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Upland Oak Forests of the Ridge and Valley Province in Southwestern Virginia

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ABSTRACT

Upland forest communities of the Ridge and Valley Province in southwestern Virginia are usually dominated by various species of oak, of which chestnut oak (*Quercus prinus*) and northern red oak (*Q. rubra*) are the most important. American chestnut (*Castanea dentata*), formerly a codominant species in the tree stratum of these communities, was almost completely eliminated during the first half of this century by the chestnut blight. Although both chestnut oak and red oak sometimes occur in nearly pure stands, the more common expression is for an admixture of various other species, including red maple (*Acer rubrum*), hickory (*Carya* spp.), black oak (*Quercus velutina*) and white oak (*Q. alba*), to be represented in the tree stratum. Throughout the region, more mesophytic communities primarily occur in sheltered ravines and coves, and hemlock (*Tsuga canadensis*)-yellow birch (*Betula lutea*)-red spruce (*Picea rubens*) communities occupy a few of the most mesic high-elevation sites.

INTRODUCTION

The purpose of this paper is to provide an overview of the general pattern of upland forest community composition for a portion of the Ridge and Valley physiographic province of southwestern Virginia. Our specific objectives are (1) to first identify and then describe the major community types consistently encountered in the particular geographic area being considered and (2) to relate the spatial distribution of these community types to the environmental complex-gradients associated with differences in elevation and topographic position. The present paper supplements previously published reports (e.g., Stephenson 1982, Adams and Stephenson 1983) of upland forest vegetation in this same area of southwestern Virginia.

THE STUDY AREA

The quantitative data upon which this paper is based were collected during the period of 1975-1986 from the Mountain Lake area of Giles County in southwestern Virginia, which is within the Ridge and Valley Province of the southern Appalachian Mountains (Fenneman 1938). The Ridge and Valley is a region of extensively folded and thrust-faulted Paleozoic strata. The general pattern is that of a more or less parallel series of elongated, often relatively level-crested ridges which run in a southwest-northeast direction. The ridges are capped with resistant quartzites, conglomerates, and sandstones; the less resistant shales and limestones have eroded away, producing the intervening valleys (Butts 1940). The underlying geological formations of the stands sampled in the present study consist primarily of sandstones, siltstones, and shales (Haynes 1974). Climatological data from the University of Virginia Mountain Lake Biological Station (elevation 1168 m) in Giles County indicate that average monthly temperatures range from a low of -3.7°C in January to a high of 18.5°C in July. The mean annual precipitation is 134 cm (U. S. Dept. Commerce 1972-1983).

Braun (1950) included the Mountain Lake area within the Ridge and Valley Section of the Oak-Chestnut Region. The study area lies close to the western boundary of the Oak-Chestnut Region where the latter gives way to the Mixed Mesophytic Region. The major species of trees composing the forests of the ridges are various species of oak, of which chestnut oak (*Quercus prinus*) and northern red oak (*Q. rubra*) are the most important. American chestnut (*Castanea dentata*), formerly a codominant species in the tree stratum of these communities, was almost completely eliminated during the first half of this century by the chestnut blight (Stephenson 1974, 1986).

METHODS

Field Sampling

Quantitative data on vegetation and topographic variables were collected from a total of 43 forest stands in the Mountain Lake area. All of the sampled stands met the following selection criteria: (1) a relatively homogeneous unit of vegetation, (2) located in an area of essentially uniform topography, and (3) no evidence of appreciable recent (< 40 yrs) disturbance by man or other causes.

For each stand, quantitative data for the tree stratum were obtained from a single 20 by 50 m (0.1 ha) rectangular plot laid out with its long axis parallel to the contour of the slope. Species and diameter were recorded for all woody stems ≥ 10 cm DBH (diameter at breast height [1.37 m]). Topographic variables measured or determined for each stand included elevation, percent slope, slope aspect, and slope position. Slope aspect was transformed in the manner described by Beers et al. (1966). As such, a transformed aspect value is the cosine transformation of azimuth, so that 45° (NE aspect) = 2.0 and 225° (SW aspect) = 0.0. Slope position was derived subjectively from maps and field observations. An index of slope position was assigned to each stand on the basis of 1 = upper slope, 2 = mid-slope, 3 = lower slope, and 4 = ravine or cove. Identification of hickories to species was not always possible and all individuals were simply recorded as *Carya* spp. However, pignut hickory (*C. glabra*) is the most common species of hickory in the general study area. Nomenclature used for vascular plants follows that of Radford et al. (1968).

Data Analyses

Field data were converted to absolute measures. Density (number of stems per hectare) and basal area (m^2 per hectare) were determined for all species represented in the tree stratum. These data were then used to calculate species importance value indices. As used in this paper, importance values are one-half the sum of relative density and relative basal area (i.e., maximum value = 100).

Species diversity indices were calculated for the tree stratum using Shannon's formula (Shannon and Weaver 1963) and importance values as measures of species abundances. The general formula of this index is

$$\text{Species diversity } (H') = -\Sigma \text{ pi log pi}$$

where pi is the proportion of the total for all species represented by species i. This index varies from a value of 0 for a community containing a single species to some maximum value for a community containing many species, each with a low level of importance.

A weighted average (Whittaker 1967) was calculated for each sampled stand by first assigning synthetic moisture indices (Goff and Cottam 1967) to all species represented in the tree stratum and then multiplying the importance value for each species present in that stand by the appropriate index. The synthetic moisture indices used in this study were 0 (for species usually limited to mesic sites), 1 (for species characteristic of submesic sites), 2 (for species characteristic of subxeric sites), and 3 (for species usually limited to xeric sites). Indices were assigned on the basis of the species groupings given in Whittaker (1956) and are consistent with distributional data available for other areas in the southeastern United States.

The 43 stands were subjected to Detrended Correspondence Analysis (Hill 1979, Hill and Gauch 1980), using the Cornell Ecology Program DECORANA (Hill 1979). This method of ordination was chosen because it has been shown to be relatively effective in a number of other studies (Gauch 1982). The ordination was computed using importance value indices.

RESULTS AND DISCUSSION

Vegetation and site parameters of the 43 stands sampled in the present study are summarizd in Table 1. All of the stands were located at elevations >775 m and seven occurred at elevations >1219 m. Sampled stands occupied a wide range of topographic positions, ranging from exposed ridgetops to lower, protected slopes of ravines. Based on the average value for transformed aspect (1.1), "mesic" and "xeric" exposures were about equally represented. Total density of the tree stratum averaged 580 stems/ha and the average basal area was 28.9 m^2/ha. The latter figure is near the midpoint of the range reported for mature, temperate deciduous forests (25.8 to 32.2 m^2/ha) by Held and Winstead (1975). Mean values calculated for species diversity (H') and species richness were 2.01 $\pm$ 0.7 and 7 $\pm$ 0.3, respectively.

Thirty species were represented in the tree stratum, but only 17 of these achieved an average (based on pooled data from all 43 stands) importance value >0.5 and thus are included in Table 2. Red oak and chestnut oak were clearly the most important species present, with red maple (*Acer rubrum*), hickory, white oak (*Q. alba*), and hemlock (*Tsuga canadensis*) the only other species with an average importance value >5.0. However, hemlock was present in only six stands.

The positions of the 43 stands on the two-dimensional DCA ordination are shown in Figure 1. The first axis would seem to relate most closely to an environmental moisture complex-gradient (sensu Whittaker 1967), with stands dominated by tree species characteristic of more xeric sites located on the left side of the ordination and those dominated by species characteristically found on more mesic sites on the right side. The correlation of DCA ordination scores for the first axis and weighted averages calculated for sampled stands was highly significant ($r = 0.85$, $p<0.01$). Because communities dominated by tree species characteristic of truly xeric sites do not occur at higher elevations in the area of Giles County sampled

TABLE 1. Summary data for vegetation and site characteristics of 43 stands sampled in the Mountain Lake area of southwestern Virginia.

Parameter	Range	Mean ± SD
Elevation (m)	775-1280	1079 ± 131
Aspect*	0.1-2.0	1.1 ± 0.7
Slope position**	1-4	2.1 ± 1.0
Slope (%)	2-85	33 ± 20
Density (N/ha)***	280-990	580 ± 131
Basal area (m^2/ha)***	17.4-50.0	28.9 ± 7.2
Species richness***	4-12	7 ± 2.0
Species diversity (H′)***	0.76-2.71	2.01 ± 0.46

*aspect is cosine transformation of azimuth (Beers et al. 1966), so that 45° = 2.0 and 225° = 0.0
**1 = upper slope, 2 = mid-slope, 3 = lower slope, and 4 = ravine or cove
***stems ≥ 10 cm DBH

TABLE 2. Composition of the tree stratum (stems ≥ 10 cm DBH) for all 43 stands.

Species	Moisture index	No. of stands present	Average importance value
Quercus rubra	1	40	28.3
Quercus prinus	2	26	20.4
Acer rubrum	1	35	10.1
Carya spp.	1	26	7.2
Quercus alba	2	19	5.5
Tsuga canadensis	0	6	5.2
Quercus velutina	2	14	3.8
Betula lutea	0	5	2.6
Betula lenta	1	20	2.4
Picea rubens	0	4	2.4
Robinia pseudoacacia	2	19	2.3
Magnolia acuminata	0	18	2.2
Amelanchier arborea	1	15	1.2
Oxydendrum arboreum	2	7	1.2
Acer saccharum	0	6	1.0
Nyssa sylvatica	2	7	0.7
Fagus grandifolia	0	1	0.6
Other species[1]	0-3	1-5	2.9
Total			100.0

[1] *Acer pensylvanicum, Castanea dentata, Cornus florida, Fraxinus americana, Hamamelis virginiana, Liriodendron tulipifera, Ostrya virginiana, Pinus rigida, Pinus strobus, Prunus serotina, Quercus coccinea, Sassafras albidum,* and *Tilia heterophylla*

in this study (Stephenson 1982), both the compositional gradient along the first axis and the moisture gradient to which it corresponds are truncated. Therefore, the most xeric portion of each of the two gradients is better designated as subxeric than xeric. The arrangement of stands along the second axis of the ordination appears to be most closely related to elevation ($r = 0.35$, $p < 0.05$). Most of the stands located toward the top left corner of the ordination are found at elevations >1100 m, whereas the majority of the stands located toward the lower left are at elevations <1100 m. However, stands located at the highest elevations actually occur near the middle of the second ordination axis and thus represent exceptions to this general pattern.

Clusters of stands sharing the same leading dominants and thus considered to represent a particular community type are encircled on the ordination (Figure 1). Average importance values for all of the more important species present in the group of stands assigned to each community type are given in Table 3. Community types are named on the basis of the major dominants; these names are provided with each community type (Figure 1). Five different clusters of stands are apparent on the ordination, although for one of these (the cluster located in the upper left corner) the degree of spatial separation of member stands indicates considerable compositional heterogeneity. In addition, one stand dominated by a tree species (beech [*Fagus grandifolia*]) not encountered in any other stand was considered compositionally unique and thus was not assigned to any of the five community types. One community type is located on the far right side of the ordination, whereas all of the others occupy positions on the left. Stands making up the former are dominated by tree species (including two conifers) generally associated with only the most mesic sites, whereas the member stands of the latter are dominated by species (mostly oaks) characteristic of submesic or subxeric sites. The lack of any distinct separation among the four community types located on the left side of the ordination is undoubtedly the result of the constancy of chestnut oak and red oak. Although stands strongly dominated by chestnut oak occurred on apparently more xeric sites than those occupied by stands in which red oak achieved a high level of dominance, the usual situation was for both species to be present. Only in stands located on the most mesic sites or at the highest elevations sampled (>1219 m) was chestnut oak completely lacking. As a general observation, the three oak-dominated community types that fall within the lower half of the ordination form a sequence that reflects a transition in dominance from chestnut oak to red oak. Collectively, these two species are relatively less important and certain other species (particularly white oak and hickory) more important in stands making up the one community type located in the upper half of the ordination.

Information as to the elevation and general location (i.e., topographic position) of stands making up each community type is given in Table 4. Although the ranges of elevation recorded for member stands of the five community types are broadly overlapping the mean values calculated for the groups of stands representing the various community types suggest that the distribution of community types can be related to an elevation complex-gradient, with chestnut oak-black oak at the lower end of the gradient and red oak-red maple at the higher end. Moreover, when the locations of member stands of a particular community type are examined, the general pattern is for these stands to occur in roughly comparable situations with

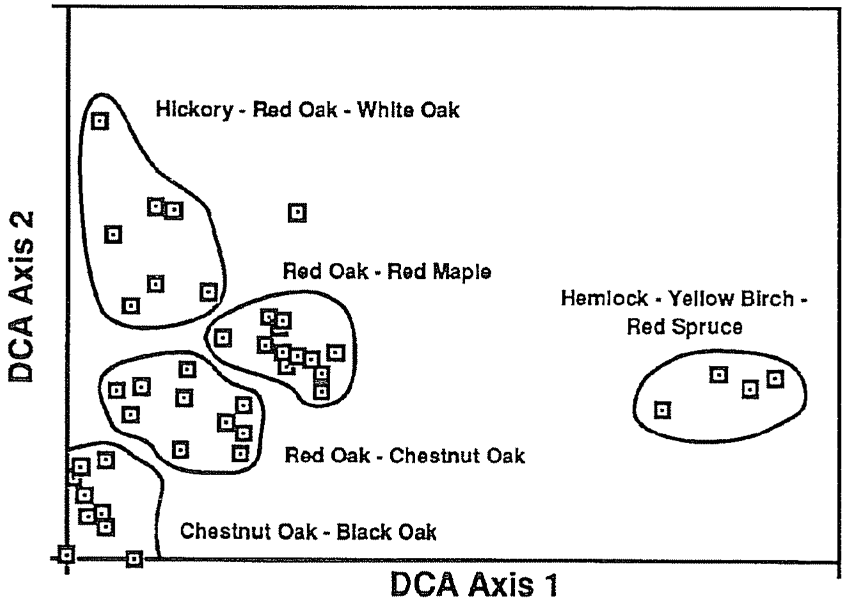

FIGURE 1. DCA ordination of sampled stands based on importance values of species represented in the tree stratum. Solid lines delimit community types named on the basis of the leading dominants.

respect to slope position and aspect. For example, stands assigned to the chestnut oak-black oak community type are nearly all on south facing slopes and most are located at lower or mid-slope positions (mean value for slope position [SP] = 2.3). Stands assigned to the hickory-red oak-white oak community type also occur on south-facing slopes, but these stands are located at mid- to upper slope positions (SP = 1.6) In contrast, all of the stands making up the hemlock-yellow birch-red spruce community type occur in ravines or coves (SP = 4.0). Mean values of slope position for stands of the red oak-chestnut oak and red oak-red maple community type were 2.3 and 1.4, respectively. The mean values of weighted averages calculated for member stands of the five community types would seem to indicate that these community types occupy clearly different situations with respect to site moisture conditions, with chestnut oak-black oak (mean value = 177) as the most xeric and hemlock-yellow birch-red spruce (mean value = 36) as the most mesic. Mean values for the red oak-chestnut oak, hickory-red oak-white oak, and red oak-red maple community types were 144, 128, and 101, respectively. The one stand not assigned to any community type (Figure 1) had a weighted average of 49, which is well within the range of values (5-74) calculated for the most mesic of the five community types. On this basis, this stand would be considered just as mesophytic. The main reason it does not occur close to the stand cluster considered to represent a hemlock-yellow birch-red spruce community type on the ordination is that it lacks the appreciable coniferous component that the member stands of this cluster share in common. In fact, this one stand would appear to represent a relatively high-elevation example of the mixed mesophytic community type as described by Braun (1950) for other areas of the Appalachian Mountains. McCormick and Platt (1980)

TABLE 3. Composition of the tree stratum (stems ≥ 10 cm DBH) for the five community types. Figures given are average importance values for all stands in each community type. Number of stands in each type is shown in parentheses under each type name.

Species	Community Type				
	Chestnut oak-black oak (9)	Red oak-chestnut oak (10)	Hickory-red oak-white oak (7)	Red oak-red maple (12)	Hemlock-yellow birch-red spruce (4)
Quercus rubra	5.5	29.8	23.0	57.8	0.9
Quercus prinus	54.8	28.8	9.2	1.4	-
Acer rubrum	7.0	12.0	4.0	16.7	3.7
Carya spp.	6.6	4.8	28.7	1.3	-
Quercus velutina	13.5	4.2	0.6	0.2	-
Quercus alba	1.8	8.0	18.5	3.2	-
Betula lenta	-	2.3	0.8	4.6	5.7
Magnolia acuminata	0.4	2.0	1.4	4.6	0.4
Robinia pseudoacacia	3.2	2.7	4.6	0.9	-
Tsuga canadensis	-	-	-	-	42.6
Picea rubens	-	-	-	0.2	18.1
Betula lutea	-	-	0.7	0.6	23.2
Amelanchier arborea	-	0.4	0.5	3.7	0.7
Oxydendrum arboreum	2.9	0.4	2.1	-	-
Acer saccharum	0.7	-	4.7	0.9	-
Other species	3.6	4.6	1.2	3.9	4.7
Total	100.0	100.0	100.0	100.0	100.0

reported that mixed mesophytic communities dominated by such species as basswood (*Tilia americana*), buckeye (*Aesculus octandra*), black birch (*Betula lenta*), and white ash (*Fraxinus americana*) occur at elevations <850 m on the relatively mesic lower slopes of Beanfield Mountain, which is within the general study area. However, with the possible exception of this single example, stands representing a mixed mesophytic community type were not encountered in the present study and thus would seem to be relatively uncommon at the elevations we sampled. Nevertheless, the fact that we have designated the most mesic expression of upland forest vegetation in the Mountain Lake area as "hemlock-yellow birch-red spruce" should not be interpreted as meaning that other types of mesophytic communities having a rather different composition do not exist. It should be noted that the occurrence of mixed mesophytic communities at even higher elevations in the Balsam Mountains of extreme southwestern Virginia was reported by Rheinhardt and Ware (1984).

Based on the mean value of species diversity (H′) calculated for the group of stands assigned to each of the five community types, the red oak-chestnut oak (H′ = 2.17) and hickory-red oak-white oak (H′ = 2.14) community types were

TABLE 4. Summary data on the five community types.

Community type	Elevation (m) Range	Elevation (m) Mean	Location
Chestnut oak-black oak	775-1125	962	Lower to mid-slope
Red oak-chestnut oak	855-1110	1016	Lower to mid-slope
Hickory-red oak-white oak	900-1145	1068	Mid-slope to upper slope
Hemlock-yellow birch-red spruce	1051-1170	1123	Ravines and coves
Red oak-red maple	1095-1280	1204	Mid-slope to upper slope

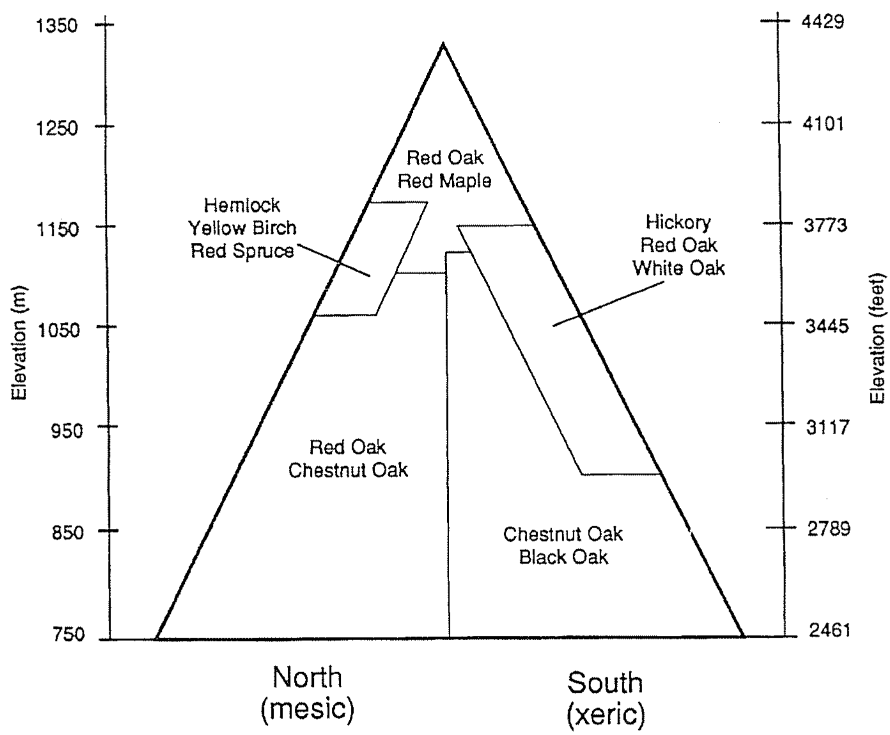

FIGURE 2. Generalized diagram showing the spatial distribution of the five major community types recognized in this paper.

characterized by the highest diversity, whereas the red oak-red maple community type was characterized by the lowest diversity (H′ = 1.80). The values obtained for the hemlock-yellow birch-red spruce and chestnut oak-black oak community types were H′ = 1.89 and H′ = 1.95, respectively.

The spatial relationships of the five community types, as indicated by the information presented in Table 4, are graphically illustrated in Figure 2. It should be pointed out that this model is very general and also based upon quantitative data on forest community composition from just one portion of the Ridge and Valley province. Because the Ridge and Valley is so geologically and topographically heterogeneous, it is characterized by a relatively diverse pattern of vegetation. As such, the applicability of the model to the upland forest vegetation of the entire region is questionable. Nevertheless, the data presented herein do suggest that it is possible to identify relatively well-defined community types and to elucidate vegetation-environment relationships for at least a specific topographic area.

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