VEGETATION COMPOSITION AND STRUCTURE OF A LARGE BOREAL PEATLAND COMPLEX IN THE WESTERN ADIRONDACKS OF NEW YORK STATE

by

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Abstract

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Large boreal peatland complexes are at the southern extent of their range in New York State and contribute considerably to regional biodiversity with their distinctive flora and fauna. The goal of this study is to inform conservation management of peatland ecosystems by providing information on the composition and structure of vegetation across environmental gradients; information that is lacking for the region. I sampled vegetation along gradients of water chemistry, canopy openness, microtopography, coarse woody debris and forest structure in 50 plots within a large boreal peatland complex in the Adirondack region of New York State. I classified ecological communities based on the most important gradients to emerge from an ordination of understory vegetation - pH and canopy openness- and I describe the composition and structure of the vegetation of those classifications. This work presents empirical data on vegetation, environmental gradients and disturbance history of a large Adirondack peatland complex, all of which is important to conservation management efforts.

Keywords: Peatland Complex, Adirondacks, Ecological Communities, Boreal Habitat.

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Introduction

Large boreal peatland complexes (>200ha) are located at the southern extent of their geographic range in the Adirondack region of New York State and contribute considerably to regional biodiversity with their distinctive flora and fauna (Davis and Anderson 2001, Glennon 2014, Jenkins 2010, Moore 2002). Adirondack peatlands are critical habitat for several boreal species in decline, including boreal birds and vascular plant species (Glennon 2014, Kapfer, et al. 2011, Lachance et al 2005, Zuckerberg 2009) and are sites that may function as climate change refugia for such species (Nekola 1999, Bedford and Goodwin 2003, Raney 2014). While there are strong regulatory measures in place to protect peatland resources in this region, these ecosystems remain threatened by human-caused global environmental change, particularly climate change and nitrogen deposition (Berendse et al. 2001, Hilke and Galbraith 2013, Jenkins 2010). Conservation management of peatlands under changing environmental conditions (e.g., climate change, nitrogen deposition) requires a good understanding of how environmental gradients and disturbance structure peatland plant communities (Forrester et al. 2005, Hunter et al. 1988, Smith et al. 2011).

The over-arching impacts of global climate change on biodiversity include shifts in the distribution and phenology of species, novel ecological communities, and changes in structure and function of biological systems (Allen and Breshears 1998, Beckage et al. 2008, Staudinger et al. 2013, Williams et al. 2006). These effects are particularly evident in ecosystems at the periphery of their ranges which are acutely sensitive to climate change because they occur at the extremes of their environmental tolerances (Doak and Morris 2010, Loarie et al. 2009, Reich and Oleksyn 2008). In addition to climate change, increased nitrogen deposition, which is high in the Adirondack region of New York State (Driscoll et al. 2003), contributes to a loss of biodiversity

by changing competitive dynamics and altering vegetation structure (Berendse et al. 2001). Observed responses of boreal peatland vegetation to climate change and/or N deposition include the invasions of trees and woody plants in open bogs resulting in loss of boreal plant species and diminished structural diversity of habitat required by boreal birds (Berg et al. 2009, Kapfer et al. 2011, Lachance et al. 2005).

Hydrology is critical driver to peatland ecology and is influenced by both biotic and abiotic factors acting at multiple scales (Charmann 2002, Crum 1988, Lemly and Cooper 2011, Mitsch and Gosselink 2000, Sjors 1950). At the coarsest scale, abiotic global climatic factors such as precipitation, temperature and solar radiation are the basis of a positive annual water budget: a necessary condition for the rate of plant biomass accumulation to exceed that of decomposition resulting in the development of peat soils. Peatlands occur at all latitudes but dominate boreal and maritime regions because cooler temperatures and anoxic conditions from greater precipitation contribute to decreased vegetation decomposition rates (Mitsch and Gosselink 2000). Geology plays a central role in the hydrology of peatlands in that topography (i.e., watershed size, position, and steepness) influences the amount of precipitation, surface, and ground water available to peatlands and the rate at which water moves through these systems (Charman 2002, Mitsch and Gosselink 2000). Local bedrock and soil types contribute to peatland water chemistry, particularly pH and nutrient availability; important factors in vegetation composition and structure (Mitshch and Gosselink 2000). At finer scales, peatland hydrology is shaped by biotic factors. *Sphagnum* L. (Sphagnum) is often a dominant plant in nutrient-poor boreal peatlands (Crum 1988). With a high cation exchange capacity it is able to efficiently take up base cations, acidifying surface water and creating conditions favorable to its own persistence (Charmann 2002, Crum 1988, Eppinga et al. 2007). The release of organic acids

from decomposition of catotelm (i.e., deeper, persistently saturated) peat is another mechanism contributing to peatland acidification (Charmann 2002). Both of these processes create a harsh environment that few plants can tolerate (Crum1988, Eppinga et al. 2007). Water chemistry in peatlands is further influenced by historic vegetation which has been shown to affect ground-water flow and nutrient availability (Podniesinski and Leopold 1996).

At a fine scale, microtopography and light availability are well documented drivers of plant diversity within peatlands (Ehrenfeld 1994; Anderson and Leopold 2004, Johnson and Leopold 1994, Eppinga et al. 2007). Microtopography contributes to microsite heterogeneity by providing a gradient of hydrology, substrate diversity, temperature, chemistry and competitive dynamics responsible for the distribution of species, functional groups and variation in tree growth rates (Andrus 1983, Eppinga et al. 2007, Karlin and Bliss 1984, Partaley and Fahey 1986, Macdonald and Yin 2001). The nature and character of microtopography vary from forested to open peatland sites even within a single peatland complex. In forested peatlands microtopography is strongly influenced by downed coarse woody debris associated with wind disturbance and are characterized by tip-ups, exposed logs, organic sediment and open water (Ehrenfeld 1995). In open *Sphagnum*-dominated peatlands microtopography is controlled by the competitive dynamics of plant functional groups (Sphagnum mosses, herbs, shrubs and trees) and the varying rates of hydrology-dependent plant growth and decomposition (Eppinga et al. 2007, Foster 1983). In some cases this competitive dynamic results in linear strings and flarks or, more commonly in the Adirondacks, rounded, symmetrical hummocks associated with the root systems of shrubs (Kenkel 1988). Light availability contributes to peatland vegetation distribution and diversity by creating microsite diversity, allowing early successional species to become established, and creating structural heterogeneity (Connell 1989). Canopy gaps have

been shown to be critically important to the maintenance of vascular plant biodiversity in forested *Thuja occidentalis* L. (northern white- cedar) dominated peatlands in New York State (Anderson and Leopold 2002).

In light of the observed changes in peatland vegetation resulting from human-caused global environmental change and because of the high conservation value of peatland species and habitat in New York State, the goal of this study is to inform management and conservation of these systems by reporting how vegetation structure varies across gradients of water chemistry, light availability, microtopography, downed coarse woody debris and forest structure within a large Adirondack peatland complex. Peer-reviewed journal publications of large Adirondack peatland complexes are lacking especially when plant community structure is considered along explicitly measured environmental gradients (D.J. Leopold, personal communication, September 2014). The objectives of this study are to: 1) identify how vegetation is structured by these environmental gradients, and 2) describe and compare the vegetation composition, structural characteristics and environmental gradients of these peatland plant communities.

Methods

Site description

Glacial Lake Saint Agnes (GLSA) peatland complex, named for a chapel that served the several logging camps in the area in the early 20th century (Potter and Potter 2011), is located at 43°57' N and 74°45' W in a remote part of the west-central Adirondacks in the Town of Long Lake, Hamilton County, New York (Figure 1). This peatland complex occurs on a glacial outwash plain divided by sinuous eskers and abutting low hills with bedrock geology classified as biotite and hornblende granitic gneiss (NYS APA 2000a, 2000b). A layer of lake sediment from soil pits in the basin provides evidence that a glacial lake existed at the site immediately following the retreat of Holocene glaciation (Potter and Potter 2011) which occurred about 10,000 years before present (Overpeck 1985). The GLSA peatland complex is the headwaters of the Shingle Shanty Brook, a first order stream in the Black River watershed draining into Lake Ontario near Watertown, NY, and it is a part of one of the largest (~1500 ha) wetland complexes in the Adirondacks (Lapoint et al. 2004). This wetland complex may best be considered a multiple-unit peatland (sensu, Davis and Anderson 2001). The section of the peatland included in this study covers approximately 400 ha with an elevation ranging between 525 and 535 m. Long-term mean annual temperature (from 1912 to 2012) in the area is 5.78± 0.29°C and mean annual cumulative precipitation is 1066 ±11.5 mm, based on records from a weather station at Wanakena, NY, located approximately 24 km north of the study site (CDIAC 2014).

Notable historic forest disturbances in the area include logging and wind-throw. In the adjacent uplands, *Picea* spp., were harvested beginning in the late 19th century (McCarthy 1919, Pinchot 1896, Potter and Potter 2011) but the extent of harvesting in the peatland is unclear. Both upland and lowland forests in the area were affected by two extreme wind disturbance events, the November 1950 extra-tropical cyclone and the July 1995 derecho storm (NYS APA 2000c,

Potter and Potter 2011), as well as numerous less intense windstorms. Salvage logging in the upland forests surrounding the peatland complex immediately followed the 1995 windstorm after which logging and development rights of the 6300 ha property that includes the GLSA peatland were extinguished as part of a conservation easement placed on the property in 1999. Ecological communities in the GLSA peatland complex were previously classified as black spruce-tamarack bog, dwarf shrub bog and marsh headwater stream following Edinger et al. (2002) and some were ranked as exemplary based on size, quality of the site and limited human impacts to the watershed (Gebauer and Olivero 2002).

Data collection

Site selection. The GLSA peatland complex is a remote site with no development in the watershed and a well-documented land-use and disturbance history. Fifty sampling locations were randomly located across the peatland complex via stratified random sampling using ESRI ArcMap 9.0 with Geospatial Analyst extension. Strata were previous ecological community delineations of black spruce tamarack bog, dwarf shrub bog, and northern white cedar fen//shrub fen (Gebauer and Olivero 2002, Langdon and Curran 2010). Plots were 5 × 5 m with ten 0.25 m^2 quadrats (subplots) placed along micro-elevation transects (Figure 2).

Environmental data collection. Micro-elevation was measured by establishing a horizontal line with a carpenter's laser-level (Bosch Inc.) on a tripod. The line was established at an arbitrary height above two 5 m transects, one due north and due west originating at the same point: the southeast corner of each plot. The distance from this line to the surface of the peatland was measured every 0.5 m along the transects. Measurements were subtracted from the micro-elevation value of the lowest elevation measured in a plot to find the relative elevation in respect

to site-specific low point (Ehrenfeld 1994). Plot mean elevation is mean value of the 21 micro-elevation measurements per plot. Plot elevation variance and plot coefficient of variance of micro-elevation were also calculated from micro-elevation measurements. A 0.25 m^2 (0.5 × 0.5 m) quadrat frame was placed along this micro-elevation transect. Mean quadrat elevation was calculated from the two micro-elevation measurements at the quadrat corners. A microtopographic index for each plot was the number of quadrats in a plot with a mean micro-elevation greater than the mean of all of the micro-elevation measurements across the peatland. Canopy openness was measured at 0.5 m and 1.5 m above the ground in each plot using hemispherical canopy photographs analyzed with Gap Light Analyzer (Frazer and Canham 1999). At 1.5 m above the surface of the peatland two photographs were taken 2.5 meters along each 5 m micro-elevation transect to obtain 1.5 m plot mean canopy openness (openh; n=98). At 0.5 m above the center of each quadrat a hemispherical photograph was taken and the 10 values for each plot were averaged obtain 0.5 m canopy openness (openl; n=490). Missing 1.5 m canopy openness values in one plot were estimated from the means of other close, similar plots. Surface water pH and conductivity were measured from water samples collected from the 50 plots in the same three day period. One missing value was estimated by averaging the values of the nearest surrounding plots. A peat soil sample was taken and classified with the Von Post scale for assessing peat decomposition (NYNHP 1997). Depth of peat was measured to the nearest 0.5m after at least 5 attempts at each plot with a 6m probe.

Vegetation data collection. Quadrat cover of all vascular and non-vascular plants was estimated with Daubenmire cover classes (Daubenmire 1959). The mean cover of species in the 10 quadrats was used as an estimate of cover for the plot. All species of non-vascular plants were identified at least to genus; vascular plants were identified to species. Nomenclature follows the

New York Flora Atlas (NYFA 2012). The number of trees and tall shrubs in the plots was counted by species in 3 vertical strata: less than 1.0 m (seedlings), 1.0 - 3.0 m (saplings) and taller than 3 m (trees). Diameter breast height (DBH) was measured for all trees taller than 3.0 m in the plot. Volume of downed coarse woody debris in the plot (trees 5cm or greater diameter at the large end) was calculated and decay class (1-6) was assigned following McGee and Leopold (1999). Downed trees were classed as "tip-ups" or "snaps" based on whether they had been up-rooted or broken off at the bole. Age structure was calculated from increment cores taken at 1.0 m from five trees selected via point center quarter method (the fifth tree was the next nearest in an additional randomly selected quarter) centered on the southeast corner of each plot (n=125). Tree rings were counted but not age-corrected for height of core or off-center cores.

Statistical analysis.

To identify how vegetation is structured by environmental gradients I used nonmetric multidimensional scaling (NMS) to ordinate understory vegetation following Kruskal (1964). I used Multi-Response Permutation Procedures (MRPP) following Mielke and Berry (2001) to test the statistical strength of my community classifications. I used Indicator Species Analysis (ISA) following Dufrene and Legendre (1997) to identify plant species indicative of environmental conditions of communities defined below. Finally, I used basic descriptive statistics to describe the vegetation and structural characteristics of communities within the peatland complex, including microtopography, canopy openness and coarse woody debris.

For NMS, I used mean cover of vascular plants as the response variable (i.e., in the primary matrix). Vascular plant species occurring in two or fewer plots (< 4% of plots) were excluded from the analysis to minimize the effects of outliers or coincidental rare species on the

analysis following McCune and Grace (2002), leaving 59 total species for the ordination. The following environmental (and habitat) variables were used for the secondary matrix to quantify environmental gradients: (1) number of woody stems per plot taller than 3m; (2) basal area per plot; (3) number of woody stems 1-3m tall; (4) microtopography indices (plot elevation variance, plot coefficient of variance of elevation, number of quadrats in a plot with a mean micro-elevation greater than mean micro-elevation of all quadrats across the peatland); (5) volume of coarse woody debris; (6) mean canopy openness at 0.5 m and 1.5 m height; (7) conductivity (μS/cm); (8) pH and; (9) mean of the absolute cover of *Sphagnum* in quadrats per plot. I used a Sorensen distance measure with a random starting configuration and 250 runs with real data to run the NMS and the same distance measure for the Multi-Response Permutation Procedures (MRPP). For the NMS ordination, a two-dimension final solution was selected via the software's autopilot mode as this dimensionality resulted in the least stress. The final stress of best solution was 12.3, a stress score that results in reliable interpretation (McCune and Grace 2002). A Monte Carlo test of final stress with 250 runs led me to conclude that the final stress could not have been obtained by chance ($p = 0.004$). There were 500 iterations in the final solution and the default stability criteria was met (final instability=0.00001).

My interpretation of the results of the NMS led me to base ecological community classifications on pH and canopy openness, the two strongest gradients identified in the NMS analysis. The classifications used were forested bog, open bog, and fen. I use these terms in their broadest sense following Davis and Anderson's (2008) convention that distinguishes bog or fen *sensu lato* (a more general term) from bog or fen *sensu stricto* a chemo-hydrological characterization. I tested the strength of these classifications with MRPP, a procedure of testing the hypothesis of no difference between groups (McCune and Grace 2002). The area of GLSA

peatland complex is approximately 405 ha, and was mostly classified as forested bog (266 ha) or open bog (45 ha) and fen (7 ha). The remainder of the GLSA peatland complex, classified in 2002 as Marsh Headwater Stream or Shrub Swamp by Gebauer and Olivero (2002) following Edinger et al. (2002) and was not sampled. The area classified as fen had highly variable canopy openness; thus, forested and open plots in this area were lumped.

Indicator species analysis (ISA) followed Dufrene and Legendre (1997) where relative frequency of occurrence and relative abundance of species are combined using the formula:

Equation 1

$$IV_{kj} = 100(RA_{kj} \cdot RF_{kj})$$

In this approach IV_{kj} is the indicator value of species j in group k, RA_{kj} is the relative abundance of species j in group k and RF_{jk} is the relative frequency of occurrence of species j in group k. Using this method the indicator value reaches its maximum when all individuals of a species are found in a single group of sites and in all of those sites (Dufrene and Legendre 1997). To evaluate the statistical strength of the indicator value we used a Monte Carlo test with 4999 randomization runs on data from the three groups defined above. Once the strength of our groupings of understory vegetation was established, we described and compared the vegetation structure, coarse woody debris, microtopography and canopy openness of the communities with analysis of variance.

Results

Peatland-wide vegetation and environmental variables. I recorded 98 species of vascular plants and 6 genera of non-vascular plants and no non-native species in 50 plots across the Glacial Lake St. Agnes peatland complex (Appendix A). The most frequently occurring vascular plants were black spruce (occurring in 47% of subplots), *Vaccinium myrtilloides* Michx. (velvet-leaved huckleberry), *Carex trisperma* Dewey (three-seeded sedge), and *Maianthemum trifolium* L. (three-leaved Solomon's plume) (all >40% frequency). The most frequently occurring non-vascular plants were *Sphagnum* spp. (occurring in 93% of subplots), *Pleurozium schreberi* (Brid.) Mitt. (red-stemmed moss) and the liverwort *Bazzania trilobata* (L.) A.Gray (38% and 7% respectively). Tree stem density (woody stems > 3 m) ranged from 0 to 8,400 stems ha^{-1} (mean 1,712 stems ha^{-1}), shrub stem density (woody stems 1-3 m) ranged from 0 to 30,800 stems ha^{-1} (mean 6,344 stems ha^{-1}), coarse woody debris volume ranged from 0.0 m^3 ha^{-1} to 460.5 m^3 ha^{-1} (mean 48.6 m^3 ha^{-1}). pH was bimodally distributed ranging from 3.45 to 6.38, with peak frequencies from 3.5 to 4.0 and 5.5 to 6.0 (Figure 3a). Conductivity ranged from 24.8 to 135.7 µS/cm (mean = 67.94 µS/cm). Canopy openness at 1.5 m was also bimodally distributed and ranged from 11.7% to 87.8% openness with peak frequencies between 15% -20% openness and 75% - 80% openness (Figure 3b). Canopy openness at 0.5 m was lower and ranged from 3.0% to 90% (mean = 38.1%). The relative micro-elevation in respect site-specific low point ranged from 0.0 cm to 118.0 cm (mean = 20.7 cm). Peat depth at the 50 plots ranged from 1 m to greater than 6 m. Soil samples were classified in Von Post peat soil categories of H1, H2, H3, H4, and H5 with the majority of samples classified as H2 and H3 (NYNHP 1997).

Vegetation structure along environmental gradients. NMS final solution accounted for a large proportion of variability in plant composition (r^2 = 0.855) with most variance accounted by Axis 1 (68.4%) and less by Axis 2 (17.2%) (Figure 4). The ordination suggests that pH (axis 1) and canopy openness (axis 2) were the most important gradients affecting plant community composition (Table 1, Figure 3). Axis 1 corresponds mainly to a gradient of pH (r^2= 0.78) and less so to a gradient of Sphagnum absolute cover (r^2=0.35), and number of woody stems 1-3 m tall (r^2= 0.35), while axis 2 corresponds mainly to a gradient of canopy openness at 1.5 m and 0.5 m above ground (r^2= 0.44 and r^2= 0.40, respectively) and partly to number of woody stems taller than 3m (r^2= 0.20), and coarse woody debris volume (r^2= 0.18).

We based our classification of communities within the GLSA peatland complex on the bimodal distribution of pH and canopy openness reported in the previous section (Figures 3a and 3b). Based on these variables, the peatland communities were differentiated in forested bogs (pH <5.1, canopy openness <50%), open bog (pH <5.1, canopy openness >50%) and fen (pH >5.1) following our own data and that published in Edinger et al. (2014). Plots classified as fen were not differentiated into forested and open sites due to the heterogeneous character of the canopy and small sample size. This classification resulted in 20 forested bog plots, 20 open bog plots, and 10 fen plots. The results of the MRPP (Appendix B) indicate rejection of the null hypothesis of no difference between groups ($p < 0.0001$) and all pairwise comparisons suggest significant differences among the three community types as well ($p< 0.0001$) indicating the robustness of the community classification. The chance correlated within-group agreement statistic (A) (Forested Bog vs. Open Bog 0.1513; Forested Bog vs. Fen 0.1685; Open Bog vs. Fen 0.2628) indicates that there is greater heterogeneity among the groups than that expected by chance, implying a distinctive species composition of groups defined by this classification approach.

Plant community composition and structure. The Glacial Lake St. Agnes peatland complex is composed primarily of *Picea mariana* (P. Mill) B.S.P. (black spruce) dominated forested bog which make up about 66% (266 ha) of the total area. The open bog community makes up 11% (45 ha) of the peatland area and is dominated by stunted *P. mariana* and ericaceous dwarf shrubs. The area classified as fen makes up 2% (7 ha) of the peatland complex. In total, there were 46 vascular plant species occurring in forested bog sites, 32 occurring in open bog sites and 65 occurring in fen sites (Appendix A). Vascular plant species richness was significantly higher in the fen than in the forested bogs or open bogs approximately reflecting environmental differences between these three community types in pH, microtopography, canopy openness and downed coarse woody debris (Table 2). Indicator species analysis identified thirteen statistically significant indicator species for fen vegetation and one for forested bog. In open bog sites there were no clear indicator species but two species may have marginal potential as indicator species ($p<0.1$; Table 3).

Canopy height across the GLSA peatland complex ranged from two meters to 15 meters, with most common height class being two to three meters. Stem density varied across the peatland communities in different strata (Figure 5, Table 4). Mean stem density of woody stems taller than 3 m was greatest in the forested bog (2,880 stems ha^{-1}) followed by fen (1,840 stems ha^{-1}) and open bog (500 stems ha^{-1}) (Table 4). There was a significant difference in density of woody stems taller than 3 m between forested bog and open bog ($p = <0.001$). Mean stem density of woody stems 1- 3 meters tall was significantly higher in the fen (mean = 23,130 stems ha^{-1}; $p = 2.55e-07$) than in forested bog or open bog. There was no significant difference in woody stem density less than 1 m between communities but unlike forested bog and fen, seedling stem density of the open bog was almost entirely composed (96%) of a single species

Picea mariana, while stem density of other community types were composed of other trees and tall shrubs (Figure 5).

Total downed coarse woody debris in the forested bog was 72.8 ± 3.74 $m^3 \cdot ha^{-1}$, 1.1 ± 0.34 $m^3 \cdot ha^{-1}$ in the open bog and 90.6 ± 21.6 $m^3 \cdot ha^{-1}$ in the fen (Table 5). *Picea mariana* and unknown accounted for most of the downed CWD in forested and open bog sites and *Thuja occidentalis* accounted for all of the downed CWD in the fen sites (Figure 9). Distribution of downed CWD by decay class in the forested bog sites was skewed very slightly to least decayed classes in forested bog and open bog sites. In fen sites downed CWD was skewed strongly to most advanced decay class (Figures 6a, 6b, and 6c). Trees that had snapped at the bole accounted for 76% of downed CWD in the forested bog sites, 100 percent of the downed CWD in the open bog sites, and only 13 percent of the total downed CWD in the fen sites where downed CWD consisted of only tip-ups (Table 5). Snag basal area was 2.3 $m^2 \cdot ha^{-1}$ in the forested bog (7.8 percent of total basal area), 0.04 $m^2 \cdot ha^{-1}$ in the open bog (accounting for 2.7 percent of total CWD) and no snags were found at fen sites.

Tree size class distribution is shown in Figure 7a, 7b, and 7c. *Picea mariana* dominates larger diameter classes of the forested bog. *Abies balsamea* (L.) Mill. (balsam fir)*, Acer rubrum* L. var. *rubrum* (red maple) *and Betula alleghaniensis* Britt. (yellow birch) dominate the smallest size classes (Figure 7a). In one forested bog plot *Thuja occidentalis* was present in the larger size classes and the greatest number of snags occurred in the 5 cm size class. In the open bog, trees taller than three meters were sparse, of smaller diameter and dominated by *Picea mariana* with some *Larix laricina* (DuRoi) Koch (Larch). There were no trees greater than the 10 cm size class in the open bog (Figure 7b). In the fen sites, all size classes of trees taller than three meters were

dominated by *Thuja occidentalis.* The smaller size classes contained *Larix laricina* and *Acer rubrum* (Figure 7c).

Tree age class distribution is shown in Figure 8. Increment cores were not age-corrected for height of the core (1 m) therefore these results under-estimate overall tree age. The mean age at 1 m of all trees in the sample (n=125) was 55.4 years with a standard deviation of 27.9 years. *Picea mariana* had the highest mean age at 1 m (66.7 ± 23.5 yrs.), followed by *Thuja occidentalis* (52.1 ± 43.2yrs), *L. laricina* (49.8 ± 22.8 yrs.), and *Abies balsamea* (39.0 ± 11.4 yrs.). The distribution of tree age (Figure 8) was slightly positively skewed (skewness = 1.135344) with the greatest number of trees in the sample between the 1940's and 1970's (i.e., 30 – 60 age classes) and peaking 1970's. *P. mariana* accounted for all of the oldest trees in the forested bog, was the most common canopy tree to be established until the 1970's and was not present in younger age classes. *L. laricina* was less common in the canopy, with the oldest trees established in the 1920's. Earliest establishment of *A. balsamea* dated to the 1940's and this species dominated the establishment period of the 1980's. The very few *Acer rubrum and Betula alleghaniensis* in the sample were the latest trees to become established, with *B. alleghaniensis* dominating the 1990's and *A. rubrum* dominating the 2000's (Figure 8). Simple linear regression models showed a significant relationship between age and DBH for *Picea mariana* (p = 2.69E-04), *Abies balsamea* (p = 0.0069) and *Thuja occidentalis* (p = 6.66E-05) but not for *Larix laricina* (Figure 9). However, these linear regression models only accounted for a small amount of the variance in all species but *T. occidentalis* (r^2= 0.69).

Discussion

Ecological community classification as a coarse-filter for protection of endangered species is a well-established and pragmatic approach to biodiversity conservation management (Edinger et al. 2014, Norton 1986). This approach is founded on the assumption that focusing on a scale of biological organization broader than that of species (i.e., the ecological community) is an efficient method for species protection because it facilitates the prioritization of land acquisition by identifying sites most likely to have rare species. But the 'community-as-coarse-filter' approach has been criticized because species' response environmental gradients are independent of one another (Gleason 1926) and thus the ecological community is merely a categorization of differing biotic variables that occur along continuous gradients (Whittaker 1962). The community-as-coarse-filter approach can result in exclusion of rare or endemic species and oversimplified descriptions of vegetation structure and composition (Hunter et al. 1988). An alternative to the community-as-coarse-filter approach suggested by Hunter et al. (1988) is to focus conservation efforts on yet a broader scale –the physical landscape - in order to better maintain biodiversity. Yet this approach requires greater resources for conservation and ecological assessments across highly variable sites, potentially resulting in a lack of finer-scale vegetation information. Large boreal peatland complexes are mosaics of ecological communities that share a common physical attributes: landscape position and substrate. Thus large peatlands are an example of an ecosystem that is well suited to the physical-landscape-approach to conservation management. In this study I have treated the physiognomically diverse GLSA peatland complex as a single unit, sampling vegetation across important environmental gradients while measuring those gradients. This approach informs management of large Adirondack peatland complexes in 3 ways. First, it provides descriptive account of the vegetation of the

peatland complex as a whole; information that is lacking in this region where large peatland complexes are common (Lapoint et al. 2004). Second, it provides empirical data on how vegetation is structured along environmental gradients within the peatland complex informing classification of ecological communities. Finally it elucidates the disturbance history and other structural aspects of the peatland complex important to other biodiversity conservation management efforts such as mimicking natural disturbance and climate change adaptation planning.

Peatland-wide vegetation. One broad implication of this work is simply that there can be over-looked pockets of higher floristic diversity within large Adirondack peatlands. The Glacial Lake St. Agnes peatland complex is composed primarily of forested bog and open bog communities of extremely weak minerotrophy. The area classified as fen makes up only 2% of the peatland complex and has the greatest vascular plant species richness. Previous efforts to describe ecological communities at the GLSA peatland complex had not captured the relatively species-rich fen areas because of 1) the difficulty of distinguishing *Thuja occidentalis* from *P. mariana* in aerial imagery and 2) limited time for field-confirmation of aerial image interpretations (Gebauer and Olivero 2002). Such an oversight results from the practical application of the community-as-coarse-filter approach: there are limited resources for conservation work; each site cannot be intensively surveyed; community classification therefore relies on interpretation of aerial imagery that cannot distinguish certain communities. Understanding that pockets of relatively high floristic diversity can occur and have been over-looked in large Adirondack peatland complexes is important information for the management of such sites and provides a compelling argument for their further study.

Analysis of vegetation structure along environmental gradients. The most important gradients structuring vegetation in the GLSA peatland complex were pH and canopy openness. Community classification based on these variables provided groups with strong and significant differences. The areas classified here as forested bog and open bog are equivalent to the New York Natural Community classification of black spruce-tamarack bog (BSTB) and dwarf shrub bog (DSB), respectively (see, Edinger et al. 2014). The area classified here as fen is most similar to the New York Natural Community classification of northern white cedar swamp (NWCS) or Natural Areas of Maine classification of open cedar swamp (Edinger et al. 2014, Maine Natural Areas Program 2014).

Among different peatland sites the separation of bog and fen vegetation occurs along differing thresholds of pH because each site is greatly influenced by vegetation history and local hydrology (Podniesinski and Leopold 1998, Sjors and Gunnarsson 2002). No range of pH is reported for BSTB in Edinger et al. (2014) (see Figure 10). Maine Natural Areas Program (2014) reports the values for pH in equivalent Black Spruce Bog community as 4.2 -5.2. At the GLSA peatland the black spruce tamarack bog community occurs at a lower pH (3.45 – 5.09) than that reported for Maine. The fen community at the GLSA peatland has a circum-neutral pH ranging from 5.57 - 6.38. Values of pH for NWCS are not reported in Edinger et al. (2014) where this community is characterized as 'minerotrophic'. The NWCS classification also includes extremely rich northern white cedar dominated peatlands of central New York with far higher species richness than that of the GLSA peatland complex (Anderson and Leopold 2002) a fact that compels closer investigation of this community type to distinguish circum-neutral NWCS communities from far richer NWCS communities.

Canopy openness was the second most important variable to structure understory vegetation across the GLSA peatland complex. The strong separation of understory vegetation between forested and open bog sites based on a threshold of 50% canopy openness at 1.5 m provides empirical evidence supporting the separation of forested peatland from open peatland the subsystem level reported in Natural Communities of New York (Edinger et al. 2014). Yet values of canopy openness reported in Edinger et al. (2014) at the community level state that black spruce tamarack bog canopy openness ranges from 80% canopy openness to 10%. Given that I had sampled the ecotones between forested and open bog sites throughout a peatland complex with four discrete open bog areas I feel that this threshold for separation of vegetation along a gradient of canopy openness is not specific to this peatland. The area classified as fen had discontinuous canopy with only few mature northern white cedar trees. The high volume of downed CWD of this area suggests that it may have been fully forested in the past and that canopy cover of this community varies over time as reported in Edinger et al. (2014).

Composition and Structure of Vegetation Communities. Indicator species analysis showed that forested bogs sites in the GLSA peatland species are indicated, though weakly, by *Trientalis borealis* a species common in both upland and wetland sites. *T. borealis* occurred in only 30% of the plots and on hummocks with low canopy openness. The lack of statistically significant indicator species in the open bog suggests that 1) abundant species in this vegetation community overlap with that of the forested bog, and 2) least abundant species (e.g., *Platanthera blephariglottis* (Willd.) Lindl. var. *blephariglottis* (white-fringed orchis)) were under-sampled and therefore eliminated from the analysis, and 3) the timing of sampling failed to capture the full diversity of the understory vegetation in the open bog sites. The higher species richness of fen sites resulted in a number of statistically significant indicator species for this community

type. *Calamagrostis canadensis* and *Lycopus uniflorus* both had high indicator values for fen sites and have been shown to be species with high importance values in other fens (Johnson and Leopold 1994).

The distribution of age, size class, and volume of coarse woody debris in areas classified as forested bog in the GLSA Peatland complex suggests that this is a forest recovering from an intense logging disturbance, followed by wind and insect disturbances of varying intensity. The positive coefficient of skewness for age distribution and the inverse J-curve of the size class distribution of *P. mariana* in the GLSA peatland complex (Figure 9) is consistent with that reported for similar forests still recovering from intense logging disturbances of the early twentieth century (Groot and Horton 1994, Rossi et al. 2009). Once age is corrected for height of increment core (±40 yrs.), establishment of the largest age cohort occurred follows early 20th century logging reported by Potter and Potter (2011). Though not spatially explicit, 300,000 cords of pulpwood were removed from the area between 1904 and 1910. The presence of a few older trees in the sample may be a result of partial logging of the site or that harvesting of pulpwood took place in only some areas of the peatland complex. Another possible explanation for presence of older trees is that minimum diameter cut limits were in practice in this immediate area as early as the 1880's (McCarthy 1919, Pinchot 1896, Potter and Potter 2011).

The distribution and the maximum age of *L. laricina* in GLSA peatland complex are indicative of this species' recovery from insect disturbance. The earliest establishment period of *Larix laricina* (1920's) does not reflect the moderately long life (150 – 180 yrs.) of this species and correlates with recovery of this tree following an historic outbreak of *Pristiphora erichsonii* (Hartig) (Larch Sawfly) in the Adirondacks (Bonkoungou et al. 1983). In a study in the Oswegatchie Plains (approximately 20 km to the northwest of the GLSA peatland complex) Bonkoungou et al. (1983) found that establishment and growth rates of *L. laricina* were closely

related to past outbreaks of larch sawfly and that little to no *L. laricina* establishment occurred between 1910 and 1930. Further, trees that had been established prior to the larch sawfly outbreak were more likely to have rot (Bonkoungou et al, 1983). Combined with high mortality rates of *L. laricina* during defoliation by larch sawfly (Beckwith and Drooz, 1956, Turnock, 1954), these factors may have contributed to greater susceptibility to the wind-throw events that subsequently affected the GLSA peatland complex, accounting for the absence of *L. laricina* predating the 1920's.

In the forested bog the low number of snags (the majority being of small diameter classes), the nearly normal distribution of downed coarse woody debris by decay class, and the high percentage of coarse woody debris from trees that snapped at the bole rather than having tipped up, together suggest that tree mortality at this site is commonly a result of intraspecific culling of less competitive trees, rather than wind-thrown tip-ups of vigorous trees. At least one plot in the peatland complex was clearly a site affected by the intense straight line winds of the 1995 derecho storm; a conclusion based on the observation at this site that 1) all downed coarse woody debris were trees that had been be tipped-up and felled in the same direction, 2) there were no trees greater than 3 m, and 3) the 1- 3 m layer was dominated by *Betula alleghaniensis*, a gap successional tree and *Abies balsamea* a shade tolerant and aggressive colonizer of available substrate. This area of intense blowdown however, was confined to a relatively small area of the peatland. In Fen sites the absence of standing snags greater than 3 m tall and the high proportion of downed coarse woody debris classed as tip-ups is consistent with findings that more fertile or transitional peatlands are less likely to escape disturbance (Groot and Horton 1993). The strong negatively skewed distribution of decay class in which *Thuja occidentalis* was the only species

indicates that the disturbance event to affect this area was either intense or that these trees were possibly more vulnerable to wind-throw because of hydrologic variability of the site.

The disturbance history and forest structure of the GLSA Peatland Complex has implications for boreal bird habitat management. The evidence of a major insect disturbance 90 years previous suggests that the number of standing dead trees at this site is periodic; a fact which would have implications for cavity-dwelling birds (e.g., *Picoides* spp.). The relatively low basal area, the small size class of most snags, and the normal distribution of downed CWD by decay class suggests that there is a limited supply of dead trees for foraging for these birds. For instance, *Picoides arcticus* Swainson (black-backed woodpecker) have been shown to successfully breed in unburned conifer forests with at least 35 $m^3 \cdot ha^{-1}$ of dead wood (standing and recently downed CWD) (Tremblay et al. 2009). I estimate the volume of standing and recently downed CWD in the GLSA peatland complex to be between 19.34 $m^3 \cdot ha^{-1}$ and 34.82 $m^3 \cdot ha^{-1}$ (see Appendix D), less than that reported as a minimum observed for successful breeding by Tremblay et al. (2009). This is a rough estimate of volume and breeding black-backed woodpeckers have been observed in point counts in the GLSA peatland complex (Langdon unpublished data 2011 - 2014) suggesting that the larger area of peatland complex compensates for the low per hectare volume of standing dead wood needed for successful breeding. But the distribution of standing and downed CWD more broadly suggests that the disturbance history of boreal peatland forests may play an important role in the recent decline of boreal cavity-dwelling species in the Adirondacks reported by Glennon (2014).

Forest structure at the GLSA peatland is comparable to that reported by Ross (2008) in a habitat assessment of spruce grouse, an endangered species in New York State (see Appendix E). The weak relationship between age and diameter of trees at the GLSA peatland complex is

consistent with findings reported elsewhere (MacDonald and Yin 1999) and is illustrated by the comparison of values reported by Ross (2008): the trees of the GLSA peatland are more than a decade older yet very similar in diameter. The age/diameter relationship of black spruce has been shown to become stronger as forested peatlands are drained indicating that hydrology - particularly along a gradient of microtopography - plays an important role in tree growth rates in peatland forests (MacDonald and Yin 1999). It is therefore important to consider management techniques that retain structural characteristics of microtopography and standing and downed CWD when managing peatland forests for early successional habitat.

Strengths and weaknesses of this study. The objectives of this study are to identify how vegetation is structured by environmental gradients in a large boreal peatland complex and to describe the vegetation and structural characteristics of the site. This project differs from other community classification efforts in that I avoided the subjective selection of plot locations in the field based on an a priori notion of its representativeness of community type or homogenous vegetation. Rather, plots were selected at random within broad physiognomic classifications that were structurally heterogeneous. Particularly shrubby or difficult to sample sites were not avoided and I feel this approach allowed me to capture the range of variation in vegetation structure between peatland vegetation communities; a result that strengthens the NMS ordination. Another sampling approach would have been to sample along transects located between areas of different vegetation, though this may have limited the amount of structural variability captured by my sampling design, particularly in the forested bog plots which were in some cases more than 4 km apart. The study would have been improved if I had expanded sampling to other sections of the peatland complex that have greater a diversity of fen sites. Doing so would have added more sites with higher pH, greater variability in canopy openness

and eliminated concerns of spatial dependencies from physically close plots in the fen area. The strength of the ordination and indicator species analysis would have been improved if I had identified bryophytes, particularly *Sphagnum* spp. to species. Sampling vegetation at two different times in the growing season would have also increased the strength of the ordination and indicator species analysis by allowing me to better distinguish common open peatland species (particularly in the family Cyperaceae) and to capture spring ephemerals. Finally, the strata I used to describe woody vegetation (0-1m, 1-3m, >3m) was efficient in an ecosystem with varying tree height but it is difficult to reconcile with approaches commonly used in New York State. In retrospect I would have followed strata defined by NYNHP (1997).

Large boreal peatland complexes in the Adirondack region of New York State are ecosystems with diverse vegetation structure that contribute considerably to regional biodiversity. Conservation management of these ecosystems requires descriptive information of vegetation structure that can be used as a reference for mimicking natural disturbance, classification of ecological communities and climate change adaptation planning. By approaching large peatland complexes from a physical landscape rather than explicitly from a communities-as-coarse-filter approach I feel that I have captured a wide range of structural diversity of this ecosystem. Such an approach may not be practical or applicable to other ecosystems however it is appropriate with large peatlands because of the fundamentally similar edaphic conditions and landscape position.

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Tables

Table 1: Correlation matrix of NMS results with r values, r^2 values and Kendall tau rank correlation coefficient. The variables with the highest loadings for each axis (highest r^2) are in bold italics.

		Axis 1			Axis 2		
Variable Description	**Abbreviation**	**r**	**r-sq**	**tau**	**r**	**r-sq**	**tau**
Number of woody stems taller than 3 m	tstems	-0.282	0.08	-0.377	0.451	0.203	0.446
Basal Area of trees taller than 3 m	baplot	-0.259	0.067	-0.391	0.368	0.135	0.474
Number of woody stems 1 - 3 m tall	sstems	-0.588	0.345	-0.317	-0.32	0.102	-0.115
Microtopography index	high	0.228	0.052	0.138	0.239	0.057	0.174
Coefficient of variance of plot elevation	cvelev	-0.134	0.018	-0.096	0.127	0.016	0.001
Variance of plot elevation	elevvar	0.159	0.025	0.097	0.203	0.041	0.131
Volume of downed coarse woody debris	CWDvol	-0.331	0.109	-0.401	0.421	0.177	0.509
Canopy openness at 0.5 m	openl	0.492	0.242	0.482	-0.63	0.397	-0.502
Canopy openness at 1.5 m	openh	0.442	0.196	0.43	-0.663	***0.439***	-0.519
Conductivity	cond	0.169	0.028	0.029	0.268	0.072	0.154
pH	pH	-0.881	***0.777***	-0.45	-0.321	0.103	-0.092
Absolute abundance of *Sphagnum* spp.	sphagaa	0.593	0.352	0.476	-0.059	0.003	-0.086
Depth of peat at plot	pdepth	0.459	0.211	0.422	-0.329	0.108	-0.241

Table 2: Peatland vegetation structure variable means. All variables were analyzed with analysis of variance for differences between community types. The significance of differences between communities (Tukey HSD) is indicated with superscripts.

Variable	MEAN (SE) Site Type			F value	p
	Fen (n=10)	Forested Bog (n=20)	Open Bog (n=20)		
Vascular Plant Richness (species m^{-2})	8.8 (0.54)^{b}	5.54 (0.30)^{a}	5.08 (0.24)^{a}	27.83	1.06E-08
pH	5.9 (0.07)^{c}	4.0 (0.09)^{b}	3.8 (0.03)^{a}	169.6	2.00E-16
Micro-elevation (cm)	14.8 (0.52)^{a}	19.9 (0.68)^{b}	24.6 (1.26)^{c}	19.48	4.93E-09
1.5 m canopy openness (%)	44.5 (7.43)^{b}	20.9 (1.56)^{a}	75.6 (2.30)^{c}	89.22	2.00E-16
Downed CWD (m^3 ha^{-1})	90.6 (48.90)^{b}	70.8 (16.61)^{b}	1.1 (0.63)^{a}	5.471	0.00731
	Stem Density (stems ha^{-1})				
3 m or taller	1840.0 (653.74)^{ab}	2880.0 (429.05)^{b}	500.0 (153.21)^{a}	6.503	9.32E-05
1 - 3 m	23120.0 (4289.04)^{b}	7000.0 (1201.93)^{a}	5460.0 (939.55)^{a}	21.33	2.55E-07
Less than 1 m	31160.0 (7612.26)^{a}	27300.0 (2720.35)^{a}	35200. (6242.81)^{a}	0.642	5.31E-01

Table 3: Indicator species analysis of forested bog, open bog, and fen. Indicator values (IV) range from 0 – 100% with 100% percent being perfect indication (i.e., presence of a species in a particular group without error. The results of the Monte Carlo test (p-value, mean and standard deviation of IV) used to test the hypothesis of no difference in IV between groups are reported.

Species	Community	Value (IV)	Mean	St.Dev	p value
Dalibarda repens	Forested bog	6.1	10.2	5.0	0.7684
Oxalis montana	Forested bog	15.0	8.1	4.4	0.1772
Sorbus americana	Forested bog	15.0	8.1	4.3	0.1870
Trientalis borealis	Forested bog	24.0	12.2	5.6	0.0464
Drosera rotundifolia var. *rotundifolia*	Open Bog	15.8	14.7	5.6	0.3561
Eriophorum virginicum	Open Bog	23.5	12.1	5.8	0.0792
Sarracenia purpurea	Open Bog	20.0	9.6	5.1	0.0694
Amelancier cf. *bartramiana*	Fen	30.0	8.2	4.4	0.0054
Aronia melanocarpa	Fen	18.6	9.8	5.0	0.0856
Aster cf. *umbellatus*	Fen	52.0	12.5	5.6	0.0002
Calamagrostis canadensis var. *canadensis*	Fen	70.0	12.1	5.5	0.0002
Chelone glabra	Fen	40.0	8.6	5.1	0.0010
Clematis virginiana	Fen	40.0	9.1	4.8	0.0012
Eutrochium maculatum var. *maculatum*	Fen	30.0	8.2	4.5	0.0062
Galium asprellum	Fen	50.0	10.4	5.2	0.0002
Glyceria canadensis	Fen	30.0	8.5	4.5	0.0068
Glyceria striata	Fen	30.0	8.2	4.4	0.0064
Hydrocotyle americana	Fen	60.0	11.3	5.4	0.0002
Lycopus uniflorus	Fen	60.0	11.6	5.6	0.0004
Lysimachia terrestris	Fen	50.0	10.5	5.4	0.0004
Triadenum virginiana	Fen	30.0	8.2	4.4	0.0066

Table 4: Estimated mean (SE) stem density of species by strata in community types.

Forested bog			
Species	0-1m	1-3m	>3m
Abies balsamea	5920 (1591.2)	820 (247.2)	580 (171)
Acer rubrum	5700 (2254.7)	460 (333.5)	80 (126.5)
Alnus incana spp. *rugosa*	620 (241.4)	160 (51.6)	0 (0)
Betula alleghaniensis	520 (286.6)	500 (822.2)	120 (0)
Larix laricina	1400 (682.4)	220 (189.7)	340 (360.6)
Nemopanthus mucronatus	640 (279)	1880 (561.1)	40 (0)
Picea Mariana	7880 (1730)	1320 (861.4)	1220 (204.1)
Thuja occidentalis	240 (0)	0 (0)	80 (0)
Viburnum nudum var. *cassinoides*	3660 (988.6)	1220 (409.3)	120 (89.4)
[1]Other	720 (280.3)	80 (51.6)	20 (0)
Dead	0 (0)	340 (205.6)	280 (62.5)
TOTAL	27300 (1465.6)	7000 (500.8)	2880 (200.3)
Open bog			
Species	0-1m	1-3m	>3m
Abies balsamea	0 (0)	0 (0)	0 (0)
Acer rubrum	0 (0)	0 (0)	0 (0)
Alnus incana spp. *rugosa*	0 (0)	0 (0)	0 (0)
Betula alleghaniensis	0 (0)	0 (0)	0 (0)
Larix laricina	200 (115.5)	340 (88.6)	80 (0)
Nemopanthus mucronatus	420 (316.2)	20 (0)	0 (0)
Picea Mariana	33840 (5838.5)	4320 (700.5)	380 (175.8)
Thuja occidentalis	0 (0)	0 (0)	0 (0)
Viburnum nudum var. *cassinoides*	640 (209.1)	220 (413.1)	0 (0)
[1]Other	60 (0)	0 (0)	0 (0)
Dead	40 (0)	560 (219.1)	40 (0)
TOTAL	35200 (5726)	5460 (679.3)	500 (133.1)
Fen			
Species	0-1m	1-3m	>3m
Abies balsamea	2360 (1530.1)	360 (210.4)	360 (256.1)
Acer rubrum	1240 (657.1)	40 (0.0)	120 (85.4)
Alnus incana spp. *rugosa*	11920 (2733.0)	14960 (3915.2)	400 (273.3)
Betula alleghaniensis	0 (0.0)	0 (0.0)	0 (0.0)
Larix laricina	0 (0.0)	0 (0.0)	40 (0.0)
Nemopanthus mucronatus	0 (0.0)	0 (0.0)	0 (0.0)
Picea Mariana	0 (0.0)	0 (0.0)	0 (0.0)
Thuja occidentalis	9280 (5555.6)	5760 (1857.3)	880 (265.3)
Viburnum nudum var. *cassinoides*	320 (278.4)	280 (0.0)	0 (0.0)
[1]Other	6040 (2601.5)	1680 (923.4)	40 (0.0)
Dead	0 (0.0)	40 (0.0)	0 (0.0)
TOTAL	31160 (7612.3)	23120 (4289.0)	1840 (653.7)

[1]Other includes *Amelanchier* cf. *bartramiana*, *Aronia melanocarpa, Betula papyrifera, Cornus sericea, Fagus grandifolia, Ilex vericillata, Pinus strobus, Salix* spp., and *Sorbus americanum.*

Table 5: Distribution of down coarse woody debris (CWD) volume (m^3 ha^{-1}) in communities by species, object type, and decay class. Object types are snap and tip-up where snap is a downed log that was a snapped bole from in or out of the plot and tip-up was a tree that was uprooted. Decay classes adapted from McGee and Leopold (1999).

	Mean(SE)		
	Forested Bog	**Open Bog**	**Fen**
Total Downed CWD (m^3 ha^{-1})	72.8 (3.74)	1.1 (0.36)	90.6 (21.87)
Species			
Abies balsamea	0.2 (0.12)	-	-
Alnus incana ssp. *rugosa*	0 (NA)	-	-
Betula alleghaniensis	0.7 (NA)	-	-
Picea mariana	40.3 (3.47)	0.1 (na)	-
Thuja occidentalis	5.8 (15.86)		90.6 (22.92)
Unknown	25.7 (2.87)	1 (0.4)	-
Object Type			
Snap	55.3 (3.5)	1.1 (0.37)	11.7 (7.85)
Tip-up	17.5 (4.36)	-	78.9 (24.2)
Decay Class			
1	3.4 (2.04)	-	0.2 (0.32)
2	8.2 (2.1)	0.4 (0.5)	0.1 (na)
3	21.1 (2.4)	0.6 (0.38)	1.5 (0.22)
4	14.6 (3.72)	0.1 (na)	0.5 (0.35)
5	14.9 (6.87)	-	13.5 (7.27)
6	10.6 (4.34)	-	74.9 (31.1)

Figures

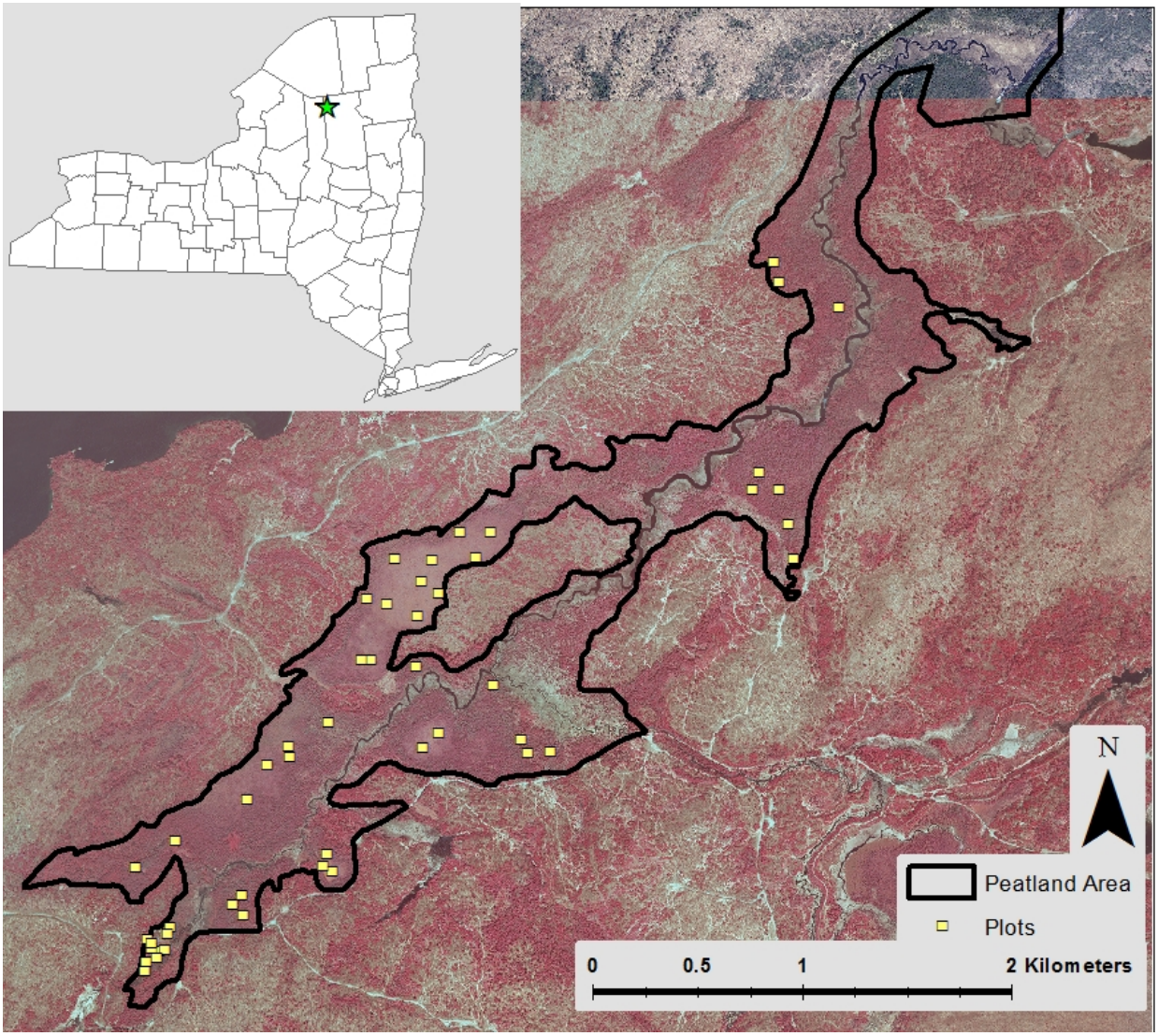

Figure 1: The Glacial Lake St. Agnes Peatland Complex in the Adirondack Region of New York State with plot locations.

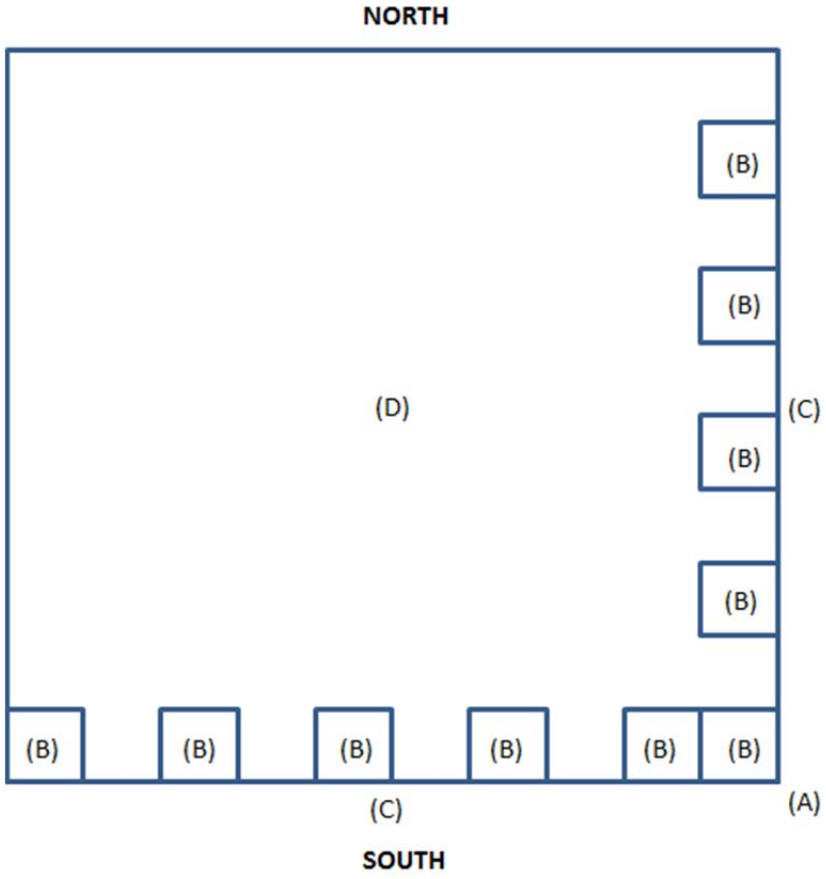

Figure 2: Plot design. A 5.0 by 5.0 meter plot was established at a randomly selected location in the peatland complex. A laser level on a tripod at Point A was used to establish a horizontal line at an arbitrary height along the east and south side of the plot. Starting from point A, distance to ground was measured every 0.5 m along the North and West transects (i.e., the right side and bottom of the figure) for 21 micro-elevation measurements per plot. (B) A 0.25 m^2 (0.5 × 0.5 m) quadrat frame was placed along these transects to measure aerial cover of species. A hemispherical canopy photo was taken at 0.5 m above each quadrat. (C) A hemispherical canopy photo was taken at 1.5 m above the ground 2.5 m along the micro-elevation transects. (D) Within the 5.0 x 5.0 m plot, woody stems taller than three meters were counted and DBH was measured. Woody stems in the 1 – 3 m tall stratum and the less than 1.0 m tall stratum were counted. Downed coarse woody debris volume was measured and assessed, a water sample was taken for pH and Conductivity at a low point in the plot, a peat soil sample was taken and assessed for Von Post soil class, and depth of peat was measured to refusal with a 6 m probe.

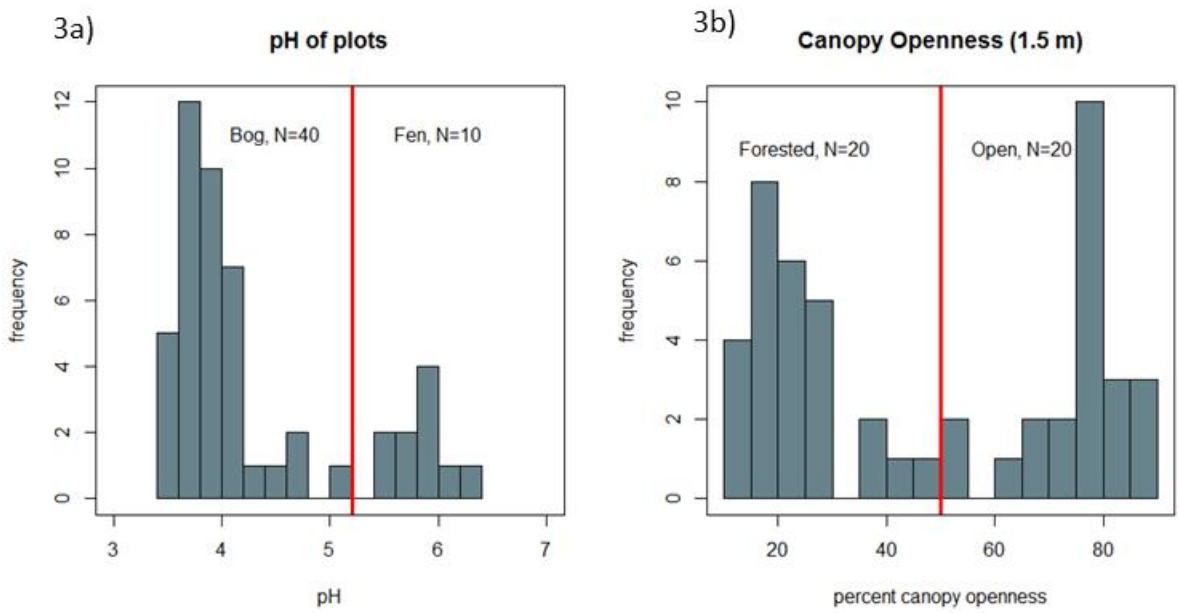

Figure 3: Distribution of pH and 1.5 m canopy openness values. These two bimodally distributed variables were the strongest drivers of vegetation structuring in the peatland and were the basis of the comm unity classification. (4a) Plots with pH values below 5.1 were generically classified as bog and the remainder were classified as fen. (4b) Bog plots with 1.5 m canopy openness values of less than 50% were classified as forested bog; those with 1.5 m canopy openness values of greater than 50% were classified as open bog.

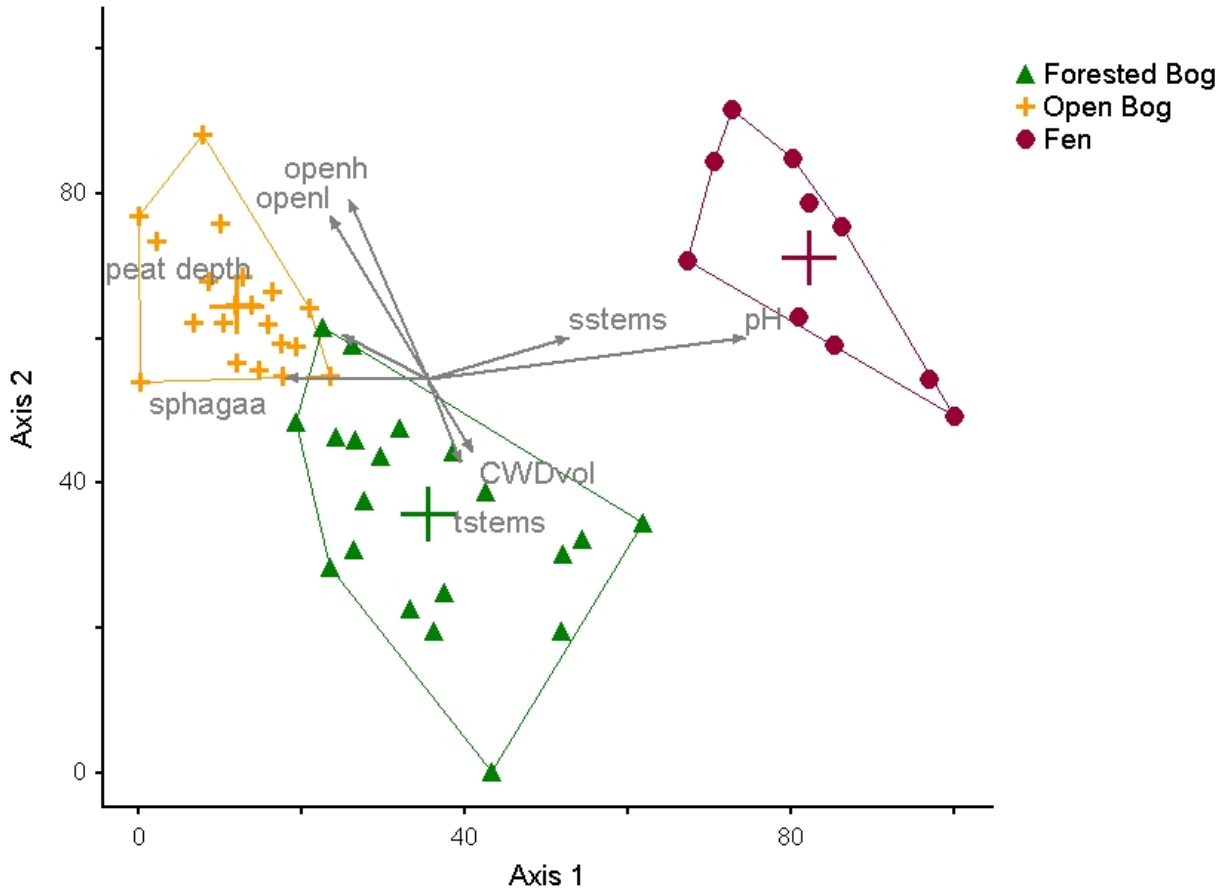

Figure 4: Graph results of NMS of vegetation abundance data and environmental variables. The symbols are sample units: orange crosses represent open bog plots, green triangles represent forested bog plots and red circles represent fen plots. Arrows represent variables with r^2 values greater than 0.20. Abbreviations of environmental variables in are as follows: pH is hydronium ion concentration of water sample; sstems is number of stems in the 1-3 meter strata; openh is mean canopy openness at 1.5 m; openl is mean canopy openness at 0.5 m; tstems is number of woody stems taller than 3 m; sphagaa is mean percent cover of Sphagnum; peat depth is depth of peat to refusal. Correlations are shown in Table 1.

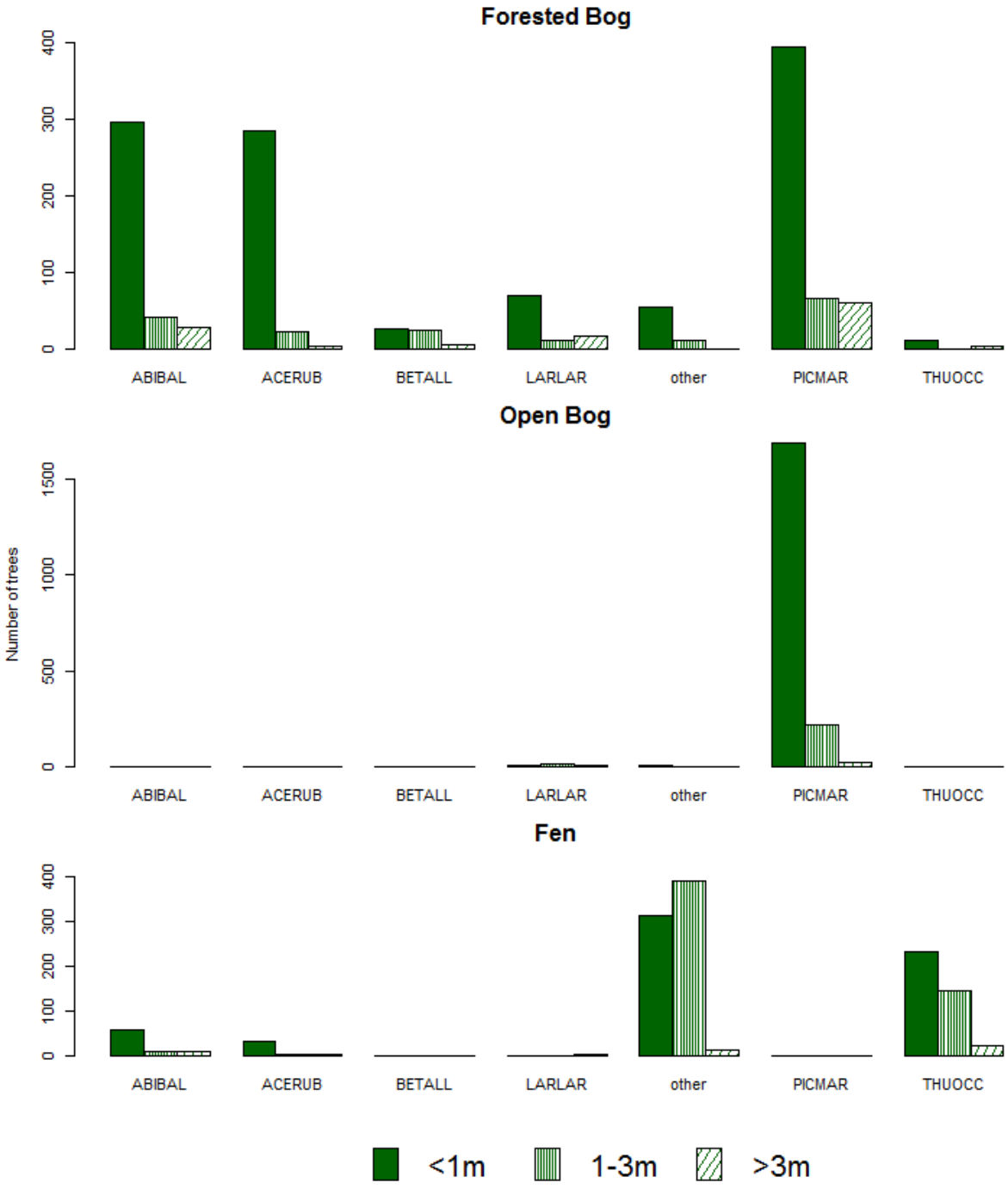

Figure 5: Stem density of strata by species in forested bog open bog and fen. Note that the y-axes are of different scales. Other includes Amelanchier cf. bartramiana, Aronia melanocarpa, Betula papyrifera, Cornus sericea, Fagus grandifolia, Ilex vericillata, Pinus strobus, Salix spp., Sorbus americanum, and Spirea alba var. latifolia.

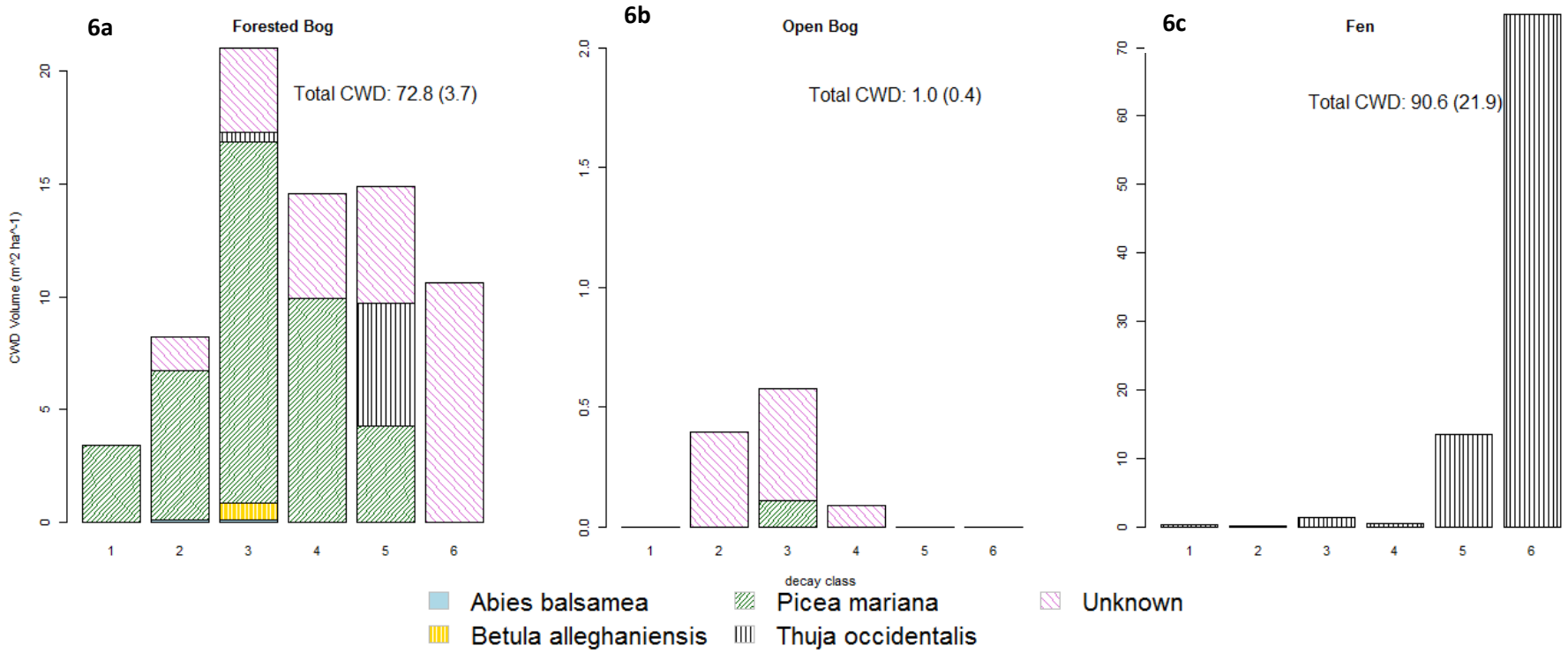

Figure 6a, 6b and 6c: Distribution of downed CWD by decay class in a) forested bog, b) open bog, and c) fen. Note that the y-axes vary.

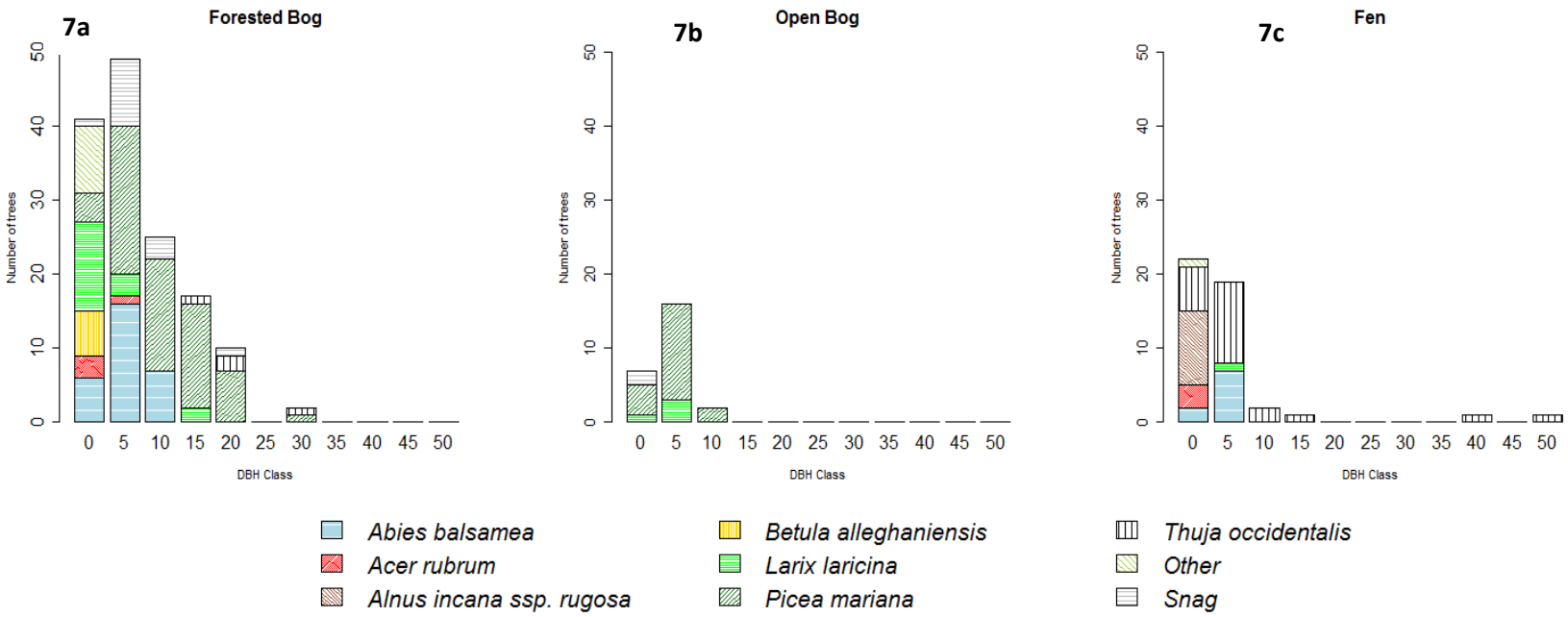

Figure 7a, 7b and 7c: Size (DBH) class distribution of trees taller than 3m in 7a) forested bog, 7b) open bog and 7c) fen. Size classes are: 0 = 0-4.9cm, 5 = 5-9.9 cm, 10 = 10.0-14.9cm, etc

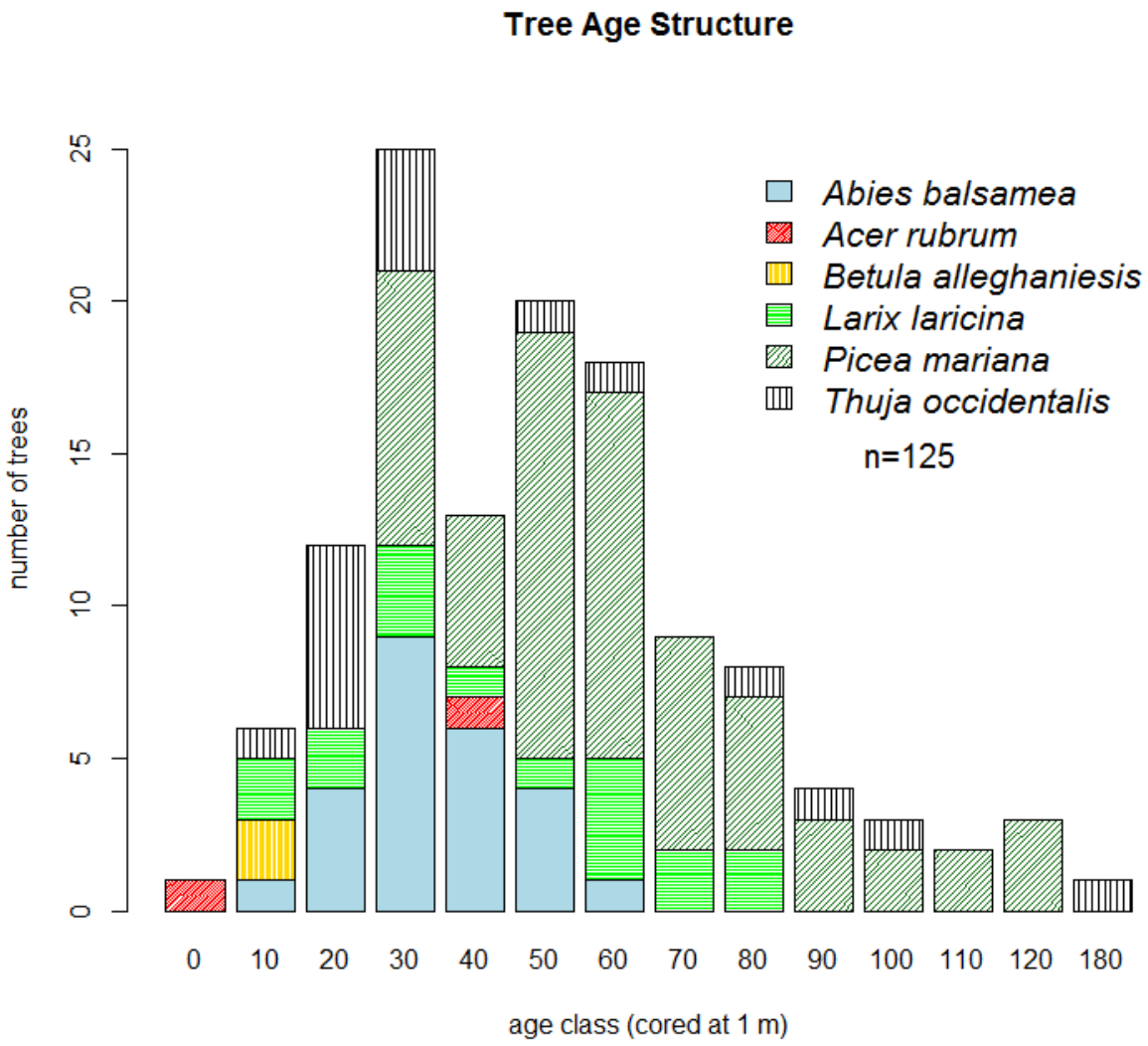

Figure 8: Tree age class distribution for trees sampled throughout the peatland complex. Age classes are: 0 = 0-9 annual rings, 10 = 10-19 annual rings, 20 = 20-29 annual rings, etc. Note the discontinuous X-axis.

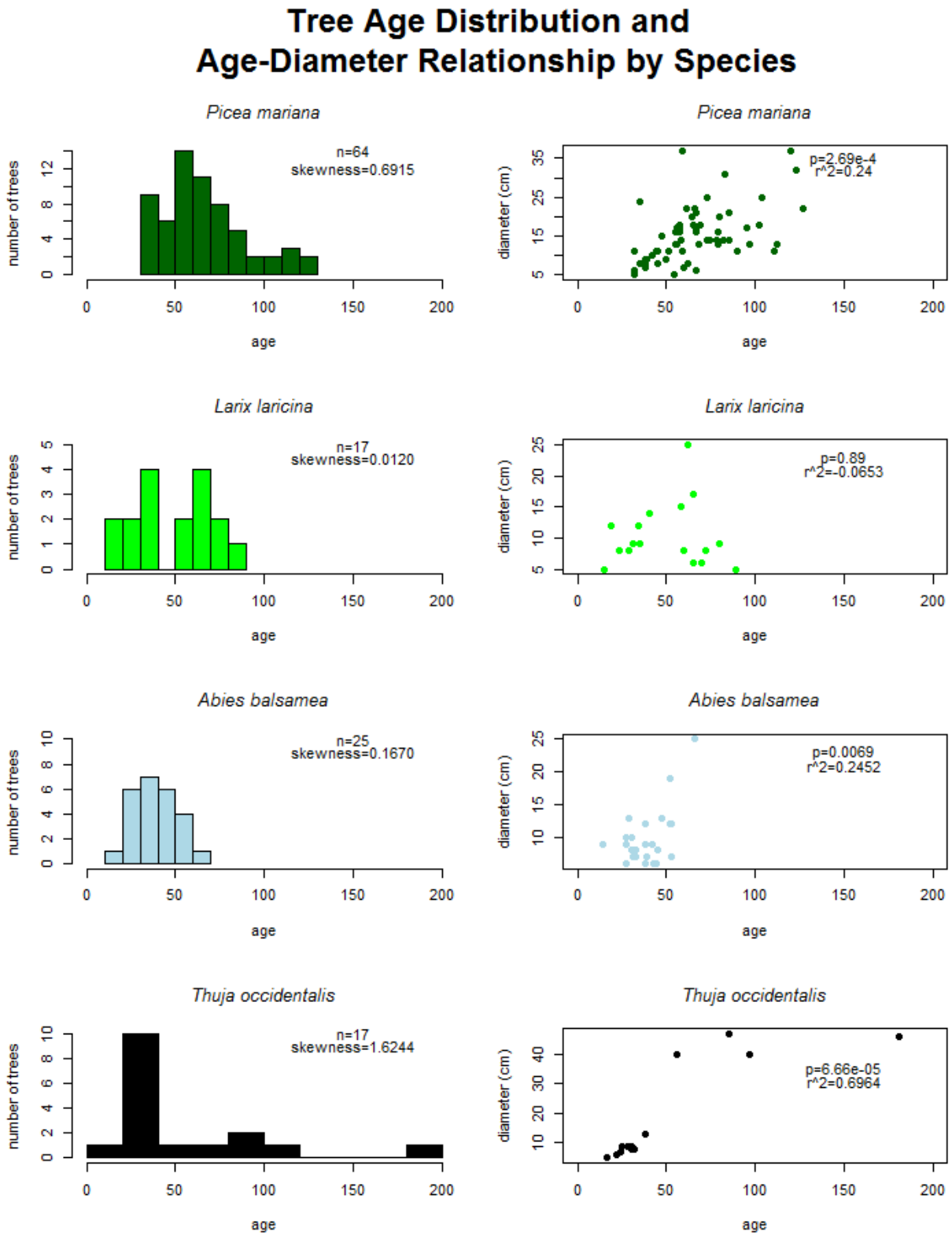

Figure 9: Age distribution and simple linear regression models of tree species in forested bog and fen.

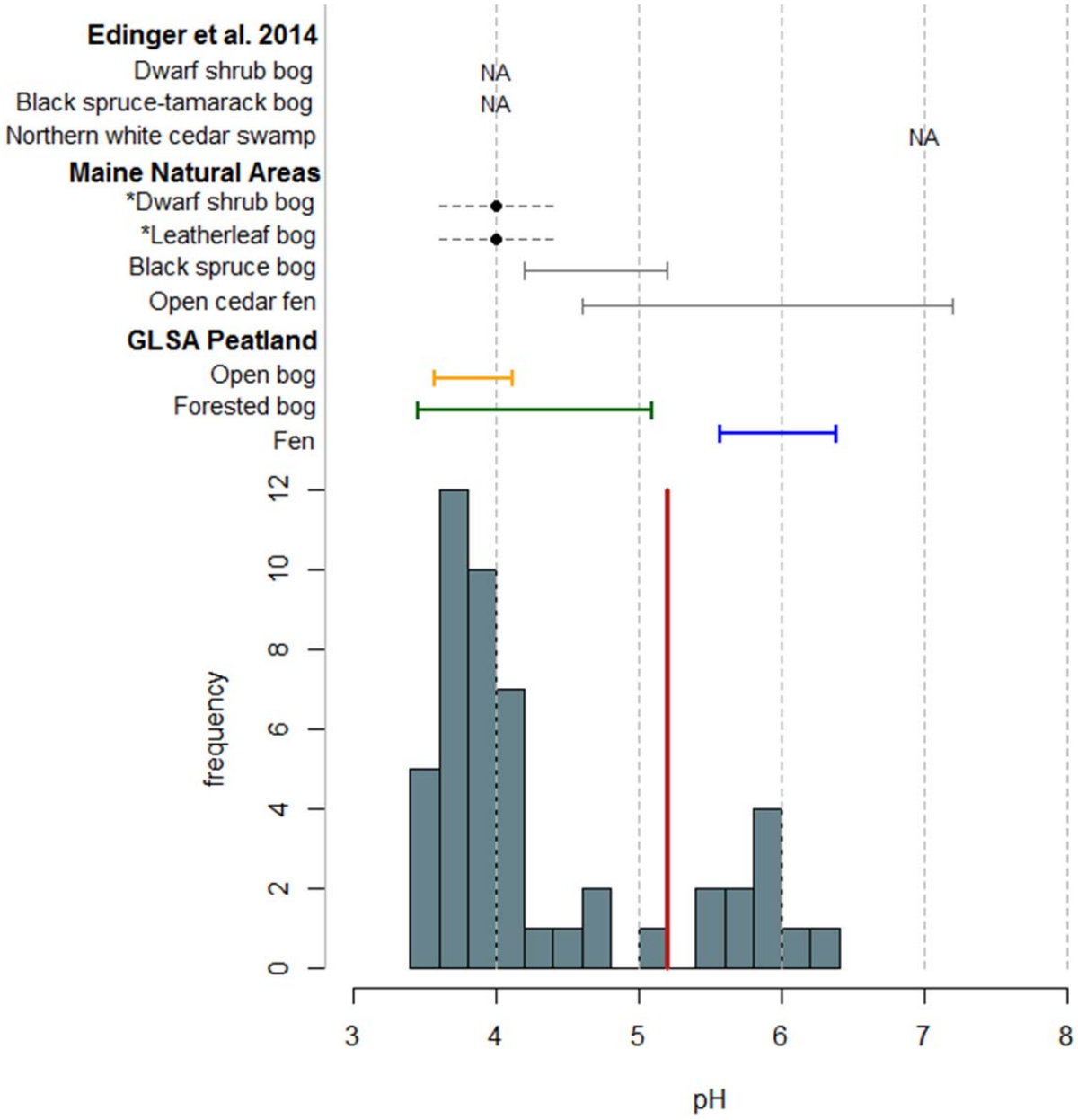

Figure 10: Frequency distribution of pH values at the GLSA peatland complex and reported range of pH values of other northeastern peatland ecological community classifications. * indicates mean or estimated mean values reported.

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Appendix A: Plant species frequency and mean (se) percent cover in communities of the GLSA peatland complex. Species are ordered by plot frequency across all data. † indicates a bryophyte not included in the NMS ordination. * indicates vascular plant species not included in the NMS ordination because plot frequency ≤4%.

Species	Fen		Forested Bog		Open Bog	
	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover
†*Sphagnum* spp. L.	86	41.7 (10.11)	91	56.9 (7.04)	99	76.8 (4.57)
Picea mariana (P. Mill) B.S.P.	1	15.5 (0.00)	41	15.5 (3.87)	77	40.7 (6.54)
Vaccinium myrtilloides Michx.	3	2.5 (0.00)	48	17 (4.03)	61	21.7 (3.85)
Carex trisperma Dewey	-	-	71	22 (4.98)	34	12.1 (3.03)
Maianthemum trifolium L.	17	8.6 (2.12)	35	14.4 (2.94)	60	11.2 (2.29)
Vaccinium oxycoccos L.	-	-	12	3 (0.59)	86	6.8 (1.94)
Rhododendron groenlandicum (Oeder) Kron & Judd	-	-	20	13.7 (3.14)	77	11.9 (2.46)
†*Pleurozium schreberi* (Brid.) Mitt.	5	7.7 (2.25)	65	19.8 (5.03)	28	18.9 (4.19)
Chamaedaphne calyculata (L.) Moench	-	-	5	12.2 (2.6)	73	13.1 (3.03)
Gaultheria hispidula (L.) Muhl. ex Bigel.	1	2.5 (0.00)	72	14.2 (3.46)	2	11.2 (1.68)
Kalmia polifolia Wang.	-	-	1	18.7 (4.02)	68	11 (3.08)
Kalmia angustifolia L.	2	15.5 (0.00)	34	8 (2.25)	25	7.1 (2.11)
Alnus incana (L.) Moench ssp. *rugosa* (DuRoi) R.T. Clausen	68	15 (4.59)	10	11.7 (3.13)	-	-
Viburnum nudum L. var. *cassinoides* (L.) Torrey & A. Gray	3	11.2 (2.37)	29	17.4 (3.77)	12	8.5 (2.95)
Eriophorum vaginatum L.	-	-	-	-	42	17.1 (3.51)
Cornus canadensis L.	1	15.5 (0.00)	37	9.4 (1.94)	3	2.5 (0.00)
Abies balsamea (L.) Mill.	13	6.2 (3.23)	30	21.5 (5.28)	-	-
Carex spp. L	20	7.5 (2.9)	1	2.5 (0.00)	23	14.3 (3.37)
Thalictrum pubescens Pursh.	61	14.1 (4.95)	-	-	-	-
Andromeda polifolia L. var. *glaucophylla* (Link) DC.	-	-	3	7.7 (1.59)	27	7.2 (1.87)
Carex echinata Murry ssp. *echinata*	57	28.9 (7.38)	-	-	-	-

Species	Fen		Forested Bog		Open Bog	
	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover
Rubus pubescens Raff. var. *pubescens*	57	8.6 (2.39)	-	-	-	-
Acer rubrum L. var. *rubrum*	8	4.1 (1.45)	22	6.3 (1.66)	2	2.5 (0.00)
Coptis trifolia (L.) Salisb.	2	2.5 (0.00)	21	9.3 (2.04)	6	9.2 (4.09)
Spiraea alba DuRoi. var. *latifolia*	47	19.5 (4.75)	-	-	-	-
Nemopanthus mucronatus (L.) Loesener ex Koehne	-	-	17	16.3 (3.83)	6	10.5 (2.49)
Thuja occidentalis L.	40	26.9 (7.79)	1	9 (2.06)	-	-
Calamagrostis canadensis (Michx.) P. Beauv. var. *canadensis*	39	7.6 (3.23)	-	-	-	-
†*Bazzania trilobata* (L.) A. Gray	-	-	18	12 (3.71)	1	#DIV/0!
Carex pauciflora Lightf.	-	-	-	-	18	6.2 (1.33)
†*Dicranum* spp. Hedw.	-	-	10	8 (2.52)	6	8.1 (2.5)
Dryopteris cristata (L.) A. Gray	29	7.4 (2.03)	-	-	-	-
Osmunda cinnamomea L.	10	8.7 (3.68)	8	32.8 (7.27)	-	-
Doellingeria cf. *umbellata* (P. Mill.) Nees.	21	6.2 (1.9)	1	9 (2.06)	-	-
Maianthemum spp. F.H. Wigg.	-	-	12	11.1 (2.73)	-	-
Hydrocotyle americana L.	22	4.7 (2.51)	-	-	-	-
Larix laricina (DuRoi.) Koch	-	-	9	9.1 (3.35)	3	9.6 (3.55)
Rubus hispidus L.	14	9.9 (2.11)	4	9 (1.55)	-	-
Glyceria canadensis (Michx.) Trin.	21	19.2 (6.52)	-	-	-	-
Lysimachia terrestris (L.) BSP.	20	6.9 (2.86)	-	-	-	-
†*Polytrichum* spp. Hedw.	-	-	8	5.8 (1.3)	1	26.8 (3.56)
Trientalis borealis Raf.	2	2.5 (0.00)	8	4.2 (1.02)	-	-
Brachyelytrum erectum (Schreb.) P. Beauv.	16	17.7 (4.81)	-	-	-	-
Cornus sericea L. ssp. *sericea*	16	21.3 (5.07)	-	-	-	-
Drosera rotundifolia L. var. *rotundifolia*	5	5.1 (1.84)	1	2.5 (0.00)	5	2.5 (0.00)
Dalibarda repens L.	8	5.8 (1.9)	3	6.8 (1.5)	1	15.5 (0.00)
Galium asprellum Michx.	15	5.7 (3.01)	-	-	-	-

Species	Fen		Forested Bog		Open Bog	
	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover
Lycopus uniflorus Michx.	15	6.8 (2.01)	-	-	-	-
Aronia melanocarpa (Michx.) Ell.	9	20.1 (4.56)	-	-	3	2.5 (0.00)
Betula alleghaniensis Britt.	-	-	7	17.2 (4.35)	-	-
Onoclea sensibilis L.	14	13.1 (3.87)	-	-	-	-
Clematis virginiana L.	13	6.5 (1.97)	-	-	-	-
†*Hylocomium splendens* (Hedw.) Schimp.	3	2.5 (0.00)	5	11.3 (2.55)	-	-
Triadenum spp. Raf.	13	3.5 (1.14)	-	-	-	-
Solidago spp. L.	12	6.5 (3.35)	-	-	-	-
Carex leptalea Wahlenb.	11	29 (9.18)	-	-	-	-
Eriophorum virginicum L.	-	-	1	2.5 (0.00)	5	12.1 (5.84)
Maianthemum canadense Desf.	1	2.5 (0.00)	4	2.5 (0.00)	2	2.5 (0.00)
Eriophorum spp. L.	-	-	-	-	5	25.5 (3.08)
Iris versicolor L.	10	28.1 (8.3)	-	-	-	-
Sorbus americana Marsh.	-	-	5	6.4 (1.4)	-	-
Carex disperma Dewey.	9	14.3 (5.61)	-	-	-	-
Thelypteris palustris Schott var. *pubescens*	9	6.8 (2.06)	-	-	-	-
Dennstaedtia punctilobula (Michx.) Moore	-	-	4	16.6 (4.44)	-	-
**Carex aquatalis* Wahlenb.	-	-	4	18.2 (3.29)	-	-
**Carex oligosperma* Michx.	-	-	-	-	4	9.9 (1.55)
Chelone glabra L.	7	2.5 (0.00)	-	-	-	-
Eutrochium maculatum (L.) E. Lamont var. *maculatum*	7	8.1 (2.2)	-	-	-	-
**Juncus pelocarpus* Meyer	7	28.2 (7.05)	-	-	-	-
Oxalis montana Raf.	-	-	4	4.4 (1.1)	-	-
Sarracenia purpurea L.	-	-	-	-	4	6.2 (1.42)
**Carex magellanica* Lam. ssp. *irrigua*	-	-	-	-	3	2.5 (0.00)
Glyceria striata Hitchc.	6	4.7 (1.68)	-	-	-	-
**Prunus virginiana* L.	5	7.7 (2.25)	-	-	-	-

Species	Fen		Forested Bog		Open Bog	
	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover
**Triadenum virginicum* (L.) Raf.	5	5.1 (1.84)	-	-	-	-
**Viola* spp.	1	2.5 (0.00)	2	5.8 (1.45)	-	-
**Huperzia* cf. *lucidula* (Michx.) Trevis.	-	-	2	17.6 (6.76)	-	-
**Polygonum* spp.	4	2.5 (0.00)	-	-	-	-
**Tiarella cordifolia* L.	4	2.5 (0.00)	-	-	-	-
Amelanchier cf. *bartramiana* (Tauch) Roemer	3	11.2 (2.37)	-	-	-	-
**Arisaema triphyllum* (L.) Schott ex Schott & Endl.	3	2.5 (0.00)	-	-	-	-
**Gaultheria procumbens* L.	-	-	2	11.2 (1.68)	-	-
**Spirea* spp. L.	-	-	2	6.8 (1.68)	-	-
**Viola cucullata* Ait.	3	2.5 (0.00)	-	-	-	-
**Aralia nudicaulis* L.	-	-	1	9 (2.06)	-	-
**Arceuthobium pusillum* C. Peck	-	-	1	2.5 (0.00)	-	-
**Carex canescens* L.	2	9 (2.91)	-	-	-	-
**Geum canadense* Jacq.	2	2.5 (0.00)	-	-	-	-
**Ilex verticillata* (L.) A. Gray	2	9 (2.91)	-	-	-	-
**Lycopus* spp. L.	-	-	1	2.5 (0.00)	-	-
**Platanthera blephariglottis* (Willd.) Lindl. var. *blephariglottis*	-	-	-	-	1	2.5 (0.00)
**Platanthera clavellata* (Michx.) Luer.	2	2.5 (0.00)	-	-	-	-
**Platanthera psycodes* (L.) Lindl.	2	15.5 (0.00)	-	-	-	-
**Senecio* spp. L.	2	2.5 (0.00)	-	-	-	-
**Acer pensylvanicum* L.	-	-	1	2.5 (0.00)	-	-
**Hypericum* spp. L.	1	2.5 (0.00)	-	-	-	-
**Prunus serotina* Ehrh.	-	-	1	2.5 (0.00)	-	-
**Rhynchospora* spp. Vahl.	-	-	-	-	1	15.5 (0.00)
**Rubus* spp. L.	1	2.5 (0.00)	-	-	-	-
**Sambucus nigra* L. *ssp. canadensis*	1	2.5 (0.00)	-	-	-	-

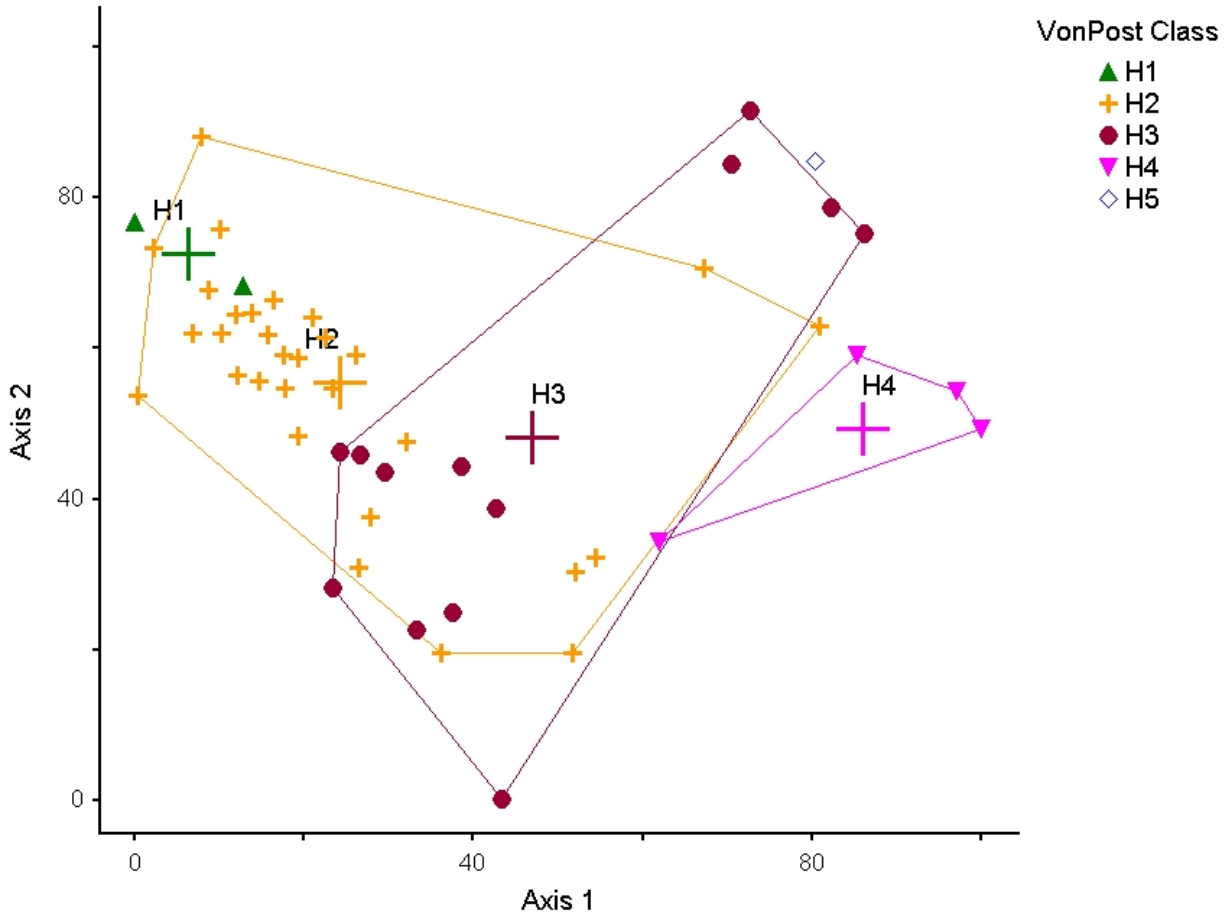
Species	Fen		Forested Bog		Open Bog	
	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover	Frequency %	Mean (se) Cover
**Triadenum fraseri* (Spach) Gleason	1	15.5 (0.00)	-	-	-	-
**Vaccinium macrocarpon* Ait.	-	-	1	2.5 (0.00)	-	-

Appendix B: MRPP results for testing the hypothesis of no difference between communities classified by pH and canopy openness.

```
****************** Multi-Response Permutation Procedures (MRPP)
******************
PC-ORD, 6.0
 3 Nov 2014, 11:43:35


GLSA_PLOT_MRPPcomm_20141102

        Groups were defined by values of: comm
        Input data has:      50 smplUnit by     59 response
        Weighting option: C(I) = n(I)/sum(n(I))
        Distance measure: Sorensen (Bray-Curtis)

     GROUP:     1
Identifier:     1
      Size:    20      0.63203927    = Average distance
Members:
 1        2        3        4        5        6        7        8
 9        11       12       13       14       15       20       21
 23       24       25       42

     GROUP:     2
Identifier:     2
      Size:    20      0.46671649    = Average distance
Members:
 10       16       17       18       19       22       31       32
 33       34       35       36       37       38       39       40
 41       43       44       45

     GROUP:     3
Identifier:     3
      Size:    10      0.65208351    = Average distance
Members:
 26       27       28       29       30       46       47       48
 49       50

        Test statistic: T =      -26.199158
           Observed delta =      0.56991901
           Expected delta =      0.74519370
        Variance of delta =      0.44757288E-04
        Skewness of delta =      -1.1356313

        Chance-corrected within-group agreement, A =    0.23520689
          A = 1 - (observed delta/expected delta)
          Amax = 1 when all items are identical within groups (delta=0)
          A = 0 when heterogeneity within groups equals expectation by chance
          A < 0 with more heterogeneity within groups than expected by chance

        Probability of a smaller or equal delta, p =    0.00000000


-------------------------------------------------------------------
PAIRWISE COMPARISONS
```

```
Note: p values not corrected for multiple comparisons.

      Groups (identifiers)
       Compared             T             A             p
       1  vs.      2    -18.79009117    0.15131314    0.00000000
       1  vs.      3    -16.23808050    0.16855048    0.00000001
       2  vs.      3    -18.57873552    0.26287441    0.00000001
------------------------------------------------------------------

****************************** MRPP finished ******************************
```

Appendix C: Nonmetric multidimensional scaling of understory vegetation grouped by VonPost peat soil decomposition class and results of MRPP testing differences among groups.




```
****************** Multi-Response Permutation Procedures (MRPP)
*****************
PC-ORD, 6.0
 2 Nov 2014, 23:07:24


GLSA_PLOT_MRPPSOIL_20141102

        Identifiers for excluded groups:
                 5

        Groups were defined by values of: soil
        Input data has:      49 smpl Unit by     59 response
        Weighting option: C(I) = n(I)/sum(n(I))
        Distance measure: Sorensen (Bray-Curtis)

     GROUP:     1
Identifier:     3
```

```
      Size:    13      0.75665215    = Average distance
Members:
 1        2        4        8        9        11       12       13
 14       26       28       47       48

     GROUP:     2
Identifier:     2
      Size:    30      0.64580052    = Average distance
Members:
 3        5        6        10       15       16       18       19
 20       21       22       23       24       25       29       32
 33       34       35       36       37       38       39       40
 41       42       43       44       45       49

     GROUP:     3
Identifier:     4
      Size:     4      0.69406197    = Average distance
Members:
 7        27       30       50

     GROUP:     4
Identifier:     1
      Size:     2      0.46600735    = Average distance
Members:
 17       31

        Test statistic: T =      -7.1243036
           Observed delta =      0.67181135
           Expected delta =      0.73893258
        Variance of delta =      0.88763598E-04
        Skewness of delta =     -0.69401033

        Chance-corrected within-group agreement, A =    0.09083538
          A = 1 - (observed delta/expected delta)
          Amax = 1 when all items are identical within groups (delta=0)
          A = 0 when heterogeneity within groups equals expectation by chance
          A < 0 with more heterogeneity within groups than expected by chance

        Probability of a smaller or equal delta, p =    0.00000195


-----------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

      Groups (identifiers)
       Compared             T             A             p
       3  vs.      2     -6.36491960    0.04458162    0.00024872
       3  vs.      4     -2.93613484    0.06131760    0.01602543
       3  vs.      1     -3.10433331    0.08463827    0.01222768
       2  vs.      4     -7.57362782    0.07727545    0.00004515
       2  vs.      1     -0.71452944    0.00902669    0.20869574
       4  vs.      1     -2.72667074    0.26106440    0.01800845
-----------------------------------------------------------------

****************************** MRPP finished ******************************
 2 Nov 2014, 23:07:24
```

Appendix D: Estimation of volume of standing and dead wood for comparison with Tremblay et al. 2009.To obtain an estimation of volume of standing dead and recently downed wood I selected all dead trees from plots classified as forested bog. I did not measure heights of individual trees but I did measure representative canopy height at each plot. I calculated volume of standing wood per ha by substituting representative canopy height for height (h) in the formula for the volume of a cone:

$$\pi r^2 \cdot h/3$$

and the volume of a cylinder:

$$\pi r^2 \cdot h$$

Where r= DBH/2.

To this value I added the volume of downed CWD ha^{-1} in decay class 1 and 2 to obtain the estimate.

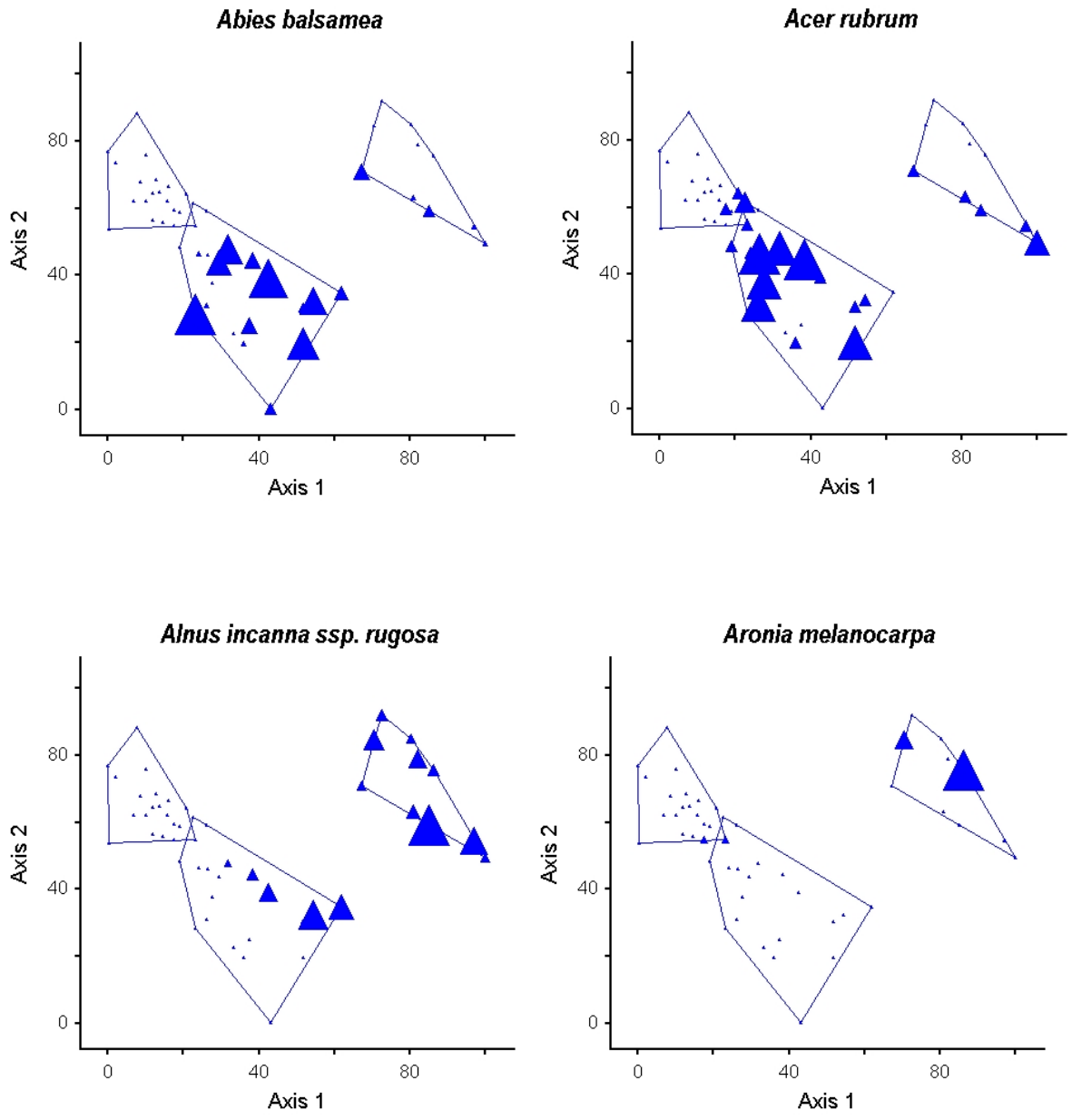
Using the equation for volume of a cone provides a low estimate of standing dead wood volume. Using the equation for volume of a cylinder provides a high estimate of standing dead wood volume.

Appendix E: Values for forest structure reported by Ross 2008 in a survey of spruce grouse habitat in the northwestern Adirondacks. Ross compared forest structure of peatlands in areas with persistent, transient and extirpated populations of spruce grouse.

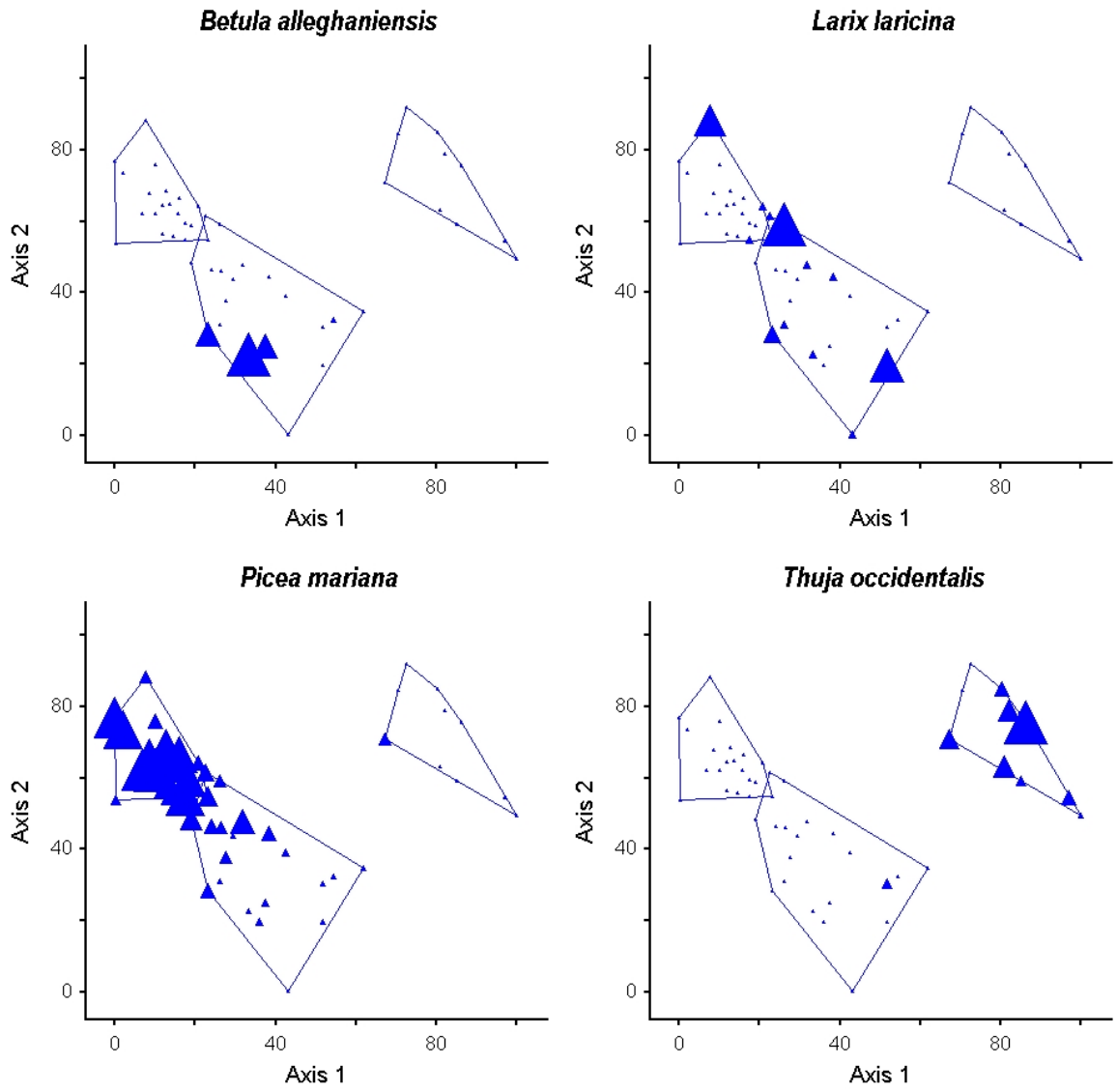
Variable	MEAN (SE) Ross (2008) Site Type			GLSA Values
	Persistent (n = 67)	Transient (n = 32)	Extirpated (n = 100)	
Tree DBH (cm)	13.64 (0.40)	14.89 (0.59)	15.54 (0.33)	15.2 (0.68)
Tree Height (m)	11.21 (0.23) [a]	12.09 (0.34) [ab]	12.52 (0.30) [b]	11.1 (1.22)
Tree Age (years)	45.24 (1.28) [a]	45.98 (2.22) [a]	52.98 (1.64) [b]	66.3 (2.93)
Tree Density (trees/ha)	1154.24 (1.08)	1313.39 (1.13)	1102.26 (1.07)	1270.6 (206.46)
Sapling DBH (cm)	5.06 (0.13)	5.63 (0.18)	5.30 (0.14)	NA
Sapling Height (m)	4.86 (0.18) [a]	6.17 (0.34) [b]	5.24 (0.23) [a]	NA
Sapling Density (sap/ha)	1687.44 (1.11) [a]	922.38 (1.26) [b]	1192.98 (1.11) [ab]	NA
Percent Canopy	61.47 (1.97)	65.84 (2.93)	66.07 (2.00)	79.1 (1.16)

Appendix F: NMS graph results by species. Point locations are sample units (i.e., plots). Point size is based on species mean cover per plot. See Table 1 for correlation matrix of NMS and Figure 3 for grouping variables. Graphs are grouped by trees, tall shrubs, shrubs, and herbs and are ordered alphabetically therein.

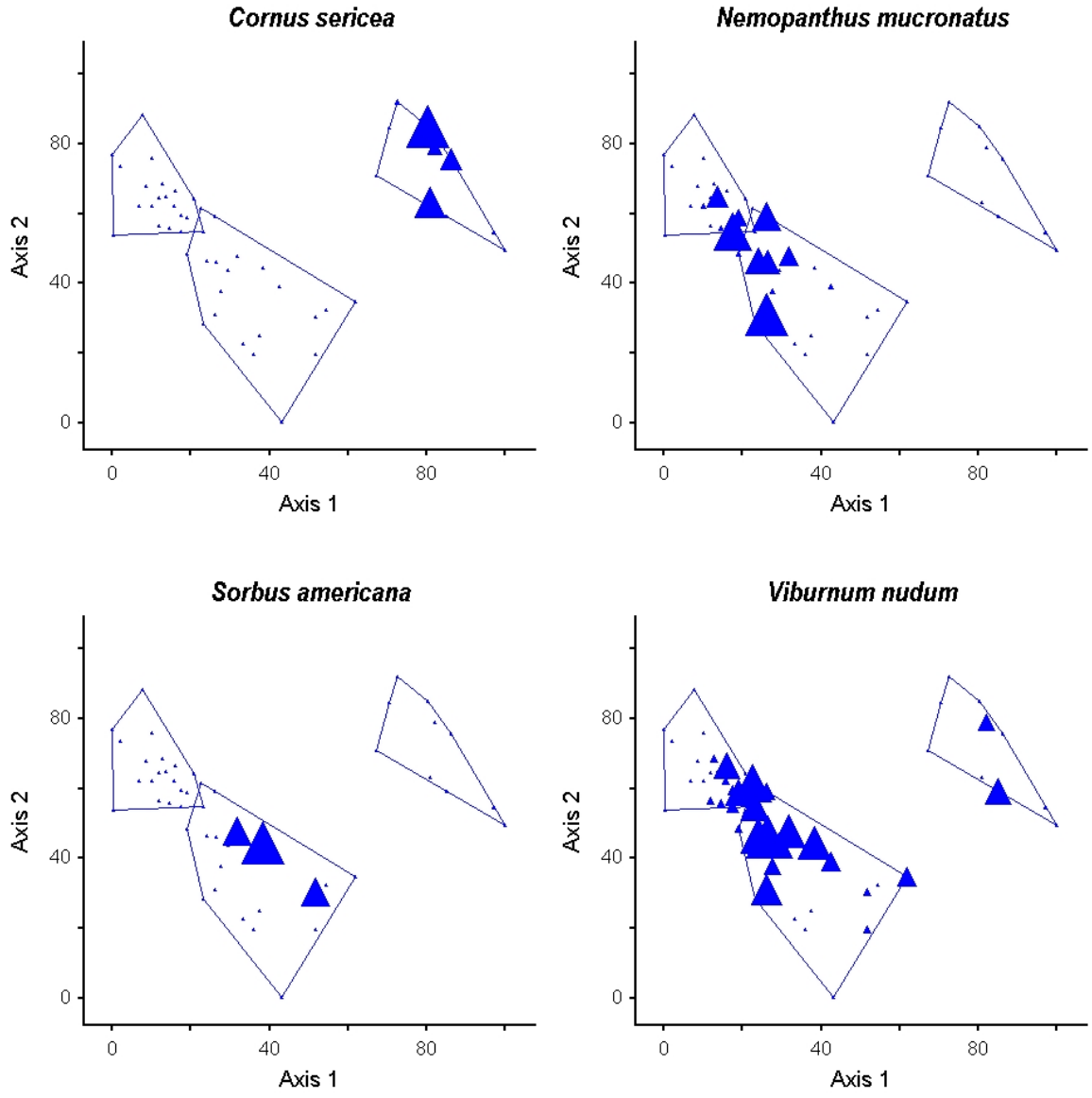
Trees:



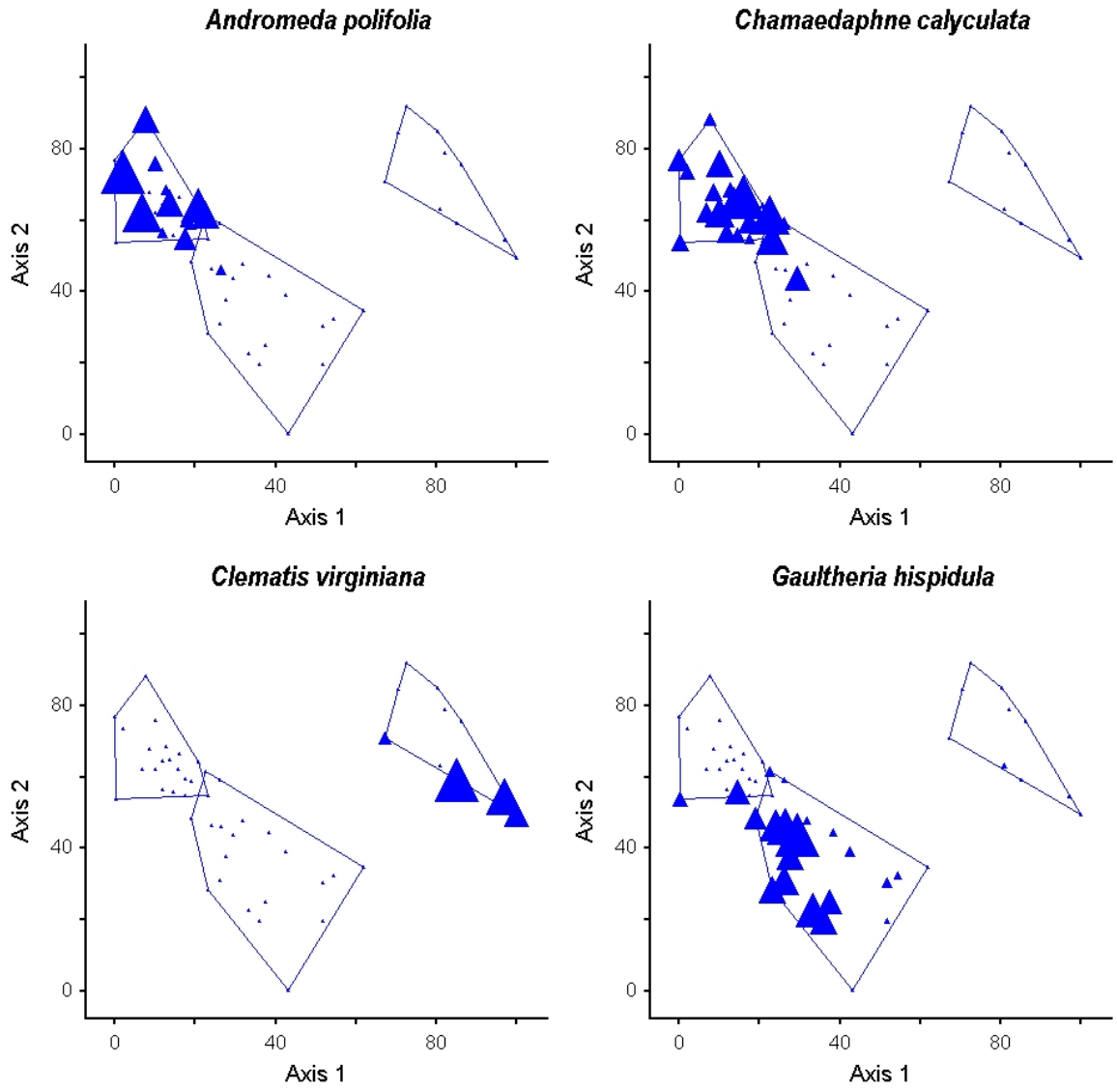
Appendix F, trees (cont.):



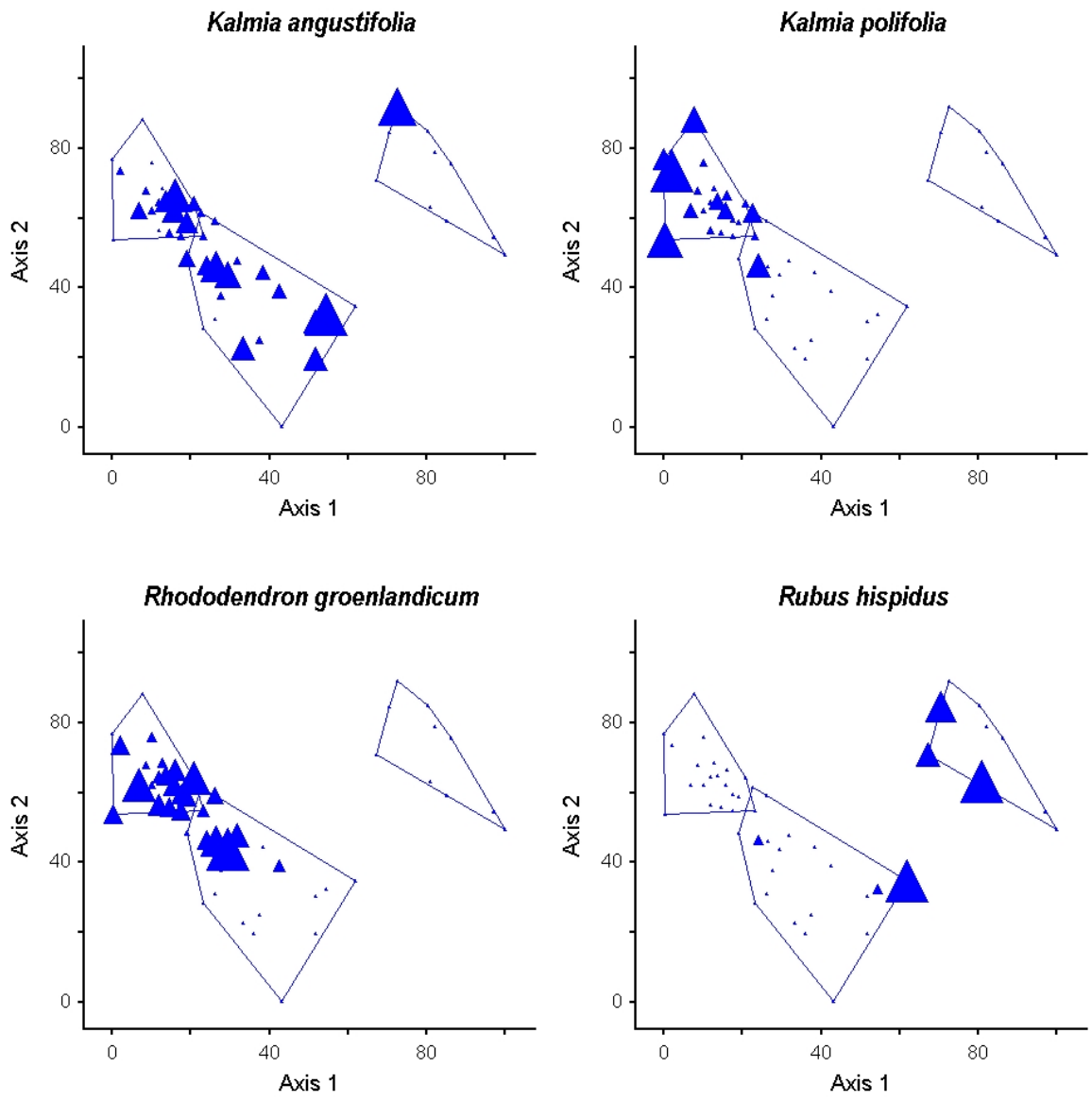
Appendix F, tall shrubs (cont.):



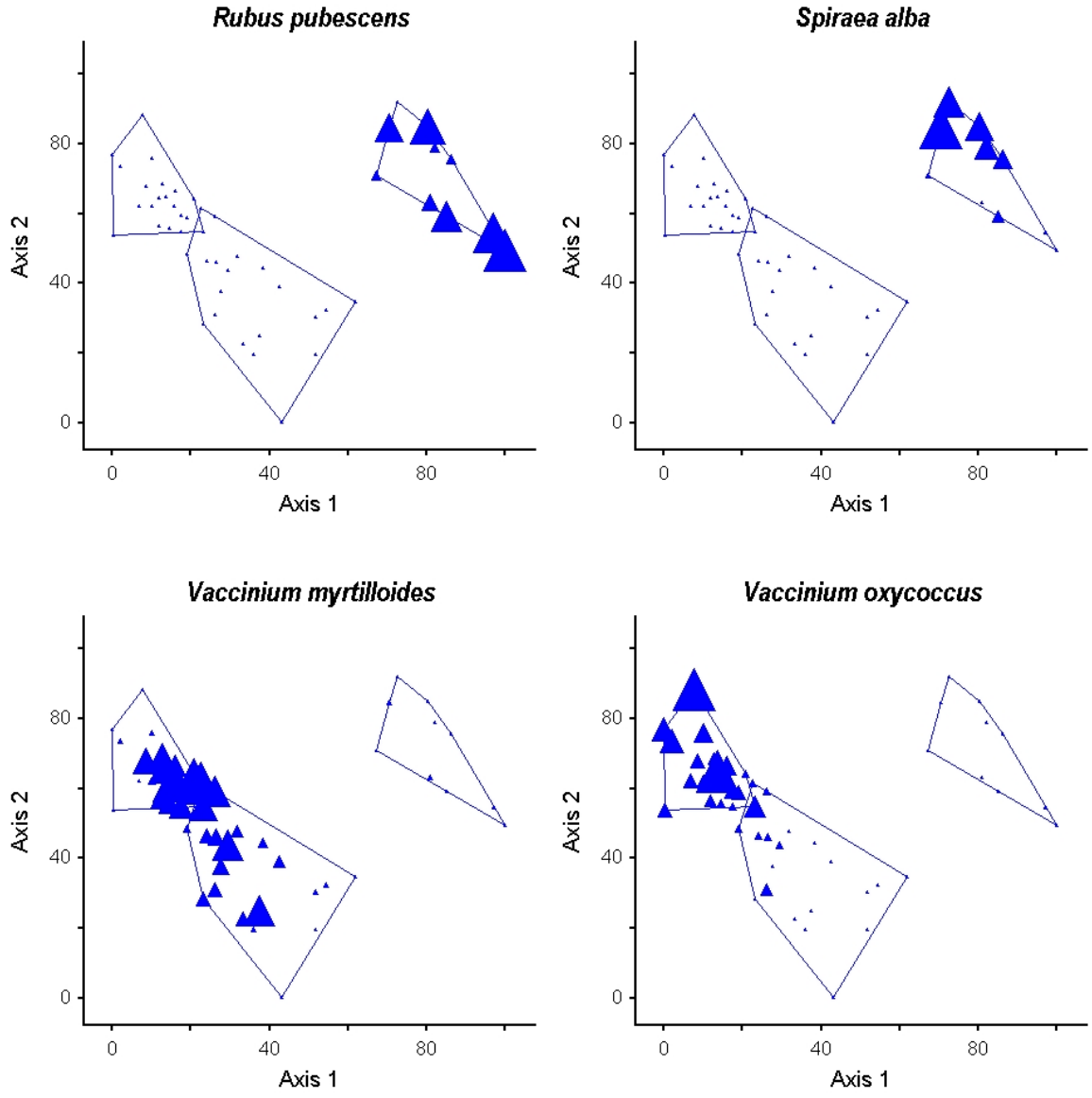
Appendix F, short shrubs (cont.):



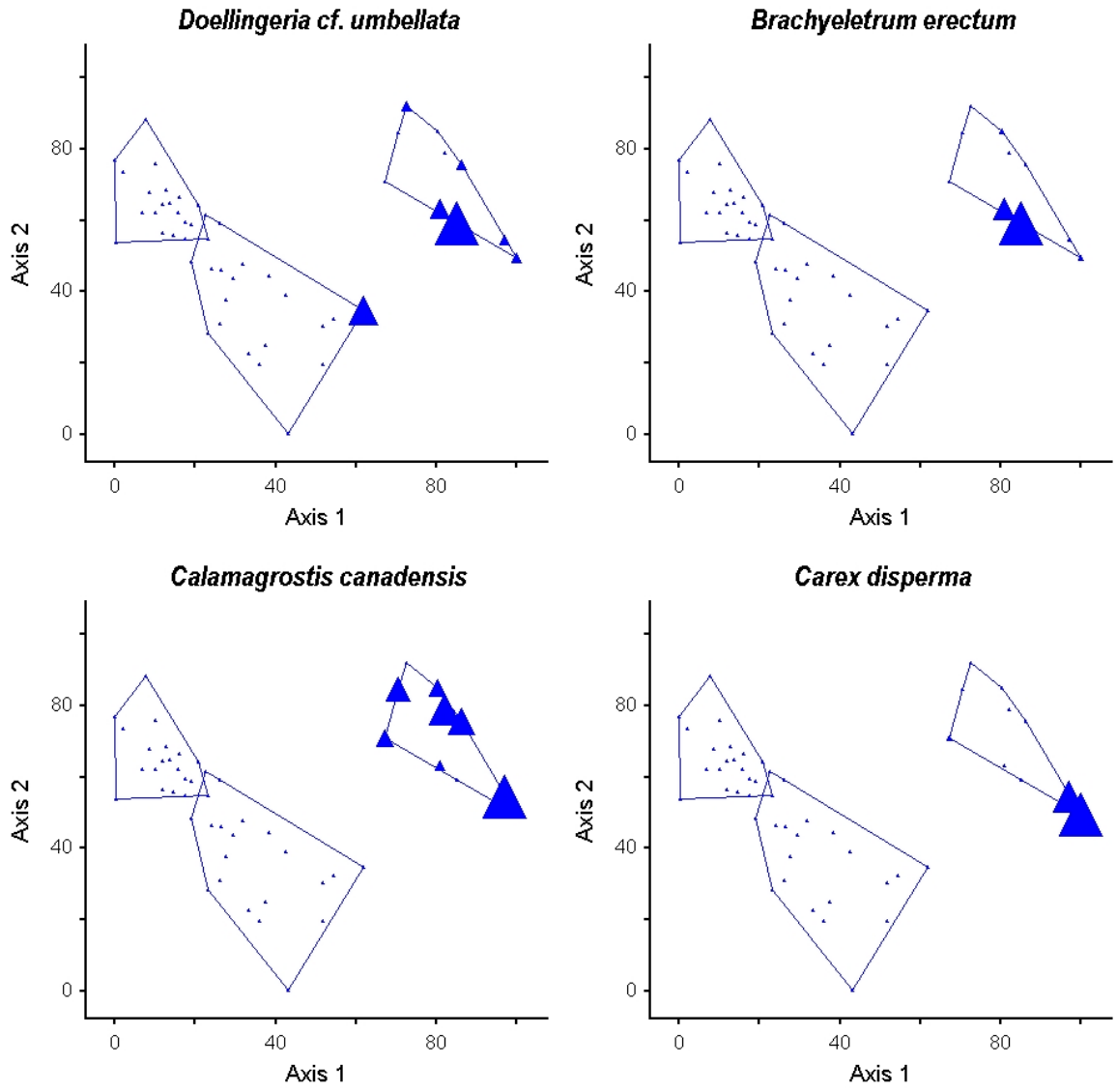
Appendix F, short shrubs (cont.):



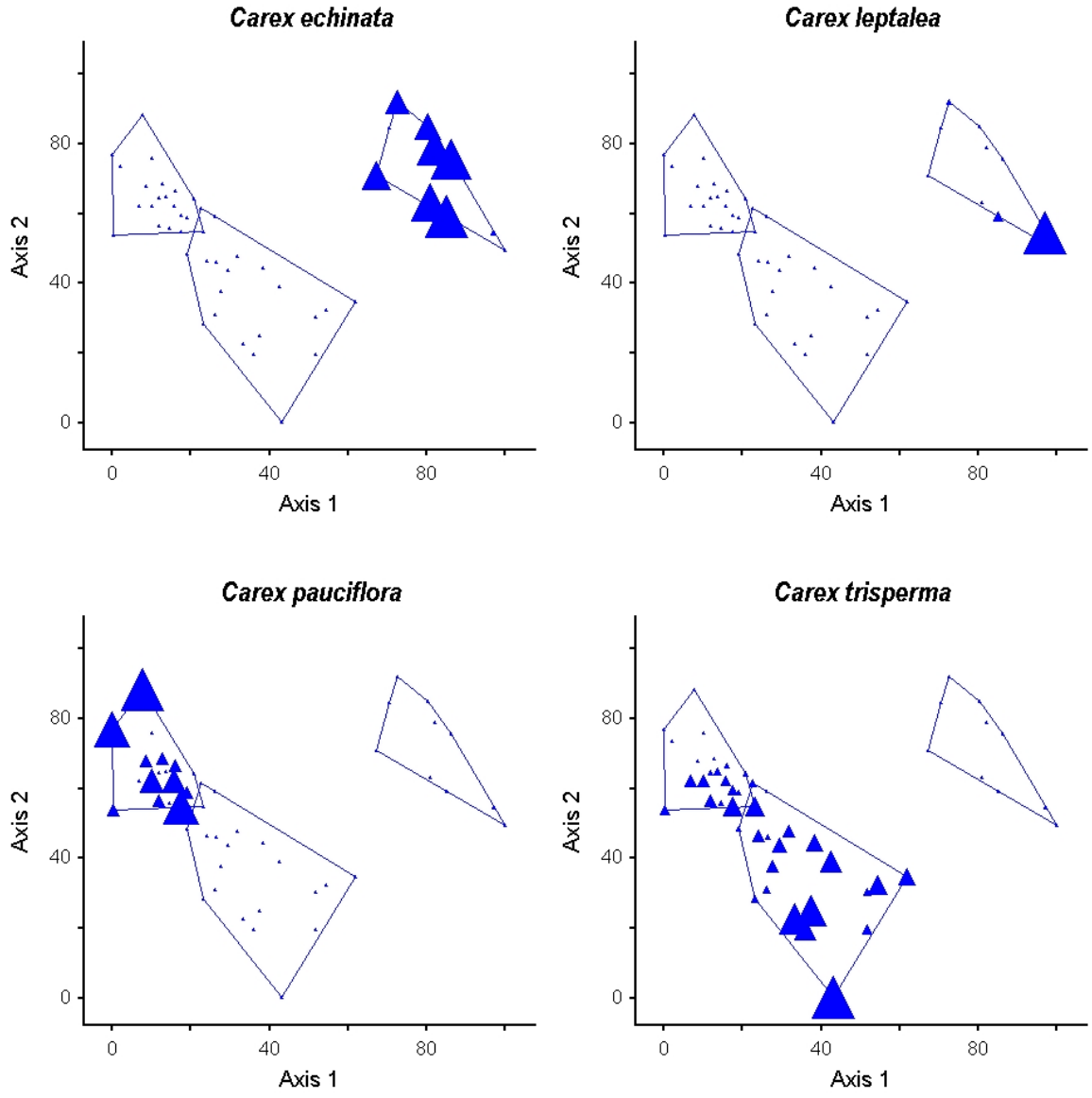
Appendix F, short shrubs (cont.):



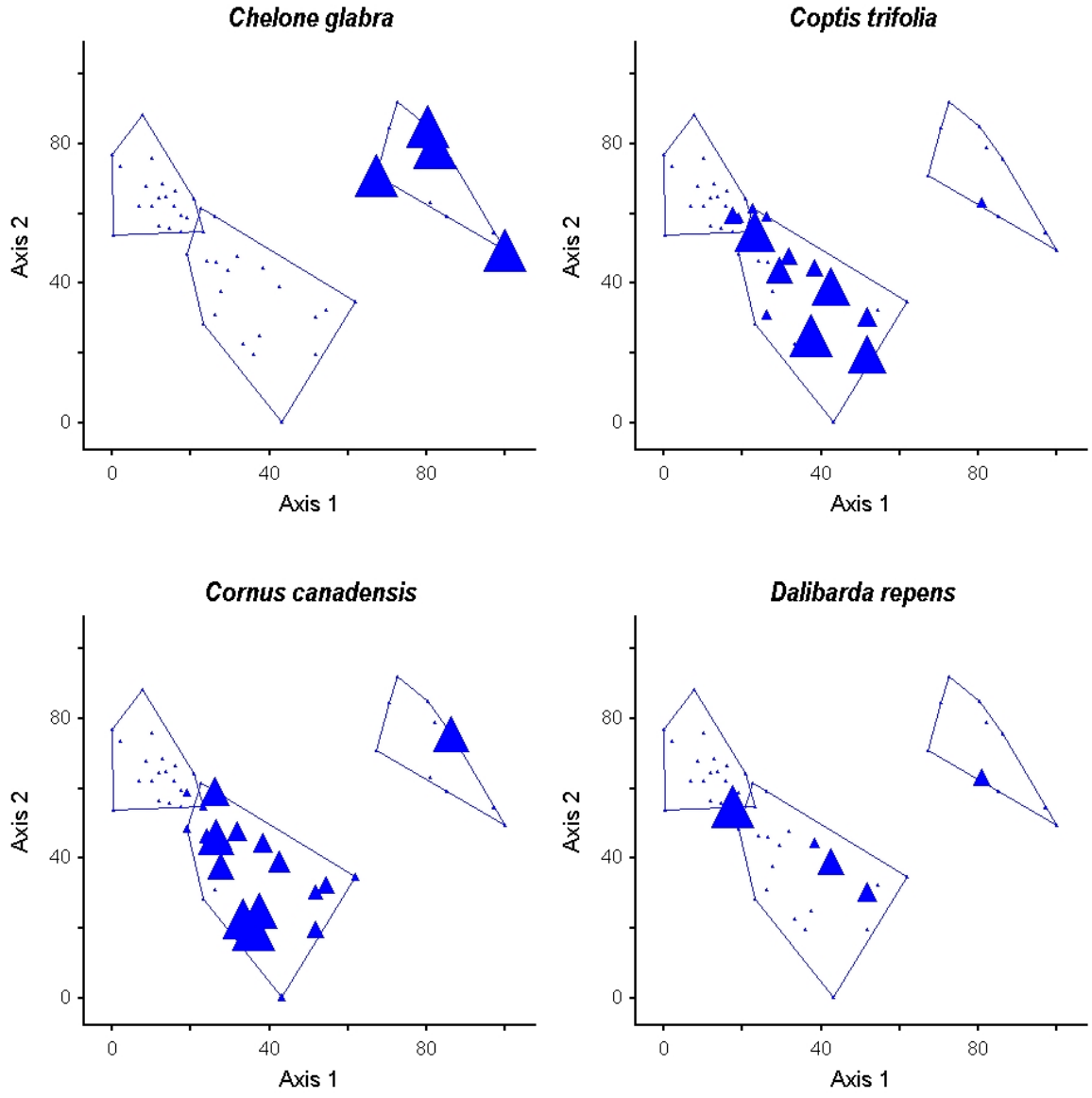
Appendix F, herbs (cont.):



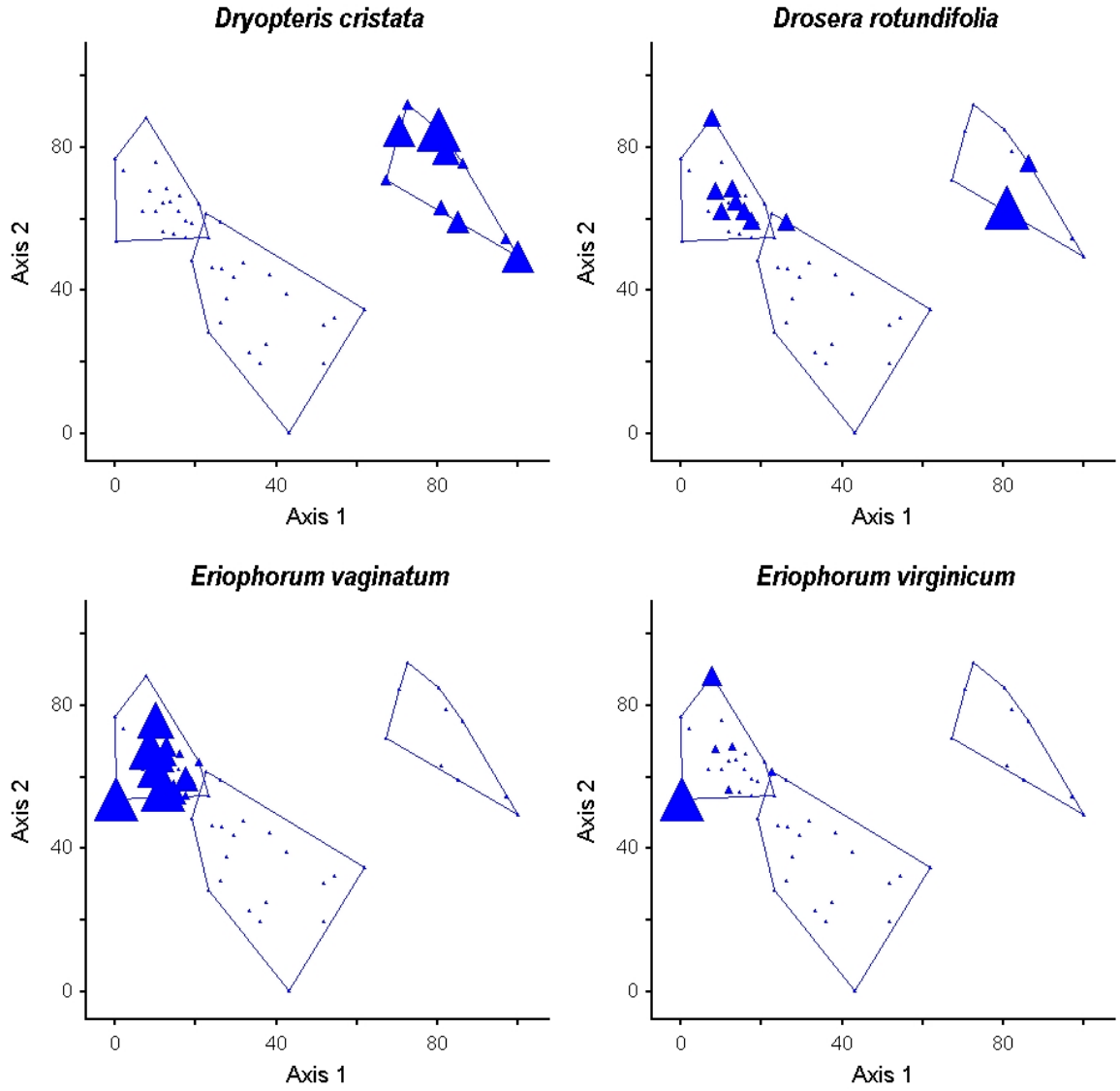
Appendix F, herbs (cont.):



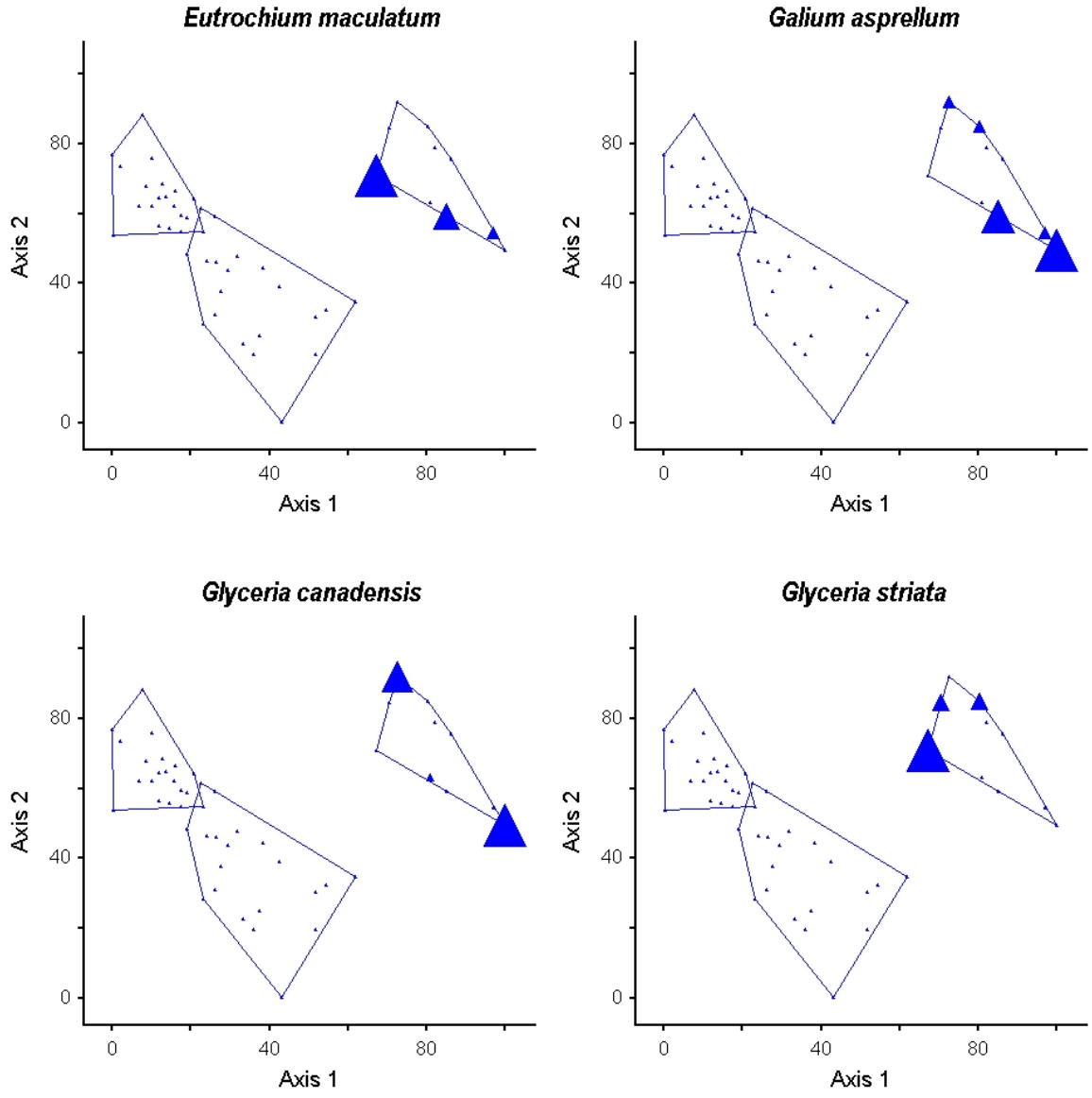
Appendix F, herbs (cont.):



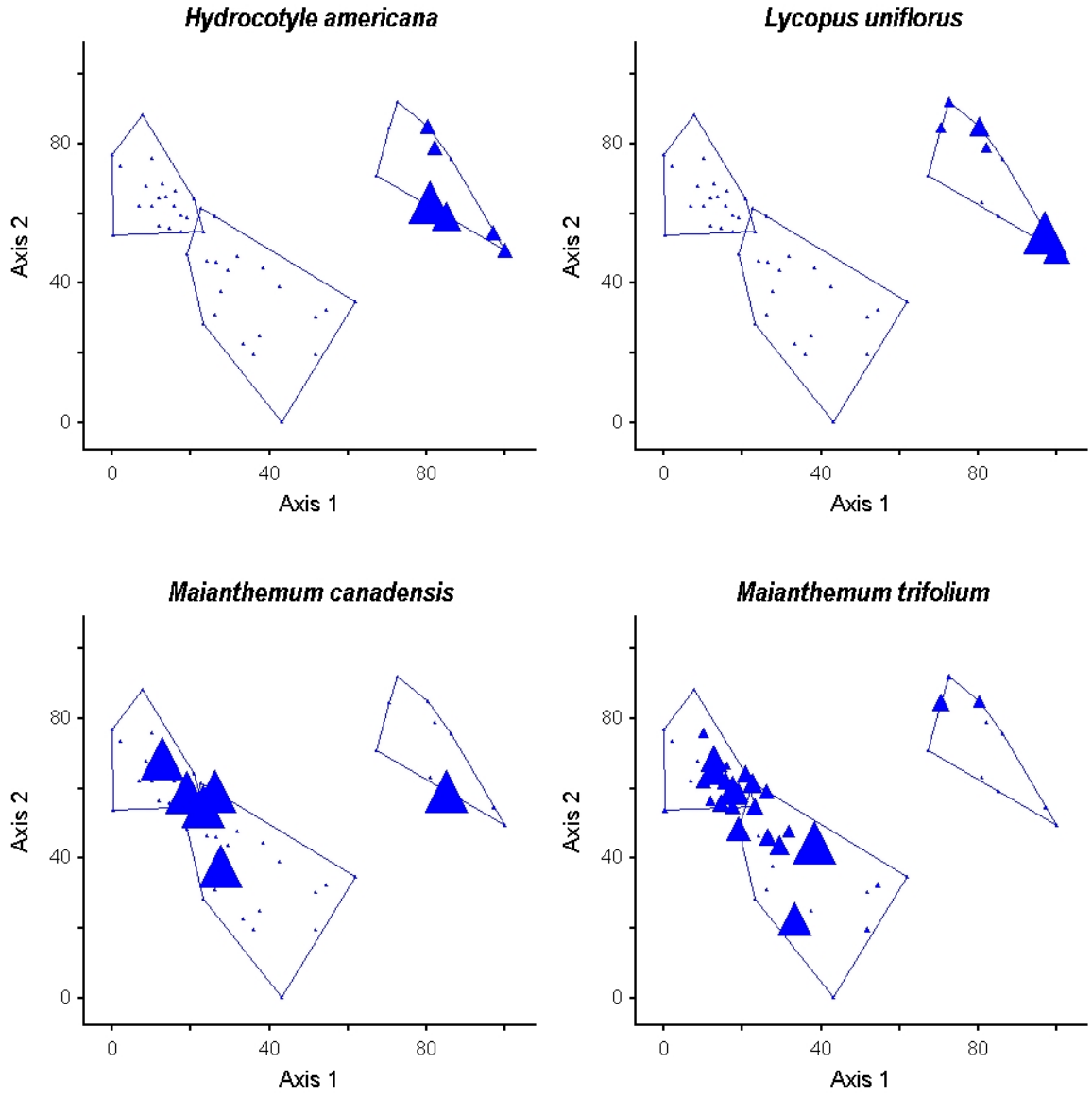
Appendix F, herbs (cont.):



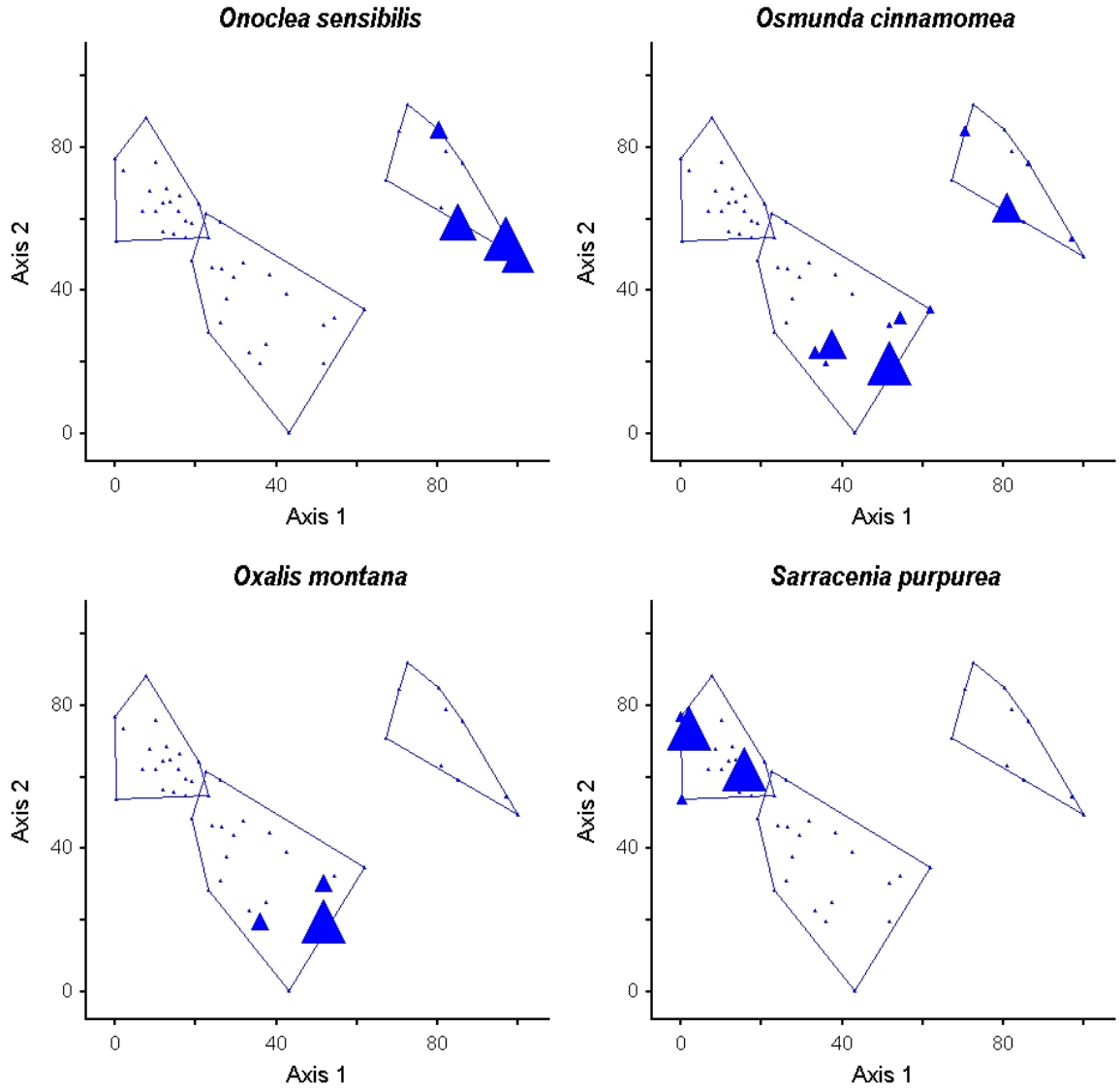
Appendix F, herbs (cont.):



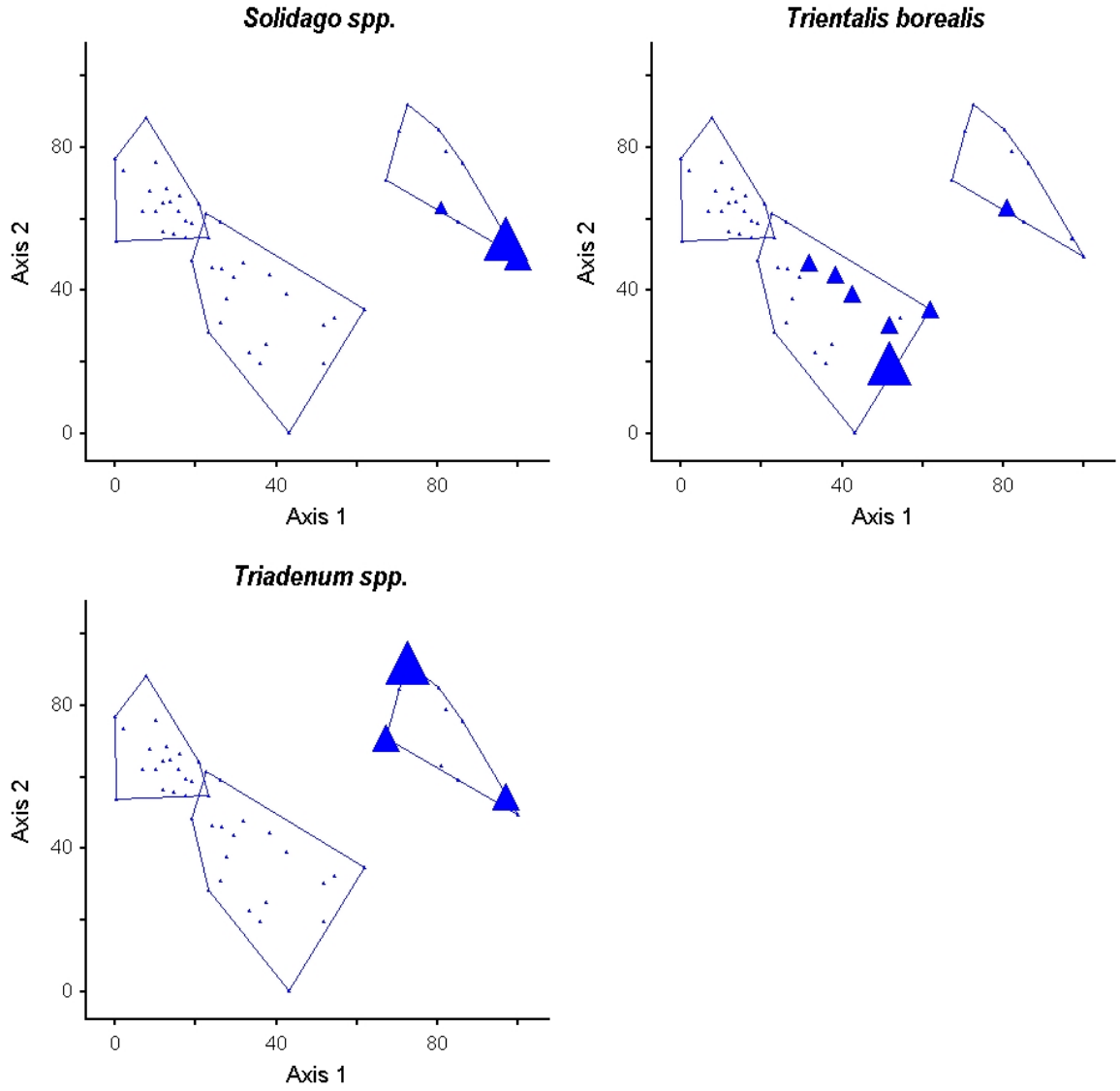
Appendix F, herbs (cont.):



Appendix F, herbs (cont.):



Appendix F, herbs (cont.):



Vita
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Education

Masters of Science Candidate, Ecology. SUNY ESF. Thesis: Vegetation composition and structure of a large boreal peatland complex in the Adirondacks of New York. [Expected Graduation Date December, 2014.]

Bachelors of Science (ecology major, GIS minor) 2009, State University of New York College at Plattsburgh.

Bachelor of Arts (philosophy major, music minor) 1993 State University of New York College at Plattsburgh.

Work Experience

Twenty-three years of experience implementing and supporting conservation science and natural resource protection measures in the Adirondacks on public and private land for state and nonprofit organizations through education, research and resource management.

Employment History

US EPA Wetlands Program Development Grant Project Coordinator, 'Building a Monitoring Framework for Detecting Wetland Response to Climate Change in The Adirondack Park'; Phase I: July 2012-December 2014; Phase II April 2014 - present. New York State Adirondack Park Agency, Contractor.

- Coordination, development and implementation of a multi-partner federal scientific research project.

Supervisor: Ed Snizek (518) 891-4050

Project Manager; May 2009 – present. Shingle Shanty Preserve and Research Station

- Management and development of a 15,000 acre biological field research station.
- Development of management plan for this property based on an ecological assessment and inventory that included extensive botanical field work and interpretation of aerial photography for delineation of ecological communities.
- Grant writing, outreach and recruitment of research scientists.
- Collaboration with researchers and institutions for planning and implementation of field research and field biology courses.
- Field technician on a diverse field research projects.

Supervisor: Ross Whaley (518) 359-9631

Research Assistant; Spring 2009. Lake Champlain Research Institute

- Data management and support work related to an aquatic invertebrate research project.

Supervisor: Dr. Timothy Mihuc (518) 564-3039

Grass River Steward; Summer-Fall 2007 and 2008. Adirondack Park Invasive Plant Program

- Research, implementation and coordination of an aquatic invasive species eradication project (European frogbit – *Hydrocharis morsus-ranae*) on the Grasse River, St. Lawrence County, NY.
- Development of eradication guidelines and recommendations for other *H. morsus-ranae* eradication projects.

Supervisor: Hilary Smith (518) 891-2082

Community Trail Project Supervisor; Summer-Fall 2007 and 2008. Henry Uihlein and Mildred A.Uihlien Foundation Trust

- Planning, implementation and construction of a 2-mile community trail system for a private foundation including hiring and supervision of four person crew, payroll and budget; operation of heavy equipment.

Contact: James McKenna (518) 523-3061

Conservation Labor Supervisor/Interior Caretaker; 1999-2006. New York State Department of Environmental Conservation (NYSDEC), Bureau of Operations.

- Trail and facility maintenance, public education, enforcement of rules and regulations and search and rescue in back-country and front-country settings.
- Supervision of volunteers and employees on field projects.

Supervisor: A. Philip Johnstone (518) 897-1314

Assistant Forest Ranger; Summer 2004, Summers 1995-1998. NYSDEC Bureau of Public Protection

- Public education, enforcement of rules and regulations, and search and rescue in the High Peaks Wilderness Area of the Adirondacks.

Supervisor(s): Forest Ranger Lt. Brian C. Dubay, F.R. John Chambers, F. R. Ret. C. Peter Fish (518) 897-1300

Training and certifications

- GIS (ESRI ArcGIS 3.2 - 10.2, spatial analyst, ERDAS stereo analyst, ArcPad), Microsoft Office Suite, R statistical environment.
- Photogrammetry, air-photo interpretation.
- Avalanche safety and snow science (40hrs)
- Chainsaw safety and operations (N.Y.S. Dept. of Labor/O.S.H.A Logging Standard.)
- F.C.C. licensed Extra Class amateur radio operator and volunteer examiner.
- S-130 wildfire training.

Grants received

- Northeast States Research Consortium grant award for development of baseline data for Shingle Shanty Preserve and Research Station (2010) $12,500.
- Northern New York Audubon grant award for Bird Surveys in Lowland Boreal Habitat at Shingle Shanty Preserve and Research Station, Long Lake, New York (2011, $1150; 2013,$1150; 2014, 1,000).

Awards

- Presidential Award for Student Excellence, SUNY Plattsburgh 2009.
- Lake Champlain Research Institute Undergraduate Research Award in Ecology, SUNY Plattsburgh 2009.
- Lake Champlain Research Institute Undergraduate Research Presentation Award, SUNY Plattsburgh 2009.

- New York Division of Women's National Farm and Garden Association Inc. Scholarship. 2008.

Presentations

- Developing a monitoring protocol to detect wetland response to climate change in the Adirondack Park. New York State Adirondack Park Agency Board Meeting, October 2013; Lake Champlain Basin Program Technical Committee, November 2013.
- Shingle Shanty Preserve and Research Station: An overview of goals and achievements. December 2011. Biolunch Seminar. New York State Museum, Albany, NY.
- Distribution of vegetation along gradients of light and microtopography in a wind disturbed peatland complex in the Adirondacks. MS Research. Eco-lunch seminar, Department of Environmental and Forest Biology, SUNY ESF. 2011, 2012, 2013.
- European Frogbit (*Hydrocharis morsus-ranae*) in the Adirondack / Lake Champlain Region: Reproductive Biology, Ecology, and Eradication. Christopher Martine, Sasha Dow-Kitson, and Stephen Langdon. 2011 Northeast Natural History Conference. Albany NY. [Co-author, not presenter].
- Eradication of the Aquatic Invasive European Frogbit (*Hydrocharis morsus-ranae)* from the Grass River Wild Forest, Adirondack Park, New York (poster), at Botany 2008: Botany without Boarders conference, Vancouver, B.C.

Published

- Assessment of Overnight User Behavior in the High Peaks Wilderness Area: Strategies for Trends Analysis, in *Proceedings of the 2003 Northeastern Recreation Research Symposium.* U.S.D.A. Forest Service General Technical Report NE-317.

Other

- Adirondack Botanical Society member.
- Composed and recorded soundtrack for the documentary film 'Through Paddle: A 720 Mile Journey on the Northern Forest Canoe Trail' Produced and Directed by Mike Lynch 2011.
- Musical arrangement for Nature Documentary "Plants are Cool Too" theme song and soundtrack Episode 1.
- Guitar class instructor for the Lake Placid Center for the Arts workshops 2008-2010.
- Self-Employed Musician – Extensive solo and ensemble performance and recording experience.