VEGETATION PATTERNS IN A SECTION OF THE OBED WILD AND SCENIC RIVER, CUMBERLAND COUNTY, TENNESSEE

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Abstract. The vegetation of a section of the Obed Wild and Scenic River in Cumberland County, Tennessee was sampled and analyzed. Hierarchial agglomerative cluster analysis was used to establish six community types: chestnut oak-white oak, white oak, tulip poplar, beech-red maple-sugar maple, beech-tulip poplar-white oak, and river birch. Using discriminant analysis, these community types were shown to be rather distinct vegetationally but not all were environmentally distinct. The most important environmental variables segregating the community types were slope position factors. Examination of the diameter distributions curves of all and selected species in each type indicated that the chestnut oak-white and the white oak types were relatively stable, the tulip poplar and river birch types were successional and disturbance related, and that the beech-red maple-sugar maple and beech-tulip poplar-white oak types were apparently undergoing some compositional changes following disturbance.

Key Words: Agglomerative cluster analysis, Cumberland Plateau, community types, diameter distributions, discriminant analysis, mesophytic forests, Obed River, succession, vegetation.

INTRODUCTION

Gorges of the Cumberland Plateau of Tennessee support a complex and variable vegetation which can change greatly over short distances. In the present study we examine the vegetation in a section of the Obed River gorge. We wish to objectively define the forest community types in this area, to determine the major environmental variables segregating these community types, and to examine possible successional relationships using diameter distributions.

THE STUDY AREA

The Obed River is located in Cumberland and Morgan Counties, Tennessee in the Central Upland Region of the Cumberland Plateau. The particular area studied here is located between Adams Bridge and Potters Ford, approximately 36° 4' N and 84° 57' W in Cumberland County within the boundaries of the Obed Wild and Scenic River and the Catoosa Wildlife Management Area. The region has a flat to rolling topography into which the river gorge has been cut (Stearns, 1954).

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The climate of the Cumberland Plateau in Tennessee has been classified as humid, mesothermal (Thornthwaite, 1948). Precipitation is greater on the Plateau and evapotranspiration is less than in the adjacent Great Valley to the east or Highland Rim to the west (Dickson, 1960, Safley and Parks, 1974), and consequently severe drought is less frequent of the Plateau than in the immediate adjacent areas (Vaiksnoras and Palmer, 1973). Yearly precipitation at Crossville, 15 km south of the study site, averaged 137 cm from 1931 to 1970 and the mean annual temperature has been 13°C (Hinkle, 1978).

The Obed River has carved a long, narrow gorge into the Pennsylvanina strata of the Plateau surface. The strata exposed along the river at Adams Bridge are Rockcastle conglomeratic sandstone, forming the cliffs along the gorge, Vandever shale, underlying much of the slopes, and Bon Air (Newton) sandstone at the present level of the river (Stearns, 1954). Mississippian limestones which are commonly exposed in the deeper gorges of the Plateau (Caplenor, 1965) are not exposed along the Obed River.

Soils of the Obed gorge have been mapped (Hubbard et al., 1950) and they consist primarily of Rough stony land, Muskingum soil material; small areas of alluvial Holston and Pope soils occur on river terraces and floodplains. The soils of the gorge slopes are derived from sandstone and shale culluvium; they are variable, often rocky, acid, and have not been mapped in detail.

Braun (1950) included the Cumberland Plateau of Tennessee within the mixed Mesophytic Forest Region, but recognized that mixed mesophytic forests were confined to gorges of the Plateau; Kuchler (1966) similarly mapped the area as mixed mesophytic forest. Hinkle (1978) has shown that mesophytic forests are restricted to middle and lower gorge slopes, heads of gorges, and other protected sites. Previous studies of gorge vegetation have concentrated on dissected areas of the western third of the Plateau (Caplenor, 1965; Quarterman et al., 1972; Sherman, 1978) and the Big South Fork of the Cumberland River (Safley, 1970). Data from the Obed River are included in regional studies by Hinkle (1978), Schmalzer (1978) and Schmalzer et al., (1978).

METHODS

This section of the Obed River gorge was sampled in the summer of 1977 as part of a regional study of Cumberland Plateau vegetation (Hinkle, 1978; Schmalzer, 1978). Fifty-eight circular plots (0.04 ha) were placed on north and south aspects on upper, middle and lower slopes, terraces and floodplains within this section of the river gorge; only uneven age stands with no evidence of recent disturbance were sampled. The canopy layer, trees greater than 12.5 cm dbh, were recorded by taxon in 5 cm dbh classes; the sapling layer, trees and shrubs ranging from 2.5 cm to 12.5 cm dbh, were recorded by taxon. Nomenclature used here follows that of Radford et al. (1968). Specimens were identified in the field by reference to Shanks and Sharp (1963) and Wharton and Barbour (1973).

A soil pit was dug near the center of each plot and samples of the A and B horizons were collected. Depth to bedrock (to 91 cm), thickness and stone content of each horizon were recorded. Slope angle was measured in four directions from plot center. Aspect was also determined. Evidence of past disturbance such as fire scares or cut stumps was recorded.

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

Absolute and relative densities and basal areas of the canopy and sapling species in each plot were calculated by summing relative density and relative basal area (IV= RD + RBA = 200).

Hierarchial agglomerative cluster analysis (Orloci, 1967) was used to classify plots into groups (community types) of similar canopy composition.

Diameter distributions of selected dominant species in the community type were examined to clarify successional patterns in the types (Schmelz and Lindsey, 1965; Johnson and Bell, 1975; Buchholz and Pickering, 1978).

Discriminant analysis was used to examine the relationships between selected vegetation and environmental parameters (Dixon, 1975; Nie et al., 1975).

Discriminant analysis is a multivariate statistical technique which has been applied to plant community data in a number of recent studies (Hinkle, 1978; Kercher and Goldstein, 1977; Matthews, 1979; Norris and Barkham, 1970; Schmalzer et al, 1978). Discriminant analysis is designed to force defined groups to be as statistically distinct as possible by weighting and forming linear combinations of the variables used as discriminators. The analysis provides several kinds of information of ecological value. Assuming multivariate normality, significance tests between groups indicate whether signicant differences exist. Standardized coefficients of the discriminant functions may be interpreted like the beta weights in regression analysis; the magnitude of the coefficients represents the relative contribution of that variable to the discriminant function. Plots of the group centroids along the discriminant functions (axes) allow a graphical representation of group differences. A classification technique is also provided in discriminant analysis. Classification functions predict groups membership; reclassification of group members permits evaluation of classification success and is a measure of success in discriminating between the groups.

RESULTS

Classification Analysis

Six community types were identified using the agglomerative cluster analysis (Fig. 1). Importance values of the canopy taxa in the six types are given in Table 1 and the understory composition is summarized in Table 2. The six community types, named after their leading dominant canopy species, are the white oak type, chestnut oak-white oak type, beech-red maple-sugar maple type, beech-tulip poplar-white oak type, tulip poplar type, and river birch type.

TABLE 1. Canopy Composition of Obed River Communities (MEAN IV)[a]
Community Types

Species	CO-WO	WO	TUL	BE-RM	BE-TUL	RM
Acer rubrum	7.55	3.89	8.88	20.40	5.50	30.80
A. saccharum	0.45	8.61	8.25	19.30	4.33	3.00
Betula lutea			1.00			
B. nigra			10.38	13.00		129.20
Carpinus caroliniana				3.30	1.50	20.60
Carya cordiformis			0.75	5.10		
C. glabra	8.82	18.00	14.13	1.90	3.17	
C. ovalis		1.22		4.00	1.17	
C. ovata	2.91	5.56	8.75	7.30	12.67	
C. tomentosa	25.55	6.28	6.25	16.90		
Cornus florida	4.36	1.22	0.75	0.70	1.50	
Fagus grandifolia	4.55	9.67	3.50	31.60	83.50	4.00
Fraxinus americana	1.55	2.44	2.50	4.70	4.17	
Juglans nigra		0.33		1.10		
Liriodendron tulipefera	11.18	13.44	77.13	17.20	32.00	9.80
Magnolia acuminata	1.73	4.61	1.75	1.90	3.83	
Nyssa sylvatica	0.64	3.50	2.13	5.30		
Oxydendrum arboreum	4.27	2.89	5.25	0.60	4.33	
Pinus strobus	7.18	0.39	18.50			
P. virginiana	4.00	0.39	1.50			
Prunus sylvatica			1.63	2.50		
Quercus alba	29.64	74.39	4.25	7.30	29.67	
Q. coccinea	4.64	0.56				
Q. falcata		0.89				
Q. prinus	48.45	10.00		1.70	7.50	
Q. rubra	10.73	19.33	10.88	4.70		
Q. stellata		0.39				
Q. velutina	21.55	1.56				
Tilia americana		7.94	7.13	13.50		
T. heterophylla					3.17	
Tsuga canadensis			2.75	11.50		
Ulmus americana		0.50			2.17	2.40

[a]CO-WO, chestnut oak-white oak; WO, white oak; TUL, Tulip poplar; BE-RM, beech-red maple-sugar maple; BE-TUL, beech-tupip poplar-white oak; RB, river birch.

TABLE 2. Understory Composition of Obed River Communities
(Mean Sapling RD)

Species	CO-WO	WO	TUL	BE-RM	BE-TUL	RB
Acer rubrum	19.82	18.00	11.38	16.00	5.00	13.60
A. saccharum	1.73	12.89	17.75	13.80	8.00	0.80
Amelanchier aroborea	0.09					
Asimina triloba			0.38	1.60		4.40
Betula nigra			0.30			
Carpinus caroliniana		6.89	18.38	17.10	16.83	31.80
Carya glabra	3.09	6.17	1.50	1.50	0.83	
C. ovalis		0.22				
C. ovata	0.18	0.11	0.25	0.60		
C. tomentosa	6.09	2.78	0.38	1.50	0.17	
Castanea dentata	0.45	0.11				
Cercis canadensis	1.45	1.39	0.13	2.30	0.83	
Cornus amomum			0.25			
Cornus florida	20.18	18.83	25.25	17.90	27.17	
Corylus americana		0.39	0.38			
Crataegus sp.	0.09	0.39				
Fagus grandifolia	0.27	3.00	5.25	3.90	7.83	3.00
Fraxinus americana		1.17	0.75	1.20	0.83	2.00
Hamamelis virginiana	0.73	0.11	0.63	0.40		
Ilex opaca		0.06	2.63		0.83	
Kalmia latifolia	7.73	0.83				
Lindera benzoin		0.83		1.10		37.20
Liquidambar styraciflua			0.63		5.00	
Liriodendron tupipfera	2.18	0.78	0.63	2.30	1.10	0.80
Magnolia acuminata	0.27	0.44	0.38	0.10		
M. macrophylla					0.50	
M. tripetala		0.28		0.10	0.50	
Nyssa sylvatica	3.27	3.67		3.60	2.50	
Ostrya virginiana	0.64	1.22	0.50	0.40	0.83	
Oxydendrum arboreum	8.82	5.56	2.75	1.60	4.67	
Pinus strobus	8.86	2.44	2.63			
P. virginiana	0.45	0.72				
Quercus alba	5.09	4.94	2.50	5.70	2.33	
Q. coccinea	0.18	0.06				
Q. prinus	5.45	1.16		0.60		
Q. rubra	1.09	1.17	1.50	0.90		
Q. velutina	1.00					
Sassafras albidum	1.00	0.17	0.38			
Stewartia ovata	0.27	0.89				
Tilia americana		1.72	2.50	3.40	1.50	
T. heterophylla		0.11		0.30	3.67	
Tsuga canadensis			0.50	2.20		
Ulmus americana			0.75		1.00	
Vaccinium stamineum	0.27		0.06			
Vitis sp.				0.30		0.60

[a]CO-WO, chestnut oak-white oak; WO, white oak; TUL, tulip poplar; BE-RM, beech-red maple; BE-TUL, beech-tulip poplar; RB, river birch.

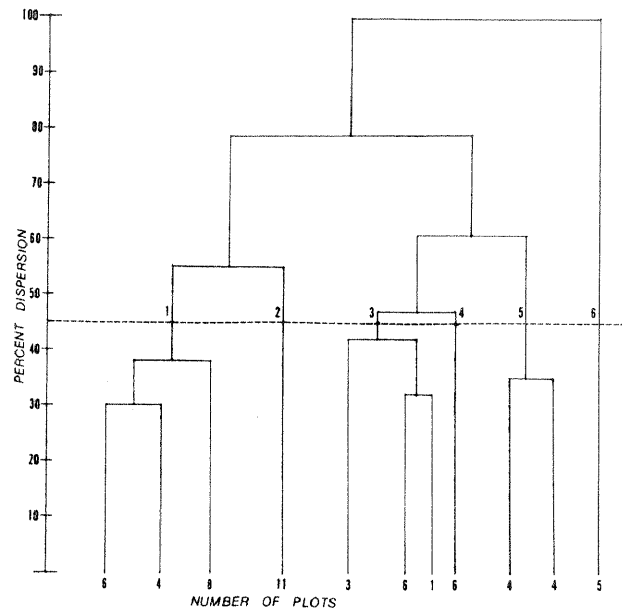

Figure 1. Dendrogram of cluster analysis on the Obed River sample plots; communities are defined at the 45% dispersion level. 1=white oak, 2=chestnut oak-white oak, 3=beech-red maple-sugar maple, 4=beech-tulip poplar-white oak, 5=tulip poplar, 6=river birch.

Diameter Distributions

In order to clarify successional relationships of these community types diameter distributions were constructed (Figs. 2-7). In the chestnut oak type, both chestnut oak (*Quercus prinus* L.) and white oak (*Q. alba* L.) were reproducing and the type appeared to be relatively stable (Fig. 2). White oak was also reproducing in the white oak type (Fig. 3).

Tulip poplar (*Liriodendron tulipifera* L.), however, was reproducing to only a limited extent in the tulip poplar type (Fig. 4) and will probably be replaced, in part, by other mesic taxa; tulip poplar is maintained in mesic forests by gap phase reproduction (Buckner and McCracken, 1978). The river birch type showed an even more clear-cut pattern (Fig. 5); river birch (*Betula nigra* L.) was absent from all the smaller diameter classes. River birch is generally a pioneer species on river floodplains (Oosting, 1942; Wolfe and Pittillo, 1977). It is thus dependent for its perpetuation on a disturbance regime which creates open floodplain areas (White, 1979).

The status of the beech communities was less clear (Fig. 6-7) and both showed gaps and peaks which may be related to past selective logging. Beech

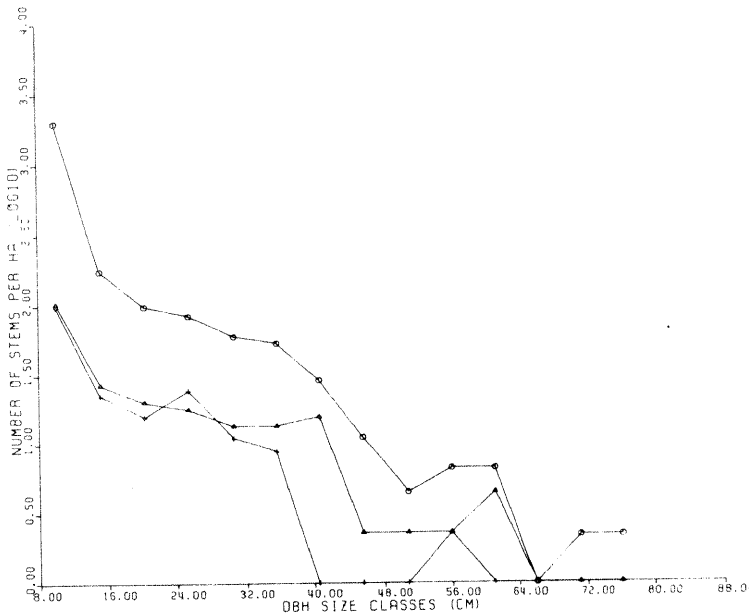

Figure 2. Diameter distributions of the chestnut oak-white oak type. In this and subsequent diameter distributions the sapling layer (2.5 - 12.5 cm dbh) is plotted as a single point at 10 cm. All species (hexagon), chestnut oak (triangle), and white oak (x) appear.

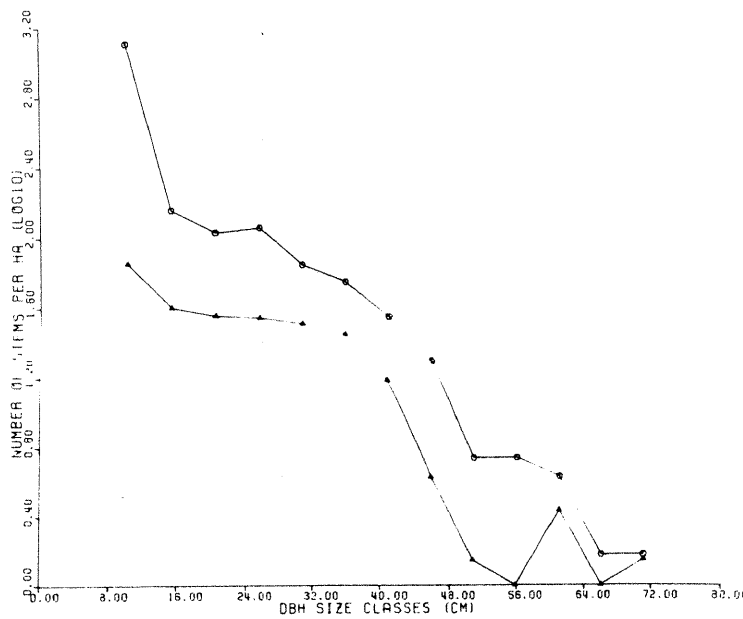

Figure 3. Diameter distributions of the white oak type. All species (hexagon) and white oak (triangle) appear.

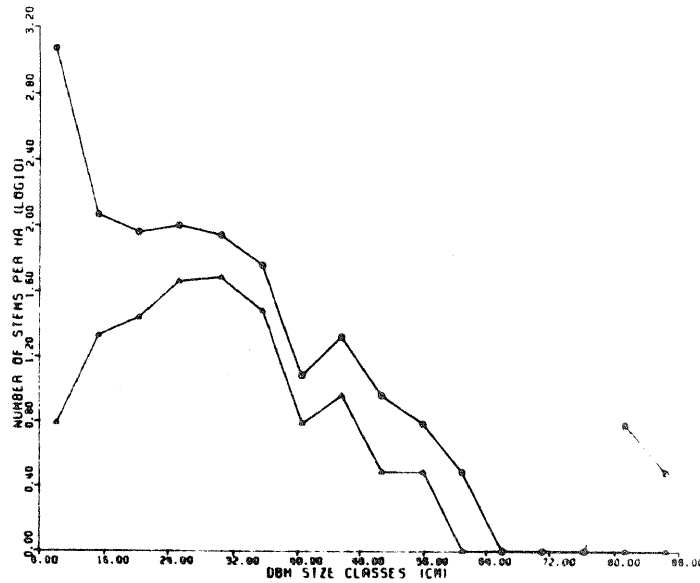

Figure 4. Diameter distributions of the tulip poplar type. All species (hexagon) and tulip poplar (triangle) appear.

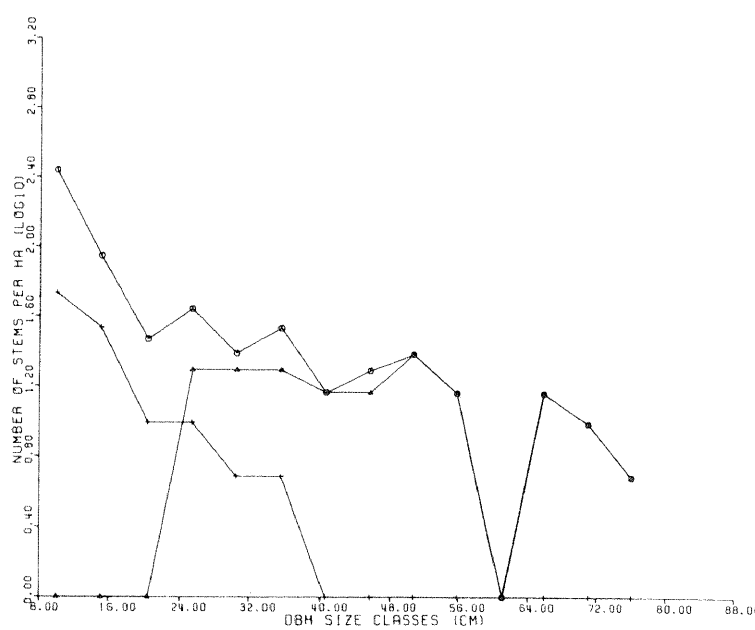

Figure 5. Diameter distributions of the river birch type. All species (hexagon), river birch (triangle), and red maple (x) appear.

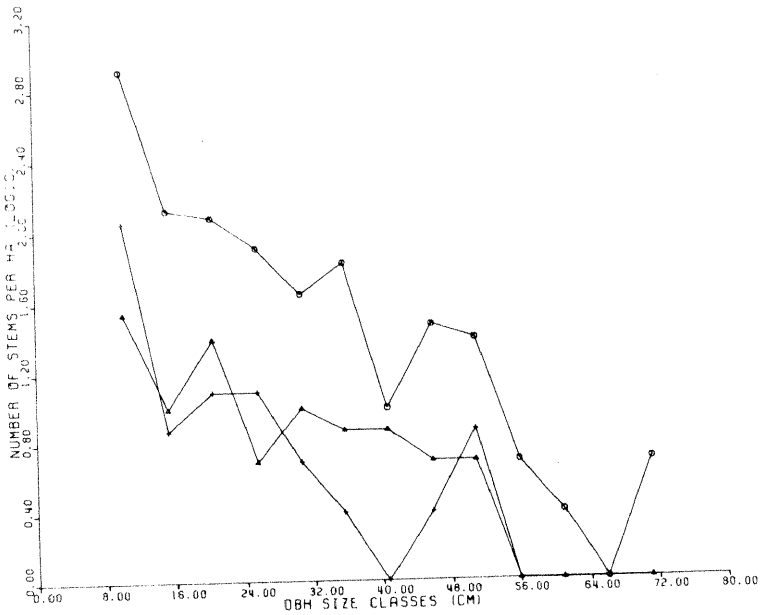

Figure 6. Diameter distributions of the beech-red maple-sugar maple type. All species (hexagon), beech (triangle), and red maple (x) appear.

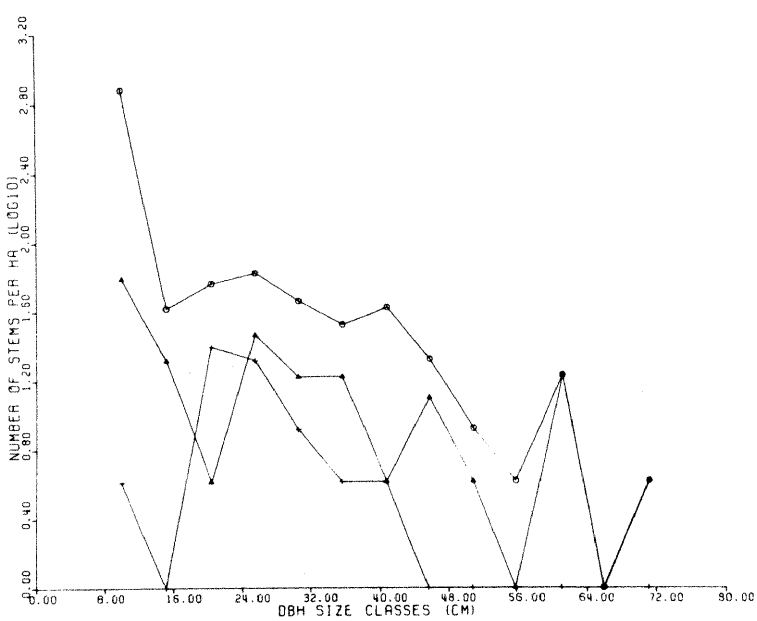

Figure 7. Diameter distributions of the beech-tulip poplar-white oak type. All species (hexagon), beech (triangle), and tulip poplar (x) appear.

(Fagus grandifolia Ehrh.), red maple (Acer rubrum L.) and sugar maple (A. saccharum Marsh.) were all reproducing in the first type (Fig. 6). Beech was reproducing in the beech-tulip poplar-white oak type but tulip poplar showed only limited reproduction (Fig. 7). Some compositional changes will probably occur in these two types.

Discriminant Analysis

Discriminant analysis of the six community types using vegetation data indicated that the community types were significantly different; F-values between the types were significant and classification success was high (Table 3).

The community types were not as well differentiated by discriminant analysis using selected environmental variables. Not all of the community types had significantly different F-values and classification success was much lower than with the vegetation variables (Table 4). The beech-red maple, beech-tulip poplar, and tulip poplar types particularly occurred in environments similar with respect to the variables examined.

Discriminant analysis did contribute to an environmental interpretation of the communities. The first discriminant axis (Fig. 8), which accounts for 57.9% of the variance, was most closely related to slope position (Table 5). The position of the community types along the first axis tended to confirm the slope position-vegetation relationships inferred in other studies on the Plateau (Hinkel, 1978; Schmalzer, 1978).

DISCUSSION

The vegetation in the Obed River Gorge is similar in several ways to that reported by other workers in the Appalachian Plateau. In the Obed Gorge, the white oak type occurs at middle to lower slope position on north- and south-facing slopes. White oak, northern red oak (Quercus rubra L.), pignut hickory (Carya glabra (Mill.) Sweet), and tulip poplar are important in the canopy; dogwood (Cornus florida Mill.), red maple, and sugar maple are predominant in the understory. White oak communities are widespread in coves and gorges of the Cumberland Plateau (Caplenor, 1965; Hinkle, 1978; Schmalzer, 1978). White oak types are common on the uplands of the Plateau; however, the associate species are typical of the more xeric oak forests (Hinkle, 1978).

The chestnut oak-white oak type occurs on upper north- and south-facing slopes. Chestnut oak, white oak, black oak (Quercus velutina Lam.), and mockernut hickory (Carya tomentosa (Poir.) Nutt.) are important in the canopy; dogwood and red maple are predominant in the understory. Chestnut oak types occur on upper slopes of many Plateau coves (Caplenor, 1965; Hinkle, 1978; Schmalzer, 1978; Sherman, 1978).

The beech-red maple-sugar maple community occurs on lower slopes, in draws, and on second terraces. Beech, red maple, sugar maple, tulip poplar, mockernut hickory, and basswood (Tilia americana L. or Tilia heterophylla Vent.) are important in the canopy; dogwood, blue beech (Carpinus caroliniana Walt.), red maple, and sugar maple are predominant in the understory. Braun (1950) describes a similar beech-sugar maple type in Pickett County, Tennessee. Hinkle (1978) describes beech and beech-tulip poplar communities in several locations

TABLE 3. Discriminant analysis of Obed River communities using canopy species importance values.

Classification Matrix[a]

Community	CO-WO	WO	TUL	BE-RM	BE-TUL	RB
CO-WO	100.0					
WO		100.0				
TUL			100.0			
BE-RM				100.0		
BE-TUL					100.0	
RB						100.0

Matrix of F-values[b]

Community	WO	TUL	BE-RM	BE-TUL	RB
CO-WO	22.619	26.802	19.225	22.678	44.958
WO		14.565	14.348	15.708	42.641
TUL			10.618	14.785	30.014
BE-RM				10.865	23.180
BE-TUL					22.899

[a]Percent classification success.
[b]All F-values are significant at $\alpha \leq .01$.

TABLE 4. Discriminant analysis of Obed River communities using environmental variables.

Classification Matrix[a]

Community	CO-WO	WO	TUL	BE-RM	BE-TUL	RB
CO-WO	72.7	18.2	0.0	0.0	9.1	0.0
WO	33.3	22.2	16.7	5.6	22.2	0.0
TUL	0.0	37.5	25.0	12.5	25.0	0.0
BE-RM	10.0	10.0	0.0	40.0	40.0	0.0
BE-TUL	0.0	0.0	50.0	16.7	0.0	33.3
RB	0.0	0.0	0.0	0.0	20.0	80.0

Matrix of F-values[b]

Community	WO	TUL	BE-RM	BE-TUL	RB
CO-WO	2.46	4.48	4.77	4.58	7.46
WO		2.06	2.66	1.55*	4.52
TUL			2.72	1.31*	3.67
BE-RM				1.28*	3.74
BE-TUL					1.37*

[a]Percent classification success.
[b]Degrees of freedom = 15,38; $F_{.05} = 2.20$; $F_{.10} = 1.85$.
*Not significant at $\alpha = .10$.

TABLE 5. Coefficients of environmental variables on the first two discriminant axes.

VARIABLE	AXIS 1	AXIS 2
Transformed aspect	0.019	0.613
Distance from top of slope	0.170	-1.145
Slope position	0.768	0.393
Slope angle	-0.458	-0.054
Soil depth	-0.443	-0.219
Bedrock type	-0.027	0.183
O horizon thickness	0.639	0.009
A horizon thickness	0.024	0.229
Stone content - A horizon	0.409	0.366
Sand content - A horizon	-0.598	0.361
Sand content - B horizon	0.029	-0.331
pH of the A horizon	-0.013	0.939
pH of the B horizon	-0.127	0.479
Gorge depth	0.440	-0.012
Total water holding capacity	0.370	0.530
Canonical correlation	0.886	0.738
Percent variance	57.9	17.8

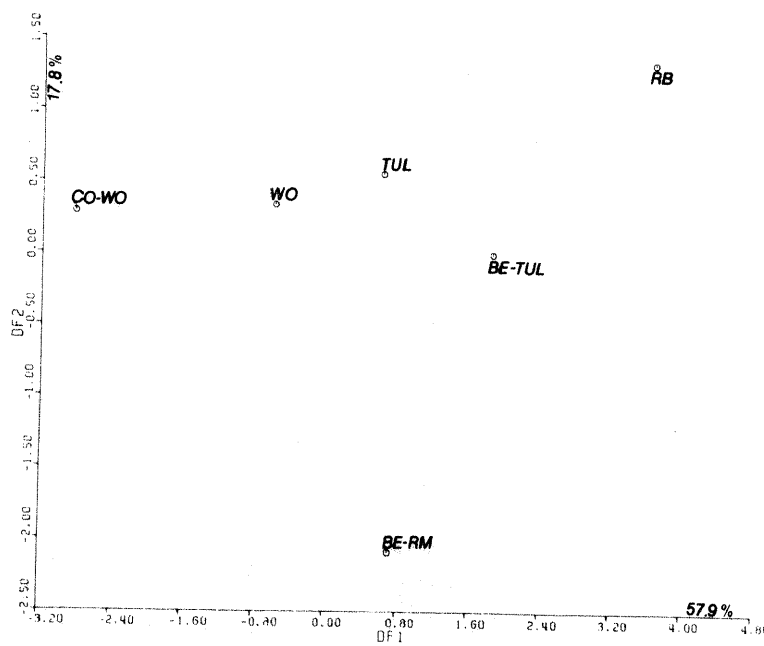

Figure 8. Discriminant analysis of the community types using selected environmental variables.

in the northern part of the Cumberland Plateau in Tennessee.

The beech-tulip poplar-white oak type occurs on lower slopes and terraces. Beech, tulip poplar, white oak, and shagbark hickory (Carya ovata (Mill.) K. Koch) are important in the canopy; dogwood and blue beech are predominant in the understory. Braun (1950) describes similar beech-white oak forests in Pickett County, Tennessee, 56 km to the northeast. Safley (1970) describes a white oak-beech type along the Big South Fork of the Cumberland River, 48 km to the north.

The tulip poplar type occurs on lower slopes and terraces. Tulip poplar, white pine (Pinus strobus L.), pignut hickory, and northern red oak are important in the canopy; dogwood, blue beech, sugar maple, and red maple are predominant in the understory. The importance of tulip poplar in secondary cove forests of the Cumberland Plateau has been noted by Braun (1950), Caplenor (1965), and Carpenter (1976).

The river birch type occurs on the river floodplain. River birch (Betula nigra L.) is the most important canopy species and spicebush (Lindera benzoin (L.) Blume.), blue beech, and red maple are predominant in the understory. Braun (1950) found river birch to be a common floodplain species in the southern half of the Mixed Mesophytic Forest Region; Safley (1970) described a similar river birch community along the Big South Fork of the Cumberland River. The type has also been noted on the flat to rolling Plateau surface (Hinkel, 1978).

At a higher level in the classification dendrogram (Fig. 1), one could distinguish three major vegetation types along this section of the Obed River. These are a mixed oak forest of middle and upper slopes, a mesic deciduous forest of lower slopes and terraces in which beech, sugar maple, and tulip poplar are important taxa and a floodplain river birch forest.

The successional status of these community types is revealed to some extent in the diameter distribution curves. Several general patterns are interpretable from diameter distribution curves defining stand structure. Schmelz and Lindsey (1965) summarize four:

1. a nearly straight line indicative of relatively little stand disturbance,
2. a sharp peak in the line indicative of severe disturbance at the particular size classes,
3. a curve characterized by a plateau indicative of significant recovery after disturbance, and
4. a line with a widely deviating negative slope indicative of a late stage in recovery.

Johnson and Bell (1975) have suggested that examination of individual species curves reveal detail about stand history. Applying these concepts to stands on the surface and in the ravines of the Plateau, Hinkle (1978) demonstrated the high degree of disturbance common to many definable community types. It appears that this is the case in the Obed Gorge as demonstrated by the species curves.

Although discriminant analysis of the six community types indicates that based on vegetation parameters the communities are distinct, they are not so well differentiated when segregated by environmental variables. Of particular interest is the lack of environmental distinction of the samples defining beech-red maple, beech-tulip poplar, tulip poplar types. These communities are all essentially lower slope communities and even though they were well separated from the other types, they are apparently only vegetationally different from each other due to disturbance history. Indications are that they occur in areas of similar environmental characteristics. As indicated by the diameter distribution curves these stands have a history of disturbance.

These results suggest that the lack of environmental discreteness revealed by discriminant analysis is related to the disturbance history and successional relationships among the community types. Similar patterns have been suggested for other gorges and the Plateau surface (Hinkle, 1978). Different communities occupy similar habitats because of their differing histories. However, lack of environmental separation could also occur if the environmental variables measured or estimated are not the ones actually discriminating between the communities or if the transitions between the communities are gradual rather than distinct.

SUMMARY AND CONCLUSIONS

The vegetation of the section of the Obed River gorge investigated here displays a considerable variation in a relatively small geographic area. Chestnut oak-white oak, white oak, tulip poplar, beech-red maple-sugar maple, beech-tulip poplar-white oak, and river birch communities all occur.

Discriminant analysis using environmental variables reveal the importance of slope position as an important discriminating environmental variable but indicate that not all of the communities are environmentally distinct.

Results from the evaluation of diameter distribution curves indicate that under present conditions the chestnut oak-white oak type and the white oak type are relatively stable, the tulip poplar type and the river birch type are successional and probably disturbance dependent. The beech types are of an intermediate status following past anthropogenic disturbances.

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