CASTANEA 70(3): 184–203. SEPTEMBER 2005

Vegetation Patterns within the Lower Bluestone River Gorge in Southern West Virginia

J.S. RENTCH,[1]* R.H. FORTNEY,[2] S.L. STEPHENSON,[3] H.S. ADAMS,[4] W.N. GRAFTON,[1] R.B. COXE,[5] and H.H. MILLS[6]

[1]Division of Forestry, West Virginia University, PO Box 6125, Morgantown, West Virginia 26506-6125;
[2]Department of Environmental and Civil Engineering, West Virginia University, PO Box 6103, Morgantown, West Virginia 26506-6103;
[3]Department of Biological Sciences, SCEN 632, University of Arkansas, Fayetteville, Arkansas 72701;
[4]Division of Arts and Sciences, Dabney S. Lancaster Community College, Clifton Forge, Virginia 24422;
[5]Western Pennsylvania Conservancy, 209 Fourth Avenue, Pittsburgh, Pennsylvania 15222;
[6]Department of Earth Sciences, Tennessee Technological University, Cookeville, Tennessee 38505

ABSTRACT

Seven forest community types are described for a 2,100 ha study area in the lower Bluestone River Gorge in southern West Virginia. This is a remote, steeply sloped area, part of a large natural area that provides habitat to several plants not known elsewhere in the state. It is an example a topographic setting underrepresented in quantitative studies of forest vegetation in the region. Forest types were derived from cluster analysis of quantitative data on composition and structure of large tree (dbh $\geq$ 10 cm) strata obtained from 51 0.1 ha quadrats, the majority of which were included in a series of eleven transects that extended from the bottom of the gorge to a point near the rim. Multi-response permutation procedures verified the community classification. Mean topographic and soil characteristics for each community type were then compared using analysis of variance. The community types recognized conform to forest cover-types widely distributed throughout the region. Non-metric dimensional scaling indicates that topographic variables have a strong influence on the distribution of community types within the gorge. However, due to the presence of limestones and calcareous shales at midslope position, variation in soil nutrient quality tended to account for more of the variation in vegetative composition. Various species of *Quercus* were prominent overstory trees in six of seven community types. The continued dominance of *Quercus* spp. seems most likely on the more nutrient poor, west- southwest-facing sites at mid- to upper-slope positions. On more mesic, better quality growing sites, *Acer saccharum* and *A. rubrum* exhibit overwhelming importance in the understory and are likely to increase in importance.

INTRODUCTION

Forest researchers in the eastern United States have long recognized the influence of environmental gradients on spatial variability of site quality, species composition and forest growth. Whittaker (1956) and Day and Monk (1974) used elevation and topography as a surrogate for soil moisture to account for vegetation patterns in the mountains of western North Carolina. Other studies have attributed differences in forest composition and site quality to a combination of physical site variables and soil nutrients (e.g., Hicks and Frank 1984, Elliott et al. 1999), slope aspect (e.g., McCarthy et al. 1984), soil water-holding capacity and local topography (e.g., Yeakley 1993, Stephenson and Mills 1999), slope position (e.g., Adams and Stephenson 1983), or processes of energy exchange and differing thermal regimes between north- and south-facing sites (e.g., Lee and Sypolt 1974). Still others have attributed variance in forest composition and structure to disturbance history, both natural and anthropomorphic (Abrams et al. 1995, Orwig and Abrams 1999).

* email address: jrentch2@wvu.edu

The Bluestone River Gorge is located within the Mixed Mesophytic Forest Region of the Eastern Deciduous Forest Biome as described by Braun (1950). Based upon results obtained from previous botanical investigations in the gorges of southern West Virginia, the Bluestone River Gorge appears to have a distinctive flora compared to the other major gorges (e.g., the New River, Meadow River, and Gauley River) located in the same region and the same drainage basin in southern West Virginia. There are several West Virginia plant species reported only in the Bluestone Gorge region. Prominent examples include northern white cedar (*Thuja occidentalis* L.), downy arrowwood (*Viburnum rafinesquianum* J. A. Schultes), Allegheny cliff fern (*Woodsia appalachiana* T.M.C. Taylor), wild onion (*Allium oxyphilum* Wherry), and Canby's mountain lover (*Paxistima canbyi* Gray). There is also an unusual mixture of northern and southern species in the gorge, as typified by the presence of Canada yew (*Taxus canadensis* Marsh.) and Dutchman's pipe (*Aristolochia macrophyllum* Lam.). In addition, white pine (*Pinus strobus* L.), honey locust (*Gleditsia tricanthos* L.), and black walnut (*Juglans nigra* L.) are all found in the Bluestone drainage and virtually nonexistent along the Gauley and Meadow Rivers (Grafton 1993). The distinctiveness of the gorge's flora is undoubtedly the result of a number of factors, but two appear particularly evident. First, the presence of interbedded rock strata consisting of limestones and calcareous or circumneutral sandstones and shales helps to enrich some of the soils found within the gorge. Second, the northward flow of the Bluestone River probably allowed for a greater migration of southern species into the region than might otherwise have been the case. Core (1966) hypothesized that the New River, because it flowed into West Virginia from the south, was a migration corridor for southern Appalachian species into the state. It seems likely that the Bluestone has also served as a similar migratory route for plants.

Most studies of the region have been largely botanical and floristic surveys (e.g., Philips 1969, Oxley 1975, Norris 1992, Grafton 1982, Suiter and Evans 1995). Few have considered the distribution and composition of forest communities of the gorges in southern West Virginia, and none have proposed a numerical classification of plant communities or quantitatively evaluated relationships between plant communities and physical and environmental factors in the Bluestone River Gorge. In 1994, the Bluestone River Gorge was included in a reconnaissance study that also considered the other major gorges in southern West Virginia (Fortney et al. 1995). This study was continued during 1995, when it was restricted to the Bluestone River, and served as the basis for the more intensive study described herein. The purpose of this study was to (1) quantitatively describe the composition, structure, and general distribution patterns of the major types of forest communities found within the Bluestone National Scenic River section of the Bluestone River Gorge and (2) assess interactions between forest community types and underlying physical and environmental factors.

THE STUDY AREA

Archeological surveys suggest that Paleo-Indians occupied the immediate study area as early as 12,500 years before present, and that the area was more or less continuously occupied by native Americans until the onset of European settlement (Marshall and Fuerst 1982, Marwitt 1982, Maslowski 1982). The earliest European arrivals established permanent settlements near the mouth of the Little Bluestone River between 1750 and 1760 (Jim Phillips, per. comm.). Further settlement was facilitated by the completion of a turnpike in 1848, following, in part, the Bluestone and Little Bluestone Rivers toward Beckley, West Virginia (Maslowski and Woody 1984).

The construction of Chesapeake and Ohio Railroad through Summers County in 1872 marked the beginning of an active lumber industry. The first commercial timber cutting in the area was associated with manufacture of barrel staves from white oak (*Quercus alba* L.) (Brooks 1910). Black walnut was said to be so plentiful that it was used for fencing (Miller 1981), and prior to 1880, raw black walnut logs were exported to Europe (Brooks 1910, Miller 1981). Brooks (1910) noted extensive cutting along the Bluestone River after 1877, but also indicated that extensive stands of virgin white pine remained in the area. These were logged by the Bluestone Land and Lumber Company between 1907 and 1916; additional high-grade harvests occurred during the 1940s and 1950s.

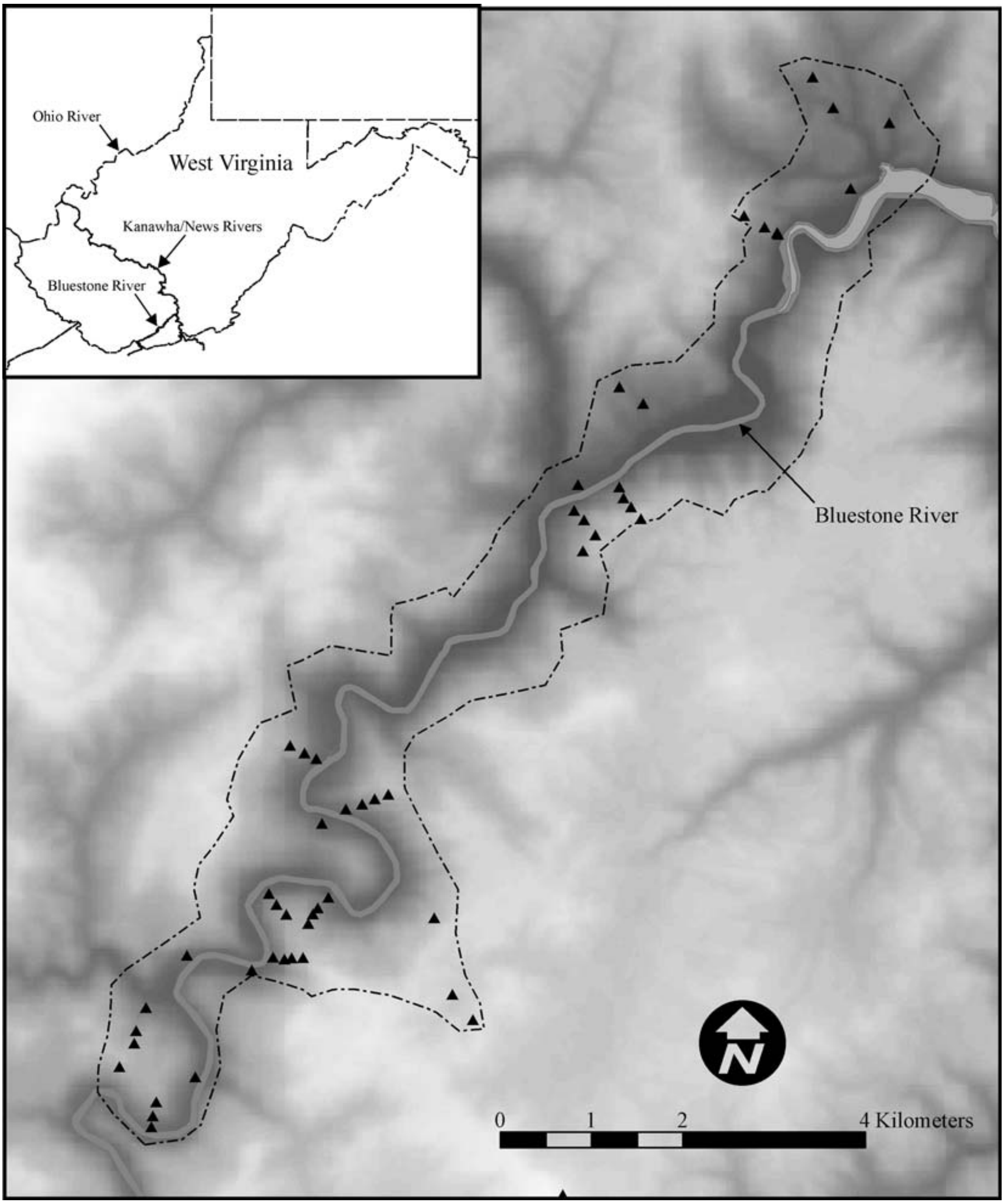

Figure 1. Site map of lower Bluestone River Gorge study area showing sample quadrat locations with a greyscale 30 m digital elevation map background. Lighter shades indicate higher elevations.

The 2,100 ha study area, embracing parts of southwestern Summers County and adjacent northern Mercer County in West Virginia (Figure 1), is located within the Appalachian Plateau physiographic province. It consists of portions of Pipestem Resort State Park, the Bluestone Wildlife Management Area, and Bluestone State Park, all within an area designated in 1988 as the Bluestone National Scenic River. In this area, rock strata are essentially flat-lying, although in detail the structure consists of gentle and fairly symmetrical folds of relatively low amplitude, involving dips of no more than several degrees. The long axes of the folds are oriented approximately northeast-southwest. The folds have little or no effect on the topography, although the direction of dip may locally control the direction of groundwater flow and outcroppings of various rock strata. The Bluestone River arises in Tazewell County in southwestern Virginia and flows 124 km to the New River in southern West Virginia. The river's drainage basin is 1,200 km^2 in extent. From the head of the Bluestone to its mouth, the alignment of the river is relatively straight, being approximately parallel to the northeast-southwest strike of the rock strata. On a smaller scale, however, the river shows numerous entrenched meanders along its course.

The topography of the study area consists of flat-topped ridges separated by deep, V-shaped valleys, with a typical relief of 250–300 m. On the steep valley walls, shaley slopes alternate with several sandstone benches. Maximum slope angles commonly range from 30 to 45°, although they may be steeper locally where cliffs are present. Most of the study area is underlain by the late Mississippian Age Mauch Chunk Group, the sediments of which represent a nonmarine depositional environment, with shale and sandstone predominant, and red beds very predominant near the top of the Group. Scattered unmapped, thin coal seams occur, and may locally increase soil acidity. Reger (1926) reported that a general section of the Mauch Chunk in the study area shows 30.8% sandstone, 61.7% shale, 7.2 % limestone, and 0.3% coal.

Three formations of the Mauch Chunk crop out in the area. From oldest to youngest (and from lowest to highest) these are the Hinton Formation, the Princeton Conglomerate, and the Bluestone Formation. The Hinton underlies the valley floors and the lower to middle portions of the valley walls. The thickness of this formation exceeds 340 m. Limestone and some shale layers of this unit commonly show marine fossils, despite the fact that the bulk of the Hinton is nonmarine in origin. Sandstones are frequently hard and massive enough to form cliffs and ledges (Reger 1926).

Above the Hinton is the Princeton Conglomerate, which generally is a coarse, massive conglomerate, varying in thickness from 6 to 20 m. This formation is usually extremely hard and contains scattered quartz pebbles throughout and may have impure limestone pebbles near its base. On Tallery Mountain, there are numerous outcrops, and this is the formation primarily responsible for the plateau on the mountain crest, and most of the flat-topped ridges in the study area. Above the Princeton is the Bluestone Formation, which attains a thickness of 180 m, although in many locations is much thinner because of erosion. The rocks of the Bluestone are generally similar to those of the Hinton, except that limestone beds are not present (Reger 1926).

Ridgetop, bench, and side slope soils in the lower Bluestone River gorge study area belong primarily to Calvin-Berks series (Sponaugle et al. 1984). They are approximately 60% Calvin stony silt loam (high base substratum), 25% Berks stony silt loam, and 15% other soils. These are coarse, well drained soils formed in acid and lime-influenced material weathered from shale, siltstone, and sandstone. Depth to bedrock averages 50 to 100 cm; surface horizons are acid-very acid, however, because of the high base substratum, pH typically increases with soil depth (Sponaugle et al. 1984).

Climate of the study area is temperate, with distinct summer and winter seasons. January is the coldest month, with an average daily minimum temperature of −5.6°C, and July is warmest, with an average daily maximum temperature of 28.8°C (Sponaugle et al. 1984). Average annual precipitation totals 90 cm, approximately 60 percent of which occurs April through September. Total snowfall, ice pellets, and hail average 48.8 cm per year (Suiter and Evans 1995). The average midafternoon humidity is 60 percent, and thunderstorms occur approximately 45 days per year (Sponaugle et al. 1984).

METHODS

The general approach used in the present study was to first sample forest communities and then to use these data to assess vegetation-environment relationships. This approach is based upon the concept of direct gradient analysis as described by Gauch (1982). In brief, it involves sampling vegetation at predetermined intervals along an environmental gradient that can be recognized in the field. In the study area, we considered topographic position, as representative of a moisture-complex gradient (*sensu* Whittaker 1956) to represent the primary underlying basis for the vegetation-environment relationships. In order to obtain the data necessary to assess these relationships, potential sites for transects were located on 7.5 minute series topographic maps and then established in the field. Each transect extended from a point near the river at the bottom of the gorge to a point on the upper slope near the rim of the gorge. A series of three or four 20 by 50 m (0.1 ha) quadrats was placed along each transect.

During the 1994 to 1999 field seasons, eleven different transects encompassing a total of 37 quadrats were established. Five additional quadrats were established to encompass vegetation types observed but not encountered along any of the transects, such as along river floodplains and in communities with unusual vegetation. In addition, data from nine quadrats from the West Virginia GAP project (Coxe, unpubl. data) were incorporated into the database, for a total of 51 (Figure 1). Mean transect length was 345 $\pm$ 24 m (horizontal distance), and mean distance between quadrats was 150 $\pm$ 17 m. Relief between uppermost and lowest quadrats averaged 183 $\pm$ 24 m.

Quadrats were typically placed with their long axes parallel to the contour of the slope. Within each 0.1 ha quadrat, composition and structure of the vegetation were determined using standard sampling methods (e.g., Stephenson and Adams 1986). Diameters at breast height (1.37 m) of all live large trees ($\geq$10 cm dbh) and small trees (2.5 cm $\leq$ dbh $<$ 10 cm) were recorded by species in the entire 0.1 ha quadrat, as were saplings (stems $<$2.5 cm dbh but $\geq$1.0 m tall). Numbers of shrubs (including woody vines) were recorded by species in four, nested 5 by 5 m plots placed at regular intervals along the centerline of the 0.1 ha quadrat. Estimates of percent cover of herbaceous plants were recorded from ten, nested 1 by 1 m plots placed at 5 m intervals along the centerline. All cover values were estimated using a cover class rating scale described by Daubenmire (1968). Nomenclature for vascular plant species follows Kartesz (1999).

Topographic features recorded for each quadrat included slope position (floodplain, lower slope, midslope, upper slope, or ridgetop), slope inclination, slope aspect, and elevation. For some longer transects, lower- and upper-midslope quadrats were sampled. Elevation, inclination, and aspect were recorded at several locations within each quadrat and averaged.

In order to determine tree ages, increment growth cores were extracted at breast height from several dominant or co-dominant trees either within or (in a few instances) in the general vicinity of each quadrat. Cores were processed and growth rings counted in the manner described in Stokes and Smiley (1968). Soil samples were collected from the upper 10 cm at four locations within each quadrat and pooled to form a composite sample. Analysis of soil pH and percent organic matter, and concentrations of calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), aluminum (Al), and total nitrogen (N) (all in ppm) were determined by a commercial soils laboratory.

Species Importance Value (IV) indices for trees and small trees were calculated as one-half the sum of relative basal area and relative density; for herbaceous plants species IV equaled one-half the sum of relative cover and relative frequency (Smith 1996). Community composition patterns were assessed using cluster analysis of the large tree data set (PC-ORD, Ver. 4.0, McCune and Mefford 1999). Species IV was used as input data. We used the Sorenson distance as the distance measure, and Nearest Neighbor as the method of linkage. To reduce the number of empty cells in the matrix and the coefficient of variation of the original species data set, species that occurred in less than three quadrats were deleted. Based on the cluster analysis of the large tree quadrat data, similar groupings were applied to small tree, sapling, shrub, and herbaceous strata to characterize species composition within each strata for each community type. We include data from the sapling and shrub data, although these are not reported in tables. The large tree groupings were also applied to site and soil variables. To evaluate site and soil differences between cluster-analysis large tree community groupings, one-way analysis of variance (PROC GLM, SAS Institute, Release 8.0, 1999) was performed. Duncan's test was used to identify significantly different group mean values.

We used multi-response permutation procedures (MRPP, McCune and Mefford 1999) to assess the relative strength of the cluster analysis results, and to determine within-group homogeneity of each community type. MRPP is a nonparametric multivariate procedure for testing the hypothesis of no difference between species composition of two or more *a priori* groups of plots (McCune et al. 2002). This procedure calculates a T-statistic as the weighted mean within-group ranked distance in species space. This statistic describes the separation between groups; the more negative T is, the stronger the separation between groups. A p-value is used to evaluate the likelihood of achieving the observed difference (T) by chance. This procedure then calculates an A statistic that is an estimate of the within-group homogeneity, compared to random expectation. When all plots are identical within groups, $A = 1$; if homogeneity within groups equals expectation by chance, then $A = 0$.

Relationships between species composition and underlying environmental gradients were evaluated using nonmetric multidimensional scaling (NMDS, McCune and Mefford 1999). NMDS was conducted using 40 runs of real data and 400 iterations, along with 100 runs of randomized data for a Monte Carlo test of significance that similar results cold have been achieved by chance along ($p < 0.01$). Following Monte Carlo testing, a three-dimensional solution was chosen for the final ordination using the best solution in the preliminary analysis as the starting point for the final run. We report the final stress of the ordination and coefficients of determination (R^2) for ordination axes 1–3, calculated as the proportion of the variation explained in the reduced matrix relative to the original matrix. We then used a secondary matrix consisting of topographic and soil nutrient variables to help interpret the ordination results. Aspect was cosine-transformed after Beers et al. (1966), and pH was input as hydrogen ion concentration. Large tree cluster analysis groupings were included as categorical variables. No soil nutrient data were available for the nine GAP quadrats.

RESULTS

Vegetation Patterns

Seven community types, represented by 3 to 15 quadrats, were delineated by cluster analysis of large tree IV data (Figure 2). Community types were named on the basis of the two or three most dominant tree species (using IV), and were more or less equally divided between mesic and xeric communities. Percent chaining of the cluster analysis was 3.7%. Two quadrats did not link with any other quadrat/cluster until less than 45% of the information remained; these were considered outliers and not included in the cluster analysis. Results from MRPP support the community types proposed by cluster analysis. The T-statistic, the estimate of mean separation between groups, was negative (−16.2) and highly significant ($p < 0.001$). The A-statistic, the estimate of within-group homogeneity, was relatively high (0.56). In community ecology, values for A are commonly <0.1 (McCune et al. 2002).

White oak-Northern red oak-Black oak type (15 quadrats). This type was distinguished from other oak-types by the importance of *Quercus alba* L. (Table 2). Average Sorenson distance was 0.19, suggesting a relatively homogeneous group. This community-type tended to occur at mid- to upper-slope positions on south facing slopes (Table 1). Age for the three oak species averaged 80–100 years. Important overstory associates were *Q. prinus* L., *Acer saccharum* Marsh. and *Carya ovata* (Mill) K. In the small tree and sapling strata, *A. saccharum*, *A. rubrum* L., and *Cornus florida* L. were most important (Table 3). The most abundant shrubs and herbaceous species were *Vaccinium pallidum* Ait., *V. stamineum* L., *Carex pennsylvanica* Lam., and *Potentilla simplex* (Michx.), respectively (Table 4). Although oaks dominated the overstory, small tree IVs for the three oak species were 3.6, 0.9, and 1.4, respectively; sapling densities for the same species were 69 stems ha^{-1}. Low understory presence of oaks suggest the potential for change in future overstory composition.

Chestnut oak-Northern red oak-Red maple type (7 quadrats). These communities were also relatively homogeneous (average Sorenson distance = 0.17), and tended to occur at a mid-slope to upper-slope position. Average aspect was southwest-facing, although two quadrats were northwest-facing. These communities were approximately 80–100 years old, although one older residual *Q. prinus* individual was 278 years.

On average, five oak species were present, with a pooled large tree and small tree IVs of 47.4 and 7.6, respectively. In the sapling stratum, 129 ± 68 oak stems ha^{-1} were present,

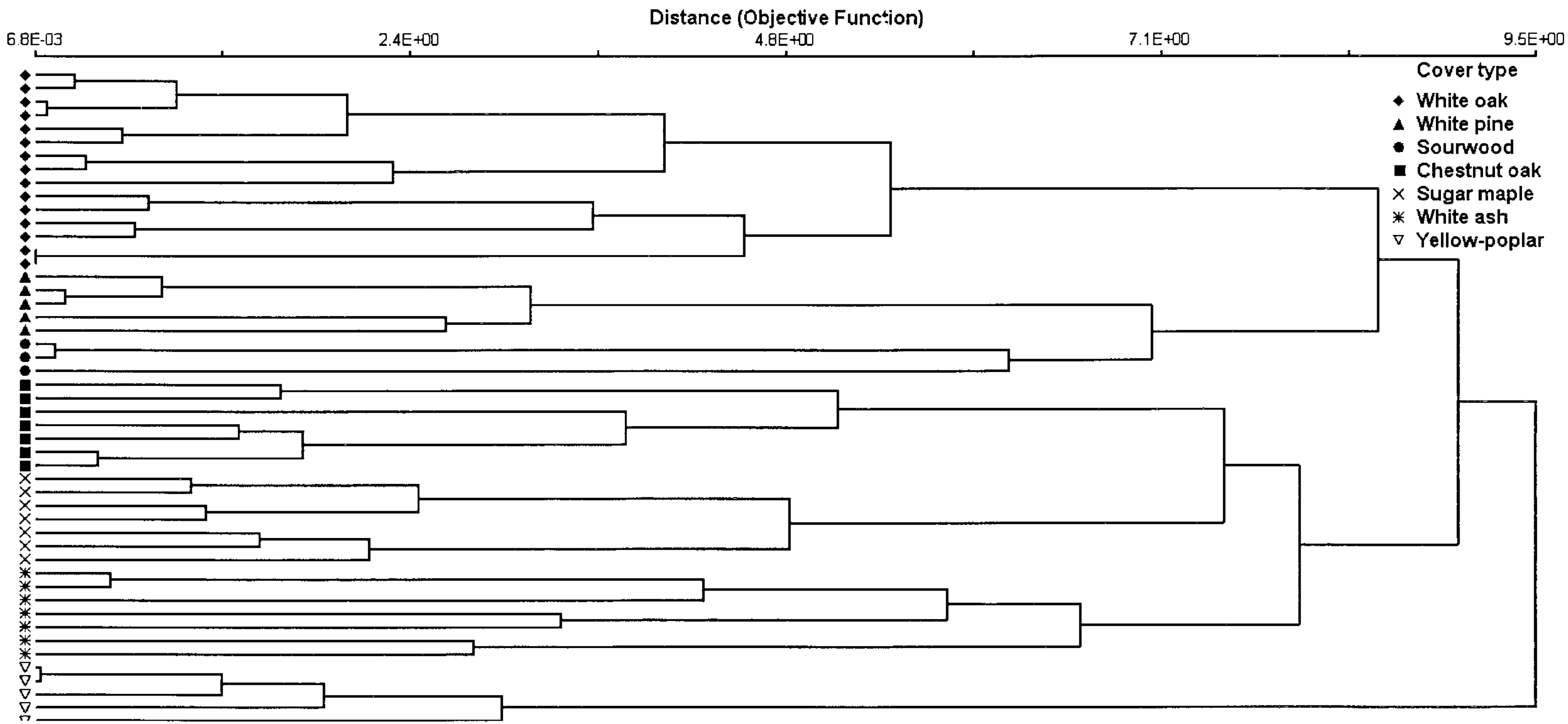

Figure 2. Cluster analysis of 49 sample quadrats using large tree stratum (dbh $\geq$ 10 cm) species IV as input data. Sorenson distance is the distance measure, and quadrats were linked using Nearest neighbor method. Only the first dominant of each community-type is shown in the legend.

Table 1. **Means of plot and soil variables for 49 quadrats grouped by large tree cover-type classification. Means are compared using PROC-GLM; means in the same row with different letters are significantly different (Duncan, $p < 0.05$)**

Community type	White oak-No. red oak-Black oak	Chestnut oak-No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar-Sugar maple-Cucumber	White pine-Mixed oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Number of plots	15	7	7	5	5	7	3
N[1] Large tree	9.9_a	10.6_a	11.3_a	9.8_a	10.4_a	10.6_a	10.3_a
N Small tree	11_a	10_{ab}	9.6_{ab}	6.8_b	10.6_{ab}	8.3_{ab}	12_a
N Sapling	12.9_a	13.1_a	8.6_a	6.6_a	13_a	11_a	12_a
N Shrub	4.4_{ab}	5.6_a	3.2_{ab}	3_{ab}	5.2_a	2.3_b	3_{ab}
N Herb	13_{ab}	7.5_b	14_{ab}	15.6_{ab}	9.2_b	17.4_a	11.7_{ab}
H′[2] Large tree	1.8_{ab}	1.9_a	2.0_a	1.6_{ab}	1.6_{ab}	1.6_a	1.3_b
H′ Small tree	1.8_a	1.8_a	1.7_{ab}	1.4_b	1.9_a	1.5_b	2.0_a
H′ Sapling	1.9_{ab}	1.9_{ab}	1.3_{bc}	1.0_c	1.9_a	1.8_{ab}	1.8_{ab}
H′ Shrub	1.0_{ab}	1.1_a	0.78_{ab}	0.59_{ab}	1.0_{ab}	0.39_b	0.60_{ab}
H′ Herb	2.2_{abc}	1.6_c	2.4_{ab}	2.3_{ab}	1.7_{bc}	2.5_a	2.1_{abc}
Elevation (m)	592	663	580	533	526	522	666
Slope position	MS	US	LS-MS	LS-MS	MS	LS-MS	US
Aspect	S	SW	NE-E	NE	SW	E	SW
pH	5.0_a	4.3_{ab}	5.8_a	5.9_a	4.1_b	5.1_a	4.3_{ab}
C_a (ppm)	1064_{bc}	471_c	2192_a	1720_{ab}	202_c	1765_{ab}	663_c
Mg (ppm)	146_{ab}	75_{bc}	213_a	195_a	44_c	142_{ab}	88_{bc}
K (ppm)	142_{abc}	86_{bcd}	197_a	160_{ab}	59_d	135_{abc}	78_{cd}
Fe (ppm)	142_a	188_a	90_a	102_a	195_a	121_a	138_a
Al (ppm)	672_a	694_a	488_a	543_a	777_a	643_a	682_a
N (ppm)	11.8_a	11.1_a	16.6_a	18.1_a	11.0_a	18.9_a	13.9_a

N[1] = number of species; H′[2] = Shannon diversity index.

dominated by *Q. prinus* and *Q. rubra* L. *Acer rubrum* and *Fagus grandifolia* Ehrh. were most abundant in the small tree stratum. *Pinus strobus* was well represented in both the large and small tree strata. Shrub species diversity was relatively low; however, total shrub density was 2nd highest of the seven community types. Ericaceous species such as *Kalmia latifolia* L., *Gaylussacia baccata* (Wang.) K. Koch, *V. pallidum*, and *V. stamineum* were numerous, with a combined stem density of 3,485 ha^{-1}. *Chimaphila umbellata* L. Bart., common in dry acid woods (Strasbaugh and Core 1977), was the most abundant herb. Soils of this and the *Q. alba*-dominated community, consistent with their elevation, aspect, and slope position, were acidic, below average in base cations such as Ca, Mg, and K, and above-average in Fe concentrations, although the differences were statistically significant only for Ca.

White pine-Mixed oak type (5 quadrats). The average IV of *P. strobus* in these communities was 38.0. These communities appear to have undergone harvesting around 1940; average dbh-age of *P. strobus* was approximately 60 years. The oak component was more or less equally divided between *Q. alba*, *Q. prinus*, *Q. rubra*, and *Q. velutina* Lam. *Oxydendrum arboreum* L.(DC) and *A. rubrum* were most important in the small tree and sapling strata. Overall species diversity tended to be relatively low. In contrast, shrub diversity was higher than average (species N = 5.2, H′ = 1.00) and shrub density was highest of the community types (8493 ± 988 stems ha^{-1}). Species diversity in the herbaceous stratum was low (H′ = 1.7), where *Gaultheria procumbens* L., *Polystichum acrostichoides* (Michx.) Schott and sedges (e.g., *C. pennsylvanica*) were most common.

White pine-Mixed oak communities occurred on a range of slope positions and percent slopes (ranging from 3% on a bottomland site to 58% on an upper-slope position). However, slope position was most often mid-slope, and aspect was primarily southwest-facing. These quadrats

Table 2. Summary of large tree species composition (dbh $\geq$ 10 cm) by large-tree cover type classification. Data are average Importance Values (IV) indices. Only species with total IV > 2 are shown

Community type	White oak-No. red oak-Black oak	Chestnut oak-No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar Sugar maple-Cucumber	White pine-Mixed Oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Acer rubrum	1.9	12.1	2.9	1.4	7.5	2.5	2.6
Acer saccharum	5.0	1.6	1.1	6.7	1.1	28.2	—
Aesculus flava	1.3	—	3.7	0.5	0.7	3.3	—
Betula lenta	0.2	0.5	—	0.3	2.3	0.2	—
Carya alba	1.4	0.8	5.0	2.6	—	1.5	0.4
Carya glabra	3.7	1.0	1.1	0.6	1.4	7.6	1.1
Carya ovata	5.0	0.6	4.4	0.5	1.5	3.3	21.0
Fagus grandifolia	3.3	5.0	0.2	4.9	0.4	0.4	—
Fraxinus americana	3.1	1.0	22.9	4.1	0.6	5.3	0.8
Juglans nigra	0.2	0.4	—	0.9	—	0.5	—
Juniperus virginiana	0.4	—	2.8	—	—	0.1	—
Liriodendron tulipifera	4.4	7.4	2.2	50.8	2.7	6.1	0.2
Magnolia acuminata	0.3	0.4	0.3	4.7	0.9	0.2	—
Nyssa sylvatica	1.2	1.3	—	—	0.8	—	0.2
Oxydendron arboreum	2.0	2.4	—	0.9	9.3	1.1	43.1
Pinus ridgida	—	—	3.5	—	0.7	—	—
Pinus strobus	2.0	6.2	—	4.4	38.0	1.0	3.4
Pinus virginiana	—	—	—	—	—	—	2.7
Platanus occidentalis	—	0.3	0.6	—	—	4.5	—
Populus grandidentata	—	4.2	—	—	—	—	—
Prunus serotina	0.8	4.8	2.9	—	0.3	—	—
Quercus alba	26.7	2.6	1.8	1.0	5.6	1.7	2.4
Quecus coccinea	1.6	2.9	—	—	1.8	—	2.8
Quercus muehlenbergii	—	2.1	0.6	—	—	1.4	—
Quercus prinus	9.0	21.5	1.9	0.3	7.4	5.3	4.3
Quercus rubra	11.0	17.3	9.1	1.2	7.2	9.7	2.8
Quercus stellata	0.1	—	0.9	—	—	—	1.4
Quercus velutina	10.1	1.0	0.2	0.8	9.9	1.3	9.8
Robinia pseudoacacia	1.3	0.4	7.9	0.8	—	1.1	0.4
Sassafras albidum	0.3	—	0.2	4.4	—	—	—
Tilia americana	—	—	18.3	2.6	—	4.6	—
Tsuga canadensis	1.0	1.3	2.7	4.2	0.1	7.3	0.2
Ulmus rubra	0.2	—	2.1	0.2	—	—	—
Total	97.6	99.2	99.2	98.9	99.9	98.2	99.6

Table 3. Summary of small tree species composition (2.5 cm $\leq$ dbh $<$ 10 cm) by large-tree cover type classification. Data are average Importance Value (IV) indices. Only species with total IV $>$ 2 are shown

Community type	White oak-No. red oak-Black oak	Chestnut oak-No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar Sugar maple-Cucumber	White pine-Mixed Oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Acer pensylvanica	—	—	0.2	—	1.3	0.7	—
Acer rubrum	11.8	23.3	7.1	4.4	13.5	—	16.2
Acer saccharum	12.6	8.5	23.3	46.4	9.3	40.5	—
Aesculus flava	0.6	—	4.5	4.3	0.7	8.1	—
Amelianchier arborea	9.1	3.6	0.2	0.4	0.3	2.2	7.4
Asimia triloba	—	—	—	1.9	—	0.9	—
Betula lenta	—	—	—	1.1	2.9	—	—
Carya alba	2.6	1.0	7.8	—	0.5	0.4	—
Carpinus caroliniana	4.6	8.6	2.7	2.1	0.6	0.1	—
Carya glabra	3.6	2.7	0.9	—	1.7	1.5	6.4
Carya ovata	5.2	0.2	2.8	—	1.8	—	12.6
Cercis Canadensis	2.4	1.0	6.4	—	—	—	1.8
Cornus florida	11.0	6.3	1.9	8.6	9.8	2.4	4.9
Fagus grandifolia	5.0	12.5	3.5	5.0	8.3	4.4	2.2
Fraxinus americana	3.3	0.8	11.5	0.5	0.7	5.9	2.9
Hamamelis virginica	1.2	0.3	2.7	—	—	1.1	0.3
Liriodendron tulipifera	—	—	1.0	2.9	0.8	—	4.3
Magnolia acuminata	0.1	1.1	—	4.0	1.3	—	0.8
Nyssa sylvatica	2.8	1.3	—	—	6.1	—	1.1
Ostrya virginiana	2.3	0.5	1.5	—	1.5	0.9	0.3
Oxydendron arboreum	3.2	6.3	—	0.9	22.3	0.7	18.1
Pinus strobus	3.6	10.4	0.5	—	8.9	2.2	3.3
Pinus virginiana	0.2	2.0	—	—	—	—	6.6
Prunus serotina	0.2	—	1.6	0.3	—	—	—
Quercus alba	3.6	1.0	0.7	—	1.1	—	2.1
Quercus prinus	2.4	2.4	0.0	—	1.7	1.7	—
Quercus rubra	0.9	4.2	5.6	1.8	0.4	3.6	2.1
Quercus velutina	1.4	—	0.2	—	0.4	0.3	1.0
Sassafras albidum	0.3	—	—	—	1.0	—	1.0
Tilia americana	0.1	—	4.3	1.1	1.1	4.4	—
Tsuga canadensis	0.6	1.0	—	13.7	2.2	17.4	3.0
Ulmus rubra	3.4	—	4.1	—	—	0.2	—
Total	98.1	99.0	95.2	99.6	100.2	99.5	98.2

Table 4. Summary of herbaceous species composition by large-tree cover type classification. Data are average Importance Value (IV) indices. Only species with total IV > 2 are shown

Community type	White oak-No. red oak-Black oak	Chestnut oak- No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar Sugar maple-Cucumber	White pine-Mixed Oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Adiantum pedatum	—	—	6.1	2.1	—	5.4	—
Ageratina altissima	—	—	2.9	1.1	—	—	—
Aizia aurea	—	—	—	—	0.9	1.2	—
Apios americana	0.2	—	—	—	—	2.6	—
Arisaema triphyllum	—	—	—	1.2	—	1.2	—
Asplenium ebenoides	—	—	0.5	—	—	1.7	—
Botrychium matricariifolium	—	—	—	1.5	—	—	—
Brachyelytrum erectum	0.8	—	—	—	—	1.1	—
Carex albursina	0.7	—	0.1	1.6	—	0.3	—
Carex flaccosperma	—	—	—	6.4	—	—	—
Carex hirsutella	1.0	—	—	—	1.2	1.0	2.8
Carex laxiflora	1.1	—	2.6	—	2.0	1.1	—
Carex pensylvanica	10.3	4.0	0.2	—	12.0	0.4	18.2
Carex plantaginea	0.2	0.5	1.8	0.3	—	0.4	—
Carex squarrosa	—	—	—	2.3	—	—	—
Carex woodii	—	3.1	—	—	—	—	—
Caulophyllum thalictroides	—	—	—	—	—	3.5	—
Chimaphila maculata	3.0	11.4	0.6	0.3	2.7	—	—
Cimicifuga racemosa	—	—	—	8.1	—	0.8	—
Cunila origanoides	1.1	—	—	—	0.6	—	4.0
Danthonia compressa	5.4	—	0.1	—	—	—	6.6
Dichanthelium boscii	0.8	—	3.6	—	—	1.5	—
Dichanthelium clandestinium	0.5	—	—	—	—	—	2.4
Dichanthelium dichotomum	0.1	—	0.9	—	0.6	0.6	—
Dioscorea quaternata	—	3.0	0.4	—	—	—	6.6
Dioscorea villosa	1.5	4.2	—	1.2	—	3.1	8.3
Diphasiastreum tristachym	2.9	—	—	—	—	—	—
Disporum lanuguinosum	0.3	—	—	—	—	1.9	—
Dyopteris marginalis	—	—	6.7	—	—	0.9	—

Table 4. Continued

Community type	White oak-No. red oak-Black oak	Chestnut oak- No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar Sugar maple-Cucumber	White pine-Mixed Oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Galearis spectabilis	—	—	—	—	—	—	2.8
Galium aparine	0.2	—	0.8	2.1	1.6	—	—
Galium circaezans	1.4	—	0.8	2.4	0.5	1.2	—
Galium triflorum	—	6.8	1.1	3.4	—	—	—
Gautheria procumbens	1.8	0.5	—	—	16.0	—	2.8
Geranium maculatum	1.5	—	0.1	1.4	2.3	2.9	—
Goodyera pubescens	—	4.7	—	—	0.5	—	—
Hieracium venosum	2.0	—	—	—	3.4	—	4.4
Houstonia longifolia	1.0	—	0.1	—	0.6	—	—
Hypericum perforatum	0.1	—	—	3.8	—	—	—
Lapaortea canadensis	1.8	—	2.1	—	—	5.5	—
Maianthemum racemosa	—	—	—	—	—	—	2.8
Monarda fistulosa	—	1.1	0.8	0.3	—	1.7	—
Muhlenbergia sylvatica	—	—	1.6	0.5	0.6	—	—
Osmunda claytoniana	—	—	2.3	2.3	—	0.4	—
Oxalis grandis	—	—	2.0	0.4	—	—	—
Oxalis stricta	0.4	—	0.2	1.4	—	—	—
Paronychia canadensis	0.3	—	—	—	—	—	1.5
Parthenocissus quinquefolia	—	1.6	0.9	—	—	—	—
Phegopteris hexagonoptera	—	—	1.2	1.4	—	—	—
Pilium pumila	—	—	5.4	0.9	—	3.1	—
Poa cuspidata	—	—	—	—	1.2	—	2.8
Polygonatum biflorum	1.2	—	—	1.9	—	0.8	2.8
Polygonatum pubescens	0.6	13.0	—	0.8	—	—	—
Polystichum acrostichoides	1.5	—	6.6	6.6	8.7	4.3	2.2
Potentilla simplex	11.2	2.0	0.7	0.5	5.4	0.2	6.3
Prenanthes alba	1.4	1.5	—	—	—	—	—
Prenanthes serpentaria	—	4.2	—	0.7	0.5	—	—

Table 4. Continued

Community type	White oak-No. red oak-Black oak	Chestnut oak- No. red oak-Red maple	White ash-Basswood-No. red oak	Yellow-poplar Sugar maple-Cucumber	White pine-Mixed Oak	Sugar maple-No. red oak-Hemlock	Sourwood-Shagbark-Black oak
Sanguinaria canadensis	0.7	—	0.4	1.9	—	—	—
Solidago arguta	0.4	—	0.9	—	2.2	—	2.8
Solidago caesia	1.9	1.4	1.7	—	—	2.7	—
Stellaria pubescens	3.6	5.0	2.5	2.6	2.1	5.4	—
Symnphotrichum divericatus	1.8	—	4.8	4.5	—	3.5	—
Symphyotrichum cordifolius	0.7	—	0.8	—	4.4	—	1.5
Thalictrum dioicum	—	—	1.1	5.4	—	1.5	—
Verbesina alternifolia	—	—	—	—	—	3.8	—
Vicia caroliniana	0.4	—	1.4	—	—	—	0.4
Viola blanda	—	3.0	—	3.6	—	0.4	—
Viola rotundifolia	1.4	—	—	—	3.8	—	—
Viola sagittata	—	—	—	—	4.0	—	—
Viola sororia	1.7	1.5	2.7	1.4	0.9	2.6	—
Zizia aptera	—	—	—	0.4	—	—	2.8
Total	69.3	72.2	69.5	76.7	78.8	68.8	84.6

showed the lowest ($p < 0.05$) pH, and Ca, Mg, and K concentrations of the eight community types, and the highest concentrations of Fe and Al.

White ash-Basswood-Northern red oak (7 quadrats). This community is broadly defined as mixed mesophytic—both *Aesculus flava* Aiton and *Tilia americana* L. were present in the large and small tree strata (Braun 1950). Within-group homogeneity of this group was high; average Sorenson distance was 0.20. *Tilia americana* was occasionally quite abundant; in two quadrats, average IV was 60. Age of dominant *Q. rubra* averaged 89 ± 32 years (no white ash or basswood were cored). Slope position and slope aspect for these quadrats were variable; however, most occurred at lower elevations on east-facing slopes. As with the *Q. alba*-dominated community, oak presence in the small tree and sapling strata was very low, probably indicating a future decline in oak overstory importance. *Acer saccharum* was the most abundant small tree, although all three community dominants were well represented in the understory. Overall shrub density was relatively lowest of the seven community types. (1,625 ± 344 stems ha^{-1}). Values for soil pH were high, as were levels of Ca, Mg, and K, ($p < 0.05$). Conversely, levels of Fe and Al were among the lowest of the seven types.

Sugar maple-Northern red oak-Eastern hemlock type (7 quadrats). These mesic quadrats occurred at lower- to mid-slope positions with an east-facing slope aspect. *Acer saccharum* was the predominant large and small tree species. The genus *Carya* was represented by four species, of which *C. glabra* (Mill.) Sweet was most abundant. *Fraxinus americana* L., *A. flava*, and *Tsuga canadensis* were important components of the small tree stratum. Shrub diversity was also quite low; average species richness and diversity values were 2.3 and 0.4, respectively. However, the herbaceous stratum of this community type was the richest examined. Quadrats averaged more than 17 herbaceous species, and average species diversity was 2.5. In terms of soil conditions, these quadrats generally occurred on the better quality sites; pH averaged 5.1, and base cation concentrations were generally high. The presence of *Asplenium ×ebenoides* and *Quercus muehlenbergii* Engelm., species common to limestone outcroppings (Strausbaugh and Core 1977), suggests the importance of slope position and underlying geology to the species composition of this community type.

Yellow-poplar-Sugar maple-Cucumber communities (5 quadrats) were found on the better growing sites in the gorge. *Acer saccharum* and *Magnolia acuminata* L., although termed community dominants, had much lower importance when compared to the average IV of 50.8 for *Liriodendron tulipifera* L. These communities were youngest of those sampled; average age of *L. tulipifera* was 54 ± 19 years. They occurred at lower to midslope positions on northeast-facing slopes. Concentrations of Ca, Mg, and K were exceeded only by the White ash-Basswood-Northern red oak type.

Because of the dominance of *L. tulipifera*, large and small tree species diversity were relatively low. This was the only community type that did not have an oak species as one of the top-three overstory species; only *Q. rubra* exceeded an average IV of 1.0. In the small tree and sapling strata, *A. saccharum* was most abundant. The presence of *T. canadensis* was also notable in the small tree stratum, but this species was absent from the sapling stratum, somewhat surprising, given its shade tolerance (Baker 1949; Burns and Honkala 1990). In contrast to woody strata, herbaceous diversity was high ($N = 15.6$); 58 different herbaceous species were identified in the five quadrats.

The Sourwood-Shagbark-Black oak type was represented by three quadrats, occurring on upper-slope and ridgetop positions at an average elevation of 666 m. Average slope aspect was southwest-facing. *Oxydendron arboreum* was the most important species in the large- and small-tree strata. *Acer rubrum* and *C. ovata* were also abundant in the small tree stratum. Shrub diversity in this type was low ($H' = 0.6$). Consistent with slope position and aspect, these quadrats were relatively acidic (pH = 4.3) and low in base cation concentrations.

Environmental Gradients

The ordination of the 41 sample quadrats was achieved with a final stress of 15.6 for the three-dimensional solution (Figure 3). Community data sets often have final stress values between 10 and 20, and values less than 20 indicate more or less reliable solutions

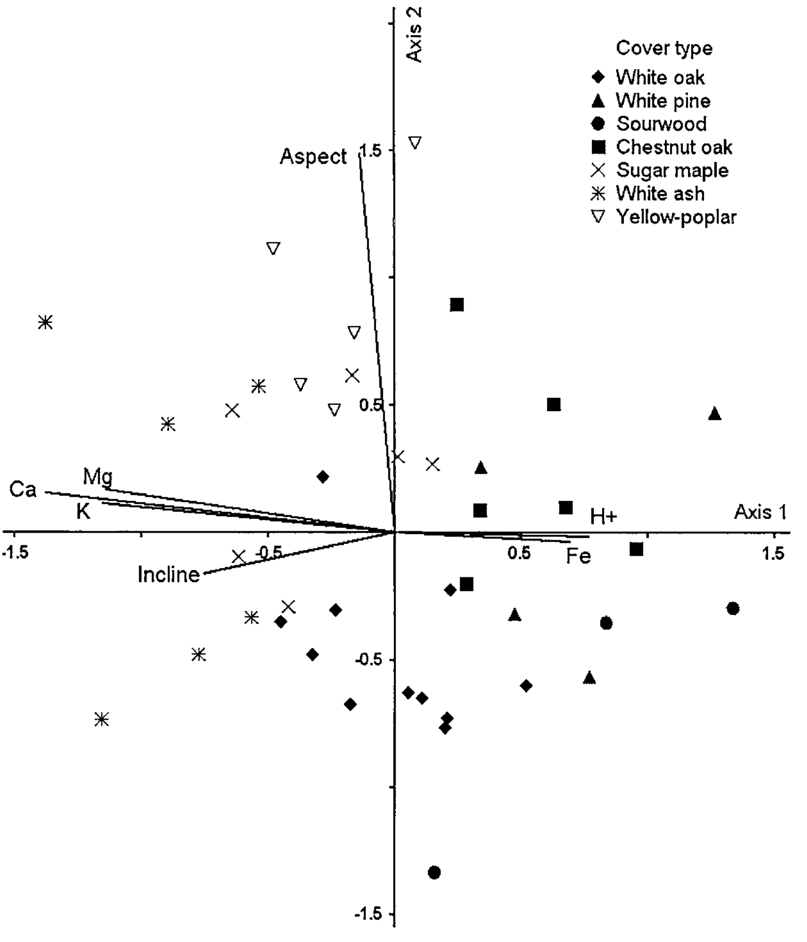

Figure 3. Ordination, using nonmetric multidimensional scaling, of 49 sample quadrats in species space, using large-tree (dbh $\geq$ 10 cm) species IV as input data. Only the first dominant of each community-type is shown in the legend. Correlation values $\geq |0.50|$ with secondary axis of site variables are shown as vectors. Coefficients of determination (R^2) for axes 1 and 2 were 20.9 and 36.2, respectively.

(McCune et al. 2002). The ordination was significantly different from the Monte Carlo simulation ($p < 0.01$). The proportion of variation explained by axes 1–3 was 20.9%, 36.2%, and 16.9%, respectively (total = 74.0%). Elevation, slope inclination and slope-aspect showed strong correlations with ordination axes. However, due to the influence of calcareous strata within the Hinton Formation at midslope, underlying geology and soil nutrient status tended to explain more variation in the ordination than topography. The break point tended to correspond to the transition between the Hinton Formation of the Mauch Chunk, occurring from valley floor to approximately midslope position, and the overlying Princeton Conglomerate and Bluestone Formation.

Mesophytic communities were arrayed to the left on axis 1, while xerophytic, oak- and pine-dominated communities occurred mostly in the lower right-hand side of the ordination. For axis 1, the strongest correlations occurred for H^+ concentration (+0.53) and base cation concentrations; correlations with Ca Mg, and K were −0.74, −0.67, and −0.67, respectively, while the correlation with Fe was +0.51. Axis 1 was also negatively correlated with slope-inclination and positively correlated with elevation (−0.45 and +0.43, respectively), suggesting that quadrats were ordered from low elevation, steep-sloped, circumneutral, high nutrient status quadrats on the left to more acidic, and nutrient poor quadrats on the right. For axis 2, the most significant correlation was aspect (+0.71). Note that because of the aspect transformation and the assignment of the maximum value to northeast aspects, axis 2 points to the northeast. Therefore, quadrats along the left side of axis 2 had a more northerly exposure.

DISCUSSION

Our study was designed to identify major forest cover types by sampling at predetermined intervals along a gradient that could be recognized in the field. We did not expect to detect all forest types; for example, the gorge is known to contain communities with *Thuja occidentalis*, *Gleditsia tricanthos*, and *Juglans nigra*, and *J. cinera*, and these were either not encountered in the field, or found but in widely scattered locations. While the study did identify the major forest cover types of the gorge, estimates of the relative importance of each forest type can only be loosely inferred from the number of sample quadrats identified for each type. However, our findings generally conform to those of Sturm (1977), who mapped forest cover type in Pipestem State Park (a portion of which is included in our study area). He found that the park was approximately evenly divided between oak and pine communities on the one hand, and more mesophytic communities on the other. Better and more current estimates of percent forest cover would require a combination of more intensive sampling and analysis of aerial imagery.

The forests communities of the Bluestone River Gorge are characterized by a compositionally and structurally diverse flora that is associated with a correspondingly complex array of environmental gradients. Among these environmental parameters, the importance of aspect and inclination was confirmed. However, variability in soil nutrient status, particularly base cation concentrations, was generally more important than aspect in explaining vegetation distribution. For the large tree strata, Ca, Mg, and K were strongly correlated with Axis 1, and absolute correlation values exceed those for topographic variables.

The vegetation-soil nutrient relationships documented in this study contrast with vegetation patterns described in other studies in the region. For example, McCay et al. (1997) found elevation to be the strongest gradient in separate ordinations of plots in the Allegheny Mountains and Ridge and Valley sections of eastern West Virginia. They considered soil texture and horizon depth, but not individual soil nutrient concentrations. In the southern Appalachians, Whittaker (1956), Golden (1981), and Callaway et al. (1987) all identified elevation as the key environmental gradient for interpreting vegetation patterns, with topographic moisture and soil characteristics identified as the second and third critical gradient (Newell and Peet 1998). Muller (1982) reached a similar conclusion for a mixed mesophytic forest in eastern Kentucky, where no variable, other than elevation, accounted for more than 20% of the variation. The fact that *r*-values for elevation were weaker than those for base cations in this study may be, in part, due to dips in rock strata and the appearance of outcroppings of the Hinton Formation at slightly different elevations. The influence of topography may have also been mitigated by the relatively narrow range of elevation encompassed by the transects (maximum relief = 243 m), and the fact that even though aspect was fairly well-represented in quadrat site selection, the overall alignment of the gorge was in a southwest to northeast direction, parallel to the strike of the rock strata.

Some community types and species were more strongly associated with soil nutrient status than others. Not unexpectedly, the three mesophytic communities were associated with high pH, and higher concentrations of Ca, Mg, K, and total N, and lower concentrations of Fe. In addition, IVs of *A. saccharum*, *F. americana*, and *L. tulipifera*, were also strongly correlated ($r > 0.40$) with Ca and Mg. Muller (1982), Leopold and Parker (1985) and Elliott et al. (1999) found similar relationships for *A. saccharum* and *L. tulipifera* in Kentucky and North Carolina, respectively. Conversely, the Sourwood, Chestnut oak, and White pine communities occurred on the infertile end of the soil nutrient gradient, with relatively low pH, low Ca, Mg, and K concentrations, and higher than average levels of Fe and Al. These results are consistent with downslope leaching of nutrients from these sites (Racine 1966). Correlations between *P. strobus* IV and Ca, Mg, and K concentrations were all strongly negative (−0.40 or less), as were correlations of *Q. prinus* IV and Ca, Mg, and K. In contrast, *Q. alba* and *Q. rubra*-dominated

Table 5. Rank frequency of species abundance, by species IV, of large (dbh > 10 cm) and small (2.5 cm < dbh < 10 cm) trees for 51 quadrats in the Bluestone

	Rank frequency							
	Large tree				Small tree			
Species	**1st**	**2nd**	**3rd**	**4th**	**1st**	**2nd**	**3rd**	**4th**
Quercus rubra	3	5	9	4		2	3	3
Quercus alba	7	6	5	2				2
Acer saccharum	6	6	2	6	17	5	4	5
Quercus prinus	3	5	5	3	1		2	1
Quercus velutina	2	6	4	2			1	
Liriodendron tulipifera	5	2	4	3			2	2
Pinus strobus	5	3	1	3	2	5	2	
Acer rubrum	1	2	3	6	8	8	7	7
Fraximus americana	3	5		3	1	4		2
Carya ovata	2	2	3		2	1	1	
Oxydendrum arboreum	3	1	2	1	4		2	3
Tilia americana	2		2	2		1	1	3
Carya glabra	1	2		2		1	4	1
Fagus grandifolia	1	3			3	2	2	3
Aesculus flava		2	1	1		5	1	
Carya alba			1	3	1			
Tsuga canadensis			3		3	1	1	3
Magnolia acuminata			1	2		1	1	
Quercus muehlenbergii			1	1				
Platanus occidentalis	2							
Nyssa sylvatica	1			1	1	2		
Robinia pseudoaccacia	1			1				1
Juglans nigra		1			1			
Pinus virginiana		1						
Juniperus virginiana			1					
Pinus rigida			1					
Cercis canadensis	1				1	1	2	2
Quercus macrocarpa				1				
Amelanchier arborea					2	3	4	
Carpinus carolinana					3	2	2	1
Cornus florida						6	4	5
Hamamelis virginiana						1		1
Prunus serotina								1
Ulmus rubra					1			1

communities showed relatively fewer and weaker relationships with topography and soil nutrient status. Neither of the two oak species showed a significant correlation between species IV and soil cation concentrations or soil pH.

Total species richness for the tree, small tree, sapling, shrub, and herbaceous strata were 44, 45, 48, 34, and 215, respectively. Fourteen different tree species were identified as community-type indicators, with a mean IV of 36.8. Overall, species of *Quercus* were the most predominant overstory trees. Eight *Quercus* species occurred in the study quadrats, and either *Q. alba*, *Q. rubra*, *Q. velutina*, or *Q. prinus* were predominant in six of the seven community types identified from cluster analysis. *Quercus alba* was the single most prominent overstory tree species, ranking first in seven out of 51 quadrats, and scoring among the top four species in 20 quadrats (Table 5). However, in the understory (small tree and sapling strata), only five *Quercus* species were present, and their relative importance was considerably lower.

The near absence of *Quercus* from the understory, particularly on better quality growing sites, conforms to reports of oak regeneration declines elsewhere in eastern deciduous forests

(Parker et al. 1985, Abrams 1992, Loftis and McGee 1993). Prospects for continued *Quercus* dominance here appear best on the mid- to upper-slope sites with south and west-facing aspects—those positions currently occupied by White oak-Northern red oak-Black oak and Chestnut oak-Northern red oak-Red maple communities. On sites where oak regeneration is less abundant, *A. saccharum* and *A. rubrum* appear as likely successional replacements. *Acer saccharum* was ranked first in six overstory quadrats, however, in the understory, it was the most abundant species in 17 quadrats, and was ranked 1–4 in 31 quadrats.

Fagus grandifolia, *Prunus serotina* Ehrh., and *A. rubrum* have frequently been cited as beneficiaries of the past half-century of fire suppression and intensive harvesting practices, and declines in oak regeneration (Abrams 1992, 1998; Lorimer 1984, 1993). However here, *F. grandifolia* ranked in the top four overstory species only four times, and only ten times in the small tree stratum. Its relatively low importance was somewhat surprising, given its association with *A. saccharum* and *T. americana* on cooler, moister, north-facing sites (Eyre 1980, Burns and Honkala 1990), and the deliberate avoidance of this species by loggers (Trimble 1977). *Acer rubrum*, as an overstory tree, was most abundant in the oak-dominated quadrats, where the probability of successful oak regeneration was also highest. In the small tree stratum, however, this species was second only to *A. saccharum* in importance, ranking first[t] eight times, and 30 times in the top four ranks. This species acts as both an early and late successional species, exhibits a high degree of morphological and physiological plasticity, and may thrive on sites with highly variable edaphic and topographic conditions (Gottschalk 1994, Abrams 1998).

CONCLUSIONS

Classification of overstory tree species by importance values suggests that seven forest community-types comprise major components of the vegetation of the lower Bluestone River Gorge. These seven types conform to widely recognized forest cover-types (see Eyre 1980). Species of *Quercus* were the most common overstory tree in the study area; of the seven community types, six identified *Quercus* spp. as a community-type indicator. Ordination of the overstory tree data indicates topographic characteristics have a strong influence in the distribution of species and community types. However, as a result of the occurrence of rock strata consisting of limestones and calcareous shales at approximately mid slope, soil nutrient quality exerted a relatively stronger influence on the distribution of tree species and forest composition. The continued importance of *Quercus* spp. in the study site seems most likely on the poorest quality sites. On better sites, *A. saccharum* and *A. rubrum* have captured a share of the overstory; a possibly more predominant future status is suggested by their overwhelming importance in the understory.

ACKNOWLEDGMENTS

Will Ravenscroft provided invaluable assistance in preparation of the map of the study area. Partial funding provided by the National Park Service. This is Scientific Article No. 2894 of the West Virginia University Agricultural and Forestry Experiment Station, Morgantown, West Virginia.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests. BioScience 42:346–353.

Abrams, M.D. 1998. The red maple paradox. BioScience 48:355–364.

Abrams, M.D., D.A. Orwig, and T.E. Demeo. 1995. Dendroecological analysis of successional dynamics for a presettlement-origin white-pine—mixed-oak forest in the southern Appalachians, USA. J. Ecol. 83:123–133.

Adams, H.S. and S.L. Stephenson. 1983. A description of the vegetation on the south slopes of Peters Mountain, southwestern Virginia. Bull. Torrey Bot. Club 110:18–22.

Baker, F.S. 1949. A revised tolerance table. J. For. 47:179–181.

BARANSKI, M.J. 1975. An analysis of variation within white oak (*Quercus alba* L.). North Carolina Agricultural Experiment Station. Tech. Bul. No. 236.

BEERS, T.W., P.E. DRESS, and L.C. WENSEL. 1966. Aspect transformation in site productivity research. J. For. 64:691–692.

BRAUN, E.L. 1950. Deciduous forests of eastern North America. The Blakiston Company, Philadelphia, Pennsylvania.

BROOKS, A.B. 1910. Forestry and wood industries. West Virginia Geological Survey, Volume 5. Acme Publishing Co., Morgantown, West Virginia.

BURNS, R M. and B.H. HONKALA, (tech. cords). 1990. Silvics of North America. Volume 2. U.S. Department of Agriculture For. Serv. Agric. Handb. No. 654.

CALLOWAY, R.M., E.E. CLEBSCH, and P.S. WHITE. 1987. A multivariate analysis of forest communities in the western Great Smoky Mountains National Park. Amer. Midl. Naturalist 118:107–120.

CORE, E.L. 1966. The vegetation of West Virginia. McClain Printing Company, Parsons, West Virginia.

DAUBENMIRE, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row, New York, New York.

DAY, F.P. and C.D. MONK. 1974. Vegetation pattern on a Southern Appalachian watershed. Ecology 55: 1064–1074.

ELLIOTT, K.J., J.M. VOSE, W.T. SWANK, and P.V. BOLSTEAD. 1999. Long-term patterns in vegetation-site relationships in a southern Appalachian forest. J. Torrey Bot. Soc. 126:320–334.

EYRE, F.H. (ed.). 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.

FORTNEY, R.H., S.L. STEPHENSON, and H.S. ADAMS. 1995. Reconnaissance vegetation study of the Bluestone, New, and Gauley River Gorges. p. 42–50. *In:* Proceedings of the New River Symposium, April 7–8, 1995. Daniels, West Virginia. Quality Printing Company, Sutton, West Virginia.

GAUCH, H.G., JR. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York, New York.

GOLDEN, M.S. 1981. An integrated multivariate analysis of forest communities of the central Great Smoky Mountains. Amer. Midl. Naturalist. 106:37–53.

GOTTSCHALK, K.W. 1994. Shade, leaf growth and crown development of *Quercus rubra*, *Quercus velutina*, *Prunus serotina* and *Acer rubrum* seedlings. Tree Physiol. 14:735–749.

GRAFTON, W.N. 1982. Plants and vegetation of the New River Gorge. p. 69–74. *In:* Proceedings of the New River Symposium, May 6–8, 1982, Beckley, West Virginia. Quality Printing Company, Sutton, West Virginia.

GRAFTON, W.N. 1993. Vascular flora on the lower sections of Gauley, Meadow, and Bluestone Rivers. p. 123–134. *In:* Proceedings of the New River Symposium, April 15–17, Wytheville, Virginia. Quality Printing Company, Sutton, West Virginia.

HICKS, R.R., JR. and P.S. FRANK. 1984. Relationship of aspect to soil nutrients, species importance and biomass in a forested watershed in West Virginia. For. Ecol. Manage. 8:281–291.

KARTESZ, J.T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland, 1st ed. *In:* Kartesz, J.T. and C.A. Meachum (eds.). Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, University of North Carolina, Chapel Hill, North Carolina.

LEE, R. and C.R. SYPOLT. 1974. Toward a biophysical evaluation of forest site potential. For. Sci. 20:145–153.

LEOPOLD, D.J. and G.R. PARKER. 1985. Vegetation patterns on a southern Appalachian watershed after successive clearcuts. Castanea 50:164–186.

LOFTIS, D.L. and C.E. MCGEE (EDS.). 1993. Oak regeneration: serious problems, practical recommendations. U.S. Department of Agriculture For. Serv. Res. Pap. NE-356.

LORIMER, C.G. 1984. Development of the red maple understory in Northeastern oak forests. For. Sci. 30:3–22.

LORIMER, C.G. 1993. Causes of the oak regeneration problem. p. 14–39. *In:* Loftis, D. L. and C.E. McGee (eds.). Oak regeneration: serious problems, practical recommendations. U.S. Department of Agriculture For. Serv. Res. Pap. NE-356.

MARSHALL, P.D. and D.N. FUERST. 1982. Inventorying the New River: an archeological, historical, and architectural survey. p. 61–68. *In:* Proceedings of the New River Symposium, May 6–8, 1982, Beckley, West Virginia. Quality Printing Company, Sutton, West Virginia.

MARWITT, J.P. 1982. Test excavations at three late Prehistoric village sites at Bluestone Lake, Summers County, West Virginia. p. 195–197. *In:* Proceedings of the New River Symposium, May 6–8, 1982, Beckley, West Virginia. Quality Printing Company, Sutton, West Virginia.

MASLOWSKI, R.F. 1982. Archeology of the Bluestone Reservation. p. 185–197. *In:* Proceedings of the New River Symposium, May 6–8, 1982, Beckley, West Virginia. Quality Printing Company, Sutton, West Virginia.

MASLOWSKI, R.F. and J.L. WOODY. 1984. Historic sites in Crumps Bottom, Bluestone Reservation. p. 183–192. *In:* Proceedings of the New River Symposium, April 12–14, Boone, North Carolina. Quality Printing Company, Sutton West Virginia.

MCCARTHY, B.C., T.I. VIERHELLER, and W.A. WISTENDAHL. 1984. Species ordination of upper slope oak-hickory stands of southeastern Ohio. Bull. Torrey Bot. Club 111:56–60.

MCCAY, D.H., M.D. ABRAMS, and T.E. DEMEO. 1997. Gradient analysis of secondary forests of eastern West Virginia. J. Torrey Bot. Soc. 124:160–173.

MCCUNE, B. and M.J. MEFFORD. 1999. PCORD for windows: multivariate analysis of ecological data. Ver. 4.0. MjM Software, Glenedon Beach, Oregon.

MCCUNE, B., J.B. GRACE, and D.L. URBAN. 2002. Analysis of ecological communities. MjM Software Design, Glenedon Beach, Oregon.

MILLER, J.H. 1981. History of Summers County from the earliest settlement to the present time, by James H. Miller. Self-published, Hinton, West Virginia.

MULLER, R.N. 1982. Vegetation patterns in the mixed mesophytic forest of eastern Kentucky. Ecology 63:1901–1917.

NEWELL, C.L. and R.K. PEET. 1998. Vegetation of Linville Gorge Wilderness, North Carolina. Castanea 63:275–322.

NORRIS, S.J. 1992. Rare species survey of Bluestone Scenic River, West Virginia. Natural Heritage Program, Division of Natural Resources, National Park Service Cooperative Agreement CA 4000-0-9020.

ORWIG, D.A. and M.D. ABRAMS. 1999. Impacts of early selective logging on the dendroecology of an old-growth, bottomland hemlock-white pine-northern hardwood forest on the Allegheny Plateau. J. Torrey. Bot. Soc. 126:234–244.

OXLEY, E. 1975. Floristics and vegetation of the gorge region of Indian Branch. Unpublished report prepared for Pipestem State Park, Pipestem, West Virginia.

PARKER, G.R., D.J. LEOPOLD, and J.K. EICHENBERGER. 1985. Tree dynamics in an old-growth deciduous forest. For. Ecol. Manage. 11:31–57.

PHILLIPS, V. 1969. The botany of the New River Valley between Glen Lyn, Virginia and Gauley Bridge, West Virginia. Ph.D. dissertation, West Virginia University, Morgantown, West Virginia.

RACINE, C.H. 1966. Pine communities and their site characteristics in the Blue Ridge escarpment. J. Elisha Mitchell Sci. Soc. 82:172–181.

REGER, D.B. 1926, Mercer, Monroe, and Summers Counties: West Virginia Geological Survey.

SAS INSTITUTE. 1999. SAS, Release 8.0. SAS Institute, Inc., Cary, North Carolina.

SMITH, R.L. 1996. Ecology and field biology, 5th ed. Harper Collins College Publishers, New York, New York.

SPONAUGLE, K.N., D.E. MCKINNEY, L. WRIGHT, JR., C.E. NELSON, R.E. PYLE, and C.L. MARRA. 1984. Soil survey of Mercer and Summers Counties, West Virginia. Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C.

STEPHENSON, S.L. and H.S. ADAMS. 1986. An ecological study of balsam fir communities in West Virginia. Bull. Torrey Bot. Club. 113:372–381.

STEPHENSON, S.L. and H.H. MILLS. 1999. Contrasting vegetation of noses and hollows in the Valley and Ridge Province, southwestern Virginia. J. Torrey Bot. Soc. 126:197–212.

STOKES, M.A. and T.L. SMILEY. 1968. An introduction to tree-ring dating. University of Arizona Press, Tucson, Arizona.

STRAUSBAUGH, P.D. and E.L. CORE. 1977. Flora of West Virginia. Seneca Books Inc., Grantsville, West Virginia.

STURM, R.L. 1977. Comparison of forest cover types in seven environmentally diverse areas in West Virginia. M.S. thesis, West Virginia University, Morgantown, West Virginia.

SUITER, D.W. and D.K. EVANS. 1995. Vascular flora of the New River Gorge National River, West Virginia rare species and plant migrations. p. 144–153. *In:* Proceedings of the New River Symposium, April 7–8, 1996, Daniels, West Virginia.

THORNBURY, W.D., 1969. Principles of geomorphology, 2nd ed. Wiley, New York, New York.

TRIMBLE, G.R. 1977. A history of the Fernow Experimental Forest and the Parsons Timber and Watershed Laboratory. U.S. Department of Agriculture For. Serv. Gen. Tech. Rep. NE-28.

WHITTAKER, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26:1–80.

YEAKLEY, J.A. 1993. Hillslope soil moisture gradients in an upland forested watershed. PhD dissertation, University of Virginia, Charlottesville, Virginia.

Received October 6, 2003; Accepted October 20, 2004.