ABSTRACT

PHILLIPS, ROSS JOHNSON. Classification and Predictive Modeling of Plant Communities in the Gorges State Park and Gamelands, North Carolina. (Under the direction of Thomas R. Wentworth.)

A method of rapid field assessment and predictive modeling was developed to characterize vegetation communities of the Gorges State Park and Gamelands and to create predictive community maps for the area. This method placed an emphasis on locating rare communities using expert information, existing databases, aerial photography, and random encounters in efforts to provide information to researchers and park personnel about community locations. Approaches for classifying these communities were examined to identify which would provide suitable units for modeling community types. I sampled 102 field locations and assigned their vegetation to 16 different community types. Predictive community maps were generated using discriminant functions incorporating digital terrain data, including elevation, slope, relative slope position, terrain shape index, and weighted landform index. Three sets of discriminant functions were created to meet the different needs of persons interested in using these maps. Photo-interpreted cover classes were also including in the modeling process as filters. Map accuracies ranged from 65% to 75%, with those using only discriminant functions (without filtering) yielding higher accuracies.

CLASSIFICATION AND PREDICTIVE MODELING OF PLANT COMMUNITIES IN THE GORGES STATE PARK AND GAMELANDS, NORTH CAROLINA

By
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Chair of Advisory Committee

BIOGRAPHY

Ross Phillips was born and raised in Jacksonville, Florida. He attended St. Mark's Episcopal Day School and St. Johns Country Day School for elementary and high school education, respectively. After graduating from St. Johns in 1992, he attended Clemson University in Clemson, South Carolina, where he obtained a Bachelor of Science in Biological Sciences in 1996. He worked as a research assistant at Clemson University helping to construct a Piedmont prairie until accepting a job with the U. S. Geological Survey at the Indiana Dunes National Lakeshore studying savanna, prairie, and sand dune communities. In 1998 he accepted a position with the National Park Service at Shenandoah National Park in Virginia where he participated in research examining the extent of ice storm damage suffered by the park's natural resources, surveying a high elevation meadow, and re-establishing the park's monitoring program for rare and endangered plant species. In August of that same year he was accepted into the Graduate School at North Carolina State University in Botany. He currently works for the U.S. Forest Service studying fuel loading in pine/hardwood communities in the southeast.

ACKNOWLEDGEMENTS

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INTRODUCTION

Quick and relatively inexpensive methodologies are becoming increasingly important in efforts to identify and protect areas of biological significance. As deforestation and land development continue to increase in the tropics, these diverse areas are being lost at alarming rates. Closer to home, researchers are concerned with cataloguing parks and preserves to give us a better idea of existing resources and to decide which ones should be targeted for management and preservation. A method to assess quickly areas of biological importance can be an important tool for conservationists and land managers prior to park establishment or in parks that already exist. It can help guide the development process for a park or provide input for establishment of long-term research and management practices.

The purpose of this project was to develop a rapid assessment technique that would adequately capture the community types and environmental gradients for the Gorges State Park and Gamelands in the southeastern Blue Ridge escarpment of the southern Appalachian Mountains. This information was combined with predictive modeling using discriminant function analysis to produce community maps that can help guide subsequent animal studies and park facility planning. The specific objectives of this research were to:

1) Identify a classification technique that would provide classification units suitable for predictive modeling of plant community types of the Gorges State Park and Gamelands;
2) Develop discriminant functions based on digital terrain data that would adequately distinguish between different community types;
3) Generate predictive community maps using discriminant functions and aerial photography;

4) Compare the performance of using discriminant functions only to predict community occurrences versus using the combination of these functions and aerial photography for prediction; and
5) Relate this information to managers involved in development planning for the state park.

Chapter 1 – Literature Review

Rapid Assessment

The Rapid Assessment Program (RAP) and Rapid Ecological Assessment (REA) combine satellite imagery, aerial photography and overflights, and expert knowledge with field sampling to survey quickly an ecosystem's flora and/or fauna and to produce vegetation and wildlife habitat maps for more expedient recommendations for protection (Parker and Bailey, 1991; Abate, 1992; Maragos and Cook, 1995). Rapid assessment has been used to examine the successional status of tropical rain forest in Singapore (Turner et al., 1996); to direct biodiversity planning in Madagascar (Smith et al., 1996); and to identify areas for conservation in Paraguay (Keel et al., 1993), Belize (Parker et al., 1993a), Bolivia (Parker and Bailey, 1991; Parker et al., 1993b; Schulenberg and Awbrey, 1997a), Papua New Guinea (Mack, 1998), Peru (Foster et al., 1994; Schulenberg and Awbrey, 1997b), and southwest Guyana (Parker et al., 1993c).

Field methods vary from researcher to researcher, but traditionally long rectangular plots 50 meters (m) x 2 m in size are used for vegetation sampling (Parker and Bailey, 1991; Keel et al., 1993). Turner et al. (1996) modified this technique by clustering 4 circular plots totaling 0.2 hectare (ha) around a central point. In both cases diameter at breast height (DBH) of trees, shrubs, and lianas is measured and species are recorded. The purpose is to characterize the vegetation, determine dominant species, and create importance values based on relative frequency, relative density, and relative dominance in an expeditious manner. Vegetation analysis associated with this methodology has primarily focused on number and types of species present with little attention given to vegetation community types (Keel et al., 1993).

While these surveys were performed prior to establishment of parks or preserves, this methodology should also be considered a management tool for existing parks or soon-to-be developed parks to guide management of their natural resources. It should be emphasized that these rapid surveys do not replace long-term research; they provide preliminary data that can be used as input into the development of research projects and management strategies. The recent development of the Gorges State Park in the southeastern Blue Ridge escarpment provided the opportunity to apply this concept.

Study Area

The Gorges State Park and Gamelands were established in April 1999 after the state of North Carolina, in cooperation with the Nature Conservancy and other organizations, arranged to purchase from Duke Power Company approximately 4000 ha in Transylvania County, North Carolina. This area was known to support diverse flora and fauna and was labeled as an area of high priority for conservation, as residential developments have begun to threaten the natural habitats of this area.

The Blue Ridge escarpment is located in the southern part of the Appalachian Mountains in North and South Carolina. It is a transitional zone between the Piedmont and mountains and rises from an elevation of approximately 300 to 1400 m in a distance of 16 kilometers (km). The Blue Ridge escarpment generally runs in a northeast-southwest direction, but in this area it turns and has an east-west trend for about 45 km. This orientation, in addition to the rapid increase in elevation, results in extremely high rainfall as the warm, moisture-laden winds from the Gulf of Mexico meet the mountains, giving this area the distinction of being the wettest location in eastern North America with 200-250 centimeters (cm) of precipitation per year (Billings and Anderson, 1966). The high amount of precipitation has caused erosion of the underlying rocks over thousands of years and resulted in a number of gorges, including the Eastatoe, Toxaway, Horsepasture, Thompson, Whitewater, and Chattooga. The climate of this area is characterized by moderate temperatures year round with temperatures seldom falling below freezing and few if any days of extreme heat (Billings and Anderson, 1966).

The unique features of the southeastern Blue Ridge escarpment (transition between Piedmont and mountains, high precipitation, moderate temperatures, rugged/highly dissected terrain) have created an area with a diverse flora harboring a number of endemics, including *Shortia galacifolia*. Over the years the southern Appalachians and the Blue Ridge escarpment have received considerable attention for their biodiversity. (See Cooper (1963) for a discussion of earlier botanical exploration of this region.) In the 1960's the Highlands Biological Station helped initiate a long-term research program in the southeastern Blue Ridge escarpment to gain a better understanding of the ecology of this area (Cooper and Hardin, 1970). Cooper (1963) conducted a vegetation survey of the Toxaway Gorge and identified 6 major community types: riverbank communities; Virginia pine communities of disturbed areas along river bottoms; mixed mesophytic forests below 640 m; oak forests above 640 m on river slopes; upland oak forests; and pine leads. He also identified another group as "Other Communities" which included seeps, spray zones, cliffs, and moist rock surfaces in the rivers.

Mowbray (1966) focused on the Bearwallow Gorge, describing its vegetation and species distributions with relation to environmental gradients (moisture and temperature). He identified 4 major community types, which were similar to those recognized by Cooper (1963): riverbank communities; mixed mesophytic communities including subtypes of mixed bottomland forest and moist cove forest; chestnut oak forests; and scarlet oak-pine forests. The most noticeable trend for species distributions was related to moisture and elevation differences while the temperature gradient was more difficult to interpret.

Racine (1966) studied the pine communities in the Thompson Gorge to identify whether or not distinct types existed and to determine their distributions with respect to soil and topographic positions. He recognized 2 types: pine and pine-oak communities. Each type had 2 associations: the Pitch Pine-Virginia Pine Association and the Table Mountain Pine-Virginia Pine Association for the pine community, and the Pitch Pine-Scarlet Oak Association and the Shortleaf Pine-Oak Association for the pine-oak community. Of the different environmental factors identified, the narrowness of the ridge had the most important effect on pine dominance.

Mowbray and Oosting (1968) conducted a comprehensive study of the Thompson Gorge, examining vegetation gradients and phenology with respect to environmental factors. They recognized general community types of mixed bottomland forest, upland oak forest, mixed oak ridge top forest, and oak-pine and pine-oak forests. Environmental gradients examined included insolation, temperature for air and soil, deficit of vapor pressure, wind, evaporation, precipitation, soil moisture, and soil physical and chemical properties.

Through the 1970's and 1980's vegetation studies were continued in the area. Racine and Hardin (1975) surveyed the Green River Gorge in the eastern portion of the Blue Ridge escarpment, where they recognized communities of hemlock forest, cove hardwood forest, successional hardwood forest, river birch forest, pine forest, oak forest with subtypes of chestnut oak, scarlet oak, white oak, and red oak, and non-forest vegetation. They also attempted to map these vegetation communities using aerial photos. For this area they concluded that topography and cultural history were responsible for vegetation differences.

Vegetation analysis of the Thompson Gorge was conducted by Wentworth (1980), who identified 3 general community types: pine-dominated, oak-dominated, and mixed mesophytic. The major environmental gradient for communities in this gorge was determined to be a complex of moisture and temperature.

Numerical Classification

Ecologists frequently use cluster analysis as a tool in vegetation analysis for identifying relatively homogeneous groupings in data. A variety of different methods exist for cluster analysis: agglomerative vs. divisive, polythetic vs. monothetic, and hierarchical vs. non-hierarchical. The approach used for this research was an agglomerative, polythetic, hierarchical technique of numerical classification that groups sample units based on similarities, which are measured by an ecological distance (McCune and Mefford, 1997). This method begins with each sample point as a unique entity and then groups similar points together based on all attributes from the data simultaneously. These groups continue to be combined until a single, large group is produced consisting of all the sample points. It is hierarchical in the sense that each small group belongs to a larger, more heterogeneous group. The researcher decides upon the number of significant groups defined for the dendrogram.

A number of options concerning distance measurement and grouping techniques are available to the researcher and the decision of which method should be used depends on the objectives of the study. The use of Sorensen's distance is becoming more common in ecological research because it provides a more realistic representation of ecological distance (Faith et al., 1987). The various group linkage techniques also have advantages and disadvantages that should be considered when deciding which method should be used. Lance and Williams (1967) and Sneath and Sokal (1973) recommend using a flexible linking strategy, also known as flexible â. This method allows the researcher to contract or expand the dendrogram depending upon the value of â used, which can range from 1 to –1. If the researcher is interested in identifying distinct discontinuities or has trouble interpreting a fragmented dendrogram, then a "dilating" strategy should be used with â set to –0.25 (Lance and Williams, 1967). Work by Ulrey (personal communication) indicates that using a â of –0.50 provides the most interpretable results.

Ordination

It is becoming more common for ecologists to combine cluster analysis with ordination techniques to analyze their data and fine-tune their classifications. Ordination is the ordering of sample units in n-dimensional space with respect to underlying environmental gradients. It can be applied as direct or indirect gradient analysis. Direct gradient analysis assumes certain environmental gradients are important for vegetation composition at the beginning of the project and these gradients are investigated. Indirect gradient analysis makes no assumption prior to the start of the project. Instead, environmental gradients influencing vegetation composition appear as the data are analyzed. Various methods of ordination exist, including Bray-Curtis ordination, principal component analysis (PCA), reciprocal averaging (RA), detrended correspondence analysis (DCA), canonical correspondence analysis (CCA), and nonmetric multidimensional scaling (NMS). Each method has its advantages and disadvantages, but NMS using Sorensen's distance appears to be the most effective for ecological data (Faith et al., 1987; Minchin, 1987).

Discriminant Analysis and Predictive Modeling

Discriminant function analysis (DFA) discriminates between different categories based on a set of predictor variables. It attempts to find linear combinations of *n* independent variables that maximize between-group variance while minimizing within-group variance and to assign unclassified observations to one of *k* classes (Lowell, 1991). It operates under the assumptions that the observations come from a random sample; each group has a normal distribution with respect to the discriminator variables; none of the discriminating variables are linear combinations of other variables; the variance/covariance matrix is the same for all groups; and each observation was initially classified correctly (Klecka, 1980). Discriminant analysis can be used to identify how well a set of characteristics discriminates between groups and which are the most powerful discriminators, or, for classification, to assign unclassified cases to specific groups or to reclassify cases.

DFA has been used in ecology for habitat modeling (Clark et al. 1993), prediction of animal distributions (Austin et al., 1996; Corsi et al., 1997; Knick and Dyer, 1997), studies of niche differentiation (Mann and Shugart, 1983), spatial modeling of ecological succession (Lowell, 1991), and classification of communities (Heikens and Robertson, 1995).

Chapter 2 – Classification of plant communities

INTRODUCTION

Resource inventories of parks and preserves typically occur after their establishment. This delay results in the possibility that the resources to be protected actually suffer some disturbance. The recent establishment of the Gorges State Park in the southeastern Blue Ridge escarpment (Figure 2-1) provided a unique opportunity to identify the resources (in particular, plant communities) in the area before development of park facilities (trails, camp sites, maintenance operations, visitor center, etc.). In order to study these complex communities and to relate the information to other persons, one must group the communities into manageable units (community types or groups) that share similar characteristics. Various attributes exist for classifying these units: physiognomy, vegetation dynamics, environmental conditions, species dominance, floristic composition, or any combinations of these approaches (Whittaker, 1978); the researcher must decide which of these is most appropriate based on the objectives of the study.

The southeastern Blue Ridge escarpment is an area of high biodiversity as a result of its unique location and high rainfall. The escarpment is situated in the transitional zone between the Piedmont and mountains of North and South Carolina and as a result the flora is characterized by species from both regions. The high amounts of precipitation have eroded the underlying rocks to produce an area of rugged terrain marked by various gorges created by the Eastatoe, Toxaway, Bearwallow, Horsepasture, Thompson, Whitewater, and Chattooga Rivers. The highly dissected terrain and mild climate combine to form a variety of microenvironments that served as refugia for species from earlier geological periods, contributing further to the diversity of this area (Billings and Anderson, 1966). Work conducted in the 1960's focused on identifying natural communities, environmental gradients, and rare species in the escarpment (Cooper, 1963; Billings and Anderson, 1966; Mowbray, 196; Racine, 1966). Other studies continued through the 70's and 80's (Racine and Hardin, 1975; Wentworth, 1980) in efforts to gain further understanding of community composition and distributions.

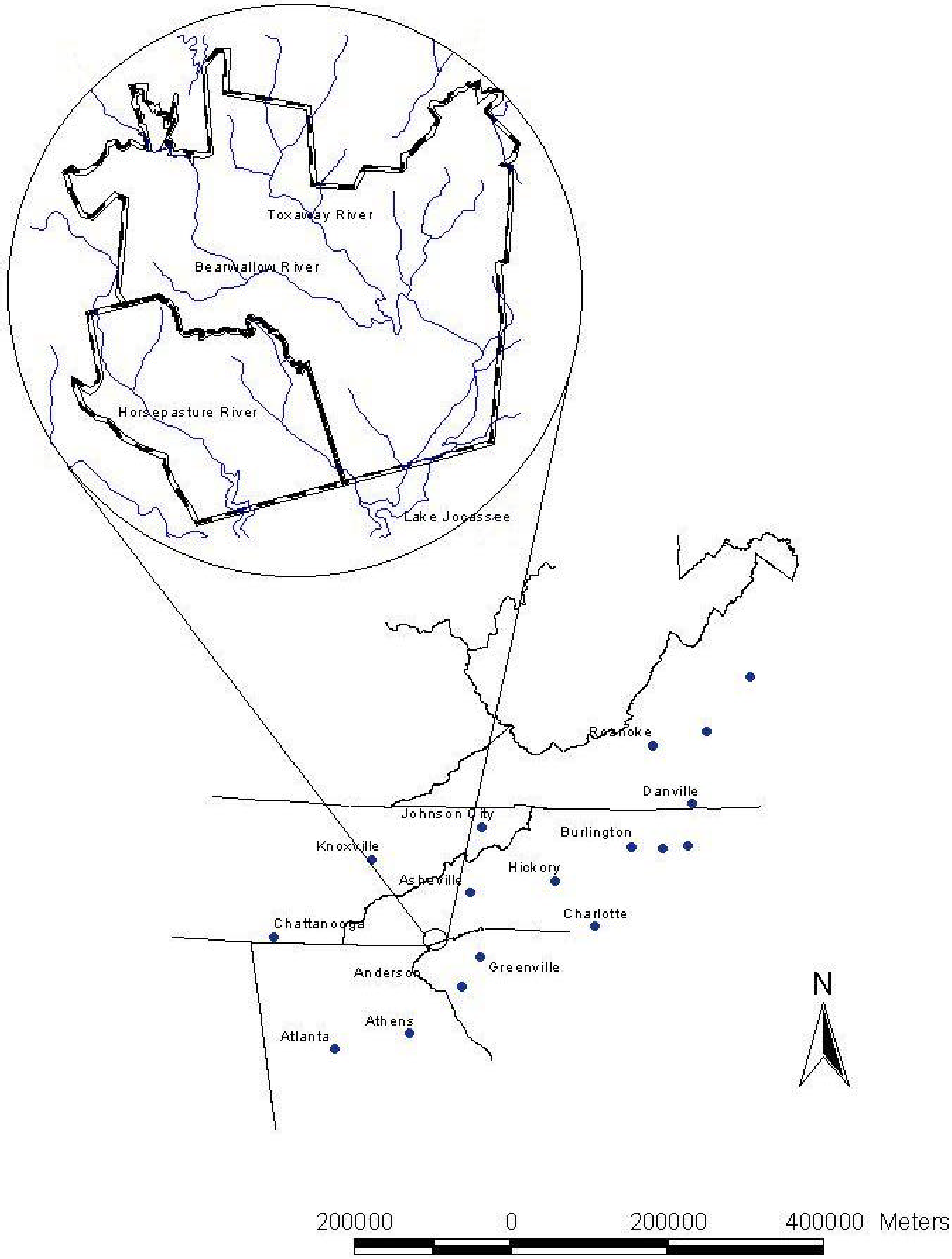


Figure 2-1. Location of Gorges State Park and Gamelands, Transylvania County, North Carolina.

The goal of the field survey was to locate rare communities in the study area so they could be protected as the park infrastructure was developed. The amount of time allowed for a vegetation survey of this area was limited due to the development schedule of the park. Therefore, a methodology to inventory quickly the vegetation communities of the area, and one that could also capture the underlying environmental gradients responsible for community distribution was needed. The sampling method developed was a modification of rapid assessment techniques that emphasized location of rare communities. Rapid assessment techniques have been used to sample expeditiously high diversity areas in the tropics to help make recommendations about conservation and preservation (Parker and Bailey, 1991; Keel et al., 1993; Parker et al., 1993a; Parker et al., 1993b; Parker et al., 1993c; Foster et al., 1994; Schulenberg and Awbrey, 1997a; Schulenberg and Awbrey, 1997b; Mack, 1998). This method was then combined with predictive modeling using discriminant function analysis to create predictive maps that could be used in guiding future research and development plans for the park. The focus of this chapter is to identify a classification scheme that would provide useful classification units for predictive modeling of community types in the Gorges State Park and Gamelands.

METHODS

Field Sampling

From May - August 1999 a field survey using a modification of rapid assessment techniques was conducted to identify plant community types and locations within the Gorges State Park and Gamelands. This survey placed a particular emphasis on locating rare communities while at the same time capturing the variation of the more common community types. Sample points were determined using: i) a systematic sampling grid of 500m x 500m; ii) interpretation of topography by ecologists familiar with the region who identified specific areas of interest that might be suitable for the occurrence of rare communities; iii) existing inventories of rare species and habitats in the area (e.g., NC Heritage Program database); and iv) interpretation of aerial photographs to identify areas that might support rare communities based on topographic position as well as unique visual properties (e.g., rock outcrops or large trees in a specific area possibly signifying old growth forest). In addition to these methods, any random encounters of rare communities at locations not already targeted were also sampled.

Navigation to each sample point was achieved using topographic features and global positioning system (GPS) when satellites could be obtained. Upon reaching the appropriate area (or what was considered to be the appropriate area), I drove a permanent stake into the ground to mark the site. The stake was ½ inch conduit cut to a length of 40cm and was driven into the ground 30cm or as far as possible. The sample point was geo-referenced in Universal Transverse Mercator (UTM) North American Datum (NAD) 1927 using a mapping grade GeoExplorer®. Due to the rugged nature of the landscape the GPS unit could not always obtain satellite readings. In such cases the location of the point was approximated on a 7.5 minute topographic map of the Reid quadrangle using surrounding land features in addition to compass and altimeter readings and subsequently transferred to a digital topographic map from which the coordinates were extracted.

Circular 0.1 ha plots were established at each sample point. Community variables included leaf phenology, physiognomic class, stand age, and community size. A species list was generated for each sample point and percentage cover for each species was estimated using cover classes (Peet et al., 1998). Relative dominance based on percentage cover was noted by strata for each species. Height and cover of each stratum (canopy, subcanopy, shrub, and herb) were estimated. Dominant ground cover was noted as bedrock, litter, bare soil, large or small rocks, and/or woody debris and any evidence of past disturbance or presence of any rare plant or indicator species were recorded. The basal area of trees surrounding the sample points was estimated using a two-factor metric prism. For each tree counted, its species and DBH (noted as greater or less than 90 cm) were recorded.

Community types identified for each sample point were classified according to Schafale and Weakley's *Classification of Natural Communities in North Carolina: 4th Approximation* (working draft) (referred to as "4th Approximation" from this point on).

Community types identified for this area were: Acidic Cove Forest (Typic Subtype) (AC), Canada Hemlock Forest (Typic Subtype) (CH), Chestnut Oak Forest (Dry Heath Subtype) (CODH), Chestnut Oak Forest (Herb Subtype) (COH), Chestnut Oak Forest (Rhododendron Subtype) (COR), Chestnut Oak Forest (White Pine Subtype) (COWP), Montane Cliff (Acidic Subtype) (MCA), Montane Cliff (Mafic Subtype) (MCM), Montane Oak-Hickory Forest (Acidic Subtype) (MOH), Montane Oak-Hickory Forest (White Pine Subtype) (MOHW), Pine Oak Heath (Typic Subtype) (POH), Rich Cove Forest (Montane Intermediate Subtype) (RC), Rocky Bar (Twisted Sedge Subtype) (RB), Spray Cliff (SC), Swamp Forest Bog Complex (Typic Subtype) (SFB), and White Pine Forest (WP). Table 2-1 shows the sample size for each community type and method of sample point identification. (For a complete list of sample points and their community types see Appendix A. A species list for the study area is provided in Appendix B.)

Description of site physical characteristics for each sample point was in accordance with the method of Peet et al. (1998). Soil samples and photo documentation were also taken for every site where these were possible. I collected ten soil subsamples dispersed throughout the site. For each subsample the litter layer was removed and the top 10 cm of soil was collected. The soil samples will be analyzed and used in future data interpretation. At least 2 photographs were taken for each site either along the slope or in the direction that best exemplified the community type.

Numerical Classification

Cluster analysis was performed using PC-ORD software, version 3.18 (McCune and Mefford, 1997) to identify similar groups of sample points. The method used was polythetic, agglomerative, and hierarchical. This method begins with each sample point as a unique entity and then groups similar points together based on all attributes from the data simultaneously. These groups continue to be combined until a single, large group is produced consisting of all the sample points. It is hierarchical in the sense that each small group belongs to a larger, more heterogeneous group. The researcher decides upon the number of significant groups defined for the dendrogram.

Table 2-1. Breakdown of community types by sample point identification. Community classification according to Schafale and Weakley's 4^{th} Approximation. Headings of "Expert", "Aerial", "Grid", and "Random" denote method by which sample locations were identified. "Expert" - input from ecologists familiar with the area; "Aerial" - input from aerial photo interpretation; "Grid" - 500m x 500 m grid; "Random" - random encounter of community in field.

Community	Expert	Aerial	Grid	Random	Total
Acidic Cove Forest (Typic Subtype)	7		12		19
Canada Hemlock Forest (Typic Subtype)	1		2		3
Chestnut Oak Forest (Dry Heath Subtype)	1		23	1	25
Chestnut Oak Forest (Herb Subtype)			3		3
Chestnut Oak Forest (Rhododendron Subtype)			2	1	3
Chestnut Oak Forest (White Pine Subtype)			1		1
Montane Cliff (Acidic Subtype)	3				3
Montane Cliff (Mafic Subtype)	1				1
Montane Oak-Hickory Forest (Acidic Subtype)			8	1	9
Montane Oak-Hickory Forest (White Pine Subtype)			1		1
Pine Oak Heath (Typic Subtype)		2	8	1	11
Rich Cove Forest (Montane Intermediate Subtype)	2		1	6	9
Rocky Bar (Twisted Sedge Subtype)		2			2
Spray Cliff	4			1	5
Swamp Forest Bog Complex (Typic Subtype)	1				1
Waterfall	2				2
White Pine Forest			4		4
Total	22	4	65	11	102

The sample points were grouped using Sorensen's distance with flexible β = -0.5. Flexible β affects the tightness of the dendrogram. The researcher decides which value of β he would like to use, which can range from 1 to –1. If the resulting dendrogram is not easily interpretable, the researcher should use a more negative β (e.g., -0.25) (Lance and Williams, 1967). However, work by Ulrey (personal communication) indicates that using β = -0.5 yields more interpretable results than β = -0.25. The number of groups was set initially to the number of community types identified by the field survey (12) and refined based on the results from interpretation of the dendrograms.

Ordination

Non-metric multidimensional scaling (NMS) was performed to investigate further the environmental conditions underlying the vegetational differences. NMS creates an ordination in which the stands are arranged in n dimensions such that interstand distances in the ordination are, to the maximum extent possible, in the same rank order as the interstand distances measured using an appropriate distance measure (Minchin, 1987). Tests performed using NMS and Sorensen's distance on simulated data revealed that this method performed better than other ordination techniques in recovering the structure of the data (Faith et al., 1987; Kenkel and Orloci, 1986; Minchin, 1987).

Before NMS was performed, an outlier analysis was conducted to identify plots that had distances greater than 2.5 standard deviations from the mean of all interplot distances. These "outliers" were removed and NMS was performed on the remaining plots. I used Sorensen's distance in a two-dimensional NMS analysis, and each axis was transformed using varimax rotation. This rotation assigns the greatest amount of compositional variation explained by the ordination to axis 1, the second greatest to axis 2, and so on for the total number of axes specified. (Preliminary analyses were run with 3 and 4 axes, but the reduction of stress for any additional axes over 2 was not significant.) To reduce the problem of falling into a local minimum, which would result in an inaccurate representation of the data, the ordination was conducted 10 times using random starting numbers to achieve the lowest minimum stress for the specified axes.

Species and environmental overlays were then projected onto the ordination to help identify the underlying latent structure.

RESULTS

Cluster Analysis

Cluster analysis for percentage cover of species yielded 10 distinguishable groups with little chaining (Figure 2-2). The dendrogram had 2 major branches representing dry and mesic sites. Within the "dry" branch I recognized 4 groupings (Groups 1-4). Group 1 was the largest and most variable. It was characterized by many of the common species of the study area: *Acer rubrum*, *Oxydendrum arboreum*, *Kalmia latifolia*, *Pinus strobus*, *Quercus prinus*, *Quercus coccinea*, and *Quercus alba*. Average species richness for this group was 31. Community types associated with Group 1 were CODH, MOH, POH, and WP. The variability within this group resulted from the widespread species shared between the common community types (Chestnut Oak Forest and Montane Oak-Hickory Forest). However, in a few cases rare communities were also included in this group: WP and POH.

Group 2 had a significant component of yellow pines differentiating it from vegetation of all other dry sites. Generally yellow pines (*Pinus rigida* and *Pinus virginiana*) made up 40% or more of the percentage cover within the canopy and subcanopy. These plots averaged 29 species with *Q. prinus*, *A. rubrum*, *Symplocos tinctoria*, *K. latifolia*, *Nyssa sylvatica*, and *O. arboreum* contributing significant cover in addition to the yellow pines. Stands identified within this group were all POH except one CODH, which could be considered a transition from POH to CODH.

********** CLUSTER ANALYSIS: SORENSEN DISTANCE, FLEXIBLE BETA   ********

```
NMS NC Gorges (Percentage Cover)
Flexible beta value selected is  -.500
Percent chaining =   1.24

                         Distance (Objective Function)
          .025           8.423          16.821          25.219          33.617
          |-------+-------+-------+-------+-------+-------+-------+-------+
                         Information remaining (%)
     100.000          75.000          50.000          25.000            .000
          |-------+-------+-------+-------+-------+-------+-------+-------+
AP-101 (POH)    |----|
GP-073 (POH)    |    ||
GP-148 (CODH)   |-|  ||
GP-168 (CODH)   | |--||-----|
GP-149 (MOH)    |-|   |     |
RP-111 (CODH)   |     |     |
GP-052 (WP)     -|----|     |
GP-072 (POH)    -|          |---|
GP-109 (CODH)   ||          |   |
RP-103 (POH)    |||         |   |
GP-169 (MOH)    |||-|       |   |
GP-187 (POH)    | | |-------|   |
GP-225 (CODH)   --| |           |
GP-158 (MOH)    |---|           |
GP-162 (CODH)   |               |--------|
GP-090 (CODH)   |----|          |        |                      GROUP 1
GP-177 (CODH)   |    |          |        |
GP-189 (CODH)   |    |-----|    |        |
GP-173 (WP)     ||   |     |    |        |
GP-207 (CODH)   |||  |     |    |        |
GP-188 (MOHW)   -||--|     |    |        |
GP-219 (WP)     --|        |----|        |
GP-156 (MOH)    |          |             |-------|
GP-191 (MOH)    |--------| |             |       |
GP-175 (CODH)   |        | |             |       |
GP-159 (CODH)   |        |-|             |       |
GP-231 (CODH)   |--|     |               |       |
GP-182 (CODH)   |  |-----|               |       |
GP-217 (CODH)   ---|                     |       |
AP-102 (POH)    |--|                     |       |
GP-087 (POH)    |  |---------------------|       |
GP-049 (POH)    |-||                             |              GROUP 2
GP-203 (POH)    | ||                             |----------------------------|
GP-051 (CODH)   | |                              |                            |
GP-201 (POH)    |-|                              |                            |
GP-167 (POH)    |                                |                            |
GP-101 (CODH)   ---|-----|                       |                            |
GP-150 (COH)    ---|     |---------|             |                            |
GP-138 (CODH)   |        |         |             |              GROUP 3       |
GP-208 (COH)    |--------|         |---|         |                            |
GP-194 (CODH)   |                  |   |         |                            |
GP-190 (COH)    ----------|----|   |   |         |                            |
GP-204 (COWP)   ----------|    |---|   |         |                            |
GP-193 (CODH)   |              |       |---------|                            |
GP-206 (CODH)   |--------------|       |                                      |
GP-205 (CODH)   |                      |                                      |
GP-163 (CODH)   --|--------|           |                                      |
RP-106 (COR)    --|        |-----------|                        GROUP 4       |
GP-220 (COR)    -|---------|                                                  |
RP-108 (MOH)    -|                                                            |
AP-103 (RB)     ---|------------------------|                   GROUP 5       |
AP-104 (RB)     ---|                        |                                 |
EP-101 (SC)     -------------|              |                                 |
EP-109 (SC)     -|-----|     |-----|        |-------------|                   |
EP-110 (SC)     -|     |-----|     |----|   |             |     GROUP 6       |
```

```
EP-118 (MC)     -------|           |    |   |             |                   |
RP-109 (SC)     -------------------|    |---|             |                   |
EP-107 (MC)     ------|-------|         |                 |                   |
EP-112 (MC)     ------|       |-----|   |                 |                   |
EP-113 (MC)     --------------|     |---|                 |     GROUP 7       |
EP-115 (SFB)    ----------------|---|                     |                   |
EP-119 (CODH)   ----------------|                         |                   |
EP-102 (RC)     -----|------|                             |                   |
RP-101 (RC)     -----|      |----|                        |                   |
EP-117 (RC)     --|-|       |    |                        |-------------------|
RP-110 (RC)     --| |-------|    |                        |
GP-082 (AC)     ----|            |------------------|     |     GROUP 8
GP-048 (AC)     |--------|       |                  |     |
GP-165 (AC)     |        |-|     |                  |     |
GP-092 (RC)     ---------| |-----|                  |     |
GP-066 (AC)     ------|----|                        |     |
RP-102 (RC)     ------|                             |     |
EP-103 (AC)     |--|                                |     |
EP-121 (AC)     |  |----|                           |     |
GP-050 (AC)     -|-|    |-----|                     |     |
GP-125 (CH)     -|      |     |                     |-----|
GP-146 (CH)     --------|     |---|                 |
EP-111 (CH)     ------|-|     |   |                 |           GROUP 9
GP-047 (WP)     --|---| |-----|   |                 |
GP-129 (AC)     --|     |         |-----------|     |
EP-122 (AC)     --------|         |           |     |
EP-116 (AC)     ---|----|         |           |     |
EP-120 (AC)     ---|    |---------|           |     |
GP-064 (AC)     -----|--|                     |     |
GP-181 (AC)     -----|                        |-----|
EP-104 (AC)     ----|---|                     |
GP-157 (AC)     ----|   |------------|        |
GP-174 (AC)     ------|-|            |        |
GP-226 (AC)     ------|              |        |
EP-114 (AC)     -------|             |--------|
GP-180 (COR)    ||     |-------|     |
GP-209 (MOH)    ||--|  |       |     |                          GROUP 10
GP-211 (CODH)   -|  |--|       |-----|
RP-107 (RC)     ----|          |
GP-117 (MOH)    -------|-----| |
GP-130 (AC)     ----|--|     |-|
GP-218 (MOH)    ----|        |
RP-104 (RC)     ----------|--|
RP-105 (RC)     ----------|
************************ Cluster analysis completed ************************
```

Figure 2-2. Cluster analysis using Sorensen's distance and flexible â=-0.5. Plot numbers are followed by 4th Approximation community types indicated in parentheses. Plot numbers are preceded by codes indicating method of establishment: aerial photo (AP); expert input (EP); grid point (GP); and random encounter (RP). Community Codes: (AC) Acidic Cove Forest; (CH) Canada Hemlock Forest; (CODH) Chestnut Oak Forest (Dry Heath Subtype); (COH) Chestnut Oak Forest (Herb Subtype); (COR) Chestnut Oak Forest (Rhododendron Subtype); (COWP) Chestnut Oak Forest (White Pine Subtype); (MCA) Montane Cliff (Acidic Subtype); (MCM) Montane Cliff (Mafic Subtype); (MOH) Montane Oak-Hickory Forest; (MOHW) Montane Oak-Hickory Forest (White Pine Subtype); (POH) Pine Oak Heath (Typic Subtype); (RC) Rich Cove Forest (Montane Intermediate Subtype); (RB) Rocky Bar (Twisted Sedge Subtype); (SC) Spray Cliff; (SFB) Swamp Forest Bog Complex; (WP) White Pine Forest.

Group 3 had a significant amount (50-95%) of *Q. prinus* and/or *Q. coccinea* and did not have as dense a *K. latifolia* shrub layer as plots assigned to Group 1. This group was also characterized by the presence of *A. rubrum*, *Gaylussacia ursina*, and *O. arboreum* and an average species richness of 30. Communities associated with this group were CODH, COH, and COWP.

The last group of dry sites (Group 4) appeared to have an influence of *Rhododendron maximum*, which seems a little unusual for dry-site communities. *R. maximum* is typically associated with more mesic sites like coves, north facing slopes, and riverbanks. However, the composition of the overstory (*Q. prinus* and *Q. coccinea*) resulted in these plots being grouped with the drier sites. These plots had a low average species richness of 24, possibly resulting from the shading of herbaceous plants by the dense *R. maximum* layer. Community types associated with this group were CODH, COR, and MOH.

The mesic branch was comprised of 6 groups (Groups 5-10). These groups were generally characterized by having a large component of *Liriodendron tulipifera*, except for Groups 5 and 6, which did not have overstory species. Group 5 was composed of rocky areas that were disturbed by fluctuations in the water level of the river on a regular basis. Significant species for this group were *Carex torta*, *Laportea canadensis*, *Xanthorhiza simplissima*, and *Hypericum* species. Average species richness was 25. Plots within this group were identified as RB.

Group 6 was characterized by steep terrain and wet conditions in which bryophytes, *L. canadensis*, *Saxifraga micranthidifolia*, and *Thalictrum clavatum* dominated. Average richness for this group was 29. Community types identified for Group 6 were SC and MCM.

Plots classified into Group 7 were generally characterized by areas of steep slopes and exposed rock and had low species diversity (24). *L. tulipifera*, *R. maximum*, and *Hydrangea radiata* were common in these areas. Stands within this group were classified as MCA, SFB, and CODH.

Group 8 had the highest average species richness (51) and was distinguished by species typical of rich soils. *Fraxinus americana*, *Halesia tetraptera*, *Asimina triloba*, and *Polygonatum biflorum* were significant within this group in addition to *L. tulipifera*. Community types identified for Group 8 included RC and AC. The acidic coves assigned to this group fall on the rich side of this community type and contain such species as *Adiantum pedatum*, *F. americana*, *Laportea canadensis*, and *Tilia heterophylla*, in addition to species more commonly associated with acidic coves (e.g., *Tsuga canadensis*, *Leucothoe fontanesiana*, *Tiarella cordifolia*, *Betula lenta*).

Plots with significant cover of *T. canadensis* (in general, greater than 50%) were assigned to Group 9. Other species that were important for this group were *L. tulipifera*, *R. maximum*, *B. lenta*, and in some cases *Liquidambar styraciflua*. Average species richness for these plots was 32. Community types included in this group were CH, AC, and WP.

Plots of Group 10 were characterized by high species richness (49). *L. tulipifera, P. strobus, Magnolia fraseri, Robinia pseudo-acacia*, and *Q. prinus* characterized the overstory of this group; there also appeared to be an influence from *C. alba* within this group. Community types identified in this group were AC, COR, MOH, CODH, and RC.

Ordination

Preliminary investigations showed that two axes were sufficient for explaining the underlying structure of the data set. Axis 1 accounted for the most variation with a coefficient of determination (r^2) of 0.600 while r^2 for axis 2 was 0.241. Projection of environmental vectors onto the ordination indicated that TSI was positively associated with axis 1 (r^2=0.361) while elevation had a negative association (r^2=0.207) with the primary axis (Figure 2-3). Elevation also had a positive relationship with the secondary axis (r^2=0.174) that could indicate a temperature gradient.

Overlay of species vectors showed that *L. tulipifera*, *Parthenocissus quinquefolia, Polystichum acrostichoides*, and *Tiarella cordifolia* had a strong, positive association with axis 1 (r^2=0.586, 0.584, 0.574, and 0.530, respectively) and Groups 6 and 10. *Q. coccinea, K. latifolia, and O. arboreum* had a strong relationship with Groups 1 and 2 and were significantly negatively associated with axis 1 and positively associated with axis 2 (Figure 2-4).

The distribution of groups identified by cluster analysis along axis 1 indicated a strong relationship with TSI (Figure 2-3) progressing from exposed sites to more topographically protected ones from left to right on the primary axis. Elevation showed a trend with axis one and axis two contributing to the separation of Groups 9 and 10. While the same trends were evident with the 4th Approximation community types, the separation between classes was not as distinct (Figure 2-5).

DISCUSSION

Numerical classification is a single factor approach, in this situation relying solely on species composition, while the 4th Approximation is a multi-factor approach that takes into account environmental variables, soil pH and fertility, geology, moisture regime, landform, structure, dominant species, and natural disturbance regime in addition to floristic composition. Both are equally valid classification methods that provide different representations of vegetation in the study area based on different relationships. The question then becomes: which method might be more appropriate for the classification and mapping of communities in the Gorges State Park considering the objectives of the project – to successfully predict the locations of rare communities?

The cluster analysis depended on species presence and their percentage cover, thus, the analysis focused on existing vegetation. While this method is a single factor approach, species composition indirectly provides information about essential environmental factors as illustrated by Figure 2-3, where groups exhibit a relationship with TSI and elevation in NMS space. Species require a certain range of environmental conditions to survive and reproduce successfully. As one moves across the landscape these conditions change, resulting in different combinations of environmental factors and, thus, the occurrence of different species. In other words, species composition can be considered a surrogate measure of environmental conditions. Therefore, even though

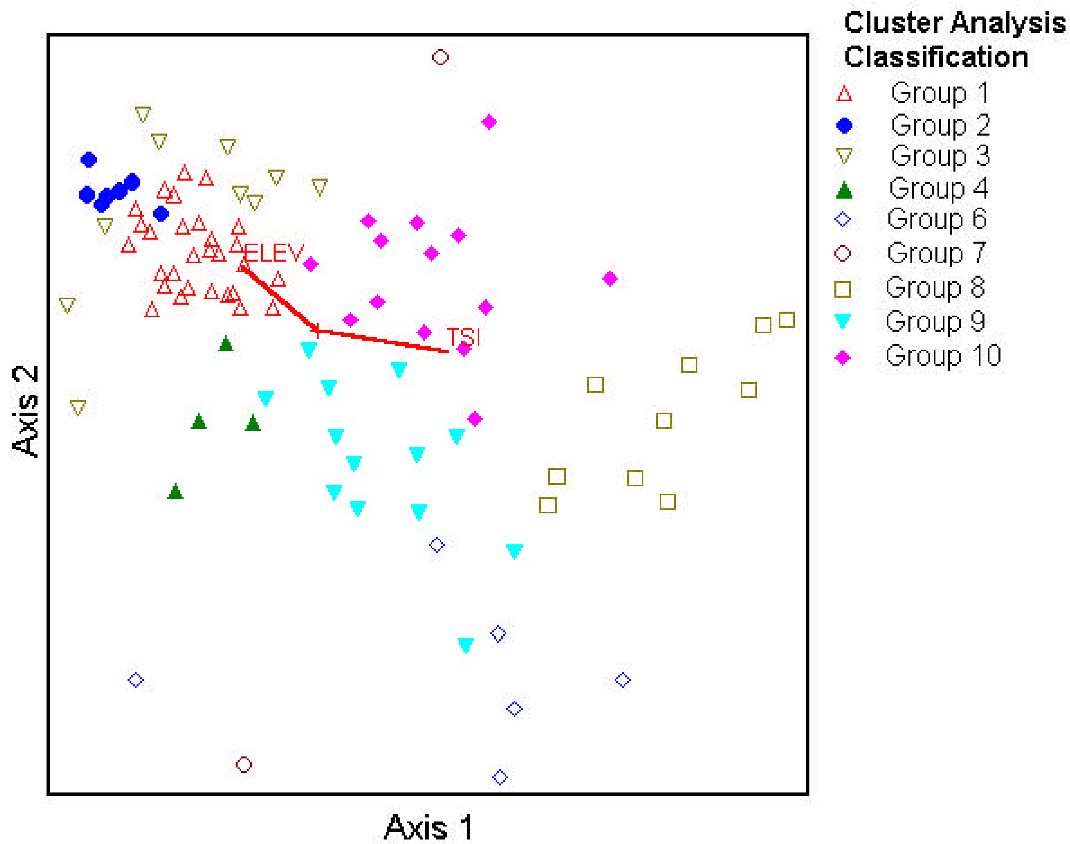


Figure 2-3. NMS with overlay of types identified by cluster analysis. Significant environmental variables are shown as vectors.

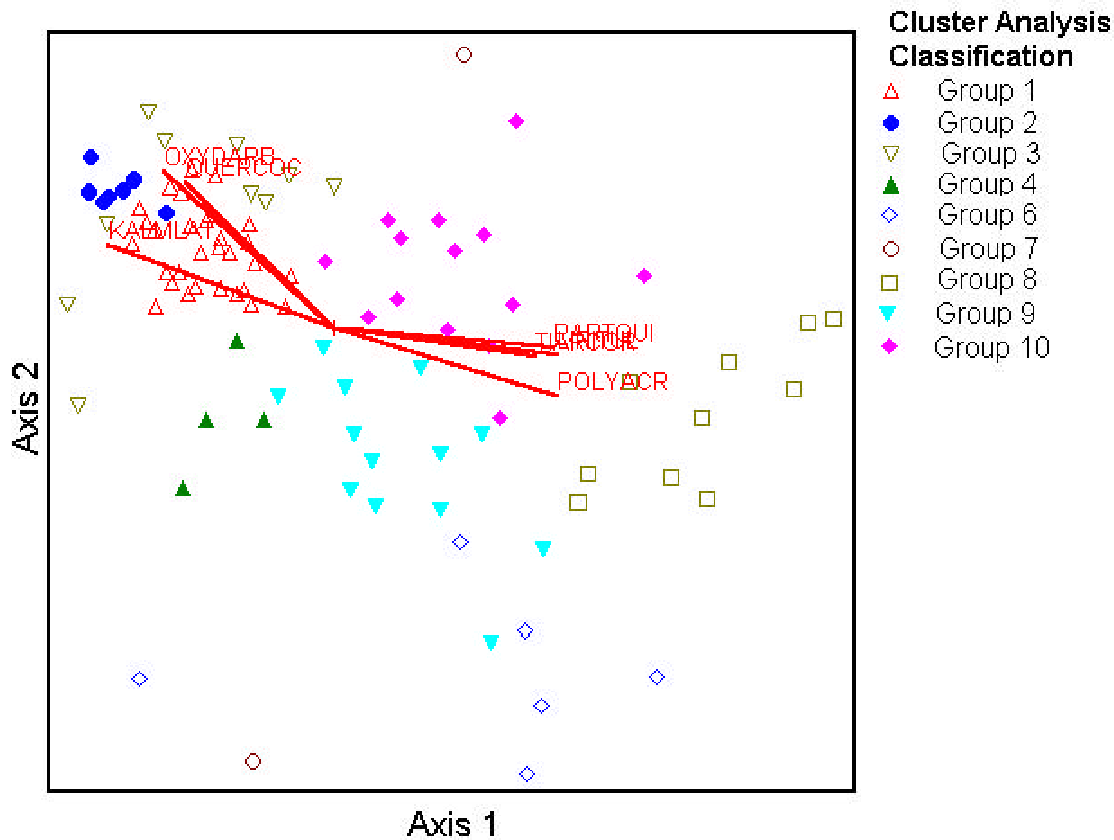


Figure 2-4. NMS with overlay of types identified by cluster analysis. Species are shown as vectors. Species codes: KALMLAT – *Kalmia latifolia*, LIRITUL – *Liriodendron tulipifera*, PARTQUI – *Parthenocissus quinquefolia*, POLYACR – *Polystichum acrostichoides*, OXYDARB – *Oxydendrum arboreum*, QUERCOC – *Quercus coccinea*, and TIARCOR – *Tiarella cordifolia*.

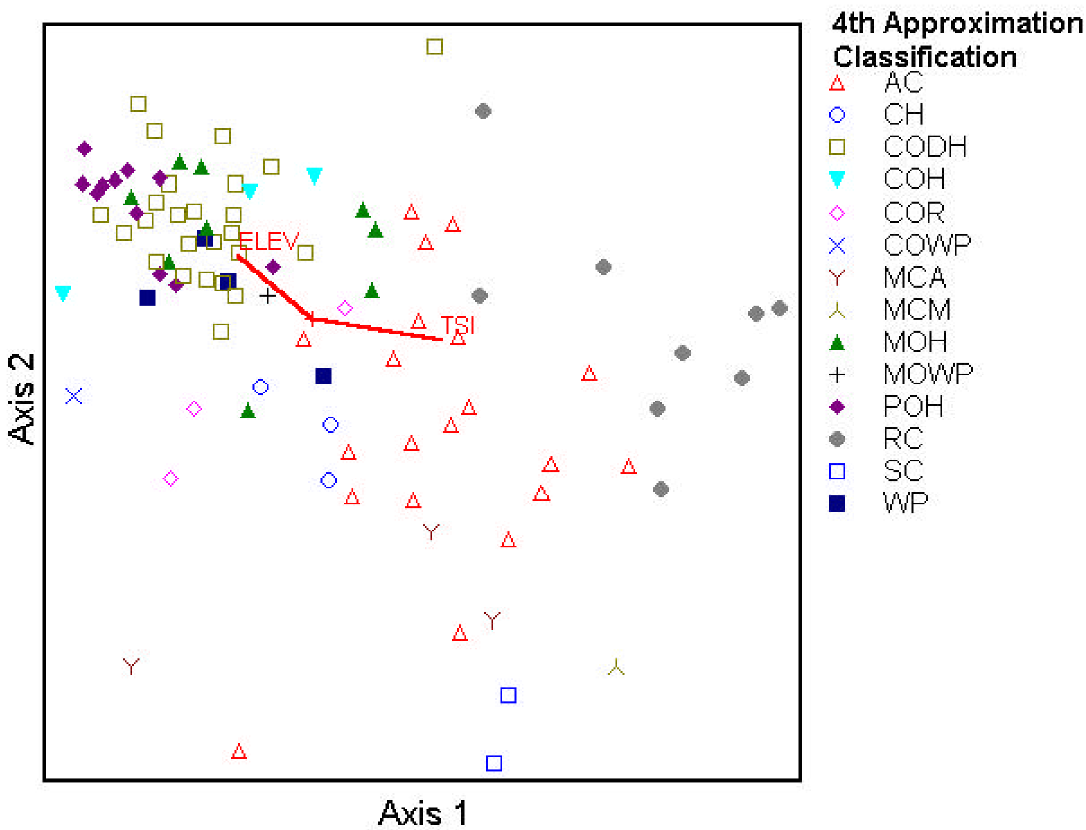


Figure 2-5. NMS with overlay of types identified according to the 4th Approximation. Significant environmental variables are shown as vectors. Abbreviations: ELEV – elevation and TSI – terrain shape index.

numerical analysis is focusing on one factor, it is actually providing information about a complex of variables.

Conversely, the 4th Approximation incorporates various factors into its classification to infer the potential vegetation for a specific location given human disturbance is removed. These factors play an important role in distinguishing between community subtypes (e.g., Rich Cove Forest (Montane Intermediate Subtype) vs. Rich Cove Forest (Rich Subtype) in which soil fertility is significant, and Rich Cove Forest (Montane Intermediate Subtype) vs. Rich Cove Forest (Foothills Subtype) in which elevation influences the plant assemblages), but result in a less distinct separation along the ordination axes.

Cluster analysis recognized distinct groups that corresponded to the 4th Approximation classification of rare communities. Groups 2, 5, 6, and 7 coincided with POH, RB, SC, and MC, respectively. Group 8 was similar to RC with the addition of rich acidic cove forests characterized by a richer herbaceous layer than typically expected. The common species had a major effect on cluster analysis group formations. The other types recognized by this method were generally a mixture of common community types with the exception of Group 9, which was primarily composed of plots identified as AC. These conglomerations of common community types result from species that have broad ranges in the study area, which caused plots that were significantly different with respect to structure, environmental conditions, and species composition to be classified as a single community type. For example, plots located on narrow ridge tops and dominated by *P. virginiana* and *P. rigida* with a dense understory of *K. latifolia* were distinctly different than those dominated by *Q. prinus*, *Q. alba*, *Q. coccinea*, and *P. strobus* and a shrub layer of *K. latifolia* and *G. ursina*; however, they were grouped with these communities as a result of the *K. latifolia* influence.

Moisture/fertility and temperature gradients explain much of the compositional variation for southeastern Blue Ridge escarpment (Mowbray, 1966; Mowbray and Oosting, 1968; Wentworth 1980). Analysis of environmental factors supported this idea as illustrated by the fact that TSI and elevation accounted for much of the differences between community types. Analyses of soils collected for the sites will provide information that could help explain further compositional variation.

Cluster analysis has the advantages of objectivity, repeatability, and being a quantitative approach. It illustrated the highly structured nature of the data, indicating that distinct differences existed between types, which provided important information for the modeling process (Chapter 3). It also showed how the influence of a few common species could result in differences in classification where plots that are essentially different structurally and floristically were grouped into the same type because of the presence of one or two common species. The 4th Approximation provides more ecologically meaningful groups by incorporating other environmental and physical factors in addition to species composition and, therefore, appears to be a more suitable classification scheme for predictive modeling of the communities of the Gorges State Park and Gamelands.

Chapter 3 – Predictive mapping of vegetation communities

INTRODUCTION

Knowledge about the distribution of plant communities is a basic need for the fields of ecology, natural resource management, and conservation. This knowledge is especially important for studying rare or uncommon species, developing management plans for protecting these species, or reducing impact to their habitats. However, it can be difficult to obtain sufficient data about distribution of plant communities in a short amount of time or for remote areas. To address this problem I developed a method for rapid assessment of plant communities and incorporated an approach for predictive modeling and mapping of these communities. Field surveys targeted toward rare communities were combined with predictive modeling to produce community maps for the Gorges State Park and Gamelands in Transylvania County, North Carolina. These predictive maps were created using discriminant function analysis of digital terrain data and a vegetation map developed from aerial photography.

Discriminant function analysis (DFA) discriminates between different categories based on a set of predictor variables. It attempts to find linear combinations of *n* independent variables that maximize among-group to within-group variability and to assign unclassified observations to one of *k* classes (Lowell, 1991). This statistical procedure has been used in ecology for habitat modeling (Clark et al. 1993), prediction of animal distributions (Austin et al., 1996; Corsi et al., 1997; Knick and Dyer, 1997), niche differentiation (Mann and Shugart, 1983), spatial modeling of ecological succession (Lowell, 1991), as well as classification of communities (Heikens and Robertson, 1995).

Vegetation responds to small changes in terrain, mostly as a result of variation in temperature and moisture. These factors are associated with terrain features that can be measured in the field or with the use of digital elevation models (DEMs). The terrain variables, such as slope, aspect, terrain shape index (McNab, 1989), and landform index (McNab, 1993) are then combined to produce digital terrain models (DTMs). The DTMs, in turn, can be used to predict distributions of tree species (Naesset, 1995; Bolstad et al., 1998) or communities (Fels, 1994). In addition to using discriminant function analysis and digital terrain data, I incorporated aerial photographs into the modeling process to increase the accuracy of community prediction.

The objectives of this section of the project were to: 1) develop discriminant functions that adequately distinguish between different community types; 2) generate community maps using discriminant functions and aerial photography; 3) compare the performance of using only discriminant functions to predict community occurrences against using the combination of these functions and aerial photography for prediction; and 4) relate this information to managers involved in development planning for the state park.

METHODS

Field Survey

A field survey with particular emphasis on rare communities was conducted from May - August 1999 to identify plant communities and locations of those communities within the boundaries of the Gorges State Park and adjacent gamelands. (See Chapter 2 for detailed description of field methods.) Plots were established using a 500m x 500m grid, expert knowledge of the study area, the North Carolina Natural Heritage Program's database, interpretation of aerial photographs, and random encounters with rare communities in the field. These sample units were geo-referenced in UTM NAD27 so they could be incorporated into a spatial database. Due to the rugged nature of the landscape, the GPS unit could not always obtain satellite readings. In such cases the locations of plots were approximated on the topographic map using surrounding land features and compass and altimeter readings. Upon returning from the field I transferred the locations of plots to a digital topographic map from which the coordinates were extracted. A total of 102 points were sampled and classified into 16 community types (Table 2-1).

Aerial Photography Interpretation

Aerial photography interpretation (PI) was conducted for the study site using 1:40,000 NAPP photos taken April 2, 1998. Stands of homogeneous vegetation were delineated as polygons and assigned to one of the following cover categories: all deciduous, all evergreen, deciduous with scattered hemlock, deciduous with trace hemlock, deciduous with scattered white pine, deciduous with trace white pine, hemlock dominated, deciduous with evergreen understory, or shrub dominated. These polygons were then digitized and brought into a GIS environment. For detailed description of methodology and results see Bunyan (unpublished).

Discriminant Function Analysis (DFA)

Discriminant functions were developed using SAS statistical software version 7.0 (SAS Institute Inc., 1998) and digital terrain data were generated by John Fels. The coordinates for each sample point were re-projected from UTM NAD27 meters into State Plane NAD83 meters and overlaid on the digital terrain data. The digital terrain data for each plot were then extracted.

In some cases only a few plots represented community types. These types were combined with other plots in order to generate covariance matrices for the DFA. For example, MCM was represented by only one plot, so it was combined with MCA to yield a Montane Cliff class (MC) with 4 plots. Plots that were classified as “Transitional” were grouped into classes that they most closely resembled. Decisions for grouping these plots were based on comparisons of the raw data from a given plot with means from plots belonging to potentially related types (i.e., plots indicated as transitional from AC to MOH were compared to the means of AC and MOH stands and then assigned to the type that had a similar mean). Appendix C contains the list of classes and associated sample sizes used for DFA.

The data were randomly divided into calibration and validation sets (70% and 30%, respectively). The calibration set was examined to identify any unusual values for plots within each community type. This was done by separating the data into respective community types and visually inspecting for “outliers”. Appropriate ranges for each digital terrain variable were determined by plot location and values for each variable were examined to identify any “outliers”.

Determination of which variables to use in the analysis was performed using PROC STEPDISC (SAS Institute Inc., 1990a). This procedure selects which variables should be included in the model based on the significance level of an analysis of covariance F-test and the squared partial correlation for predicting a specific variable from the CLASS variable (SAS Institute Inc., 1990a). The selected variables were then used with the calibration set to develop discriminant functions using the PROC DISCRIM procedure (SAS Institute Inc., 1990b). Eight digital terrain variables were initially input into the model: solar irradiation (abeers), azimuth (azm), elevation (elev), slope, relative slope position index for a radius of 6 and 12 surrounding pixels (rpos6 and rpos12, respectively), terrain shape index (tsi), and weighted landform index (wlfi). Using the STEPDISC procedure with forward stepwise option, variables were input into the model successively until no more significant variables remained (SAS Institute Inc., 1998).

A total of 11 functions was generated, one for each community type, and these were applied to the validation set. Three different sets of functions (Appendix D) were developed to meet the needs of different users having different interests. The first set generated was based on the assumption that all communities had an equal chance of occurring at a location (prior probabilities equal). This approach assumed that rare communities had the same chance of occurrence at a specific location as did common communities. Since the field survey was biased toward the rare communities, this set erred on the side of inclusiveness (i.e., it included all possible locations of these community types plus many others not supporting these communities). This approach results in many errors of commission from the point of view of the rare communities.

The second set of functions used hypothesized values of each community type’s coverage within the park boundaries as the probability that the community would occur at a location. Consultation with ecologists familiar with the region yielded the following values: 30% CODH, 20% MOH, 15% AC, 10% COH, 5% COR, 5% COWP, 5% POH, 4% MOWP, 2.5% RC, 2% CH, 1% WP, 0.4% MC, 0.09% RB, and 0.01% SC. The prior probabilities were set to these values and another set of functions was generated. In this situation common communities have a greater likelihood of occurring at sites than rare communities, which results in under-representation of the rare communities (errors of omission).

The third set of functions generated was based on the output from the discriminant functions in set one. It was observed that RB and SC were grossly over-predicted; therefore these 2 types were removed from the data set and the analysis was re-run.

Model Generation

Using ERDAS IMAGINE image analysis software version 8.4 Spatial Modeler (ERDAS Inc., 2000), I applied the discriminant functions to DTMs created by John Fels to produce an image for each community type. I assigned a value to every pixel indicating the likelihood that the pixel belonged to that specific community type. This process was repeated for all community types so that there were a total of 11 images. The 11 images were then stacked to produce a single image in which each pixel had 11 values corresponding to the 11 community types.

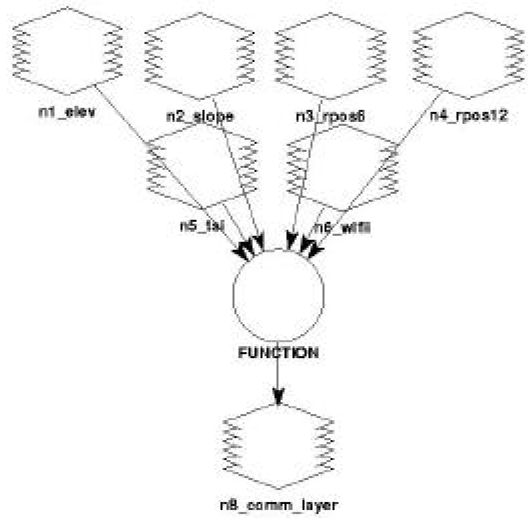
I generated another image that consisted of the maximum values as determined by the discriminant functions for each pixel. This image was then indexed with the stacked image to identify from which layer (community type) the maximum value came, and the pixel was assigned to the appropriate type. This process was repeated for each set of functions, resulting in 3 maps. Figure 3-1 shows a graphical representation of the model used for generating each community map.

The PI cover categories were then used as a filter to constrain the community types that could be associated with each pixel. These cover categories were general groups that could include one to many of the community types identified. Using the rules defined in the accuracy assessment of the PI vegetation map (Bunyan, unpublished), community types were assigned to the appropriate cover categories (Appendix E). Small communities (e.g., RB, MC, and SC) were included in each cover category since they could occur beneath the tree canopy, making it difficult to identify them from the aerial photos.

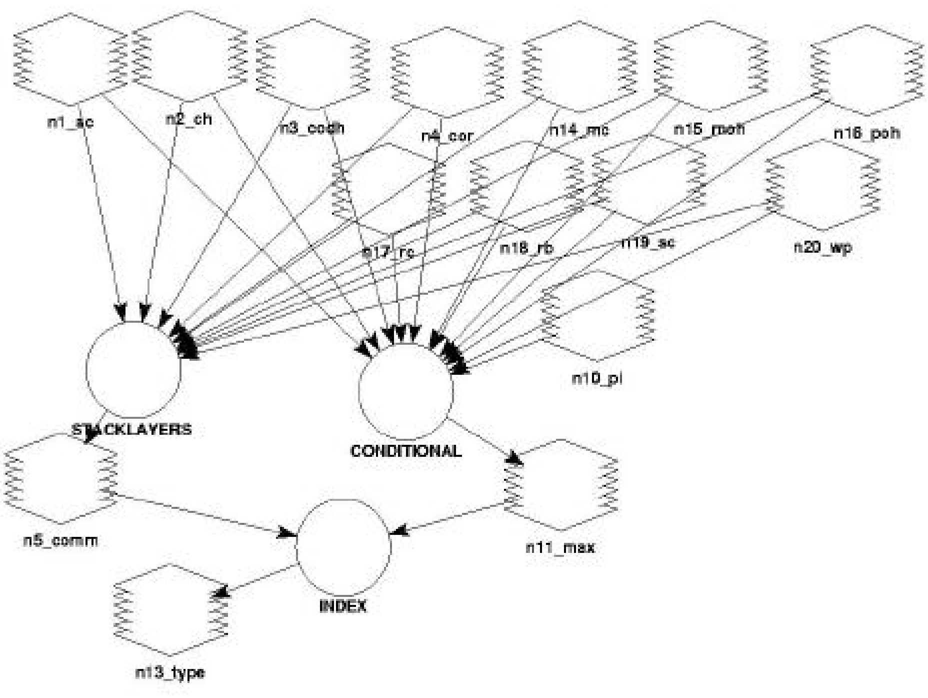
An image was generated identifying the maximum value for each pixel under the appropriate constraints. This image was indexed to the stacked image as done previously, and the pixel was assigned to the corresponding community type. This process was performed 3 times, once for each function set, resulting in 3 community maps. Thus a total of 6 maps were generated, 3 based solely on the functions (Figures 3-2 through 3-4) and 3 based on both the functions and PI cover categories (Figures 3-5 through 3-7).

Accuracy Assessment

The images were exported into the geographic information system (GIS) and displayed with the field points to examine each map's accuracy. For the accuracy assessment, the common communities (CODH, COH, COR, COWP, MOH, MOHW) were grouped into one type called "matrix" (MATRIX). Two field points were excluded from the accuracy assessment because they fell outside the range of the PI map. Each field point was buffered to 30 m to account for positional error in both the geo-referenced coordinates and digital elevation model from which the terrain variables were derived. Overall producer's and user's accuracies were computed. Producer's accuracy measures the probability a category originally visited in the field is identified correctly by the map while user's accuracy measures the reliability of the map to the user (i.e., the probability that an area mapped as community A actually is A). Since different parties might be more concerned with producer's or user's accuracy depending on their objectives, both are reported with standard errors.



A.



B.

Figure 3-1. Graphical display of the model used for creating predictive community maps. Stacked boxes indicate input layers (e.g., community types, PI cover categories). Circles denote functions performed. See text for explanation of function steps. A) Illustration of how each community layer was generated from the environmental variables. B) Illustration of how community layers were combined to produce predictive community map.

RESULTS

Discriminant Function Analysis

Using STEPDISC, elevation, slope, rpos6, rpos12, tsi, and wlfi were determined to be significant (Table 3-1). Validation results were based on the 30 plots withheld from the generation of the discriminant function. Table 3-2 contains the correct classification rates for the validation data of DFA. Discriminant function set 1 (DF set 1), which assumed each community type had an equal chance of occurring at a location, had the highest classification rate at 69%. However, given that the rare communities were of interest, I did not consider important misclassifications between "matrix" community types (Chestnut Oak Forest (CO), COR, and MOH). Recalculating the total correct classification rate yielded 75%. Community types that were most readily distinguished included MC, RB, and SC, with 100% correctly classified, and POH, with 82%. CH, COR, and MOH had 66.67%, 67%, and 63% classification rates, respectively, while the remaining communities had rates of 50% or less. Using the hypothesized coverages of the community types within the park (DF set 2), the classification rate dropped to 65% correct (corrected for matrix community misclassifications the classification rate was 80%). The large increase after correction for matrix community misclassification results from the matrix communities having a greater weight than the uncommon communities, as based on the prior probabilities. MC, CO, COR, and MOH performed the best at 100%, 81%, 67%, and 63%, respectively. All other types were 50% or lower. Removing RB and SC from the data set (DF set 3) produced an overall rate of 67% correctly classified (corrected for matrix misclassifications the classification rate rose to 74%). MC had the highest rate of 100%, while POH had 82%, MOH and RC 75%, and CH and COR 67%.

Table 3-1. Significant terrain variables identified by forward stepwise STEPDISC procedure.

Variable	Partial R-Square	F Value	Pr>F	Wilks' Lambda	Pr < Lambda
wlfi	0.5923	8.57	<.0001	0.4077043	<.0001
slope	0.4193	4.19	0.0002	0.2367607	<.0001
elev	0.4038	3.86	0.0005	0.1411679	<.0001
rpos6	0.2953	2.35	0.0216	0.0994855	<.0001
rpos12	0.2678	2.01	0.0495	0.0728392	<.0001
tsi	0.2927	2.23	0.0291	0.0515196	<.0001

Table 3-2. Correct classification rates for validation set for each set of discriminant functions. Percentages based on the number of plots classified correctly for each community type. "TOTAL" indicates the overall correct classification for each set of discriminant functions. Percentages in parentheses are based on the correct classification of rare communities only, i.e. misclassifications between common communities were not included in the overall correct classification rate.

Community Type	DF set 1	DF set 2	DF set 3
AC	50.00%	50.00%	50.00%
CH	66.67%	33.33%	66.67%
CO	47.62%	80.95%	52.83%
COR	66.67%	66.67%	66.67%
MC	100.00%	100.00%	100.00%
MOH	62.50%	62.50%	75.00%
POH	81.82%	18.18%	81.82%
RC	50.00%	50.00%	75.00%
RB	100.00%	0.00%	N/A
SC	100.00%	0.00%	N/A
WP	33.33%	0.00%	33.33%
TOTAL	68.96% (75.37%)	65.49% (80.44%)	66.67% (73.97%)

Accuracy Assessment of Community Maps

The images generated in IMAGINE were brought into GIS and accuracy assessments were performed (Figures 3-2 through 3-7). For DF set 1 without using the vegetation map as a filter (Table 3-3a), MC, RB, MATRIX, and SC had high producer's accuracies (100%, 100%, 86%, and 83%, respectively). User's accuracy was highest for CH at 100%, POH at 90%, MATRIX at 86%, and SC at 83%. Producer's accuracy for DF set 2 without the filter (Table 3-3b) was similar to that of DF set 1 (no filter) in that

MATRIX, MC and RB had the highest accuracies (100%) while CH and RB had user's accuracies of 100%. Table 3-3c shows DF set 3 without a filter had a producer's accuracy for MC 100% and MATRIX 83%. CH, POH, and MATRIX had high user's accuracies of 100%, 88.89%, and 85.37%, respectively.

Incorporating the filter into generation of the community map resulted in slightly lower accuracy overall (Table 3-4a-c). However, 2 community types (AC, POH) seemed to be significantly affected. The producer's accuracy for AC increased from 58% to 84% in DF set 1 while the producer's accuracy for POH dropped from 73% to 18% in DF set 1 and DF set 3. Other communities with high producer's accuracy for DF set 1 were MC (100%), RB (100%), and SC (83%). High user's accuracies were associated with POH (100%), MATRIX (89%), and SC (83%). DF set 2 with the filter applied resulted in high producer's accuracies for MC (100%), RB (100%), and MATRIX (93%) while RB and SC had 100% for user's accuracies. MC (100%) and MATRIX (81%) had high producer's accuracies for DF set 3 with filter applied, while RC and MATRIX had high user's accuracies (86% and 85%, respectively).

Standard errors and confidence intervals were computed for all maps. Table 3-5 contains the sample size and standard errors for DF set 1 (with no filter applied) for illustrative purposes. The majority of the community types are characterized by large standard errors resulting from the small sample sizes, an obvious limitation of the data.

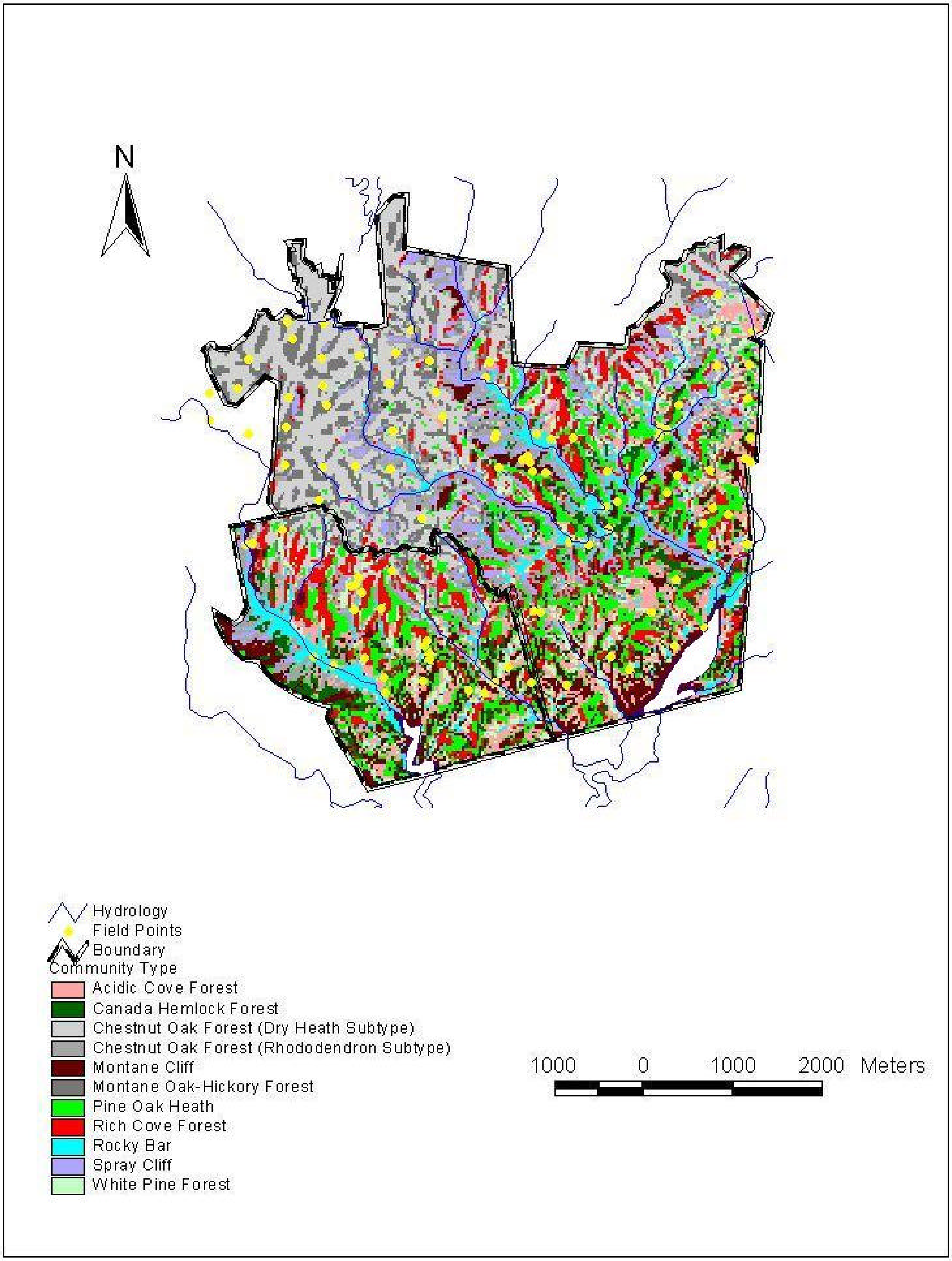


Figure 3-2. Predictive community maps using DF set 1 (priors set equal).

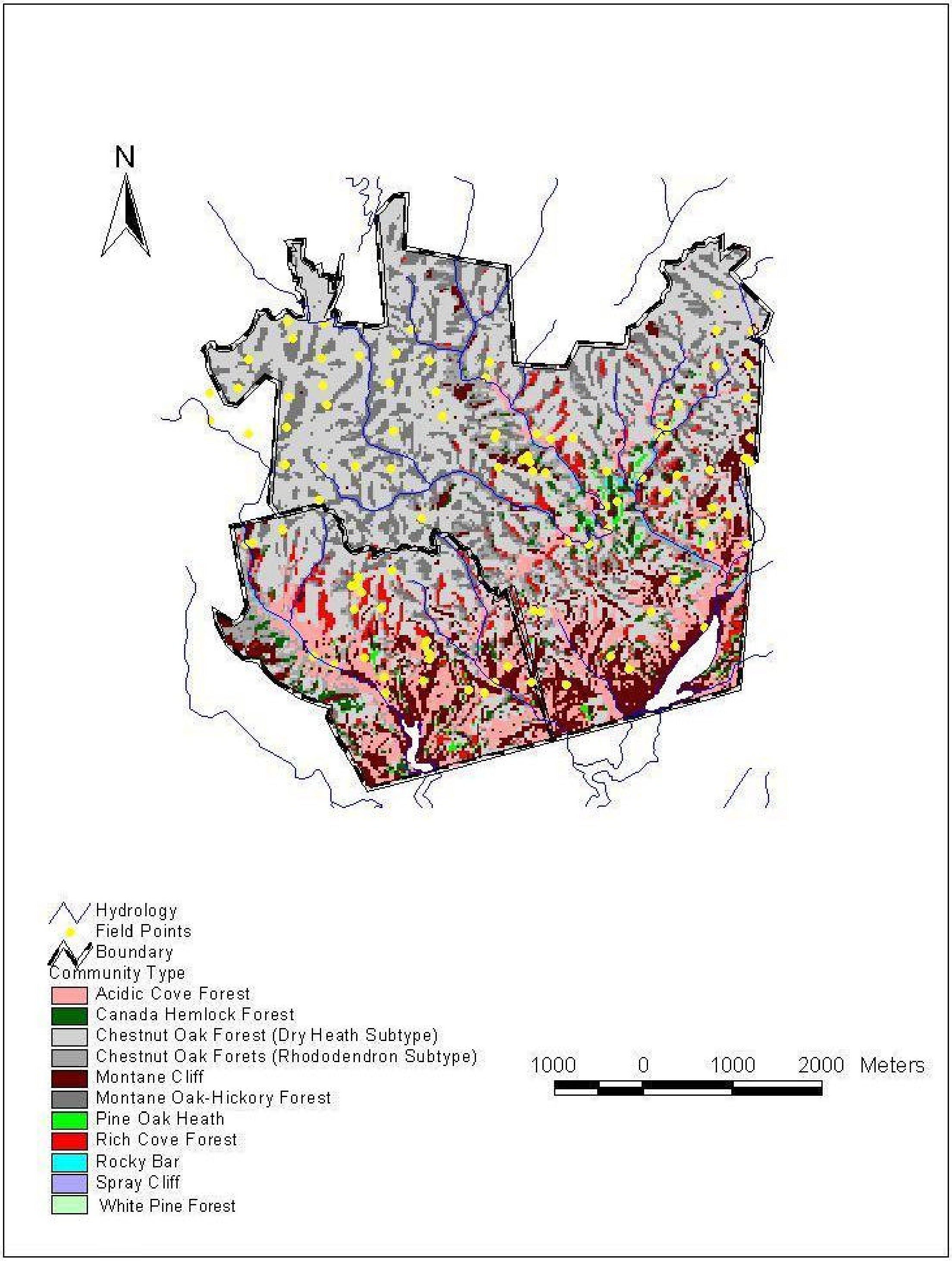


Figure 3-3. Predictive community maps using DF set 2 (priors set to specified values).

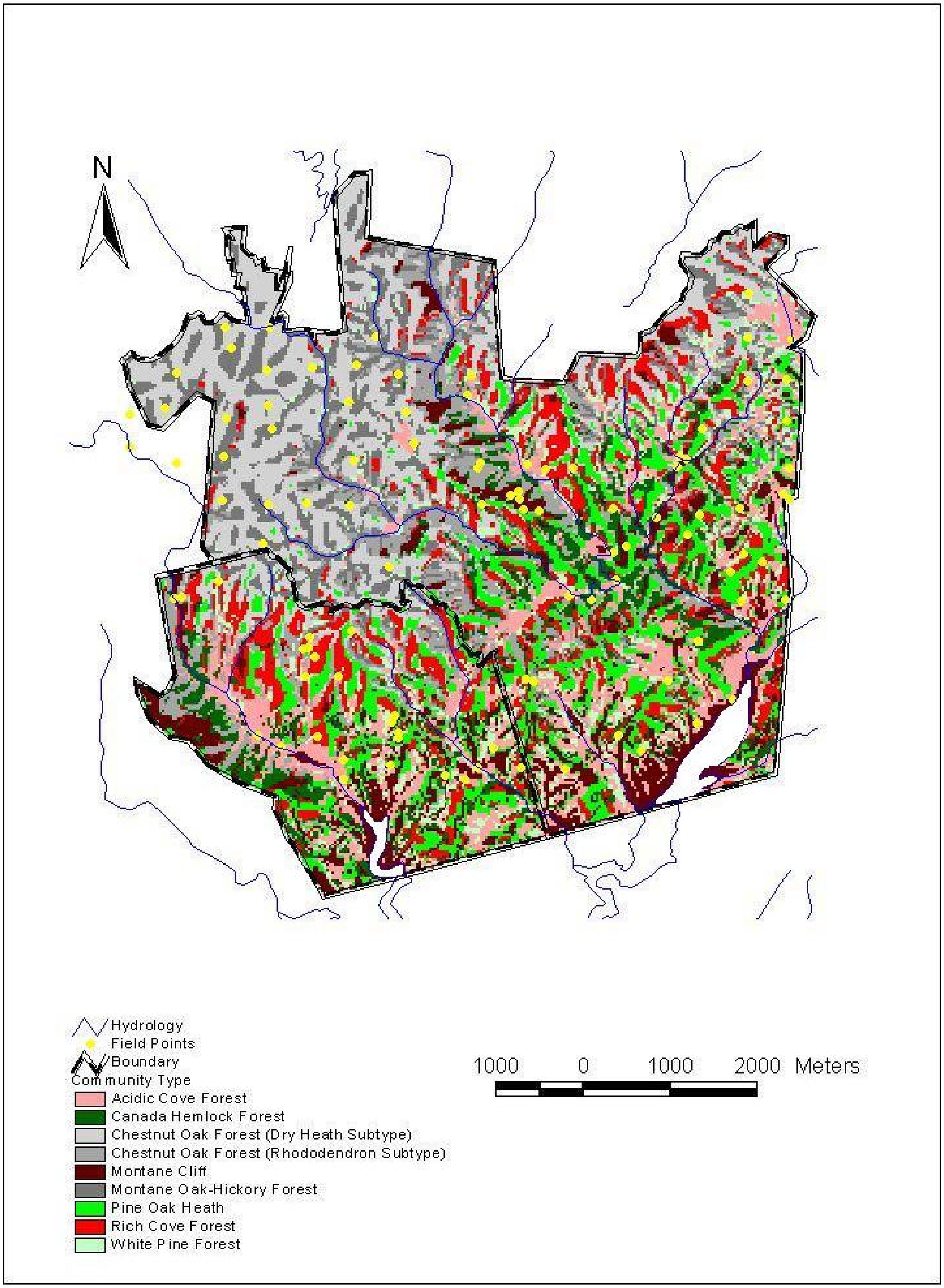


Figure 3-4. Predictive community maps using DF set 3 (Rocky Bar and Spray Cliff communities removed).

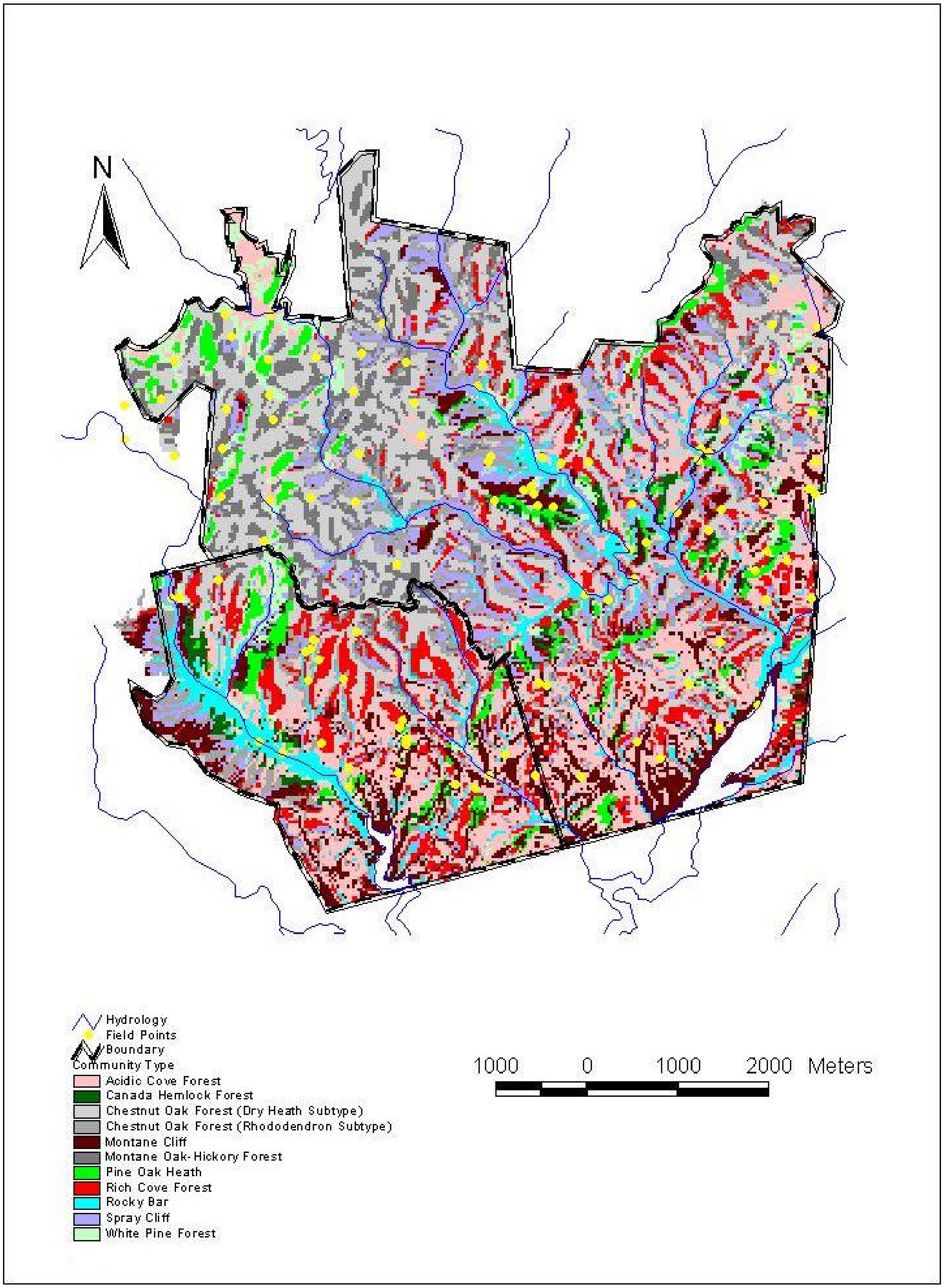


Figure 3-5. Predictive community map using DF set 1 (priors set equal) and PI cover categories as a filter.

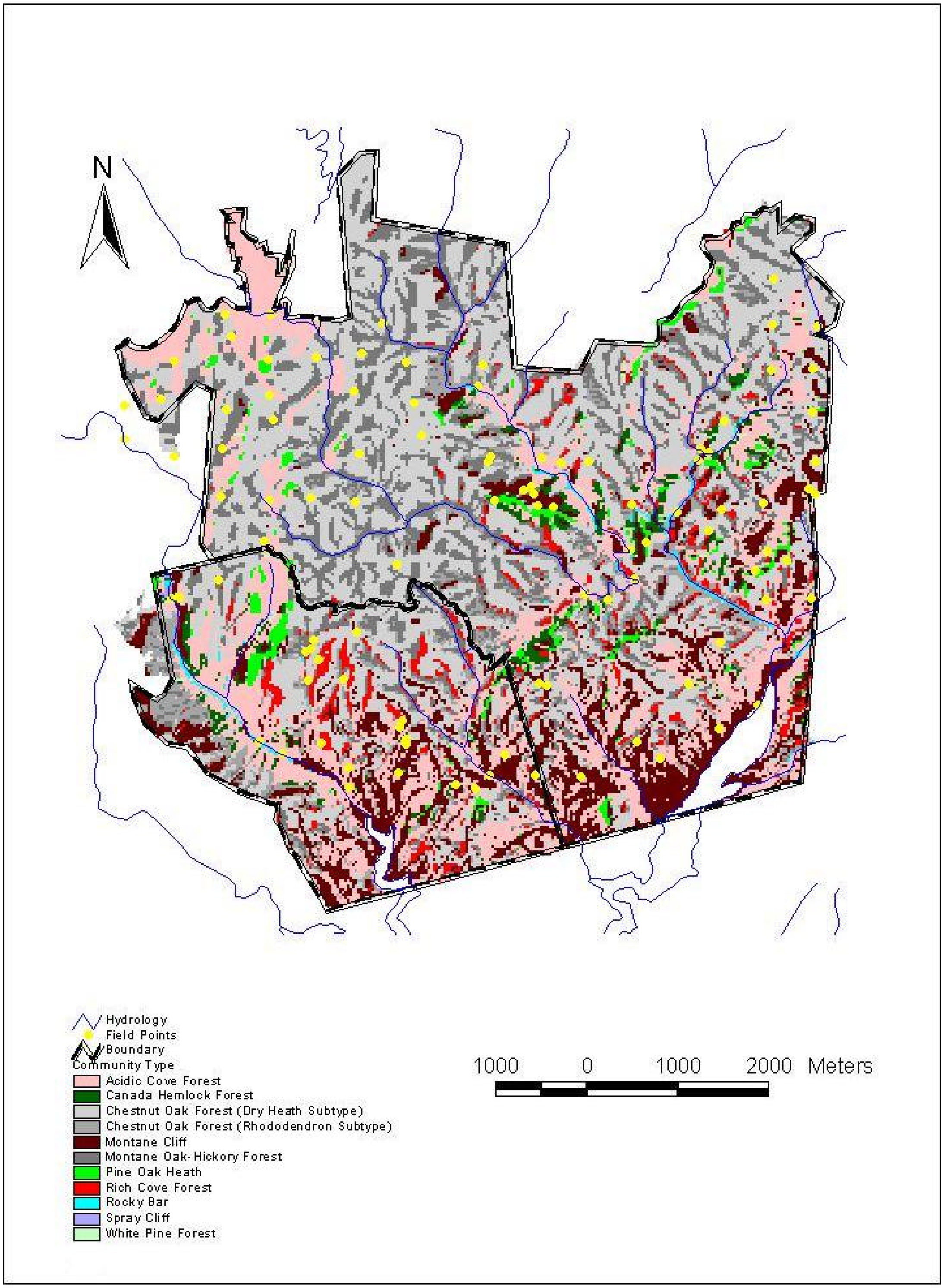


Figure 3-6. Predictive community map using DF set 2 (priors set to specified values) and PI cover categories as a filter.

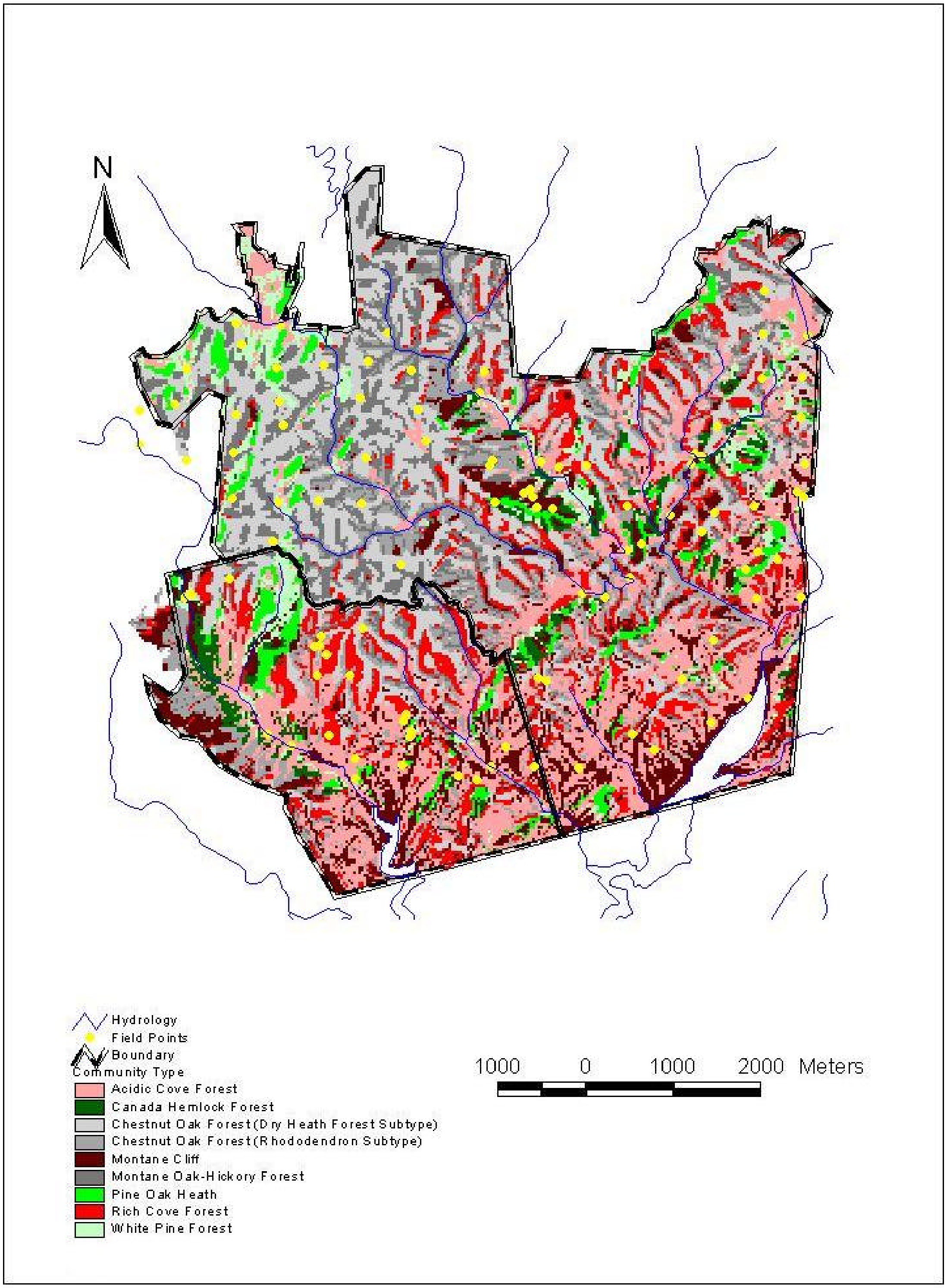


Figure 3-7. Predictive community map using DF set 3 (Rocky Bar and Spray Cliff communities removed) and Pi cover categories as a filter.

Table 3-3. Accuracy assessment for community maps without using the PI cover categories as a filter. (AC) Acidic Cove Forest; (CH) Canada Hemlock Forest; (MATRIX) Matrix including Chestnut Oak Forest, Chestnut Oak Forest (Rhododendron), and Montane Oak-Hickory Forest; (MC) Montane Cliff; (POH) Pine Oak Heath; (RC) Rich Cove Forest; (RB) Rocky Bar; (SC) Spray Cliff; (WP) White Pine Forest; (PA) Producer's Accuracy; (UA) User's Accuracy.

(a) DF set 1
Field Data

		AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
ed Types	AC	11		2		2					15	73.33%
	CH		2								2	100.00%
	MATRIX	3		36			1			2	42	85.71%
	MC	2		1	4	1	2				10	40.00%
	POH	1				8					9	88.89%
	RC	1		2			5				8	62.50%
	RB		1					2	1		4	50.00%
	SC						1		5		6	83.33%
	WP	1		1						2	4	50.00%
	TOTAL	19	3	42	4	11	9	2	6	4	100	
	PA	57.89%	66.67%	85.71%	100.00%	72.73%	55.56%	100.00%	83.33%	50.00%		75.00%

(b) DF set 2
Field Data

		AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
Predicted Types	AC	11	1			1	1		1		15	73.33%
	CH		2								2	100.00%
	MATRIX	4		42		7	2		4	2	61	67.21%
	MC	3			4	3	2			2	14	28.57%
	POH					0					0	0.00%
	RC	1					4		1		6	66.67%
	RB							2			2	100.00%
	SC								0		0	0.00%
	WP									0	0	0.00%
	TOTAL	19	3	42	4	11	9	2	6	4	100	
	PA	57.89%	66.67%	100.00%	100.00%	0.00%	44.44%	100.00%	0.00%	0.00%		65.00%

(c) DF set 3
Field Data

		AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
Predicted Types	AC	12	1	1		1				1	16	75.00%
	CH		2								2	100.00%
	MATRIX	3		35			1			2	41	85.37%
	MC	2			4		2				8	50.00%
	POH			1		8					9	88.89%
	RC	1		3			6				10	60.00%
	RB							0			0	0.00%
	SC								0		0	0.00%
	WP	1		2		2				1	6	16.67%
	TOTAL	19	3	42	4	11	9	0	0	4	92	
	PA	67.52%	66.67%	83.33%	100.00%	72.73%	66.67%	0.00%	0.00%	25.00%		73.91%

Table 3-4. Accuracy assessment for community maps using the PI cover categories as a filter. (AC) Acidic Cove Forest; (CH) Canada Hemlock Forest; (MATRIX) Matrix including Chestnut Oak Forest, Chestnut Oak Forest (Rhododendron), and Montane Oak-Hickory Forest; (MC) Montane Cliff; (POH) Pine Oak Heath; (RC) Rich Cove Forest; (RB) Rocky Bar; (SC) Spray Cliff; (WP) White Pine Forest; (PA) Producer's Accuracy; (UA) User's Accuracy.

(a) DF set 1
Field Data

Predicted Types

	AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
AC	16		3		5				1	25	64.00%
CH		2	1							3	66.67%
MATRIX	1		32		1				1	35	88.57%
MC	1		1	4	3	2				11	36.36%
POH					2					2	100.00%
RC	1		3			6				10	60.00%
RB		1					2	1		4	50.00%
SC						1		5		6	83.33%
WP			2						2	4	50.00%
TOTAL	19	3	42	4	11	9	2	6	4	100	
PA	84.21%	66.67%	76.19%	100.00%	18.18%	66.67%	100.00%	83.33%	50.00%		71.00%

(b) DF set 2
Field Data

	AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
AC	13	1	2		3	3		1	2	25	52.00%
CH		2						2		4	50.00%
MATRIX	2		39		5			1	1	48	79.17%
MC	3			4	3	2			1	13	30.77%
POH					0					0	0.00%
RC	1		1			4		1		7	57.14%
RB							2			2	100.00%
SC								1		1	100.00%
WP									0	0	0.00%
TOTAL	19	3	42	4	11	9	2	6	4	100	
PA	68.42%	66.67%	92.86%	100.00%	0.00%	44.44%	100.00%	16.67%	0.00%		65.00%

(c) DF set 3
Field Data

Predicted Types

	AC	CH	MATRIX	MC	POH	RC	RB	SC	WP	TOTAL	UA
AC	15	1	2		4				1	23	65.22%
CH		2				1				3	66.67%
MATRIX	2		34		2				1	39	84.62%
MC	1		1	4	3	2				11	36.36%
POH			2		2					4	50.00%
RC	1					6				7	85.71%
RB							0			0	0.00%
SC								0		0	0.00%
WP			3						2	5	40.00%
TOTAL	19	3	42	4	11	9	0	0	4	92	
PA	78.95%	66.67%	80.95%	100.00%	18.18%	66.67%	0.00%	0.00%	50.00%		70.65%

Table 3-5. Sample size and standard errors for DF set 1 (no filter applied). (N) sample size; (PA) Producer's Accuracy; (UA) User's Accuracy; (SE) Standard Error; and (UD) Undefined.

DF set 1

Community	N	PA	SE	UA	SE
AC	19	57.89%	23.71	73.33%	24.33
CH	3	66.67%	86.60	100.00%	UD
MATRIX	42	85.37%	11.15	85.37%	11.15
MC	4	100.00%	UD	40.00%	34.52
POH	11	75.00%	27.24	90.00%	21.14
RC	9	55.56%	37.47	62.50%	39.47
RB	2	100.00%	UD	50.00%	69.40
SC	6	83.33%	37.23	83.33%	37.23
WP	4	50.00%	69.40	50.00%	69.40

DISCUSSION

Overall classification rates from DFA were comparable except for DF set 2, where matrix communities were weighted more heavily than rare communities. AC and POH appeared to be affected the most when the filter was incorporated into the modeling. Reasons for the increase of AC producer's accuracy are not quite clear; however, the ability to identify evergreen within the canopy from aerial photos seemed to benefit the prediction of this community. Producer's accuracy of POH decreased with the filter because photo interpretation of these communities was difficult due to their small sizes and irregular shapes along the ridge tops and upper side slopes.

Because rare communities were targeted for field survey, the approach taken resulted in gross over-prediction when not restricted by the prior probabilities or the PI cover map. The community map resulting from DF set 1 without the filter (Figure 3-2) illustrates this point. In this situation relatively small omission errors for rare communities (i.e., high producer's accuracy) were obtained. Omission errors occur when an area that actually is community type A is not classified as A. In other words, the actual locations of a specific community are omitted from areas classified as that particular community type. With the large over-prediction of the rare communities it is likely that all possible areas where these communities occur have been predicted as rare habitat. Conversely, in DF set 2 with no filter (Figure 3-3) there is a high rate of commission error associated with the rare communities. Commission errors result in the classification of an area as A when it is actually community type B (i.e., the area was incorrectly committed to a different type).

These issues were taken into account during the modeling process because I realized that some users of the maps would have different objectives. In the case of individuals planning park facility construction, Figures 3-2, 3-4, 3-5, and 3-7 would probably be of more interest since these would alert users to possible occurrence of a rare community in a particular area and users could modify their plans accordingly. However, if users were interested in locating rare habitats for faunal surveys, they might be more interested in Figures 3-3 and 3-6. In these maps rare communities are under-represented, but those areas indicated as rare would have a high likelihood of rare community occurrence. Therefore, users could efficiently utilize their time in the field by not having to visit sites that were incorrectly identified as possible rare community locations.

Obviously, limitations with the procedure used in this study exist. The rare communities for this area typically have specific terrain signatures. MC occurs in areas with steep slopes; SC is also associated with steep slopes and water sources; POH are typically found on narrow knife-ridge tops; and RC are located in protective coves. However, these features may not have been distinct on the 30m x 30m DEM where knife-ridges could have been smoothed out or steep slopes lessened, which could result in difficulty distinguishing between the community types based solely on the terrain variables. The cliff communities were usually small in extent and could have been lost within the DEM pixels. The ruggedness of the landscape also caused difficulty in predicting these community types. With steep slopes located throughout this region, MC and SC were grossly over-predicted. RB was also considerably over-predicted because they were assigned to any area with a relatively flat slope. RC appeared to occur midslope within many coves or ravines. However, RC is usually associated with lower slope positions in areas of high soil fertility and high soil pH, primarily a result of geology. Unfortunately, this information was not included in the models used.

Another significant limitation to this study is the small sample size. As mentioned earlier, this had a significant impact on the modeling and PI processes. Standard errors for the rare communities were high, resulting in wide confidence intervals. Given the time constraint imposed on the field survey, an attempt was made to sample the most points in a minimum amount of time. Rare community sites were targeted for this survey; however, the locations of these communities were inferred from topography and knowledge of the area. Therefore, when these sites were visited in the field the identified rare community was not always encountered. Another factor that limited the sample size was the difficulty of navigation within this landscape. Steep slopes, lack of trails, and bad roads slowed progress in the field.

More field data need to be collected to provide a better assessment of the models' accuracy. Modeling is an iterative process with model development and validation occurring continuously (Stormer and Johnson, 1986). The data collected by the North Carolina Vegetation Survey (Peet et al. 1998) could provide additional information and increase sample sizes to improve the models. Should these models provide acceptable results, the methodology used for this project could provide a template for predictive mapping of other areas.

CONCLUSIONS

Using a multi-factor classification approach, this methodology was able to recognize adequately the community types found in the Gorges State Park and Gamelands and identify the underlying environmental gradients affecting community variation. The analyses presented support previous conclusions that moisture and temperature accounted for the majority of the variation for community types in the southeastern Blue Ridge escarpment. Predictive modeling using digital terrain data and aerial photo interpretation yielded acceptable results with approximately 75% accuracy. The methodology employed in this research appears to be a useful tool for assessing quickly the vegetation communities of the Gorges State Park and Gamelands and can be used for classification of other areas.

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APPENDICES

APPENDIX A. Gorges State Park sample point coordinates and community types.

Point Name: AP-101
Source: Aerial
Coordinates: 3881489 N 326459 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: AP-102
Source: Aerial
Coordinates: 3882080 N 325472 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: AP-103
Source: Aerial
Coordinates: 3881275 N 322585 E
Community: Rocky Bar (Twisted Sedge Subtype)

Point Name: AP-104
Source: Aerial
Coordinates: 3881406 N 322316 E
Community: Rocky Bar (Twisted Sedge Subtype)

Point Name: EP-101
Source: Expert
Coordinates: 3883273 N 326399 E
Community: Spray Cliff

Point Name: EP-102
Source: Expert
Coordinates: 3881406 N 323011 E
Community: Rich Cove Forest (Montane Intermediate Subtype)

Point Name: EP-103
Source: Expert
Coordinates: 3881140 N 323307 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-104
Source: Expert
Coordinates: 3884289 N 328286 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-105
Source: Expert
Coordinates: 3884683 N 320785 E
Community: Spray Cliff

Point Name: EP-106
Source: Expert
Coordinates: 3882953 N 321336 E
Community: Waterfall

Point Name: EP-107
Source: Expert
Coordinates: 3884582 N 327074 E
Community: Montane Cliff (Acidic Subtype)

Point Name: EP-108
Source: Expert
Coordinates: 3885352 N 324645 E
Community: Waterfall

Point Name: EP-109
Source: Expert
Coordinates: 3884704 N 327103 E
Community: Spray Cliff

Point Name: EP-110
Source: Expert
Coordinates: 3884672 N 327179 E
Community: Spray Cliff

Point Name: EP-111
Source: Expert
Coordinates: 3883664 N 326514 E
Community: Canada Hemlock Forest (Typic Subtype)

Point Name: EP-112
Source: Expert
Coordinates: 3884035 N 325503 E
Community: Montane Cliff (Acidic Subtype)

Point Name: EP-113
Source: Expert
Coordinates: 3884214 N 325164 E
Community: Montane Cliff (Acidic Subtype)

Point Name: EP-114
Source: Expert
Coordinates: 3883370 N 323791 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-115
Source: Expert
Coordinates: 3884789 N 324045 E
Community: Swamp Forest Bog Complex (Typic Subtype)

Point Name: EP-116
Source: Expert
Coordinates: 3883041 N 326123 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-117
Source: Expert
Coordinates: 3882317 N 322958 E
Community: Rich Cove Forest (Montane Intermediate Subtype)

Point Name: EP-118
Source: Expert
Coordinates: 3884001 N 326849 E
Community: Montane Cliff (Mafic Subtype)

Point Name: EP-119
Source: Expert
Coordinates: 3882419 N 322877 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: EP-120
Source: Expert
Coordinates: 3881407 N 323931 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-121
Source: Expert
Coordinates: 3881305 N 325023 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: EP-122
Source: Expert
Coordinates: 3880937 N 324703 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-047
Source: Grid
Coordinates: 3880918 N 323317 E
Community: White Pine Forest

Point Name: GP-048
Source: Grid
Coordinates: 3881082 N 323856 E
Community: Transition from Acidic Cove Forest (Typic Subtype) to Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-049
Source: Grid
Coordinates: 3880975 N 324490 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-050
Source: Grid
Coordinates: 3881082 N 324855 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-051
Source: Grid
Coordinates: 3881094 N 325356 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-052
Source: Grid
Coordinates: 3881081 N 325856 E
Community: White Pine Forest

Point Name: GP-064
Source: Grid
Coordinates: 3881582 N 323856 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-066
Source: Grid
Coordinates: 3881656 N 323888 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-072
Source: Grid
Coordinates: 3881309 N 326723 E
Community: Transition from Acidic Cove Forest (Typic Subtype) to Pine-Oak Heath (Typic Subtype)

Point Name: GP-073
Source: Grid
Coordinates: 3881643 N 327353 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-082
Source: Grid
Coordinates: 3882081 N 322855 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-087
Source: Grid
Coordinates: 3882104 N 325381 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-090
Source: Grid
Coordinates: 3882120 N 327020 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-092
Source: Grid
Coordinates: 3881913 N 327777 E
Community: Transition from Rich Cove Forest (Montane Intermediate Subtype) to Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-101
Source: Grid
Coordinates: 3882628 N 323374 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-109
Source: Grid
Coordinates: 3882582 N 327355 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-117
Source: Grid
Coordinates: 3883160 N 321838 E
Community: Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-125
Source: Grid
Coordinates: 3883082 N 325856 E
Community: Canada Hemlock Forest (Typic Subtype)

Point Name: GP-129
Source: Grid
Coordinates: 3883063 N 327846 E
Community: Transition from Acidic Cove Forest (Typic Subtype) to Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-130
Source: Grid
Coordinates: 3883086 N 328344 E
Community: Transition from Acidic Cove Forest (Typic Subtype) to Montane Oak-Hickory (Acidic Subtype)

Point Name: GP-138
Source: Grid
Coordinates: 3883601 N 322328 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-146
Source: Grid
Coordinates: 3883582 N 326356 E
Community: Canada Hemlock Forest (Typic Subtype)

Point Name: GP-148
Source: Grid
Coordinates: 3883808 N 327208 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-149
Source: Grid
Coordinates: 3883600 N 327851 E
Community: Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-150
Source: Grid
Coordinates: 3883506 N 328071 E
Community: Chestnut Oak Forest (Herb Subtype)

Point Name: GP-156
Source: Grid
Coordinates: 3884082 N 321856 E
Community: Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-157
Source: Grid
Coordinates: 3884050 N 322380 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-158
Source: Grid
Coordinates: 3884084 N 322839 E
Community: Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-159
Source: Grid
Coordinates: 3884056 N 323322 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-162
Source: Grid
Coordinates: 3884099 N 324846 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-163
Source: Grid
Coordinates: 3884048 N 325324 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-165
Source: Grid
Coordinates: 3884082 N 326356 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-167
Source: Grid
Coordinates: 3884039 N 327340 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-168
Source: Grid
Coordinates: 3884120 N 327796 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-169
Source: Grid
Coordinates: 3884236 N 328362 E
Community: Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-173
Source: Grid
Coordinates: 3884513 N 321330 E
Community: White Pine Forest

Point Name: GP-174
Source: Grid
Coordinates: 3884604 N 321860 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-175
Source: Grid
Coordinates: 3884927 N 322413 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-177
Source: Grid
Coordinates: 3884582 N 323356 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-180
Source: Grid
Coordinates: 3884583 N 324807 E
Community: Chestnut Oak Forest (Rhododendron Subtype)

Point Name: GP-181
Source: Grid
Coordinates: 3884582 N 325356 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-182
Source: Grid
Coordinates: 3884542 N 325877 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-187
Source: Grid
Coordinates: 3884599 N 328357 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-188
Source: Grid
Coordinates: 3885061 N 320779 E
Community: Montane Oak-Hickory Forest (White Pine Subtype)

Point Name: GP-189
Source: Grid
Coordinates: 3885140 N 321174 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-190
Source: Grid
Coordinates: 3885035 N 321885 E
Community: Chestnut Oak Forest (Herb Subtype)

Point Name: GP-191
Source: Grid
Coordinates: 3885195 N 322359 E
Community: Montane Oak Hickory Forest (Acidic Subtype)

Point Name: GP-193
Source: Grid
Coordinates: 3885256 N 323282 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-194
Source: Grid
Coordinates: 3885144 N 323948 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-201
Source: Grid
Coordinates: 3885019 N 327350 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-203
Source: Grid
Coordinates: 3885137 N 328314 E
Community: Pine-Oak Heath (Typic Subtype)

Point Name: GP-204
Source: Grid
Coordinates: 3885545 N 321303 E
Community: Chestnut Oak Forest (White Pine Subtype)

Point Name: GP-205
Source: Grid
Coordinates: 3885840 N 321925 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-206
Source: Grid
Coordinates: 3885589 N 322335 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-207
Source: Grid
Coordinates: 3885632 N 322862 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-208
Source: Grid
Coordinates: 3885678 N 323368 E
Community: Chestnut Oak Forest (Herb Subtype)

Point Name: GP-209
Source: Grid
Coordinates: 3885582 N 323856 E
Community: Transition from Acidic Cove (Typic Subtype) to Montane Oak-Hickory (Acidic Subtype)

Point Name: GP-211
Source: Grid
Coordinates: 3885582 N 324695 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-217
Source: Grid
Coordinates: 3885582 N 327856 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-218
Source: Grid
Coordinates: 3885606 N 328310 E
Community: Montane Oak-Hickory (Acidic Subtype)

Point Name: GP-219
Source: Grid
Coordinates: 3886082 N 321856 E
Community: Transition from White Pine Forest to Montane Oak-Hickory Forest (Acidic Subtype)

Point Name: GP-220
Source: Grid
Coordinates: 3886082 N 322356 E
Community: Chestnut Oak Forest (Rhododendron Subtype)

Point Name: GP-225
Source: Grid
Coordinates: 3886082 N 327856 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name: GP-226
Source: Grid
Coordinates: 3886082 N 328356 E
Community: Acidic Cove Forest (Typic Subtype)

Point Name: GP-231
Source: Grid
Coordinates: 3886582 N 327856 E
Community: Chestnut Oak Forest (Dry Heath Subtype)

Point Name:	RP-101
Source:	Random
Coordinates:	3882098 N 323235 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-102
Source:	Random
Coordinates:	3884521 N 325570 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-103
Source:	Random
Coordinates:	3883380 N 327719 E
Community:	Pine-Oak Heath (Typic Subtype)

Point Name:	RP-104
Source:	Random
Coordinates:	3882971 N 321412 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-105
Source:	Random
Coordinates:	3884175 N 325278 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-106
Source:	Random
Coordinates:	3884266 N 325249 E
Community:	Chestnut Oak Forest (Rhododendron Subtype)

Point Name:	RP-107
Source:	Random
Coordinates:	3884521 N 324778 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-108
Source:	Random
Coordinates:	3886007 N 323592 E
Community:	Transition from Acidic Cove (Typic Subtype) to Montane Oak-Hickory (Acidic Subtype)

Point Name:	RP-109
Source:	Random
Coordinates:	3882532 N 322898 E
Community:	Spray Cliff

Point Name:	RP-110
Source:	Random
Coordinates:	3882403 N 322819 E
Community:	Rich Cove Forest (Montane Intermediate Subtype)

Point Name:	RP-111
Source:	Random
Coordinates:	3881465 N 323939 E
Community:	Chestnut Oak Forest (Dry Heath Subtype)

APPENDIX B. Species list for the Gorges State Park and Gamelands.

Nomenclature follows Weakley (unpublished). Determinations were made by Ross Phillips. J. D. Pittillo, Department of Biology, Western Carolina University, helped with identification of *Carices* and confirmed identifications for unknown specimens.(* Indicates species which had not yet been addressed by Weakley; therefore, these specimens were classified according to Radford et al (1968)).

Fern and Fern Allies

Aspleniaceae
Aslpenium monantum Willendow
Asplenium platyneuron (Linnaeus) Britton
Asplenium resiliens Kunze

Dennstaedtiaceae
Dennstaedtia punctilobula (Michaux) T. Moore
Pteridium aquilinum (Linnaeus) Kuhn var. *latiusculum* (Desvaux)

Dryopteridaceae
Athyrium asplenoides (Michaux) A.A. Eaton
Cystopteris protusa (Weatherby) Blasdell
Deparia acrostichoides (Swartz) M. Kato
Dryopteris intermedia (Muhlenberg ex Willendow) A. Gray
Polystichum acrostichoides (Michaux) Schott

Lycopodiaceae
Huperzia lucidulum (Michaux) Trevisan
Diphasiastrum digitatum (Dillenius ex A. Braun) Holub

Ophioglossaceae
Botrychium dissectum Sprengel
Botrychium virginianum (Linnaeus) Swartz
Botrychium species

Osmundaceae
Osmunda cinnamomea Linnaeus

Polypodiaceae
Pleopeltis polypodioides (Linnaeus) E. G. Andrews & Windham

Pteridaceae
Adiantium pedatum Linnaeus

Thelypteridaceae
Phegopteris hexagonoptera (Michaux) Fee
Thelypteris noveboracensis (Linnaeus) Nieuwland

Selaginellaceae
Selaginella apoda (Linnaeus) Spring

Gymnosperms

Pinaceae
Pinus rigida P. Miller
Pinus strobus Linnaeus
Pinus virginiana P. Miller
Tsuga canadensis (Linnaeus) Carriere

Monocotyledons

Araceae
Arisemea triphylla (Linnaeus) Schott

Convallariaceae
Polygonatum biflorum (Walter) Elliott

Cyperaceae
Carex blanda Dewey
Carex debilis Michaux
Carex plantaginea Lamarck
Carex rosea Schkuhr ex Willendow
Carex torta F. Boott
Carex species
Scirpus cyperinus (Linnaeus) Kunth

Dioscoreaceae
Dioscorea batatas Duchesne
Dioscorea quaternata J.F. Gmelin
Dioscorea species

Iridaceae
Iris species

Juncaceae
Juncus effusus Linnaeus
Juncus gymnocarpus Coville
Luzula species

Liliaceae
Clintonia umbellatum (Michaux) Morong*
Liliaceae species

Medeola virginiana Linnaeus

Melanthiaceae
Chamaelirium luteum (Linnaeus) A. Gray
Maianthemum racemosa (Linnaeus) Link
Veratrum parviflorum Aiton*
Xerophyllum asphodeloides (Linnaeus) Nuttall

Orchidaceae
Cypripedium acaule Aiton
Goodyera pubescens (Willdenow) R. Brown ex Aiton filius

Poaceae
Andropogon species
Arundinaria gigantea (Walter) Walter ex Muhlenberg
Danthonia sericea Nuttall
Danthonia species
Dichanthelium clandestinum Linnaeus
Dichanthelium commutatum (Shultes) Gould
Dichanthelium species
Microstegium japonica (Trinius) A. Camus
Muhlenbergia species
Piptochaetium avenaceum (Linnaeus) Parodi
Poaceae species
Trisedum pensylvanicum (Linnaeus) Baeuvois ex R. S.*
Vulpia species

Smilaceae
Smilax biltmoreana (Small) J.B.S. Norton ex Pennell
Smilax glauca Walter
Smilax rotundifolia Linnaeus
Smilax tamnoides Linnaeus
Smilax species

Trilliaceae
Trillium species

Uvulariaceae
Uvularia perfoliatum Linnaeus
Uvularia puberula var. *puberula* Michaux

Dicotyledons
Aceraceae
Acer rubrum Linnaeus

Adoxaceae
Sambucus canadensis Linnaeus
Viburnum acerifolium Linnaeus

Anacardiaceae
Toxicodendron radicans (Linnaeus) Kuntze

Annonaceae
Asimia triloba (Linnaeus) Dunal

Apiaceae
Apiaceae species
Cicuta maculata Linnaeus
Sanicula canadensis Linnaeus
Sanicula marlandica Linnaeus
Sanicula species
Zizia trifoliata (Michaux) Fernald

Aquifoliaceae
Ilex opaca Aiton

Araliacea
Aralia nudicaulis Linnaeus
Aralia racemosa Linnaeus
Aralia spinosa Linnaeus

Aristolochiaceae
Hexastylis species

Asteraceae
Ageratina altissima King & H.E. Robinson
Antennaria species
Aster acuminatus Michaux*
Aster curtsii Torrey & A. Gray*
Aster cordifolius Linnaeus
Aster divaricatus Linnaeus
Aster dumosus Linnaeus
Aster undulatus Linnaeus
Aster species
Coreopsis major Walter
Helianthus species
Hieracium venosum Linnaeus
Eupatorium fistulosum Barratt
Eupatorium perfoliatum Linnaeus
Eupatorium pupureum Linnaeus
Eupatorium species
Erigeron pulchellus Michaux
Krigia montana (Michaux) Nuttall
Prenanthes alba Linnaeus
Prenanthes species
Polymnia species
Solidago species

Balsaminaceae
Impatiens capensis Meerburg

Berberidaceae
  Caulphyllum thalictroides (Linnaeus) Michaux

Betulaceae
  Alnus serrulata (Aiton) Willendow
  Betula allegheniensis Britton
  Betula lenta Linnaeus
  Carpinus caroliniana Walter

Bignoniaceae
  Anisostichus capreolata (Linnaeus) Bureau

Brassicaceae
  Brassica species

Calycanthaceae
  Calycanthus floridus Linnaeus

Caprifoliaceae
  Lonicera japonica Thunberg
  Symphoricarpos orbiculatus Moench

Celastraceae
  Celastrus orbiculatus Thunberg
  Euonymous americana Linnaeus

Clethraceae
  Clethra acuminata Michaux

Cornaceae
  Cornus florida Linnaeus
  Cornus alternifolia Linnaeus

Diapensiaceae
  Shortia galacifolia Torrey & A. Gray
  Galax urceolata (Poiret) Brummitt

Ebenaceae
  Diospyros virginiana Linnaeus

Ericaceae
  Chimaphila maculata (Linnaeus) Pursh
  Epigea repens Linnaeus
  Gaylussacia baccata (Wangenheim) K. Koch
  Gaylussacia ursina (M.A. Curtis) Torrey & A. Gray
  Kalmia latifolia Linnaeus
  Leucothoe fontansiana (Steudell) Sleumer
  Oxydendrum arboreum (Linnaeus) de Candolle
  Rhododendron catawbiensis Michaux
  Rhododendron maximum Linnaeus
  Rhododendron minus Michaux
  Rhododendron species
  Vaccinium corymbosum Linnaeus
  Vaccinium pallidum Aiton
  Vaccinium staminium Linnaeus

Euphorbiaceae
  Euphorbia corollata Linnaeus

Fabaceae
  Amphicarpa bracteata (Linnaeus) Fernald
  Baptisia tinctoria (Linnaeus) Ventenat
  Cassia nictitans Linnaeus*
  Desmodium nudiflorum (Linnaeus) de Candolle
  Desmodium species
  Robinia hispida Linnaeus
  Robinia pseudoacacia Linnaeus

Fagaceae
  Castanea dentata (Marshall) Borkhausen
  Castanea pumila (Linnaeus) P. Miller
  Fagus grandifolia Ehrhart
  Quercus alba Linnaeus
  Quercus coccinea Muenchhausen
  Quercus falcata Michaux
  Quercus marlandica Muenchhausen
  Quercus montana Willendow
  Quercus rubra Linnaeus
  Quercus velutina Lamarck

Hamamelidaceae
  Fothergilla major (Sims) Loddiges
  Hamamelis virginica Linnaeus
  Liquidambar styriciflua Linnaeus

Hydrophyllaceae
  Hydrophyllum virginianum Linnaeus

Hypericaceae
  Hypericum mutilum Linnaeus*
  Hypericum species

Iteaceae
  Itea virginica Linnaeus

Juglandaceae
  Carya alba (Linnaeus) Nuttall ex Elliott
  Carya glabra (P. Miller) Sweet
  Carya ovata (P. Miller) K. Koch
  Carya species
  Juglans cinerea Linnaeus

Lamiaceae
  Collinsonia canadensis Linnaeus

Lycopus virginicus Linnaeus
Monarda clinipodia Linnaeus
Pycnanthemum incanum (Linnaeus) Michaux
Mint species

Lauraceae
Lindera benzoin (Linnaeus) Blume
Sassafras albidum (Nuttall) Nees

Magnoliaceae
Liriodendron tulipifera Linnaeus
Magnolia fraseri Walter

Moraceae
Morus rubra Linnaeus

Nyssaceae
Nyssa sylvatica Marshall

Oleaceae
Fraxinus americana Linnaeus
Ligustrum sinese Loureiro

Onagraceae
Circaea species

Orobanchaceae
Conopholous americana (Linnaeus) Wallroth

Oxalidaceae
Oxalis species

Papaveraceae
Sanguinaria canadensis Linnaeus

Passifloraceae
Passiflora lutea Linnaeus

Phrymaceae
Phryma leptostachya Linnaeus var. *leptostachya*

Phytolaccaeae
Phytolacca americana Linnaeus

Platanacaea
Platanus occidentalis Linnaeus

Polygonaceae
Polygonum sagittatum Linnaeus*

Primulaceae
Lysimachia quadrifolia Sims

Ranunculaceae
Actea pachypoda Elliott
Aquilegia canadensis Linnaeus
Clematis virginiana Linnaeus
Ranunculus hispidus Michaux
Ranunculus recurvens Poiret
Ranunculus species
Thalictrum clavatum de Candolle
Thalictrum dioicum Linnaeus
Xanthorhiza simplissima Marshall

Rosaceae
Agrimonia pubescens Wallroth
Agrimonia species
Amelanchier arborea (F. Michaux) Fernald
Amelanchier species
Fragaria virginiana Duchesne
Gillenia trifoliata (Linnaeus) Moench*
Potentilla simplex Michaux
Prunus serotina Ehrhart
Prunus species
Rubus canadensis Linnaeus
Rubus species

Rubiaceae
Galium latifolium Michaux
Galium triflorum Michaux
Galium species
Houstonia purpurea Linnaeus
Housontia serpyllifolia Michaux
Mitchella repens Linnaeus

Salicaceae
Salix sericea Marshall

Santalaceae
Pyrularia pubera Michaux

Saxifragaceae
Huechera americana Linnaeus
Heuchera parviflora Bartling
Heuchra species
Hydrangea radiata Walter
Saxifraga michranthidifolia (Haworth) Steudel
Tiarella cordifolia Linnaeus

Scrophulariaceae
Chelone species
Pedicularis canadensis Linnaeus
Scrophularia species

Styraceae

Halesia tetraptera Ellis

Symplocaceae
Symplocos tinctoria (Linnaeus) L'Heritier de Brutelle

Tiliaceae
Tilia americana Linnaeus var. *heterophylla* (Ventenat) Loudon

Urticaceae
Boehmeria cylindrica (Linnaeus) Swartz
Laportea canadensis (Linnaeus) Weddell
Pilea pumila (Linnaeus) A. Gray

Violaceae
Viola eriocarpa Schweinitz*
Viola species

Vitaceae
Parthenocissus quinquefolia (Linnaeus) Planchon
Vitis aestivalis Michaux
Vitis rotundifolia Michaux
Vitis vulpina Linnaeus
Vitis species

APPENDIX C. Groups used for DFA and associated sample sizes. Community types with small sample sizes were grouped with similar community types in order to compute covariance matrices for DFA.

Group		Sample Size
Acidic Cove Forest (Typic Subtype)		19
Canada Hemlock Forest (Typic Subtype)		3
Chestnut Oak Forest		29
Chestnut Oak Forest (White Pine Subtype)		1
Chestnut Oak Forest (Herb Subtype)		3
Chestnut Oak Forest (Dry Heath Subtype)		25
Swamp Forest Bog Complex (Typic Subtype)		1
Chestnut Oak Forest (Rhododendron Subtype)		3
Montane Cliff		4
Montane Cliff (Acidic Subtype)		3
Montane Cliff (Mafic Subtype)		1
Montane Oak-Hickory		10
Montane Oak-Hickory Forest (Acidic Subtype)		9
Montane Oak-Hickory Forest (White Pine Subtype)		1
Pine Oak Heath (Typic Subtype)		11
Rich Cove Forest (Montane Intermediate Subtype)		9
Rocky Bar (Twisted Sedge Subtype)		2
Spray Cliff		7
Spray Cliff		5
Waterfall		2
White Pine Forest		4
	Total	102

APPENDIX D. Discriminant functions. Community codes: (AC) Acidic Cove Forest; (CH) Canada Hemlock Forest; (CO) Chestnut Oak Forest; (COR) Chestnut Oak Forest (Rhododendron Subtype); (MC) Montane Cliff; (MOH) Montane Oak-Hickory Forest; (POH) Pine Oak Heath; (RC) Rich Cove Forest; (RB) Rocky Bar; (SC) Spray Cliff; (WP) White Pine Forest.

(a) DF set 1

AC	CH	CO	COR	MC	MOH	POH	RC	RB	SC	WP
-21.0404	-34.5756	-27.5787	-39.4616	-73.1739	-35.9342	-19.6476	-30.7954	-24.2160	-47.119	-25.5583
0.0435	0.046	0.0522	0.0571	0.0620	0.0587	0.0417	0.0480	0.0383	0.0603	0.0473
0.1435	0.0959	0.1583	0.1441	0.3529	0.1564	0.1708	0.2894	-0.003	0.1687	0.1797
54.0608	90.8667	50.2532	73.4836	141.4656	76.6726	36.1127	86.3680	41.8941	94.2977	72.5195
-52.644	-108.9449	-55.9872	-77.7850	-156.764	-76.0406	-48.8741	-79.6926	-41.9777	-90.034	-59.9020
-33.7977	-56.8083	-34.5646	-60.3556	-87.0387	-35.7799	-25.8213	-41.0898	-39.9606	-48.0624	-45.697
85.4075	143.278	88.1166	132.1713	182.8169	106.0361	71.1206	87.9119	122.6284	142.1690	88.6911

(b) DF SET 2

AC	CH	CO	COR	MC	MOH	POH	RC	RB	SC	WP
-22.9375	-38.4877	-28.377	-42.4574	-78.6953	-37.3613	-22.6434	-34.4843	-31.2291	-56.3290	-30.1634
0.0435	0.046	0.0522	0.0571	0.0620	0.0587	0.0417	0.0480	0.0383	0.0603	0.0473
0.1435	0.0959	0.1583	0.1441	0.3529	0.1564	0.1708	0.2894	-0.003	0.1687	0.1797
54.0608	90.8667	50.2532	73.4836	141.4656	76.6726	36.1127	86.3680	41.8941	94.2977	72.5195
-52.6435	-108.9449	-55.9872	-77.7850	-156.7635	-76.0406	-48.8741	-79.6926	-41.9777	-90.034	-59.9020
-33.7977	-56.8083	-34.5646	-60.3556	-87.0387	-35.7799	-25.8213	-41.0898	-39.9606	-48.0624	-45.697
85.4075	143.278	88.1166	132.1713	182.8169	106.0361	71.1206	87.9119	122.6284	142.1690	88.6911

(c) DF SET 3

AC	CH	CO	COR	MC	MOH	POH	RC	WP
-21.0387	-34.0435	-27.9264	-39.4963	-73.33	-35.7734	-20.0104	-31.2700	-25.8370
0.0439	0.0464	0.0530	0.0577	0.0635	0.0590	0.0426	0.0492	0.0481
0.1636	0.1153	0.1867	0.1736	0.3883	0.1816	0.1954	0.3162	0.2051
60.6056	96.1170	59.5547	82.8290	153.1842	84.3011	44.5274	95.634	80.8472
-56.9817	-111.3441	-62.131	-83.8006	-163.5224	-80.9381	-54.2593	-85.9029	-65.7558
-37.7458	-59.9484	-40.0841	-65.5068	-94.1297	-40.786	-30.8064	-47.1112	-50.7061
80.479	136.7233	82.3180	124.9538	172.8934	99.9689	66.1341	81.945	83.1718

APPENDIX E. Community types associated with PI cover categories. These groupings formed the decision rules for filtering the models to produce community maps.

Photo Interpreted Cover Types (Type – Name)	Acceptable Community Types
1 - All Deciduous (100%)	Acidic Cove Forest
	Chestnut Oak Forest
	Montane Cliff
	Montane Oak Hickory Forest
	Rich Cove Forest
	Rocky Bar
	Spray Cliff
2 - All Evergreen (100%)	Acidic Cove Forest
	Canada Hemlock Forest
	Montane Cliff
	Pine Oak Heath
	Rocky Bar
	Spray Cliff
	White Pine Forest
3 - Deciduous with Scattered Hemlock	Acidic Cove Forest
	Montane Cliff
	Rich Cove Forest
	Rocky Bar
	Spray Cliff
4 - Deciduous with Trace Hemlock	Acidic Cove Forest
	Montane Cliff
	Rich Cove Forest
	Rocky Bar
	Spray Cliff
5 - Deciduous with Scattered White Pine	Acidic Cove Forest
	Chestnut Oak Forest
	Chestnut Oak Forest (Rhododendron Subtype)
	Montane Cliff
	Montane Oak Hickory Forest
	Rich Cove Forest
	Rocky Bar
	Spray Cliff
6 - Deciduous with Trace White Pine	Acidic Cove Forest
	Chestnut Oak Forest
	Chestnut Oak Forest (Rhododendron Subtype)
	Montane Cliff
	Montane Oak Hickory Forest
	Rich Cove Forest
	Rocky Bar
	Spray Cliff
8 - Hemlock Dominated	Canada Hemlock Forest
	Montane Cliff
	Rocky Bar
	Spray Cliff

APPENDIX E continued.

Photo Interpreted Cover Types (Type – Name)	Acceptable Community Types
10 - Deciduous with Evergreen Understory	Acidic Cove Forest
	Chestnut Oak Forest
	Chestnut Oak Forest (Rhododendron Subtype)
	Montane Cliff
	Montane Oak Hickory Forest
	Rich Cove Forest
	Rocky Bar
	Spray Cliff