in the Additional Site Information section.

Figure 1. Location of the 28 seasonal pools included in the wetland bioassessment study

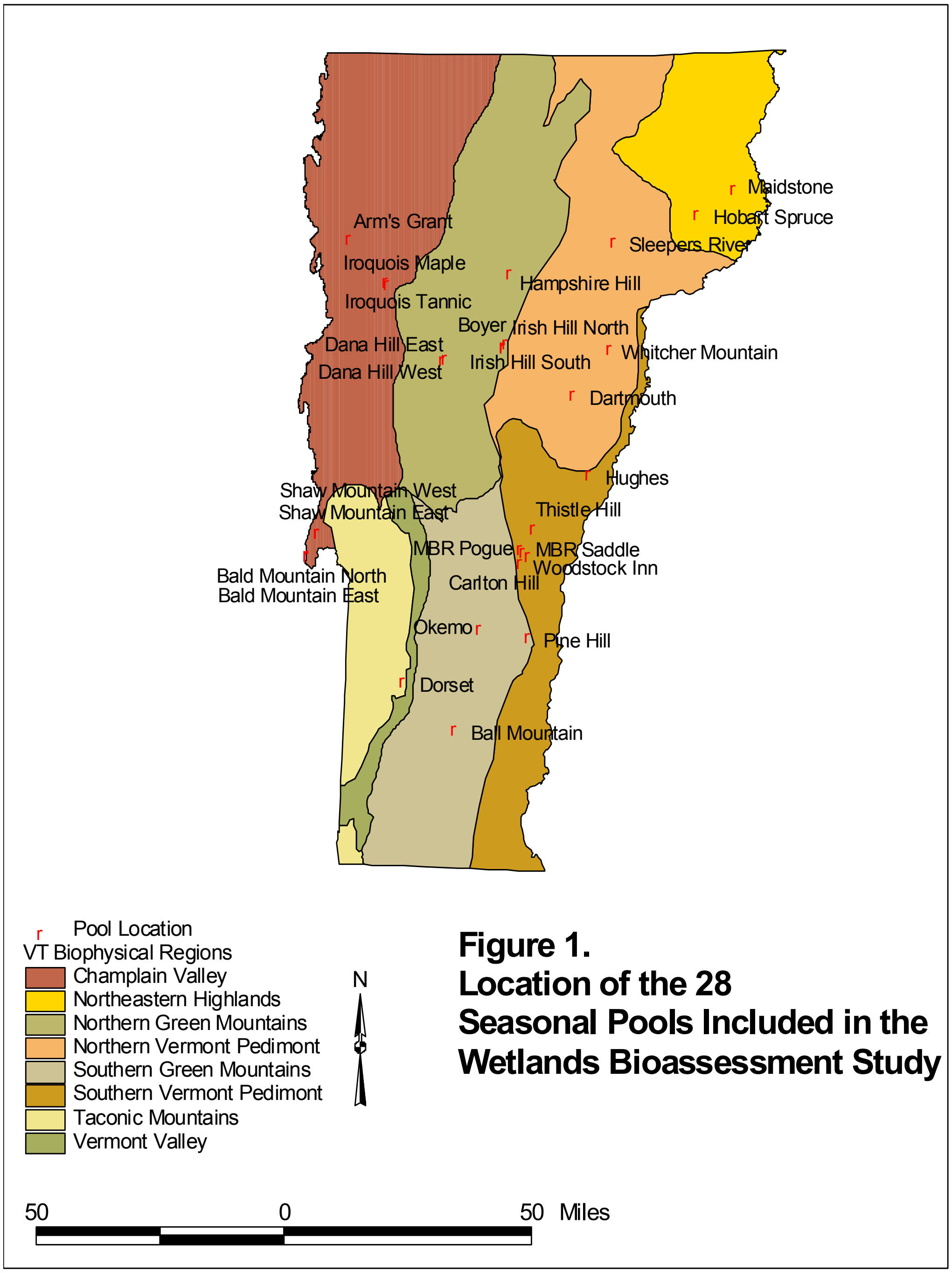


Figure 1.
Location of the 28 Seasonal Pools Included in the Wetlands Bioassessment Study

Table 1. Seasonal pool names, distribution by town and biophysical region, and years sampled.

Site name	Town	Vermont Biophysical Region	Year Sampled	
			1999	2000
Arms Grant	Burlington	Champlain Valley	-	U
Bald Mountain North	West Haven	Champlain Valley	U	U
Bald Mountain South	West Haven	Champlain Valley	U	U
Ball Mountain	Jamaica	Southern Green Mountains	U	-
Boyer	Berlin	Northern Vermont Piedmont	U	-
Carlton Hill	Woodstock	Southern Vermont Piedmont	-	U
Dana Hill East	Waitsfield	Northern Green Mountains	U	-
Dana Hill South	Waitsfield	Northern Green Mountains	U	-
Dartmouth	Corinth	Northern Vermont Piedmont	-	U
Dorset	Dorset	Vermont Valley	-	U
Hampshire Hill	Worcester	Northern Green Mountains	U	-
Hobart Spruce	Victory	Northeastern Highlands	U	-
Hughes	Thetford	Southern Vermont Piedmont	-	U
Irish Hill North	Berlin	Northern Vermont Piedmont	-	U
Irish Hill South	Berlin	Northern Vermont Piedmont	-	U
Iroquois Maple	Williston	Champlain Valley	U	-
Iroquois Tannic	Williston	Champlain Valley	U	-
Maidstone	Maidstone	Northeastern Highlands	-	U
MBR Lake (Pogue)	Woodstock	Southern Vermont Piedmont	U	-
MBR Saddle	Woodstock	Southern Vermont Piedmont	U	-
Okemo	Ludlow	Southern Green Mountains	-	U
Pine Hill	Weathersfield	Southern Vermont Piedmont	U	U
Shaw Mountain East	Benson	Champlain Valley	U	U
Shaw Mountain West	Benson	Champlain Valley	U	U
Sleepers River	Walden	Northern Vermont Piedmont	U	-
Thistle Hill	Pomfret	Southern Vermont Piedmont	U	-
Whitcher Mountain	Groton	Northern Vermont Piedmont	U	-
Woodstock Inn	Woodstock	Southern Vermont Piedmont	-	U

Data and Sample Collection and Processing Methods

A total of 28 pools were sampled and described. Amphibian populations were surveyed in each pool beginning just after ice-out, during the spring migration. Aquatic macroinvertebrate and water chemistry samples were collected twice in each pool; once during early spring and again four to six weeks later, in pools where water still remained. In pools that contained no standing water but still contained wet muck, water samples were not collected and aquatic macroinvertebrate sampling was limited to one of the three methods employed. Algae populations were sampled only once, during the second round of aquatic macroinvertebrate/water sampling. Physical habitat information was collected during the initial aquatic macroinvertebrate sampling round, and was supplemented by physical data collected during each subsequent sampling event. Pool vegetation and soils, and surrounding natural communities were assessed during summer and fall visits. Additional characterization of each pool was based on office assessments of collected and published information. This included a ranking of disturbance and information on bedrock and surficial geology.

Physical Habitat Measurements

Information on the physical environment in and surrounding each pool was collected once at each pool and was augmented with additional data collected on each visit. Latitude and longitude, elevation, maximum pool area, maximum water depth, approximate melt-out date, percent leaf litter composition, percent woody debris composition, a description of the surrounding buffer zone and an estimation of canopy cover at full leaf out were noted once for each pool. Measurements of percent canopy cover, ambient air temperature, water temperature, pool area, and pool perimeter and water depth were recorded during each site visit. Water depth continued to be monitored during any additional site visits.

During the first sampling round, **latitude and longitude** were determined using a Garmin hand-held GPS unit. These coordinates were then employed to determine site elevations using a USGS topographic quad. **Maximum pool area** was recorded by noting the extent of stained leaves and any other evidence suggesting prior inundation, and measuring the area within this perimeter according to the method described below. Likewise, **maximum water depth** was determined by an estimation of the pool's maximum depth, based on apparent maximum extent, relative to its initial depth recorded after ice-out as outlined below. An approximate **date of melt-out** was recorded for each pool based on an educated estimate or regular monitoring. **Substrate composition** and a percent estimate of leaf litter cover were recorded at each pool. A relative estimate of woody debris abundance was recorded at each pool to estimate the abundance of amphibian egg attachment sites. Also, a **150m buffer** surrounding each pool was assessed to document any nearby aquatic habitats or natural or anthropogenic disturbances. Lastly, during the second visit to each site, **percent canopy** cover was estimated at full leaf-out.

During each aquatic macroinvertebrate sampling event, **ambient air and water temperatures** were measured to the nearest 0.5 degree C, and **percent canopy cover** was visually estimated. **Pool area** was calculated by taking a measurement of maximum pool length and the average of four to five width measurements. All distance measurements less than 20m were made using a range finder; those measurements greater than 20 m were measured by pacing. Pool perimeter was measured by pacing the boundary of the pool.

A soil auger was employed to describe each pool's **soil profile** and approximate substrate depth near the deepest accessible area of the pool marked during the initial sampling round. For each soil profile the following information was collected: depth of organic layer, type of organic soil, presence of and depth to mottling in mineral soils, thickness of each soil horizon, and texture of each soil horizon. Presence of an impeding layer (bedrock or hardpan) was also noted if it was within 125 cm of the surface (the length of the soil auger). Other features of the physical environment that were noted include: categorization of the topographic position in which the seasonal pool occurs, soil moisture regime, soil drainage class, and estimation of the percent of the maximum unvegetated pool area occupied by standing water, downed wood, leaf litter, bare soil, rock, and bedrock.

Water depth was measured at a single location, marked with a wooden stake, in the deepest accessible part of the pool. The marking stake was used to monitor water depth throughout the sampling season. Depth was measured to the nearest cm from the water's surface to the top of the substrate, and again from the water's surface to the deepest penetrable layer in the substrate. Because many of the pools contained deep layers of loose, organic muck, the two depth measurements often differed substantially. Water level was marked on the stake during the initial visit, and all subsequent depth measurements were recorded relative to this marking. Poor water column visibility during the initial visit may have affected the accuracy of the surface to substrate measurement. Therefore, if the pool was dry on subsequent visits, the distance between the substrate and the original marking was re-measured and all recorded depths were adjusted accordingly.

Water Chemistry Sampling And Analytical Procedures

Water samples were collected at each pool during both sampling rounds provided the pool contained sufficient water during the second visit. Water samples were consistently collected before any other sampling activities occurred in the pool to avoid disrupting the substrate. Water samples were taken from the deepest area of the pool in smaller pools, and several merters in from the edge in larger pools. Samples were collected from the same area of each pool during both rounds of sampling. Sample collection followed the protocol outlined in the Quality Assurance Project Plan (QAPP). All containers were rinsed twice with distilled water, and then twice with pool water prior to filling with the actual sample. Samples were transferred to a cooler on return to the vehicle. At more remote sites, samples may have been at ambient temperatures for up to 4 hours. Field pH measurements and color analysis were performed according to the procedures outlined below.

Field pH was measured with a Model 19 portable Great Lakes pH meter, according to established protocol in the VTDEC Field Methods Manual (1987). The pH meter was calibrated with standard pH 4 and pH 7 buffers prior to all measurements. **Apparent color** was measured with a Hanna Model HI 93727 portable meter, and was recorded as the average of three readings. Upon return to the VTDEC lab, samples were logged into the Laboratory Management System and designated a unique five-digit numeric identification number and a unique alphanumeric code identifying site, sample type (regular, spike or duplicate) and sampling round. Base cation samples were preserved for analysis by adding 0.25 ml HNO_3 per 125 ml of sample. All samples were then immediately refrigerated until chemical analysis for alkalinity, conductivity, anions, cations, aluminum, and laboratory pH could be completed. Samples were analyzed for aluminum only if the field pH was less than 6.0. In order to examine the reliability of the Hanna meter, the apparent color analysis was repeated within 48 hours in the lab using the Hanna meter and a Taylor Water Analyzer.

In compliance with the quality assurance/quality control guidelines outlined in the QAPP, field duplicates were collected at two different pools during each round of sampling. These samples were collected at the same location within the designated pools and were analyzed as unique samples. Field duplicates represent how variable the sampling method was and the range of values for each parameter. Sampling precision was quantified by calculating relative percent difference between duplicate analyses. Additionally, designated spike samples were collected from two pools during each round of sampling. Percent recovery values were calculated for all base cations in the spiked samples, and accuracy was expressed by calculating percent bias. Due to very low anion concentrations, accuracy of the anion analysis was determined by calculating the percent bias of internal standards analyzed during the sample analysis.

Biological Sampling Procedures

A total of 28 pools were sampled and described. Amphibian populations were surveyed in each pool beginning just after ice-out, during the spring migration. Aquatic macroinvertebrate samples were collected twice in each pool; once during early spring, and again four to six weeks later in pools where water still remained. Algae populations were sampled only once, during the second round of aquatic macroinvertebrate/water sampling. Vascular plants and bryophytes were sampled in each seasonal pool between August and October using standard plots.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates were sampled by three methods: funnel traps to catch actively swimming invertebrates (beetles, bugs, mosquitoes, crustaceans); D-net scoops to sample benthic invertebrates in the leaf litter and muck (true flies, clams, snails, and aquatic worms); and a qualitative search for any taxa missed using the two previous methods. In pools that contained no standing water during the second ammual sample, but still contained wet muck, aquatic macroinvertebrate sampling was limited to scoops and/or qualitative search methods. To ensure consistent sampling effort, two biologist set all the traps, took all the D-net scoops, and collected all but two of the qualitative samples. Upon return to the Biomonitoring and Aquatic Studies Section Laboratory, all aquatic macroinvertebrate samples were logged into a notebook and assigned a unique sequential number. This number was used by the staff biologists for tracking each sample. All invertebrate organisms were identified according to the methods outlined in the QAPP and the procedures below.

Traps: Funnel traps were constructed of plastic window screen and were designed to function like minnow traps. The traps were placed in the water such that the majority of the funnel opening was submerged, leaving a portion of the trap above the water surface to allow surface access for any trapped amphibians.
A maximum of ten traps were placed at approximately 10m intervals around the perimeter of the pool and left in place for a 24-hour period. Distinct microhabitats within a pool were not specifically targeted for trap placement. In an effort to reduce disturbance of the amphibian populations and to facilitate efficient sample collection, trap placement near large congregations of tadpoles was avoided.

Traps were not consciously placed in the same locations within a pool during the second sampling round. Moreover, if the pool decreased significantly in surface area between the first and second sampling rounds, fewer traps were set on the second round, appropriate to the pool's smaller dimensions. When water levels were marginal, traps were placed 2 or 3 cm into the substrate in order to submerge the funnel opening. In shallow water, when a smaller portion of the funnel opening was submerged, trapping potential may have been reduced. In these instances, an increased proportion of benthic invertebrates, Oligochaeta and Chironomidae, may have been collected in the traps. Traps were not set when the water level in the pool was insufficient to submerge the funnel opening.

After 24 hours, the traps were emptied in the same order they had been set, one at a time, into an enamel pan. Traps were emptied by inverting the funnels and shaking the traps several times to dislodge many of the larger aquatic macroinvertebrates (beetles, odonates, snails, caddisflies, etc.) as well as any amphibian adults (salamanders, frogs, newts) or larvae. Any amphibians collected in the traps were identified in the field, counted, and returned to the pool. When tadpole were abundant, they were carefully removed in small groups in an effort to collect any invertebrates hidden in the tadpole mass. Some invertebrates may have been overlooked during this process. Additionally, any remaining organisms were handpicked out of the mesh walls of the trap. In cases where the members of one taxon were too numerous to effectively remove from the trap (i.e., thousands of Culicidae larvae), a representative number of individuals, approximately 100 to 200 organisms, were collected and an estimated number of the remaining organisms was recorded.

All invertebrates removed from the trap were immediately preserved in 75% ethanol and the contents of each trap were stored and recorded separately. Samplers spent approximately 10 minutes emptying each trap, working either alone or in teams of two. Because sorting was done in the field, it is likely that not every animal was counted or extracted from the traps. However, samplers maintained a consistent sampling effort throughout the sampling season. The traps were dried and scrubbed with a brush to remove any remaining organisms or debris before they were redeployed.

Replicate trapping efforts were conducted once during the first sampling round, and twice during the second round. In each case, traps were set approximately 5 m apart around the perimeter of the pool as described above; every other trap was treated as belonging to the same sample (i.e., traps 1,3,5 comprised replicate A; traps 2,4,6 comprised replicate B). Sample replicates were treated as unique samples during processing and taxonomic identification. Despite the consistent 10 m spacing between traps from the same replicate, it is possible that the increased trap density affected the overall trap catches.

D-net scoops**:** After setting the traps, a standard D-frame net was used to sample the aquatic macroinvertebrates associated with the leaf litter and muck on the bottom of the pools by taking several scoops of the pool substrate. The sample consisted of a composite of three shallow scoop samples along a randomly assigned transect in each pool. The sampling transect was designated by using a compass and the time, rounded to the nearest hour, just prior to sampling. The compass was divided into twelve, thirty-degree hours, with North representing 12 o'clock noon. The direction of the transect was selected by approximating the direction corresponding to the nearest hour on the compass. If the sampling occurred at two o'clock, the sampler followed an imagined transect running 60 degrees east of North, from one side of the pool, through the middle, to the opposite side. The three sub-samples were taken by scooping a few centimeters into the substrate using the flat end of the D-net, once at each end of the transect, and once in the middle.

The quantity of material collected at each site varied with substrate composition, substrate depth, and water column visibility. However, total sample size was limited to a maximum of a two-quart volume. Duplicate scoop samples were taken at two pools during each round of sampling. Variability in sample size and substrate composition between sites directly affected sampling consistency, therefore scoop samples realistically represent a qualitative rather than a quantitative measure of invertebrate composition.

In pools containing large numbers of tadpoles, the entire composite sample was placed in a bucket of pool water and the tadpoles were removed with an aquarium dip-net. Samples were not rinsed in the field to avoid unnecessarily disturbing the pools. All of the sample material was preserved with 75-80% ethanol in the field and stored in quart jars. Upon return to the laboratory, the sampled material was rinsed through a #30 sieve to remove fine sediment. Most coarse organic material was also rinsed and removed at this time. The rinsed sample was then stored in 75% ethanol and dyed with Phloxine B. If the sample was stored for more than one month before removing, sorting, and identifying the aquatic macroinvertebrates, the sample was rinsed and re-stored in fresh 75% ethanol to prevent sample degradation. Invertebrates were then picked from the sample and sorted according to the standard BASS protocol described below.

<u>Qualitative samples</u>**:** In addition to the funnel trap and D-net scoop methods of sampling, the pools were also qualitatively sampled to ensure the inclusion of all obvious taxa. After completing both the trap and substrate scoop sampling, the sampler actively searched for any taxa that were un-represented or under-represented in the samples collected using the previous two methods. This sampling included: sweeps with the D-net through the water column, looking for organisms on woody debris and rocks, sweeps through emergent vegetation or any distinctly different micro-habitat, and collecting handfuls or scoops of muck and leaf litter.

Total sampling time varied from pool to pool due to differences in size, habitat heterogeneity, and ease of sampling access. Total sampling time ranged from 5 minutes to 45 minutes. In an effort to minimize disturbance of amphibian egg masses, qualitative sampling was limited or aborted where amphibian egg masses were prevalent. Qualitative sampling efforts were also lessened or aborted in pools with large, ubiquitous amphibian larvae populations. Any amphibian larvae collected were removed and the sample was stored and preserved according to the D-net scoop protocol. Replicate qualitative samples were not collected. Qualitative samples were picked in a selective, rather than standard manner, in order to understand the overall taxa diversity rather than relative proportions of taxa. However, the organisms collected were taxonomically identified according to the protocol outlined below.

<u>Taxonomic Identification</u>**:** Each sample was rinsed of ethanol through a #30 sieve and spread evenly over a 12 inch by 18 inch white enamel tray, divided equally into twenty-four, sequentially numbered grids. A minimal amount of water was added to the sample to ease spreading, without causing organisms to float freely in the tray. A random number approach was employed to select the initial grid to be sampled. All aquatic macroinvertebrate organisms within the initial grid were removed and collected. This process was continued in the next sequential grid, until a minimum of 25% of the tray and 300 aquatic macroinvertebrates had been removed and collected. After finishing this process, a second analyst checked the sample for completeness. Additionally, the second analyst searched for, and collected as a separate qualitative sub-sample, any uncommon taxa not previously encountered in the sample. Once this process had been completed, the collected organisms were sorted into

major taxonomic groups and preserved in 75% ethanol for further identification, and the remaining sample material was discarded.

All organisms were identified to the lowest taxonomic level possible according to the guidelines outlined in the QAPP and described below. Due to a greater than anticipated sample volume, BASS contracted taxonomic services to Aquatec Biological Services for taxonomic identifications of all Diptera, Chironomidae, Oligochaeta and Trichoptera. All other taxonomic groups were identified by BASS. All samples were sorted to the genus/species level under a dissecting microscope and each organism was identified using standard taxonomic keys.

Taxonomists adhered to the following protocol for organisms requiring greater magnification, primarily Chironomidae and Oligochaeta. After sorting to the genus/species level under a dissecting microscope, the taxonomist mounted the greatest of twenty percent or ten animals from each taxon to confirm the identification. If more than two taxa were identified amongst the mounted specimens, the taxonomist either re-sorted the sample and repeated the mounting protocol, or assigned a count to each taxon identified, based on percent composition of mounted animals.

Both Aquatec Biological Services and BASS maintained a reference collection of identified species. Additionally, all organisms were archived according to sample identification number and major taxonomic groupings to ensure a long-term record. All taxonomists assigned a confidence level to each determination. Two taxonomists were responsible for each taxonomic group, to allow for in-house verifications on difficult identifications. BASS taxonomists reviewed all identifications within their area of expertise made by the outside contractor.

Algae

Algae sampling primarily targeted diatoms, however, filamentous algae were collected when present. An attempt was made to collect both benthic and planktonic diatom samples from each pool during the second round of sampling. Because several pools had dried by the second round of sampling, some sites do not have corresponding algae samples. Benthic algae samples were collected at all pools, however only 13 of the pools contained sufficient water to collect suspended algae samples. To maintain a consistent sampling effort, two biologists collected all algae samples.

Prior to collecting algae samples, all sampling bottles were first rinsed with distilled water and then with pool water, as described in the water chemistry section. Planktonic algae was sampled by collecting 500 ml of pool water near the deepest section of the pool in smaller pools, and several meters from the edge in larger pools.

In order to accurately represent the benthic algae populations in each pool, benthic algae was sampled by collecting leaf litter, sticks, rocks, and any other distinct substrate matter present, in a new, clean plastic bag at intervals approximating the funnel trap placement. Often times, the sampler’s activity in the pool was limited by the presence of amphibian egg masses. Once the substrate samples had been collected, attached algae was removed by scraping or brushing both sides of the substrate with a toothbrush, and rinsing the scraped substrate with pool water. This rinse water was collected and transferred into a separate 500 ml collection bottle. Any moss collected was gently squeezed in the rinse water to remove any associated algae. When present, filamentous algae was collected and added directly to the benthic algae sample. If the pool lacked standing water, substrate was collected for the benthic algae sample, however, the substrate samples were scraped in the lab and rinsed with distilled water. Benthic algae samples rinsed with distilled water were noted in the data records. All samples were transported in a cooler and immediately stored in a freezer upon return to the laboratory. However, samples collected at remote sites may have been at ambient temperatures for up to four hours. After all samples were collected, the frozen samples were sent overnight delivery to Dr. Jan Stevenson at the University of Kentucky (later relocated to Michigan State University) to assess species composition.

Amphibians

The amphibian survey began before the first round of aquatic macroinvertebrate sampling, and continued through the second round of macroinvertebrate sampling. In 1999, early warm spring rain events, which normally trigger amphibian emergence, did not occur over most of the state; thus, sampling was initiated during early warming spring temperatures. The spring rains did occur in 2000, and thus sampling was initiated at the typical time. Each pool was visually surveyed for adults, egg masses, and spermatophores. The sampler counted and identified each egg mass in the field; where egg masses were too numerous to count accurately, an estimate was recorded (e.g., “about 50”, or “over 100”). All breeding adults encountered were also identified and counted in the field. Due to the difference in timing of breeding among different species, egg masses of wood frogs had occasionally already hatched at the time of sampling. When wood frog tadpoles were encountered, their presence was recorded. The presence of spermatophores was recorded when encountered, although species was not determined. Additionally, physical habitat information was recorded including: descriptions of amphibian habitat used, physical characteristics of the pool, water and ambient air temperatures, prevalent weather conditions, and descriptions of the surrounding habitat. As noted in the aquatic macroinvertebrate section, amphibians trapped during aquatic macroinvertebrate sampling were counted and identified in the field, and new observations of egg masses, spermatophores, larvae and adults were recorded and compiled with previously collected amphibian data.

Quantitative Vegetation Sampling

Quantitative vegetation sampling in seasonal pools followed The Nature Conservancy "Quantitative Community Characterization" methodology (Sneddon 1993), except that the plot boundaries varied in size so as to include the entire seasonal pool, as defined by high water marks in the pool's basin. Under this method vegetation cover was estimated by stratum for the following layers: emergent trees, tree canopy, tree subcanopy, tall shrubs, short shrubs, herbaceous, and non-vascular (bryophytes). Species lists were developed for each stratum and percent cover was estimated for each species. Additionally, total canopy closure was estimated for each seasonal pool. Very few trees and shrubs were found growing in the seasonal pools themselves. Therefore, for the tree and shrub strata, species were identified and their percent cover estimated for the portion of the plants overhanging the pool high water sampling area. For the few seasonal pools with woody plants rooted in the sampling area, a note was made of this fact on the data sheet so that the abundance of these species could be used in the pool data analysis process. A copy of the plot data sheet (Form 3: Quantitative Community Characterization) is included in an appendix. Unknown vascular plants and bryophytes were collected and later identified.

Taxonomy and nomenclature for ferns, fern allies, and gymnosperms follows Flora of North America (Flora of North America Editorial Committee 1993). Vascular plant taxonomy follows Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Gleason 1991). Bryophyte taxonomy follows Anderson, et al. (1990) for mosses, except for Spagnaceae, which follows Anderson (1990). Liverwort taxonomy follows Stotler and Crandall-Stotler (1977).

During planning for this project, it was anticipated that there would be distinct zonation of rooted vegetation in many seasonal pools and that this vegetative zonation would be sampled by a transect method. In fact, very little zonation was observed and therefore no transect sampling was conducted.

Additional Site Information

Mapping of Surrounding Natural Communities

The natural communities and any significant human alterations were mapped and described for a 100 m radius around each seasonal pool during the site visit conducted between August and October. This was accomplished by pacing 100 m in the four cardinal directions from the edge of each seasonal pool and noting distances to changes in slope, boundaries of natural community types, and landscape fragmentation features. Each upland and wetland natural community encountered was assigned to 1 of the 80 types described in the Vermont community classification system (Thompson and Sorenson 2000). Within each natural community a 10x prism plot was taken to describe the forest dominants and estimate basal area. Forest canopy closure was estimated. Total cover of the shrub, herb, and bryophyte strata were also estimated and dominant species in each stratum were listed. Abundance of downed woody debris was also noted. The current condition of each natural community was assigned to a three-point scale described below in **Table 2**. Potential landscape fragmentation features that were noted and described included: forest clearcuts, agricultural fields, trails, logging roads, gravel or paved roads, and other development. When available, printed copies digital orthophotos from the 1990s were used as the base for mapping natural communities and fragmenting features.

Watershed Area

The watershed area of each seasonal pool was estimated based on topographic information gathered at each site during the natural community mapping process in conjunction with use of topographic maps and digital orthophotos.

Bedrock and Surficial Geology

The types of bedrock and surficial features can have significant influence on the water chemistry of surface waters and the drainage characteristics of seasonal pools. Field notes were taken describing these features and this information was compared to published maps on Vermont bedrock geology (Doll 1961), surficial geology (Doll 1970), and various county soil surveys produced by the Natural Resources Conservation Service.

Disturbance Ranking

A simple process was developed for ranking the level of human disturbance in and directly adjacent to each seasonal pool in order to allow comparisons between pools. In order to maximize objectivity and repeatability, this process uses categories of disturbance type and disturbance severity. Five disturbance types were evaluated for each pool: logging, hydrologic alteration, water quality alteration, agriculture, and development. Each of these disturbance types was assigned a disturbance severity rank: 0 = None, 1 = Minimal, 2 = Moderate, and 3 = High. A total disturbance rank for each pool was obtained by adding the severity ranks for each disturbance category. The disturbance categories of logging, agriculture, and development were rated based on the level and abundance of these activities in the pool's watershed and a 150-m radius circle surrounding each pool. The categories of hydrologic alteration and water quality alteration were rated based on a professional judgment assessment of the degree to which any disturbance would be expected to alter the water quality or hydrologic regime of a pool. For example, a small woods road located immediately downslope of a seasonal pool that results in raising a seasonal outlet of the pool, might be rated "1" for development, but "3" for hydrologic alteration (total disturbance rank of "4"). A pool adjacent to a large paved or gravel road which alters the pool hydrology and water quality might be rated "3" for development, hydrologic alteration, and water quality alteration (total disturbance rank of "9").

In addition to this disturbance ranking process, each pool was also given overall ranks for "current condition" and "landscape quality" (**Table 2**). These simple categories have been developed by the network of state Heritage Programs and The Nature Conservancy and have proved very useful in comparing the quality of natural community examples.

Table 2. Ranking for current condition and landscape quality

Current Condition of Community (check one): 1 = great, no signs of anthropogenic disturbance, no exotics, etc. 2 = moderate, some signs of anthropogenic disturbance, exotics, etc. 3 = poor, obvious signs of anthropogenic disturbance, lots of exotics, etc.
Landscape Quality (check one): 1 = surrounded by 1,000+ acres of intact matrix of natural communities 2 = surrounded by forest or undisturbed communities but there may be developed land or clearcutting nearby 3 = surrounded by fragmented forest, agricultural land or rural development 4 = surrounding area intensely developed

Data Analysis Methods

Precision and accuracy

Results from replicate field samples (macroinvertebrates and water chemistry) were compared to estimate sampling precision. Percent standard error (PSE) or relative percent difference (RPD) was used to describe precision. Analytical precision and accuracy for water chemistry was estimated by calculating RPD of duplicate analyses and percent recovery/percent bias of spiked samples.

Accuracy of aquatic macroinvertebrate data was ensured through standard laboratory procedures. Aquatic macroinvertebrate field samples were picked in the laboratory and checked by a second biologist. Taxonomic accuracy was achieved through the use of standard taxonomic keys for all identifications. The taxonomist assigned an identification confidence level to each determination. BASS maintains a reference collection of all identified taxa to assure consistent identifications. Some portions of the aquatic macroinvertebrate taxonomy were contracted to Aquatec Biological Services. Aquatec provided a reference collection to the BASS laboratory to ensure accuracy between taxonomists. At each laboratory, two people were responsible for identifying each taxonomic group, which allowed for in-house verifications on difficult identifications. Finally, all samples were archived by sample identification number and major taxonomic groupings to ensure a long-term record.

Macroinvertebrates

Macroinvertebrate data were reported as presence/absence and relative abundance of taxa by site and method. Taxa data were reduced to metrics for some analyses. Biological metrics are descriptors of communities that have primarily been applied to aquatic ecosystems. They describe characteristics such as taxa richness, density, and trophic and structural composition. These metrics used in combination or individually, are used to assess the ecological health of a community. For each metric to be useful, an expectation or standard must be established. Criteria for biological metrics are normally calibrated on data from least-disturbed sites, or reference sites. These sites set the standard; the upper limit by which all other sites may be compared. Prior to calibrating and assigning appropriate criteria scoring, however, potential metrics must be shown to consistently discriminate between reference sites and disturbed sites. Seventeen potential biological metrics were evaluated for their effectiveness in discriminating between disturbed and reference seasonal pools. Reference sites were designated as those sites with total disturbance values of less than 3, while disturbed sites showed values of 6-10. T-tests were used to determine if disturbed pools showed significantly different metric values from reference pools for each of the candidate metrics. The Mann-Whitney-U test was selected if data was non-normally distributed.

In order to investigate the level of macroinvertebrate sampling effort that would be efficient, representative, and would yield the most useful information, the characteristics of macroinvertebrate sampling methods were evaluated. The effects of multiple sampling techniques on estimates of total richness were evaluated by looking at taxa that were unique or common between methods. In order to evaluate optimal trap replication for taxa richness estimates, trap sampling efficiency was evaluated by using a jacknife estimate. Data is presented as a percentage of “expected” taxa of the actual observed from multiple trap collections.

Multivariate Analysis Techniques

Two-way indicator species analysis (TWINSPAN) (Hill 1979) was used to cluster seasonal pool sites by similarity of the aquatic macroinvertebrate and vegetation assemblages. TWINSPAN simultaneously classifies species groups and site groups and displays both on a two-way table. The analysis begins with division one, which divides the dataset into two dissimilar groups. The following divisions are conducted on both initial groups, each time splitting a group into two groups until a selected number of groups is achieved. The divisions were based on site presence-absence data for macroinvertebrates and percent cover data for vegetation. The analyses were run using the PC-ORD, version 4.2 (McCune and Mefford 1999). TWINSPAN was also used to classify sites using a combined macroinvertebrate/vegetation species presence data set. Macroinvertebrate and vegetation species lists were edited to remove rare species prior to analysis with TWINSPAN.

Detrended Correspondence Analysis (DCA)(Hill 1979; Hill and Gauch 1980) was used in order to further explore the similarities and differences between pools and to investigate the relationships between plant and macroinvertebrate communities and environmental variables. DCA ordinates species and sample plots using reciprocal averaging (Hill 1979). The resulting graphs or ordinations of plots (seasonal pools in this study) help to show similarities and differences between plots. Environmental parameters can be analyzed along with the plot ordinations to help elucidate the ecological basis behind plot groupings.

Site Reports

Individual site reports were prepared and are provided in **Appendix A.** These reports present a description of the site’s overall significance, physical setting and water chemistry, surrounding landscape conditions and evidence of alteration and disturbance, pool vegetation and surrounding terrestrial communities, and the amphibians and macroinvertebrates observed using the pool. Each site report includes a location map and one or more photos of the pool.

RESULTS AND DISCUSSION

Raw Data Presentation

Physical and Chemical

In general, pools sampled for this project were relatively high in elevation, had small watersheds, were not in the vicinity of other wetlands, and had an average maximum water depth and total wetted depth near 0.5 m. Physical parameters are summarized in **Table B1 of Appendix B.** The maximum pool water depth recorded in spring was almost a meter (0.93 m) at Dorset Pool. The average maximum depth (of springtime measurements) was 0.4 meter. The total wetted depth (included pool sediment) was 0.4 m, with a range of 0.2-1.06 m.

The majority of pools were located at mid elevations. Twenty sites were located at an elevation of at least 900 feet. Average elevation for pools sampled was 1196 feet. At 200 ft in elevation ,Arms Grant was the only low elevation site (< 500 feet) sampled. The majority (57%) of pools were located within 150 m of other seasonal pools (16 of 28 pools). Only 18% (5 of 28 pools) were located within 150 m of other wetlands. Most of the pools had small watersheds (range of 1,600 m^2 - 12,288 m^2, mean of 5,514 m^2). Only four pools had watersheds greater than 10,000 m^2.

Table 3 provides a summary of some key environmental conditions at the 28 pools. The environmental data shown was used in the multivariate analyses described in the Data Analysis section.

Table 3. Some key environmental conditions at the 28 Pools sampled.

Pool Name	Pool Elevevation (feet)	Dominant Soil Texture	Organic Soil Depth (cm)	Pool Watershed Area (sq. m)	Pool Perimeter (m)
Arm's Grant	200	sand	25	11300	150
Bald Mountain North	805	silt loam	10	6000	148
Bald Mountain South	780	silt loam	10	4500	54
Ball Mountain	960	organic	22	4100	35
Boyer	1300	organic	90	4020	80
Carlton Hill	1100	organic	15	3000	64
Dana Hill East	1460	organic	70	3000	107
Dana Hill South	1720	organic	25	4500	110
Dartmouth	2000	sandy loam	1	2500	105
Dorset	800	organic	15	2500	87
Hampshire Hill	1580	silt loam	20	5000	44
Hobart Spruce	1980	sandy loam	120	6750	85
Hughes	1020	organic	30	9000	87
Irish Hill North	1450	organic	20	11250	111
Irish Hill South	1450	sandy loam	5	11250	145
Iroquois Maple	700	organic	10	3000	80
Iroquois Tannic	700	silt loam	2	3000	60
Maidstone	1660	silt loam	1	12288	145
MBR Lake	1160	clay loam	2	1600	74
MBR Saddle	1190	organic	27	4000	40
Okemo	1130	organic	95	5600	115
Pine Hill	950	organic	120	9750	120
Shaw Mountain East	580	organic	35	6000	124
Shaw Mountain West	580	organic	30	3500	163
Sleepers River	1958	silt loam	15	4000	44
Thistle Hill	1730	organic	30	2500	105
Whitcher Mountain	1480	sandy loam	10	2500	28
Woodstock Inn	1080	silt loam	2	7990	58

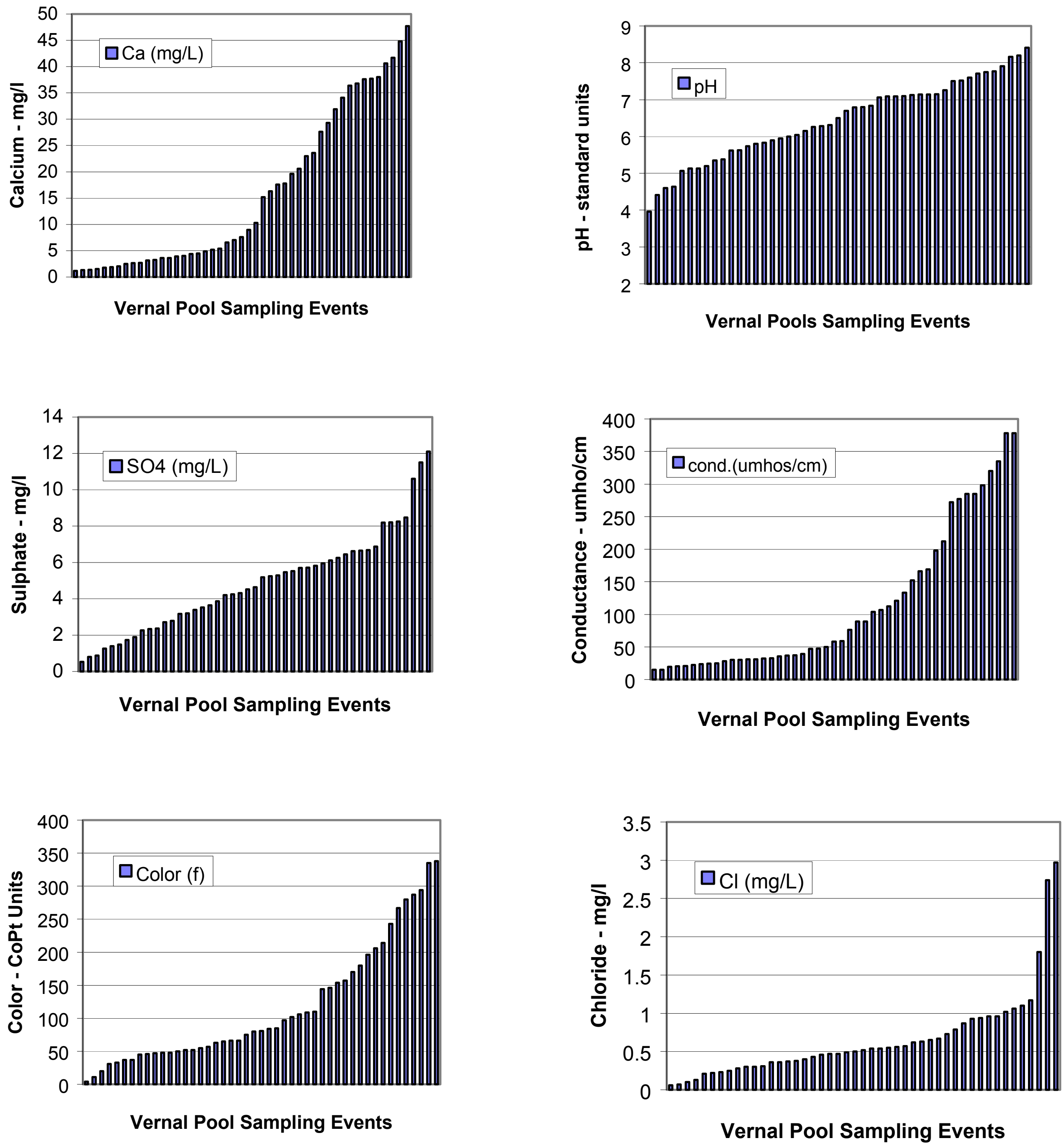
Table B2 in **Appendix B** presents the chemistry values for all seasonal pools sampled during the 1999 and 2000 seasons. The following table (**Table 4**) presents the ranges and means for each parameter along with when and where the highs and lows were observed.

Table 4. Water chemistry ranges, means, and locations of lowest and highest values.

Parameter	Ranges	Mean	Lowest	Highest
Color (Pt-Co)	7 - 484	130	Woodstock Inn (Early Spring 2000)	Hobart Spruce (Late Spring 1999)
Field pH (st. units)	4.41 – 8.41	---	Ball Mt. (Early 1999)	Shaw Mt. (East) (Early 2000)
Laboratory pH (st. units)	4.48 – 8.03	---	Hughes (Early 2000)	Shaw Mt. (East) (Early/Late 2000)
Alkalinity (mg/l $CaCO_3$)	(-) 0.1 - 178	51.0	Dana Hill (East) (Early 1999)	Shaw Mt. (West) (Early 2000)
Conductivity (uS/cm)	14.9 - 378	107	Hobart Spruce (Early 1999)	Dorset (Early/Late 2000)
Calcium (mg/l)	1.12 – 47.7	15.0	Hobart Spruce (Late 1999)	Dorset (Late 2000)
Magnesium (mg/l)	0.196 – 21.5	3.97	Dana Hill (East) (Early 1999)	Dorset (Late 2000)
Sodium (mg/l)	0.2 – 1.53	0.63	(a)	Dorset (Late 2000)
Potassium (mg/l)	0.183 – 2.80	1.02	Shaw Mt. (East) (Late 2000)	Maidstone (Late 2000)
Aluminum (mg/l) [(b)]	68 - 1250	298	Iroquois (Tannic) (Early 1999)	Hobart Spruce (Late 2000)
Sulfate (mg/l)	0.2 – 0.63	4.40	Whitcher Mt. (Early 1999)	Woodstock Inn (Late 2000)
Chloride (mg/l)	0.02 – 2.97	0.58	Hampshire Hill (Early 1999)	Dorset (Early 2000)
Nitrate (mg/l)	0.02 – 0.63	0.05	(c.)	MBR Saddle (Late 1999)

a. Several were at the 0.2 mg/l MDL.
b. Not collected if pH was < 6.00.
c. Most were at the 0.02 mg/l MDL.

Figure 2. Ranges of selected chemical parameters among the 28 seasonal pools are shown in the following figures. Figures show the distribution of values among all sampling events at all pools and represent the range of water chemistry characteristics among the 28 seasonal pools sampled.



Disturbance Ranking

The results of the disturbance ranking process for all 28 pools are presented in **Table 5**. Of the disturbance types, logging was rated as the most significant, with 21 of the pools showing some disturbance and the highest sum of individual ranks by disturbance type. Hydrologic alterations and expected effects on water quality were noted at 18 pools. None of the pools were determined to be disturbed by agricultural activities and seven were disturbed by some form of development (roads, trails, buildings, or golf course). Total disturbance rank for the pools ranged from highs of "10" for Carlton Hill (directly adjacent to a gravel road) and "8" for Boyer (surrounding clearcut and skid road at outlet) and Okemo (surrounded by a golf course), to a low of "0" for the two Bald Mountain pools, the two Shaw Mountain pools, and Pine Hill. All five of the latter pools occur in very high quality landscapes with little human disturbance and by professional judgement the pools are in very good condition.

Reference quality pools were determined to be those with a total disturbance rank of "3" or less and with no individual disturbance type ranked above "2" (moderate). Maidstone is the only pool considered reference quality having an individual disturbance type rank of "2". Although there was recent logging around this pool, bordering trees remain and there was no physical disturbance to the pool itself. Five pools were determined to be permanent based on observations over the two field seasons.

Table 5. Disturbance and condition ranking of the 28 pools sampled.

Pool Name	Logging Rank (1)	Hydrologic Alteration Rank (1)	Water Quality Rank (1)	Agri-culture Rank (1)	Devel-opment Rank (1)	Total Disturbance Rank	Landscape Quality(2)	Current Condition(2)	Reference Quality Pool
Arm's Grant	1	1	2	0	2	**6**	4	2	**No**
Bald Mtn North	0	0	0	0	0	**0**	1	1	**Yes**
Bald Mtn South	0	0	0	0	0	**0**	1	1	**Yes**
Ball Mountain	1	1	1	0	0	**3**	1	2	**Yes**
Boyer	3	3	2	0	0	**8**	2	3	**No permanent**
Carlton Hill	1	3	3	0	3	**10**	3	3	**No permanent**
Dana Hill East	1	0	0	0	0	**1**	1	1	**Yes**
Dana Hill South	2	1	1	0	0	**4**	2	2	**No**
Dartmouth	3	1	2	0	0	**6**	3	3	**No**
Dorset	1	2	0	0	2	**5**	3	2	**No**
Hampshire Hill	2	1	1	0	0	**4**	2	2	**No**
Hobart Spruce	2	1	1	0	0	**4**	2	2	**No permanent**
Hughes	2	1	1	0	0	**4**	2	2	**No**
Irish Hill North	3	2	2	0	0	**7**	2	2	**No**
Irish Hill South	3	2	2	0	0	**7**	2	2	**No**
Iroquois Maple	1	0	0	0	0	**1**	2	1	**Yes**
Iroquois Tannic	1	1	1	0	2	**5**	3	2	**No**
Maidstone	2	0	1	0	0	**3**	2	2	**Yes**
MBR Lake	0	1	1	0	2	**4**	2	2	**No**
MBR Saddle	0	2	2	0	2	**6**	2	3	**No**
Okemo	2	2	2	0	2	**8**	3	2	**No**
Pine Hill	0	0	0	0	0	**0**	2	1	**Yes**
Shaw Mtn East	0	0	0	0	0	**0**	1	1	**Yes permanent**
Shaw Mtn West	0	0	0	0	0	**0**	1	1	**Yes permanent**
Sleepers River	1	0	0	0	0	**1**	1	1	**Yes**
Thistle Hill	1	2	1	0	0	**4**	2	2	**No**
Whitcher Mtn	1	0	0	0	0	**1**	1	1	**Yes**
Woodstock Inn	2	2	2	0	0	**6**	3	2	**No**
Sum by Type of Disturbance	36	29	28	0	15				

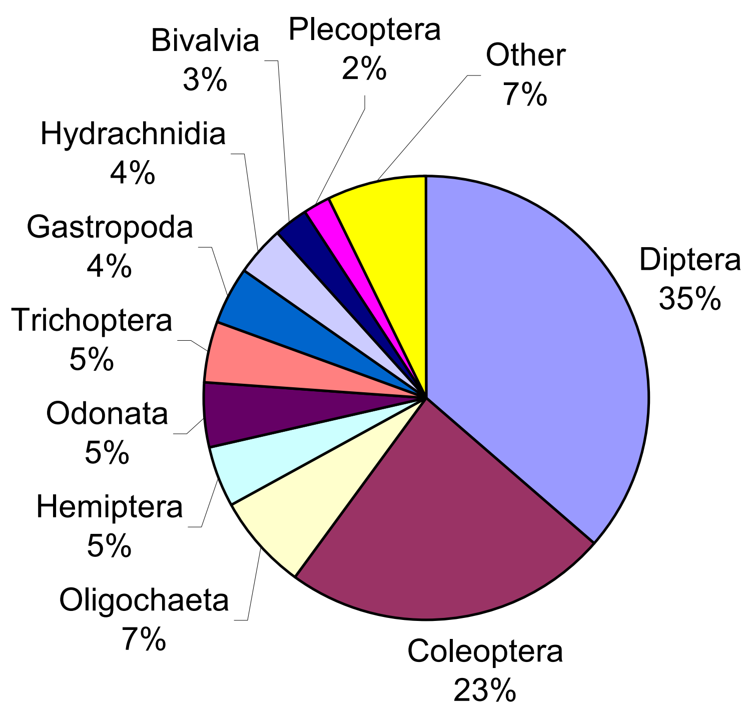
(1) Disturbance severity ranks: 0 = none, 1 = minimal, 2 = moderate, 3 = high
(2) See Table 2 for explanation of landscape quality and current condition ranking codes.

Biological

Aquatic Macroinvertebrates

A taxa list for all aquatic macroinvertebrate species is presented in **Appendix B: Table B9**. Aquatic macroinvertebrate species lists for each site are presented in the individual site reports **(Appendix A)**. Of all the taxa collected, two orders composed the majority of all taxa found in this study: Diptera (35% of total taxa richness) and Coleoptera (23%) (**Figure 2)**. All other orders individually composed no more than 7% of total richness. The "Other" category on **Figure 2** includes the following orders: Hirudinea, Lepidoptera, Ephemeroptera, Tricladida, Megaloptera, Anostraca, Isopoda, Neorhabdocoela, Conchostraca. Each of these orders had no more than five taxa from any of the seasonal pools.

Figure 3. Aquatic macroinvertebrate percent taxonomic richness by order. Percentages are based on a comprehensive project taxonomic list from all pools and all sampling methods**.**



Non-Insect Invertebrates

The following section discusses the occurrence of aquatic macroinvertebrates by taxonomic class.

Crustacea: There are four subclasses of crustaceans found in the seasonal pools sampled. These include Branchiopoda, Malacostraca, Copepoda, and Ostracoda. While Copepoda and Ostracoda were collected, counted and archived, they were not specifically sought after, and were not identified beyond subclass. No further consideration of these groups will be given in this report.

Branchiopoda: There are three major groups of Branchiopoda found in Vermont's seasonal pools: Anostraca, Conchostraca and Cladocera. The cladocerans were collected, counted and archived, but were not identified and will not be discussed here.

Anostraca (fairy shrimps): *Eubranchipus bundyi* was the only species of fairy shrimp found in the pools sampled. Many could only be identified as *Eubranchipus* sp. because they were immature.

Conchostraca (clam shrimp): *Lynceus brachyurus* was the only clam shrimp found in the pools. It was collected at one site, Arms Grant, in late spring. This seasonal pool was sampled prior to this study on June 24, 1997 and at that time, *L. brachyurus* was the dominant macroinvertebrate. Apparently, they can be abundant in favored habitats during wet summers and prefer longer lasting pools (Smith 1995).

Malacostraca: In Vermont surface waters there are three groups of Malacostraca: Amphipoda, Decapoda, and Isopoda. Amphipoda were not collected from any these seasonal pools. Decapoda (crayfish) are not generally collected from temporary waters in Vermont. Only one crayfish was observed in the 28 pools: a large unidentified crayfish from Carlton Hill, suggesting this is a permanent pool.

Isopoda (sowbugs): There are two isopods typically found in permanent waters in Vermont, but *Asellus* (*Caecidotea*) *racovitzai* is more likely found in cooler spring fed streams. *Asellus communis* was the most abundant taxon found in Bald Mountain North during the early spring sampling of 1999. *Asellus* sp. (immature, but believed to be *A.communis*) was also found in Shaw Mountain East in the late spring of 1999, but was not found in other seasonal pools. It is unlikely that Bald Mountain North holds water in the summer, but Shaw Mountain East may hold water in shallow pockets in some years. Other seasonal pools deemed permanent did not contain sowbugs. The isopods can be found in shallow pockets of water (Bell 1971) and possibly even wet substrates.

Oligocheata (aquatic worms): Four families of oligochaetes were collected from these seasonal pools along with the familiar earthworm Lumbricina. There were eight species of Naididae, eight species of Tubificidae, two species of Lumbriculidae and unidentifiable Enchytraeidae. One of the most common worms collected was *Lumbriculus variegatus*, a common and widespread species (Brinkhurst 1986). Others frequently collected included *Nais communis, Dero digitata* and *Tubifex tubifex*.

Hirudinea (leeches): While leeches were never abundant, three species were collected from seven seasonal pools. These were *Placobdella picta, Helobdella stagnalis* and *Oligobdella biannulata* and all are from the family Glossiphoniidae. All of the seven pools where leeches were collected have extended hydroperiods containing pockets of wet soils and refugia during the summer periods.

Mollusca (clams and snails)*:* In general, clams and snails prefer waters with higher pH and calcium levels for shell formation. Those seasonal pools with the best buffering capacity (high pH and Ca) tended to support the greatest abundance and diversity of mollusks. The mollusks living in temporary waters have adapted to these conditions and often have certain physiological similarities. Many are short lived, have the ability to survive long periods of hibernation and aestivation, and are tolerant to drought and extreme temperatures (Batzer 1999)

Bivalvia (clams): No freshwater mussels (order Unionoida) were collected from any of the 28 pools. Only a few fingernail clams (order Veneroida) have seasonal pool adaptations. Six species of fingernail clams from all three genera were collected from the pools. *Pisidium casertanum* was the most widespread and abundant. It was found in 21 mostly well buffered pools (the exception was Thistle Hill with a pH of 5.48 and an alkalinity of 5.95 mg/l $CaCO_3$). This species is amphibious (Smith 1995) and has been collected in Vermont from among moist leaves and soil from dried up pools. It was collected from Whitcher Mountain, Dartmouth, Dorset and Hobart Spruce where no other clams or snails were found. Other *Pisidium* clams collected were *P. ventricosum*, found in five pools, and *P. ferrigneum* from Shaw Mountain West. The second most common fingernail clam was the *Sphaerium* clam *Sphaerium occidentale*. This clam was collected from 10 seasonal pools. This species is found exclusively in temporary pools (Smith, 1995, Mackie 1983). Two species of *Musculium* clams were collected from four pools including both *Musculium securis* (from Shaw Mountain West) and *M. partumeium* (from Shaw Mountain West and Arms Grant). Hampshire Hill and Irish Hill South had populations of immature (unidentifiable past genus) *Musculium*. Shaw Mountain West had the most diverse fingernail clam fauna in that all six species collected from these pools were found there.

Gastropoda (Snails): A total of 12 species of snails were collected from three families: Lymnaeidae (four species); Physidae (four species); and Planorbidae (four species). The most commonly collected snails were *Gyraulus parvus* (nine pools), *Stagnicola elodes* (eight seasonal pools), *Physa sp*. (immature) (six seasonal pools), *Aplexa elongata* (five pools) and *Fossaria modicella* (five seasonal pools). Most of these are cosmopolitan species and can inhabit temporary waters. The preferred habitat of *Aplexa elongata* is temporary waters, but has been collected in various types of more permanent wetlands (Jokinen 1992). It was not found during this study in any of the permanent pools. Shaw Mountain East had the most diverse snail community with nine species followed by Shaw Mountain West with eight species. All three families were collected from these pools.

Hydrachnidia (Mites): Only the true water mites were identified. Soil mites (Oribitei), all tentatively identified as *Hydrozetes sp*. were picked from the samples, but not counted. Mites prefer less acidic conditions and were not abundant in the more acidic seasonal pools. Some genera found in these pools are well adapted to seasonal pools including *Thyas sp*., *Hydryphantes sp*., and *Piona sp*. (Pennak 1978). *Thyas sp*. was collected from 21 seasonal pools and was by far the most commonly encountered species. *Tiphys* sp.and *Hydrachna* sp. were also frequently collected. There were 11 hydrachnid genera collected. Pools with the greatest diversity were Irish Hill North, Irish Hill South, Dartmouth, Shaw Mountain West and Shaw Mountain East. Each of these pools contained five species. All of these pools lacked significant canopy cover, either as a result of silvicultural activities or because of their large size.

Turbellaria (Flatworms): Two orders of flatworms were collected: Neorhabdocoela and Tricladida. No attempt was made to identify the neorhabdocoels beyond the order level. The small green neorhabdocoel with reddish cocoons, *Dalyellia viridis,* has been identified from other pools in Vermont and it is possible some of the neorhabdocoels collected are this species. Five pools contained flatworms from the order Neorhabdocoela.

Two species of Tricladida were collected. *Dugesia tigrina* was found in three seasonal pools and is the most common flatworm in Vermont, found in a variety of habitats. According to Smith (1995) it can be found in permanent warm water habitats. Only one of the three seasonal pools, Shaw Mountain West, was deemed permanent, but Pine Hill may contain saturated soils in most years. The third pool, Bald Mountain South, is thought to dry up during the summer periods. The triclad, *Hymanella retenouva* was collected from five seasonal pools and is indicative of temporary waters (Smith 1995). This flatworm was found in Carlton Hill, a pool considered to be permanent. It can tolerate a wide range of pH values as two of the pools were acidic (Ball Mountain and Pine Hill) while others, like Woodstock Inn, were well buffered.

Aquatic Insects

All major orders of aquatic insects were found in the study pools. Even a few species of stoneflies, generally associated with flowing waters, were collected from a limited number of pools. The greatest diversity of insects came from the orders Diptera (true flies) and Coleoptera (beetles), accounting for 58 % of the species collected.

<u>Trichoptera (caddisflies)</u>: Caddisflies were found in 27 of the 28 pools, absent only from Maidstone. Twenty-five of the pools had *Limnephilus indivisus*, a species common to temporary and semi-permanent woodland ponds and marshes (Flint 1962). Twelve of the pools contained only a single species of caddisfly, and in 10 of those pools that species was *L. indivisus*. Those pools with the greatest Trichoptera richness (Dorset, Carlton Hill, Shaw Mountain East, and Okemo) had four species. *L. indivisus* and *Ptilostomis sp*. were found in all of these pools and *Anabolia sp*. was found in all but Shaw Mountain East. *Anabolia sp*. and *Ptilostomis sp*. were each found in six pools, making them the second most common caddisflies.

<u>Ephemeroptera (mayflies)</u>: Three species of mayflies, *Callibaetis* sp., *Siphlonurus* sp. and an unidentified Leptophlebiidae (probably *Leptophlebia* sp.) were found in five pools. These species are capable of surviving temporal, and often inhospitable conditions. All can frequently be collected from small, shallow pools (Edmunds et. al.1976). Shaw Mountain East and Thistle Hill had two species. Boyer, Bald Mountain North and Dana Hill South each had a single species. Two of the five pools were considered semi-permanent and two have short hydroperiods. *Siphlonurus sp.* was found in those pools with the shortest hydroperiods.

<u>Plecoptera (stoneflies)</u>: A total of nine individual stoneflies were found in six pools from five families. The Plecoptera are flowing water organisms and their presence in few pools in limited numbers suggests that pools are not a habitat where they prosper. Two of the six pools where they were found are considered permanent, but even those do not have significant inlets, outlets or the stoneflies preferred hard substrate. Six of the stoneflies were immature, allowing for only family level identifications. Woodstock, the only pool where three of the stonefly taxa were found, shows evidence of an intermittent tributary that may be a source of the occasional organisms found. The taxa encountered (Leuctridae, Nemouridae, and Taeniopterygidae) are typical of small, forested, sometimes intermittent streams in Vermont. Stonefly presence in seasonal pools is unusual and the exception, but may indicate the presence of connectivity with stream habitat. Further assessments of these pools might further elucidate why these predominantly flowing water taxa were collected.

<u>Megaloptera (hellgramites and alderflies)</u>: Two taxa of Megaloptera were found in 12 seasonal pools. The most commonly collected was the lotic fishfly, *Chauloides* sp. found in all pools. The alderfly *Sialis* sp. was also collected from two pools. Dana Hill East and Hobart Spruce contained both taxa.

<u>Lepidoptera (butterflies and moths).</u> Lepidoptera were collected from eight pools and represented two families (Pyralidae and Tortricidae). There were two taxa of Pyralidae (*Synclita* sp. and *Acentria* sp*)* and one taxa of Totricidae (*Archips* sp.). Many of the Lepidoptera were unidentifiable, possibly terrestrial.

Odonata (damselflies and dragonflies): There was considerable diversity with at least 14 Odonate taxa collected from 16 pools. In many cases, identifications were limited to family level, group (between two families) and even suborder identifications because they were collected as early instars. As a result, a total taxa count is impossible.

Zygoptera (damselflies): *Lestes* sp. was the most widely collected damselfly, taken from 10 pools. Three additional genera were collected from Shaw Mountain East and two more from Shaw Mountain West, resulting in six genera collected from all pools. Both Shaw Mountain East with four taxa, and Shaw Mountain West with three taxa were the pools with the most diverse damselfly communities. This may be due to the fact that they are permanent.

Anisoptera (dragonflies): *Aeshna tuberculifera/umbrosa* was the most widely collected dragonfly taken from six seasonal pools. Seven additional taxa were collected from either one or two pools apiece. The pools with the greatest diversity were Shaw Mountain West (five taxa), Shaw Mountain East (three taxa), Hobart Spruce (three taxa), and Boyer (three taxa). These pools are all permanent.

Hemiptera (true bugs): Seven families of hemipterans were collected from 20 of the seasonal pools. Species identifications were not always possible because many of the specimens were immature. The families Corixidae (water boatmen) and Notonectidae (backswimmers) were the most abundant. Corixidae from the genera *Callicorixa* and *Hesperocorixa* were found in seven of the pools. Corixids have adapted to seasonal pool environments to the greatest degree of all true bugs, where they have the ability to take full advantage of the food resources (Wiggins 1980). Backswimmers were identified to three species: *Notonecta insulata, N. irrorata,* and *N. undulata*. *Notonecta* sp. can be voracious consumers of mosquitoes and other insects and may be found in great numbers in seasonal pools (Wiggins 1980).

The pools with the greatest true bug diversity were Shaw Mountain East (nine taxa), Hobart (seven taxa), Shaw Mountain West (six taxa), Dartmouth and Maidstone (five taxa each). Three of these are permanent seasonal pools where overwintering probably occurs. Hemipterans overwinter in permanent waterbodies and utilize seasonal pools during the springtime (Wiggins 1980).

The Hemipterans were some of the more interesting aquatic insects collected from the pools. The largest was a species of giant water bug *Lethocerus americanus* (five pools), and one of the smallest is the pygmy backswimmer *Neoplea striola* (one pool). Water scorpions, *Ranatra fusca* are stick-like predators and were found in five pools. These three species were generally found in the largest, or more permanent pools.

Coleoptera (beetles): Beetles were second only to the Diptera (true flies) in terms of pool taxa richness. The Coleoptera were exceptionally diverse and found in all the pools. A total of 74 taxa were collected. The families Curculionidae (weevils) and Staphylinidae (rove beetles) along with the dytiscid genera *Hydroporus* and *Agabus* were not identified to species. Speciation of the adults of these taxa would have increased the beetle richness. Larval keys are not available for most species level identifications. The greatest diversity was in the families Dytiscidae (predaceous diving beetles-37 taxa) and Hydrophilidae (water scavenger beetles-19 taxa). Even lacking species-level identifications, these two families accounted for at least 75 % of the beetle species.

Some beetles can overwinter in dry pools as eggs, larva and less frequently as adults. Overwintering genera collected from these pools include species from the Dytiscidae: *Agabus, Hydroporus, Rhantus;* Haliplidae: *Haliplus, Peltodytes;* Hydrophilidae: *Anacaena, Helophorus,* *Hydrobius* and Scirtidae: *Cyphon* sp.(Wiggins 1980). *Agabus* sp. was the most frequently collected overwintering resident, being found in 23 seasonal pools. *Hydroporus* sp. (19 pools) and *Dytiscus* sp. (17 pools) were also regularly collected from these pools. The genera *Agabus* and *Hydroporus* are species-rich in New England's seasonal pools (Larson, personal communication). Six species were identified from the genus *Hygrotus,* which was found in nine pools. *H. turbiditus* was the most common, being observed in four pools. Four species of the genus *Dytiscus* were found in the pools. *D. verticalis* was the most prevalent, being found in nine pools. The most frequently collected overwintering member of the Hydrophilidae family was *Hydrobius fuscipes*, found in 20 pools.

Other beetles are non-wintering spring migrants to pools. These overwinter primarily in permanent waters. Overwintering genera (not necessarily all species) found in these pools are the Dytiscidae; *Acilius*, *Colymbetes*, *Dytiscus, Graphoderus, Hydaticus, Laccophilus* and *Rhantus*, Gyrinidae; *Gyrinus* and Hydrophilidae; *Cymbiodyta, Enochrus, Hydrochara* and *Tropisternus* (Wiggins 1980). *Acilius* was the most frequently collected spring arrival and found in all pools with the exception of Carlton Hill. Its absence here is probably coincidental and unlikely to be related to the landscape disturbance that characterizes this pool. There were three species found, with *A. semisulcatus* collected most from 23 pools. *A. sylvanus* and *A. mediatus* were found roughly equivalently in half the pools as *A. semisulcatus*. All three pecies were often found together.

The most frequently collected non-wintering Hydrophilidae beetle genus was *Tropisternus.* Five species of this genus were collected from 11 pools with *T. mixtus* found in five pools. Eight pools had three species of Gyrinidae (whirlygig) beetles. The most commonly found were *G. affinis* and *G. lecontei*.

Diptera (true flies): Dipteran larvae had the greatest richness and were often the dominant aquatic insects found in the study pools. Thirteen families of true flies were collected. Thirty-five percent of the taxa collected were from the Family Chironomidae: fifty-two taxa of non-biting midges were collected. The six most commonly observed were *Chironomus sp*. (24 pools), *Polypedilium trigonus* (17 pools), *Limnophyes* sp. (15 pools), *Larsia* sp. (14 pools), *Phaenopsectra* sp. (13 pools), and *Pseudosmittia* sp. (13 pools). Members of these genera were often the dominant taxa in the pools.

Mosquitoes (Family Culicidae) were ubiquitous, being collected from 27 of the 28 pools. No mosquitoes were captured from Maidstone. Eighteen species were identified from the genera, *Aedes, Ochlerotatus, Anopheles, Culex,* and *Culiseta.* For this report, the genus *Ochlerotatus* was identified as the pre-revised genus *Aedes*. All of the species of *Aedes* reported here (with the exception of *A. vexans*) are now in the genus *Ochlerotatus*. The species found most frequently in seasonal pools were *A. excrucians* (19 pools), *A. communis* (18 pools), and *A. provocans* (15 pools). The pools with the greatest richness were Hughes and Pine Hill (nine species), Whitcher and Shaw Mountain East (eight species), Shaw Mountain West and Dana Hill East (six species).

Three genera of Phantom Midges (*Mochlonyx, Chaoborus, Eucorethra*) were collected from the seasonal pools. *Mochlonyx* sp. was routinely found in all but Iroquois Tannic and Hobart Spruce and was often a dominant taxon. Fourteen pools had the genus *Chaoborus* of which there were four species (*C. trivittatus, C.americanus, C.albatus* and *C.flavescens*). *C. trivittatus* was found in all fourteen pools where Chaoborids were present**.**

Amphibians

A summary of amphibian presence and absence is presented in **Table 6**. The two most common amphibians found at the pools were the wood frog (*Rana sylvatica*) and the spotted salamander (*Ambystoma maculatum*). They were found at 27 of 28 sites (96.4%). The least common species was the Jefferson salamander (*Ambystoma jefersonian x laterale*), found at only 25% of the sites (7 of 28). Green frogs (*Rana clamitans*) and eastern newts (*Notophthalmus viridescens*) were found at 54% (15 of 28) and 64% (18 of 28) of the sites.

Table 6. Summary of amphibian occurrence in the 28 study pools . U= present

Site Name	Wood Frog	Spotted Salamander	Salamander unidentified	Jefferson Salamander	Green Frog	Eastern Newt
Arms Grant	U	U	U			
Bald Mountain North	U	U	U	U	U	U
Bald Mountain South	U	U	U	U	U	U
Ball Mountain	U	U	U		U	U
Boyer	U	U	U	U	U	U
Carlton Hill Rd.	U	U			U	
Dana Hill East	U	U				
Dana Hill South	U	U				U
Dartmouth	U	U				U
Dorset	U	U				
Hampshire Hill	U	U			U	U
Hobart Spruce	U	U	U		U	U
Hughes	U	U	U			U
Irish Hill North	U	U			U	U
Irish Hill South	U	U			U	
Iroquois Maple	U	U	U	U	U	
Iroquois Tannic		U				U
Maidstone	U	U			U	U
MBR Lake	U	U			U	U
MBR Saddle	U	U		U	U	
Okemo	U	U				U
Pine Hill	U	U	U			
Shaw Mountain East	U	U	U	U	U	U
Shaw Mountain West	U	U	U	U	U	U
Sleepers River	U	U	U		U	
Thistle Hill	U	U				U
Whitcher Mountain	U	U	U			U
Woodstock Inn	U					
Cumulative Presence	**96.4%**	**96.4%**	**46.4%**	**25.0%**	**53.6%**	**64.3%**

All species of adult amphibians were identified at the following sites: Ball Mountain, Bald Mountain North, Bald Mountain South, Boyer, Shaw Mountain East and Shaw Mountain West.

Wood frog and Ambystomid salamanders are characteristic of seasonal pools as they cannot withstand predation pressure from predatory fish populations. The presence of these amphibians indicates resident breeding populations. Green frogs spend a year in the larval stage and therefore would not breed successfully in pools that become dry annually. The presence of green frogs in a seasonal pool indicates transient individuals (usually juveniles) using a pool temporarily for purposes other than breeding. Eastern newt presence may indicate more permanent waters, or less dependable reproductive success.

Plants

The percent cover of vascular plant and bryophyte species identified in the 28 pools is presented in **Appendix B, Tables B3 and B4.** **Table B3** of this Appendix includes both the overhanging woody plants as well as the vascular plants and bryophytes rooted in each pool. **Table B4** includes only those species that are rooted in each of the pools. The information in **Table B4** was used in the multivariate analyses described in later sections.

There was extreme variability in both the plant species composition and the overall abundance of plants in the 28 pools visited. Canopy cover from overhanging trees of surrounding upland forests ranged from 5 to 100 percent, with an average canopy cover over the pools of 28 percent. There was similar variability in rooted herbaceous plant cover in the pools, with cover ranging from 0 to 95 percent and averaging 28 percent.

A total of 99 species of vascular plants and bryophytes were identified growing within the pools' high water marks. However, species richness was low for all pools, ranging from highs of 25 species at Hughes and 21 species at Arm's Grant and Okemo, and lows of 0 species at Ball Mountain and only 2 species at Bald Mountain South, Iroquois Tannic, MBR Saddle, and Pine Hill. The species that occurred with the greatest frequency in the 28 pools were sensitive fern (*Onoclea sensibilis*) (20 pools), marsh fern (*Thelypteris palustris*) (15 pools), common water-horehound (*Lycopus uniflorus*) (10 pools), and cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), and mad-dog skullcap (*Scutellaria lateriflora*) (9 pools).

Several rare to uncommon species were identified in the 28 pools. Green dragon (*Arisaema dracontium*) grows in the Iroquois Maple and is considered rare and is on the Vermont State Threastened Species List. Short-awn Foxtail (*Alopecurus aequalis*) is an uncommon species in Vermont and grows in the Arm's Grant. Other uncommon species were alkali-grass (*Puccinella fernaldi*), which grows in the Hobart Spruce and yellow water-crowfoot (*Ranunculus flabellaris*), which grows in the Shaw Mountain West. The moss *Physcomitrium immersum* is a new species for Vermont and is generally considered rare across its range.

Only three non-native species of vascular plants were found in the 28 pools. Common nightshade (*Solanum dulcamara*) grows in eight of the pools, never with more than three percent cover. Self-heal (*Prunella vulgaris*) and watercress (*Rorippa nasturtium-aquaticum*) each occur in only one pool each.

The most frequent tree species in the uplands adjacent to the pools were red maple (*Acer rubrum*) (20 pools), eastern hemlock (*Tsuga canadensis*) (18 pools), sugar maple (*Acer saccharum*) (15 pools), American beech (*Fagus grandifolia*) (15 pools), and American ash (*Fraxinus americana*) (15 pools).

Algae

Algae (diatom) data are available only for the thirteen pools sampled in 1999. These data are summarized in **Table 7**. Additional data are presented in **Table B5 of Appendix B**. Because the data are incomplete, algae data were not included in the overall pool classification analysis.

Table 7. Percent composition of diatom genera at thirteen seasonal pools, 1999. Number of species represents those species making up at least one percent of the composition in any one pool. Shaded columns indicate "alkaline" pools identified by TWINSPAN; non-shaded columns are "acid" pools identified by TWINSPAN.

Genus	Number of Species	Ball Mt.	Boyer	Dana Hill East	Dana Hill South	Hampshire Hill	Hobart	Iroquois Maple	MBR Saddle	Pine Mt.	Shaw Mt. East	Sleepers R.ver	Thistle Hill	Whitcher Mt.
Achnanthes	4		24					2			16	9		
Cymbella	1		3					1			1	1	3	
Diatoma	1											7		
Eunotia	11	98	2	43	3	91	4	37	68	95	1	8	48	88
Fragilaria	3		3		87						2	1		
Frustulia	3			2		1	11						2	
Gomphonema	7		17		2		2	15	28		23	12	14	1
Meridion	1												2	
Navicula	10		18	2	1			24	1		24	7	2	2
Neidium	2						4							
Nitzschia	7		6		3		17	5			22	10	2	1
Pinnularia	13	2		52		4	58	9		5			3	6
Planothidium	1		3								8			
Stauroneis	2		5		2	3	3	5	2		1	18	2	
Synedra	1		19								1	27		2
Tabellaria	2												21	

The most speciose genera were *Pinnularia, Eunotia*, and *Navicula*, accounting for nearly 50 % of the species encountered. *Eunotia spp.* was the only genus that was found in all thirteen pools. This genus was also a dominant component of the diatom flora in several of the pools. The genera *Neidium* and *Tabellaria* were found in only one pool each.

Some descriptive observations on algae species distribution are made below.

> *Eunotia curvata subarcuata* was one of the most common and at times dominant taxon observed. It comprised more than 80% of the diatom flora in four pools (Ball Mtn., Hampshire Hill, Pine Mtn., Witcher Mtn.) but was rare (<1%) or not observed in three pools (Boyer, Shaw Mt. East, Hobart). The three pools where it was rare are considered to be permanent rather than seasonal pools.
>
> *Gomphonema parvulum* was relatively common, occurring in ten of the thirteen pools, and was moderately abundant (>10%) in four of the pools: Boyer, Pine Mtn., MBR Saddle, and Thistle Hill.

Fragilaria construens was rare or absent in 12 of the 13 pools, but made up 87% of the diatom fauna in one pool – Dana Hill South.

Tabellaria flocculosa was observed in only one pool, Thistle Hill, where it was moderately abundant (20%).

Synedra rumpens was observed in four pools, in two of which (Boyer and Sleepers) it was moderately abundant

A TWINSPAN of weighted taxa presence/absence was conducted on the 13 pools. The first division produced two groups of pools that appeared to be differentiated primarily by pH and related ionic parameters. There were significant differences between the groups in the mean values of pH ($P<0.001$, Paired t-test), calcium and alkalinity ($P=0.002$, Mann Whitney Rank Sum). The "acid" pools included Ball Mountain, Dana Hill East, Hampshire Hill, Hobart, MBR Saddle, Pine Mountain, Thistle, and Witcher Mountain. The "alkaline" pools included Boyer, Dana Hill South, Iroquois Maple, Shaw Mountain East, and Sleepers River. There was no difference in disturbance rank between the groups.

Table 8. Selected parameter statistics for "acidic" and "alkaline" pools identified by TWINSPAN of diatoms.

Parameter	**Mean/*Median* A**	**SD A**	**Mean/*Median* B**	SD B	P
Calcium mg/l	3.43	na	18.6	na	0.002 (MW-U)
pH	5.35	0.52	6.91	0.58	< 0.001 (T-test)
Alkalinity mg/l	4.45	na	49	na	0.002 (MW-U)
Disturbance	2.88	2.03	2.8	3.27	0.960 (t-test)
Perimeter m	71	37	88	31	0.416 (t-test)
Percent Canopy	77	21	54	38	0.178 (t-test)

Zooplankton.

This study was not designed to characterize the zooplankton communities and the macroinvertebrate sampling methods used are not recommended procedures for collection of zooplankton. Treatment of these data will be limited to the following discussion. During the scoop, trap and qualitative sampling, considerable numbers of microcrustaceans were collected inadvertently and sorted out during the sample processing. They have been identified to the order Cladocera and subclasses Copepoda and Ostracoda. At least one representative of these groups and often all three were found in all the pools with the exception of Maidstone. The lack of their presence in this seasonal pool is more likely an oversight in sample processing as these groups are generally ubiquitous to freshwater habitats. Cladocerans were found in 21 pools, Ostracods in 23 pools and Copepods in 25 pools. Seventeen pools had all three groups.

Quality Assurance and Quality Control

The following is a general summary of quality assurance results for macroinvertebrate and chemical analyses. A more detailed assessment of quality assurance and quality control for sampling and analysis of water chemistry is provided in **Appendix C**. A more detailed discussion of the macroinvertebrate sampling methods is included in a separate section of this report.

Aquatic Macroinvertebrates

Precision

Precision was measured as percent standard error for selected attributes or percent similarity between replicate samples from within a pool. Trap and scoop sampling methods were replicated. Taxa richness estimate precision will be discussed for the purpose of evaluating general sampling precision.

Scoop Taxa Richness: Percent standard error for eight sets of duplicate scoops averaged 27% with a range of 13-39%. Precision in the estimate of this metric is influenced by both rare and abundant taxa. However, the percent standard error appears to be relatively unaffected by the abundance of organisms captured.

Rare taxa had a significant influence on the variability of taxonomic richness estimates. Approximately 50 percent (31-63%) of the differences in taxa richness between the duplicate pair were cases where two or fewer individuals of a taxon appeared in one sample and that taxon was absent in the other sample.

Abundant taxa influenced the precision of richness values as well. Approximately 12% (0-28%) of the differences in taxa richness between the replicate pair were cases where 10 or more individuals of a taxon appeared in one sample and that taxon was absent in the other. Dipterans were the taxonomic group most likely to be abundant in one replicate and absent, or nearly absent, in the other replicate.

In summary, the scoop sampling method was not particularly precise. Large differences in abundance and taxa captured make it difficult to evaluate the effectiveness or representativeness of the sampling effort. Field observations of the methodology suggest that the presence of debris, plant material, leaves and litter in the pools made consistent sampling effort along transects very difficult, resulting in the observed differences in results. Samplers were also inhibited by attempts to disturb the pool as little as possible, particularly when larval amphibians were present and active.

Trap Sampling Precision: Composite trap samples from four sites were replicated. One composite trap sample consisted of the entire contents of a trap set (from two to eight traps). A field replicate consisted of duplicating an entire trap set. For example, in Arms Grant pool, two sets of eight traps were deployed and processed as separate samples. Sample A consists of the composited contents from one set of eight traps; sample B the contents of the second set of eight traps. The numbers compared here are the composited totals for a set of traps.

Total Taxa Richness per trap set: The total number of taxa collected per trap set was calculated. Total taxa from the paired trap sets were compared for assessing precision. The mean percent standard error was 4.7 with a range of 0-8.6. Variability between traps within a trap set was high.

Rare or uncommon taxa were a significant component of the trap samples. For example, on the average, 50% of the total taxa collected by a set of traps appeared in only one of the trap array. In the most extreme case, with a set of eight traps, fourteen of twenty taxa (70%) occurred in only one of the eight traps.

Abundant taxa were less common. When more than two traps were set, an average of 11% of the taxa occurred in all traps. For example, in one set of eight traps, 1 of 20 taxa (5%) was captured by all eight traps. When only two traps were set, approximately 50% of the taxa were captured by each trap. The taxa most likely to occur in all traps were the phantom midge *Mochlonyx cinctipes,* and the dipteran, *Dixella sp.*

Trap sets produced a more precise estimate of taxa richness than did the scoop sampling.

Accuracy

Accuracy of aquatic macroinvertebrate data was ensured through standard laboratory procedures. Aquatic macroinvertebrate field samples were picked in the laboratory and checked by a second biologist. Taxonomic accuracy was achieved through the use of standard taxonomic keys for all identifications. The taxonomist assigned an identification confidence level to each determination. The BASS maintains a reference collection of all identified taxa to assure consistent identifications. Some portions of the aquatic macroinvertebrate taxonomy were contracted with the environmental consulting firm Aquatec Biological Services. Aquatec provided a reference collection to BASS to ensure accuracy between taxonomists. At each laboratory, two people were responsible for identifying each taxonomic group, which allowed for in-house verifications on difficult identifications. Finally, all samples were archived by sample ID # and major taxonomic groupings to ensure a long-term record.

Method characteristics

Each sampling method was targeted to sample certain communities. Traps were intended to collect swimming or crawling organisms, scoops collected aquatic macroinvertebrates associated with the leaf litter and muck, and qualitative samples collected taxa that were not represented or under-represented with the previous two methods. The majority of taxa encountered in this project were collected at some point in trap samples, although the traps were not always the most efficient method of capturing the taxa encountered. The scoop and qualitative samples supplemented the traps. Overall, traps were the most effective sampling method for collecting total richness of organisms (59%), followed by the scoop method (22%) and the qualitative method (19%)

The trap method collected the greatest taxa richness for the following orders: Coleoptera, Hemiptera, Ephemeroptera (equal with Scoop), and Neorhabdocoela, (equal with Scoop). The scoop method collected the greatest taxa richness for the following Orders: Diptera, Gastropoda (equal with Qualitative), Oligochaeta, Ephemeroptera (equal with Traps), Lepidoptera, Megaloptera (equal with Qualitative), Neorhabdocoela, (equal with traps). The qualitative method collected the greatest taxa richness for the following Orders: Gastropoda (equal with Scoop), Trichoptera, Hydrachnidia, Plecoptera, Odonata and Bivalvia, Megaloptera (equal with Scoop).

A more detailed discussion of macroinvertebrate sampling method performance is presented in the Aquatic Macroinvertebrate Sampling Method Evaluation.

Water Chemistry

Field Method Precision

Water chemistry sampling precision was quantified as relative percent difference (RPD) between field duplicates. Field duplicates were highly variable due to the shallow, easily disturbed bottom and biologically rich nature of the pools. As a result, these field duplicates reflect the range of variability for each parameter and determines the representativeness of a sample at a given time in a seasonal pool. RPD varied between the thirteen parameters assessed. Mean parameter RPD values ranged from 0.78% for field pH to 10.2% for color. Field duplicate data quality objectives were exceeded for the following parameters: color, alkalinity, conductivity, magnesium, chloride, and aluminum. Many of the high RPDs were for very low concentration samples, where fairly small absolute differences in analytical results have a high RPD. Field duplicate and laboratory duplicate objectives for low level samples are typically based on an absolute difference between samples, not as a percentage. High RPDs at low concentrations may reflect inappropriate data quality objectives rather than indicate unacceptable data quality.

Laboratory Analysis Precision

Water chemistry analytical precision was quantified as relative percent difference (RPD) between lab duplicates. Laboratory duplicate means were within data quality objectives, with mean parameter RPDs ranging from 0.2percent for pH and 3.7percent for alkalinity.

Laboratory Analysis Accuracy

Accuracy is expressed as percent recovery or percent bias and is determined from the analysis of quality control reference samples that differ from the calibration standard. Due to very low anion concentrations, accuracy of the anion analysis was determined by calculating percent bias of internal spike standards. During 1999, these standards were analyzed concurrently with the water samples. In 2000, these were calculated directly from pool samples. The mean percent recovery and the per cent bias were within data quality objectives for all parameters.

Detailed tables of chemistry quality assurance results are in **Appendix C**.

Aquatic Macroinvertebrate Sampling Method Evaluation

Three sampling methods were used to sample macroinvertebrates from pools: traps, scoops, and qualitative collecting. Macroinvertebrates were collected at least twice from each pool using all methods (except when conditions prohibited sample collection). It was assumed that the three methods would target different components of the invertebrate fauna and would result in a fairly complete inventory of taxa present at the time of sampling. The following discussion will examine some of the characteristics of each method.

Scoop Method:

The scoop method, as described in the methods section, involves using a D-frame net to "scoop" sediment and debris at three locations along a randomly selected diameter transect in the pool, targeting fauna associated with sediments and debris.

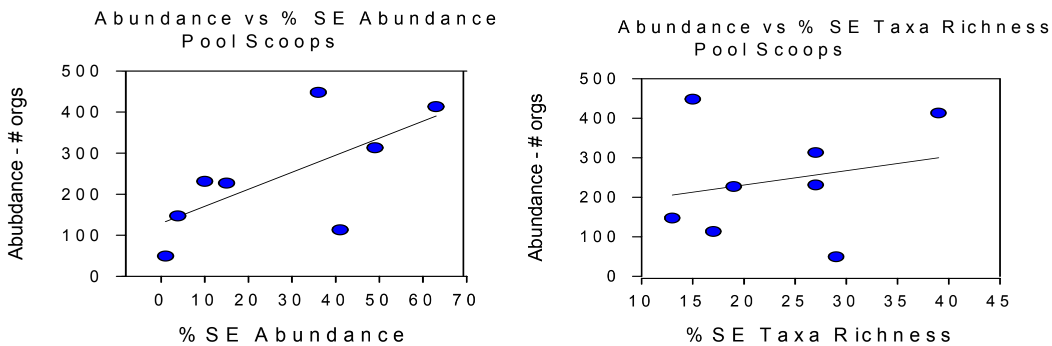
Precision: Duplicate scoop samples were collected at eight sites. Precision for aquatic macroinvertebrate samples was measured as percent standard error for selected attributes between duplicate samples from within a pool. **Table 9** summarizes the precision estimates for the following selected metrics: Abundance, Taxa Richness, and Diptera Percent Composition. The percent standard error of the mean (percent SE) is the standard error divided by the mean of the replicates. The percent SE was calculated for each duplicate pair (n=8) of scoop samples. The three metrics represent calculations that may be effected in different ways by sampling effort and method precision.

Table 9. Percent standard error summary for replicate scoop samples from seasonal pools.

Metric	Average for all pools (range of pool means) n=8	Percent Standard Error			
		Min	Max	Mean	Median
Abundance	243 (49-448)	1	63	27	26
Taxa Richness	15 (7-21)	13	39	23	23
Diptera Percent Composition	54 (7-94)	0.2	28	12	12

The scoop sampling method was intended to standardize sampling effort and to collect a sample representative of pool conditions. This method was not intended to be quantitative. An evaluation of abundance precision was used to assess relative consistency in sampling effort between scoop samples. Abundance percent standard error for eight sets of replicate scoops was quite variable, averaging 27% with a range of 1-63%. Percent standard error appears to be greater (indicating less precision) in samples with a higher number of cumulative organisms (**Figure 4**). That relationship in the samples assessed is driven primarily by high abundances of Chironomidae in one of two replicates, suggesting a high degree of patchiness in the distribution of some Diptera larvae.

Figure 4. Abundance vs. percent standard error (percent SE) of abundance and taxa richness.



Percent standard error of taxa richness estimates for eight sets of replicate scoops averaged 23% with a range of 13-39%. Mean precision for taxa richness was similar to but less variable than that for abundance. Precision in the estimate of taxa richness is influenced by both rare and abundant taxa. However, the percent standard error appears to be relatively unaffected by the abundance of organisms captured (**Figure 4**).

Rare taxa had a significant influence on the variability of taxonomic richness estimates. Approximately 50% (range 31-63%) of the differences in taxa occurrence between the replicate pair were cases where two or fewer individuals of a taxon appeared in one sample and that taxon was absent in the other sample.

Abundant taxa influenced the precision of richness values as well. Approximately 12% (0-28%) of the differences in taxa occurrence between the replicate pair were cases where ten or more individuals of a taxon appeared in one sample and that taxon was absent in the other.

The calculation of taxa richness is independent of specific taxonomic composition. Two samples with the same "taxa richness" may have no taxa in common. Replicate scoop samples often showed differences in taxa sampled that were not evident when simply looking at taxonomic richness. The number of taxa that were unique to a replicate (a taxon that occurred in one of the replicates but not in both) as a percentage of the total cumulative taxa from both replicates, ranged from 47-76% and averaged 60%. Conversely, on the average, less than half of the taxa collected by replicate scoop samples from a pool were common to both samples. **Figure 5** presents taxa richness for each replicate scoop sample compared to the total cumulative taxa from both samples A and B. For the eight pairs of samples, the ratio between the mean (n=2) taxa richness and the total taxa (mean/total) ranged from 0.62 to 0.77 and averaged 0.70.

Dipterans were the taxonomic group most likely to be abundant in one replicate and absent, or nearly absent, in the other replicate.Variability in dipteran percent composition was calculated. Percent standard error for eight sets of replicate scoops averaged 12% with a range of 0.2-28.0%. Mean Diptera percent composition ranged from 7-94% among the eight replicate pairs.

Figure 6 shows a typical taxa distribution from a single pair of scoop replicates. A total of 10 taxa from the combined samples were identified, with only 4 of the 10 taxa common to both samples.

Figure 5. Replicate scoops - A, B and total taxa

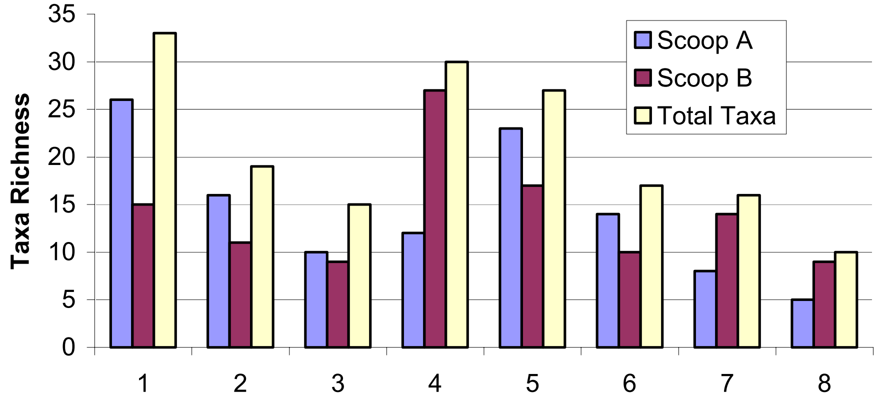
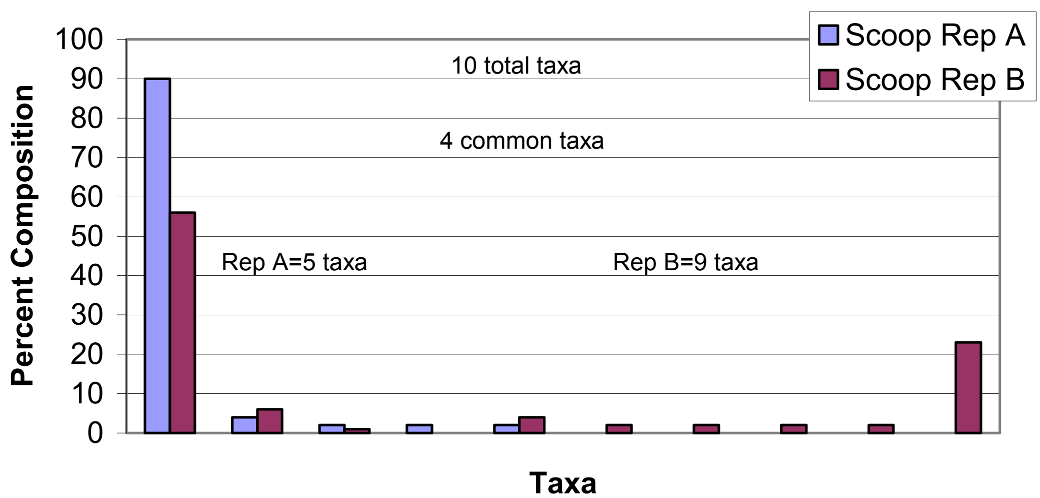
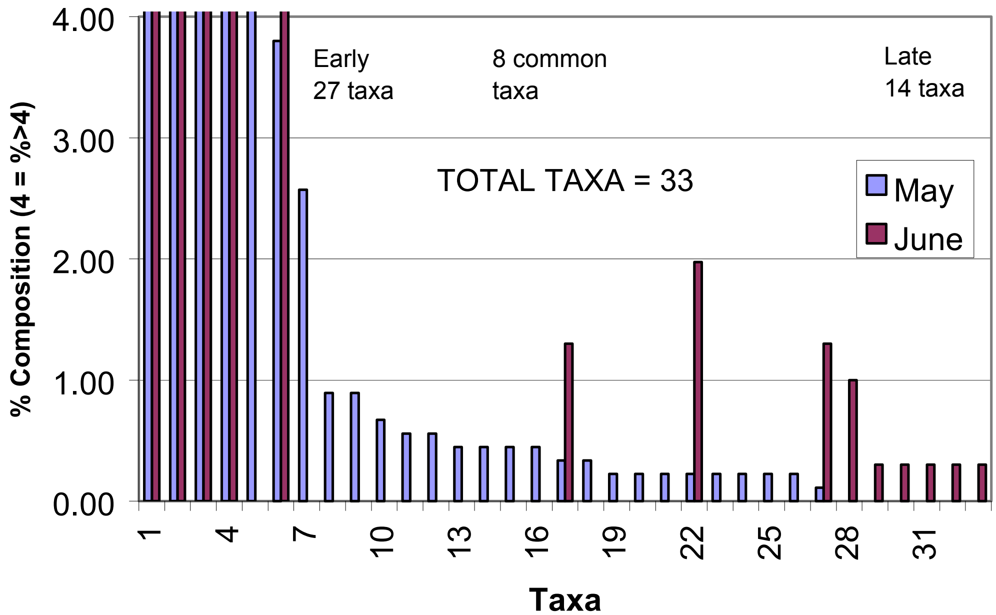


Figure 6: Taxa occurrence in replicate scoop samples from a single pool.



Taxa encountered varied considerably with the date of sampling. In most pools, one early sample was collected, usually in the mid-April to mid-May time period, with a second sample collected four to six weeks later. In most cases, there were drastic differences in the taxa encountered between the two visits. **Figure 7** shows a typical example from Dartmouth, which was sampled in May and June of 2000.

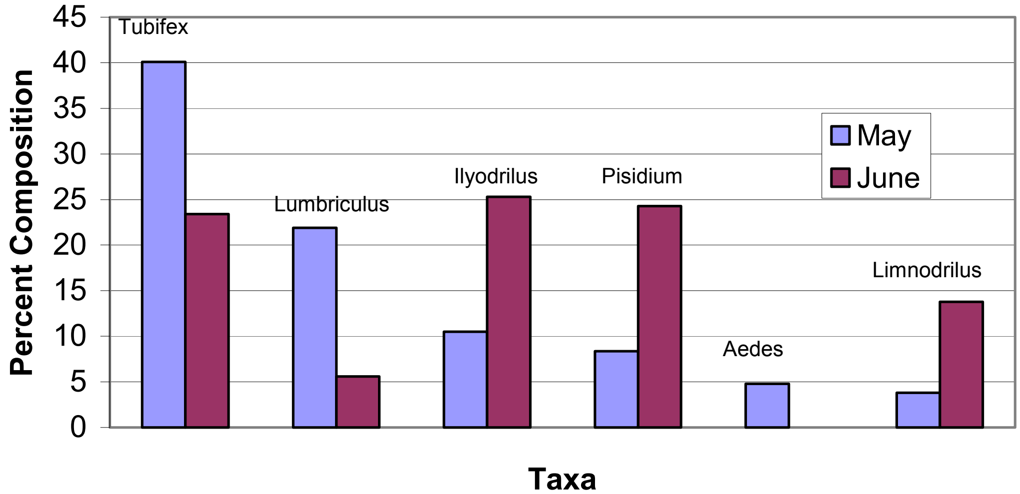
Figure 7: Dartmouth pool early and late visit scoop samples – all taxa.



In May, 27 taxa were identified. In June, 14 taxa were identified. The combined taxa list for the two sampling events totaled thirty-three unique taxa. Only 8 of the 33 taxa (24%) were common to both sampling events: 19 of the taxa encountered in May were not observed in the June sample; 6 taxa encountered in June were not observed in the May sample. The major differences were due to the presence or absence of rare or infrequently occurring taxa making up less than one percent of the sample composition (23 of 33 taxa).

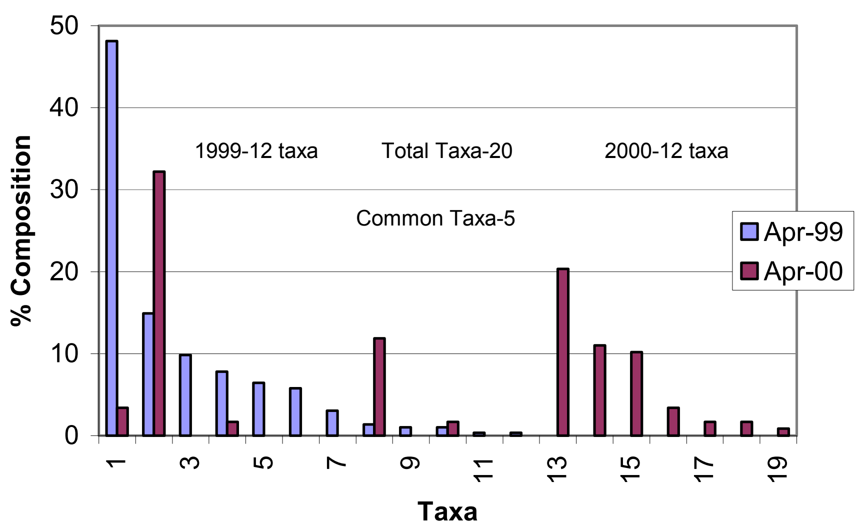
Of the six taxa that made up more than four percent of the May sample, five were encountered at greater than two percent composition in the June sample (**Figure 8)**. These taxa were mostly non-insect animals - Oligochaetes and Bivalvia – more-or-less permanent residents associated with sediments and debris. As was often the case, mosquitoes were abundant early in the season and less frequent or absent later in the season.

Figure 8: Dartmouth pool early and late visit scoop samples – dominant taxa.



Patterns of taxa presence, absence, and dominance were similarly variable between years in those pools that were sampled in both 1999 and 2000. **Figure 9** shows early visit scoops from Bald Mountain North for two years. Samples were collected in April of 1999 and 2000. Taxa richness in both years was twelve, however only five taxa were common to both years. Three of the taxa which were dominant (>4%) in 1999 (*Promenetus exacuous, Nais variabilis,* and *Hemonais waldvogeli)* were not encountered in 2000. Three of the dominant taxa in 2000 (*Mochlonyx* sp*., Nais communis,* and *Lumbriculus variegates)* were not encountered in 1999.

Figure 9: Bald mountain north scoops, early site visit – 1999 and 2000.



General: From a physical point of view, the scoop method is very disruptive. Samplers were forced to be restrained in their vigor at times when there were large quantities of amphibian eggs and/or larvae present in the pool, thus compromising the consistency of the effort. There was a general feeling of discomfort among the samplers at the degree of disturbance produced by the method, particularly in small pools and at critical amphibian life stages. At times, larval mosquitoes were so dense that nets quickly became clogged, compromising the effort to sample other fauna. The scoop sampling method was not particularly precise. Large differences in abundance and taxa captured make it difficult to evaluate the effectiveness or representativeness of the sampling effort. Field observations of the methodology suggest that the presence of debris, plant material, leaves and litter in the pools made consistent sampling effort along transects difficult. The method was most consistent in sampling non-insect taxa associated with sediment and debris such as worms, bivalves, and gastropods as well as some sediment-associated dipterans such as *Chironomus sp.* However, even among those taxa there was some significant inconsistency across space and time (**Figures 5 - 9**).

Trap Method:

Trap sampling was conducted at all pools at least twice when adequate standing water was present. The number of traps comprising a "sample" was proportional to the size of the pool (traps/sample ranging from 2-10). The target animals for this methodology were free-swimming insect and non-insect invertebrates, including dipterans, coleopterans and anostrachans.

Precision: Composite trap samples from four sites were replicated. A composite trap sample combined the contents of a trap set (from 2-8 traps). A field replicate consisted of replicating an entire trap set. For example, in Arms Grant pool, two sets of eight traps were deployed and processed as separate samples. Sample A consisted of the composite contents from one set of eight traps; sample B was the contents of the second set of eight traps. The numbers compared here are the composite totals for each set of traps. **Table 10** summarizes results for several metrics.

Table 10. Trap precision for selected biological metrics by site.

Site	# traps	Density/Unit			Total Richness			Mean Richness/Trap		
		A	B	%SE	A	B	%SE	A	B	%SE
Arms Grant	8	17	31	29.2	20	22	4.8	4.9	6.2	11.7
Iroquois Maple	2	37	28	13.8	14	14	0	10.5	10	2
Maidstone	6	32	32	0.0	20	18	5.3	7.8	7.5	2
Pine Hill	7	28	33	8.2	19	16	16	8.1	6.6	10.2

Summary precision data for selected biological metrics (abundance, total taxa richness, coleopteran taxa richness, and mean taxa per trap) for trap sample replicates are presented in **Table 11**.

Table 11. Selected biological metrics summary for trap precision (n=4).

Metric	Mean Metric Value (Range n=4)	Minimum % Standard Error	Maximum % Standard Error	Mean % Standard Error	Median % Standard Error
Mean Abundance/trap	30 (24-33)	0	29	13	11
Total Taxa Richness All Traps in Set	18 (14-21)	0	8.6	4.7	5.1
Total Coleopteran Taxa Richness All Traps in Set	9.5 (5.5-12)	0	27	11	9
Mean Taxa/Trap	7.7 (5.5-10)	2	11.7	6.5	6.1

Rare taxa (taxa occurring in less than 50% of the traps in a set) were a significant component of the trap samples. For example, on the average, 50% of the total taxa collected by a set of traps appeared in only one of the traps in the set. In the most extreme case, with a set of eight traps, 14 of 20 taxa (70%) occurred in only one of the eight traps, or conversely, only 6 of the 20 total taxa were captured by more than one of the eight traps in the set.

Abundant taxa (taxa occurring in more than 50% of the traps in a set) were encountered less frequently than rare taxa. When more than two traps were set, an average of 11% of the taxa occurred in all traps. For example, in one set of eight traps, 1 of 20 taxa (5%) was captured by all eight traps. When only two traps were set, approximately 50% of the taxa were captured by both traps. Relatively abundant and highly mobile taxa, such as phantom midges, were the taxa most likely to occur in all or a majority of the traps.

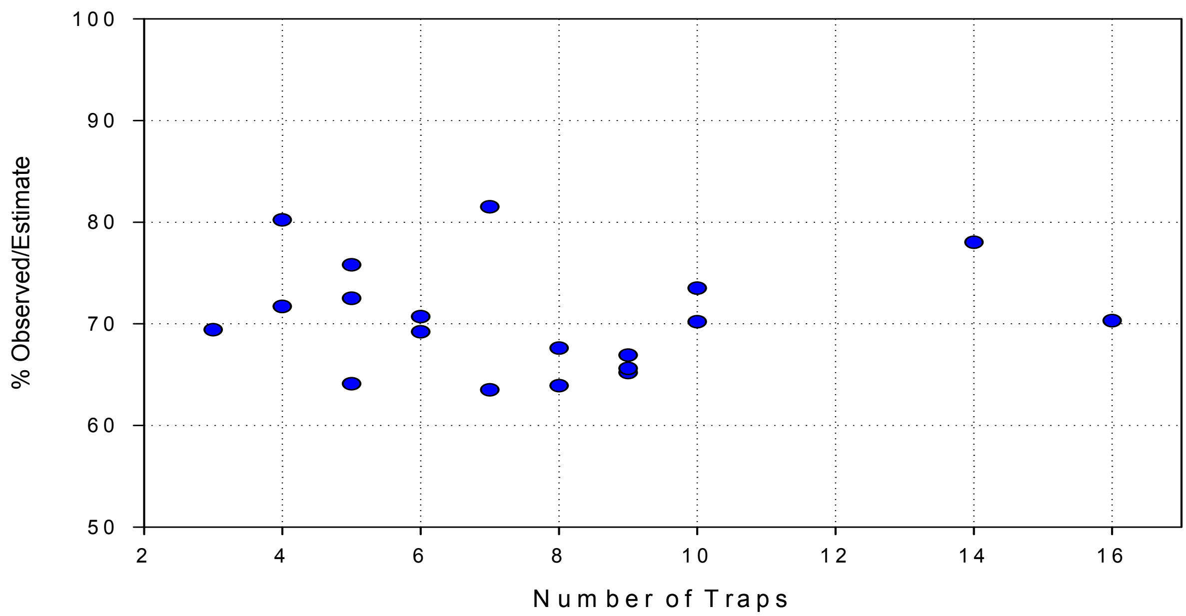
Trap Efficiency : Sample representativeness for traps was evaluated by comparing the first-order jackknife estimate of total taxa with the observed total for 19 sampling events. The number of traps set varied from 3 to 16 per pool, depending on pool size. Pools that had more than 10 traps were the result of replicates. The proportion of the total observed taxa of the jackknife estimate ranged from 63.5 to 81.5% with a mean of 70.4% (**Table 12)**.

Table 12. The observed number of taxa, the first-order Jackknife estimate of total taxa and the percent of the observed of the estimate for 19 sampling events on seasonal pools sampled in 1999-2000.

Number of Traps	Observed Taxa	Jackknife Estimate	Percent Observed / Estimate
16	31	44.1	70.3
14	23	29.5	78.0
10	17	24.2	70.2
10	25	34.0	73.5
9	18	26.9	66.9
9	30	46.0	65.2
9	17	25.9	65.6
8	17	26.6	63.9
8	20	29.6	67.6
7	12	18.9	63.5
7	15	18.4	81.5
6	20	28.3	70.7
6	32	46.2	69.2
5	10	15.6	64.1
5	10	13.2	75.8
5	10	13.8	72.5
4	15	18.7	80.2
4	17	23.7	71.7
3	12	17.3	69.4
Mean			**70.4**
Range			**63.5 - 81.5**

Figure 10 demonstrates that the proportion of the observed of the estimate was not significantly correlated with the number of traps (Pearson Product Moment Correlation Coefficient = 0.940, p=0.018).

Figure 10. Trap efficiency. Number of traps vs. percent observed/estimated.



Figures 11 and 12 represent the relationship between the mean number of taxa captured in one trap, the total taxa captured in a set of traps and the number of traps in a set. The mean number of taxa captured per trap was independent of the number of traps set – differences between groups sorted by number of traps were not significantly different (One-way Anova, p = 0.53). The total number of taxa captured increased with more traps although the only statistically significant differences (Tukey pairwise comparison p<0.05) were between the extremes – 2, 3 and 4 traps vs. 9 and 10 traps. The ratio of total to mean taxa increases with more traps set.

Figure 11: Multiple trap performance – mean taxa per trap and total taxa present in trap sets, with the number of traps in the set ranging from 2 to 10 as indicated.

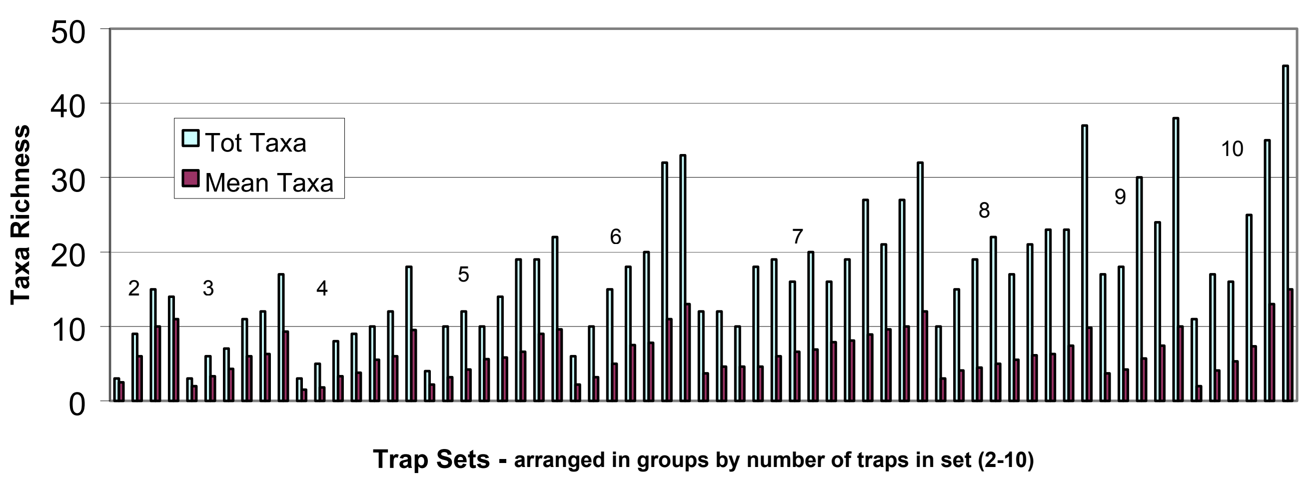
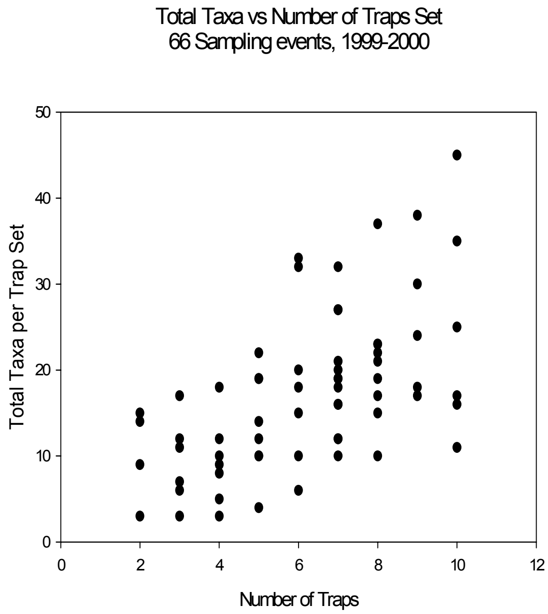
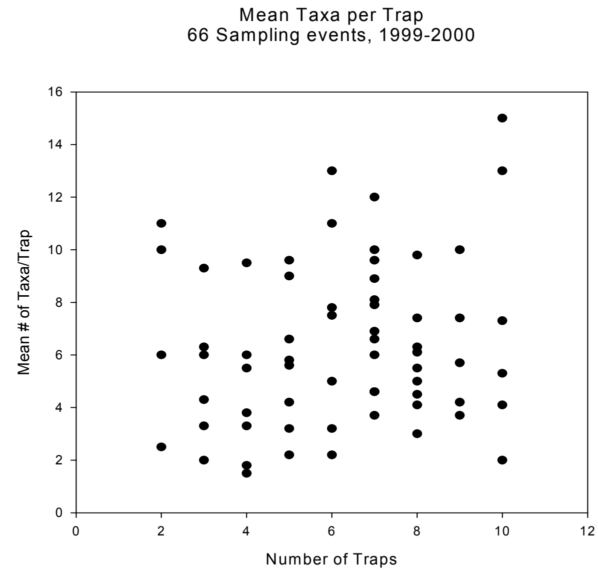


Figure 12: Total and mean taxa in relation to the number of traps in a sample.

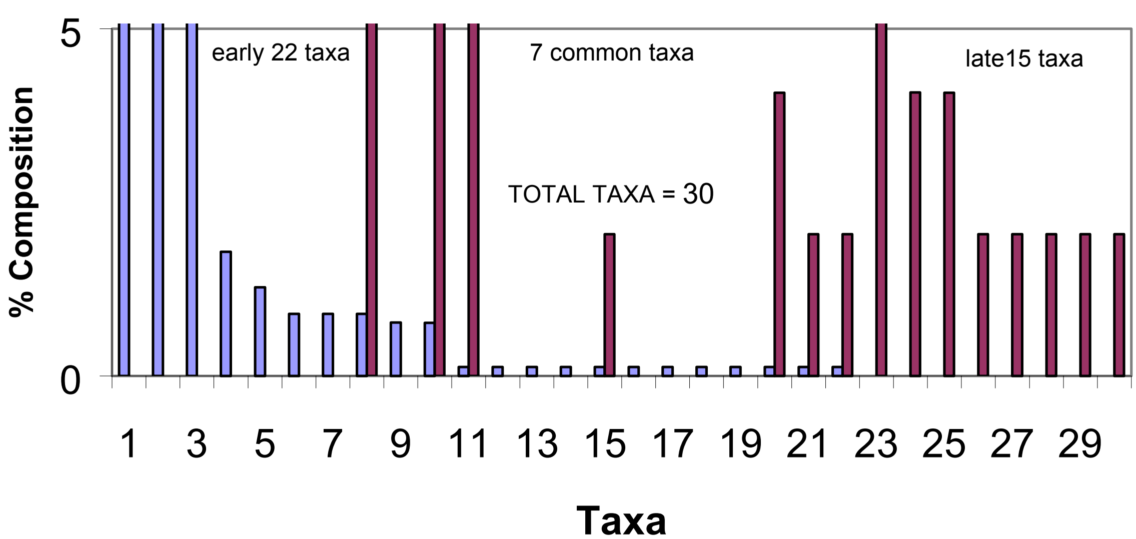




The more traps that were set, the more taxa were captured. However, the number of traps set was dependent on pool size, so the larger the pool the more traps were set. It is likely that the positive relationship between the number of traps and the number of taxa is a function of multiple factors in addition to trap number, including pool size and perimeter, percent canopy, and disturbance.

As with scoop samples, there was considerable temporal variability in species occurrence. Differences in taxonomic structure between sampling dates was even more dramatic than for scoop samples, given the volatile and ephemeral nature of many of the organisms targeted by the trap method. **Figure 13** shows taxa occurrence in May and June trap samples from Dartmouth seasonal pool.

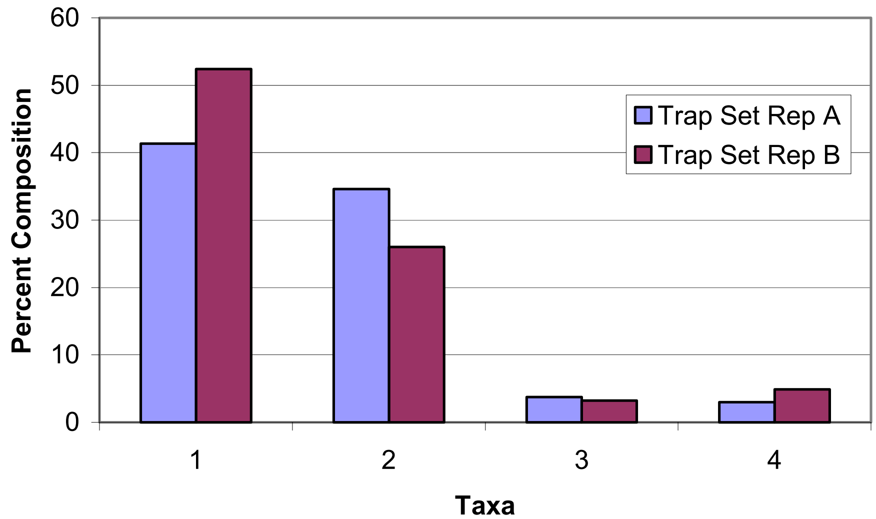
Figure 13: Early and late trap samples from Dartmouth Pool.



A combined 30 taxa were identified from the two sampling events, with only seven taxa common to both events. None of the dominant taxa were common to both events. The early sample was dominated by mosquitos and hemipterans while the late sample was dominated by beetles and non-mosquito dipterans.

As with the scoop samples, the dominant taxa were fairly well replicated with rare taxa exerting a strong influence on the observed differences in taxa richness between replicates (**Figure 14)**.

Figure 14: Trap replication of dominant taxa. Total taxa from the two replicates was 28, with 14 taxa (50%) common to both samples.



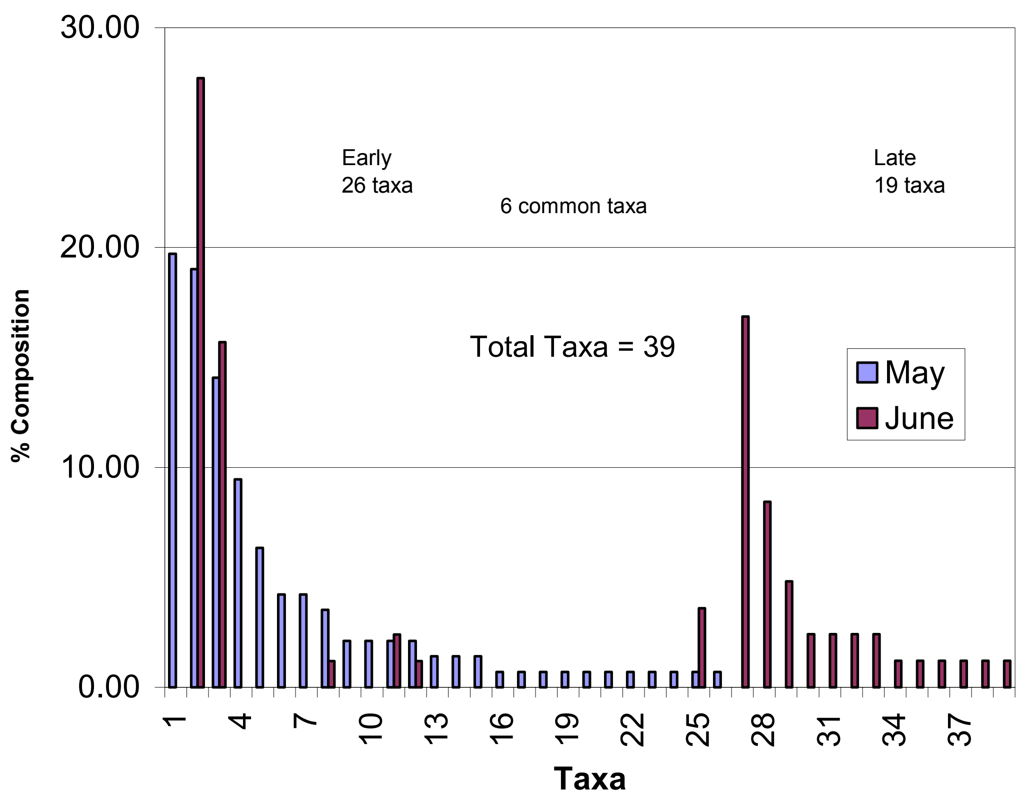
General: Traps were very successful at capturing mobile species, including the expected swimmers such as dipterans and coleopterans, and crawlers and grazers such as trichopterans and gastropods. In addition to mobile swimming species, traps also frequently "captured" less mobile species associated with muck and debris. This is most likely as a result of close contact with the sediments, particularly when water levels were low and traps were pushed into the debris and sediment in order to submerge the opening. Trap sampling requires two visits to a pool, which can be logistically challenging in some cases. A liability of trap sampling is the efficiency of the traps in sampling adult amphibians. Sampling personnel preferred not to set traps when adult amphibians were known to be present. In all cases, it is important to not totally submerge the trap and to leave an air-space for trapped amphibians. Not all circumstances can be anticipated. In at least one case, overnight rainfall while traps were set raised the pool water level significantly, submerging the traps and causing several amphibian mortalities.

Qualitative Method:

The qualitative method was a search and capture approach designed to complement trap and scoop sampling by capturing large, or possibly rare taxa missed by other methods. No attempt has been made to evaluate precision of this method.

As with scoops and traps, the taxa encountered showed significant temporal variability (**Figure 15**). Samples collected from Dartmouth pool showed very different taxonomic occurrences from May to June. Of a total of 39 taxa encountered over the two sampling events, only six taxa were common to both sampling events. The early sample dominant taxa not encountered in the late sample included: *Aedes* spp*., Eubranchipus bundyi, Pisidium* sp . Dominant taxa appearing in the later sample but not the early included: *Dytiscus* sp*., Limnophora* sp*., Corixidae* . Dominants in both samples included *Lumbriculus* sp. and *Bezzia* sp. Similar patterns of taxa occurrence variability were shown between replicates and years.

Figure 15: Dartmouth seasonal pool early and late qualitative sampling.

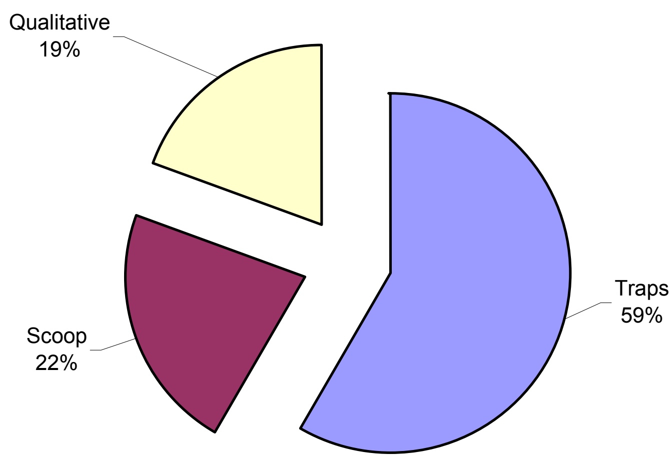


General: Qualitative sampling was, by definition, somewhat subjective and moderately inhibited by a general concern regarding excessive pool disruption during critical amphibian breeding stages.

Comparative Method Sampling Characteristics

Each sampling method was intended to target certain aquatic invertebrate communities. In practice, traps collected primarily swimming or crawling organisms, scoops collected primarily aquatic macroinvertebrates associated with the leaf litter and muck, and qualitative samples collected taxa that were un-represented or under-represented with the previous two methods. Thus, in general, the methodologies performed as anticipated in regards to targeted community components. The majority of taxa were collected with the trap method; the scoop and qualitative samples supplemented the traps. Overall, traps were the most effective sampling method for collecting total richness of organisms (59%), followed by the scoop method (22%) and the qualitative method (19%) (**Figure 16**).

Figure 16. Total aquatic macroinvertebrate cumulative taxa richness by method.



Total Taxa Richness By Method: Total taxa richness by method is presented in **Figure 17** and **Figure 18**. The trap method collected the greatest taxa richness for the following orders: Coleoptera, Hemiptera, Ephemeroptera (equal with Scoop), and Neorhabdocoela, (equal with Scoop). The scoop method collected the greatest taxa richness for the following Orders: Diptera, Gastropoda (equal with qualitative), Oligochaeta, Ephemeroptera (equal with traps), Lepidoptera, Megaloptera (equal with qualitative), Neorhabdocoela, (equal with traps). The qualitative method collected the greatest taxa richness for the following Orders: Gastropoda (equal with scoop), Trichoptera, Hydrachnidia, Plecoptera, Odonata and Bivalvia, and Megaloptera (equal with scoop).

Figure 17. Total aquatic macroinvertebrate taxa richness by method for the eight most abundant orders.

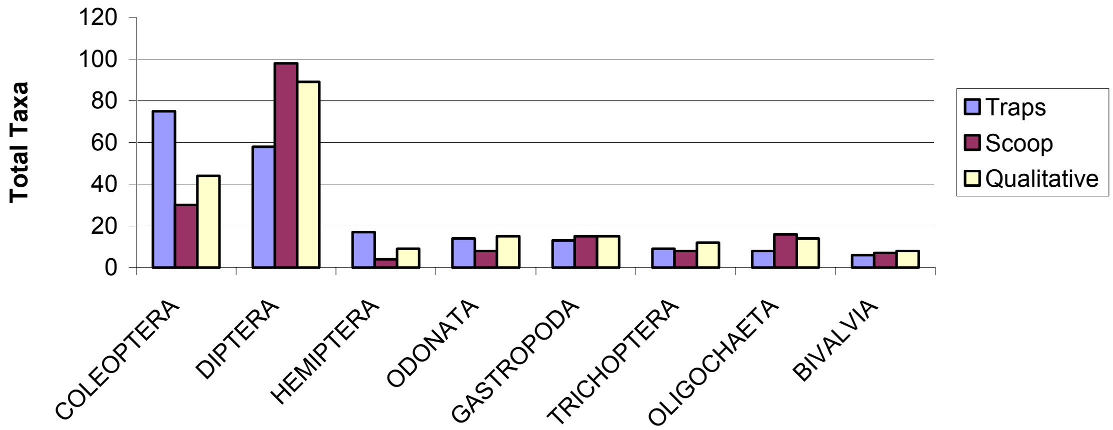
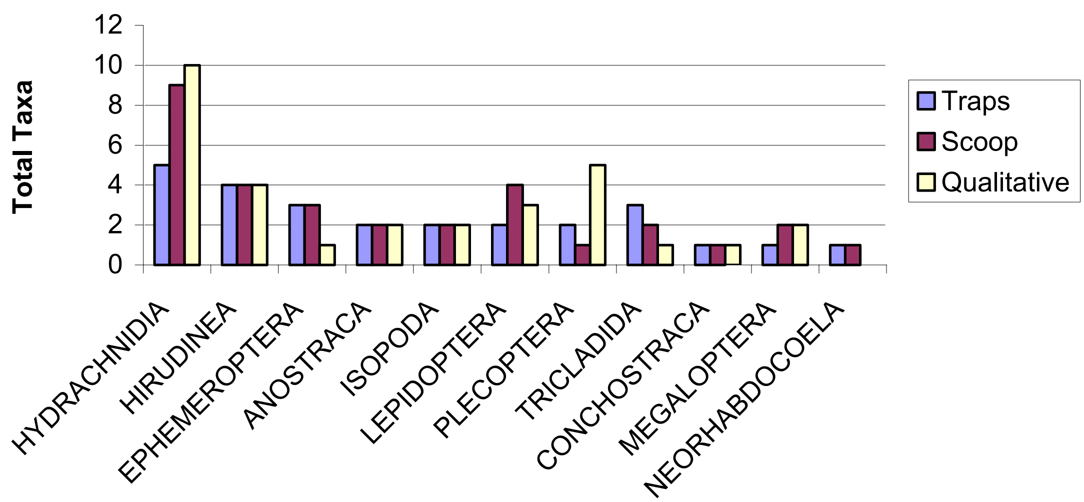
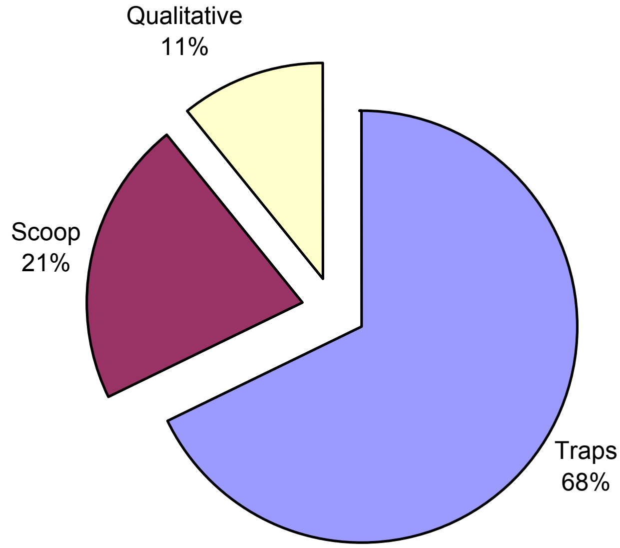


Figure 18. Total aquatic macroinvertebrate taxa richness by method for 11 least abundant orders.



Cumulative Taxa Richness By Method: Traps represented 68% of all cumulative taxa collected (**Figure 19**); scoops represented another 21%; and qualitative represented the remaining 11 %. Traps were determined to collect the greatest number of total taxa. As a result, cumulative taxa richness was based upon the trap method. Species found in scoops, but not in traps were added to the cumulative count and species found in the qualitative method but not found in the scoop or trap methods were included in the qualitative count.

Figure 19. Cumulative aquatic macroinvertebrate taxa richness by method.



The greatest cumulative trap taxa richness were found for Coleoptera, Diptera, Hemiptera, Odonata, Gastropoda, Trichoptera, Bivalvia, Hirudinea, Ephemeroptera, Anostraca, Isopoda, Tricladia, Conchostraca, and Neorhabdocoela (**Figure 20 and Figure 21**).

The majority of Coleoptera and Diptera taxa were found in trap samples. The greatest cumulative richness of Oligochaeta taxa was present in the scoop samples. Hydrachnids were equally represented in the qualitative and the trap samples.

The three sampling methods resulted in equal taxa richness for the following orders: Hirudinea, Anostraca and Isopoda.

Figure 20. Cumulative aquatic macroinvertebrate taxa per method for the eight most abundant orders.

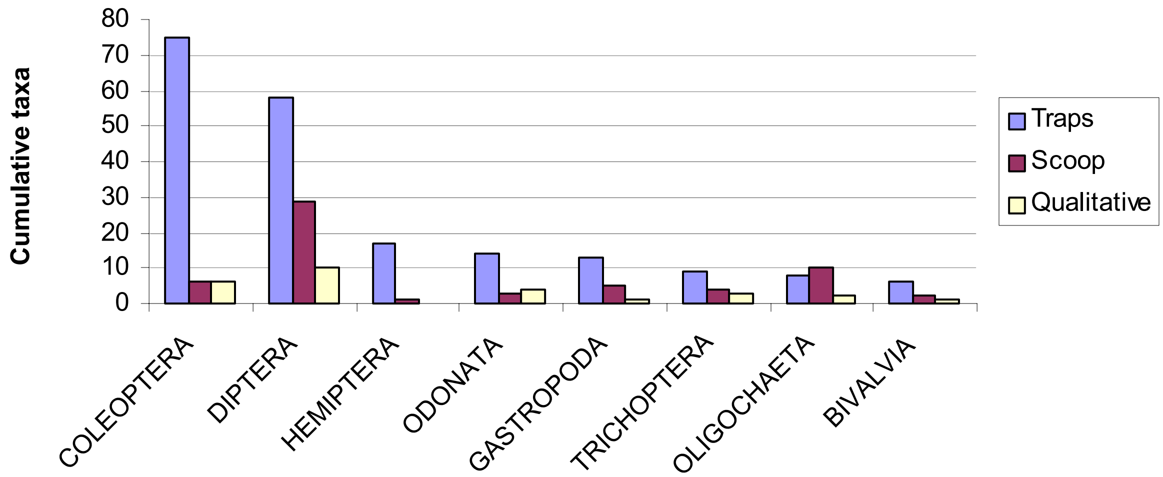
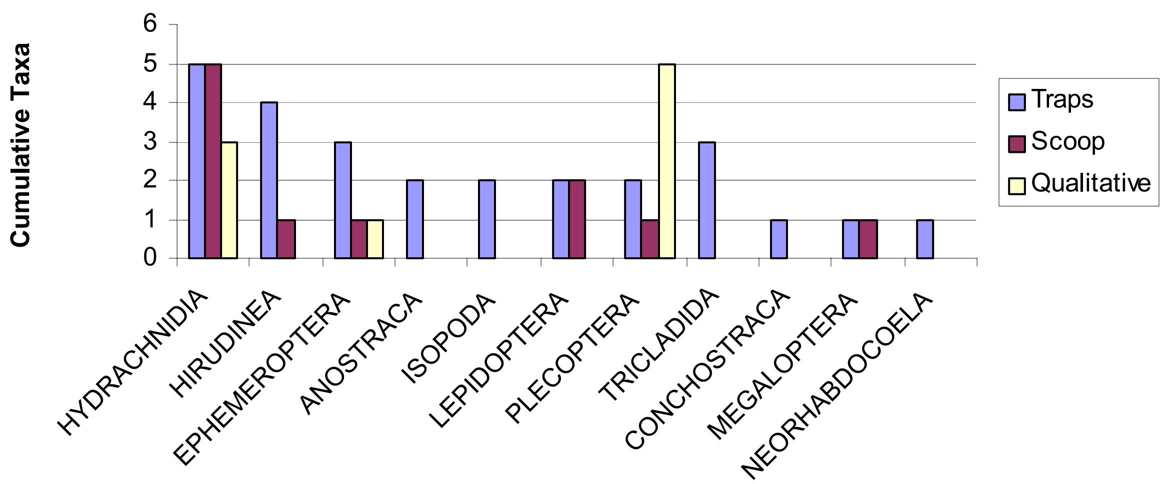


Figure 21. Cumulative aquatic macroinvertebrate taxa per method for the 11 least abundant orders.



Discussion:

Temporal Considerations: Most sites were sampled twice for macroinvertebrates during the year – once in early spring and again in late spring/early summer. Observations of the data show that in many cases, there were large differences between the early and late spring samples, particularly in regard to taxa richness and taxa occurrence. Temporal variability of taxa occurrence and relative abundance was so extreme that there was often little resemblance in the taxonomic structure of the fauna observed between replicates, between dates, and between years at the same pool regardless of sample method. Populations of many taxa, both dominant (>4%) and rare (<1%), in these seasonal pools were extremely variable and of short duration. The taxa encountered at any specific time will varygreatly depending on temporal variations in factors which favor the initiation of life cycle development, including temperature, snowmelt, and hydrology. The term ephemeral is truly appropriate for invertebrate populations in these pools.

Mosquitoes, phantom midges, and fairy shrimp were the most likely organisms to exhibit short term growth and be dominant for short periods of time, usually early in the season. Coleopterans were more likely to be very diverse, but in very low numbers and usually later in the season. Non-insect organisims such as oligochaetes, bivalves, and gastropods, with less explosive life cycles, were more likely to be found independent of temporal considerations. There was no consistency in regards to the most likely time to find maximum taxa richness. **Figure 22** shows taxa richness for qualitative samples from early and late season samples by l pool. No consistent pattern of seasonal taxa richness is evident. Similar results were shown for trap and scoop samples. **Figure 23** shows taxa richness by site and pool by season, demonstrating the unpredictability of maximum taxa occurrence by season.

Taxonomic Considerations: Much of the variability in the occurrence of taxa was driven by rare or infrequently encountered taxa. For all methods, the number of taxa encountered was dominated by taxa comprising less than one percent of the overall sample abundance. Taxonomic resolution was high for this project, resulting in extensive species lists. The ecological significance of high taxonomic resolution was not evaluated to any great extent by this project. Some classification and ordination analyses were conducted using only dominant taxa in order to test the significance of rare taxa in the classification process. This project also did not evaluate the effects of order or generic taxonomic resolution on the utility of the data to derive significant ecological classifications.

Sampling Effort Considerations: The sampling effort put forth in this project was significant and probably not practical for routine evaluations. Each of the sampling methods implemented as a part of this project has strengths and weaknesses that can affect the goals and objectives of any particular project. The data generated by this project will be useful in determining appropriate methods and level of effort that will meet the objectives of a variety of sampling strategies.

Figure 22: Qualitative sampling taxa richness by pool and season**.** Maximum taxa richess was variable but was more likely to occur early in the season (13 pools) rather than late (9 pools).

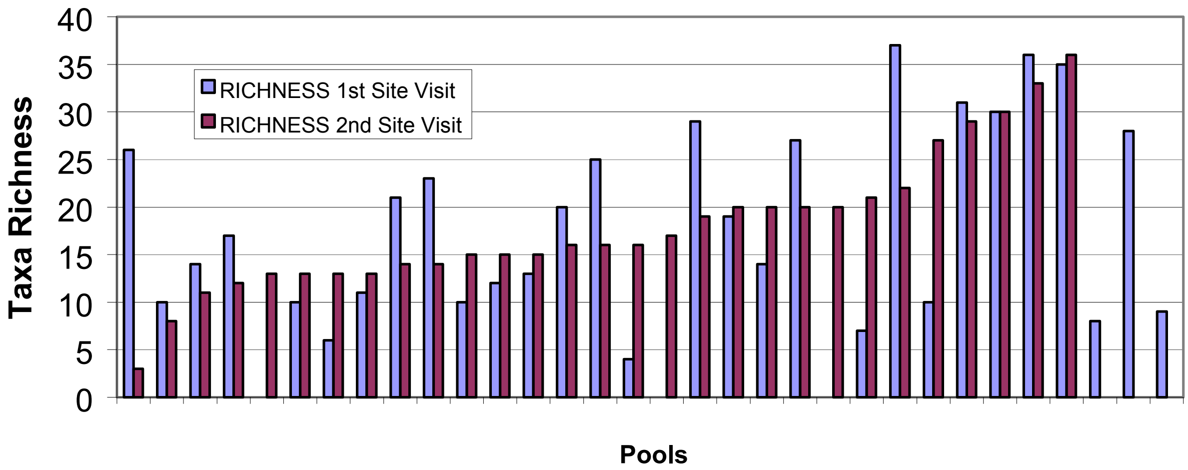
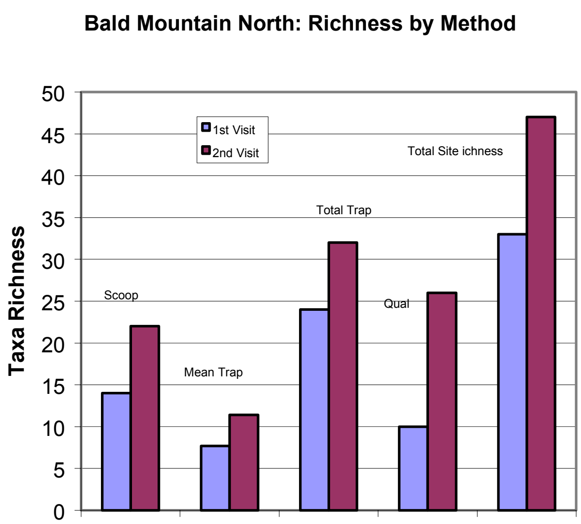
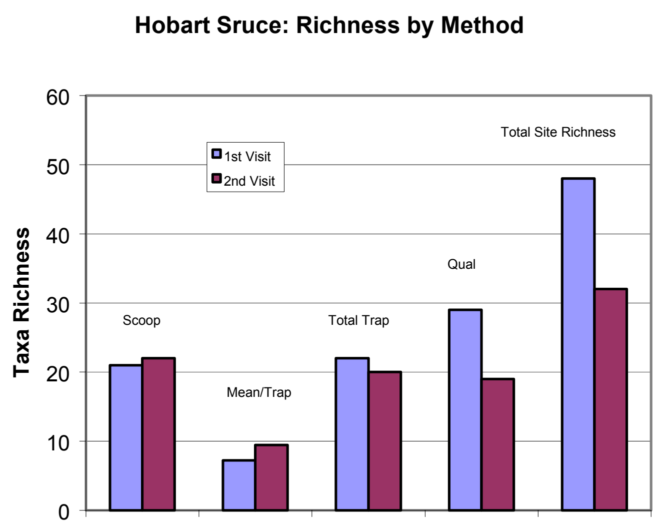


Figure 23: Taxa richness by method and season at two pools. The timing (early vs. late spring) of maximum taxa richness occurrence varied among pools.





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Classification and Ordination

Classification and Ordination of All 28 Pools Using Vegetation and Aquatic Macroinvertebrate Data

As a first step in classifying the 28 pools, Two-Way Indicator Species Analysis (TWINSPAN) was used with a combined dataset of aquatic macroinvertebrates and vegetation. This analysis included all pools, regardless of the level of human disturbance. The intention was to identify types of seasonal pools, recognizing that impaired pools may be identified as a type themselves. For this and all subsequent clustering and ordination analyses using vegetation, only those plants that were rooted in the pools were included in the data set. Although this eliminates almost all the tree species and most shrubs from the analyses, it was decided that these tree and shrub species reflect the environmental conditions in the adjacent uplands rather than the conditions in the pools themselves. The vegetation rooted in pools, as defined by the pools' high water levels, are expected to reflect the environmental conditions in the pools.

For this and subsequent analyses using combined vegetation and macroinvertebrate data, the relative abundance values for plant species (percent cover) were transformed to presence and absence in order to be consistent with the macroinvertebrate data. In addition, those species that occurred in only one pool were eliminated from the analysis. For this dataset of aquatic macroinvertebrates and vegetation, this reduces the number of taxa to 254 (117 plant species and 137 macroinvertebrate taxa).

The two-way ordered table resulting from this TWINSPAN identifies two primary groups of pools in Level 1, Division 1 of the analysis. The two-way ordered table was used to identify a total of four groups of pools that appear to be ecologically meaningful, based on divisions derived from Levels 1 through 3 of the analysis. The full output table is included in **Appendix B**. **Table B6. Table 13** shows the two primary pool groups and the four pool subgroups. The positive and negative indicator species associated with the two primary groups are also shown. The disturbance ranks assigned to the pools are included for comparison.

It appears from this TWINSPAN analysis and the resulting lists of indicator and preferential species that the aquatic macroinvertebrates play a greater role in the classification of the pool types than do the vascular plants and bryophytes. The development and testing of metrics in later sections of this report, therefore, focus primarily on aquatic macroinvertebrate species.

Table 13: Groups of pools and their indicator (I) and preferential species (P) identified in TWINSPAN analysis of 28 pools. Disturbance ranks are included in parentheses after each pool name. Groups 1 and 2 are derived from the level 1, division 1 portion of the analysis. Subgroups 1-4 are derived from levels 1-3 of the analysis.

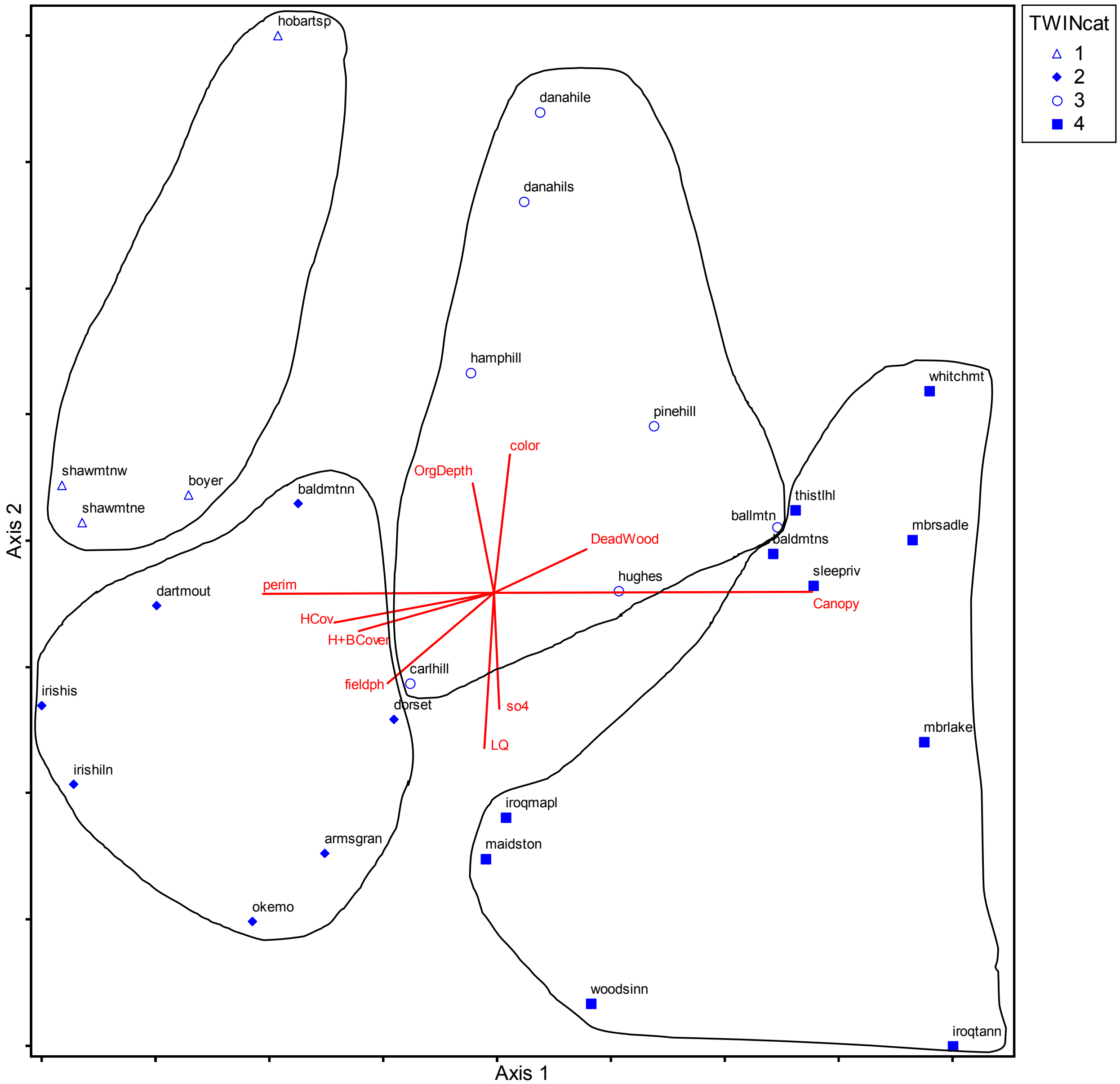
	Group 1		**Group 2**	
	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Pool Names	Hobart Spruce (4) Boyer (8) Shaw Mt. East (0) Shaw Mt. West (0)	Arms Grant (6) Bald Mtn. North (0) Dorset (5) Okemo (8) Dartmouth (6) Irish Hill N. (7) Irish Hill S. (7)	Dana Hill E. (1) Dana Hill S. (4) Hampshire Hill (6) Ball Mt. (3) Carlton Hill (10) Hughes (4) Pine Hill (0)	Iroquois Tannic (5) Woodstock Inn (6) MBR Lake (4) MBR Saddle (6) Thistle Hill (6) Whitcher Mt. (1) Sleepers River (1) Bald Mt. South (0) Iroquois Maple (1) Maidstone (3)
Indicator (I) and Preferential (P) Species (Division 1)	*Haliplus* sp. (I) *Dytiscus fasciventris* (I) *Aedes fitchii* (I) *Hygrotus turbidus* (I) *Solanum dulcamera* (P) *Haliplus longulus* (P) *Placobdella* sp. (P) *Neoporus undulatus* (P) *Odontomyia* sp . (P) *Pisidium* sp. (P)		*Osmunda cinnamomea* (P) *Cyphon* sp. (P) *Pseudosmittia sp* (P) *Aedes diantaeus* (P) *Aedes cinereus* (P) *Phaenopsectra sp* (P) *Acilius mediatus* (P) *Hymanella retenuova* (P)	

Detrended Correspondence Analysis (DCA) was used to ordinate the same combined data set of aquatic macroinvertebrates and vegetation. A secondary matrix of 23 environmental variables was included in the analysis in order to elucidate patterns between the grouping of pools and these variables (**Table 14**). In addition to physical and chemical variables, a categorical variable of the four pool subgroups identified in the TWINSPAN was also used in order to relate the ordination to this earlier grouping analysis. The DCA joint plot of the 28 pools, with each pool coded by its TWINSPAN subgroup and vectors showing the most important environmental variables is shown in **Figure 24**.

Table 14. Description of the environmental variables used in the DCA analysis of the 28 pools.

Elev	elevation
TWINcat	four TWINSPAN groupings from the analysis of 28 pools using 275 species of aquatic macroinvertebrate and rooted vegetation (see **Table 14**)
CanType	canopy type: 1= deciduous, 2 = mixed, 3 = evergreen
DeadWood	percent cover of dead wood greater than 10 cm in diameter lying in the seasonal pool
SoilText	soil texture categories: 1 = sand, 2 = sandy loam, 3 = silt loam, 4 = clay loam, 5 = organic muck
OrgDepth	depth of organic soil horizon in cm
HCov	percent of maximum pool area covered by herbaceous plants
NCov	percent of maximum pool area covered by bryophytes
H+BCover	percent of maximum pool area covered by herbaceous plants and bryophytes
Canopy	percent of maximum pool area covered by tree canopy
DistRank	disturbance rank: 0-3 are considered reference quality pools, 4-10 are considered impaired
LQ	landscape quality surrounding pool: 1 = high quality unfragmented landscape, 4 = highly fragmented landscape (see Table 2)
CC	current condition of the pool: 1 = great, 2 = moderate, 3 = poor **(see Table 2)**
WatShed	watershed area in m^2
Perim	perimeter of maximum pool area in meters
Color	water color of pool
Fieldph	pool water pH measured in the field
Alk	pool water alkalinity
So4	pool water sulfate concentration
Ca	pool water calcium concentration
K	pool water potassium concentration
Mg	pool water magnesium concentration
Na	pool water sodium concentration

Figure 24. DCA joint plot of 28 pools with pools coded by their TWINSPAN Subgroups and important environmental variables shown as vectors. The four TWINSPAN Subgroups are also enclosed within freehand polygons to further show their separation.



The TWINSPAN subgroup 1 and 2 pools separate from each other, with subgroup 1 in the upper left and subgroup 2 in the lower left of the DCA ordination. Similarly, subgroups 1 and 2 are graphed on the left side of the ordination. Subgroups 3 and 4 are on the right side of the ordination, opposite from subgroup 1and 2. TWINSPAN subgroup 3 is in the upper central portion of the ordination and subgroup 4 is graphed in the lower right. Although the four TWINSPAN subgroups can all be separated on this DCA ordination, it also clearly shows that the 28 pools form a continuum of variation, as is expected in nature.

The DCA joint plot (**Figure 24**) shows the most important environmental variables and their correlations with Axis 1 and 2 of the ordination. Percent canopy cover has a strong positive correlation with Axis 1 ($r^2 = 0.630$), with those pools that have relatively closed canopies on the right side of the ordination. The pools' perimeters are negatively correlated with Axis 1

($r^2 = 0.457$), as is the percent of the maximum pool area covered by herbaceous vegetation ($r^2 = 0.317$). The inverse relationship between pool canopy cover and perimeter reflects the fact that for small pools the canopy of the adjacent upland forest closes over the pool, whereas for large pools, the adjacent upland trees only cover the fringe of the pool. This clear inverse relationship only applies to undisturbed pools, however, as percent canopy cover is also affected by disturbance, especially logging. Several of the pools on the left side of the graph have been heavily logged and therefore have low percent canopy cover (Irish Hill North and South, Dartmouth, and Boyer).

Axis 2 of the DCA joint plot has positive correlations with depth of organic soil ($r^2 = 0.217$) and pool water color ($r^2 = 0.272$), and negative correlations with landscape quality rank ($r^2 = 0.346$) and sulfate concentration ($r^2 = 0.230$). Greater depth of organic soil is expected to occur in pools with more permanent soil saturation or inundation, such as Hobart Spruce and Boyer. Water color is closely related to the presence and decomposition of organic matter in the soils. A high landscape quality rank means that the pool is located in a disturbed or fragmented landscape. Disturbance rank is also negatively correlated with Axis 2 ($r^2 = 0.148$), with a high disturbance rank meaning that the pool and its surrounding buffer have been disturbed by human activities. In general, the disturbed pools in fragmented landscapes are graphed in the bottom half of the ordination, although several pools with high (Boyer) to moderate (Hampshire Hill and Thistle Hill) levels of disturbance are graphed in the top half of the ordination. It is clear that disturbed and reference pools cannot be separated consistently by this analysis.

An important result of these TWINSPAN and DCA analyses was the identification of the Subgroup 1 pools, all of which were considered to be permanent pools based on field observations. Although the Carlton Hill pool did not fall out with the Subgroup 1 pools, it is also a permanent pool. Based on the field observations and these analyses, these five permanent pools were eliminated from further analyses of the subject seasonal pools.

The above-described TWINSPAN and DCA analyses were also used on a combined dataset of aquatic macroinvertebrates, vegetation, and amphibians. Very similar results were obtained by adding the five species of amphibians, and no further discussion of this analysis seems warranted.

Classification and Ordination of the 23 Seasonal Pools Using Vegetation and Aquatic Macroinvertebrate Data

TWINSPAN and DCA analyses were also run on the aquatic macroinvertebrate and vegetation data for the 23 seasonal pools, excluding the five permanent pools. As with the previous analyses, those species that occurred in only one seasonal pool were eliminated, in this case reducing the number of taxa in the analyses to 240. The TWINSPAN output is provided as **Table B10** of **Appendix B**. The TWINSPAN seasonal pool groupings with their indicator and preferential species are presented in **Table 15** and the DCA joint plot showing TWINSPAN groupings and environmental variable vectors is presented in **Figure 25**.

The results of this second round of combined taxa analyses are similar to the results from the first round, although the axes are reversed in the DCA graph. Axis 1 of the DCA ordination has a strong negative correlation with percent canopy cover (r^2=.619), with those pools that have a relatively high percent canopy cover on the left side of the ordination (generally TWINSPAN subgroups 1 and 2). Axis 1 has a positive correlation with pool perimeter ($r^2 = 0.402$), herbaceous and bryophyte percent cover (r^2=.384), and watershed area (r^2=.318). Subgroups 3 and 4 pools generally have higher values for these environmental variables and are graphed on the right side of the ordination. There is also a positive correlation between Axis 1 and the total disturbance rank ($r^2 = 0.320$), with many of the disturbed sites graphed on the right side of the ordination.

Axis 2 has a positive correlation with dissolved sulfate concentration ($r^2 = 0.397$) and dissolved sodium concentration ($r^2 = 0.559$) and a negative correlation with elevation ($r^2 = 0.319$).

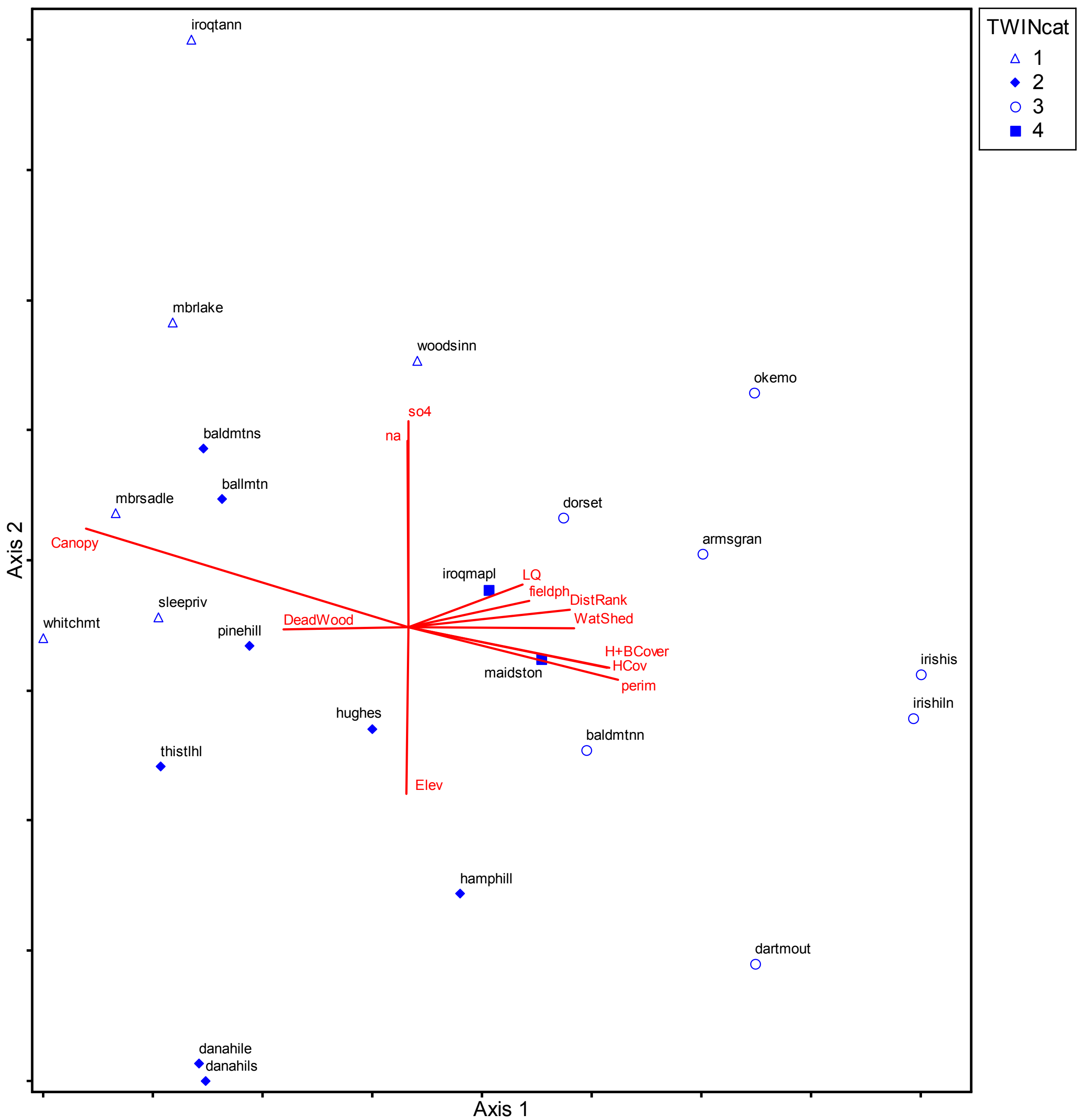
Based on this and the previous analyses it can be concluded that variations in aquatic macroinvertebrate and plant species composition are related to variations in environmental characteristics of each pool, especially percent canopy cover, pool perimeter, depth of organic soil, water chemistry, and watershed area. The duration and frequency of seasonal inundation are likely some of the most important environmental variables in determining pool biota, but accurate measurements of these variables would require multiple visits to each pool over several years and was beyond the scope of this project. Other than the separation of the permanent pools in the analysis of the 28 pools, the DCA ordination shows a continuum in variation between the pools, with no clear-cut types. Furthermore, it can be concluded that the TWINSPAN and DCA of these datasets cannot be used to distinguish conclusively between undisturbed and highly disturbed seasonal pools, using the disturbance rank as an indictor of disturbance.

As with the previous analysis of 28 pools, it appears from this TWINSPAN of 23 pools and the resulting lists of indicator and preferential species that the aquatic macroinvertebrates play a greater role in the classification of the pool types than do the vascular plants and bryophytes. The development and testing of metrics in later sections of this report, therefore, focus primarily on aquatic macroinvertebrate species.

Table 15. Groups of pools and their indicator (I) and preferential species (P) identified in TWINSPAN analysis of 23 seasonal pools. Disturbance ranks are included in parentheses after each pool name.

	Group 1		Group 2	
	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Pool Names	Iroquois Tannic (5) MBR Lake (4) Woodstock Inn (6) MBR Saddle (6) Sleepers River (1) Whitcher Mt. (1)	Bald Mt. S. (0) Ball Mt. (3) Hughes (4) Pine Hill (0) Dana Hill E. (1) Dana Hill S. (4) Hamp. Hill (6) Thistle Hill (6)	Arm's Grant (6) Bald Mt. N. (0) Dorset (5) Okemo (8) Dartmouth (6) Irish Hill N. (7) Irish Hill S. (7)	Iroquois Maple (1) Maidstone (3)
Indicator (I) and Preferential (P) Species (Division 1)	*Limnophyes* sp. (P) *Cyphon* sp. (P) *Aedes diantaeus* (P) *Aedes cinereus* (P) *Pseudosmittia* sp. (P) *Dryopteris intermedia* (P)		*Acilius sylvanus* (I) *Dytiscus fasciventris* (I) *Aedes fitchii* (I) *Hydrochara obtusata* (P) *Laccophilus maculosus* (P) *Hygrotus turbidus* (P) *Dytiscus verticalis* (P) *Tropisternus mixtus* (P) *Haliplus* sp. (P) *Hygrotus* sp. (P)	
Indicator (I) and Preferential (P) Species (Divisions 2 and 3)	*Aplexa elongata* (I), *Lumbricina* sp. (I)	*Polypedilum trigonus* (I), *Phaenopsectra sp* (I), *Lumbriculus variegatus* (I), *Aedes diantaeus* (P), *Omisus* sp (P)	*Eubranchipus bundyi* (P), *Hygrotus turbidus* (P), *Dytiscus fasciventris* (P), *Aedes fitchii* (P), *Pisidium* sp. (P), *Solanum dulcamera* (P)	none

Figure 25. DCA joint plot of 23 seasonal pools with pools coded by their TWINSPAN macroinvertebrate and plant groupings and important environmental variables shown as vectors.



Development of Biological Metrics Based on Aquatic Macroinvertebrates and Classification of Reference-Quality Seasonal Pools

Testing Candidate Aquatic Macroinvertebrate Metrics

The remaining analysis of the macroinvertebrate community will include data from only pools that were determined to be truly temporary or "seasonal." As stated previously, five pools were considered permanent, leaving 23 seasonal pools for analysis.

Reference quality (least-disturbed) seasonal pools were defined as pools with a total disturbance value of 0-3. The nine reference-quality pools are Bald Mountain North, Bald Mountain South, Ball Mountain, Dana Hill East, Iroquois Maple, Maidstone, Pine Hill, Sleepers River, and Whitcher Mountain. Shaw Mountain East and Shaw Mountain West are also reference quality, but since they are regarded as permanent pools they will not be treated here. Fourteen seasonal pools were considered as disturbed, showing disturbance ratings of 4-8 out of a possible score of 10 (See **Table 6**).

An important step in developing biocriteria is to identify metrics that clearly distinguish between reference and disturbed pools. Seventeen candidate biological metrics were tested for their ability to determine impact by comparing metric values between the reference and disturbed pool groups. T-tests or Mann Whitney U tests were used to measure significance of candidate metrics between the 9 reference pools and the 14 disturbed pools. There were no statistically significant differences ($p<0.05$) in metric values between the reference and the disturbed pool groups (**Table 16)**.

Table 16. Results of t-tests or Mann Whitney-U tests (MWU) in candidate macroinvertebrate metrics between 9 reference seasonal pools and 14 pools in disturbed watersheds. All comparisons were non-significant ($p>0.05$). MWU tests were conducted when data could not be made to exhibit normal distribution or show non-heterogeneity of variance by common transformations.

Biological Metric	P
Density	0.176 (MWU)
Richness	0.808
Dominant Single Taxa	0.070
Dominant Three Taxa	0.548
Species Diversity	0.262
% Coleoptera	0.359
% Diptera	0.061
% Ephemeroptera	0.586 (MWU)
% Plecoptera	0.265 (MWU)
% Trichoptera	0.988
% Others	0.246
% Collector- Gatherers	0.576
% Collector- Filterers	0.220
% Predators	0.592 (MWU)
% Shredder- Detrivores	0.848
% Shredder- Herbivores	0.431 (MWU)
% Scrapers	0.975 (MWU)

If both, indicators of watershed disturbance and the biological condition metrics are valid, it is possible that few differences actually exist in the invertebrate assemblages between degraded and reference pools. Environmental conditions of seasonal pools by definition are harsh. Consequently all seasonal pools can, in a sense, be considered as disturbed. Only organisms that are hardy, and resistant to changing conditions, would be expected to occur in such conditions- even in seasonal pools unaffected by human activities. Assemblages that are found in seasonal pools would therefore be tolerant and theoretically resistant to many human impacts.

There are several other explanations for the lack of correspondence between total disturbance values and the biological metrics tested. The metrics themselves may not have been accurate reflections of the biological condition of the assemblages. Other metrics, possibly relating to specific taxa, such as species indicators should be explored in future efforts. Another explanation is that by adding the rankings of each diturbance type to derive a single total value, the assumption was made that all individual types exerted equal effect in the macroinvertebrate community. It is more likely, however, that some disturbance types exert more impacts on communities than others. The injection of values that have little or no effect on macroinvertebrates into a single disturbance value may obscure any true associations with disturbance types that do impart an influence. Lastly, it may be that none of the individual measures of total disturbance tested impose significant impacts on macroinvertebrate assemblages. As a result, other disturbance measures should be considered or existing ones be individually tested for their biological impact

The association between disturbance rating and macroinvertebrate assemblage structure will be further examined in the next section using TWINSPAN.

Classification of Aquatic Macroinvertebrate Natural Assemblage Types in Seasonal pools

TWINSPAN was used to classify macroinvertebrate assemblage types. The TWINSPAN included all 23 seasonal pools because no differences in biological metrics could be established between reference and disturbed pools. Two TWINSPANs were conducted on the dataset, differing in the number of taxa included in the analysis. The first analysis included only taxa occurring at two or more sites (resulting in 146 taxa); and the second analysis included only taxa composing 4% or more of any sample and occurring at two or more sites. Both used presence-absence data. The two TWINSPANs produced similar first-division groupings, as well as indicator and preferential taxa (**Table 17**)

Only three of the 23 pools (Bald Mountain South, Woodstock Inn and Iroquois Tannic) varied in group membership depending on the dataset used. The two first division groups (referred to as negative and positive groups) were made up of 14 pools in the negative group and 9 pools in the positive group for both TWINSPANs **(Table 17**).

Indicator and preferential taxa (those with the strongest preferences for one group) also differed little between the TWINSPANs. Indicator taxa are those preferential taxa that show the strongest affinity for a particular group. The negative group indicator taxon for the 82-taxa analyses was *Cyphon* sp., the marsh beetle. The 146-taxa analysis had no clear indicator species but *Cyphon* sp. was among the strongest preferentials. *Acilius sylvanus*, a diving beetle was the indicator taxa for the positive group in both analyses. (**Table 17).**

Since the marsh beetle, *Cyphon* sp. was an indicator taxa for the negative group in one TWINSPAN and a strong preferential taxa in the other, and *A. sylvanus* was the consistent indicator for the positive group, the two groups will be referred to as the *Marsh Beetle Assemblage* and the *Diving Beetle Assemblage.* In addition to the indicator, *A. sylvanus*, preferential taxa for the Diving Beetle assemblage group include *Dytiscus fasciventris, Laccophilus maculosus* (also predacious diving beetles) and *Hydrochara obtusa,* a scavenger beetle. Many beetle taxa use these pools seasonally and overwinter in permanent waters.

Table 17. Pool placement, indicator taxa, and preferential taxa first division TWINSPANs for two datasets for 23 seasonal pools.

	146 Taxa		82 Taxa	
	Negative (14 pools)	Positive (9 pools)	Negative (14 pools)	Positive (9 pools)
Pool Membership (In order of table presentation)	Iroquois Tannic Woodstock Inn MBR Lake MBR Saddle Whitcher Mt. Bald Mt. South Ball Mt. Hughes Pine Hill Sleepers R Thistle Hill Dana Hill East Dana Hill South Hamp. Hill .	Dartmouth Arms Grant Irish Hill North Irish Hill South Okemo Bald Mt. North Dorset Iroquois Maple Maidstone	Ball Mt. Hughes Iroquois Tannic Whitcher Mt. MBR-Lake MBR-Saddle Sleepers R Thistle Hill Bald Mt -North Bald Mt -South Pine Hill Dana Hill East Dana Hill South Hamp. Hill	Dartmouth Dorset Iroquois Maple Woodst. Inn Arms Grant Irish Hill North Irish Hill South Okemo Maidstone
Indicator Taxa	none	*Acilius sylvanus*	*Cyphon* sp.	*Laccophilus maculosus,* *Lestes* sp., *Acilius sylvanus,* *Lumbricina* sp.
Preferential Taxa	*Aedes cinereus,* *Cyphon* sp., *Aedes diantaeus*	*Acilius sylvanus,* *Dytiscus fasciventris,* *Aedes fitchi,* *Hydrochara obtusata,* *Laccophilus maculosus*	*Cyphon* sp., *Aedes diantaeus,* *Psuedosmittia* sp., *Phaenopsectra* sp.	*Laccophilus maculosus,* *Lestes* sp., *Acilius sylvanus,* *Lumbricina sp*

It would be useful to be able to predict, with some degree of certainty, the type of seasonal pool assemblage type by its physical and chemical characteristics. To that end, 18 physical and chemical descriptors from the two TWINSPAN-defined assemblage types were compared. The group means from physical and chemical both TWINSPAN-defined groupings are presented in **Table 18.** Since group pool membership changed little between the two TWINSPAN analyses, group means for these variables were similar. In general, the Marsh Beetle pools were characterized as smaller (shorter perimeter and watershed size), with more canopy cover and moderately to mildly acidic conditions. Correspondingly these pools had lower specific conductance, alkalinity, and dissolved calcium and magnesium concentartions. The Diving Beetle pools were generally larger and less acidic with greater specific conductance and alkalinity. Although mean values of some variable significantly differed, all variable values overlapped between the pool types. As a result, no physical descriptor measured here could consistently differentiate between the two pool assemblage types. Despite this, however, a *reasonable* prediction may be made on the biological pool type based on a combination of physical and chemical attributes relating to levels of base cations.

Table 18. Mean physical and chemical attributes and disturbance ranking of two TWINSPAN first division groupings for 23 seasonal pools. The 146x23 matrix includes only taxa that occurred in at least 2 of the 23 pools, and the 82x23 includes taxa occurring in at least 2 pools and comprising 4% or more in at least one sample. Parametric (or where data was non-normal-nonparametric) t-tests were conducted on the 82x23 dataset; p values are presented in the last row, significant results are in bold.

	146 x 23		82 x 23		
Group Size	14	9	14	9	p
% Canopy	78.8	32.6	80.5	29.8	**<0.001**
Perimeter (m)	77.1	108	75.4	110.6	0.597
Color (Pt-Co units)	139.4	111.8	149.5	96.1	0.550
PH	5.9	6.6	5.7	6.9	**<0.001**
Alkalinity	21.8	56.6	14.5	67.8	**<0.001**
Specific Conductance	59.6	113.4	46.3	134.2	0.875
Tot. Aluminum	201.7	160.8	197.5	174.5	-
Chloride	0.5	0.8	0.5	0.8	**<0.001**
Nitrates	0.1	0	0.1	0	**<0.001**
Sulfates	4.6	4.0	4.0	5.0	0.367
Calcium	9.1	15.2	6.5	19.3	**0.020**
Potassium	1.1	1.1	1.0	1.2	0.580
Magnesium	1.0	5.2	0.8	5.5	**0.010**
Sodium	0.6	0.7	0.6	0.7	0.777
Elevation	1258	1150.0	1249.4	1163.3	0.670
Depth of Organic Layer (cm)	26.6	21.6	28.1	19.3	**<0.001**
Disturbance Ranking	2.9	5.1	2.6	5.4	**0.005**
Watershed size	4810.0	7087.6	4532.1	7519.8	**0.001**

The TWINSPAN output table for the dataset including only taxa that appeared in two or more sites and made up at least 4 % of the total from a sample (82 taxa) is shown in **Table 19**. These restrictions eliminated most rare taxa from the analysis, allowing common taxa to drive the TWINSPAN grouping. This appears to be the more robust approach because recording rare taxa can be influenced by sampling method. Employing only common taxa in this analysis minimizes the effects on sample composition of using different sampling methods in future work. Common taxa are more likely to be collected regardless of method and sampling intensity. While truncating the species used in the analysis may decrease the effects of sampling variability on the results, some information may be lost in the process. While taxa occurring in only one pool are not likely to influence the results of the analysis, less abundant but widely distributed taxa, if consistently sampled, may contribute to the ability to determine pool condition or class.

DCA was performed on the 82 taxa dataset from the 23 seasonal pools. The resulting joint plot shows that assemblages were arrayed in axes 1 and 2 by pH, percent canopy cover, and dissolved potassium concentrations (**Figure 26**). The plot can be divided down the middle with the left side representing Marsh Beetle Pools and the right side, Diving Beetle Pools. This is a further indication that aquatic macroinvertebrate community structure is partially driven by pH, percent canopy cover (also related inversely to pool perimeter), and base cations (calcium, magnesium, sodium, and potassium).

Table 19. A TWINSPAN conducted on macroinvertebrate taxa that appeared in two or more sites and made up at least 4 percent of the total from any sample.

```
                      1121122  112 1111
                40426701239569783311285

  3  Aeshna     --------1--11----------   000000
 22  dossuari   -----------11----------   000000
 75  tritum     -----------11----------   000000
  9  biannula   --------1---1----------   000001
 48  micropse   ------1-1-1111---------   000001
  1  abductus   --------11-------------   00001
  2  ablabesm   -----1--1-1--1---------   00001
 27  exacuous   --------11-------------   00001
 72  tigrina    ---------11------------   00001
 50  monopelo   --------1-11-----1-----   00010
 61  procladi   --------1-111-1--------   00010
 63  psectrot   --------1111111-----1--   00010
 10  canadens   -1------111--1----1----   00011
 47  mediatus   ---1-11-1111-1--1-----1   00011
 14  cinereus   -1-11----1111----------   00100
 20  diantaeu   11---1-1--11-1---------   00100
 19  cyphon     11-111---111-----------   00101
 64  Pseudosm   11-1-1-1111--1--------1   00101
 65  punctor    ---1--1----1-----------   00101
 81  zavrelia   ---1-1---1-------------   00101
 58  phaenops   11-1---11-1111--1-----1   00110
 66  retenuov   1-1------11------1-----   00110
 32  hydraena   ----111---1----------1-   00111
 40  Limnephi   ---1-1------1-----1----   00111
 82  zavrelim   ---1--11---11---1------   00111
 15  communis   1111111-1111--11--1--1-   0100
 41  limnophi   --1-------------------1   0100
 43  limnophy   111111-1-11-1-1--11-1--   0100
 68  staphyli   1---1--11-1----------11   0100
 24  elongata   ----111---------11---1-   0101
 36  intruden   -1-1--1---1---11-------   0101
 37  larsia     ---11111-1--1-111---1--   0101
 74  trichuru   --11------------1------   0101
 59  Physa      ----11------1-------11-   011000
  4  agabus     -1111111-1111111-111-11   011001
 33  hydropor   11--111111--11-1111-1-1   011001
 35  indivisu   11111111111-1111111111-   011001
 49  mochylon   11-11111111111111111111   011001
 71  thyas      1111111--11-111111111-1   011001
 62  provocan   ----111-111-1-11-11--1-   011010
 77  tubifex    -----11-111111111-1-11-   011010
 79  variegat   11---111111111111-1111-   011010
 13  chironom   11-1111111111111111-1--   011011
 28  excrucia   11111-----11111---1111-   011011
  8  bezzia     -1------1-11111---1111-   01110
 12  chauliod   1-------1-111------111-   01110
 52  naiscomm   --------1--1111-----11-   01110
 26  Eristali   ---------11------1-----   01111
 42  limnopho   ---------1--1-1-------1   01111
 60  Placobde   --------1-----1--------   01111
 23  elodes     --------111-------111--   100
 30  hesperoc   ------1-11--11111-11-11   100
 53  natarsia   ----------11--1-----1--   100
 76  trivitta   --------111--1--1--1111   100
 25  enchytra   --1-1111111-1-11111-111   10100
 67  semisulc   -11--1111-1-11111111111   10100
 11  casertan   ---111111---1111111111-   10101
 16  corynone   ---11-----1------11-1--   10101
 17  culicoid   ---1-------1---1-----1-   10101
 55  occident   ----1--1----1---11-11--   1011
 45  lumbrici   --1-11---------11111-11   11000
  7  audeni     ----1-------11111---111   11001
 18  curculio   -------------1-----1111   11001
 54  notonect   --------1----11--1-11--   11001
 73  tipula     -------------1-1--1----   11001
  5  alluaudo   1---------1----1----11-   110100
 44  longulus   --------1----------111-   110100
 70  templeto   -1--------1---1---1-1--   110100
  6  american   --------1----------11--   110101
 51  musculiu   -------------1----1-1--   110101
```

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                 1121122  1     12 1111
               40426701239569783311285

 57  parvus     --------11------1-111--   110101
 34  Ilybius    ---------1----1--1-11--   11011
 21  Doithrix   ---------------------11   1110
 29  gyrinus    ---------------1---1--1   1110
 38  lenticul   --------------1----1--1   1110
 69  sylvanus   --------1-----1-1-1-111   1110
 39  lestes     ----------------111111-   11110
 56  odontomy   ------------------111--   11110
 80  ventrico   ------------------111--   11110
 31  hydrachn   --------------1-1--1---   11111
 46  maculosu   --------------111-1---1   11111
 78  udekemia   --------------1111-----   11111

                00000000000000111111111
                00000000111111000000001
                0001111100011100001111
                   01111
```

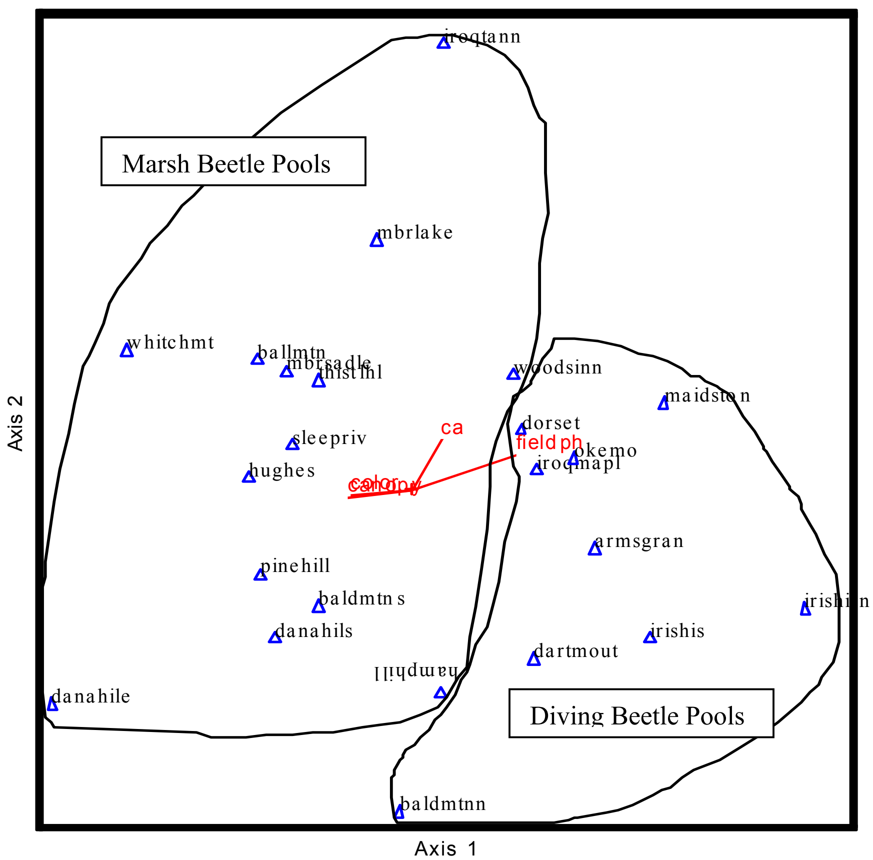
Left Group (negative)-Marsh Beetle Assemblage Type (n=14)

Ball Mt
Hughes
Iroquois Tannic
Whitcher Mt.
MBR Lake
MRBR Saddle
Sleepers River
Thistle Hill
Bald Mt. North
Bald Mt. South
Pine Hill
Dana Hill East
Dana Hill South
Hampshire Hill

Right Group (postive) – Diving Beetle Assemblage Type (n=9)

Dartmouth
Dorset
Iroquois Maple
Woodstock Inn
Arms Grant
Irish Hill North
Irish Hill South
Okemo
Maidstone

Figure 26. A DCA joint plot of aquatic macroinvertebrate assemblages of 23 seasonal pools from 1999-2000.



Disturbance Ratings. The correlation between disturbance ratings and metrics was revisited using the results of the TWINSPAN. **Table 20** shows macroinvertebrate assemblage group membership of pools and their associated disturbance ratings. The disturbance rankings between the groups were significantly different (p=0.005; t-test) with the Marsh Beetle pools having lower disturbance values - mean of 2.6 vs.5.4 for Diving Beetle pools). This indicates that disturbance (as characterized by the disturbance rating) may have an influence on assemblage composition in addition to some of the physical and chemical factors. All 17 candidate biological metrics were tested for significant differences between the two assemblage types. Four differed significantly between groups. These were percent dominance-single taxa (p=0.04; T-test), percent dominance-3 taxa (p=0.03), species diversity index (p=0.04), and percent dipterans (p=0.03). It is possible that the division of reference vs. disturbed pools (as determined by disturbance ranking) did not group pools as accurately as did TWINSPAN, which was based on assemblage taxonomic structure. As before, with other variables, there was much overlap in metric value range between the two assemblage types. This indicates that further efforts to identify viable metrics that consistently reflect biological response to disturbance may yet produce positive results.

Table 20. TWINSPAN groups from the first division of 23 seasonal pools on the 82 taxa dataset of macroinvertebrates collected during 1999-2000. Total watershed disturbance values are given with each pool. Reference pools (total disturbance rating <4) are in italics.

Marsh Beetle Pools	Diving Beetle Pools
MBR-Lake-6	Okemo-8
Iroquois Tannic-5	Irish Hill North-7
MBR-Saddle-4	Irish Hill South-7
Hughes-4	Arms Grant-6
Dana Hill South-4	Woodstock Inn-6
Hampshire Hill-4	Dartmouth-6
Thistle Hill-4	Dorset-5
Sleepers River-1	*Maidstone-3*
Whitcher Mountain-1	*Iroquois Maple-1*
Dana Hill East-1	
Pine Hill-0	
Bald Mountain North-0	
Bald Mountain South-0	
Ball Mountain-0	

Table 21 presents a list of the 15 taxa found in at least 70% of the seasonal pools. In some pools, these were the dominant taxa. Certain genera, such as *Agabus* and *Hydroporus* probably contain numerous species, that are not cosmopolitan.

Table 21. A list of cosmopolitan aquatic macroinvertebrate taxa (occurring in at least 70% of sites) from the 23 seasonal pools.

Order	Genus	Species	Order	Genus	Species
Coleoptera	*Agabus*	sp.	Diptera	*Mochlonyx*	*cinctipes*
	Hydroporus	sp.	Trichoptera	*Limnephilus*	*indivisus*
	Acilius	*semisulcatus*	Hydrachnidia	*Thyas*	sp
	Hydrobius	*fuscipes*	Bivalvia	*Pisidium*	*casertanum*
Diptera	*Aedes*	*communis*	Oligochaeta	*Enchytraeidae*	*unid*
	Aedes	*excrucians*		*Lumbriculus*	*variegatus*
	Aedes/Ochlerotatus	*group*		*Tubifex*	*tubifex*
	Chironomus	sp.			

Discussion of Macroinvertebrates and Hydroperiod

Pools do not persist for the same period each year, as they are dependant on snowfall, runoff, and often seasonally "perched" groundwater. This study was not designed to determine the hydrologic period of the study pools. More frequent assessments spanning years would be necessary to provide suitable information. However the five pools not treated in the analysis (Shaw Mountain East and West, Hobart, Carlton Hill, and Boyer) were determined to be permanently inundated due to observations during 1999-2000 and the presence of deep organic soil layers. The remaining 23 pools were seasonally inundated and best described by a full range of soil drying conditions from surface saturation to complete drying.

Six of the pools (MBR Lake, Thistle Hill, Iroquois Tannic, Iroquois Maple, Dana Hill South, and Dana Hill East) were dry by the late spring sampling period and presumably have the *shortest* duration of inundation. Five of these pools were classified as Marsh Beetle pool types and one, a Diving Beetle type. These pools went dry in the spring of 1999, a year with little snow pack and runoff. These short duration pools may not have dried if there had been more snowfall that year. Conversely, those pools considered to have *long* durations may in some years actually have standing water for a complete year. Hydroperiod variability is probably normal.

There did not appear to be a relationship between pool perimeter and duration. The short duration pools averaged 89 m in perimeter while the longer duration pools averaged 84 m. The 23 seasonal pools showed a full range of hydrologic conditions. The expected durations for these pools based on observations from 1999 and 2000 are presented in **Table 22**.

Two-thirds of all seasonal pools (4 of 6 short duration and 12 of 17 long duration pools) were inundated in the fall. The longer duration pools that are inundated in the fall have basins capable of supporting water almost continuously over the course of the warmer months if there is adequate precipitation.

Pool duration is a critical factor in determining the viability and the variability of an aquatic macroinvertebrate population. The longer the hydroperiod, the more opportunities for the aquatic macroinvertebrate community to develop a more complex biological structure. A short duration pool appears to provide an adequate hydroperiod for Marsh Beetle assemblage type, but not for the Diving Beetle assemblage type. This is especially true for predators such as diving beetles and *Lestes* sp.

Table 22. Expected duration of seasonal pools based on observations from 1999-2000.

	Short (dry in spring)	Long (dry by late summer)	Autumnal Pool?
Marsh Beetle Pools			
Iroquois-Tannic	U		No
MBR Lake	U		No
MBR Saddle		U	Yes
Woodstock Inn		U	Yes
Bald Mt. South		U	Yes
Ball Mt.		U	Yes
Hughes		U	No
Pine Hill		U	Yes
Sleepers River		U	Yes
Thistle Hill	U		Yes
Whitcher Mountain		U	Yes
Dana Hill East	U		Yes
Dana Hill South	U		Yes
Hampshire Hill		U	Yes
Diving Beetle Pools			
Dartmouth		U	No
Irish Hill North		U	No
Irish Hill South		U	Yes
Arms Grant		U	No
Dorset		U	No
Okemo		U	Yes
Bald Mt. North		U	Yes
Iroquois Maple	U		Yes
Maidstone		U	No

Short duration pools are more likely to support aquatic macroinvertebrate communities with life histories able to tolerate desiccation. Additionally, it was expected that the long duration pools would have supported a more diverse community than the short duration pools. Mean species richness data from this study however, did not support that expectation. There was no significant difference in the mean taxa richness between the six short duration pools and the 17 long duration pools ($p=0.719$, t-test). The same results were obtained when just the long duration pools with fall inundation were compared to the short duration pools. Before conclusions can be drawn however it should be remembered that the partitioning of pools into the two permanence categories was based on just two years of observation. As mentioned previously more observations during addition years needs to be completed to gain a valid estimate of permanence for these seasonal pools.

Discussion of Vascular Plants and Level of Disturbance in the 28 Pools

Biological metrics were not developed for vascular plants and bryophytes as they were for aquatic macroinvertebrates. Although it may be worth pursuing this in future studies, at this time there are still some observations to be made about vascular plant species composition in the pools relative to their level of disturbance.

Invasive, non-native species are commonly associated with disturbance in wetland and upland natural communities. It is interesting to note that only three non-native species of vascular plants were found in the 28 pools. Common nightshade (*Solanum dulcamara*) is non-native, but not considered an aggressive invader. It grows in eight of the pools, never with more than three percent cover. Six of these pools are considered disturbed (Arms Grant, Dorset, Irish Hill North and South, Okemo, and Woodstock Inn) and two are in very high quality, undisturbed landscapes (Shaw Mountain East and West – both considered permanent pools). Self-heal (*Prunella vulgaris*), a naturalized Eurasian species, grows at the margin of Carlton Hill, a highly disturbed permanent pool. Watercress (*Rorippa nasturtium-aquaticum*) grows in Woodstock Inn pool, a disturbed seasonal pool. Although these non-native species clearly occur more frequently in disturbed pools, their presence in a pool is not a definitive indicator of pool disturbance level.

Several vascular plant species identified in the study pools are native annuals and perennials that have ruderal life cycle strategies. Ruderal species are typically adapted to stressful environments or those with fluctuating environmental conditions and they commonly have periods of dormancy and then rapid reproduction. Although classification of species as ruderal is largely based on professional judgement, it may be a group that warrants more investigation in future studies. Seasonal pools in undisturbed settings are themselves habitats with wildly fluctuating environmental conditions (inundation to dessication) and ruderal species are to be expected here. However, disturbed pools are under additional stresses and appear to harbor either additional ruderal species or the same species in greater abundance than undisturbed pools. In many of the cases mentioned below, the high abundance of some species is related to an increase in light associated with conopy removal or thinning by logging adjacent to the pools.

Marsh spikerush (*Eleocharis palustris = E. smallii*) is a perennial that can also produce abundant seeds and spread, especially in areas of exposed moist to wet soils with lots of light. It is abundant in Irish Hill North (30% cover) and present in Irish Hill South, both pools for which the canopy has been removed by logging.

Blunt spike-rush (*Eleocharis obtusa* = *E. ovata*) is an apparent annual found growing on wet soils. This species occurs in low abundance (0.5% cover) at the reference Dana Hill East pool, but is very abundant (40% cover) at Dartmouth pool, where the canopy has been entirely removed by logging.

Nodding beggar's-ticks (*Bidens cernua*) is a native annual species of wetlands. Nodding beggar's-ticks occurs in five of the study pools (Dana Hill East, Dartmouth, Hobart Spruce, Irish Hill North, and Shaw Mountain East), but only reaches high abundance (25% cover) at the Dartmouth pool, where the canopy has been removed by logging. It is interesting to note that this species only represents one percent cover at Irish Hill North, the other of these five pools that has been highly disturbed by logging. The species represents 10 percent cover at both Hobart Spruce and Shaw Mountain East, pools with low levels of human disturbance.

Lobed beggar's-ticks (*Bidens connata*) is also a native annual species of wetlands. It is abundant at Boyer (20% cover) and present at Irish Hill South (1% cover), both pools with high levels of logging disturbance.

Rice cutgrass (*Leersia oryzoides*) is a native, perennial, wetland grass that spreads in muddy, exposed soils by rooting at the nodes on the culm and by abundant seed production. This species occurs in eight pools, two of which are reference quality permanent pools (Shaw Mountain East and West). The species has its greatest abundance at Irish Hill North (40% cover) and Boyer (25% cover), two pools disturbed by logging.

CONCLUSIONS

The following conclusions can be made regarding the objectives for this study of seasonal pools as they are listed at the beginning of this report (see Project Description and Overview).

1. Methods of sampling aquatic macroinvertebrates in seasonal pools were evaluated in detail. The scoop method was found to be very disruptive to the pools, especially of critical amphibian life stages. This method was also found to be inconsistent in the number of taxa collected and the abundance collected, in part because of accumulation of debris in the scoop. The scoop method was most consistent in sampling taxa associated with the sediment. The trap method was very successful at capturing mobile species, but also collected sediment associated species. Trap sampling requires at least two visits to each pool and may capture adult amphibians as well. An interesting finding of the macroinvertebrate sampling was that there is extreme temporal variability in the relative abundance and occurrence of taxa in a pool. This variability was so extreme that there was little resemblance in the composition of macroinvertebrates between sampling replicates, between multiple sample dates over one season, or between years at the same pool, regardless of the sampling method. Methods for sampling vegetation, amphibian populations, and water quality in seasonal pools and other wetland ecosystems were well established prior to this study and were not evaluated in detail for this project.

2. Although the basic environmental conditions in which seasonal pools develop are very specific (small basin with a small surface watershed and a combination of water-accumulation and substrate type that allows for spring and/or fall inundation), the biological and water chemistry characteristics of individual pools vary greatly. The primary environmental gradients associated with the pools studied were percent canopy cover (and the closely related pool perimeter), depth of organic soil, and several water chemistry parameters based on DCAs run on macroinvertebrate and plant composition of pools. Vascular plants and bryophytes were not effective in classifying either reference quality or disturbed seasonal pools sampled in this study. Aquatic macroinvertebrate composition of the pools were used to identify two types: diving beetle pools and marsh beetle pools.

3. The data collected on the presence and absence of amphibians and their egg masses was not useful by itself in classifying pools or as a means of distinguishing between reference and disturbed pools.

4. None of the 17 aquatic macroinvertebrate metrics tested can be recommended for use in measuring biological impacts from human disturbance due to 1) the lack of statistically significant differences in metrics between disturbed pools and reference quality pools, and 2) the lack of structural differences between the disturbed and reference pools as evidenced by a TWINSPAN of all 23 pools.

5. Parametric and non-parametric hypothesis tests contrasting TWINSPAN-defined groups from the total 23-pool dataset showed that one of the two groups had four physical and chemical variables that differed significantly ($p<0.005$, t-test or Mann-Whitney- U test). These were percent canopy cover, pool perimeter, pH, and dissolved magnesium concentration. With additional seasonal pool data, these variables (and possibly elevation) may eventually be used to differentiate seasonal pools types. The current dataset however shows much overlap in all values tested between the two seasonal pool types. As a result, only a modest predictive value can be generated on the parameters that significantly differed between types.

RECOMMENDATIONS

Additional reference-level seasonal pools from as varied locations as possible could be sampled for invertebrates, plants, and amphibians to supplement the dataset. This would assist in the identification of additional reference seasonal pool types. Experience from this project indicates that aquatic macroinvertebrates may be the group that would be most productive to focus on for any future work. Also, more clearly degraded sites should be added to the dataset so that any differences that do exist in metrics between reference and disturbed sites missed during the present evaluation may be identified during a second analysis. Developing additional biological metrics for testing should also be considered.

Seasonal pools are highly significant for the amphibian breeding habitat that they provide. In this study, we identified the presence and absence of all amphibian life stages encountered in each pool. Given the scope of the project, however, it was not possible to evaluate the breeding success of each species at each pool. Although evaluating breeding success of amphibians may be a labor-intensive and time-consuming undertaking, it may also be one of the best measures of ecological integrity of seasonal pools and the surrounding upland forests and should be considered in future studies of this kind.

Variability in the duration and timing of inundation in seasonal pools is clearly a dominant factor determining aquatic macroinvertebrate, amphibian, and plant species composition in a particular pool. Full documentation of pool hydroperiod was beyond the scope of this study, but should be pursued in future studies of this kind. Hydroperiod could be measured by multiple visits to each pool or possibly with the use of remote data loggers.

PART 2 – NORTHERN WHITE CEDAR SWAMPS

PROJECT DESCRIPTION AND OVERVIEW

The majority of past bioassessment work has focused on aquatic ecosystems and has been used successfully to develop metrics that reflect ecological integrity of these systems. Based largely on support from the US Environmental Protection Agency, bioassessment work has expanded to wetlands, although the majority of wetlands bioassessment work has been on wetlands with emergent or submerged vegetation. There have been relatively few bioassessment studies of wetlands with saturated or seasonally saturated soils. Notable exceptions are the recent works by Mack (2001) on a variety of wetland types in Ohio and Laidig and Zampella (1999) on Atlantic white cedar swamps in the New Jersey Pine Barrens.

The selection of northern white cedar swamps as the wetland community for this bioassessment study was based on several factors. The Vermont Fish and Wildlife Department's Nongame and Natural Heritage Program (NNHP) completed a three-year, statewide study of northern white cedar swamps that was funded by the US Environmental Protection Agency (Sorenson et al. 1998). This study provided relatively complete information on the distribution of cedar swamps in Vermont and their vegetational and ecological variability. The vegetation and ecological data collected during this study was easily adapted to examination for bioassessment purposes.

Northern white cedar swamps clearly present a challenge for typically aquatic-based biological assessments in that they often contain almost no standing water at any time of the year. In these wetlands, truly aquatic organisms may be scarce or nonexistent, therefore, focus must be shifted to more terrestrial plant and animal assemblages. As part of this assessment, we evaluated vegetation and breeding bird data that the NNHP gathered in the earlier statewide inventories of northern white cedar swamp sites and augmented these with new data from additional cedar swamps using previously established protocols. We also assessed the feasibility of sampling aquatic macroinvertebrates. In an effort to limit the natural variability between cedar swamp sites, we focused our efforts on the "typical" northern white cedar swamps as described in the NNHP's cedar swamp study (Sorenson et al. 1998) and the Vermont natural community classification (Thompson and Sorenson 2000).

The overall goal was to identify specific attributes that can serve as indicators of ecological integrity in northern white cedar swamps.

The specific objectives were to (1) identify assemblages of plants (vascular and bryophytes), species of birds, and assemblages of aquatic macroinvertebrates that may serve as indicators of ecological integrity for northern white cedar swamps.

REGULATORY PROTECTION OF NORTHERN WHITE CEDAR SWAMPS IN VERMONT

State

Wetlands that are identified on the National Wetlands Inventory (NWI) maps are initially designated as significant for one or more functions and values and are protected under the Vermont Wetland Rules. A total of 262 northern white cedar swamps were identified in Vermont (Sorenson et al. 1998), and of these, 202 are part of an NWI mapped wetland. An additional 21 of these 262 wetlands are within 50 meters of an NWI mapped wetland and are likely to be contiguous to these mapped wetlands. Therefore, at least 77 percent of Vermont's northern white cedar swamps are protected under the Vermont Wetland Rules, and possibly as many as 85 percent. The Vermont Wetland Rules protect the functions and values of these wetlands and most activities that would result in permanent alteration of these wetlands and adjacent 50 foot buffer zones will require review under the Rules. There are also activities such as logging that are considered allowed uses under the Rules.

There may be additional protection for some of these cedar swamps that are associated with projects that fall under the jurisdiction of Vermont's Act 250 land development law. Several criteria in the Act 250 review process relate to cedar swamps, including rare and irreplaceable natural areas, wildlife habitat, shorelines, and aesthetics.

Local

Several Vermont statutes provide authorization for Vermont towns and cities to protect wetlands at the local level. This can be accomplished through the Town's municipal plan, zoning, and subdivision regulations, shoreland protection bylaws, health ordinances, and flood hazard regulations.

Federal

Section 404 of the Clean Water Act establishes programs to regulate the discharge of dredged and fill material, excavation, and mechanized land clearing in waters of the United States. The USEPA and the United States Army Corps of Engineers administer the program jointly, with assistance from the United States Fish and Wildlife Service and the Vermont Agency of Natural Resources. Federal wetland permits are not valid in Vermont without first obtaining a State of Vermont Section 401 Water Quality Certification from the VT DEC Wetlands Office. Under Section 401 of the Clean Water Act, all federal permits are reviewed by state programs to assure compliance with state water quality standards.

METHODS

Site Selection

The Vermont Nongame and Natural Heritage Program conducted a statewide inventory of northern white cedar swamps and red maple-northern white cedar swamps in 1996 and 1997 (Sorenson et al. 1998). The landscape analysis phase of this inventory used standard Heritage Program methodology, including review of existing databases, aerial photos and maps, contact of knowledgeable individuals, and aerial reconnaissance from a low-flying airplane. Through this process 262 northern white cedar swamps and 54 hardwood-cedar swamps were identified and, of these, 70 of the highest quality swamps representing the full geographic range of the communities were visited for detailed study and sampling of vegetation and surface water pH and conductivity. The highest quality swamps were identified as those with little or no evident human alteration of the vegetation or hydrology, and with mostly intact, forested, upland buffers. These features were determined through review of 1994 1:40,000 aerial photographs and through reconnaissance from a low-flying airplane. This first level of site selection for the 1998 study was based primarily on professional judgment. A more formal process of ranking the type and severity of disturbance at each swamp was conducted as part of this bioassessment project.

In addition to the 70 swamps visited for the 1998 study, four additional northern white cedar swamps were selected for the current project. These four sites were selected from the known occurrences as yet unsampled northern white cedar swamps identified during the initial cedar swamp inventory, and included three relatively disturbed examples and one reference quality example of this community type. Selection of these four swamps was made based on observation notes from the initial inventory. Based on available information from the 1998 cedar swamp study, swamps were selected that appeared to best fit the “typical” variant of northern white cedar swamp, instead of one of the other three variants of the community identified in this study (Sorenson et al. 1998). The reason for this selection process was to attempt to minimize the natural variability in vegetation and environmental conditions between sites, so as to improve the effectiveness of evaluating anthropogenic alteration of these wetlands. Larger swamps were selected when possible so as to better accommodate the breeding bird survey methods. Final site selection was also dependant on obtaining approval of landowners. In addition to these four new sites, two reference quality cedar swamps identified in the 1998 study were revisited to conduct breeding bird surveys. **Figure 27** shows the location of all the studied cedar swamps and hardwood-cedar swamps in Vermont and the 36 "typical" northern white cedar swamps that were the focus of this bioassessment project.

Data Collection and Processing Methods

Field methods for the four new swamps visited for this study were the same as for the initial NNHP inventory of northern white cedar swamps (Sorenson et al. 1998). They consisted of both general observations 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 type and depth with a Dutch auger and/or 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 each swamp was obtained and the variations and gradients present were observed and documented. In smaller swamps, such reconnaissance may cover 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 observe a great deal of the natural variation in the wetland in an expedient and relatively rapid manner.

Biological Sampling Methods

Quantitative Vegetation Sampling

Vegetation sampling was conducted during the summer of 1999 and followed The Nature Conservancy "Quantitative Community Characterization" methodology (Sneddon 1993). After initial reconnaissance in each swamp, plots were subjectively located in areas of homogeneous vegetation that characterized the portion of the swamp being sampled. Plots were located so as to avoid areas of direct recent disturbance, such as patch or clear-cuts. Although these highly disturbed areas have very different vegetation characteristics (lack of canopy and greater herbaceous and seedling cover) that reflect the high level of human alteration to the community, they were considered far too disturbed to be used in any meaningful comparison to reference swamp communities. Plots were 200 square meters (10m x 20m) and boundaries of the plot were located and marked with a 50 meter measuring tape and colored flagging. For each plot, vegetation cover was estimated and recorded by stratum for the following layers: emergent trees, tree canopy, small trees, tall shrubs, short shrubs, herbaceous, and non-vascular. Species lists were constructed by stratum and percent cover was estimated and recorded for each species. For tree species, percent cover was entered into the database separately for tree, sapling, and seedling layers and the data was also analyzed this way. Two or more average-sized northern white cedar trees were also cored to estimate stand age. All vegetation sampling data was recorded on the standard NNHP plot form.

Several aspects of the plot data were used for developing metrics for the study. These included total canopy cover, percent cover for other vegetation strata (bryophyte, herbaceous, short shrub, and tall shrub), vascular plant and bryophyte species richness, number of exotic species, and percent cover of exotic species.

Figure 27. Location of Cedar Swamps

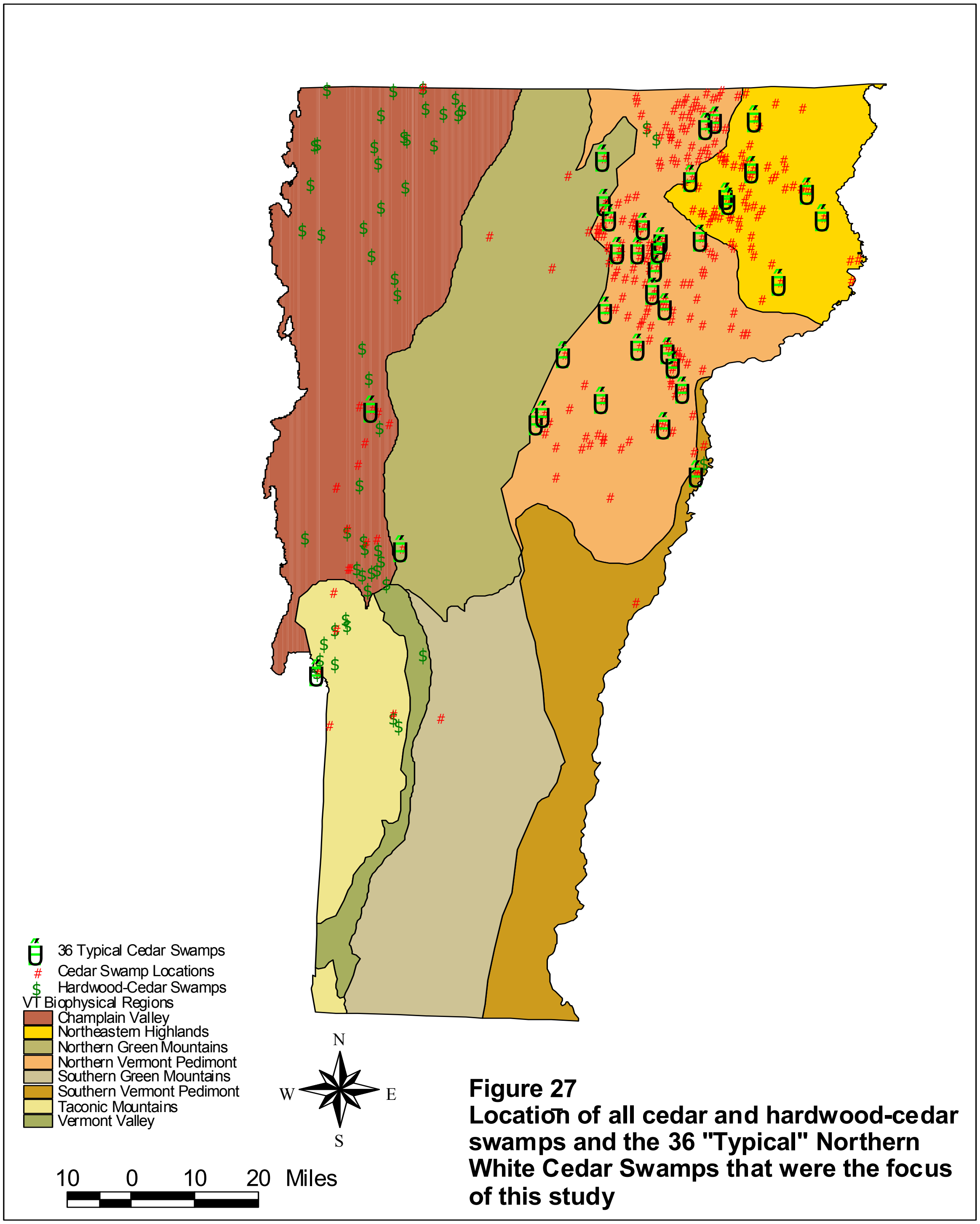


Figure 27
Location of all cedar and hardwood-cedar swamps and the 36 "Typical" Northern White Cedar Swamps that were the focus of this study

Unknown vascular plants and bryophytes were collected and later identified. Taxonomy and nomenclature for ferns, fern allies, and gymnosperms follows Flora of North America (Flora of North America Editorial Committee, 1993). Vascular plant taxonomy follows Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Gleason, 1991). Bryophyte taxonomy follows Anderson, Crum, and Buck (1990) for mosses, except for Spagnaceae, which follows Anderson (1990). Liverwort taxonomy follows Stotler and Crandall-Stotler (1977).

Breeding Bird Census

A breeding bird census was conducted in each of the six northern white cedar swamps in the spring of 1999. The procedure for this census work was the same that was used for the three other northern white cedar swamps in the 1998 study. This sampling protocol followed that used by the Vermont Institute of Natural Science in their Forest Bird Monitoring Program, which in turn are based on methods developed by the Canadian Wildlife Service in Ontario. Up to five listening stations were established at each of the six swamps. 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 cedar swamp community type. Because of the small size of some of the cedar swamps that were sampled and concern about including birds from outside the community, there were often fewer than five listening stations established at a swamp. Transects and listening stations were set up and marked with flagging in advance of each sampling event.

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 and sight. The censuses 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.

Aquatic Macroinvertebrates

Three sites were visited in early summer to assess the feasibility of sampling aquatic macroinvertebrates for bioassessment and monitoring purposes. Sampling for aquatic macroinvertebrates had been scheduled for May 1999, but due to scheduling conflicts, they were not sampled until June 1999. Unfortunately, a very dry spring caused the cedar swamps to be drier than usual. Two impaired sites and one reference site were visited during the month of June 1999. Standing or flowing water was not found at either the reference site or at one of the impaired sites. Thus, sampling was not effective. However, there was evidence that suggested the presence of water earlier in the season. The second impaired site contained many braided, slow-flowing channels and some standing water. Three of the channels and a small hollow at the base of a boulder were qualitatively sampled. The samples were preserved in the field, picked and sorted, and identified according to standard protocol.

Physical and Chemical Sampling Methods

Physical and chemical data were collected at each quantitative vegetation-sampling plot and recorded on the plot form. This included depth of organic soil, soil profile description, degree of decomposition of organic soil layers by the von Post scale, characterization of soil drainage and soil moisture regime, description of microtopography, and pH and conductivity of surface water. Organic soil depth was measured either with a Dutch auger (for depths less than 125 cm) or fiberglass chimney-sweep extension poles (up to five extensions were assembled to measure peat depths to over five meters). The small (1 cm diameter), cup-shaped, threaded base on the chimney-sweep poles worked well to collect a small sample of mineral soil underlying those organic deposits greater than 125 cm that could not be sampled with the

Dutch auger. For mineral soils, soil profiles included depth of each horizon and the following characteristics of each horizon: color, presence or absence of mottles, and texture. For organic soils, the degree of decomposition was rated using the 1-10 von Post scale. Drainage class and soil moisture regime were recorded on the plot form using standard categories. Surface water pH and conductivity were measured in the field using Oakton brand meters that were calibrated daily with standard solutions. In cases where there was no surface water in hollows, a small pit was dug and water was allowed to seep in and stabilize in the pit before measurements were made.

Disturbance Ranking

The process for ranking levels of disturbance in northern white cedar swamps was the same as that used for seasonal pools. This ranking process was applied to the 36 swamps (38 plots) that were classified as the "typical" cedar swamp variant and were used for the majority of this bioassessment project. This process was developed for ranking the level of human disturbance in and adjacent to each northern white cedar swamp in order to allow comparisons between swamps. In order to maximize objectivity and repeatability, this process used categories of disturbance type and disturbance severity. Five disturbance types were evaluated for each swamp: logging, hydrologic alteration, water quality alteration, agriculture, and development. Each of these disturbance types was assigned a disturbance severity rank: 0 = None, 1 = Minimal, 2 = Moderate, and 3 = High. A total disturbance rank for each swamp was obtained by adding the severity ranks for each disturbance category. The disturbance categories of logging, agriculture, and development were rated based on the level and abundance of these activities in the swamp and a 150 meter buffer surrounding each swamp. The categories of hydrologic alteration and water quality alteration were rated based on a professional judgment assessment of the degree to which any disturbance would be expected to alter the water quality or hydrologic regime of a swamp and were not necessarily based on empirical data. All of the rankings were based on information collected by ecologists during field survey and by subsequent review of 1992-1994 color infrared aerial photographs, digital orthophotos, and topographic maps.

As an example of this rating system, a cedar swamp that has a small closed-canopy woods road along its downslope margin might be rated "1" for development but "3" for hydrologic alteration if the woods road has altered the seasonal outlet stream from the swamp. This swamp would have a total disturbance rank of "4". A cedar swamp mostly surrounded by paved roads and parking lots that include alteration of the stream outlet and stormwater runoff, might be rated "3" for development, water quality, and hydrologic alteration, for a total disturbance rank of "9".

In addition to this disturbance ranking process, each swamp was also given overall ranks for "current condition" and "landscape quality" (**Table 23**). These simple categories have been developed by the network of state Heritage Programs and The Nature Conservancy and have proved very useful in comparing the quality of natural community examples.

Table 23. Ranking for current condition and landscape quality

Current Condition of Community: 1 = great, no signs of anthropogenic disturbance, no exotics, etc. 2 = moderate, some signs of anthropogenic disturbance, exotics, etc. 3 = poor, obvious signs of anthropogenic disturbance, lots of exotics, etc.
Landscape Quality: 1 = surrounded by 1,000+ acres of intact matrix of natural communities 2 = surrounded by forest or undisturbed communities but there may be developed land or clearcutting nearby 3 = surrounded by fragmented forest, agricultural land or rural development 4 = surrounding area intensely developed

Additional Site Information

Several other characteristics of the study swamps were evaluated either during the site visit or during subsequent office review of information. For each swamp, observations of forest structure, evidence of logging or other human disturbance in the swamp, and cores of two or more average sized cedar trees were used as the basis for labeling the swamp as old growth or not. In general, swamps were considered old growth if they had little or no evidence of recent (past 50 years) logging, multi-layered canopy structure, abundant dead or downed and decaying wood, and trees over 180 years old. The presence of recent or past beaver activity was also noted during site visits and also during the office review. Beaver activity was viewed as a natural process that could alter hydrologic regimes and may have a similar result as some types of human alteration. Only for the 36 swamps that were classified as the "typical" variant and used for the majority of this project, additional information on characteristics of the swamp buffer were generated based on office review. For each of these 36 swamps the most recent digital orthophotos and the digital National Wetlands Inventory (NWI) map for Vermont were used to determine the minimum forested buffer width and the percent of the NWI-mapped wetland perimeter with at least a 50 meter naturally vegetated buffer. The minimum forested buffer width was determined by measuring the distance in meters from the edge of the NWI-mapped wetland to any permanent disturbance, such as a road, building, parking lot, agricultural field, or lawn. The percent of the NWI-mapped wetland perimeter with at least a 50 meter naturally vegetated buffer was similarly determined by measuring the length of the wetland perimeter with at least a 50 meter vegetated buffer and expressing this as a percentage of the entire wetland perimeter.

Data Analysis Methods

Two-way indicator species analysis (TWINSPAN) (Hill 1979) was used to cluster the 74 cedar swamp plots based on their vegetation composition. This technique uses species composition and abundance data to successively divide the plots into smaller and smaller clusters based on their similarities and is very helpful in natural community classification work. Detrended Correspondence Analysis (DCA)(Hill 1979; Hill and Gauch 1980) was used in order to further explore the similarities and differences between cedar swamps and to investigate the relationships between plant assemblages and environmental variables. DCA ordinates species and sample plots using reciprocal averaging (Hill 1979). The resulting graphs or ordinations of plots (cedar swamps in this study) help to show similarities and differences between plots. Environmental parameters can be analyzed along with the plot ordinations to help elucidate the ecological basis behind plot groupings. Both TWINSPAN and DCA were run using PC-ORD, version 4.2 (McCune and Mefford 1999). Spearman Rank Order Correlation and Mann-Whitney Rank Sum Test were used to evaluate whether the candidate metrics were significantly different between the reference and disturbed cedar swamps (SigmaStat statistical software, Version 2.0 for Windows 95, NT and 3.1).

RESULTS AND DISCUSSION

Site Reports

The majority of the cedar swamps that are evaluated in this study were first visited during the 1996-1997 field seasons and site reports are included in Northern White Cedar Swamps and Red Maple-Northern White Cedar Swamps of Vermont: Some Sites of Ecological Significance (Sorenson et al. 1998). Site reports for the four new swamps visited for this study are presented in Appendix D. These four sites are Calendar Brook WMA Swamp, Molly's Brook Swamp, Martell Swamp, and Berlin Mall Cedar Swamp.

Physical, Chemical, and Other Site Characteristics

The following sections describe the characteristics of the 36 northern white cedar swamps (38 plots) that are considered the typical variant of this natural community type and that are the focus of this bioassessment study. For more information on how and why this subset of cedar swamps is the base data for this study, see the Data Analysis section below. **Table 25** provides a summary of the water chemistry, organic soil depth, and size information for the 36 "typical" northern white cedar swamps (38 plots).

Soils

Saturated soil conditions occur in all cedar swamps that were studied. In most swamps, saturation occurs to the surface for most of the year. As a result of these saturated conditions, organic soils or at least organic surface horizons, have developed in all of the study sites. Organic soil depths range from as little as 20 centimeters at Notch Swamp to as much as 5.5 meters in the deep basin of Mount Sarah Southeast Swamp. These organic soils are mostly well decomposed and fragments of wood are present throughout most of the soil profiles studied, indicating that these swamps have maintained a tree component for much of the post-glacial history.

Water Chemistry

The pH and conductivity of surface water was measured in standing water in swamp hollows or in shallow pits dug in the organic soil of hollows at each of the 38 plots. Although pH ranged from 4.7 to 7.7, only three swamps had pH readings under 6.0 (Norton Pond Northwest Arm Swamp, Notch Swamp, and West Mountain Brook Cedar Swamp). All three of these swamps occur in the Northeastern Highlands biophysical region, and specifically, they occur over granitic bedrock that tends to produce more acidic, mineral-poor waters. Twenty-two swamps had pH readings from 6.0 to 6.9, and 13 swamps had readings of 7.0 or more. The highest pH reading was 7.6 at Willoughby River Swamp. The swamps with higher pH readings tend to occur over either the Waits River (crystalline limestone) or Gile Mountain (schists and phyllites) formations, bedrock types that tend to have more soluble minerals, especially calcium.

Surface water conductivity ranged from 30 to 720 microsiemans (uS) and is weakly and positively correlated with surface water pH ($r=0.434$, $P=0.007$ using Spearman Rank Order Correlation). The extremely high conductivity of 720 uS at Berlin Mall Cedar Swamp is likely a result of stormwater runoff pollution, especially road salt, at this swamp in a highly developed area.

Size

The size of each northern white cedar swamp is presented in **Table 24**. These figures apply to the cedar swamp community only and do not include the area of the entire wetland complex, although at most of these sites the cedar swamp composes the majority or all of the wetland. Cedar swamps range from six to 165 acres, with a mean of 54 acres.

Table 24. Water chemistry, soil organic depth, and size information for the 38 plots (36 cedar swamps) used in the bioassessment study.

Site Name	Site Code	Surface Water pH	Surface Water Conductivity (µS)	Organic Soil Depth (meters)	Swamp Size (acres)
Albany Cedar Swamp	BlacS	6.6	160	1.0	12
Bald Hill Swamp	Bald	6.9	60	1.2	20
Bear Mountain Pond	Bear	6.1	40	1.1	35
Berlin Mall	BerlMl	7.2	720	0.3	6
Berlin Pond	Berlin	6.4	500	0.7	30
Black River Swamp	BlacCS	7.2	190	1.0	165
Bliss Pond Cedar Swamp	Bliss	6.5	100	2.3	18
Bruce Pond Cedar Swamp	Bruce	6.8	50	1.7	25
Calendar Brook WMA Swamp	CalBk	6.2	110	0.7	120
Cemetery Cedar Swamp	Cemeta	7.1	110	0.6	20
Coles Pond	Coles	6.6	50	1.9	40
Confluence Basin Swamp	Conflu	6.5	120	2.1	45
Dutton Brook Swamp	Dutton	7.3	90	2.4	40
East Peacham Swamp	Epeach	7.1	200	2.1	20
Ewells Mills Swamp	Ewells	7.1	170	2.6	40
Flagg Pond-1	Flag-1	7.1	110	1.0	70
Flagg Pond-2	Flag-2	7.1	130	1.5	70
Long Pond	Long	6.6	30	1.3	115
Maple Hill Swamp	Potter	6.8	100	0.6	40
Martell Swamp	Martell	6.4	60	0.6	48
Melvin Hill Swamp	PineCS	7.2	130	2.3	100
Molly's Brook Swamp	MolBk	6.4	80	1.3	125
Mount Sarah Southeast Swamp	Sarah	6.1	80	5.5	20
Mud Pond Holland	MudHol	6.8	50	2.2	100
Newbury Village Land Swamp	Newbur	6.2	60	2.3	25
Norton Pond Northwest Arm Swamp	Norton	4.7	180	1.2	40
Notch Swamp	Notch	5.9	40	0.2	25
Page Brook Swamp	Page	7.1	80	1.7	45
Pherrins- Clyde River Swamp	Bright	7.3	60	3.5	60
Pond Brook Cedars	Pond	7.2	370	3.0	25
Roy Mountain Cedar Swamp	Roy	6.4	30	3.5	20
Sawdust Pond Cedar Swamp	Sawdus	6.5	50	0.2	10
Small Mud Pond Cedar Swamp	MudMor	6.7	30	3.4	60
Tamarack Brook Flats	TamBr	6.5	30	0.6	55
Victory WMA North Cedar Swamp	VictoN	6.5	50	0.5	90
West Mountain Brook Cedar Swamp	WMtBr	5.9	30	1.5	10
Willoughby River Swamp	LWill	6.9	100	1.1	125
Willoughby River Swamp	WillR	7.6	130	0.6	125
Mean			**123.16**	**1.61**	**53.66**
Standard Deviation			**136.09**	**1.13**	**40.98**
Maximum Value		**7.6**	**720.0**	**5.5**	**165.0**
Minimum Value		**4.7**	**30.0**	**0.2**	**6.0**

Disturbance Ranking

Logging was the disturbance type that was present at the greatest number of swamps, with 29 out of 36 swamps given a rating of "low", "moderate", or "high". Only two of these 29 swamps were rated as having a high disturbance severity from logging. Disturbance from development and expected effects on water quality were noted at 25 and 24 swamps, respectively. Hydrologic alterations and disturbance from agriculture were noted at 12 swamps each. Total disturbance ranks are given in **Table 25** and ranged from "0" at Bear Mountain Pond, Melvin Hill Swamp, and Roy Mountain Cedar Swamp, to "9" at the highly disturbed Berlin Mall Cedar Swamp and Cemetery Cedar Swamp.

For this study, reference quality northern white cedar swamps were considered to be those with a total disturbance ranking of "3" or less and with no individual disturbance type ranked above "2" (moderate severity). A total of 16 of the 36 cedar swamps were considered to be reference quality based on these criteria. Martell Swamp was the only swamp considered reference quality and having an individual disturbance type rank of "2". There has been considerable logging around the northern end of this swamp, but the southern (upslope) end is in excellent condition.

Additional Site Information

Current condition and landscape quality are both closely related to the total disturbance rank, although each of these two categories evaluates a particular swamp in a slightly different way. Current condition provides an overview of the condition of a swamp at the time of a site assessment and the ranking ranges from natural conditions with little human disturbance to high level of human disturbance. Landscape quality provides a simple assessment of the landscape adjacent to a swamp and ranks the level of human disturbance in this surrounding area. As would be expected, current condition and landscape quality have strong positive correlations with total disturbance rank ($r=0.77$, $r=0.83$, respectively, $P<0.001$ using Spearman Rank Order Correlation). It is interesting to note that current condition and landscape quality are only weakly correlated with each other ($r=0.55$, $P<0.001$). This is likely because it is possible for the interior of a cedar swamp to be in very good condition (good forest structure, development of hummocks and hollows, no exotic species, and no recent logging) and still be in a fragmented landscape (with roads, clearcuts, or development nearby). In fact, there are two swamps with a current condition rating of "great" (1) that have a landscape quality rating of "surrounded by fragmented forest, agricultural land or rural development" (3), and seven swamps that have a current condition rating of "great" and landscape quality rating of 2 indicating that there are clearcuts or developed land nearby. This is an indication of the resilient nature of forested wetlands like cedar swamps.

Five of the 36 northern white cedar swamps were rated as being "old growth". Although these five sites are mature examples of northern white cedar swamps with old trees, lots of downed and dead wood, and multi-aged canopies, they have all surely seen some disturbance in the past. Three of these five swamps were assigned a total disturbance rank of "0" (the only three zeros assigned) and two were assigned a disturbance rank of "1".

The "minimum buffer width" and the "percent of wetland buffer greater than 50 meters" served as two additional metrics to evaluate the level of disturbance at individual swamps. The minimum buffer width ranged from zero to 980 meters. The percent of wetland buffer greater than 50 meters ranged from 15 percent at Berlin Mall Cedar Swamp to 100 percent at eleven swamps.

Table 25. Total disturbance ranking and other characteristics of the 36 swamps (38 plots) relating to site disturbance. Reference quality swamps (total disturbance rank of 3 or less) are listed in bold type.

Site Name	Total Disturbance Rank[(1)]	Current Condition[(2)]	Landscape Quality[(2)]	Old Growth	Minimum Buffer Width (m)	Percent Buffer >50m
Albany Cedar Swamp	6	2	3	2	0	60
Bald Hill Swamp	**1**	1	1	2	900	100
Bear Mountain Pond	**0**	1	2	1	670	100
Berlin Mall	9	3	4	2	0	15
Berlin Pond	5	2	3	2	0	50
Black River Swamp	5	3	3	2	0	70
Bliss Pond Cedar Swamp	**1**	2	2	2	75	100
Bruce Pond Cedar Swamp	4	2	2	2	30	85
Calendar Brook WMA Swamp	5	2	3	2	50	80
Cemetery Cedar Swamp	9	2	3	2	0	15
Coles Pond	**1**	1	2	1	50	95
Confluence Basin Swamp	5	2	2	2	0	70
Dutton Brook Swamp	**2**	1	2	2	0	90
East Peacham Swamp	5	2	3	2	0	80
Ewells Mills Swamp	**3**	1	3	2	20	88
Flagg Pond-1	**1**	1	2	2	165	100
Flagg Pond-2	**1**	1	2	2	165	100
Long Pond	**1**	1	2	1	200	100
Maple Hill Swamp	**3**	2	2	2	50	100
Martell Swamp	**3**	2	2	2	0	95
Melvin Hill Swamp	**0**	1	1	1	980	100
Molly's Brook Swamp	7	2	3	2	0	32
Mount Sarah Southeast Swamp	6	3	3	2	0	65
Mud Pond Holland	6	3	3	2	0	75
Newbury Village Land Swamp	**1**	1	2	2	120	100
Norton Pond Northwest Arm Swamp	5	2	2	2	0	45
Notch Swamp	4	2	2	2	0	80
Page Brook Swamp	4	2	2	2	125	100
Pherrins- Clyde River Swamp	6	2	3	2	0	55
Pond Brook Cedars	6	2	3	2	0	40
Roy Mountain Cedar Swamp	**0**	1	1	1	600	100
Sawdust Pond Cedar Swamp	4	2	2	2	0	80
Small Mud Pond Cedar Swamp	5	2	3	2	0	55
Tamarack Brook Flats	4	1	3	2	0	90
Victory WMA North Cedar Swamp	**3**	2	2	2	0	85
West Mountain Brook Cedar Swamp	**3**	2	2	2	0	90
Willoughby River Swamp (LWill)	6	2	3	2	0	60
Willoughby River Swamp (WillR)	6	2	3	2	0	60

(1) Total disturbance rank is the sum of individual swamp ranks for five types of disturbance.
(2) See Table 24 for explanations of Current Condition and Landscape Quality ranking codes

Biological

Plants

The percent cover of vascular plant and bryophyte species identified in the 74 northern white cedar swamp and red maple-northern white cedar swamp plots are included as a Microsoft Excel table as an appendix of this report. This table includes data from the 70 plots collected for the 1998 Vermont cedar swamp study (Sorenson et al. 1998), as well as the data from the four new plots collected for this bioassessment study. It is important to note that although this table includes 402 entries under the "Species" column heading, there are actually only 360 distinct species in the list, as 42 of these entries refer to tree and shrub species that are included more than once (tree, sapling, and seedling percent covers are entered separately). Of these 360 species, 283 are vascular plants, 66 are mosses, and 11 are liverworts.

Appendix B, Table B12 is a table that lists the percent cover of all vascular plant and bryophyte species present in the 38 plots determined to be the "typical" northern white cedar swamp type based on multivariate analysis techniques described below. This list includes 289 entries under the "Species" column heading, of which 260 are distinct species and the remainder are multiple listings of tree and shrub species for sapling and seedling layers. Of the 260 species, 201 are vascular plants, 49 are mosses, and 10 are liverworts.

Birds

A total of 58 species of birds were recorded at the nine northern white cedar swamps included in the breeding bird surveys (**Table 26**). In this table, the average number of individuals per listening station is recorded for each species. This figure was obtained by dividing the total number of individuals of a species by the number of listening stations at a particular swamp. This method of presenting relative abundance of species was necessary due to the variation in size of the swamps and therefore the variation in the number of listening stations for each swamp. Caution should be used in interpreting these relative abundance figures as bird species differ greatly in how easily they are detected.

To help with interpretation of this bird information, the swamps in **Table 26** are organized from least to most disturbed (left to right), and bird species are organized in order of increasing frequency in the nine swamps studied. Frequency is defined here as the number of swamps in which the species occurred divided by the total number of swamps (9). Only White-throated Sparrow occurs at all nine swamps. Three species, Northern Waterthrush, Winter Wren, and Black-capped Chickadee occur at eight of the nine swamps.

Six of the 58 species identified and listed in **Table 26** appear on the Partners in Flight priority list for the Bird Conservation Region 14, Atlantic Northern Forest (Rosenberg and Dettmers 2002).

Aquatic Macroinvertebrates

Three northern white cedar swamps were visited in early summer (June-July), to assess the feasibility of sampling aquatic macroinvertebrates for bioassessment and monitoring purposes. The very dry weather in 1999 caused the cedar swamps to be even drier than usual at that time of year. It is possible that aquatic micro-habitats in cedar swamps are not available consistently enough to sample for aquatic macroinvertebrates, however our limited sampling efforts did not conclusively elucidate the feasibility of using aquatic macroinvertebrates as biological indicators in cedar swamps. It is also unknown at this time whether the aquatic macroinvertebrate communities found in stream flowing through cedar swamps have much in common with the aquatic macroinvertebrate communities found in wet hollows of cedar swamps.

Brief descriptions of the site visits to Berlin Mall Cedar Swamp, Victory WMA North Cedar Swamp, and Martell Cedar Swamp are presented as part of the site reports in **Appendix D**, along with a list of macroinvertebrate taxa identified at Martell Swamp.

Table 26. Average number of birds per listening station in nine cedar swamps. Partners in Flight (PIF)

Site Name (disturbance rank) / Species	Bliss Pond (1)	Long Pond (1)	Dutton Brook (2)	Martell Swamp (3)	Victory (3)	Norton Pond (5)	Calendar Brook (5)	Molly's Brook (7)	Berlin Mall (9)	Frequency of Species
White-throated Sparrow	2	2	2.7	2.5	1.3	2	1.6	1	1	**1.00**
Northern Waterthrush	1	3	2	4	2	4	3.6	2	0	**0.88**
Winter Wren	2	4	2	3	0	2.5	5.2	2.5	1	**0.88**
Black-capped Chickadee	2	0	0.3	0.5	0.7	0.75	5.2	0.25	1.5	**0.88**
Blue Jay	0	0.3	0.3	0.5	0.3	0.75	0.2	0.25	0	**0.77**
Hermit Thrush	1	1	2	2.5	1	0	2	1	0	**0.77**
Veery (PIF)	1	0	0.7	0.5	1.3	1.5	0	0.5	2	**0.77**
Yellow-bellied Flycatcher	0	2	0	2.5	2	2	1.6	1	0	**0.66**
Canada Warbler (PIF)	0	3	0	2.25	1.3	0.5	0	1	0	**0.55**
Magnolia Warbler	0	1	0	0	0	1.5	2.4	2	1	**0.55**
Brown Creeper	2	0	0.7	0	0	1	0.4	0	1	**0.55**
Northern Parula (PIF)	0	0.5	0	1	0	1	3.2	0	0	**0.44**
Nashville Warbler	0	0	0	0	2.7	1	0.4	0.5	0	**0.44**
Yellow-rumped Warbler	0	1.5	0	0	0.7	2	0	2	0	**0.44**
Black-throated Green Warbler	0	1.5	2	0	0	0	1.2	0	1	**0.44**
American Crow	0	1	0.3	0	0	0	0.4	0	1.5	**0.44**
Ovenbird	1	0	0.7	0	0	0	0.8	0	1	**0.44**
American Robin	1.5	0	0	2.25	0	2.5	0	1.25	0	**0.44**
Red-breasted Nuthatch	1.5	0.3	0	0	0	0	1.6	0	0.5	**0.44**
Olive-sided Flycatcher (PIF)	0	0.5	0	0.5	0	0.5	0	0	0	**0.33**
Ruby-crowned Kinglet	0	0.5	0	0	0	0.5	2	0	0	**0.33**
Swainson's Thrush	0	2.5	0	0	0	0.5	2.8	0	0	**0.33**
Common Yellowthroat	0	0	0	0	0	1	0	1.5	3	**0.33**
Purple Finch	0.5	0	2	0	0	0.5	0	0	0	**0.33**
Yellow-bellied Sapsucker	0.5	0	0.7	0	0	0	0	1.5	0	**0.33**
Red-eyed Vireo	1	0	2	0	0	0	0	1	0	**0.33**
Dark-eyed Junco	3	0	0	0	0.7	0	1.6	0	0	**0.33**
Eastern Wood-Pewee (PIF)	0	0	0	0.5	0	0	0.8	0	0	**0.22**
Common Raven	0	0	0	0	0	0.25	0.4	0	0	**0.22**
Evening Grosbeak	0	0.3	0.3	0	0	0	0	0	0	**0.22**
Belted Kingfisher	0	0.3	0	0	0	0	0	0.25	0	**0.22**
Hairy Woodpecker	0	0	0	0	0	0	0.8	0.5	0	**0.22**
Alder Flycatcher	0	0	0	0	0	0.5	0	0.5	0	**0.22**
Great Crested Flycatcher	0	0	0	1.5	0	0	0	0.5	0	**0.22**
Red-winged Blackbird	0	0	0	1	0	0	0	1.25	0	**0.22**
Solitary Vireo	0	0	0	0	0	2	0	0	1	**0.22**
Swamp Sparrow	0	0	0	0	0	0	0	1	1	**0.22**
Mourning Dove	0	0	0.7	0	0	0	0	0	0	**0.11**
No. Saw-whet Owl	0	0	0	0.5	0	0	0	0	0	**0.11**
Northern Flicker	0	0	0	1.5	0	0	0	0	0	**0.11**
Pileated Woodpecker	0	0	0	0	0	0.25	0	0	0	**0.11**
Tree Swallow	0	0.8	0	0	0	0	0	0	0	**0.11**
Golden-crowned Kinglet	0	0	0	0	0	0	1.2	0	0	**0.11**
Yellow-throated Vireo	0	0	0	0	0	0	0.8	0	0	**0.11**
Warbling Vireo	0	0	0	0	0	0	0.4	0	0	**0.11**
Tennessee Warbler	0	0	0	0	0	0.5	0	0	0	**0.11**
Cape May Warbler	0	0.5	0	0	0	0	0	0	0	**0.11**
Blackburnian Warbler	0	0	0.7	0	0	0	0	0	0	**0.11**
Black-and-White Warbler	0	0	0	0	0.7	0	0	0	0	**0.11**
American Redstart	0	0	0	0	0	1	0	0	0	**0.11**
Mourning Warbler	0	0	0	0	0	0	0.8	0	0	**0.11**
Scarlet Tanager	0	1	0	0	0	0	0	0	0	**0.11**
Common Grackle	0	0.5	0	0	0	0	0	0	0	**0.11**
Chestnut-sided Warbler (PIF)	0	0	0	0	0	0	0	0.5	0	**0.11**
Rose-breasted Grosbeak	0	0	0	0	0	0	0	0.5	0	**0.11**
Northern Oriole	0	0	0	0	0	0	0	0.5	0	**0.11**
Broad-winged Hawk	0	0	0	0	0	0	0	0	1	**0.11**
Song Sparrow	0	0	0	0	0	0	0	0	1	**0.11**
Total Number of Bird Species	**14**	**22**	**17**	**17**	**12**	**25**	**25**	**25**	**15**	

DATA ANALYSIS

Classification of 74 Northern White Cedar Swamp Plots

There is considerable natural variability in the species composition, organic soil depth, water chemistry, and other environmental factors in northern white cedar swamps (Sorenson et al. 1998). In order to minimize this between-site natural variability so as to better focus on attributes that reflect anthropogenic disturbance, classification of northern white cedar swamps was undertaken. The first step was to use TwoWay Indicator Species Analysis (TWINSPAN) as a tool to help classify the 74 cedar swamp plots into community types, as was done in the 1998 cedar swamp study. As the current dataset of 74 plots includes both reference quality and disturbed cedar swamps, it was recognized that the disturbed sites might be classified as a separate type in the analysis.

The two-way ordered table resulting from this TWINSPAN identified four main types of cedar swamps that appear to be ecologically meaningful. The full TWINSPAN table is presented in **Appendix B, Table B13.**

Detrended Correspondence Analysis (DCA) was used to ordinate 73 of these cedar swamp plots. A secondary matrix of nine environmental variables was included in the analysis in order to elucidate patterns between the groupings of plots and the environmental variables. Data from one plot (Guildhall Swamp) was excluded from this analysis, as water chemistry readings were not obtained at this site. In addition to the eight quantitative variables relating to water chemistry (pH and conductivity), soils (organic soil depth), and vegetation structure (percent cover of canopy, tall shrub, short shrub, herbaceous, and bryophyte layers), a categorical variable of the four cedar swamp types identified in the TWINSPAN was also used in order to compare the two methods. The DCA ordination of the 73 cedar swamp plots, with each plot coded by its TWINSPAN group and hand-drawn polygon enclosing the best-fit of the four named cedar swamp types is shown in **Figure 28.**

Several of the environmental variables were correlated with Axes 1 and 2 of the DCA ordination and help explain variability in cedar swamps. Bryophyte cover was negatively correlated with Axis 2 (r^2=0.381) – the Sloping Seepage Forest type typically has a very low cover of bryophytes. Peat depth is positively correlated with Axis 1 (r^2=0.197) – the Red Maple-Northern White Cedar Swamps typically have deeper peat than other cedar swamp types. Finally, pH was also positively correlated with Axis 1 (r^2=0.166), as was conductivity to a lesser degree (r^2=0.098) – the Boreal Acidic Northern White Cedar Swamps typically have a lower pH than do the "Typical" Northern White Cedar Swamps or the Red Maple-Northern White Cedar Swamps.

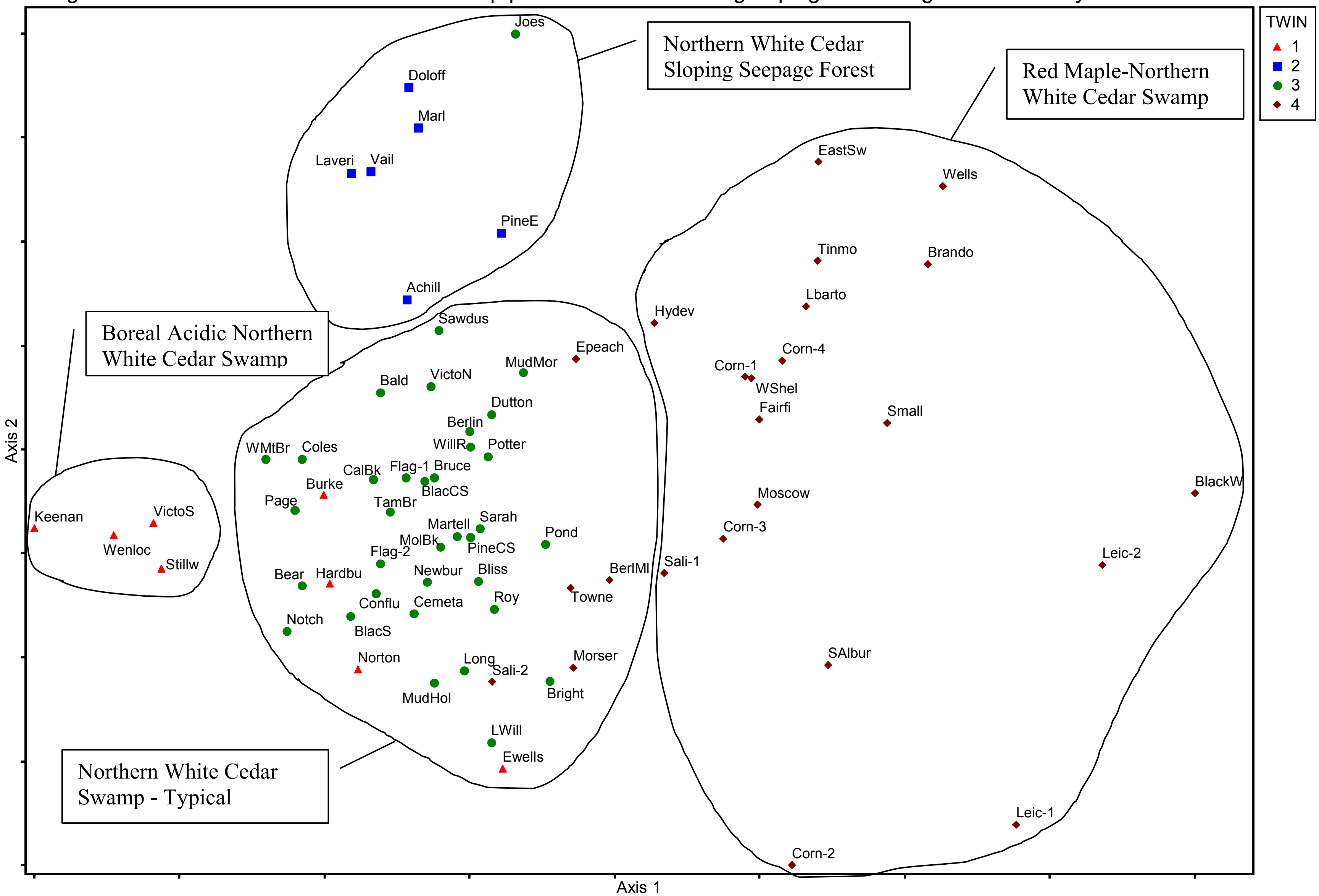
The following descriptions of the four cedar swamps types (two main community types and two variants) are taken from Northern White Cedar Swamps and Red Maple-Northern White Cedar Swamps of Vermont: Some Sites of Ecological Significance (Sorenson et al. 1998).

Northern White Cedar Swamp - Typical

The typical northern white cedar swamp in Vermont is a closed canopy conifer swamp associated with mineral-enriched ground water seepage. These swamps occur in a variety of physical settings, including wetland basins, lakesides, and valley bottoms adjacent to streams. These settings are predominantly in areas with calcareous bedrock or calcareous glacial deposits, although to the north, northern white cedar swamps occur in non-calcareous conditions as well. The organic soil horizons are shallow to moderately deep (0.2 to 5.5 meters) and are primarily well decomposed (sapric) muck, often with wood fragments throughout. The mineral substrate is variable in texture from silts to sandy gravel and bedrock. Surface waters in these ground water fed swamps are circumneutral to slightly acidic (pH ranges from 5.9 to 7.6).

Figure 28. DCA Ordination of 73 Cedar Swamp Plots with TWINSPAN groupings

Figure 28. DCA ordination of 73 cedar swamp plots with TWINSPAN groupings and assigned community names



Although northern white cedar swamps occur in stream valleys and adjacent to lakes and ponds, seasonal flooding is not characteristic.

The generally closed canopy of northern white cedar swamps creates a dark, cool forest floor. Leaning trees and blowdowns are common in more mature swamps, resulting in well developed hummocks and hollows. Hollows often contain shallow standing water. The low light levels in most northern white cedar swamps result in low abundance of shrubs and herbaceous plants, but these conditions are ideal for mosses and liverworts, which often carpet the ground.

Northern white cedar (*Thuja occidentalis*) clearly dominates the canopy of these swamps, and in some areas cedar may be the only species present. Balsam fir (*Abies balsamea*) is the most common canopy associate and is present in most swamps, occasionally as a co-dominant with cedar. Black ash (*Fraxinus nigra*) and yellow birch (*Betula alleghaniensis*) are frequently present in the canopy, but seldom in abundance. White pine (*Pinus strobus*) and tamarack (*Larix laricina*) occur in low abundance in many swamps, often as taller trees emerging from the cedar-dominated canopy. Other trees that may be present include red spruce (*Picea rubens*), black spruce (*P. mariana*), white spruce (*P. glauca*), red maple (*Acer rubrum*), paper birch (*Betula papyrifera*), and in more southern areas eastern hemlock (*Tsuga canadensis*).

The tall and short shrub layers are generally very sparse, although several species are very characteristic. In most swamps, seedling and sapling regeneration of cedar and balsam fir are the most abundant species, and may form dense thickets in areas where the canopy has been opened by blowdowns and more light reaches the forest floor. Regeneration of other tree species may also be common. The most characteristic shrubs and those present in most swamps are the low, trailing dwarf raspberry (*Rubus pubescens*), Canada honeysuckle (*Lonicera canadensis*), alder-leaved buckthorn (*Rhamnus alnifolia*), Canada yew (*Taxus canadensis*), and mountain maple (*Acer spicatum*). Other shrubs that occur commonly in these swamps include winterberry (*Ilex verticillata*), mountain holly (*Nemopanthus mucronata*), wild raisin (*Viburnum cassinoides*), red-osier dogwood (*Cornus sericea*), and speckled alder (*Alnus incana*).

The herbaceous layer of northern white cedar swamps is also sparse and is typically made up of fine-leafed sedges and low herbs scattered over mossy hummocks and hollows. The typical fine-leafed sedges include three-seeded sedge (*Carex trisperma*), two-seeded sedge (*C. disperma*), delicate-stemmed sedge (*C. leptalea*), and peduncled sedge (*C. pedunculata*). Characteristic low herbs include naked miterwort (*Mitella nuda*), bunchberry (*Cornus canadensis*), goldthread (*Coptis trifolia*), twin-flower (*Linnaea borealis*), common wood-sorrel (*Oxalis acetocella*), and starflower (*Trientalis borealis*). Other common herbs include bladder sedge (*Carex intumescens*), fowl mannagrass (*Glyceria striata*), cinnamon fern (*Osmunda cinnamomea*), oak fern (*Gymnocarpium dryopteris*), one-sided pyrola (*Pyrola secunda*), dewdrop (*Dalibarda repens*), narrow beech fern (*Phegopteris connectilis*), crested fern (*Dryopteris cristata*), foamflower (*Tiarella cordifolia*), broad-leaved twayblade (*Listera convallarioides*), oneflowered pyrola (*Moneses uniflora*), and creeping snowberry (*Gaultheria hispidula*). Golden saxifrage (*Chrysosplenium americanum*) is frequently present in seepage areas at the margins of the swamps.

Bryophytes thrive in the cool, moist, shaded conditions of cedar swamp interiors and often form nearly complete carpets over the hummocks and the hollows without standing water. Stair-step moss (*Hylocomnium splendens*) is highly characteristic, and is abundant in nearly all swamps. Almost as abundant is shaggy moss (*Rhytidiadelphus triquetrus*). The liverwort *Bazzania trilobata* is very common on dry hummocks and old tree stumps. Other common species include *Sphagnum warnstorfii*, common fern moss (*Thuidium delicatulum*), the leafy liverwort *Trichocolea tomentella*, *Sphagnum squarrosum*, *Sphagnum subtile*, and *Sphagnum centrale*. Species commonly associated with wet hollows include *Calliergon cordifolium*, *Calliergon giganteum*, *Mnium punctatum*, *Rhytidiadelphus squarrosus*, *Amblystegium riparium*, and *Campylium stellatum*.

Northern White Cedar Sloping Seepage Forest Variant

This variant of the typical northern white cedar swamp has been identified only in northeastern and northcentral Vermont, and only on the calcium-rich Waits River bedrock formation. This swamp type differs physically from the typical northern white cedar swamp in that examples of the type occur on gentle slopes and have shallow (0.1 to 0.6 meter) accumulations of highly decomposed organic soil. They are strongly associated with ground water discharge and seepage, and moving water is often evident below the swamp surface, at least in the spring. Seasonally drier conditions may be responsible for the highly decomposed and shallow nature of the surface organic soil horizon. Hummock and hollow microtopography is poorly developed. The cedar sloping seepage forest often occurs at the sloping edge of the typical cedar swamp, although it also occurs in isolation from other cedar swamp types.

The canopy of these swamps is very dense and is dominated by northern white cedar, with canopy associates similar to the typical cedar swamp type. Yellow birch is more common in the canopy than in other cedar swamp types. Tall and short shrub cover is very sparse, with seedling and sapling regeneration of canopy species, Canada honeysuckle, mountain maple, and dwarf raspberry the most frequently occurring species. Herbaceous cover is somewhat higher than in the typical cedar swamp, but there is lower species richness. The herbaceous species that characterize the cedar seepage forests are species that commonly occur in upland conditions, including evergreen woodfern (*Dryopteris intermedia*), oak fern, narrow beech fern, lady fern (*Athyrium filix-femina*), foamflower, common wood-sorrel, blue-bead lily (*Clintonia borealis*), wild sarsaparilla (*Aralia nudicaulis*), peduncled sedge, and shining clubmoss (*Lycopodium lucidulum*). The fine-leafed sedges (*Carex trisperma*, *C. disperma*, and *C. leptalea*) are absent from many sites, in contrast to their abundance in the typical cedar swamp. Creeping snowberry is also absent. Another striking difference of these sloping seepage cedar forests is the very low cover of bryophytes, and the relatively large percentage of the ground that is bare of vegetation. Shaggy moss is the most abundant species, likely reflecting this species preference for more calcareous habitats. Stair-step moss and the liverwort *Bazzania trilobata* are present in most swamps, but seldom abundant.

Boreal Acidic Northern White Cedar Swamp Variant

This variant of the typical northern white cedar swamp has been identified only from northeastern and northcentral Vermont. Soils are permanently saturated with generally acidic water, resulting in accumulations of moderately decomposed organic soils ranging from 0.8 to 3.2 meters deep (8 samples). Hummock and hollow microtopography is well developed, but there are few hollows with standing water. This cedar swamp variant often occurs in the deepest portion of a basin with the typical cedar swamp, or in association with other swamp types, such as spruce-fir-tamarack swamp and black spruce swamp.

The boreal and acidic character of this cedar swamp variant is reflected in the vegetation. Northern white cedar is the dominant canopy species, often occurring with balsam fir or black spruce. Typical shrubs include mountain holly, Canada honeysuckle, dwarf raspberry, wild raisin, velvet-leafed blueberry (*Vaccinium myrtilloides*), Labrador tea (*Ledum groenlandicum*), sheep laurel (*Kalmia angustifolia*), alder-leaved buckthorn, and occasionally speckled alder. Typical herbs and low creeping shrubs include three-seeded sedge, creeping snowberry, goldthread, bunchberry, starflower, twinflower, and dewdrop. Bryophytes often form a complete carpet, with *Sphagnum girgensohnii*, *Sphagnum centrale*, and *Sphagnum angustifolium* the most dominant and characteristic species. Stair-step moss, the liverwort *Bazzania trilobata*, and *Sphagnum warnstorfii* are also common. Shaggy moss is notably absent or in very low abundance in this swamp variant.

Red Maple-Northern White Cedar Swamp

Red maple-northern white cedar swamps occur primarily in the lowlands of western Vermont, although several examples have been identified in the northeastern portion of the state. They generally occur in areas of calcareous bedrock, a condition greatly affecting the distribution of northern white cedar at the southern portion of its range in Vermont. Red maple-northern white cedar swamps are primarily associated with the floodplains of larger rivers in the Champlain Valley, although examples also occur adjacent to Lake Champlain and the Lower Black and Barton Rivers at South Bay of Lake Memphremagog. This natural community often occurs as part of a larger wetland complex, and may grade into typical northern white cedar swamp, red maple-black ash swamp, or red or silver maple-green ash swamp. Northern white cedar is not well adapted to extended periods of flooding, and generally occurs near the limits of flooding or in portions of the swamp complexes that are flooded for shorter duration. Seasonal flooding may play a role in mineral enrichment of the large red maple-northern white cedar swamps, by depositing alluvium rich in calcium.

The organic soils of red maple-northern white cedar swamps are permanently saturated, generally well decomposed mucks with depths from 1.5 to over 5 meters. Hummock and hollow microtopography is well developed, with hollows often large and water filled, and hummocks equally large and supporting most of the woody plant growth.

The red maple-northern white cedar swamp is characterized by a tall, emergent tree layer of red maple and occasional white pine that extends above a shorter and more closed canopy dominated by northern white cedar, black ash, and red maple. Other tree species that vary in their abundance from swamp to swamp include yellow birch, paper birch (*Betula papyrifera*), balsam fir, swamp white oak (*Quercus bicolor*), red and black spruce, and tamarack. American elm (*Ulmus americana*) is an occasional species, and was likely much more common before Dutch elm disease became prevalent.

The tall and short shrub layers are both generally sparse. Sapling regeneration of cedar, red maple, and black ash can be common. Poison sumac (*Toxicodendron vernix*) is highly characteristic of red maple-northern white cedar swamps. The most frequently occurring shrubs are winterberry, dwarf raspberry, speckled alder, and alder-leaved buckthorn. Other shrubs include poison ivy (*Toxicodendron radicans*), red-osier dogwood, wild raisin, Labrador tea, and highbush blueberry (*Vaccinium corymbosum*). Canada honeysuckle, which is very common in northern white cedar swamps, is very uncommon in red maple-northern white cedar swamps.

Ferns are a common component of the herbaceous layer of red maple-northern white cedar swamps, including royal fern (*Osmunda regalis*), sensitive fern (*Onoclea sensibilis*), cinnamon fern, marsh fern (*Thelypteris palustris*), crested woodfern (*Dryopteris cristata*), and lady fern. Other common herbs include Canada mayflower (*Maianthemum canadensis*), common water horehound (*Lycopus uniflorus*), fowl mannagrass, wild sarsaparilla, starflower, naked miterwort, peduncled sedge, goldthread, bunchberry, tall meadow-rue (*Thalictrum pubescens*), white turtlehead (*Chelone glabra*), and marsh bedstraw (*Galium palustre*). The narrow-leaved sedges *Carex trisperma*, *C. leptalea*, and

C. disperma are present at some sites. The rare nodding trillium (*Trillium cernuum*) is characteristic of this community, although it is never abundant.

Bryophytes often carpet large areas of the hummocks. The most abundant species are common fern moss, shaggy moss, and stair-step moss. Tree moss (*Climaceum dendroides*) is also abundant and is characteristic of this community, occurring much less frequently in northern white cedar swamps. Other less abundant species include Schreber's moss (*Pleurozium schreberi*), *Sphagnum warnstorfii*, *Sphagnum centrale*, *Sphagnum girgensohnii*, and the liverworts *Bazzania trilobata* and *Plagiochila asplenioides*. On the edges of wet hollows, *Calliergon cordifolium*, *Calliergon giganteum*, and *Mnium punctatum* are common.

Selection of 38 Typical Northern White Cedar Swamp Plots for Bioassessment

It was clear in reviewing the output from both the TWINSPAN and DCA analysis of all cedar swamp plots that interpretation of these results would be necessary in order to select the plots that were best suited for proceeding with the bioassessment project. An important component of this step was to evaluate the analyses results and compare these to known site conditions (vegetation, environmental conditions, and location) to arrive at final selection of cedar swamp sites to be used in the bioassessment project. The purpose of this process was to select those cedar swamps that represent the "typical" cedar swamp type as identified in the 1998 study and to check if the four new swamps also fit the concept of the "typical" type. The selection process was based on the results of TWINSPAN and DCA, but also on professional judgment as to which type or variant the plots best represent. For example, although four of the TWINSPAN category 4 swamps grouped with the "typical" cedar swamp in DCA ("Towne", "Morser", "BerlMl", and "Epeach"), based on observations made at each site on the vegetation and site conditions, it was decided that two of these swamps best fit the description of Red Maple-Northern White Cedar Swamp ("Towne" and "Morser") and two of these swamps best fit the description of the "typical" cedar swamp. Similarly, there were four swamps that fell in the TWINSPAN category 1 (Boreal Acidic Cedar Swamp) that were grouped with the "typical" cedar swamps in DCA ("Burke", "Hardbu", "Norton", and "Ewells"). Based on site conditions and professional judgment, two of these were considered to best represent the Boreal Acidic Cedar Swamp variant ("Burke" and "Hardbu") and two were considered to fit best with the "typical cedar" swamps ("Norton" and "Ewells"). Only one swamp ("Joes") was misclassified by TWINSPAN as a "typical" cedar swamp, but the DCA ordination and professional judgment place this plot squarely with the Northern White Cedar Sloping Seepage Forest variant.

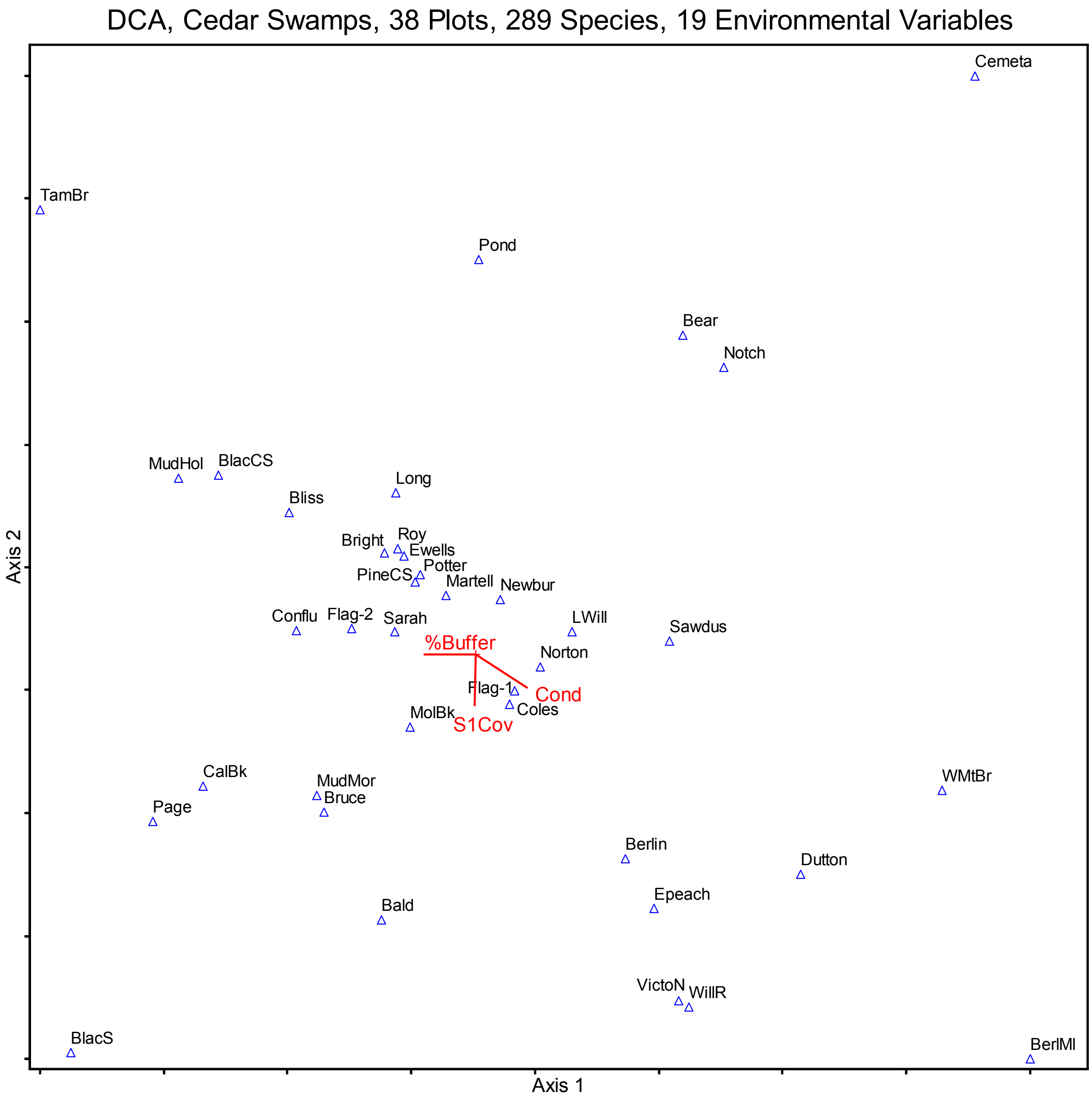
Based on this combination of analysis and professional judgment, all four of the swamps that were visited for the first time as part of this bioassessment study are placed in the "typical" cedar swamp type.

Development and Testing of Biological and Physical Metrics

TWINSPAN and DCA were also performed on the this new set of 38 "typical" northern white cedar swamp plots in order to: 1) look for meaningful additional separation of types within this group; 2) check for correlations between DCA axes and environmental variables; and 3) evaluate whether disturbance rankings and biological metrics are correlated with DCA axes. The candidate biological metrics evaluated were: percent cover for the canopy, tall shrub, short shrub, herbaceous, and bryophyte layers; total species richness; vascular plant richness; and bryophyte richness; and number of exotic plant species. Eighteen of these environmental variables, disturbance rankings, and candidate biological metrics were quantitative. Only "old growth" was a categorical variable, as each swamp was assigned a "yes" or "no".

Neither the TWINSPAN nor DCA identified any further meaningful subdivision of the 38 plots. There were only weak correlations between Axes 1 and 2 of the DCA ordination and the 19 environmental variables, disturbance rankings, and candidate biological metrics. This DCA ordination is shown in **Figure 29**. There was a weak negative correlation between Axis 1 and the percent of wetland with greater than 50 meter buffer (r^2=0.102). Conductivity was positively correlated with Axis 1 (r^2=0.103) and percent cover of tall shrubs was negatively correlated with Axis 2 (r^2=0.101).

Figure 29. DCA joint plot of 38 "typical" northern white cedar swamp plots and important environmental variables, disturbance rankings, and candidate biological metrics.



The 18 quantitative environmental variables, disturbance rankings, and candidate biological metrics were tested to see if they could be used to distinguish between the 16 reference-quality swamps (total disturbance ranking of 0 to 3) and the 22 disturbed swamps (total disturbance rank of 4 to 9). For this purpose, t-test (normally distributed populations) and Mann-Whitney rank sum test (non-normal populations) were used to compare the 16 reference-quality swamps and the 22 disturbed swamps. The results of these parametric and non-parametric tests are shown in **Table 27**.

Table 27. Results of the t-tests (t) and Mann-Whitney rank sum test (M-W) of candidate biological metrics, environmental variables, and disturbance rankings for the 16 reference swamps and 22 disturbed swamps. Means are presented for the t-tests and medians for the Mann-Whitney rank sum tests.

Metric	Reference Swamp Mean or Median	Disturbed Swamp Mean or Median	P-value	Test Used
Bryophyte % cover	85	80	0.712	M-W
Herb % cover	47	41	0.429	t
Short shrub % cover	12	19.5	0.120	t
Tall shrub % cover	2	6	0.267	M-W
Canopy % cover	85	84	0.958	t
Bryophyte richness	9.8	10.6	0.457	t
Vascular plant richness	44	44.5	0.869	t
Total richness	54	55	0.637	t
Exotics	0	0	0.207	M-W
pH	6.67	6.67	0.969	t
Conductivity (µS)	60	105	0.114	M-W
Organic soil depth (meters)	1.7	1.6	0.822	t
Size of swamp (acres)	40	43	0.813	M-W
Total disturbance rank	1	5	<0.001	M-W
Current condition	1	2	<0.001	M-W
Landscape quality	2	3	<0.001	M-W
Minimum buffer width (meters)	97.5	0	<0.001	M-W
% buffer greater than 50 meters	100	62.5	<0.001	M-W

These results indicate that, based on the data used, none of the candidate biological metrics and none of the environmental variables are effective in distinguishing between the reference and disturbed northern white cedar swamps. There are several possible explanations for this. First, it is possible that there really are very few or only minor differences in these biological metrics and environmental variables between reference and disturbed swamps and that this pattern would not change even if additional sites were studied. Second, the results may change considerably if the criteria for assigning swamps to the "reference" and "disturbed" categories were changed. If a cutoff for disturbed swamps was set at a higher total disturbance rank, it is more likely that the biological metrics and environmental variables for these "more disturbed" swamps would be different from the expanded reference swamps. Third, the methods used for assessing the level of disturbance for each swamp and the placement of a plot (sampling unit) within the swamp clearly affect these results. At disturbed swamps, plots were not located in areas of direct recent alteration, such as clearcuts, but were typically located near these areas. If the biological and environmental variables sampled in these plots near highly disturbed areas do not vary considerably from what is found in undisturbed conditions, this indicates that although the disturbance may be substantial, its effects are highly localized (at least in terms of the variables sampled here). This third explanation relates to a common criticism of using biological assessment methods in non-aquatic systems, namely, that palustrine wetlands are more robust than aquatic systems and do not have a well-mixed water column that distributes many effects of disturbance evenly throughout the system.

It is not surprising that there were significant differences in all five of the disturbance rankings between reference and disturbed swamps (**Table 28**), as the categories of "reference" and "disturbed" were based on the total disturbance rank. The other four disturbance ranking measures (current condition, landscape quality, minimum buffer width, and percent of wetland perimeter with greater than 50 meter buffer) are all closely related to total disturbance rank, even though they were derived separately.

Spearman rank order correlation was used to evaluate the strength of the associations between disturbance rankings, environmental variables, and biological metrics. These results can be separated into correlations relating to level of disturbance and correlations relating to the environmental and biological conditions in swamps. Some of the strongest associations were found between the disturbance rankings, with total disturbance rank, landscape quality, current condition, minimum buffer width, and percent of wetland perimeter with greater than 50 meter buffer all highly correlated ($P<0.001$). As stated above, this is expected, as all of these measures are alternative methods of evaluating the level of disturbance at a particular swamp. Conductivity was positively correlated ($R=0.381$, $P=0.019$) with total disturbance rank. This is likely the result of road salts and other stormwater runoff entering disturbed sites such as Berlin Mall Swamp, Pond Brook Cedar Swamp, and East Peacham Swamp. The correlation between conductivity and total disturbance is likely not strong because conductivity is also directly related to the presence of mineral-rich ground water discharge, a characteristic of many cedar swamps, regardless of their level of disturbance. The positive correlation between surface water pH and conductivity ($R=0.434$, $P=0.007$) has been documented in many studies of wetland water chemistry. The strong positive correlation between vascular plant richness and total plant richness ($R=0.934$, $P<0.001$) is simply because vascular plants make up the majority of the species contributing to total richness. The positive correlation between bryophyte richness and bryophyte percent cover ($R=0.558$, $P<0.001$) indicates that when good swamp bryophyte habitat is present (shady with stable moisture levels), the habitat is colonized by many species, not just a few.

Further Discussion of Plants, Birds, and Disturbance Level

Plants

Although none of the biological metrics evaluated were effective in distinguishing between reference and disturbed cedar swamps, a more qualitative evaluation of the plant species found in cedar swamps relative to their level of disturbance provides some more insight into the ecological integrity of the swamps. Of the 260 species of vascular plants and bryophytes identified in the 38 plots in "typical" northern white cedar swamps (**see Appendix B, Table B12**), 30 of these species only occurred in reference quality swamps (total disturbance rank of 0 to3). Of these, the moss *Calliergon obtusifolium* is an arctic and boreal species that is very rare in Vermont and, to date, known only from wet hollows in northern white cedar swamps. This rare moss only occurs in three of the reference swamp plots, but its presence here may be related to the excellent condition of these swamps in which the natural process of wind-throw tips over individual trees and maintains the hummock and hollow microtopography upon which this species depends. Similarly, 77 of the 260 species occurred only in disturbed swamps (total disturbance rank 4 to 9), however, we can make no generalizations about these species and their tolerance of disturbance.

Berlin Mall Cedar Swamp and Cemetery Cedar Swamp are the two most highly disturbed swamps studied – both have a total disturbance rank of "9". Berlin Mall Cedar Swamp has significant disturbance from adjacent development that has affected swamp hydrology and water quality. Cemetery Cedar Swamp has moderate alterations from logging, development, and agriculture, which have affected swamp hydrology and water quality. The vegetation of these two highly disturbed swamps was further examined to determine if there were species present here that reflect this level of disturbance. Three native vascular plant species, rice cutgrass (*Leersia oryzoides*), common duckweed (*Lemna minor*), and tussock sedge (*Carex stricta*), and one liverwort, *Aneura pinguis*, all occur at Berlin Mall Swamp but in none of the other 37 plots. These species are all associated wetlands that have standing water and open canopies, characteristics present at Berlin Mall Swamp. The moss, *Sphagnum teres*, also only occurs in Berlin Mall Swamp. This is a minerotrophic species typically found in open, wet fens. The open, wet conditions and the very high surface water conductivity (720µS) at Berlin Mall Swamp are similar to those found in very rich fens. Frondose beggar's ticks (*Bidens frondosa*) is a native annual species that is typically associated with disturbed, open wetlands. This species occurs at Berlin Mall Swamp and Cemetery Cedar Swamp, but in none of the other 36 cedar swamp plots. Although the presence of these several species that are uncharacteristic of cedar swamps can be explained by the specific type of disturbance found at Berlin Mall Swamp and Cemetery Cedar Swamp, these species cannot be used as general indicators of disturbance. If human disturbance at a cedar swamp alters the plant species composition, those noncharacteristic species that become established will reflect the very specific type of alteration at the swamp and the seed, spore, or propagule source from the local area.

Birds

Habitat requirements for bird species are very different from those of plants. Whereas plants typically have optimal ranges of moisture, sunlight, and nutrient availability in preferred habitats, birds generally select habitat by combinations of vegetation type and structure, and the size and juxtaposition of other community types or habitats, including open water. In addition, some species of birds are especially sensitive to the proximity of human activity and this can be a factor determining their presence in an area.

Table 28 is an abbreviated list of the bird species identified during the spring breeding bird surveys conducted in nine cedar swamps. A few observations can be made about these bird species relative to the level of disturbance in the nine swamps. There are several species that are present in almost all cedar swamps, regardless of the level of disturbance, including Blue Jay, Veery, Winter Wren, Black-capped Chickadee, and White-throated Sparrow. In contrast, the Song Sparrow occurs only at the most disturbed site, Berlin Mall Swamp, and Swamp Sparrow occurs only at Berlin Mall Swamp and Molly's Brook Swamp. Typical habitat for these species is brushy or weedy fields and forest edges for Song Sparrow and emergent and shrub wetlands for Swamp Sparrow (DeGraaf and Yamasaki 2001). Northern Waterthrush was present in all swamps except Berlin Mall. This species requires cool, shady, wet, brushy areas with open pools and hummocks (for nests) (DeGraaf and Yamasaki 2001) and is described as intolerant of disturbance from timber harvesting (Johnson and Brown 1990). Similarly, Northern Parula occurs in four swamps with disturbance rankings of "1" to "5" and is absent from Molly's Brook and Berlin Mall Swamps. This species has been described as sensitive to forest fragmentation and requiring 250 acres to sustain breeding populations (Robbins et al. 1989), and tolerant of moderate levels of timber harvesting (Johnson and Brown 1990). Olive-sided Flycatcher is a species in regional decline that prefers open forests and needs tall exposed perches near swamps, clearcuts, and beaver ponds (DeGraaf and Yamasaki 2001). This species occurs in three of the less-disturbed swamps and is absent in the two most disturbed swamps. Yellow-bellied Flycatcher is absent from Berlin Mall Swamp but found in six less disturbed swamps. This species of dense, moist, coniferous forests nests on the ground beside hummocks (Walkinshaw 1957). At Berlin Mall Swamp the hollows are very wet and the hummocks small as a result of altered swamp hydrology.

When using birds or mammals as indicators of the ecological integrity of a swamp, it is important to keep in mind both the habitat requirements of individual species and how species are likely to respond to disturbance. For example, Winter Wrens are a common species of cedar swamps and other moist forests with dense underbrush. For this species, the six-acre, highly disturbed Berlin Mall Swamp in a highly fragmented landscape is still suitable habitat in which a male had established a breeding territory, although we don't know whether the species will be successful breeding here. Northern Waterthrush are not found at this site, however, likely because of the disturbed nature of the area. Similarly, white-tailed deer rely on cedar swamps for winter food and cover and evidence of this species was found in almost all cedar swamps studied except Berlin Mall Swamp, likely because of the fragmented nature of the landscape. Other species, such as bobcat, would be expected to use only those large cedar swamps that are in relatively unfragmented landscapes. As the condition of a swamp or other habitat decreases and the surrounding landscape becomes progressively more fragmented, it is expected that there will be a stepwise loss of bird and mammal species using the area. Species highly sensitive to human disturbance will be excluded first, followed by less sensitive species, until only those species remain that are very tolerant of human disturbance or that specifically utilize habitats created by disturbance. Although the presence of a highly sensitive species such as a bobcat in a cedar swamp may be an indication of good landscape condition, it surely is not a practical or accurate indicator of swamp integrity.

Table 28. Average number of birds per listening station for nine cedar swamps. Swamps are ordered left to right by increasing total disturbance rank. The species are ordered here by their increasing frequency of occurrence. Partners in Flight priority species are indicated by (PIF).

Site Name (disturbance rank) / Species	Bliss Pond (1)	Long Pond (1)	Dutton Brook (2)	Martell Swamp (3)	Victory (3)	Norton Pond (5)	Calendar Brook (5)	Molly's Brook (7)	Berlin Mall (9)	Frequency of Species
Song Sparrow	0	0	0	0	0	0	0	0	1	**0.11**
Swamp Sparrow	0	0	0	0	0	0	0	1	1	**0.22**
Olive-sided Flycatcher (PIF)	0	0.5	0	0.5	0	0.5	0	0	0	**0.33**
Ruby-crowned Kinglet	0	0.5	0	0	0	0.5	2	0	0	**0.33**
Swainson's Thrush	0	2.5	0	0	0	0.5	2.8	0	0	**0.33**
Common Yellowthroat	0	0	0	0	0	1	0	1.5	3	**0.33**
Northern Parula (PIF)	0	0.5	0	1	0	1	3.2	0	0	**0.44**
Canada Warbler (PIF)	0	3	0	2.25	1.3	0.5	0	1	0	**0.55**
Magnolia Warbler	0	1	0	0	0	1.5	2.4	2	1	**0.55**
Brown Creeper	2	0	0.7	0	0	1	0.4	0	1	**0.55**
Yellow-bellied Flycatcher	0	2	0	2.5	2	2	1.6	1	0	**0.66**
Blue Jay	0	0.3	0.3	0.5	0.3	0.75	0.2	0.25	0	**0.77**
Hermit Thrush	1	1	2	2.5	1	0	2	1	0	**0.77**
Veery (PIF)	1	0	0.7	0.5	1.3	1.5	0	0.5	2	**0.77**
Northern Waterthrush	1	3	2	4	2	4	3.6	2	0	**0.88**
Winter Wren	2	4	2	3	0	2.5	5.2	2.5	1	**0.88**
Black-capped Chickadee	2	0	0.3	0.5	0.7	0.75	5.2	0.25	1.5	**0.88**
White-throated Sparrow	2	2	2.7	2.5	1.3	2	1.6	1	1	**1.00**

Alternatives to Biological Metrics for Assessing Ecological Integrity of Cedar Swamps

Determining the level of ecological integrity at a cedar swamp should be based on detailed evaluation of the swamp and the surrounding area and should include an assessment and evaluation of plant species composition, presence of exotic species, animal species using the swamp, community structure, microtopography, natural disturbance regimes, hydrology, water chemistry, soil type, characteristics of the surface watershed, location of ground water recharge areas for the swamp, and many other factors. In many cases it will not be possible to evaluate all of these factors thoroughly given constraints of time and funding for studies. Although the goal of identifying biological metrics that can be used as indicators of ecological integrity has great appeal, given the complexity of forested wetland systems, their relatively robust character, the expected localized influence of disturbance on the flora, and the stepwise loss of animal species, a more general tool for estimating ecological integrity may be more appropriate. A good example of a more general assessment tool is the "Element Occurrence Rank" used for ranking the ecological integrity of natural communities by the network of Heritage Programs (NatureServe). Under this system, a set of ranking specifications is developed for each natural community type (such as a northern white cedar swamp). These detailed ranking specifications identify particular ranges of community size, current condition, and surrounding landscape quality that must be present at a site in order to assign ranks of "A" (excellent viability and integrity) to "D" (poor viability and integrity). The advantage of this system is that the resulting ranks incorporate both site-scale measures of ecological integrity as well as landscape-scale measures of ecological integrity. Another advantage is that element occurrence ranks can be applied to a natural community type across its geographic range of distribution.

CONCLUSIONS

1. Aquatic macroinvertebrate sampling occurred too late in the season for two of the three swamps visited for macroinvertebrate sampling. It is imperative to sample these sites during their active hydroperiod. The Martel Swamp has a perennial stream flowing through it and this allowed sampling to occur even in the summer. It is unknown whether the macroinvertebrate biota in this stream reflects conditions in the cedar swamp or more in the stream itself. There was no open water to sample at either the Berlin Mall or the Victory Wildlife Area cedar swamps. Early spring sampling would have been beneficial at these sites to sample hollows and small streams. If aquatic microhabitats (with standing/flowing water) do not consistently occur in cedar swamps, aquatic macroinvertebrates should not be included in bioassessment or monitoring programs for cedar swamps. However, our limited efforts for this project have not conclusively shown that aquatic macroinvertebrates are not useful as biological indicators in these forested wetlands. Sampling needs to occur in the early spring (the same time as seasonal pools) or autumn when the water table is up. Lastly, in order to fully characterize the aquatic insect community, it is important to sample the different habitats, including the pools and riffles of cedar swamp streams and the cedar swamp hollows.
2. Using multivariate analysis techniques and professional judgment, the 70 cedar and hardwood cedar swamps studied in detail were separated into two main natural community types: northern white cedar swamps and red maple-northern white cedar swamps. The cedar swamps were further separated into the "typical" northern white cedar swamp and two variants: northern white cedar sloping seepage forest variant and boreal acidic northern white cedar swamp variant.
3. The 38 plots from 36 "typical" northern white cedar swamps were selected for analysis of disturbance ranking, environmental variables, and biological metrics.
4. None of the candidate biological metrics and none of the environmental variables were effective in distinguishing between the reference and disturbed northern white cedar swamps.
5. Although not identified in any of the quantitative analyses performed, several species of plants and birds can be linked to the level of disturbance in cedar swamps based on their presence and absence in plots and their specific habitat requirements. In general, noticeable changes in the flora of cedar swamps only occurs in those swamps that are highly disturbed to the point that one or more of the environmental variables driving the swamp is altered (such as change in hydrology and loss of canopy cover from logging). Bird species are sensitive to both changes in community structure and to fragmentation of surrounding habitat.
6. Given the complexity of forested wetland systems, their relatively robust character, the expected localized influence of disturbance on the flora, and the stepwise loss of animal species as the surrounding landscape is progressively fragmented, biocriteria may not be the most appropriate means of assessing and monitoring ecological integrity of cedar swamps. Perhaps a better tool for estimating ecological integrity would be a system that incorporate both site-scale measures of ecological integrity as well as landscape-scale measures of ecological integrity, such as the "Element Occurrence Rank" method used by the network of Heritage Programs and NatureServe.

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