Ordination and Classification of Mesic Hardwood Forests at Pierce Cedar Creek Institute, Barry County, Michigan

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ABSTRACT

Essential to the preservation of natural areas is a thorough knowledge of the communities within the area. We examined 30 stands within the second-growth mesic hardwood forests at Pierce Cedar Creek Institute in order describe their vegetation patterns and associated environmental parameters. Within each stand, species composition data was obtained for six forest strata: overstory trees, understory trees, saplings, shrubs/vines, and ground vegetation (separating out herbaceous plants and tree seedlings). Environmental data, including the physical and chemical characteristics of the soil, topographic parameters, and disturbance history, were also collected for each stand. Total species composition, as well as species composition of each forest stratum, was analyzed with the environmental variables using cluster analysis and non-metric multidimensional scaling ordination. One hundred forty-two species were identified from the 30 forest stands. Species richness, evenness, Shannon's and Simpson's diversity indices all indicate that the Institute's hardwood forest is diverse. Cluster analysis of species composition data from the 30 stands identified 4 groups which corresponded to 4 community types. Ordination indicated the individual stands were correlated with three important environmental gradients: a soil pH-nutrient gradient, a soil-texture and slope gradient, and a soil moisture gradient. We describe the vegetation and environmental patterns of the 4 community types providing the baseline data that will be useful in the management of the mesic hardwood forests.

INTRODUCTION

A primary goal of conservation organizations, such as that of Pierce Cedar Creek Institute, is the preservation of communities within a given natural area. Essential to this goal is the management of the preserved land, and a first step to management is a thorough knowledge of the communities that are present in the area to be preserved. The Institute has classified approximately 45% of their 661 acre property as upland forest. The remainder of the property is classified as wetland (43%), upland field and constructed prairie (10%), and open water (2%) (Howell 2010).

Mesic hardwood forests (upland forests) are typically characterized by a continuous, often dense, canopy of deciduous trees. In southern Michigan, *Acer saccharum* (sugar maple) and *Fagus grandifolia* (beech) dominate the mesic hardwood forest, but other canopy trees including northern red oak, American and slippery elm, white ash, shagbark hickory, black walnut, bitternut hickory, and tulip tree are also present (Sargent and Carter 1999). Most mesic hardwood forests have five distinct strata: overstory trees, understory trees, saplings, shrubs/vines, and ground vegetation (including herbaceous plants and tree seedlings).

A field biologist can delimit broad community types such as fen, old field, and mesic hardwood forest by their dominant vegetation, but within these community types there is variation in both vegetation patterns and the physical environment. Accurate identification of these patterns within the broad community type requires the use of a quantitative and statistical approach (Bray and Curtis 1957). Multivariate analysis, or ordination, is a tool widely used by community ecologists to examine the relationships between vegetation patterns and the physical environment (Peet 1980; Gauch 1982; McCune and Grace 2002; Peck 2010).

Investigating community structure typically involves both measuring the dominance of a species within a sample (stand) and attributes of the sample's physical environment. Then the species and environmental data for the samples are analyzed by either direct gradient analysis or indirect gradient analysis methods. With direct gradient analysis the ordination axes are derived from environmental data and then the species data is correlated to the ordination axes (Palmer 2012). The problem with this method is that the researcher must prejudge which environmental variables are the most significant in determining vegetation patterns (Beals 1984). This can lead to important patterns in the plant community data being missed because the researcher did not measure a critical environmental variable. Therefore, direct gradient analysis is most appropriately used when the researcher's goal is to learn how species are distributed along specific gradients of interest (e.g. a moisture gradient or an elevation gradient) (McCune and Grace 2002). In contrast, with indirect gradient analysis the species data is used to derive the ordinations axes. The important environmental gradients are unknown *a priori* and are inferred from the species composition data by correlating the ordination axes with the measured environmental variables (Kent and Coker, 1992; McCune and Grace 2002; Peck 2010). In other words, the species themselves will indicate what environmental variables are important in determining the structure of the community.

Ordination is defined as the placement of entities as points in an abstract space based on a set of attributes so that the points form a constellation (Beals 1984). To the ecologist, the entities are samples (stands) and the attributes are species' values in those samples. Species' values may be expressed as density or basal area (either relative or absolute), percent cover, or importance values. When performing ordination methods based on indirect gradient analysis, a matrix of dissimilarity coefficients, a measure of distance between all pairs of samples, is derived from the measured species' values (McCune and Grace 2002; Peck 2010). The assumption is that the placement of samples (stands) in the constellation is not random but is determined by the species composition of the sample. The multivariate statistical techniques employed in ordination finds an axis which accounts for the greatest variation through the constellation of points. A second axis is then located orthogonal to the first and both are projected onto a graph. Depending on the data set, additional axes may also be projected in a three-dimensional space. Those plots which graph close together are similar in species composition; dissimilar plots will graph farther apart (Beals 1984; McCune and Grace 2002; Peck 2010). Therefore, ordination allows the community to be conceptualized in terms of the continuous patterns and gradient relationships that occur in nature (Gauch and Whittaker 1972). The use of ordination can provide the baseline data necessary to land managers seeking to understand the vegetation and environmental patterns within the communities they manage.

Our goal was to gather quantitative baseline data on the composition of forest stands at the Institute using cluster analysis and vegetation ordination to answer the following questions: 1) What are the vegetation patterns within the mesic hardwood forest at Pierce Cedar Creek Institute? 2) What environmental variables are associated with those vegetation patterns? And 3), Are the six strata (overstory, understory, sapling, seedlings, shrubs/vines, and herbaceous) linked in terms of their response to environmental variables? Our baseline data will provide the Institute with useful information for forest management. In addition, it will be useful for studying how the community composition of a mesic hardwood forest changes over short-term (5 – 6 year) successional periods. In light of the on-going loss of a major canopy tree, *Fraxinus americana* (white ash), information on the short-term dynamics of the forest could be critical for successful forest management.

MATERIALS AND METHODS

Study Area

Our study was located at Pierce Cedar Creek Institute in Barry County, Michigan, USA (T2N R8W S ½ sec 19). The property is approximately 267 ha (4872 m^2) of which roughly 45% is second-growth mesic hardwood forest. The average annual rainfall in Barry Co. is 79.3 cm yr^{-1} (31.23 in), of which 60% occurs between the months of April and September, and 132.8 cm yr^{-1} (52.3 in) of snowfall (Thoen 1990). The average daily temperature is 8.83º C (47.9º F). During the winter months the average temperature is -4.1º C (24.6º F) with the average daily minimum being -8.6º C (16.5º F). During the summer months the average temperature is 20.8º C (69.5º F) with the average daily maximum being 27.8º C (82 º F). The bedrock underlying the soils of Barry Co. is dominated by shale and sandstone with some gypsum, limestone and dolomite mixed in. Overlying the bedrock is between 46 and 122 m (150 – 400 ft) of glacial drift from which the soils are formed. Due to the nature of the drift deposits, soil textures can vary greatly within a short distance. Excluding the various wetlands and areas surrounding Brewster Lake and Cedar Creek, the most predominant soil types at the Institute are Marlette loam, Perrinton loam, and Tekenick fine sandy loam. These soils are well-drained to somewhat poorly drained (Thoen 1990).

Sampling Sites

Thirty sites were selected for this study (Fig. 1). Each site was located within second-growth mesic hardwood forest from across the Institute's property, excluding the Little Grand Canyon property. Each site was devoid of any recent anthropogenic disturbance and located at least 100 m from open field to avoid edge effects. Within each site a NW corner point was located using a stratified random sampling technique, and a 0.1 ha (20 × 50m) stand was established by running 50m due East and 20 m South from the NW corner. The location of the four corners of each stand was recorded using a global positioning system (GPS) (Mobile Mapper, Thales Inc., France), and stand location data was entered into ArcMap 10.2 GIS system (Economic and Social Research Institute, Redlands, CA).

Stand Measurements

Vegetation data was collected from May to August during the summer of 2014. For each of the 30 stands, the species identity and diameter at breast height (DBH, 1.4 m above ground) was recorded for overstory trees (stems ≥ 10 cm DBH) and understory trees (2.5 cm ≤ stems < 10 cm DBH) within the 0.1 ha stand. Saplings (1 m tall < stems < 2.5 cm DBH) were tallied in each 0.1 ha stand and tree seedlings (stems less than 1 m in height) were tallied in four 25 m^2 subplots. Shrubs and vines were tallied in the same 20 m^2 subplots. All trees were marked after sampling to avoid resampling. Herbaceous species were visually estimated for percent cover in ten 1 m^2 subplots, using the cover class rating scale describe by Daubenmire (1959) where 0 – 5% cover is assigned to class 1, 6 – 25% is class 2, 26 – 50% is class 3, 51 – 75% is class 4, 76 – 95% is class 5 and 96 – 100% cover is assigned to class 6. Following Heubner et al. (2007) Importance Values (IV) for each species in each stratum was determined. For both overstory and understory tree species the IV was calculated using relative basal area and relative density. For the tree saplings, tree seedlings, and shrubs and vines, only relative density was used to calculate IV, while for herbs, percent cover was used. Species nomenclature followed Reznicek and Voss (2012).

Environmental data, including the physical and chemical characteristics of the soil, topographic parameters, and disturbance history was collected for each stand. Following Huebner et al. (2007), soil samples were collected from the top 10 cm at four locations in each

0.1 ha stand, air-dried, and mixed. The mixed soil samples from each of the 30 stands were analyzed for extractable calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), Nitrate-Nitrogen, and pH at the Michigan State University Soil and Plant Nutrient Laboratory. Particle size distribution, or soil texture, was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). In each of the 30 stands, soil percent moisture was determined at three locations (the midpoint and two ends of a centrally located 50 m transect through the 0.1 ha stand) using a Kelway® soil moisture meter (Kel Instruments Co. Inc., Wyckoff, NJ) and averaged for the stand. Slope (percent) and aspect were calculated using the GPS data points from each stand, a high resolution digital elevation model of the Institute's property, and the Zonal Statistics tool in ArcMap 10.2 GIS software.

Data Analysis

Shannon's diversity index [H'] (Shannon and Weaver 1949), Simpson's diversity index [D] (Simpson 1949), species richness (S), and evenness (E) were calculated for each sampled 0.1 ha stand using PC-ORD for Windows 6.0 (McCune and Mefford 2011). The program calculates these diversity measures as follows:

S = species richness = number of non-zero species in a sample of standard size

H' = Shannon's Diversity Index = $-\Sigma (P_i * \ln (P_i))$

D = Simpson's Diversity Index = $1 - \Sigma(P_i * P_i)$,

where P_i equals the importance probability in column i. Diversity was also calculated for individual forest strata. One-way Analysis of Variance (ANOVA) was performed to determine significant differences in diversity parameters between the forest strata. All ANOVAs were carried out via Analysis of Variance (ANOVA) Calculator One-Way ANOVA from Summary Data (Soper 2014).

In order to visualize the patterns within the forest stands on the basis of their species composition and for comparison of the within-stand strata and between-stand distribution, ordination was done using the Nonmetric Multidimensional Scaling (NMS) technique (Kruskal 1964; Mather 1976). NMS is an indirect gradient analysis method that ordinates based on ranked distances between sites, avoiding the assumption of data normality. “Stress” is used in NMS as a measure of departure from monotonicity in the relationship between the distance between stands in the original many-dimensional space and the distance in the reduced-dimensional ordination space. Analysis was done using PC-ORD (McCune and Mefford 2011).

Data was first entered into two matrices. A species matrix contained calculated importance values for tree overstory, understory, sapling, seedling, and shrub/vine strata, and percent cover values for the herbaceous stratum. To reduce noise in the data, species with fewer than 3 occurrences were deleted from the species matrix, thereby reducing the number of species from 142 to 90. Since species data was measured in different units, IV and percent cover, the data was relativized by maximum so that the quantity for each species is expressed as a proportion of maximum dominance. The second matrix contained stand environmental data and other stand parameters as described above.

An initial run was made using six-dimensional space (six axes), Sørensen distance, and 250 iterations. Plots of stress (a measure of goodness of fit) versus iteration were examined for instability and to find the lowest number of axes at which the reduction in stress gained by adding another axis was small. Monte Carlo simulation was run to determine if a similar final stress could have been obtained by chance. The stress obtained with the species data set was compared to the stress from 250 randomized versions (data shuffled within columns) of the data. A final run of 250 iterations was made using three axes, Sørensen distance, and a randomly selected starting configuration. Additional runs were performed using the same parameters but with randomly selected starting configurations, and the solutions were compared to the final run solution using a Mantel test and PC-ORD software. The Mantel test indicated that there was a strong association in the patterns of redundancy between the final solution and solutions obtained from these additional runs ($p = 0.000$), indicating that the final solution likely reflects true patterns in our data. Therefore the final solution was accepted for use in gradient analysis.

A Mantel test was used to evaluate association between the paired species matrix and matrix of stand environmental data and parameters. Individual species and stand environmental parameters were individually overlaid on the resulting ordination and the correlation between these variables and the ordination axes were examined. Pearson's correlation coefficient (r) and Kendall's rank correlation coefficient, tau (τ), was used to determine the non-parametric correlation of species and also environmental variables with ordination axes 1, 2, and 3 following Sokal and Rohlf (1995). Specifically, Kendall's tau measures the relationships between the ordination scores and the individual species or environmental variable. The relationships are reflected as the similarity of the orderings of the ranked species composition data or ranked environmental data with each ordination axis. If the two rankings were the same, tau would have a value of 1.0. If one ranking was the reverse of the other, then tau would have a value of -1.0 and if the two rankings were independent (the null hypothesis), then tau would be approximately zero. Pearson's correlation evaluates the linear relationship between species or environmental variables and the ordination axes.

Two cluster analyses were performed using PC-ORD software (McCune and Mefford 2011), one using Sørenson's distance measure with the Group Average linkage method and one using Euclidean distance with the Ward's linkage method. Group solutions were compared between the two methods for redundancy in pattern and then overlaid on the ordination.

RESULTS

Stand and Forest Strata Diversity

We report three measures of alpha diversity (within-stand diversity), species richness (S), Shannon's Index (*H'*), and Simpson's Index (D). We also report Evenness (E), a measure of the ratio of observed diversity to maximum diversity. The value of E ranges from 0 – 1, where 1 indicates that all species are equally abundant. Shannon's Index has its basis in information theory, so when considering diversity in the context of information theory, the higher the diversity, the more uncertainty there will be about which species will be sampled next from the community. The minimum value for H' is zero, obtained when the community has only one species. Therefore, if the community has a few dominant species and the other species are rare (even if there are many of them), H' approaches zero. Additionally, the method is sensitive to sample size (McCune and Grace 2002). Simpson's Index is based on probability theory and is the likelihood that two individuals chosen randomly from the community will be different species. This measure of diversity is affected very little by rare species and is relatively unaffected by sample size (McCune and Grace 2002). The value of D ranges from 0 (low diversity) to 1 – 1/S, where S is the number of species. Both Shannon's Index of diversity (H') and the Simpson's Index (D) take evenness and species richness into account.

We found 142 plant species among the 30 sampled 0.1 ha stands. Species richness values ranged from 19 to 46 species per stand with an average richness across all stands of 35.1 species (Table 1). Evenness values across all stands were found to be larger than 0.7, and evenness in

63% of the stands was greater than 0.8. The rankings of Shannon's diversity index and Simpson's diversity index were similar across the 30 stands. Both indices identified stand 3 as having the lowest diversity (H' = 2.108; D = 0.8496) and stand 17 as having the highest diversity (H' = 3.314; D = 0.9502) (Table 1). The average diversity across the 30 plots was H' = 2.886 and D = 0.9170; maximum Simpson's diversity for our dataset is D = 0.9930.

Species richness was compared between the six forest strata (Table 2). A one-way ANOVA indicated that there was significant difference between the six forest strata (p = 0.000) when they were compared as a group. However, when all possible pairs of strata were compared, the understory and the saplings were not statistically different in their species richness value. Evenness, Shannon's, and Simpson's diversity measures were each compared with one-way ANOVAs, and each was found to be significantly different across the six strata (p = 0.000). When Evenness was compared for all possible pairs of strata, the overstory and herbaceous, understory and sapling, and understory and seedling strata were not significantly different. Similarly, the overstory and shrub/vine, understory and sapling, and understory and seedling strata were not significantly different for Shannon's H'. The average of Simpson's index values across all plots by forest strata ranged from 0.2723 for saplings to 0.8359 for the herbaceous strata with a one-way ANOVA indicating significant difference across all strata and all possible pairs of strata (p = 0.000).

Gradient Analysis

Gradient analysis resulted in a three-dimensional solution representing the strongest compositional gradients (Fig. 2a). Final "stress" for the 3D solution was 12.79048, well below the recommended maximum of 20.00 (McCune and Grace 2002). The NMS ordination represented 84.9% of the variation in the dataset, with 58.8% loaded on axis 1, 15% loaded on axis 2, and 11.1% loaded on axis 3. Stands occupied different regions of species space along the axes based on their species composition. With reference to the tree overstory, Axis 1 was correlated with *Fagus grandifolia* (beech) to the right in ordination space (r =.768; τ = .496) and *Fraxinus americana* (white ash) to the left (r = -.541; τ = -.579). Because Axis 1 reflects the dominant trends in the species composition data and is strongly associated with these two species, we can infer that these species were most influential in shaping the gradient along axis 1 (Fig. 2a). The scatterplots below and to the left in Figures 2b and 2c show the relationship between the ordination score on the respective axis and the abundance response on the opposite axis. A simple regression line is drawn through the points, and Pearson's correlation coefficient (r) and Kendall's rank correlation coefficient (τ) characterize the strength of the correlation. Similar scatterplots were produce for all 90 species in our analysis, and species relationships with ordination axes were examined in light of their placement in ordination space. Similarly, axes 2 and 3 are correlated with the species that had the most influence in shaping the gradients along their respective axes. Axis 2 is positively correlated with *Ulmus rubra* (slippery elm; r =.428; τ = .297) and negatively correlated with *Acer rubrum* (red maple; r = -.574; τ = -.238) and *Populus grandidentata* (big-tooth aspen; r = -.506; τ = -.091), and axis 3 is positively correlated with *Acer rubrum* (r = .538; τ = .358) and negatively correlated with *Acer saccharum* (sugar maple; r = -.619; τ = -.432) for the tree overstory. All species from across the six forest strata showed various degrees of correlation with the various axes (data not shown).

Correlations with Environmental Parameters

The species composition of the 30 stands was closely related to several of our measured environmental parameters. Correlations between stand species composition and environmental parameters are visualized as vectors overlaid on the ordination (Fig. 3). The three ordination axes were correlated with stand aspect, slope, pH, potassium (K), calcium (Ca), magnesium (Mg), nitrate (NO_3^-), % silt, % sand, and % moisture (Table 3). Figure 3 shows vector overlays for the environmental variables that had correlation coefficients of 0.30 or greater with any axis. The strongest correlations between stand species composition and environmental parameters were, in declining order as follows: potassium (correlation with Axis 1, *r* = -.649), pH (*r* = -.638 with Axis 1), magnesium (*r* = -.576 with Axis 1), aspect (*r* = -.534 with Axis 2), slope (*r* = -.509 with Axis 2), % silt (*r* =.509 with axis 2), % sand (*r* = -.506 with axis 2), nitrate (*r* =.458 with Axis 2), % moisture (*r* =.438 with Axis 3), and calcium (*r* = -.422 with Axis 1). Nitrate is also correlated with Axis 1 but to a lesser degree than Axis 2 and calcium is correlated with Axis 1 but not as strongly as with Axis 2. Therefore, the vector lines for calcium and nitrate are intermediate between the two axes. Landform, aspect direction, and disturbance history were poorly correlated (*r* < 0.30) with all axes determined from species composition. Therefore, we can say that Axis 1 represents a nutrient-pH gradient, axis 2 a soil texture-slope gradient, and axis 3 a soil moisture gradient.

The tree species sampled from four forest strata had similar placements on the ordination. For example, *Fagus grandifolia* (beech) overstory, understory, sapling, and seedling strata were all positively correlated with the nutrient-pH gradient along Axis 1 (*r* = .768, .671, .502, and .511 respectively). *Fraxinius americana* (white ash) was also correlated, but negatively, with the nutrient-pH gradient for each of the tree strata (*r* = -.396, -.541, -.528, and -.748 respectively). Two shrubs, *Ribes cynosbati* (gooseberry) and *Rubus occidentalis* (black raspberry) were correlated with axis 1 (*r* = .409 and *r* = -.467 respectively). Two dominant herbs also responding along the nutrient-pH gradient were *Carex pensylvanica* (Pennsylvania sedge) with a strong positive correlation (*r* = .824) and *Geum canadense* (white avens) with a similarly strong, but negative, correlation (*r* = -.753). *Geum canadense* was also positively correlated with the soil texture-slope gradient (*r* = .486), and *Athyrium felix-femina* (lady-fern) was negatively correlated with the soil texture-slope gradient (*r* = -.525). The overstory trees *Acer saccharum* (sugar maple) and *Quercus rubra* (red oak) responded to the moisture gradient along axis 3 (*r* = -.619 and *r* = .538 respectively). Therefore, the species composition of the 30 stands and the placement of stands within the ordination can be explained in part by our measured environmental variables. It is likely that environmental parameters other than those measured here play a role in determining a species location in ordination space. Additionally, it appears that the six forest strata are responding similarly to the measured environmental parameters as species strongly correlated with each axis were found in the same stand.

Distribution of Species and Community Types (Cluster Groups) on the Ordination

The two different cluster analyses of the 30 forest stands (one using Sørenson's distance measure and one using Euclidian distance (Fig. 4) produced slightly different results but were convergent when 4 cluster groups were recognized. Cluster groups were generally comprised of stands that were of close physical proximity on the Institute's property (Fig.1). Table 1 gives the Importance Values (IV) of individual species by forest stratum and cluster group (community type), and the individual cluster groups are described below.

Stands in cluster groups were arranged in an ecologically interpretable pattern along the three axes of the NMS ordination (Fig. 5). Stands in groups 1 and 4 are separated from stands in groups 2 and 3 along ordination axis 1 (Fig. 5a), which accounts for the greatest variation in our dataset (58.8%). Axis 1 is correlated with the nutrient-pH gradient. Stands low on axis 1 (left) have higher nutrient and higher pH soils, while those high (right) on the axis have low nutrient and low pH soils. Stands in group 4 are independent of axis 1, being found midway along the axis, indicating that the nutrient-pH gradient is less important for this group than the others. Stands in group 4 are separated from stands in groups 1, 2, and 3 along axis 2, which is correlated with the soil texture-slope gradient and accounts for 15.0% of the variation in our dataset (Fig. 5b). Stands low on axis 2 (left) are associated with sloped topography and higher % sand soils while those stands high on axis 2 as less sloped and have higher % silt soils. Stands in groups 2 and 3 are separated from each other along axis 3 which accounted for 11.1% of the dataset variation and is correlated with the moisture gradient (Fig. 5c). Stands low on axis 3 (bottom) have higher % moisture than those high on the axis.

Cluster group 1 is comprised of six stands (Table 4; Fig. 5). These stands had *Acer saccharum* (sugar maple) and *Fagus grandifolia* (beech) as the leading dominants (species with highest IV) in the tree overstory. *Fagus grandifolia* (beech) was dominant in the tree understory and sapling strata while *Acer saccharum* was the dominant tree seedling. *Ostrya virginiana* (ironwood), typically considered an understory species, had achieved trunk diameters great enough to be categorized as an overstory tree in this group where it had a strong presence in both the overstory and understory (IV > 20.00 and >58.00, respectively). *Amphicarpeae bracteata* (hog-peanut) was the dominant vine and *Ribes cynosbati* (gooseberry) was the dominant shrub in this group. In the herbaceous stratum, *Carex pensylvanica* (pennsylvania sedge), *Circaea canadensis* (enchanters nightshade), *Galium circaezans* (licorice bedstraw), *Phryma leptostachya* (lopseed), *Geum canadense* (white avens), *Persicaria virginiana* (jumpseed),and *Viola pubescens* (dogfoot violet) were present in greater than 50% of the stands, and 20 of the 26 sampled herbaceous species were present in the group.

Nine of the ten stands of **cluster group 2** (Table 4; Fig. 5) had *Juglans nigra* (black walnut) and *Prunus serotina* (black cherry) as dominant overstory species (IV > 31.00). *Fraxinus* *americana* was also present in 9 of the 10 stands as an overstory tree but was not a dominant species (IV = 17.10), and *Carya ovata* (shagbark hickory) and *Ulmus rubra* (slippery elm) were present in 8 of the 10 stands but were less important (IV = 16.05 and 16.11 respectively). Interestingly, *Fraxinus americana* (white ash) was the dominant species in the tree understory, sapling, and seedling strata, where it was present in 6 of 10 stands for the understory stratum and all 10 stands in the sapling and seedling strata. *Rubus occidentalis* (black raspberry) was the dominant shrub and present in all stands. The herbaceous layer was well represented with 23 of our 26 sampled species being represent in this group. *Geum canadense* (white avens), *Parthenocissus quinquefolia* (virginia creeper), and *Persicaria virginiana* (jumpseed) were present in the herbaceous statum of all 10 stands in this group.

The eleven stands of **cluster group 3** (Table 4; Fig. 5) had *Quercus velutina* (black oak) as the dominant species (IV = 43.63). *Prunus serotina* (black cherry) and *Ulmus rubra* (slippery elm) were present in all eleven stands, and *Acer rubrum* (red maple) was present in ten of the eleven stands; each had an Importance Value > 25.00. Similar to group 2, *Fraxinus americana* (white ash) was present in the overstory for the majority of stands but with low importance . *Carya ovata* (shagbark hickory), *Ostrya virginiana* (ironwood), and *Ulmus rubra* (slippery elm) were dominant in the understory (IV > 30.00). Also similar to group 2, *Fraxinus americana* was dominant in the tree sapling and seedling strata. *Rosa multiflora* (multiflora rose) was dominant in the shrub/vine stratum (IV = 34.22), where it was present in all eleven stands of the group. The herbaceous stratum was dominated by the same species as in group 2 with the addition of *Viola sp*. (violet) as a dominant. Group 3 also had high diversity in the herbaceous statum with 23 of the 26 sampled species represented.

Cluster group 4 (Table 4; Fig. 5) consisted of only three stands. *Acer rubrum* (red maple) was the dominant overstory species (IV = 47.68) and was present in all three stands. *Populus grandidentata* (big-tooth aspen) and *Quercus rubra* (red oak) were also dominant in the overstory, but each was present in only two of the stands. *Acer rubrum* was dominant in the understory along with *Ostrya virginiana* (ironwood), which was also dominant in the sapling stratum. *Elaeagnus umbellata* (autumn olive) was the dominant shrub (IV = 41.38) but was present in only two of the three stands, while *Lindera benzoin* (spicebush) was well represented in all three stands. *Athyrium felix-femina* (lady-fern), *Carex pensylvanica* (pennsylvania sedge), and *Parthenocissus quinquefolia* (virginia-creeper) were present in the herbaceous layer of all three stands. The herbaceous layer of this group had lower diversity than the other three groups with only 14 of the 26 sampled species represented, and with most of those being present in only one of the three stands.

DISCUSSION

This study provided baseline data on the species composition of 30 stands positioned throughout the mesic hardwood forest at Pierce Cedar Creek Institute. We sought to answer the following questions: 1) What are the vegetation patterns within the mesic hardwood forest? 2) What environmental variables are associated with the forest vegetation patterns? And 3), Are the six forest strata (overstory, understory, sapling, seedlings, shrubs/vines, and herbaceous) linked in terms of their response to environmental variables? While the Institute has a relatively complete species inventory list for the hardwood forest, there has not been a specific study on the patterns of vegetation structure and their associated environmental parameters.

A total of 142 vascular plant species were identified from the 30 stands. Species richness averaged 35.1 species per $1000m^2$ stand indicating the Institute's forest is relatively diverse. By comparison, the forests on Mont St. Hilaire in southern Quebec, Canada (Gilbert and Lechowicz 2005) were found to average 24 vascular plant species per $50m^2$ stand, and diversity in two deciduous forests in Sweden were found to average 38.7 and 29.7 vascular plant species per $100m^2$ stand (Dupré et al. 2002).

In a literature review, Dupré et al. (2002) compiled data on 661 deciduous forests to evaluate the relationship between species richness and soil pH and nutrients. They found that soil pH and nitrogen were positively and more-or-less linearly correlated with species richness. While pH is not a nutrient, it reflects the general nutrient status of the soil because it affects the nitrification rate and the ability of plants to obtain soil nutrients. Gradient analyses of data from the 611 deciduous forests showed that ordination scores along the first axis (axis reflected the main floristic variation) was highly correlated to pH ($r^2 = 0.461$, $p < 0.001$) and nitrogen ($r^2 = 0.782$, $p < 0.001$). Our results appear to agree with Dupré et al. (2002) as pH, potassium, magnesium, and nitrogen were correlated with ordination axis 1. Nitrogen was also positively correlated with axis 2 as was calcium.

The optimum pH range for most plants is between 5.5 and 6.5 (Espinoza 2014). The pH across the 30 stands ranged from 4.4 – 6.3 with 17 of the stands falling within the optimum pH range. Of the 30 stands, stand 3 had the lowest species richness (19 species per $1000m^2$), the lowest pH (4.4), and nutrient (K, Mg, Ca, NO_3^--N) levels well below the normal range for all measured nutrients (Espinoza 2014). In contrast, stand 16 had a species richness value of 45 species per $1000m^2$. The soils of stand 16 had nutrient levels at the high end of the normal range and a pH of 6.5. Stand 11 also had a soil pH value at the high end of optimal (6.3) and nutrient levels at the high end of normal, but its species richness value was 36, which was near our average richness of 35.1 species per $1000m^2$. While our ordination axis 1 was strongly correlated with pH, K, Mg, and to a lesser degree NO_3^- and Ca, species richness did not follow this gradient in all stands. Our low pH and low nutrient stands generally had lower species richness, but stands with species richness above the average only sometimes had pH and nutrient levels at the high optimal range. This indicated that factors other than pH and nitrogen are involved in determining species richness.

As we moved through the Institute's forest, the spatial distribution of species across the 30 stands appeared to be homogeneous: most species seemed to have relatively high densities and uniform distribution. The homogeneous nature of the hardwood forest was confirmed by our Evenness values which were all greater than 0.716 (63% were greater than 0.8) on a scale of 0 – 1, where 1 indicates that all species are equally abundant. There was general agreement between the rankings of Shannon's diversity index and Simpson's diversity index across the 30 stands with both indicating relatively high diversity. It is likely that some forest species will have been missed by our sampling strategy. Therefore, the number of species found (142) must be regarded as the lower boundary of the number of species actually present in the forest community.

When species richness, evenness, and Shannon's index were compared between all possible pairs of forest strata, most strata were significantly different from each other, likely resulting from differences in growth requirements for individuals at different life stages or with different growth forms. For example, evenness was significantly lower in the overstory than the herbaceous layer although this may be a result of the recent loss of a large number of *Fraxinus americana* (white ash) from the tree overstory. Evenness was greater in the understory and significantly lower in the sapling and seedling strata. However, lower evenness of the sapling and seedling strata could be the result of our sampling strategy, which consisted of four 25m^2 subplots. Shannon's index (*H'*) also showed significantly lower diversity of saplings when compared to the understory. However, Shannon's index showed significantly higher diversity of seedlings as compared to the understory. This may be due to what appeared to be a higher than normal germination rate for tree seedlings (personal observation), which could be attributed to the heavy snow cover which persisted until late spring in 2014. There was no significant difference between strata when diversity was calculated with Simpson's index. The differences between Shannon's index and Simpson's index values for pairs of strata may be because Simpson's index is less sensitive to rare species, and since our sampling strategy involved subsamples of the 0.1 ha stand for the sapling and seedling strata, it is likely that some species sampled in the overstory and understory were missed and therefore treated as rare in the sapling and seedling strata.

The cluster analysis software within PC-ORD placed stands into Groups based on overall similarity among stands, taking into consideration IV of all species from all strata in a stand rather than just those which were most dominant. Human observational judgments can be influenced by the size and height of the major canopy species leading the observer to potentially place individual stands in different groups from the ones in which they were placed by cluster analyses. For example, stands 14 and 15 are located near each other and had the same general appearance. Additionally, the calculated IV of *Prunus serotina* in stands 14 and 15 were nearly identical, so the assignment of these stands to either group 2 or group 3 would seem to be a subjective call. The NMS ordination placed stands 14 and 15 at nearly the same location in species space (Figs. 5a-c), yet cluster analysis placed stand 14 in group 2 and stand 15 in group 3, apparently because the combined IV of *Prunus serotina* in the understory, sapling, and seedling strata was greater in group 3 than in group 2. In addition, there were some differences in the species composition of the herbaceous layer between these two stands. However, the four most dominant species in group 2 (present in all 10 stands of the group) were also dominant in group 3 (present in all eleven stands of the group).

Based on the results obtained from both the ordination and cluster analyses, the species composition of stands and groups of stands appears to be governed by a number of factors, including soil moisture, soil texture, soil pH, soil nutrients and stand topography (slope). Stands 1, 3, 4, 5, 28, and 29 comprise Group 1 of the cluster analysis. These stands are located toward the southern edge of the Institute's property with all but Stand 1 following a ridge that was timbered in the mid-late 1800's, but never plowed (Institute records). The soils in these stands have low nutrient levels, pH values that averaged 4.95, and their sand content averaged 59%.

Cluster group 2 consists of 10 stands (2, 6, 7, 8, 9, 10, 11, 12, 13, and 14), which are scattered along the southern and southeastern boundaries of the Institute's property. Group 2 stands have high nutrient soils, soil pH values that average 5.93, soils that average 56.1% sand and 33.9% silt, and soils that have the highest percent moisture, 36%, when compared to all other groups. The majority of the stands in Group 2 were farmed or pastured until the 1970s (Institute records).

Cluster group 3 is comprised of 11 stands (15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 27), which share many of the same characteristics as those in Group 2. The soils are relatively high in nutrients, and soil pH averaged 5.51. The soils of Group 3 have higher silt content, 48.8%, and lower % sand, 41.2%, when compared to the soils of Group 2. Additionally, the soil holds somewhat less moisture than those of group 2. Group 3 is separated from Group 2 by the soil texture and soil moisture gradients. Group 3 stands are scattered along the northern and northeastern boundaries of the Institute's property. These areas are believed to have been cleared prior to 1910 so that the trees in these stands are more mature than those in Group 2 (Institute records).

Groups 2 and 3 share a majority of their species in common. Where these two groups differ is in their overstory and, to some degree, understory species composition. *Fraxinus americana* (white ash) is the dominant species in both the sapling and seedling strata of these two groups. Within the stands that comprise Groups 2 and 3, the Emerald Ash Borer Beetle (*Agrilus planipennis*) has caused the death of a large number of overstory and understory *Fraxinus americana* (white ash) trees so that this species is now underrepresented in these strata as compared to the sapling and seedling strata. Many of the white ash measured and counted in this study appeared to be "barely hanging on" with greater than 50% of their canopy lost. Instead of *Fraxinus americana* (white ash), *Juglans nigra* (black walnut) and *Prunus serotina* (black cherry) are the dominant overstory trees in Group 2 where *Carya ovata* (shagbark hickory) and *Ulmus rubra* (slippery elm) are also well represented. In Group 3, *Quercus velutina* (black oak), a species typically associated with lower moisture soils, is the dominant overstory tree. *Acer rubrum* (red maple), *Prunus serotina* (black cherry), and *Ulmus rubra* (slippery elm) are also well represented in Group 3. We suspect that if the Ash Borer Beetle had not caused the death of *Fraxinus americana* (white ash) in the overstory and understory of these two groups, they would have formed one group.

Cluster group 4 consists of Stands 25, 26 and 30. Group 4 stands are all located on sites associated with slopes, and have soils that are high in sand (avg. 58%). The soils in Group 4 stands have lower percent moisture, 15%, when compared to soils of the other groups which averaged from 31% - 36% moisture. Stands 25 and 26 occur on a slope in the northwest corner of the Institute's property, a location which was likely pastured until the 1960s or 70s (Institute records), while Stand 30 is located along the Institute's southern boundary. All three stands in this group have either average or below average diversity, likely due to their relatively recent disturbance history (as compared to other plots).

From our observations of dead *Fraxinus americana* (white ash) trees, it appeared that *F. americana* had been the dominant overstory and understory tree species prior to infestation by the Emerald Ash Borer Beetle. It is not known which species will replace *F. americana* as the dominant overstory and understory tree. Will *Juglans nigra* (black walnut), *Prunus serotina* (black cherry), and *Quercus velutina* (black oak) remain the dominant species in their respective groups, or will another species, such as *Ulmus rubra* (slippery elm), become dominant in both groups and blur the boundary between them? Additionally, how will the sapling, seeding, shrub/vine, and herbaceous strata change in response to the continued loss of *F. americana* from the overstory? Will non-natives invade? Will *F. americana* become a shrub species? These questions can be answered by examining short-term successional changes within the hardwood forest. Therefore, we recommend repeating this study in 5 – 6 years. In addition to the loss of *F. americana* due to infestation by the Emerald Ash Borer Beetle, *Fagus grandifolia* (beech) trees are in danger of being lost due to Beech Bark Disease and *Quercus* sp. (oak) is threatened by Oak Wilt. If these pathogens invade, the forest species composition will be further altered. Information on forest short-term successional changes should be invaluable to those responsible for managing the forest at Pierce Cedar Creek Institute. In a broader sense, the forests at the Institute are typical of forests throughout Michigan's southern Lower Peninsula. Therefore, the information gleaned from studies at the Institute can be extrapolated to the forests throughout southern Michigan.

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Fig. 1. Location of 30 stands in second-growth mesic hardwood forest at Pierce Cedar Creek Institute, Barry County, Michigan, USA.

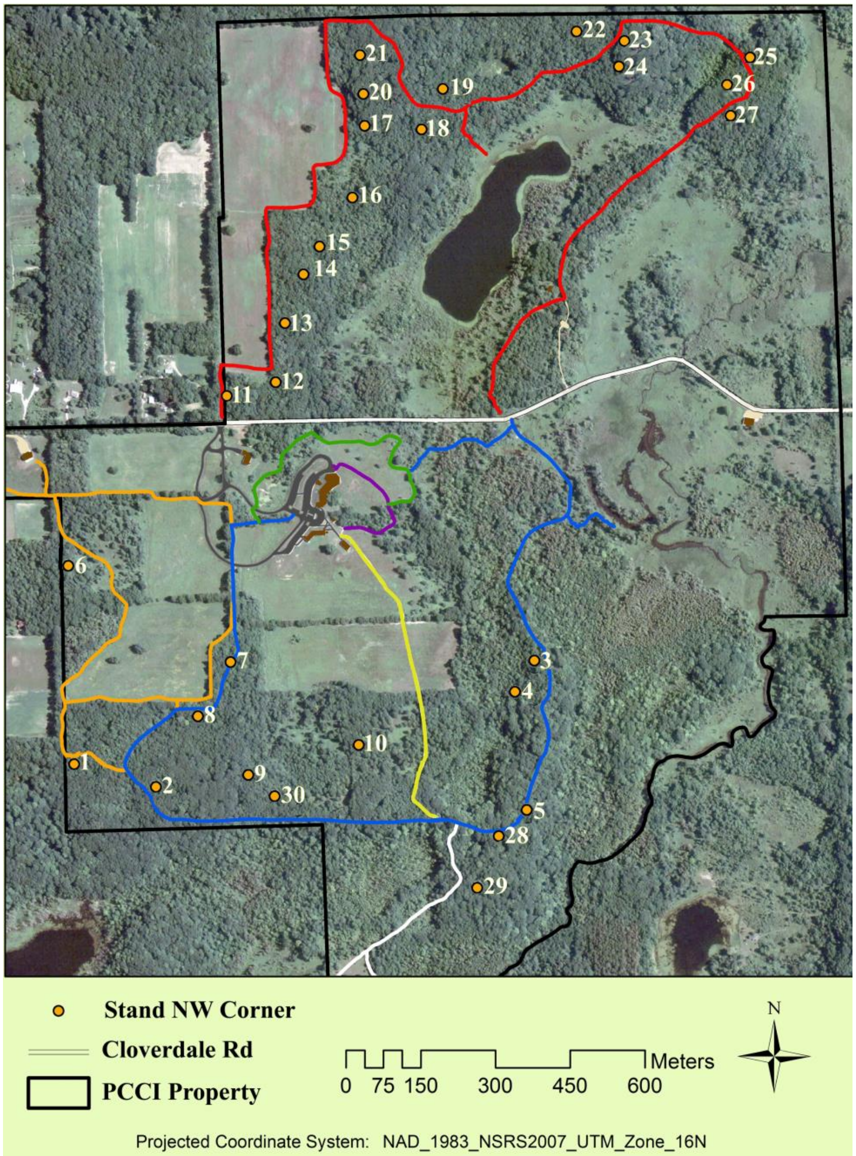
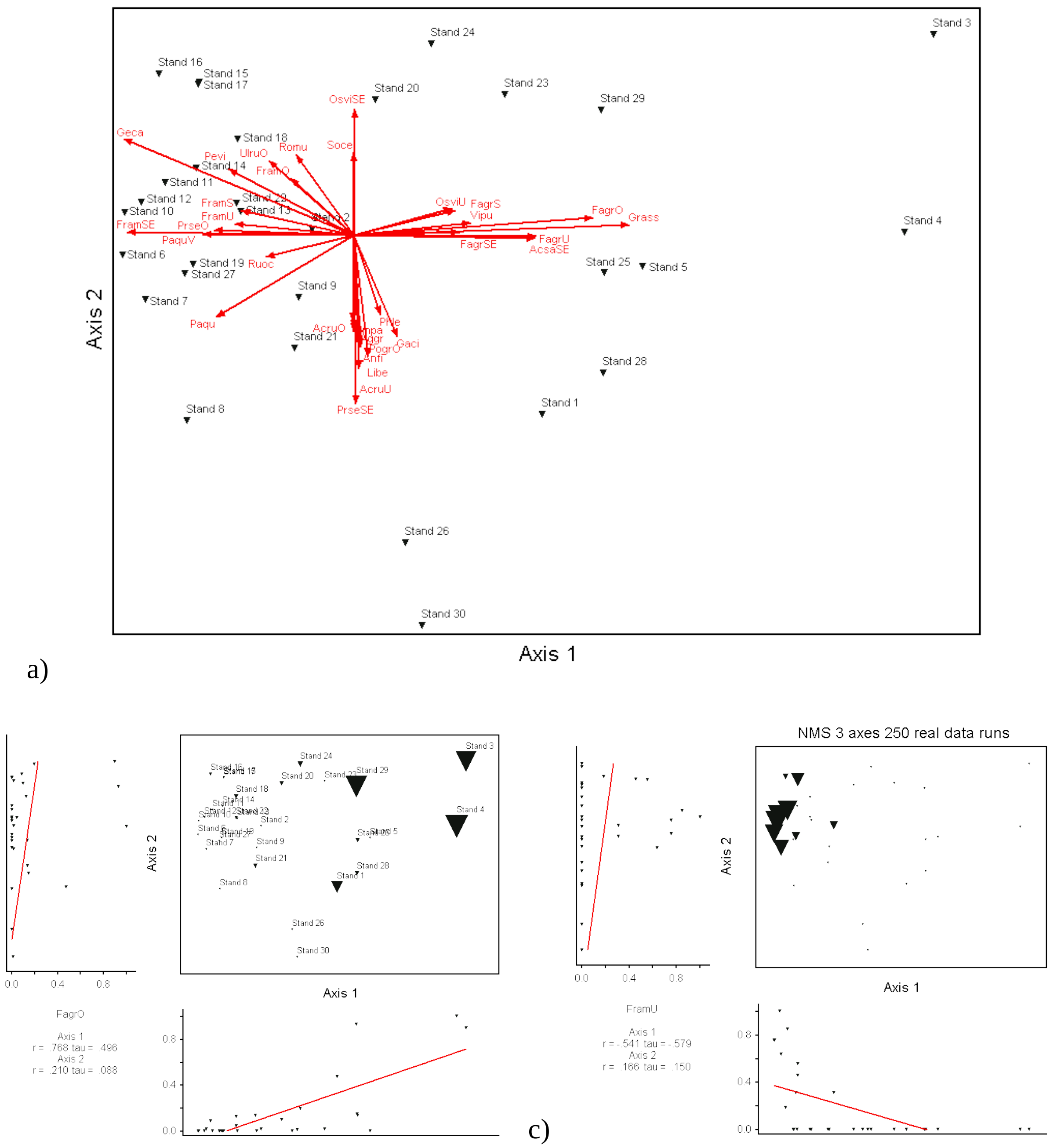


Fig. 2. a) Ordination (NMS) of 30 mesic hardwood forest stands in species space. Vectors on the ordination indicate the direction and strength of correlations between axis scores and the dominant species from various forest strata. Overlays of *Fagus grandifolia* (b) and *Fraxinus americana* (c) on the ordination. The size of the symbol is proportional to the quantity of the species in each stand. The scatterplots show the relationship between the ordination score on the axis and the abundance response on the opposite axis. A simple regression line is drawn through the points and Pearson's correlation coefficient (r) and Kendall's rank correlation coefficient (τ) characterize the strength of the correlation.

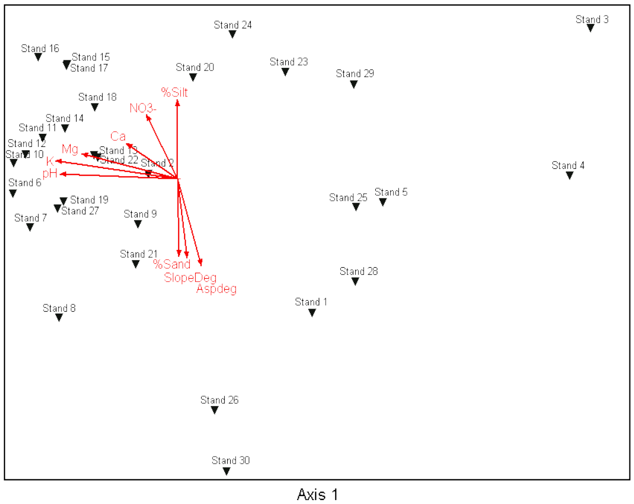


a)

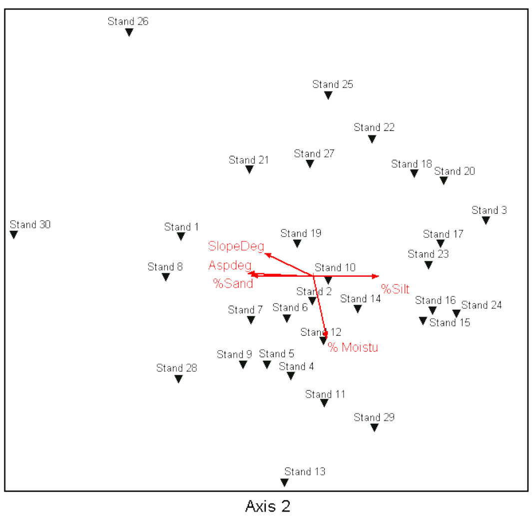
b)

c)

Fig. 3. The arrangement of stands in 3-D ordination space, with overlays of environmental parameters having Pearson's correlation coefficients (r) of 0.30 or greater with any axis.



a)



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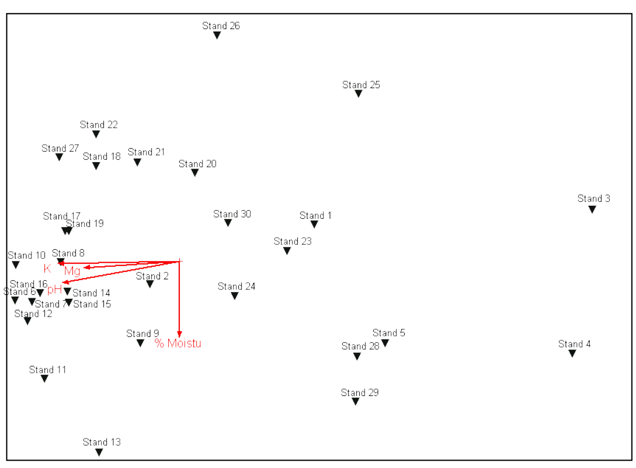


c)

Fig. 4. Cluster analysis of 30 mesic hardwood forest stands using Euclidean distance measure. Four groups where identified based on their similarity of species composition.

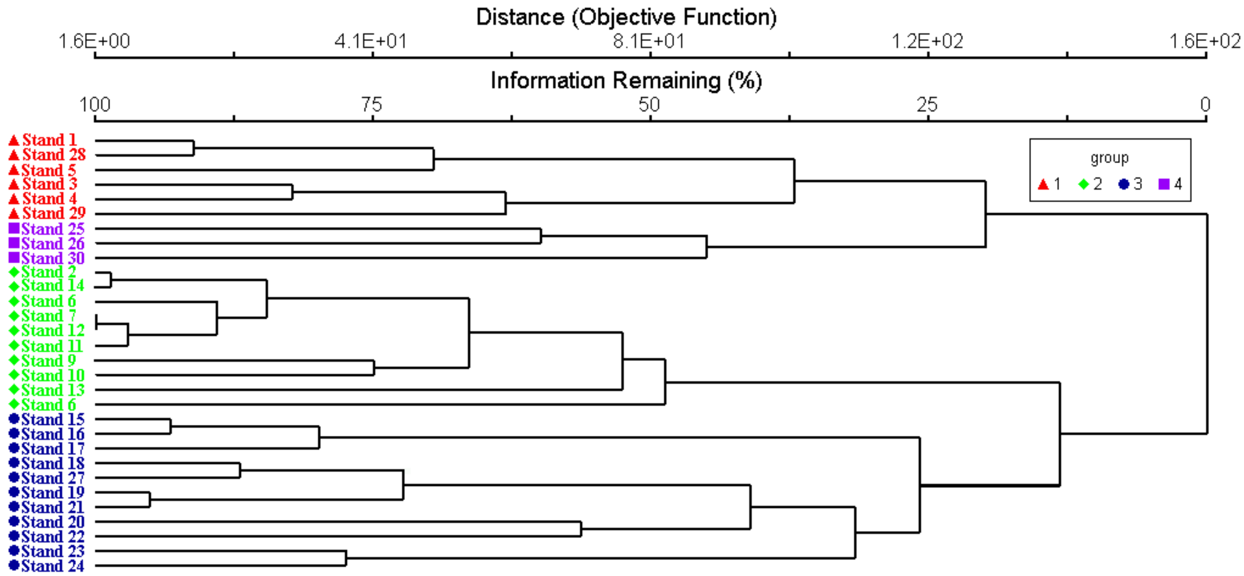
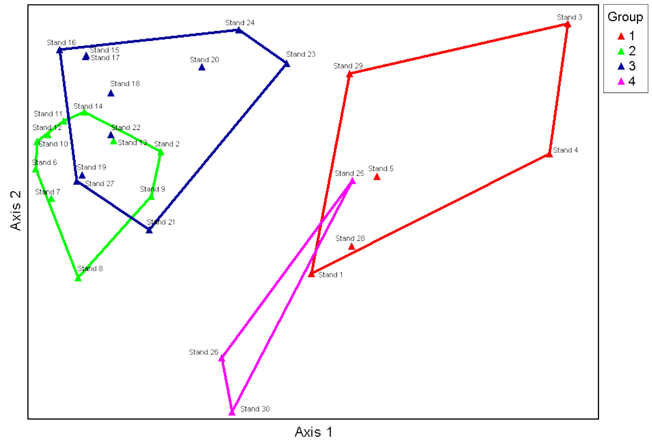
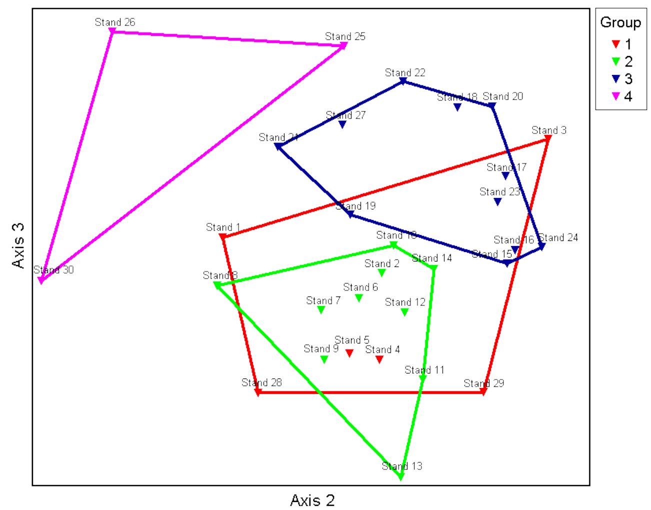


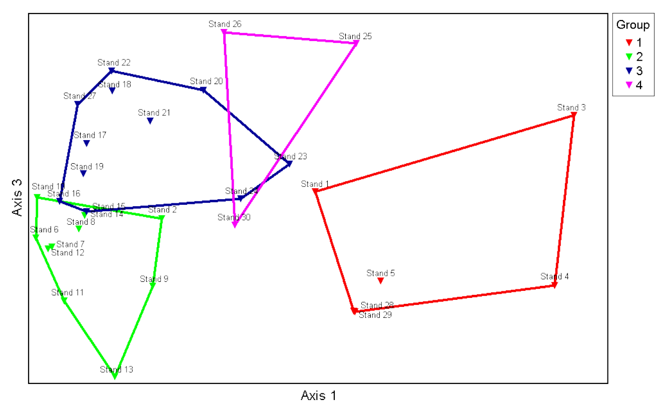
Fig. 5. NMS ordination of 30 stands in four cluster groups. a) Groups 1 and 4 are separated from groups 2 and 3 along ordination axis 1. b) Group 4 is separated from groups 1, 2 and 3 along ordination axis 2. c) Groups 2 and 3 are separated along axis 3. (See text for correlations with environmental variables and % variance accounted for by each axis.)



a)



b)



c)

Table 1. Species richness, species evenness, Shannon's index of diversity, and Simpson's index of diversity for 30 mesic hardwood forest stands and the average across all stands. *n* = 142 species

	Species Richness	Evenness (E)	Shannon's Index (*H'*)	Simpson's Index (D)
Stand 1	40	0.850	3.137	0.9410
Stand 2	38	0.791	2.879	0.9159
Stand 3	19	0.716	2.108	0.8496
Stand 4	26	0.748	2.436	0.8970
Stand 5	32	0.753	2.610	0.8944
Stand 6	40	0.853	3.147	0.9407
Stand 7	42	0.820	3.064	0.9369
Stand 8	40	0.799	2.948	0.9279
Stand 9	34	0.855	3.017	0.9342
Stand 10	43	0.832	3.128	0.9371
Stand 11	36	0.855	3.065	0.9361
Stand 12	28	0.861	2.870	0.9225
Stand 13	26	0.757	2.466	0.8735
Stand 14	29	0.886	2.984	0.9342
Stand 15	37	0.844	3.047	0.9362
Stand 16	45	0.843	3.210	0.9384
Stand 17	46	0.866	3.314	0.9502
Stand 18	37	0.867	3.129	0.9359
Stand 19	43	0.835	3.141	0.9359
Stand 20	37	0.829	2.994	0.9100
Stand 21	33	0.825	2.886	0.9048
Stand 22	41	0.781	2.901	0.9032
Stand 23	34	0.731	2.578	0.8806
Stand 24	30	0.853	2.901	0.9256
Stand 25	36	0.835	2.994	0.9206
Stand 26	25	0.861	2.772	0.9181
Stand 27	28	0.792	2.640	0.8952
Stand 28	35	0.713	2.534	0.8900
Stand 29	38	0.749	2.725	0.8948
Stand 30	35	0.828	2.946	0.9307
Average	35.1	0.814	2.886	0.9170

Table 2. Mean (±SD) and significance for species richness, species evenness, Shannon's and Simpson's index of diversity by forest strata for 30 mesic hardwood forest stands. *n* = number of species in the stratum. Analyzed together the six forest strata differed significantly for each of the measures of diversity ($\alpha = 0.05$; $p = 0.01$ or lower). When all possible pairs of strata were analyzed those within a column with the same superscript did not differ significantly at $\alpha = 0.05$.

	n	Species Richness	Evenness (E)	Shannon's Index (H')	Simpson's Index (D)
Overstory	28	8.8 (±2.2)	0.746 (±.117)[a]	1.606 (±.340)[a]	0.728 (±.045)
Understory	18	2.5 (±1.9)[a]	0.537 (±.388)[b,c]	0.626 (±.522)[b,c]	0.353 (±.117)
Saplings	16	2.3 (±1.6)[a]	0.410 (±.392)[b]	0.488 (±.500)[b]	0.272 (±.101)
Seedlings	16	5.0 (±1.9)[b]	0.517 (±.256)[c]	0.793 (±.440)[c]	0.398 (±.037)
Shrubs/Vines	17	6.1 (±2.6)[b]	0.771 (±.231)	1.391 (±.519)[a]	0.656 (±.033)
Herbaceous	59	14.9 (±3.5)	0.823 (±.110)[a]	2.213 (±.438)	0.836 (±.026)

Table 3. Correlations between ordination axes 1, 2, and 3, and the measured environmental parameters. Parameters with Pearson's correlation coefficients of 0.30 or greater on at least one axis are reported. The most strongly correlated parameter(s) for each axis are in bold type.

	Axis 1		Axis 2		Axis 3	
	r	*τ*	*r*	*τ*	*r*	*τ*
Aspdeg	.288	.260	**-.535**	-.292	.017	.021
SlopeDeg	.180	.172	**-.510**	-.287	-.188	-.094
pH	**-.638**	-.444	.125	.099	.248	.198
K	**-.649**	-.384	.244	.190	.030	-.320
Ca	**-.422**	-.221	.340	.221	.134	.115
Mg	**-.576**	-.397	.285	.212	.076	.065
NO_3^-	-.328	-.141	**.458**	.376	.221	.076
% sand	.071	-.053	**-.506**	-.329	-.088	-.090
% silt	-.016	.076	**.509**	.306	.132	.094
% moisture	-.003	-.030	.345	.220	**.439**	.323

Table 4. Importance of species by forest stratum and cluster group. Columns give the mean IV for the cluster group and (in parentheses) the number of stands of that group where the species occurred. Species with high IV and/or presence in n-1 or greater of the stands are printed in bold type. For the herbaceous species, the number of stands in which the species occurred is presented. Presence in 50% or more of the stands is indicated in bold type.

	No. of Groups	Group 1 n = 6	Group 2 n = 10	Group 3 n = 11	Group 4 n = 3
Overstory	**Code**				
Acer rubrum	Acru	16.41 (4)	15.25 (5)	**26.00 (10)**	**47.68 (3)**
Acer saccharum	Acsa	**57.67 (6)**	29.72 (7)	2.73 (5)	0.00 (0)
Carpinus caroliniana	Caca	0.89 (3)	0.20 (1)	0.10 (1)	4.48 (2)
Carya cordiformis	Caco	0.00 (0)	0.54 (1)	9.79 (8)	6.55 (2)
Carya laciniosa	Cala	0.00 (0)	0.00 (0)	3.86 (4)	0.00 (0)
Carya ovata	Caov	4.35 (4)	16.05 (8)	5.21 (7)	3.62 (2)
Cornus florida	Cofl	0.75 (2)	0.32 (1)	1.40 (5)	0.00 (0)
Fagus grandifolia	Fagr	**43.08 (5)**	0.25 (1)	4.76 (7)	3.74 (1)
Fraxinus americana	Fram	5.01 (2)	17.10 (9)	16.25 (8)	0.18 (1)
Juglans nigra	Juni	0.94 (1)	**31.54 (9)**	3.22 (2)	0.48 (1)
Ostrya virginiana	Osvi	**20.77 (6)**	5.81 (3)	25.42 (7)	15.11 (1)
Pinus resinosa	Pire	0.00 (0)	1.33 (1)	0.86 (2)	0.00 (0)
Populus grandidentata	Pogr	0.91 (1)	0.48 (1)	0.00 (0)	**40.24 (2)**
Prunus serotina	Prse	4.80 (2)	**32.96 (9)**	**27.57 (11)**	1.75 (1)
Quercus alba	Qual	2.64 (1)	1.44 (3)	3.80 (3)	0.00 (0)
Quercus rubra	Quru	2.09 (1)	3.77 (3)	7.02 (4)	**53.19 (2)**
Quercus velutina	Quve	14.33 (1)	23.91 (6)	**43.64 (10)**	14.93 (2)
Sassafras albidium	Saal	0.00 (0)	8.61 (3)	2.62 (4)	0.39 (1)
Tilia americana	Tiam	0.00 (0)	0.91 (1)	0.88 (3)	0.00 (0)
Ulmus rubra	Ulra	2.73 (2)	16.11 (8)	**29.66 (11)**	3.64 (1)
Understory	**Code**				
Acer rubrum	Acru	9.72 (1)	1.99 (1)	0.95 (1)	36.28 (1)
Acer sacharrum	Acsa	3.32 (1)	29.10 (3)	0.00 (0)	20.48 (1)
Carpinus caroliniana	Caca	14.48 (2)	2.60 (1)	0.00 (0)	0.00 (0)
Carya ovata	Caov	15.70 (1)	14.05 (2)	**31.04 (3)**	0.00 (0)
Cornus florida	Cofl	0.00 (0)	1.24 (1)	20.36 (3)	0.00 (0)
Fagus grandifolia	Fagr	**90.14 (5)**	0.00 (0)	0.00 (0)	22.86 (2)
Fraxinus americana	Fram	0.00 (0)	**60.35 (6)**	19.23 (4)	0.00 (0)
Ostrya virginiana	Osvi	58.39 (4)	15.64 (1)	**37.32 (3)**	**53.71 (1)**
Prunus serotina	Prse	0.00 (0)	12.36 (2)	2.69 (2)	0.00 (0)
Ulmus rubra	Ulra	3.75 (1)	12.36 (2)	**30.13 (5)**	0.00 (0)
Tree Sapling	**Code**				
Acer sacharrum	Acsa	0.00 (0)	0.00 (0)	3.79 (2)	8.33 (1)
Fagus grandifolia	Fagr	**19.40 (2)**	0.86 (2)	1.30 (1)	0.00 (0)
Fraxinus americana	Fram	0.00 (0)	**75.47 (10)**	**49.77 (8)**	**21.16 (2)**
Ostrya virginiana	Osvi	16.67 (1)	1.21 (1)	5.54 (3)	**20.51 (2)**
Populus grandidentata	Pogr	16.67 (1)	0.00 (0)	1.30 (1)	33.33 (1)
Prunus serotina	Prse	0.00 (0)	7.89 (5)	9.29 (4)	0.00 (0)
Quercus rubra	Quru	0.00 (0)	9.26 (6)	7.02 (4)	**5.85 (3)**
Quercus velutina	Quve	2.78 (1)	1.67 (1)	0.00 (0)	16.67 (1)
Sassafras albidium	Saal	0.00 (0)	0.00 (0)	14.07 (3)	0.00 (0)
Ulmus rubra	Ulra	0.00 (0)	7.89 (5)	5.85 (3)	0.00 (0)

Tree Seedling	Code				
Acer rubrum	Acru	0.64 (1)	22.06 (8)	12.64 (7)	**18.11 (3)**
Acer sacharrum	Acsa	**75.92 (6)**	0.19 (1)	1.91 (2)	0.00 (0)
Carya cordiformis	Caco	0.00 (0)	0.04 (1)	0.96 (2)	0.00 (0)
Carya ovata	Caov	0.77 (5)	2.18 (4)	0.25 (1)	0.83 (1)
Fagus grandifolia	Fagr	14.46 (4)	0.28 (2)	0.21 (1)	**11.49 (3)**
Fraxinus americana	Fram	**2.96 (6)**	**55.65 (10)**	**57.98 (11)**	19.40 (2)
Ostrya virginiana	Osvi	**1.04 (6)**	0.18 (1)	7.80 (8)	0.00 (0)
Populus grandidentata	Pogr	0.21 (1)	1.87 (2)	0.24 (1)	2.19 (1)
Prunus serotina	Prse	**2.16 (6)**	5.82 (7)	2.92 (5)	**29.16 (3)**
Quercus velutina	Quve	0.96 (5)	2.15 (4)	8.17 (9)	**11.29 (3)**
Tilia americana	Tiam	0.06 (3)	0.00 (0)	0.12 (1)	0.00 (0)
Ulmus rubra	Ulra	0.44 (2)	9.40 (7)	6.30 (7)	0.21 (4)
Shurb/Vine	**Code**				
Amphicarpeae bracteata	Ambr	**26.76 (4)**	9.53 (7)	3.46 (5)	6.14 (1)
Cornus foemina	Cofo	4.55 (2)	2.47 (4)	9.58 (6)	4.76 (1)
Elaeagnus umbellata	Elum	0.26 (1)	5.78 (7)	12.26 (8)	**41.38 (2)**
Lindera benzoin	Libe	4.55 (1)	2.67 (5)	0.59 (2)	**18.17 (3)**
Parthenocissus quinquefolia	PaquV	0.00 (0)	**10.88 (10)**	4.69 (9)	0.00 (0)
Rosa multiflora	Romu	3.58 (3)	9.41 (8)	**34.22 (11)**	3.51 (1)
Rubus allegheniensis	Rual	8.76 (2)	11.05 (6)	7.56 (7)	0.00 (0)
Rubus occidentalis	Ruoc	4.91 (2)	**25.63 (10)**	9.23 (9)	12.75 (2)
Ribes cynosbati	Ricy	**26.07 (4)**	11.23 (8)	15.20 (8)	12.28 (2)
Smilax hispida	Smhi	0.00 (0)	4.00 (3)	0.35 (1)	0.00 (0)
Vitis sp.	Vitus	1.56 (1)	0.82 (2)	1.50 (2)	0.00 (0)
Zanthoxylum americanum	Zaam	2.34 (1)	0.24 (1)	0.31 (1)	0.00 (0)
Herbaceous	**Code**				
Agrimonia gryposepala	Aggr	0	2	0	1
Anthyrium filix-femina	Anfi	0	2	0	**3**
Asplenium platyneuron	Aspl	0	2	0	0
Carex pensylvanica	Grass	**5**	**5**	**7**	**3**
Carex sp.	sedge	2	1	5	1
Circaea canadensis	Cica	**4**	**9**	**9**	1
Desmodium canadense	Deca	0	1	**7**	0
Elymus hystrix	Elhy	3	1	2	0
Fragaria virgiana	Frvi	1	1	2	0
Galium asprellum	Gaas	2	1	5	0
Galium circaezans	Caci	**4**	0	2	1
Geum canadense	Geca	**4**	**10**	**11**	1
Geranium maculatum	Gema	0	2	1	0
Impatiens pallida	Impa	0	1	3	1
Osmorhiza claytonia	Oscl	1	1	2	1
Parthenocissus quinquefolia	Paqu	3	**10**	**9**	**3**
Persicaria virginiana	Pevi	4	**10**	**11**	1
Phryma leptostachya	Phle	3	1	1	1
Podophyllum peltatum	Pope	2	3	**6**	1
Solidago altissima	Soal	1	2	1	0
Solidago cesia	Soce	1	0	5	0
Toxicodendron radicans	Tora	3	**5**	**6**	**2**
Thalictrum thalictroides	Thth	2	0	1	0
Urtica dioica	Urdi	2	2	4	0
Viola pubscens	Vipu	**5**	2	3	0
Viola sp.	Violet	2	2	**9**	0