DISCRIMINANT ANALYSIS OF COVE FORESTS OF THE CUMBERLAND PLATEAU OF TENNESSEE

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ABSTRACT

Coves and gorges of the Cumberland Plateau in Tennessee are occupied by a complex array of forest communities. Vegetation and environmental data from 178 .04 ha plots in five cove or gorge systems were analyzed in this study. Numerical classification analysis was used to establish fourteen plant communities. Multiple discriminant analysis using species importance values indicated that these types were distinct at the .05 significance level. Discriminant analysis using selected environmental variables indicated that several of the type were not distinct from each other on this basis. This analysis indicated that factors related to slope position which may indicate a soil moisture axis were important in segregating the communities as were factors such as pH which are related to soil nutrient status.

INTRODUCTION

Coves and gorges of the Cumberland Plateau in Tennessee are occupied by a complex mosaic of plant communities. Many of these communities were termed "mixed mesophytic" by Braun (1950) and differ considerably from the oak dominated forests of the uplands of the Cumberland Plateau.

Understanding of the vegetation-environment relationships in these coves is complicated by the species richness of these areas and the complex environmental gradients which occur there. Discriminant analysis has been used in this study as a means of examining the distribution of community types along these envirnmental gradients.

Management of cove areas that are held in the public domain as state and national parks, recreation areas, natural areas, and wildlife management areas as well as those that are used for timber production also require a better understanding of the natural vegetation of coves and gorges of the Cumberland Plateau.

THE STUDY AREA

The Cumberland Plateau is one of the major physiographic regions of Tennessee, extending from 84°30' to 85°10' longitude at the Tennessee-Kentucky border and from 85°20' to 86°10' longitude at the southern border of the state. It is bordered by the Great Valley to the east, the Cumberland Mountains to the northeast, and the eastern Highland Rim to the west. Part or all of 21 counties are located on the Plateau.

The climate of the Plateau is considered humid and mesothermal. Precipitation averages from 127 cm to 140 cm per year and thus is higher than that of the Highland Rim to the west and the Great Valley to the east of the Plateau (Dickson 1960).

Physiographically, the Cumberland Plateau is the southern extension of the Appalachian Plateau from which it is somewhat arbitrarily designated. In Tennessee, the Plateau is underlain by resistant Pennsylvanian sandstones of the Pottsville series which are responsible for maintaing the "submaturely dissected" flat to rolling surface of the Plateau. Where these sandstones have been breached, erosion of the less resistant Mississippian limestones have produced steep-sided gorges (Fenneman 1938). The eastern escarpment of the Plateau is a nearly linear ridge extending from Harriman southwest to Chattanooga and about 300 m higher than the Great Valley. The western escarpment, in contrast, is highly dissected by streams flowing west onto the Eastern Highland Rim.

Soils of the coves and gorges of the Plateau are complex and have not been mapped in detail. The soils of the upper slopes of these coves are generally derived from sandstone colluvium over shale or sandstone bedrock, are sandy in texture, and are acid. Soils of the middle and lower slopes below the level of the Mississippian strata are derived from sandstone and limestone colluvium and limestone residuum, are less acid and have a greater clay fraction.

Braun (1950) included the Cumberland Plateau of Tennessee within the Mixed Mesophytic Forest Region because of the presence of mixed mesophytic forest communities in Plateau coves and gorges. She recognized, however that "oak or oak-hickory forest prevails over the large area of submaturely dissected Plateau in Tennessee..." (Braun 1950, p. 114).

Caplenor (1965) described hemlock, mixed mesophytic, oak-hickory and chestnut oak communities in the gorges of Fall Creek Falls State Park (Bledsoe and Van Buren Counties). Safley (1970) described a variety of communities in the gorges of the Big South Fork of the Cumberland River. These included types dominated by tulip, hemlock, northern red oak, white oak, chestnut oak, shortleaf and Virginia pines. Floristic studies have been made by Sherman (1958) and Clark (1966) in Plateau coves. Recent vegetation studies have been completed by Hinkle (1978) and Schmalzer (1978).

METHODS

Old growth, uneven-age forests in coves and gorges of the Cumberland Plateau of Tennessee were selected for sampling. Plots from five such coves are included in the present study. These are Dick Cove near Sewanee, Franklin County, Doe Creek Cove, White County, a section of the Obed River Valley, Cumberland County, Flint Fork Cove in Pickett State Forest, Pickett County, and Little Piney Creek gorge, Rhea County. Circular plots of 0.04 ha were distributed in a stratified random manner by slope position. Canopy species, greater than 12.5 cm dbh, were recorded in 5 cm diameter classes by taxon. Saplings, 2.5 cm to 12.5 cm dbh were recorded by taxon. Nomenclature follows Radford et al. (1968).

A soil pit was dug near the center of each plot and samples of the A and B horizons were collected. Thickness of each horizon, depth to bedrock (to 91 cm), and stone content of each horizon were recorded.

Slope angle was measured in four directions from plot center; aspect was also measured. Evidence of past disturbance such as fire scars or cut stumps was noted.

The pH of air dry soil sampleswas determined in a 1:1 soil: water slurry (Jackson, 1968). Soil texture standards were determined using a modified Day (1956) hydrometer method. Soil texture of the other samples were determined by the "feel" method (Soil Survey Staff 1951). Water holding capacity of the soil was calculated using the methods of Longwell et al. (1963). Topographic quadrangle maps were used to determine distance from the top and bottom of the slope, gorge width, and vertical distance of the plot below the surface of the Plateau.

Absolute and relative densities and basal areas for the canopy species in each plot were calculated. An importance value was calculated as the sum of relative density and relative basal area for each species (IV = RD + RBA = 200).

Cluster analysis (Orloci 1967) was used to place plots into groups (community types) of similar species composition. Discriminant analysis (Nie et al. 1975, Dixon 1975) was used to examine the separation of types using vegetational and environmental characteristics.

THEORY AND APPLICATION OF DISCRIMINANT ANALYSIS

Discriminant analysis is a multivariate statistical procedure designed to distinguish between two or more groups of observations on the basis of a set of discriminanting variables. The analysis derives linear combinations of the discriminating variables which provide maximum separation between the groups (Pielou 1977). These linear combinations are termed discriminant functions and have the form

$$D_1 = d_{i1}Z_1 + d_{12}Z_2 + \ldots + d_{in}Z_n$$

where D_i is the score on discriminant function i, the d's are weighting coefficients, and the Z's are the standardized values of the discriminating variables (Nie et al. 1975).

The first discriminant funciton is inclined such that it represents the dimension along which the maximum group differentation occurs. The second function is idependent of the first and is inclined along the largest group differences not represented by the first function (Tatsuoka 1971).

Two quantities measure the relative importance of a given discriminant function. The canonical correlation coefficient is a measure of the functions ability to distinguish between the groups. The second measure is a relative percentage computed by dividing the eigenvalue of a given function by the sum of the eigenvalues of the functions derived; this sum is a measure of the total variance of the discriminating variables. The ration of the eigenvalue of one function to the total is the a measure of how much of this total variance is explained by that function (Nie et al., 1975).

Discriminant analysis may be used for two basic purposes, analysis and classification. One analytical application is the interpretation of the discriminant function coefficients. Ignoring sign, the magnitude of these standardized discriminant coefficients represents the relative contribution of that variable to the discriminant function. Considering the sign, if the coefficient d_{ij} is negative then increases in the variable Z_i will decrease the value of the discriminant score D_j and conversely for positive coefficients (Nie et al. 1975). If the discriminant function is plotted as an axis, then a negative coefficient of a variable will be associated with a movement in the negative direction along this axis and a positive coefficient with movement in the positive direction.

Plots of the group centroids (means) along the discriminant functions or axes allow a ready comparison of the degree of separation of these groups along the plotted functions. Significance tests (assuming multivariate normality) may be used to examine the total separation of the groups in multivariate space (Nie et al. 1975).

Classification is also a valuable feature of discriminant analysis. Once the discriminant functions have been derived, classification functions for each group may be found. These classification functions are then employed to predict the probability of group membership either for cases not included in the original analysis or for the original cases. The second option may be used as a check on the effectiveness of the classification procedure. If much misclassification occurs, this may be an indication of poor discrimination by the original variables (Nie et al. 1975).

Bias is introduced into the classification analysis because plots are placed into groups, functions are derived based on these groups, and the functions are used to classify the same plots. The "jacknife" procedure is intended to reduce this bias in that two sets of classification functions are derived. The first by the standard procedure while in the second, functions are adjusted so that the probability of a plot belonging to a group is calculated excluding that particular plot. This bias is of particular concern if the classification success of the standard procedure is not high (Dixon 1975).

Discriminant analysis has been used to define niche relationships in various animals (Anderson and Shugart 1974) and recently in sympatric herb species (Mann 1977). Norris and Barkham (1970) examined the environmental relationships of the ground flora of English beechwoods using discriminant analysis. Kessel and Whittaker (1976) found discriminant analysis to be generally unsatisfactory as an ordination technique but useful in classification. Kercher and Goldstein (1977) determined, using discriminant analysis, that "core groups" (community types) defined in the vegetation of the Walker Branch watershed, Oak Ridge, Tennessee were well classified by environmental variables and thus appeared to be environmentally distinct.

Hinkle (1978) used discriminant analysis to test the vegetational and environmental distinctness of upland and ravine communities of the Cumberland Plateau in Tennessee and also in identifying which environmental variables were most important in producing this separation. This technique has also been applied to individual coves (Hinkle et al. 1978, Schmalzer 1978).

A plant community, defined by a number of plots for which measures of species importance are available, may be conceptualized as existing in a vegetation hyperspace in which the importance of n species is represented by n axes (Goodall 1963). Each plot is a point in the space defined by coordinants of species importance values. Community types may be considered clusters of these points. The relative degree of separation between these types should be revealed by discriminant analysis.

Similarly, an environmental hyperspace may be defined where the z axes are the z environmental variables measured for the plots. The degree of separation between the communities based on environmental variables may also be revealed by discriminant analysis.

RESULTS

Classification

Fourteen community types (Table 1) were derived from the cluster analysis of 178 plots (Figure 1). These were distinct at the level where 35% of the variance is within-group and 65% is between group. Environmental characteristics of these types were also summarized (Table 2). The types noted here are described more fully in Schmalzer (1978) and are similar to those described by Hinkle (1978).

TABLE 1 IMPORTANCE VALUES OF CANOPY SPECIES IN THE COVE COMMUNITIES[1]

	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO
Acer rubrum	5.1	5.6	14.7		2.8	6.4	1.4
A. saccharum	1.3	0.4	1.1	17.0	7.7	6.9	44.1
Aesculus octandra		1.5			0.8		5.4
Betula lenta	0.5		9.2	1.2			
B. lutea						1.6	
B. nigra						6.3	
Carpinus caroliniana							
Carya cordiformis				5.2		2.9	4.7
C. glabra	8.9	7.4	3.0	2.6	15.0	8.3	6.0
C. ovalis	2.4	1.0			1.2		8.4
C. ovata	3.8	5.5	3.7	26.6	9.6	4.6	10.8
C. tomentosa	4.6	18.7	5.8	10.9	7.3		6.2
Carya sp.					0.5	1.6	
Cercis canadensis				1.2			0.6
Cladrastis lutea						1.7	
Cornus florida	2.1	3.7		2.4	1.1	0.5	1.1
Fagus grandifolia		2.9		4.2	7.7	2.0	
Fraxinus americana	1.3	1.6		1.5	2.9	4.6	12.6
Ilex opaca							
Juglans nigra				3.6	0.2	1.2	2.2
Kalmia latifolia							
Liquidambar styraciflua							
Liriodendron tulipifera	5.4	9.6	11.6	2.1	17.4	80.8	19.3
Magnolia acuminata	0.9	1.1		4.1	4.5	1.7	1.0
M. macrophylla			8.1			1.0	
Nyssa sylvatica	10.7	3.5	4.1	3.0	4.2	0.6	14.6
Ostrya virginiana					0.3		
Oxydendrum arboreum	6.1	4.6	8.2	1.2	2.5	4.9	1.1
Pinus strobus		1.3	46.3		0.9	9.1	
P. virginiana	2.3	3.1			0.7	0.8	
Platanus occidentalis							
Prunus serotina				1.4	0.2	1.6	
Quercus alba	0.6	32.8	4.3	4.7	69.4	2.5	2.8
Q. coccinea	8.2	2.7	2.4		0.7		
Q. muehlenbergii							7.5
Q. prinus	120.9	56.6	42.4	14.2	8.4	6.8	6.5
Q. rubra	8.3	22.2	3.5	93.3	20.9	12.9	32.9
Q. velutina	3.8	14.2	2.7		1.7		
Rhododendron maximum							
Robinia pseudoacacia	0.8	0.4			0.4	1.8	3.2
Sassafras albidum		1.4	1.1		0.3	0.6	0.9
Tilia americana					8.3	8.3	
T. heterophylla	0.8					11.1	1.8
Tsuga canadensis			28.1		1.2	6.2	
Ulmus americana					0.4		2.2

1 CO-chestnut oak, CO-WO-chestnut oak-white oak, WP-CO-white pine-chestnut oak, NRO-northern red oak, WO-NRO-white oak-northern red oak, TUL-tulip, SM-NRO-sugar maple-northern red oak

TABLE 1 'Continued'

	SM-SHAG	WA-SM	BAS-SM	HEM-TUL	BE-TUL	BE	RB
Acer rubrum	3.6			10.7	19.2	5.8	26.3
A. saccharum	66.3	35.9	34.4	3.7	14.3	6.5	3.7
Aesculus octandra	4.3	2.6	20.3		0.6	1.2	
Betula lenta				3.0	1.3	7.7	
B. lutea			2.1	3.9			
B. nigra	1.7				8.4		130.1
Carpinus caroliniana					4.0	0.5	24.1
Carya cordiformis	8.4	3.7	10.1				
C. glabra	1.9			0.7	1.2	0.9	
C. ovalis	4.2		3.6		2.2	0.5	
C. ovata	30.6	6.8	11.9	2.0	6.2	3.7	
C. tomentosa	7.3			1.0	18.1	2.4	
Carya sp.					1.1		
Cercis canadensis					0.6		
Cladrastis lutea	0.6	2.4	5.1				
Cornus florida	3.9		2.9	1.3	0.6	1.9	
Fagus grandifolia	0.7		3.8	6.9	41.8	93.2	4.7
Fraxinus americana	4.7	84.4	13.6		7.8	3.6	
Ilex opaca				2.5			
Juglans nigra	1.5	1.8	0.6	0.7	0.7	0.7	
Kalmia latifolia				4.0			
Liquidambar styraciflua				3.3			
Liriodendron tulipifera	3.1	9.8	9.1	26.5	27.2	16.1	8.9
Magnolia acuminata	6.8	9.8	8.3	2.5	3.9	2.9	
M. macrophylla				1.3	0.6	1.7	
Nyssa sylvatica			1.4	4.7	5.1	7.0	
Ostrya virginiana		1.0	1.6			0.6	
Oxydendrum arboreum				5.4	1.8	6.8	
Pinus strobus				3.7			
P. virginiana							
Platanus occidentalis					2.0		
Prunus serotina	1.1	1.0			2.7		
Quercus alba	27.6		2.0	0.8	6.5	12.2	
Q. coccinea				1.4			
Q. muehlenbergii	2.6	1.4			3.4		
Q. prinus	1.6	2.5	4.7	6.5			
Q. rubra	10.6	11.5	10.6	2.9	6.0	9.8	
Q. velutina						1.1	
Rhododendron maximum				1.3			
Robinia pseudoacacia	4.3	9.8	1.3				
Sassafras albidum			0.6				
Tilia americana				0.7	4.7		
T. heterophylla		13.0	42.4	11.9	4.0	2.7	
Tsuga canadensis			6.6	88.9	4.4	8.6	
Ulmus americana	2.6	2.1	2.8			1.1	2.2

1 SM-SHAG-sugar maple-shagbark hickory, WA-SM-white ash-sugar maple, BAS-SM-white basswood-sugar maple-buckeye, HEM-TUL-hemlock-tulip, BE-TUL-beech-tulip, BE-beech, RB-river birch

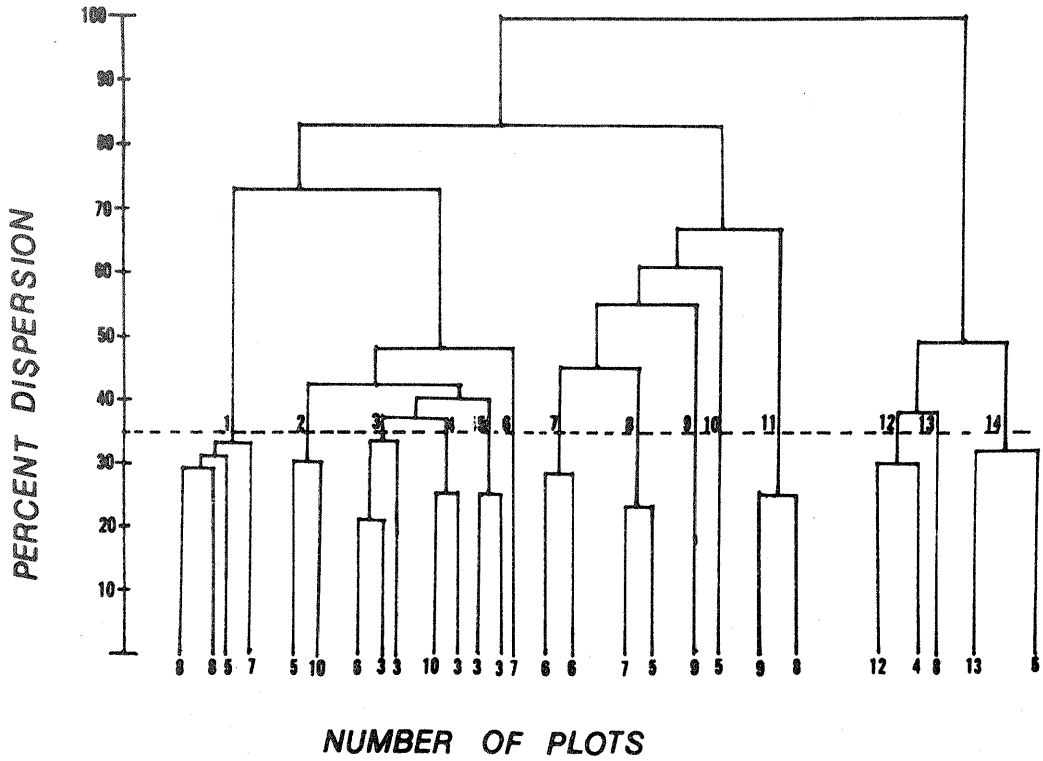

FIGURE 1. Dendrogram of cluster analysis of cove vegetation. Communities are defined at the 35% dispersion level, 1= white oak-northern red oak, 2= sugar maple-shagbark hickory-white oak, 3= sugar maple-northern red oak, 4= white basswood-sugar maple-buckeye, 5= white ash-sugar maple, 6= northern red oak, 7= beech-tulip, 8= tulip, 9= hemlock-tulip, 10= river birch, 11= beech, 12= chestnut oak-white oak, 13= white pine-chestnut oak, 14= chestnut oak.

TABLE 2 SELECTED ENVIRONMENTAL CHARACTERISTICS OF THE COVE COMMUNITY TYPES[1]

Variable	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO	SM-SHAG	WA-SM	BAS-SM	HEM-TUL	BE-TUL	BE	RB
Slope Position[2]	U	U	U,M	U,M	L,M	L,F	M,L	M,U	M	M,L	G	L,M	L,M	F
Distance from the top of the slop (m)	72.4	91.7	79.1	140.9	210.9	260.1	220.3	184.9	164.2	221.2	208.7	398.7	366.3	292.8
Transformed aspect[3]	0.91	1.03	1.05	1.33	1.06	1.22	1.10	1.35	1.55	1.42	0.55	0.98	0.70	0.0
Slope angle (5)	33.0	41.3	39.4	23.4	31.6	30.9	36.2	24.3	32.2	38.5	22.8	27.9	25.6	2.6
Sand in the A (%)	43.3	37.9	41.1	39.3	37.8	42.9	35.4	27.9	21.8	39.6	43.8	37.6	46.3	34.6
Sand in the B (%)	41.8	35.6	41.0	31.3	34.5	43.8	35.9	25.7	15.5	35.2	50.1	38.8	44.2	37.8
Clay in the A (%)	12.4	17.4	10.3	16.4	17.0	13.3	15.3	18.8	19.8	12.9	9.2	12.2	10.3	15.4
Clay in the B (%)	14.9	22.9	12.6	25.7	22.9	16.9	20.4	26.6	33.0	20.1	10.4	15.3	15.8	17.4
pH of the A	4.7	4.7	4.4	5.3	4.8	5.1	5.7	5.5	5.9	5.5	4.6	5.2	4.8	4.1
pH of the B	4.8	4.6	4.6	4.9	4.8	5.1	5.5	5.1	5.6	5.4	4.7	5.0	4.9	4.2
Total available water	7.13	7.12	8.26	9.01	9.10	8.85	9.00	6.32	7.47	8.93	10.96	9.01	10.51	20.84
Bedrock type[4]	ss, sh	ss, sh	sh, ss	sh, ls	ss, sh	ss, ls	ls, ss	ls, sh	ls, sh	ls	ss, sh	ss, ls	ls, ss	ss

1/ Values within the table are means unless otherwise specified.
2/ U-upper, M-middle, L-lower, G-gorge, F-floodplain.
3/ Transformation is after Beers et al. (1966).
4/ ss-sandstone, sh-shale, ls-limestone.

The chestnut oak type was common on upper slop positions. Chestnut oak was reproducing well based on presence in the sapling layer and the type is apparently time stable. Chestnut oak communities have previously been reported from Plateau coves (Caplenor 1965) as well as from the Cumberland Mountains (Braun 1950, Hinkle 1975) and in the Great Valley (Martin 1971).

The chestnut oak-white oak type occurred in similar sites to the previous type. The major canopy species were reproducing and the type is apparently stable. Safley (1970) reproted a white oak-chestnut oak type from the Big South Fork area similar to this type.

The white pine-chestnut oak type occurred primarily in one gorge (Little Piney Creek, Rhea County). The major canopy species were reproducing but the successional status of this community is uncertain. White pine is a constituent of certain upland forests of the Cumberland Plateau (Smith 1977), but it is not common in Plateau gorges.

The northern red oak type is apparently successional with little reproduction by northern red oak although sugar maple reproduction was heavy. Cabrera (1969) reported a similar type from the Cumberland Mountains while Martin (1966) and Hinkle (1975) reported less mesic northern red oak types also from the Cumberland Mountains.

The white oak-northern red oak type was widespread; white oak was reproducing well in this type but northern red oak was not. White oak communities have previously been reported from Plateau covers (Caplenor 1965, Safley 1970). White oak is important but with different associate species on the Plateau uplands (Hinkle 1978) and also dominates many of the forests of the adjacent Great Valley (Martin 1971).

The tulip type was apparently successional. The importance of tulip in certain secondary Plateau cove forests has previously been noted by Braun (1950), Caplenor (1965), and Carpenter (1976).

The sugar maple-northern red oak type occurred on the western escarpment of the Cumberland Plateau. Northern red oak and tulip were not reproducing well in this type. The type is somewhat similar to communities described by McCarthy (1976) from Fentress County and by Cabrera (1969) in the Cumberland Mountains.

The sugar maple-shagbark hickory-white oak type also occurred on the western escarpment of the Plateau. Shagbark hickory and white oak were not reproducing well in this type. This community differs from previously described Plateau cove types although it is certainly related to Braun's (1950) mixed mesophytic forests.

The white ash-sugar maple type occurred in sites similar to the preceeding two types. White ash reproduction may not be sufficient to maintain its importance in this type. White ash dominated types have not previously been reported from the Plateau although the species occurs in many mesophytic forests (Braun 1950).

The white basswood-sugar maple-buckeye type is apparently stable. It resembels a community described by Cabrera in the Cumberland Mountains and is similar to Braun's (1950) concept of the deciduous mixed mesophytic forest.

The hemlock-tulip type was restricted to narrow sandstone gorges and draws. Hemlock was reproducing well and tulip may persist in gaps and openings in such forests (Buckner and McCracken 1978). Caplenor (1965) described more extensive and variable hemlock communities in the gorges of Fall Creek Falls State Park and Safley (1970) described a similar tulip-hemlock type. Braun (1950) termed similar vegetation hemlock-mixed mesophytic.

In the beech-tulip type, tulip was not reproducing well but beech will probably persist in this type. Braun (1950) described beech-mixed mesophytic forests in the "Cliff Section" of the Cumberland Plateau of southeastern Kentucky and northern Tennessee. Safley (1970) described a white oak-beech type along the Big South Fork of the Cumberland River.

The beech type is related to the previous type; the degree of beech dominance in this type may be related to past logging although beech is reproducing well there. Braun (1950) described beech-white oak and beech-sugar maple-white oak types in Pickett County, Tennessee.

The floodplain river birch type is successional; red maple appears to be replacing river birch. River birch is generally a pioneer species on river floodplains (Oosting 1942, Wolfe and Pittillo 1977). Braun (1950) found river birch to be a common floodplain species in the southern half of the Mixed Mesophytic Forest Region.

Discriminant Analysis

Discriminant analysis of the types using species importance values indicated that all the types were different at the .05 significance lever (Table 3). Classification success for these types was also high (Table 4).

Discriminant analysis using selected environmental variables indicated environmental similarity between a number of the types (Table 5). The chestnut oak, white pine-chestnut oak, hemlock tulip, and river birch types were distinct environmentally from all others at the 0.05 significance level. A number of the other types were not significantly different suggesting environmental overlap. The white oak-northern red oak type overlapped with the chestnut oak-white oak, northern red oak, and tulip types. The northern red oak type also overlapped with the sugar maple-shagbark hickory and the white ash-sugar maple types. Some overlap also occurred among the sugar maple types. The white ash-sugar maple type was not environmentally distinct from the other sugar maple types. The sugar maple-northern red oak type also overlapped somewhat with the sugar maple-shagbark hickory and the white basswood-sugar maple types. The two beech types also were environmentally similar.

Examination of the classification matrix (Table 6) indicated that the overall classification success was low (37.6%). Certain types including river birch, hemlock-tulip, beech, and chestnut oak were better classified than this, while the tulip and beech tulip types were poorly classified.

The coefficients of the discriminant functions (Table 7) and the plot of the centroids of the groups along the first two discriminant functions (Figure 2) may be interpreted together in considering the environmental separation of these groups. On the first discriminant function, which accounts for 28.5% of the variance, distance from the head of the gorge, gorge width, slope position, and distance from the top of the slope were most important. The signs of these coefficients were all positive and increases in the associated variables are associated with types to the right on the first discriminant function. These factors are correlated to some degree and in general related to lower slope position and increasingly mesic conditions; this is,however a complex axis in which other environmental factors also enter.

TABLE 3. MATRIX OF CLASSIFICATION SUCCESS FROM DISCRIMINAT ANALYSIS OF COMMUNITY TYPES USING SPECIES IMPORTANCE VALUES[1]

ACTUAL TYPE	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO	WA-SHAG	BAS-SM	HEM-SM	BEE-TUL	TUL	BEE	RB
CO	100.0													
CO-WO		100.0												
WP-CO			100.0											
NRO				100.0										
WO-NRO		3.6			92.9				3.6					
TUL						100.0								
SM-NRO							91.7		8.3					
SM-SHAG								100.0						
WA-SM									100.0					
BAS-SM							7.7			92.3				
HEM-TUL											100.0			
BE-TUL												100.0		
BE													100.0	
RB														100.

[1]Values within the table are percentages of the plots of the community types.

TABLE 4. MATRIX OF F-VALUES FROM DISCRIMINANT ANALYSIS OF COMMUNITY TYPES USING SPECIES IMPORTANCE VALUES[1]

COMMUNITY TYPE	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO	SM-SHAG	WA-SM	BAS-SM	HEM-TUL	BE-TUL	BE	RB
CO		6.53	20.43	13.94	27.17	19.96	18.93	27.48	23.63	25.13	40.33	22.64	47.64	50.53
CO-WO			15.31	6.01	7.08	10.16	9.41	13.68	17.45	13.82	27.56	11.13	30.17	42.47
WP-CO				12.58	18.58	13.26	16.38	19.72	18.94	17.82	16.53	15.76	25.33	36.58
NRO					5.82	7.97	3.90	5.86	11.16	7.46	17.86	6.45	16.01	31.41
WO-NRO						9.65	9.83	10.93	17.67	13.97	27.25	9.08	30.21	44.94
TUL							8.00	14.68	15.00	9.84	18.69	7.25	25.05	35.20
SM-NRO								4.19	8.44	7.32	21.76	8.58	28.65	41.15
SM-SHAG									10.87	9.48	25.87	11.13	31.96	44.26
WA-SM										10.69	22.87	14.43	27.21	37.51
BAS-SM											19.98	10.85	28.00	39.89
HEM-TUL												21.33	35.24	41.79
BE -TUL													9.11	30.15
BE														37.97

[1]The overall F of 14.03 (d.f. 403,1656) is significant at α =.001; for values within the table, the F-value at α=.001 (d.f. 31,134) is 2.76

TABLE 5. MATRIX OF F-VALUES BETWEEN COVE COMMUNITY TYPES FROM DISCRIMINANT ANALYSIS SELECTED ENVIRONMENTAL VARIABLES[1]

COMMUNITY TYPES	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO	SM-SHAG	WA-SM	BAS-SM	HEM-TUL	BE-TUL	BEE	RB
CO		3.44	4.40	1.90	4.96	3.75	4.29	3.72	4.15	4.81	7.40	4.65	5.59	6.77
CO-WO			2.33	2.28	1.39*	2.50	3.48	3.64	3.56	5.70	7.17	4.49	7.31	7.30
WP-CO				2.45	2.58	3.24	4.20	5.18	4.29	4.66	2.47	5.52	5.89	6.42
NRO					1.55*	2.13	1.74	1.26*	1.51*	1.85	4.44	2.14	2.25	4.91
WO-NRO						1.61*	2.47	3.37	2.89	4.32	6.61	2.96	5.19	6.11
TUL							1.26*	2.59	2.19	1.79	4.70	1.62*	3.42	4.42
SM-NRO								1.54*	0.98*	1.59*	5.39	1.26*	2.69	5.39
SM-SHAG									1.13*	3.34	7.26	1.81	4.48	6.40
WA-SM										1.39*	5.32	2.16	3.24	5.33
BAS-SM											5.40	2.65	3.34	4.98
HEM-TUL												6.35	6.53	4.87
BE-TUL													1.48*	3.83
BE														3.90

1/F(15,120) at α of .001 = 2.51, at α= .05 = 1.67, at α= .10 = 1.49.

* not significant at α = .05.

TABLE 6. CLASSIFICATION MATRIX FROM DISCRIMINANT ANALYSIS OF COVE COMMUNITY TYPES USING SELECTED ENVIRONMENT VARIABLES 1, 2

ACTUAL TYPE	CO	CO-WO	WP-CO	NRO	WO-NRO	TUL	SM-NRO	SM-SHAG	WA-SM	BAS-SM	HEM-TUL	BE-TUL	BE	RB
CO	55.6	16.7	5.6	11.0	5.6						5.6			
CO-QO	18.8	50.0	12.5		12.5		6.3							
WP-CO	12.5	12.5	37.5		12.5						25.0			
NRO	14.2			28.6	14.3			14.3		14.3			14.3	
WO-NRO	7.1	21.4	7.1		25.0	10.7	3.6	10.7		7.1		3.6	3.6	
TUL	16.7				25.0	8.3	25.0				8.3		8.3	8.3
SM-NRO				8.3	8.3	16.7	25.0	16.7		8.3			8.3	
SM-SHAG	20.0	6.7		6.7				26.7	13.3	13.3				
WA-SM							16.7	16.7	50.0	16.7				
BAS-SM	7.7			7.7				7.7	23.1	30.8	15.4	7.7		
HEM-TUL			11.1							11.1	66.7	11.1		
BE-TUL					16.7	8.3			8.3	8.3		8.3	33.3	16.7
BE					17.6					5.9			58.8	17.6
RB														100.0

1/Values within table are percentages of the plots of a type.
2/Overall classification success was 37.6%.

Table 7. Standaradized Coefficients of Environmental Variables on First Two Discriminant Functions from Analysis of Cove Community Types

VARIABLE	DF-1	DF-2
Transformed aspect	-0.375	-0.050
Distant from the top of the slope	0.394	-0.092
Slope position	0.472	0.696
Slope angle	-0.156	0.109
Soil depth	0.122	-0.392
Bedrock type	-0.071	0.328
O horizon thickness	-0.056	0.255
A horizon thickness	0.104	0.259
Stone in the A horizon	0.227	0.317
Sand in the A horizon	-0.361	-0.315
Sand in the B horizon	-0.021	0.328
pH of the A (in water)	0.369	-0.518
pH of the B (in water)	-0.138	0.120
Gorge width	0.467	-0.307
Distance from the head of the gorge	0.566	0.158
Total available water	0.351	0.561
CANCORR	0.774	0.743
PERCENT	28.5	23.5

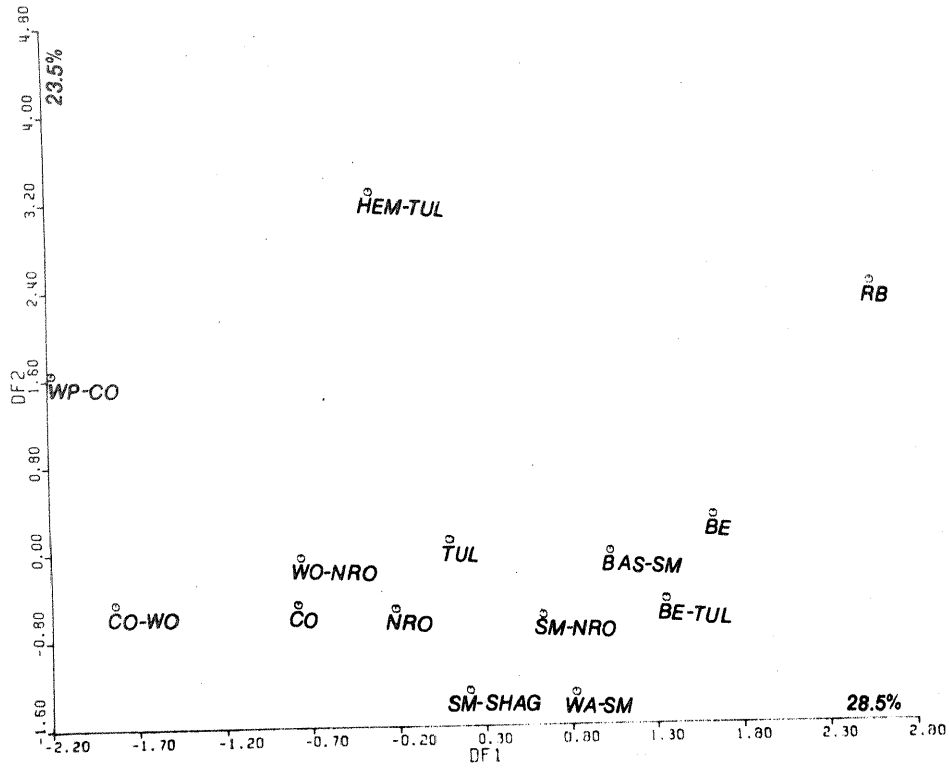

FIGURE 2. Centroids of cove community types along the first two discriminant functions from the analysis using selected environmental variables.

The second axis (23.5% of the variance) is most highly related to slope position, pH of the A horizon, and total water. Gorge and floodplain sites are at one end of this axis while cove slopes are at the other. The sign of the coefficient of pH of the A horizon is negative, indicating that increases in pH are associated with the negative direction along this axis. This is confirmed by the communities on the negative end of this axis, white ash-sugar maple, sugar maple-shagbark hickory, and the others having higher pH values than the hemlock-tulip and river birch types on the positive end of this function. Total available water also increases along this axis; the clayey soils of the sugar maple types have lower values for this variable than do the other types.

DISCUSSION AND CONCLUSIONS

The community types defined by cluster analysis were found to be vegetationally distinct by discriminant analysis. Thus it appears that cluster analysis groups plots that are most similar in vegetational composition. Whether these types represent relatively discrete communities or clusters within an overall continuum is not necessarily resolved by this analysis. They can however be successfully defined and classified.

Coefficients of the discriminant functions indicated that slope position factors which are indicative of soil moisture conditions and soil pH which probably represents available soil nutrients are important in segregating the types. Hinkle (1978) showed that the amount of potassium in the A horizon and soil pH were important in discriminanting between community types. Thus the types appear to be distributed along a complex soil moisture nutrient axis.

These community types were not so well separated by environmental variables. That separation could have a number of causes. The environmental variables used in this analysis might not be those most responsible for the separation of the types. Soil moisture and temperature, regimes were not directly measured in this study but rather were inferred from more readily measured parameters. Biological interactions such as competition or alleopathy might be responsible for the separation of the types but there is no direct evidence to support this. Finally, it may be that historical factors, past disturbance by logging, fire, and the removal of chestnut and the recovery from that disturbance, have resulted in different communities occupying similar enviroments. This seems to be a likely explanation for at least some of the lack of environmental discretenss between the types.

Several of the types which are not well distinguished environmentally appear to be successional. The tulip and northern red oak types are in this category. Within the several types in which sugar maple is important, sugar maple-northern red oak, sugar maple-shagbark hickory-white oak, white ash-sugar maple, and white basswood-sugar maple-buckeye, a considerable degree of environmental overlap existed. These types generally occurred on middle to lower slopes of coves on the western escarpment of the Cumberland Plateau, often on northern aspects. Successional relationships between these types are unclear, but only the white basswood-sugar maple-northern red oak type appears to be in compositional equilibrium.

The beech and beech-tulip types are environmentally similar to each other and may be successionally related. They are distinct, however from the sugar maple dominated types.

Some community types were quite distinct environmentally. The hemlock-tulip type occurred in distinct gorge sites. The floodplain sites of the river birch type were environmentally distinct although this type is apparently successional. The chestnut oak and white pine-chestnut oak types were distinct. The chestnut oak-white oak overlapped with the white oak-northern red oak type but was otherwise distinct.

Analysis of individual coves (Schmalzer 1978) generally supported these results. At the Obed River, Flint Fork, and Little Piney Creek sites factors relating to slope position were most important in the analysis and the distribution of communities in these sites appears to be related to the topographic moisture gradient. At these sites geology and soil parent material were rather uniform and the depth of colluvial material obscured underlying bedrock differences, such that major differences in soil texture and pH did not occur. At the Dick Cove and Doe Creek sites bedrock differences between the sandstone and shale of upper slopes and the limestone on middle and lower slopes were clearly reflected in soil texture and pH. The distribution of the community types here must be considered to be along a complex axis which includes topographic moisture status, and soil pH and textural differences.

These results are generally consistent with those of other types of gradient analysis of vegetation. Whittaker (1956) and Golden (1974) attributed the distribution of vegetation in the Great Smoky Mountains to topographic position and elevation on relatively uniform parent material. Gradients of soil moisture and temperature related to slope position and aspect were found to be important in determining species and community distribution in Thompson Gorge in the North Carolina Blue Ridge by Mowbray and Oosting (1968). Similarly, Cabrera (1969) related variation in a mixed mesophytic forest on Ash Log Mountain, Cambell County, Tennessee to aspect and topographic form.

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