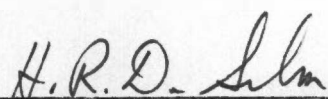
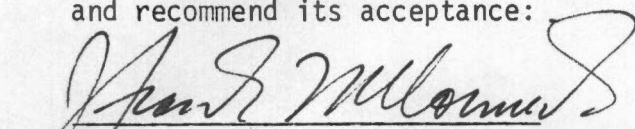
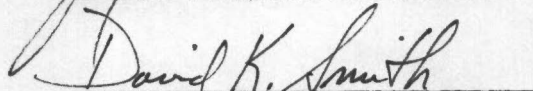


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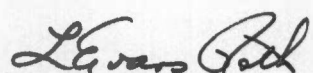
I am submitting herewith a thesis written by Bretta Elaine Perkins entitled "Vegetation of Sandstone Outcrops of the Cumberland Plateau." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.


H. R. DeSelm, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

VEGETATION OF SANDSTONE OUTCROPS
OF THE CUMBERLAND PLATEAU

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Bretta Elaine Perkins

December 1981

3055549

ACKNOWLEDGMENTS

Special thanks go to Dr. Hal R. DeSelm for suggesting this project and contributing much time in guiding it to completion. Thanks also to Drs. David K. Smith and J. Frank McCormick for serving on the committee, and for their help and advice.

Drs. DeSelm, Smith, Fred H. Norris, B. Eugene Wofford, and Aaron J. Sharp of The University of Tennessee, Knoxville, were all helpful in suggesting study sites, as was Dr. George Ramseur (University of the South), and Dr. Paul Somers and Mr. Larry Smith of the Tennessee Heritage Program. Mr. Doyle Bennefield of DeSoto State Park, Alabama and Mr. Preston Lee of Pickett State Forest, Tennessee were also cooperative in this regard.

Mr. David Peacock was an able field assistant for part of a summer.

Many people aided in plant identification. Dr. DeSelm contributed much to the identification of flowering plants. Dr. Wofford and Mr. Thomas Patrick of The University of Tennessee, Knoxville and Dr. Robert Kral of Vanderbilt University identified unknowns. Bryophytes were identified with the aid of Dr. Smith, Dr. Wilbur Peterson, and Mr. Ken McFarland. Ms. Paula T. DePriest was extremely helpful with lichen identification, providing expertise and encouragement. Mr. Brian Luther contributed to crustose lichen identification. Dr. Jonathon P. Dey provided some specimens of lichens as chemical standards, and Dr. Mason Hale aided in some identifications.

Mr. Larry Knox and Dr. Stuart Mahr of the Tennessee State Division of Geology provided valuable information on the sandstones of the Cumberland Plateau. Dr. Robert Wilson of The University of Tennessee, Chattanooga and Dr. Bill Witherspoon provided information on Lookout Mountain stratigraphy.

The computer analysis would have been impossible without the assistance of Mr. Paul Schmalzer and Ms. Ann Stocum. Thanks are also due to the personnel of The University of Tennessee Computer Center in general, and specifically, to consultants Ms. Lisa Kern, Mr. Don Broach, Mr. Bob Muenchen, and Mr. Charles Boyd. Statistical advice was provided by Drs. Dewey Bunting and S. W. Ward of The University of Tennessee, Knoxville.

Editorial assistance came from Mr. Thomas Patrick. The typing was expertly done by Mrs. Marilyn Caponetti.

In addition to those already mentioned, pertinent literature was provided by Mr. Jim Berg, Mr. Will Shefton (North Carolina Heritage Program), and Dr. Ed Schilling (The University of Tennessee, Knoxville). I also received help and encouragement in many large and small ways from many of the faculty and graduate students of The University of Tennessee, Knoxville, including Mr. Rick Busing, Dr. Paul Delcourt, Dr. Alan Heilman, and Mr. Gregg Mueller.

A very special thanks must be given to Mrs. Wallace R. Smith and the late Mr. Wallace R. Smith, who shared their home, their love of life and Nature, and their Flat Rock with me.

This research was supported in part by the Department of Botany, The University of Tennessee, Knoxville, and by a grant from the Aaron J. Sharp Fellowship.

ABSTRACT

Plant communities of sandstone outcrops in six research areas on the Cumberland Plateau were determined as follows. Sample plots were distributed within four subjectively delineated life form zones: (1) Lithophyte Zone (substrate is bare rock), (2) Cryptogam-Herb Zone (usually some soil; no woody plants), (3) Shrub-Herb Zone (some soil; woody plants); and (4) Tree Zone (trees predominate). Three strata were sampled within each zone as appropriate: (1) trees and saplings, (2) other vascular plants, and (3) non-vascular plants. Cover was estimated for each species within each sample plot. Samples within each stratum of each zone were then grouped into communities using Reciprocal Averaging Ordination. Groups were tested using Stepwise Discriminant Analysis. Sørensen's (1948) index of similarity was used to compare communities of the same stratum between zones, and contingency tables were employed to examine association of communities of different strata within each zone.

Communities were characterized environmentally by calculation of means or medians of recorded environmental variables--aspect, slope, microtopographic shape, degree of shading, canopy closure and height, thickness of soil horizons, soil depth, and soil pH. Communities were further characterized through known habitat preferences of dominant taxa, and through positions of communities on ordination axes. Average environmental conditions of zones were also compared.

The Tree Zone was vegetated by a Pinus virginiana Community in all samples with the exception of one on a northerly aspect, dominated

by Tsuga canadensis. Samples from vegetation islands surrounded by rock often had no tree species other than P. virginiana. The Tree Zone understory communities included several dominated by deciduous subsaplins (various species), and a P. virginiana Subsaplins Community, Vaccinium arboreum Community, V. vacillans and Smilax rotundifolia Community, and a Grass-Forb Community. Non-vascular plants had low frequency compared to those of other zones.

Shrub-Herb Zone vascular plant communities included V. arboreum, V. vacillans-S. rotundifolia, Kalmia latifolia, Gaylussacia baccata, P. virginiana Subsaplins, Grass-Forb, and Helianthus longifolius-Danthonia sericea Communities. Non-vascular plants were most profuse beneath the last four communities. The most frequent non-vascular communities were dominated by various proportions of Polytrichum commune, P. juniperinum, reindeer lichens (Cladina spp.), and Cladonia caroliniana.

Non-vascular plants usually had greater cover than vascular plants in the Cryptogam-Herb Zone. Cryptogams prevalent in the Shrub-Herb Zone were again important, as well as Campylopus spp. and Sphagnum spp. Vascular plant communities included Aster surculosus-Liatris microcephala, Talinum teretifolium-Grass-Annual Forb, Bigelowia nuttallii, and Panicum dichotomum Communities. Sedum smallii and Selaginella rupestris Communities were also observed on several sites.

Lithophyte Zone communities were exclusively composed of non-vascular plants: the Grimmia laevigata, Cladonia caroliniana,

Squamulose Cladonias, Powder Crustose Lichen, Filamentous Algae-Inkspot Crustose Lichen, and Mixed Crustose Lichens-Xanthoparmelia conspersa Communities; the last was the most frequent.

The six research areas were also compared floristically. Percentages of life forms proved similar between sites. Number of taxa increased with sample size (as expected) and also with outcrop size. Small outcrops, therefore, were usually depauperate. Sørensen's (1948) index of similarity was calculated between research areas and indicated that distance between the areas was not an important enough factor in their floristic similarity to be discernible through this technique.

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CHAPTER I

INTRODUCTION

I. LITERATURE REVIEW

The sandstone outcrops of the Cumberland Plateau have great scientific potential. In general, rock outcrop plants ("outcrop" used here to mean large, open, fairly horizontal bedrock exposures--excluding cliff faces and ledges, caves, boulders, and deeply shaded exposures) have long interested botanists. Floristically, they are significant for their endemics (McVaugh 1943, Murdy 1968, Baskin et al. 1968, Keener 1970, Baskin and Baskin 1975). Ecologically, outcrops serve as natural laboratories for succession study (Burbank and Platt 1964, Shure and Ragsdale 1977), for study of the autecological characteristics of their stress-tolerant species (Wiggs and Platt 1962, McCormick and Platt 1964), for competition study (Murdy et al. 1970, Sharitz and McCormick 1973), and serve as microcosms for study of effects of perturbations on ecosystems (McCormick et al. 1974, Berg 1981); lastly, they are interesting for their variety of plant communities in a relatively small area (Quarterman 1950, Platt 1951, Winterringer and Vestal 1956, Burbank and Platt 1964).

In the eastern United States, outcrops of various rock types have had different degrees of vegetation study. Most thoroughly investigated are granite outcrops of the southeastern states (Whitehouse 1933, Oosting and Anderson 1937 and 1939, McVaugh 1943,

Keever et al. 1951, Murdy 1968, Burbanck and Platt 1964, Berg 1974, Shure and Ragsdale 1977, Wyatt and Fowler 1977, Weakley 1979). Limestone outcrops have also received much attention (Freeman 1933, Erickson et al. 1942, Quarterman 1950, Ozment 1967, Finn 1968, Baskin and Baskin 1978). Platt (1951) studied the ecology of the Appalachian shale barrens, which have received mainly floristic study (Wherry 1930, Keener 1970).

Sandstone outcrop plants have been intensively studied in few areas of the eastern United States. Gattinger (1901) and Mohr (1901) gave cursory mention to sandstone outcrop plants of Lookout Mountain. Harper (1906) produced a list of taxa, noting apparent endemics, of outcrops of the Georgia coastal plain. Cooper's (1913) study of sandstone and basalt outcrops on Isle Royale, Lake Superior, was probably the earliest description of the plant communities. Griggs (1914) described sandstone cliff edge communities in the Sugar Grove Region of southern Ohio. Braun (1935) reported communities and possible successional sequences of sandstone outcrops high on Pine Mountain, Kentucky, in the Cumberland Mountains. The most complete study to date was that of Winterringer and Vestal (1956) who described microhabitats, plant communities, and the inferred succession of southern Illinois sandstone outcrops. Their work inspired numerous floristic studies of sandstone outcrops in that region, e.g., that of Ebinger (1979). Recently Stotler (1976) and his students (West and Stotler 1977) began a series on saxicolous bryophyte and macrolichen communities of southern Illinois. Floristic studies have also appeared on sandstone outcrops in West Virginia (Core 1966). At

present, there are no published accounts of Cumberland Plateau sandstone outcrop plant communities known to the author, other than brief descriptions such as those of Wharton (1977) and Smalley (1979).

II. STATEMENT OF PURPOSE

The primary purpose of the present study was to describe the plant communities of sandstone outcrops of the Cumberland Plateau using sample plots from six research areas. Samples were grouped into communities by Reciprocal Averaging Ordination and/or Hierarchical Agglomeration. Groups were verified using Stepwise Discriminant Analysis. Mean cover per unit area was then calculated for each species in each community in order to characterize the vegetation. Community microenvironments were characterized through average recorded environmental variables, known environmental preferences of the dominants, and positions of communities on ordination axes.

A secondary purpose of the study was to compare research areas floristically through Sørensen's (1948) index of similarity, life form percentages, and numbers of taxa. The relationship between number of taxa, area sampled, and outcrop size was also examined. Number of taxa is expected to increase with increasing sample size (Cain 1938). Sample size is of necessity lower on small outcrops than large outcrops, however. If outcrops can be regarded as islands, then small outcrops are expected to have fewer taxa than larger ones (MacArthur and Wilson 1967); also outcrops closest together should have the most similar floras.

III. COMMUNITY CONCEPT

A quadrat sampling method was required in order to delineate communities. However, different areas, or "zones," on these outcrops are dominated by plants of different life forms, ranging from cryptogams to trees, complicating choice of quadrat size and distribution. Thus the concept of communities within life form strata was adopted for this study, and life form zones and strata within those zones were sampled and evaluated separately.

The concept of plant communities within life form strata was pioneered by Lipmaa. In 1939 he wrote that

The elementary units of homogeneous and relatively stabilized vegetation (i.e. in equilibrium with the habitat) are one-layered associations, characterized by a definite floristic composition and by their ecology. The bulk of the species of a one-layered association belongs to the same or two related life-forms [sic].

He termed these units of vegetation, "unions." Lipmaa's (1939) taxonomic hierarchy of unions, and restriction of "life forms" to those of Raunkiaer (1934), were not adhered to in the present study, however.

Four life form zones were subjectively delineated in the present study. (1) The Lithophyte Zone had a rock substrate and a single, non-vascular, plant stratum. (2) The Cryptogam-Herb Zone had a strikingly different vegetation from that of the Lithophyte Zone, usually some soil, and two strata--herbs and non-vascular plants--treated separately. (3) The Shrub-Herb Zone was characterized by the presence of woody plants and soil; its vascular and non-vascular plants were sampled separately. (4) The Tree Zone was dominated by

trees and saplings; canopy, other vascular plants, and non-vascular plants were treated as separate strata.

CHAPTER II

THE STUDY AREA

I. THE CUMBERLAND PLATEAU

The Cumberland Plateau is the southernmost and least dissected portion of the Appalachian Plateaus physiographic province (Fenneman 1938, Thornbury 1965). It extends in a southwesterly direction from southern Kentucky to northern Alabama and extreme northwest Georgia (shown from Tennessee south in Figures 1 and 2). To the north is the Allegheny Plateau, the boundary with this province somewhat arbitrarily placed along the Kentucky River in Kentucky (Fenneman 1938, Thornbury 1965). Northeast are the Cumberland Mountains; east, the Ridge and Valley Province; west, the eastern and southern Highland Rim of the Interior Low Plateau. Southward, the Plateau includes the Warrior Tablelands, which border the Coastal Plain. The Tennessee River flows through the Plateau near the Tennessee-Alabama state line; its tributaries, the Sequatchie River and Wills Creek, separate Lookout Mountain and most of the Plateau in Alabama from the main part to the north.

The physiography of the Plateau has evolved as a result of its geology (Wilson et al. 1956, Hack 1966). The Plateau is capped by Pennsylvanian Age rock: thick horizontal beds of consolidated sandstones and shales with lesser amounts of siltstones, conglomerates, and coal. These capping strata are underlain by softer horizontal beds--chiefly limestone--of Mississippian Age. Erosion has been

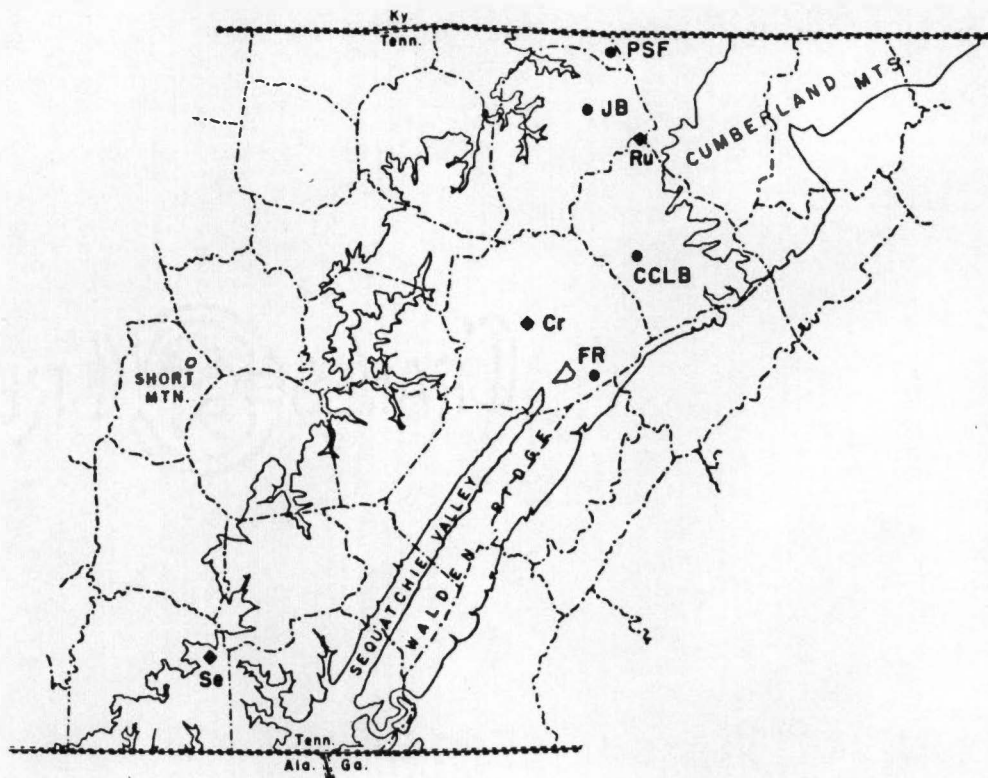


Figure 1. The Cumberland Plateau in Tennessee. Research areas are Flat Rock (FR), Clear Creek at Lilly Bridge (CCLB), the Jamestown Barrens (JB), and Pickett State Forest (PSF). Cities are Crossville (Cr), Rugby (Ru), and Sewanee (Se).

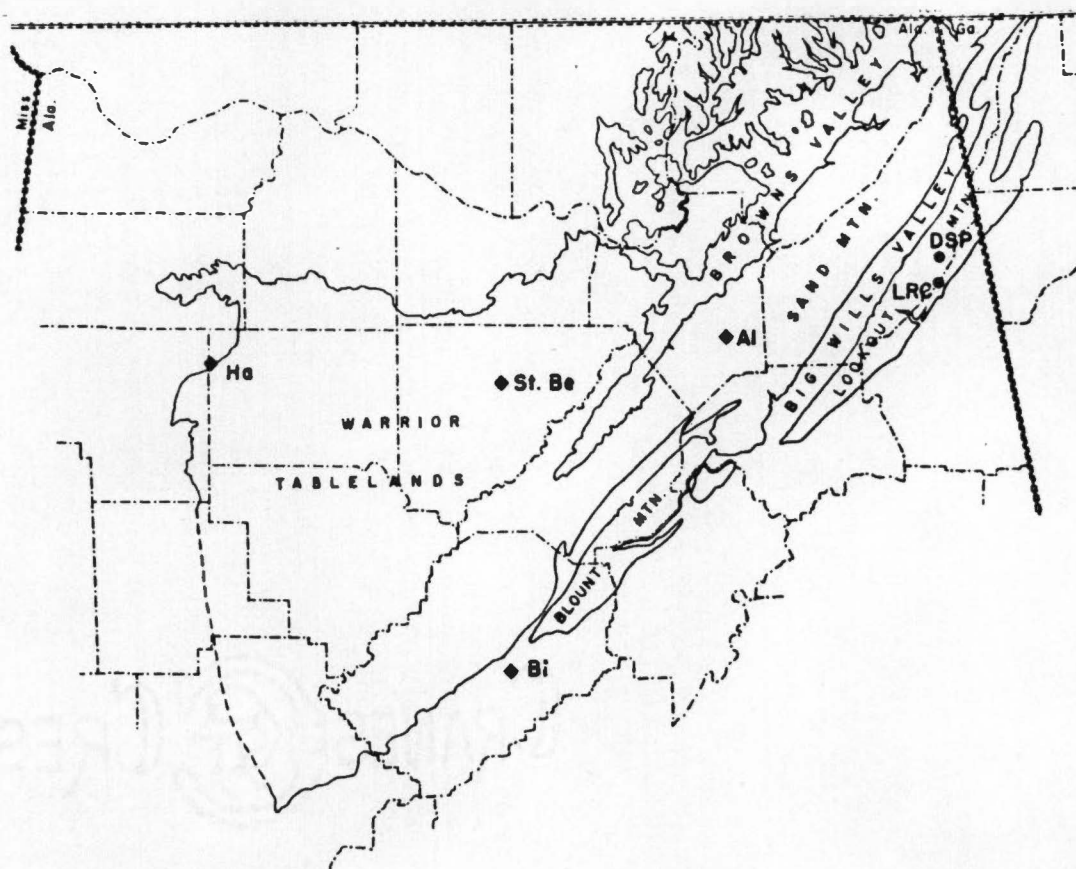


Figure 2. The Cumberland Plateau in Alabama and Georgia. Research areas are DeSoto State Resort Park (DSP), and Little River Canyon (LRC). Cities are Albertsville (Al), Birmingham (Bi), Haleyville (Ha), and St. Bernard (St. Be).

relatively slow on much of the Plateau surface, which is characterized, therefore, by gently rolling terrain. Where the resistant sandstone caprock has been breached, however, rapid erosion of softer strata ✓ has produced deep, rugged, V-shaped to U-shaped gorges (Hack 1966).

Near the end of the Pennsylvanian Age, the Allegheny orogeny (Miller 1974) uplifted the Plateau relative to the surrounding landscape and sea (to the west). At that time the Pennsylvanian sediments extended west beyond Short Mountain (Figure 1) and at least 15 miles east of the present escarpment (Miller 1974). Stream erosion reduced the Plateau to its present dimensions and created the Sequatchie, Browns, and Wills Creek Valleys.

Sandstone outcrops on the Plateau are typically bluffs above gorges. A wide expanse of rock may be exposed at the cliff edge, suitable for the characteristic vegetation that is the subject of this study. Other outcrops occur on the rolling Plateau surface where stream erosion has removed softer surface strata (such as shale) ✓ leaving a resistant sandstone "flat-rock." These types of outcrops may be distant from any large valley. An intermediate case is a gentle bluff above a shallow valley.

As long as the Plateau is subject to erosion, the type of sandstone outcrops that are the object of this study will exist, until the Pennsylvanian sandstones are removed (Hack 1966). Streams continue to expose new sandstone strata; rockfall bares previously vegetated rock; and storm and other disasters remove vegetation and shallow soil over sandstone. Assuming that these same processes have operated in

the past since uplift of the Plateau, these habitats have been available to plants for some 285 million years (Miller 1974), and to the present flora since the Pleistocene (Delcourt and Delcourt 1979).

Sandstones and sandstone conglomerates of various formations make up the caprock of the Plateau (Wilson et al. 1956). Those that commonly are exposed include, from youngest to oldest, Rockcastle, Sewanee, and Warren Point. All of these formations have a remarkably similar composition (L. Knox, personal communication). Because the strata dip toward north, sandstones exposed at the surface are progressively older from north to south.

Sandstones of the Plateau have few weatherable minerals. They ✓ produce an acidic, moderately fertile to nutrient-poor soil, which is well to excessively drained (Francis and Loftus 1977, Hinkle 1978, Smalley 1979). Hinkle (1978) reported that Plateau soils of Tennessee are Ultisols (Hapludults and Paleudults) and Inceptisols. Smalley (1979) reported fine sandy loams, sandy loams, loams, and silt loams from Plateau uplands south of the Tennessee River. In general, the soils are Inceptisols: Dystrochrepts with Udults and Udalfs (United States Department of Agriculture 1975).

The climate of the Plateau, according to the Thornthwaite (1948) system, is humid mesothermal with little or no water deficiency in any season and a thermal efficiency regime of 48.0 to 56.3%. The Holdridge (Sawyer and Lindsay 1963) system places it in the warm temperate moist forest bioclimatic formation. Table 1 lists mean monthly temperatures and precipitation for various stations on or near the Plateau (United States Department of Commerce 1957 and 1974).

Table 1. Normal monthly and annual temperature (°C) and precipitation (cm) for Plateau stations.^a

Station	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
<u>Rugby, Morgan Co., TN</u>														
Precipitation	64	12.9	12.2	13.6	11.0	10.0	11.7	13.3	11.5	8.2	6.9	9.6	11.7	132.7
Temperature	59	2.7	3.5	8.1	12.9	17.6	21.7	23.5	22.8	19.9	13.5	7.5	3.4	13.1
<u>Crossville, Cumberland Co., TN</u>														
Precipitation	41	14.1	12.3	14.5	11.2	10.2	11.1	12.8	12.6	8.1	7.6	9.4	12.9	136.7
Temperature	38	3.2	3.9	7.6	12.9	17.4	21.5	23.0	22.4	19.7	13.8	7.4	3.4	13.0
<u>Sewanee, Franklin Co., TN</u>														
Precipitation	59	13.6	12.8	15.5	11.9	10.3	11.7	13.8	11.6	7.9	8.0	10.5	12.9	140.4
Temperature	44	4.0	4.5	8.8	13.9	18.9	23.3	24.7	24.2	21.9	15.8	9.1	4.5	14.5
<u>Albertville, Marshall Co., AL</u>														
Precipitation	51	13.5	12.9	15.0	12.7	10.4	8.6	11.7	8.4	8.9	7.1	10.4	13.5	133.3
Temperature	49	5.0	6.1	10.0	15.6	20.0	23.9	25.6	25.0	21.7	16.1	10.0	5.6	15.6
<u>Haleyville, Winston Co., AL</u>														
Precipitation	40	15.2	14.7	16.3	14.2	9.6	10.2	12.7	10.4	9.6	6.6	10.9	15.0	145.5
Temperature	38	5.0	6.7	10.0	16.1	20.6	24.4	25.6	25.6	22.2	16.7	10.0	6.1	15.6
<u>St. Bernard, Cullman Co., AL</u>														
Precipitation	70	14.2	14.5	15.7	12.9	10.2	9.6	11.4	9.9	10.2	7.1	11.2	13.7	140.2
Temperature	68	5.0	6.7	10.0	16.1	20.6	24.4	25.6	25.6	22.2	16.1	10.0	5.6	15.6
<u>Birmingham, Jefferson Co., AL</u>														
Precipitation	39	12.2	13.5	15.7	11.7	9.1	10.2	13.2	10.9	9.1	6.6	9.4	13.2	135.1
Temperature	37	6.7	8.3	11.7	17.2	21.1	25.0	26.7	26.1	23.3	17.2	11.1	7.2	16.7

^aSource is United States Department of Commerce (1957 and 1974).

II. RESEARCH AREAS

Six research areas were selected on the Cumberland Plateau (Figures 1 and 2). Criteria for selection included size and number of sandstone exposures, degree of disturbance, and accessibility. Every area sampled showed some sign of human disturbance, such as refuse or campfire remains. Figure 3 is a photograph of a representative outcrop with its island and forest border vegetation and areas dominated by different life forms.

Each research area was sampled twice from June to September 1978 and also examined in other seasons. Other outcrops were examined but not sampled in Bledsoe, Cumberland, Fentress, Franklin, Grundy, Morgan, Pickett, Rhea, Scott, and Van Buren Counties, Tennessee; and DeKalb, Jackson, and Morgan Counties, Alabama. The outcrops at Bell Smith Spring in southern Illinois, studied by Winterringer and Vestal (1956), were also visited.

The southernmost research area is on Lookout Mountain, on the bluffs above Little River Canyon in DeSoto State Park, DeKalb County, Alabama (Figure 2). Two outcrops were sampled near Alabama Highway 89, which parallels the bluffs. Both outcrops are about 1220 ft above sea level. Although the stratigraphy of Lookout Mountain is undergoing revision, the rock is probably Warren Point sandstone (R. Wilson, personal communication). The first outcrop (Figure 3), at latitude 34-23-00 north, longitude 85-37-40 west, is a large and almost horizontal outcrop facing east-northeast. Although near a popular overlook and a powerline, much of the outcrop is inaccessible to most



Figure 3. Site 1 at the Little River Canyon research area. The yellow-flowering plant is Bigelowia nuttallii. Note Pinus virginiana tree in vegetation island to the left, and in the forest bordering the outcrop (background). Note also the scattered herb-dominated islands. Dark areas of the rock are wet.

automobiles and less disturbed. The second outcrop (lat 34-22-45 N, long 85-37-52 W) is smaller, and less disturbed. Its slope angle is also low, facing east-southeast. This outcrop is crossed by parallel elongate rock basins holding water after each rain, but supporting little permanent vegetation: the area between the basins was sampled.

The second research area (Figure 2, page 8) is also in DeSoto State Park (resort park area) atop Lookout Mountain, DeKalb County, Alabama. This site is a flat-rock, unassociated with a gorge. The sandstone is probably Warren Point (R. Wilson, personal communication). A single site was sampled near the head of the Lost Falls Trail (lat 34-30-10 N, long 85-37-27 W). The low slope angle faces south-southeast.

The third research area, Flat Rock, is in Cumberland County, Tennessee (Figure 1, page 7), south of Ozone, the property of Mrs. Wallace R. Smith (lat 35-49-55 N, long 84-51-06 W). Once a polling place, only the remains of a chimney, reforested old fields, and rutted jeep roads are reminders of past human use. At about 1570 ft, Rockcastle sandstone outcrops in a series of flat-rocks: two were sampled. The first outcrop slopes 2° southeast; the second slopes 3.5° south-southeast.

The bluffs above Clear Creek where it is crossed by Lilly Bridge (Figure 1) in Morgan County, Tennessee (lat 36-06-06 N, long 84-43-06 W), are the fourth research area. Elevation is about 1250 ft. These Rockcastle sandstone bluffs are popular botanical collecting sites. Three areas on top of the bluffs were sampled. The first and second

outcrop areas slope about 3° south-southeast; the third slopes 7.5° east-northeast.

The Jamestown Barrens (Figure 1, page 7), east of Jamestown, Fentress County, Tennessee, near the city reservoir, is the fifth research area. Large disturbed outcrops occur on both sides of the road above the reservoir. Two outcrops to the east (lat 36-25-50 N, long 84-51-05 W), inaccessible by road and encircled by forest, were actually sampled. These Rockcastle sandstone outcrops form a gentle, broken bluff above the reservoir. The first outcrop slopes 6° south; the second slopes 7.5° south. The area is part of a barrens study by DeSelm (in press).

The sixth research area is in Pickett State Forest (Figure 1), Pickett County, Tennessee. Two Rockcastle sandstone outcrops were sampled at the point of a ridge at Thompson Overlook (lat 36-34-35 N, long 84-46-34 W). The first outcrop, at the head of the Hidden Passage Trail, was fairly undisturbed when sampled; it slopes 7° south. The second outcrop, at the end of the ridge, is scarcely disturbed; it slopes 18° southeast.

CHAPTER III

DATA COLLECTION METHODS

I. PLOT SAMPLING

The four life form zones to be sampled--Lithophyte, Cryptogam-Herb, Shrub-Herb, and Tree Zones--usually occurred in that order from rock to forest. A modified transect method was therefore appropriate in order to distribute sample plots among the zones. Transects were extended from rock to surrounding forest or across vegetation islands, usually downslope from the Tree Zone and in the direction of aspect. Locations for transects were chosen from a number of acceptable (undisturbed) sites using a random number table. Sample plots were distributed at intervals on the transect within each zone at a random (with random number table) distance at right angles to the transect (Figure 4) (the Tree Zone canopy was sampled using a single large plot, however). This method proved adaptable to zones of different shapes and areas, and served to distribute samples widely within each zone. Zones not represented on a given transect were easily omitted.

Crevice vegetation was avoided since it would require a different sampling method. Crevices also represent a different habitat than that of a vegetation mat on shallow soil, or the surrounding forest. Even the narrowest fissures are usually vegetated with grasses, forbs, shrubs, and/or dwarf pines. They probably

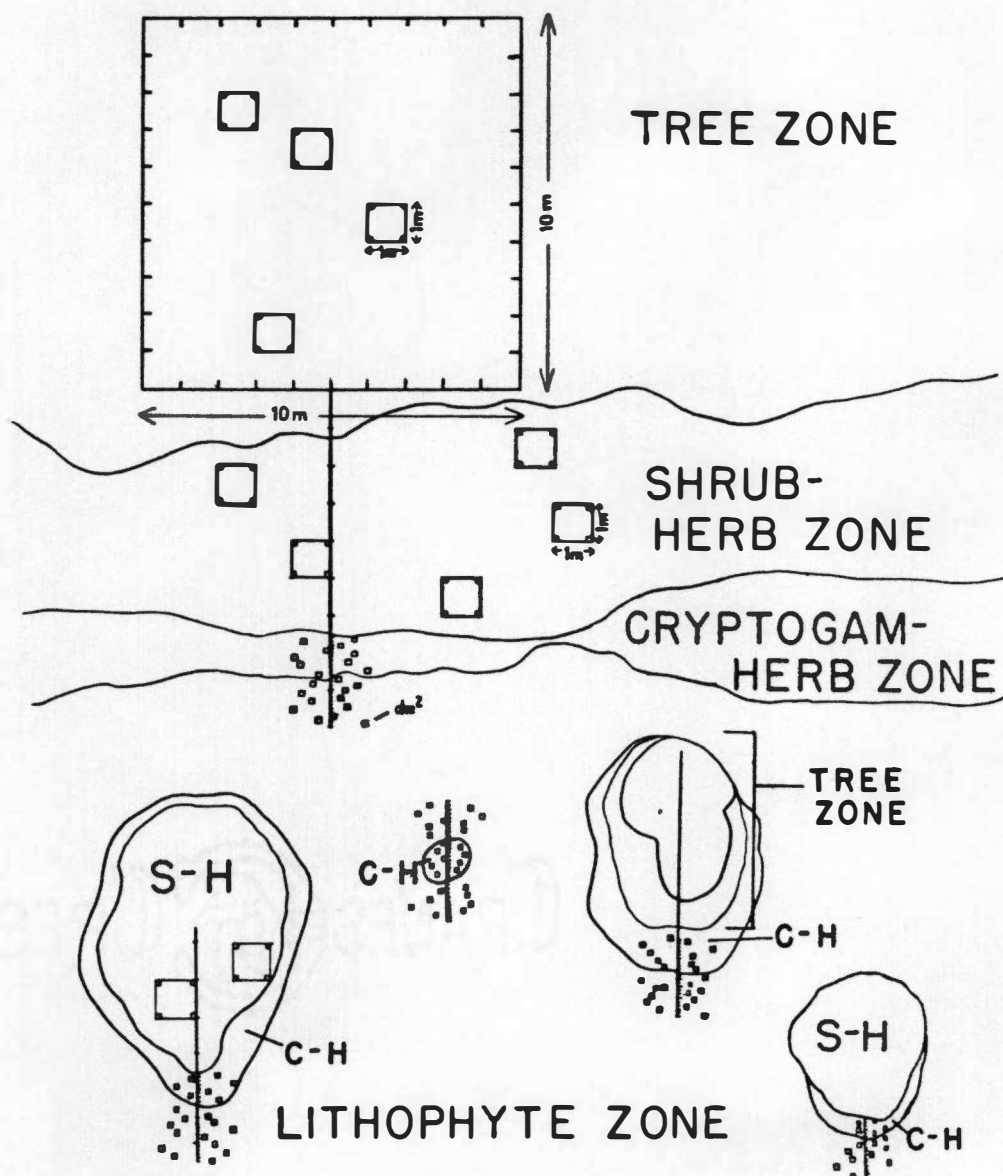


Figure 4. Distribution of sample plots along various kinds of transects. Shrub-Herb Zone is abbreviated "S-H"; Cryptogam-Herb Zone is abbreviated "C-H."

provide better drainage and more secure purchase than shallow soil over unbroken rock. Some islands may overlay crevices, but wind-thrown pines with their overturned vegetation mats demonstrate that crevices are not necessary for establishment of woody vegetation in islands on the rock surface.

Once a transect was drawn, and if a Tree Zone were present, a square 100m^2 canopy plot was placed at the forested end of the transect line. Canopy plot size and shape varied in small or disturbed stands. In the case of a small vegetation island with a tree or trees at its center, dominating the whole island, the entire island was used as both canopy and understory plot. Species and stem diameter at breast height (dbh) were recorded for individuals equal to or greater than 2.0cm dbh and at least 1.0m tall. Saplings-- 1.0 - 2.0cm dbh and at least 1.0m tall--were counted. Average canopy height and percent canopy closure were also recorded. To determine tree age, cores were removed from the largest trees in each plot using a Swedish increment borer.

Large canopy plots were divided into a grid of m^2 plots, four to eight of which were randomly selected, using a random number table, as understory sample plots. Cover of each species rooted in the plot was then estimated (cm^2). Cover of non-vascular vegetation (cm^2) was recorded from dm^2 plots placed in each corner of each understory plot. A soil sample was then dug from the center of four understory plots.

Other zones were sampled by placing square plots along the transect line. The Shrub-Herb Zone was sampled with m^2 plots placed 0 - 9m to either side of the transect line. Occasionally, as in the

Tree Zone, an entire vegetation island was used as a Shrub-Herb Zone plot. Cover of species rooted in each plot was estimated (cm^2). Also as in Tree Zone understory plots, a soil sample and four non-vascular plant subplots were taken. The dm^2 Lithophyte Zone and Cryptogam-Herb Zone plots were distributed within 1m of either side of the transect line--usually there were at least 10 per transect. In contrast to vascular plant sample plots, the absolute cover in cm^2 was estimated for non-vascular species in each dm^2 plot even if represented by only part of an individual.

Soil characteristics recorded varied between life form zones and strata. Lithophyte Zone plots had too shallow a soil to measure. Measurement of soil depth in the other zones was complicated by the growth habit of mosses and lichens that die at the base and continue to grow at the apex; the depth of mineral soil was recorded. Soil pits were dug to 30cm or bedrock. Total soil depth and thickness of each soil horizon was determined. Horizons were defined after those of the United States Soil Conservation Service (United States Department of Agriculture 1975), with two exceptions: relatively undecayed leaf litter and dying lower parts of cryptogams were not included in the O_1 horizon; and no C or R horizons could be distinguished. Soil measurements were extrapolated to the surrounding non-vascular plant subplots, and those within a Tree Zone canopy plot were averaged for that plot.

The following environmental parameters were also recorded at each plot. Aspect was recorded first as compass direction, then

recoded after the environmentally relevant system of Beers et al. (1966) (Table 2). Slope angle was measured in degrees. Microtopography and degree of shading in midsummer were scaled such that the higher the value, presumably the more environmentally moist the plot. Scaling criteria are presented in Table 2.

II. LABORATORY TECHNIQUES

Soil pH

Soil samples were removed to the laboratory and air dried. Soil pH in water (1:1 by weight) was then determined for the A horizon sampled using a pH meter, after the method of Peech (1965).

Tree Age

Tree cores were mounted in grooved wooden strips and sanded to reveal the rings. Rings were then counted under a dissecting microscope (19-30X); decades were marked with pin pricks. A minimum age was obtained for each sample. Faint rings regularly appeared near darker rings and were interpreted as false rings (Fritts 1976). No attempt was made to measure distance between rings.

III. TAXONOMIC SOURCES

Plant taxa recorded in the study are listed in the Appendix, Table 22, with their computer code names. Vascular plant names follow those of Radford et al. (1968), or, if not found in the Carolinas, those of Small (1933). In several cases, more currently accepted nomenclature is substituted.

Table 2. Scaling criteria for aspect, microtopography, and shading.

Variable	Explanation and Code
<u>Aspect</u>	Compass direction faced by the sample plot; undefined if slope is zero degrees, or if the topography is varied so as to present more than one major aspect. Code: ^a
	SW=0.00 SSW=0.08 S=0.29 SSE=0.64 SE=1.00 WSW=0.08 W=0.29 WNW=0.64 NW=1.00 ESE=1.39 E=1.71 ENE=1.92 NNW=1.39 N=1.71 NNE=1.92 NE=2.00
<u>Microtopography</u>	Coded as follows:
	(1) Dome or ridge (4) Edge of basin (2) Slope (even if 0°) (5) Drain or spillway (3) Ledge (6) Basin
	Illustrative profile:
<u>Shading</u>	Estimated degree of midsummer shading as it presumably relates to moisture stress:
	(1) No shade; fully exposed to sunlight all day; (2) Shaded in early morning only; (3) Shaded in the evening only; (4) Shaded either from morning to midday (about noon), only in the middle of the day (about 11 A.M. to 1 P.M.), or shaded both morning and evening only; (5) Shaded from the afternoon on; (6) Partial shade most of the day; (7) Full shade all day.

^aBeers et al. (1966).

Bryophyte names are in accordance with the nomenclature of Conard and Redfearn (1979), although usually identified using Crum (1976). A few names are from Sharp (1939), or from Grout (1903), and current synonyms are provided. Dicranums were determined using a key by Peterson (1979). Liverworts are named using nomenclature in Schuster (1966).

Foliose and fruticose lichens were identified using Hale (1969 and 1979) with the aid of floras by Skorepa (1973), Dey (1978), and Fink (1935). Crustose lichens were tentatively identified using keys by Skorepa (1973), Wetmore (1968), and Thomson et al. (1969). Specimens are currently being annotated.

Both color reaction tests (Hale 1969 and 1979) and, in many cases, thin-layer chromatography (Culberson 1969, 1970, 1972, and 1974; Culberson et al. 1977; Culberson and Kristinsson 1970), were used to identify lichens to species. In the field, however, some lichens could not easily be separated, and since they appeared to occupy similar habitats, were grouped into growth form types. Examples are the grouping of reindeer lichens (Cladina spp.) into "reindeer"; and squamulose Cladonias into "squamule."

CHAPTER IV

COMMUNITY ANALYSIS METHODS

I. DATA ORGANIZATION

A sample by species data matrix was produced for each stratum of each life form zone. Cover per sample plot was the matrix element (basal area/m² for trees). Data from research areas were combined. A sample by recorded environmental variable matrix was also compiled for each data set.

II. DELINEATION OF COMMUNITIES

Hierarchical Agglomeration (Cluster Analysis)

The first step in delineation of communities was to apply cluster analysis to each data set. A program adapted to The University of Tennessee Computer System by Post and Shepherd (1974) was used, which produced dendrograms in which samples were progressively grouped, or hierarchically agglomerated, by vegetational similarity, into communities. In the program, dissimilarity between each pair of samples is first calculated and the least dissimilar samples are grouped together. In the next round of agglomeration, each group is treated as a sample for calculation of a new dissimilarity matrix and regrouped. The process continues until only one group remains. Ward's (1963) method of calculating dissimilarities from the error sum of squares, i.e., sum of the squared distances (absolute) of each sample to the centroid of its group, was used.

To interpret the resulting dendrogram, e.g., that of Figure 5, a level of dispersion at which groups are meaningful, i.e., are communities, must be chosen. Dominants of samples must be noted and a horizontal line drawn across the dendrogram such that samples connected to the vertical lines intersected form reasonable communities (Mueller-Dombois and Ellenberg 1974).

A problem arose with Hierarchical Agglomeration in almost every data set in that samples with low cover were grouped into separate communities. Reciprocal Averaging Ordination therefore became the primary means of delineating communities.

Reciprocal Averaging Ordination

The second step in delineation of communities was to apply Reciprocal Averaging Ordination to each data set. Ordination estimates the geometric relationship in multi-dimensional space between all samples (Gauch 1977). Communities appear as clusters of points (samples). Ordination is less objective than cluster analysis since groups are not discrete, but was more effective with the present data. Ordination also has an advantage since each ordination axis may represent an environmental gradient (Gauch 1977). If no environmental variables are used to weight samples, values of any environmental variables measured or inferred for samples from their species may be used to interpret the axes environmentally.

Reciprocal Averaging Ordination is particularly useful because it requires neither weighting of species nor samples by environmental factors. Reciprocal Averaging also simultaneously calculates

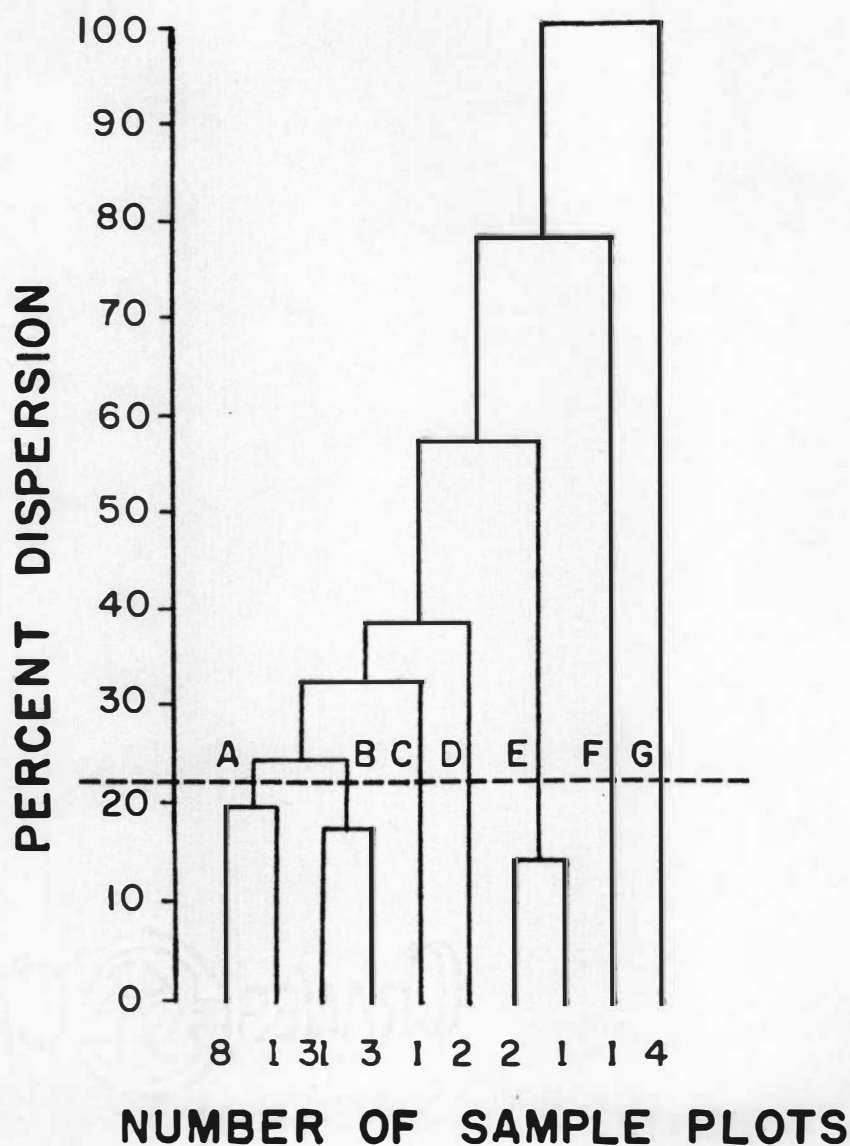


Figure 5. Dendrogram from Hierarchical Agglomeration of Shrub-Herb Zone vascular plant sample plots. The horizontal dashed line is drawn along the 22% level of dispersion from which the following communities were derived: (A) Helianthus longifolius-Danthonia sericea, (B) Grass-Forb, (C) Kalmia latifolia, (D) Vaccinium vacillans-Smilax rotundifolia, (E) Pinus virginiana, (F) V. arboreum, and (G) Gaylussacia baccata.

ordination coordinates for samples and species. An environmental interpretation of a species ordination axis, then, applies to the corresponding sample ordination axis, and vice versa. Because both graphs provide similar information, only sample ordinations are presented in the present study.

A problem of ordination is outliers--points so distinct that they force the remaining points into a tight cluster (Gauch et al. 1977). Outliers can be noted and deleted in a new ordination, however. Data matrices (in which samples and species are arrayed in the order they occur on the ordination axis with the matrix values, e.g. cover, in deciles) can also be examined since deletion of outliers scarcely changes order of the remaining samples in the data matrix.

Another problem with Reciprocal Averaging Ordination in particular is quadratic arching of points in the graph, skewing the axes (Gauch et al. 1977). Inferred environmental gradients should be compared to environmental measurements or known species environmental preferences to avoid misinterpreting skewed axes.

In the present study, a Reciprocal Averaging Ordination program developed by Gauch (1977), ORDIFLEX, was used. The procedure begins by assigning an arbitrary score, or weight, to each species. A score for each sample is then derived from the mean of the scores of its species and their attributes (in this case cover), and scaled from zero to 100. In the second round, new species scores are calculated by averaging sample scores of the plots in which they occur. The new scores are rescaled, and used to calculate new sample scores. The process continues until scores become stable. Final scores become

the coordinates of species and samples along their respective first ordination axes. Being an eigenvector technique, the program derives a second axis by correcting for the first, a third by correcting for the first two, etc. Gauch (1977) and Hill (1973) provide details of the technique. Since only the first few axes are readily interpreted environmentally, only the first three were examined in the present study.

Stepwise Discriminant Analysis

Once sample plots were grouped into communities, statistical significance of the grouping was tested with discriminant analysis. For this study the Stepwise Discriminant Analysis procedure of the Biomedical Computer Programs P-Series (BMDP) of the University of California (Dixon and Brown 1977) was used.

At each step in the analysis, each species in the data set is subjected to a one-way analysis of variance and an F-statistic calculated. That species with the highest F, i.e., the greatest variability among the groups, is then used as a variable in a predictor equation--similar to a regression equation--calculated for each group. After all steps are completed, all species have coefficients in the predictor equation. The equation is then used to calculate the centroid of each group, in turn used to calculate new F-statistics to show how closely groups are related. The equation is also used to reclassify the original samples, and the percent correctly classified into their proper community is reported. As a further test, a pseudo-jackknife procedure calculates new predictor equations, samples

are reclassified, and percent classification success is reported. Jackknifed percent classification success is presumably a less biased figure than the original (Dixon and Brown 1977).

III. DESCRIPTION AND COMPARISON OF COMMUNITIES

Vegetation

Communities were described through compilation of a table of means and standard deviations of the attributes (cover) of each species in each community and in each data set, a useful byproduct of Stepwise Discriminant Analysis (BMDP). In order to compare communities, Sørensen's (1948) index of similarity based on cover was then calculated between pairs of communities within each life form zone and stratum. To calculate similarity of communities in different zones, cover was adjusted for sample plot size differences.

To test for specificity between communities and particular research sites, or between communities of different strata within each zone, contingency tables were prepared using the Statistical Analysis System, SAS (SAS Institute 1979), FREQ procedure. The few positive results will be reported in text only. Empty cells in each contingency table prevented calculation of the Chi-square statistic.

Microenvironment

Environmental relationships of communities were assessed through calculation of means and standard errors or medians for each recorded variable with the SAS (SAS Institute 1979) MEANS procedure or by hand calculation. Duncan's (1955) new multiple range test was then used to

test for significant differences between means of different communities with respect to a given variable ($p=0.05$). Medians were tested using the Kruskal-Wallis (1952 and 1953) multiple comparisons test at $p=0.05$, followed by Dunn's (1964) multiple comparisons test ($p=0.20$).

Recorded environmental variables were also plotted along ordination axes with the PLOT procedure of SAS (SAS Institute 1979) in order to discern trends.

Linear correlation between environmental variables within each zone and stratum was tested with Pearson's product moment correlation coefficient. The PEARSON CORR procedure of the Statistical Package for the Social Sciences, SPSS (Nie et al. 1975) was employed.

CHAPTER V

RESULTS OF COMMUNITY ANALYSIS

I. NON-VASCULAR PLANT COMMUNITIES

Lithophyte Zone ✓

Six communities were delineated among the Lithophyte Zone sample plots: Cladonia caroliniana, Grimmia laevigata, Squamulose Cladonias, Filamentous Algae-Inkspot Crustose Lichen, Powder Crustose Lichen, and Mixed Crustose Lichens-Xanthoparmelia conspersa Communities (Figures 6 and 7). Their composition is included in Table 3. Discriminant analysis of the communities resulted in 69.7% classification success, 66.1% in jackknifed classification. The F-statistic (20.4 at 110/1022 df (degrees of freedom)) was significant ($p < 0.001$).

The Algae-Inkspot, Powder Crustose, and Mixed Crustose-Xanthoparmelia Communities share many taxa (Table 3), and the areas in which their sample plots occur on the ordination axes (Figures 6 and 7) overlap. These communities could be regarded as phases of a single community dominated by various crustose lichen taxa (mainly inkspot and powder); the foliose lichen, Xanthoparmelia; and filamentous blue-green and green algae, all recorded as "algae." ✓

Algae were important in the sample on partially shaded slopes (Table 4), but were also observed in periodically inundated rock drains and basins, seepage areas, and within rock (endoliths). Winterringer and Vestal (1956) reported algae in dripways on sandstone in Illinois.

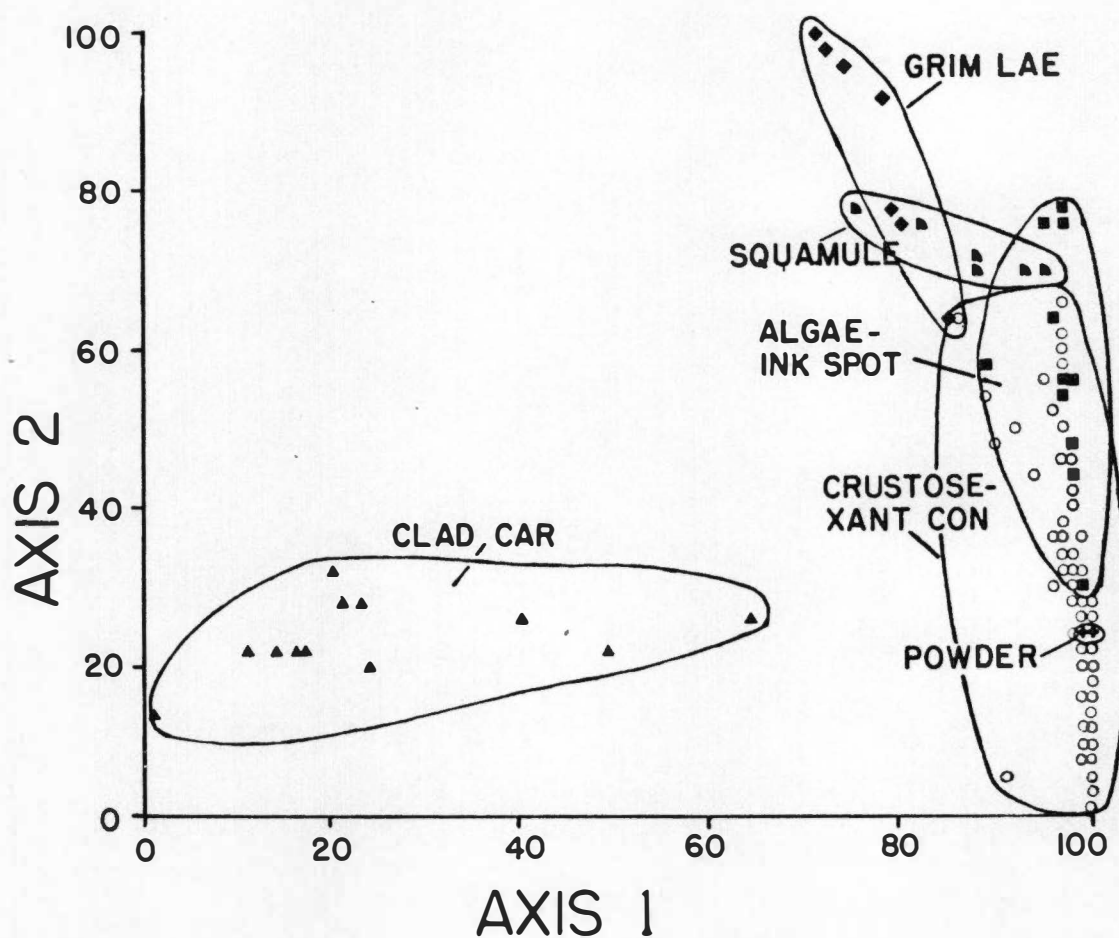


Figure 6. Relative location of Lithophyte Zone sample plots on the first two Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 2 is inferred to be a shading gradient, light intensity decreasing away from the origin.

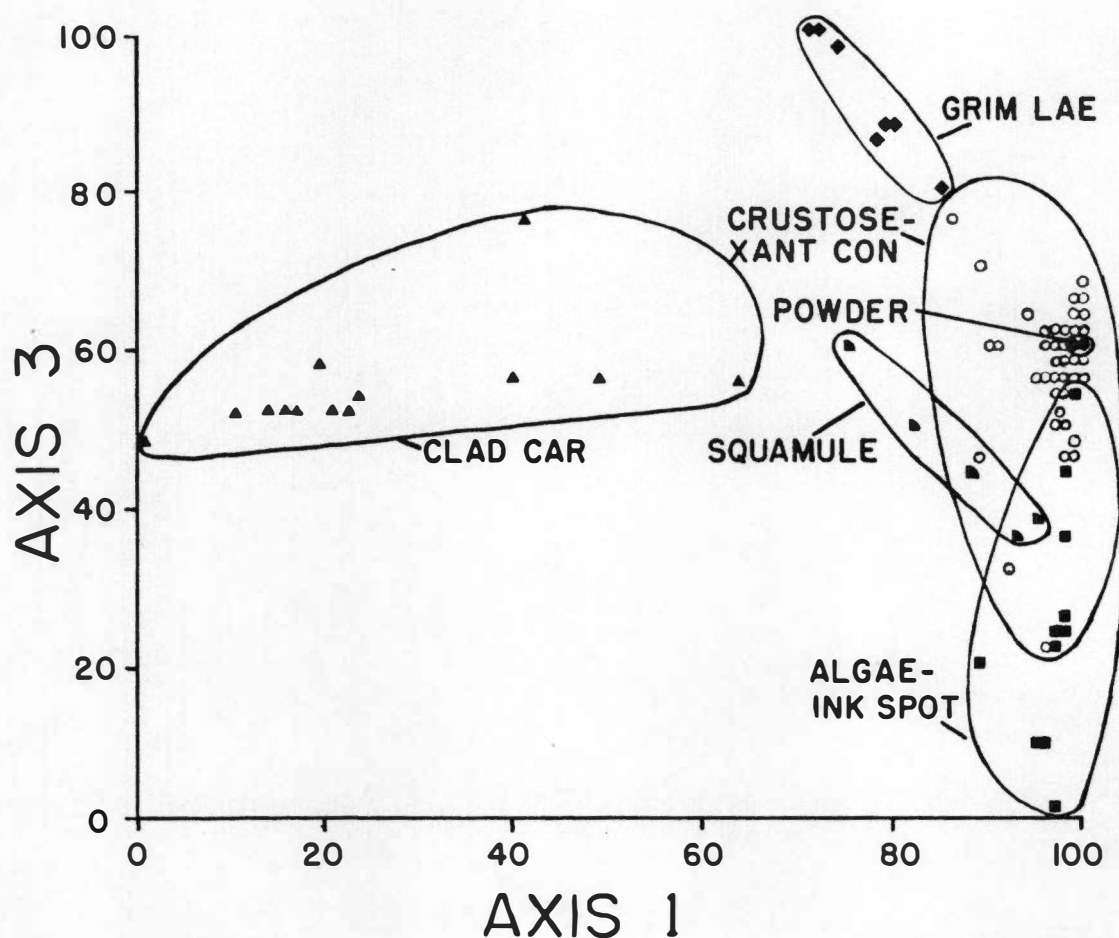


Figure 7. Relative location of Lithophyte Zone sample plots on the first and third Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 3 is inferred to be a moisture gradient, that factor increasing toward the origin.

Table 3. Mean cover (cm²/dm²) and standard error of species in the Lithophyte Zone communities.

Species ^a	Community						ALL SAMPLE PLOTS
	CLAD CAR	GRIM LAE	SQUA- MULE	POW- DER	ALGAE- INK SPOT	CRUS- TOSE- XANT CON	
ALGAE	$\bar{X}$		6.7		13.5	0.1	0.9
	SE		4.2		4.1	0.04	0.2
CAMP FLE	$\bar{X}$					0.1	^{pb}
	SE					0.05	0.04
CLAD CAR	$\bar{X}$	53.9	1.0		0.4	P	3.9
	SE	6.2	1.0		0.4	0.01	0.4
CLAD CRI	$\bar{X}$	2.9				P	0.1
	SE	2.9				0.03	0.1
CLAD FLO	$\bar{X}$	2.8					0.2
	SE	2.8					0.2
CLAD MER	$\bar{X}$					P	P
	SE					0.01	0.01
CLAD PAR	$\bar{X}$				4.1	P	0.2
	SE				1.7	0.01	0.1
CLAD SQU	$\bar{X}$	0.1			3.7	0.2	0.3
	SE	0.05			2.4	0.1	0.1
CLAD STR	$\bar{X}$	1.1	1.7	28.0		0.4	1.1
	SE	0.7	1.0	8.6		0.2	0.2
CLADOSUB	$\bar{X}$					P	P
	SE					P	P
CRUSTOSE	$\bar{X}$	0.7	0.1	0.6	0.1	3.9	3.1
	SE	0.4	0.1	0.6	0.1	0.9	0.7
GRAY CRU	$\bar{X}$		3.6	6.7		2.1	1.9
	SE		3.5	4.9		0.8	0.6
GREEN CR	$\bar{X}$				0.3	P	P
	SE				0.2	0.01	0.01
GRIM LAE	$\bar{X}$	3.3	56.7	3.3	0.3	0.2	2.1
	SE	2.8	10.2	3.3	0.2	0.1	0.3
INKSPOT	$\bar{X}$	0.3	0.9	1.4	0.6	5.4	5.0
	SE	0.2	0.3	0.8	0.6	0.5	0.5
LASA PAP	$\bar{X}$					P	P
	SE					0.04	0.04
POLY JUN	$\bar{X}$	1.5					0.1
	SE	1.1					0.1
POWDER	$\bar{X}$	1.0	4.8	0.1	6.5	14.9	12.4
	SE	0.3	2.9	0.1	1.3	1.1	0.9
PYCN PAP	$\bar{X}$			1.0	8.3	0.1	0.5
	SE			1.0	2.4	0.03	0.1
REINDEER	$\bar{X}$					0.1	0.1
	SE					0.1	0.1
SQUAMULE	$\bar{X}$		31.8			0.4	1.1
	SE		11.1			0.1	0.3
XANT CON	$\bar{X}$	2.3	5.6	0.5	0.9	8.4	7.1
	SE	1.4	2.7	0.5	0.9	1.2	1.0
Total No. Plots	18	7	6	8	13	199	251

^aSpecies abbreviations are explained in Appendix, Table 22.^bPresent but less than 0.05cm².

Table 4. Average environmental conditions of the Lithophyte Zone communities.

Variable ¹		Community						ALL SAMPLE PLOTS
		CLAD ² CAR	GRIM LAE	SQUA- MULE	POW- DER	ALGAE- INK SPOT	CRUS- TOSE- XANT CON	
Aspect	$\bar{X}$	0.20	0.41	0.48	0.76	0.58	0.91	0.81
	SE	0.03	0.27	0.14	0.25	0.15	0.06	0.05
	s ³	a	ab	ab	ab	ab	b	
Slope angle (°)	$\bar{X}$	7.5	8.0	12.5	6.9	15.1	9.4	9.5
	SE	1.0	1.3	2.6	3.2	4.4	0.6	0.5
	s	a	a	ab	ab	b	a	
Micro- topo- graphy	$\bar{X}$	2.1	1.9	2.5	3.9	2.4	2.5	2.5
	SE	0.2	0.1	0.5	0.7	0.2	0.1	0.1
	M ⁴	2	2	2	3.5	2	2	
	s	a	a	a	a	a	a	
Shading	$\bar{X}$	2.3	4.0	4.0	2.3	4.0	3.0	3.0
	SE	0.6	0.0	0.0	0.6	0.0	0.1	0.1
	M	1	4	4	3	4	3	
	s	a	ab	ab	ab	b	a	

¹Scales for variables appear in Table 2, page 21.

²Species abbreviations are explained in Appendix, Table 22.

³Results of multiple mean or median comparison tests. Communities which share a letter are not significantly different (p=0.05).

⁴Median.

Filamentous blue-green algae are common on bare limestone (Quarterman 1950). Algae are not mentioned in any granite outcrop studies examined except for that of Ashton and Webb (1977) in Australia, where both blue-green and green algae occur endolithically. Endolithic algae also occur in Israel in sandstone (Friedmann et al. 1967). An associate of algae where inundation is absent or infrequent is inkspot crustose lichen (tentatively, Sarcogyne simplex).

Powder crustose lichen is an apparently nonfruiting, crustose to endolithic species. Its diffuse black hyphae, like a fine black powder, give the rock a gray to black cast. Powder lichen sometimes occurs in nearly pure stands in shaded or occasionally inundated places (the Powder Crustose Lichen Community) but also is mixed with other taxa fully exposed to the sun (Mixed Crustose-Xanthoparmelia Community). Like algae, powder crustose lichen may represent more than one species with different environmental tolerances. Other lichens with a similar appearance, Staurothele diffractella and Verrucaria spp., are reported from granite outcrops in the southeastern United States (Whitehouse 1933, Oosting and Anderson 1939, Keever et al. 1951, Berg 1974), but were on bedrock other than sandstone in southern Illinois (Skorepa 1973).

The Mixed Crustose-Xanthoparmelia Community includes a variety of unidentified brown, gray, white, and olive-green colored crustose thalli, as well as inkspot and powder crustose lichens. This community is the most prevalent in the zone. Xanthoparmelia conspersa is often dominant in especially dry microtopographies (e.g., domes), although

occurring on a wide range of aspects and degrees of shading. It appears to be intolerant of inundation. Xanthoparmelia is very common on sandstone in southern Illinois almost everywhere water does not collect (Winterringer and Vestal 1956), and is also important on exposed dry granite (Whitehouse 1933, Oosting and Anderson 1939, McVaugh 1943, Keever et al. 1951, Berg 1974, Ashton and Webb 1977).

Dominants of the Algae-Inkspot, Powder, and Crustose-Xanthoparmelia Communities differ, therefore, in tolerance to shading and moisture (especially inundation). The communities they dominate also have different tolerances. Positions of the types on axis 2 of the sample ordination (Figure 6) suggest that the axis is a shading gradient: light intensity decreases away from the origin. Similarly, on axis 3 (Figure 7), moisture increases toward the origin. These suppositions are partially supported by recorded environmental variables (Table 4). Least shaded are the Cladonia caroliniana and Crustose-Xanthoparmelia Communities, closest to the origin on axis 2. There are no significant microtopographic differences between the communities, however. Axis 3 is probably a complex moisture gradient in which microtopography, slope, and aspect combine, differentiating habitats.

The position of the Squamulose Cladonias Community on axes 2 and 3 (Figures 6 and 7) is in keeping with proposed environmental gradients. Squamules of Cladonia, many of which could not be identified to species, usually occur in tiny cracks in the rock such as those beneath the lip of a basin, or between layers of sandstone,

in miniature cliffs and ledges. The sandstone usually has a hard surface crust, about 5 mm thick, with less consolidated rock beneath. Any crack in the surface provides a foothold for these lichens, and no doubt accesses the portion of rock likely to retain capillary moisture longest. Squamules are also occasional on apparently unfractured rock, sometimes occurring with algae. The Squamulose *Cladonias* Community, then, is a moderately mesophytic community compared to others of the zone, and is tolerant of some shade.

Cladonia caroliniana (possibly the narrow podetiate form, ✓ Cladonia dimorphoclada, at the Jamestown Barrens) was here growing on ✓ bare sandstone. It occurs in thin soil on sandstone in southern Illinois (Winterringer and Vestal 1956); among Hedwigia ciliata and Grimmia sp. mats on sandstone in the Cumberland Mountains (Braun 1935); and in thin soil on granite in North Carolina (Keever et al. 1951). In the present study, it was occasionally observed where it had been washed down into basins (usually this was normal C. caroliniana with inflated podetia), but was firmly attached to rock at the Jamestown Barrens, where it occurred downslope from a vegetation mat that graded into surrounding forest. Downslope were mats of Grimmia, often with C. caroliniana established along their upper slopes and sometimes with Xanthoparmelia, too. Whether free-living C. caroliniana clumps had originally become established on and overgrown Grimmia mats is unclear. Cladonia caroliniana, C. leporina, and Cladonia arbuscula regularly invade Grimmia mats on granite in North Carolina (Oosting and Anderson 1939, Keever et al. 1951), Georgia (McVaugh 1943), and Virginia (Berg 1974).

Grimmia laevigata occurs at Little River Canyon, Pickett State Forest, the Jamestown Barrens, and Flat Rock, but is only prevalent at the Jamestown and Pickett sites. In Jamestown, it grows in large patches on slopes below vegetation mats, especially where shaded part of the day. Grimmia laevigata occurs, however, on "sunny rock surfaces" of Piedmont granite outcrops (Keever et al. 1951). Culture experiments by Keever (1957) reveal, though, that it grows well in shade, too. Its position at the shaded end of axis 2 (Figure 6, page 31), but the dry end of axis 3 (Figure 7, page 32) is appropriate.

A community not included in sampling that deserves mention usually occurs in heavily shaded areas: the dominant is an umbilicate lichen, Lasallia papulosa; Umbilicaria mammulata is occasional. Areas dominated by these lichens are outside the scope of the study.

An additional important environmental factor that was not measured is trampling. No study areas are pristine, and degree and impact of disturbance is unknown. Some indication that trampling is important comes from observations of less disturbed outcrops near Flat Rock, which had greater cover of Xanthoparmelia and larger, more vigorous individuals. A sandstone boulder in an old field near Flat Rock is almost totally covered with lichens. The sampled Flat Rock outcrops are comparatively bare even though they have apparently not been frequented much for many years. Another indication of the impact of trampling comes from outcrops serving as public overlooks, e.g., the outcrop above Cloudland Canyon, Georgia, which is devoid of lichens to the naked eye.

Cryptogam-Herb Zone

Twelve non-vascular plant communities were delineated by ordination of Cryptogam-Herb Zone sample plots. Most distinct were Sphagnum and Aulacomnium palustre Communities, the former segregated on axis 1 and the latter an outlier on axis 2 of the ordination (not illustrated). Other communities overlapped on these axes but were distinct in the data matrices; these communities were better delineated in a second ordination in which plots dominated by Sphagnum or Aulacomnium were deleted (Figure 8), but were again crowded on the third axis (not illustrated). The Cladonia dimorphoclada, C. leporina, C. squamosa, C. strepsilis-Campylopus flexuosus, and Campylopus pilifer Communities were most distinct. Polytrichum commune-Cladonia caroliniana, C. caroliniana-P. commune, Squamulose Cladonias-C. caroliniana-P. juniperinum, P. juniperinum, and Reindeer Lichen Communities overlapped on axis 1 (Figure 8) in approximately that order (away from the origin). The P. commune-C. caroliniana and C. caroliniana-P. commune Communities are 63% similar using Sørensen's (1948) quantitative index of similarity. Compositions of the communities are included in Table 5. Discriminant analysis reveals that the communities are statistically valid (F-statistic of 44.3 at 264/2338 df; $p < 0.001$). Classification was 75.8% successful, 74.0% successful using the jackknifed procedure.

The Sphagnum Community occurs in seepage areas at the edge of the vegetation mat, sometimes under partial shade (Table 6). A low slope angle probably retards drainage from the mat that is received

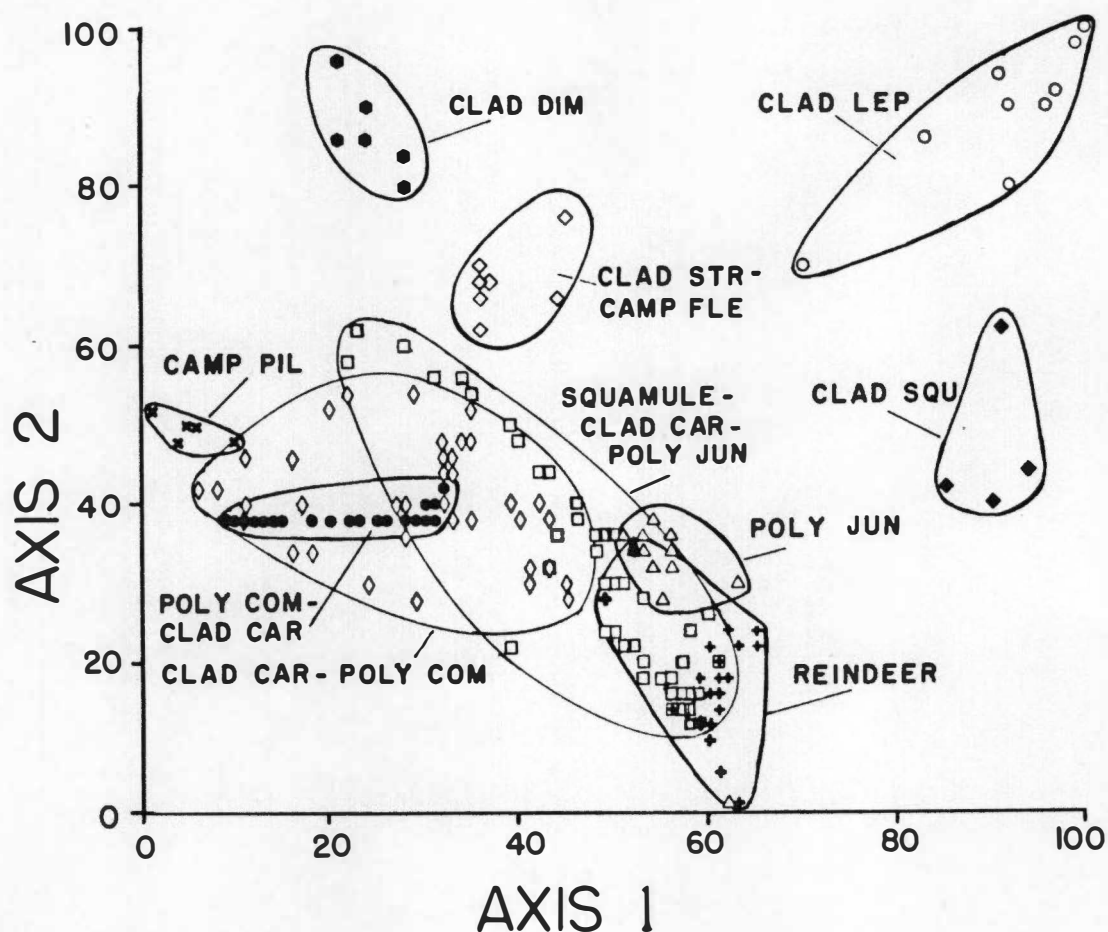


Figure 8. Relative location of Cryptogam-Herb Zone non-vascular plant sample plots on the first two Reciprocal Averaging Ordination axes, outlier plots dominated by Sphagnum spp. or Aulacomnium palustre having been deleted. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 1 is inferred to be a moisture gradient, moisture increasing toward the origin.

Table 5. Mean cover (cm^2/dm^2) and standard error of species in the Cryptogam-Herb Zone non-vascular plant communities.

Community														
Species ^a		SPHA SPP	AULA PAL	CAMP PIL	POLY COM- CLAD CAR	CLAD CAR- POLY COM	CLAD DIM	CLAD STR- CAMP FLE	REIN- DEER	POLY JUN	SQUA- MULE- POLY JUN- CLAD CAR	CLAD LEP	CLAD SQU	ALL SAMPLE PLOTS
AULA PAL	X	0.6	94.0		0.6									0.8
	SE	0.6	5.0		0.6									0.1
CAMP FLE	X				0.1	10.0	12.2	16.7	0.2		7.3	4.9		4.7
	SE				0.1	3.1	5.6	5.6	0.2		2.9	2.8		0.9
CAMP PIL	X			86.7	0.1	4.2					0.6			3.3
	SE			4.8	0.0	1.8					0.5			0.4
CAMP TAL	X	6.0												0.4
	SE	4.1												0.3
CLAD CAR	X	9.8	4.0	9.4	35.5	38.5			3.7	3.1	8.4			16.9
	SE	4.4	4.0	4.2	5.3	4.6			2.2	0.7	1.2			1.4
CLAD CUP	X										P			P ^b
	SE										0.05			0.01
CLAD DIM	X						57.7				0.1			1.3
	SE						6.4				0.1			0.1
CLAD LEP	X							2.6		0.8		74.7	4.8	3.0
	SE							1.8		0.4		7.6	4.8	0.3
CLAD PAR	X					P								P
	SE					0.04								0.01
CLAD SQU	X					0.1				0.9		0.9	64.5	1.1
	SE					0.1				0.9		0.5	14.6	0.2
CLAD STR	X				P	1.7	7.2	61.3		0.3	1.6	1.8		3.1
	SE				0.0	0.6	4.9	8.6		0.3	0.9	1.8		0.4
CLA00SUB	X				0.3	0.1								0.1
	SE				0.3	0.1								0.05
CLAD VER	X								2.2	5.3	0.6			0.8
	SE								1.3	5.3	0.3			0.4
OICR CON	X					0.1			8.7	2.1	2.2	5.1	3.0	2.1
	SE					0.1			2.1	1.6	0.9	2.6	3.0	0.4
OICR SPU	X									0.3			0.5	P
	SE									0.3			0.3	0.02
HYPN CUR	X								0.1					P
	SE								0.1					0.02
INKSPOT	X				P									P
	SE				0.0									0.0
LEUC ALB	X								2.8		0.3			0.5
	SE								1.7		0.1			0.2
POLY COM	X	1.1	1.5	1.4	46.2	13.8	3.0		0.6		1.4			10.7
	SE	0.7	1.5	1.4	6.0	3.9	2.4		0.4		0.6			1.3
POLY JUN	X					3.8		2.7	7.0	73.1	13.8	3.9	7.3	9.9
	SE					1.4		1.8	4.0	6.1	3.4	3.9	5.9	1.1
REINDEER	X	0.7				1.7			29.2	4.5	5.1	0.5	4.2	6.0
	SE	0.7				0.6			5.4	1.9	1.6	0.3	3.6	0.8
SPHA SPP	X	60.6												4.3
	SE	8.9												0.6
SQUAMULE	X	0.5				1.7			6.8	0.3	23.1			6.5
	SE	0.5				0.7			1.3	0.3	4.0			0.9
XANT CON	X										0.1			P
	SE										0.1			0.03
Total No. Plots		19	2	7	42	53	6	9	37	17	59	10	4	265

^aSpecies abbreviations are explained in Appendix, Table 22.^bPresent but less than 0.05cm^2 .

Table 6. Average environmental conditions of the Cryptogam-Herb Zone non-vascular plant communities.

Variable ¹		Community												ALL SAMPLE PLOTS
		SPHA ² SPP	AULA PAL	CAMP PIL	POLY COM- CLAD CAR	CLAD CAR- POLY COM	CLAD DIM	CLAD STR- CAMP FLE	REIN- DEER	POLY JUN	SQUA- MULE- POLY JUN- CLAD CAR	CLAD LEP	CLAD SQU	
Aspect	$\bar{X}$	0.82	--- ³	1.13	0.62	0.67	1.00	0.64	0.99	1.30	0.71	1.92	1.97	0.87
	SE s ⁴	0.18 ab	---	0.39 ab	0.26 a	0.19 a	0.00	0.00	0.17 ab	0.17 bc	0.13 a	0.00	0.03 c	0.08
Slope angle (°)	$\bar{X}$	0.8	0.0	4.6	2.4	2.3	2.3	0.6	6.2	2.9	4.5	1.0	8.0	3.3
	SE s	0.7 a	---	2.1 abc	0.8	0.5 ad	1.5 abc	0.4 ab	1.5 c	1.1 abc	0.7 bc	1.0 ab	3.5 bcd	0.3
Micro- topo- graphy	$\bar{X}$	2.2	2.0	2.0	2.0	2.1	2.0	2.0	2.1	2.0	2.2	2.0	2.0	2.1
	SE M ⁵ s	0.2 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.05 2 a	0.0 2 a	0.0 2 a	0.1 2 a	0.0 2 a	0.1 2 a	0.0 2 a	0.0 2 a	0.03
Shading	$\bar{X}$	3.9	3.0	1.0	3.0	3.0	3.3	2.3	2.6	2.6	2.7	2.9	3.8	3.0
	SE M s	0.3 4 b	1.0 3 ab	0.0 1 a	0.2 3 ab	0.2 3 ab	0.3 3 ab	0.6 1 ab	0.3 2 ab	0.2 2 ab	0.4 2 ab	0.8 1 ab	0.8 3 ab	0.1
Soil depth (cm)	$\bar{X}$	4.0	14.0	4.5	6.1	1.2	0.0	1.4	0.8	3.2	1.6	4.0	5.0	2.5
	SE s	0.6 bc	2.0 d	1.5 abc	1.1 c	0.3 a	---	0.4 ab	0.5 a	1.2 abc	0.6 a	0.7 bc	0.0	0.3

¹Scales for variables appear in Table 2, page 21.

²Species abbreviations are explained in Appendix, Table 22.

³Dashed lines indicate missing or insufficient data.

⁴Results of multiple mean or median comparison tests. Communities which share a letter are not significantly different (p=0.05).

⁵Median.

from upslope. Similar communities are reported in comparable habitats from granite on the Piedmont by Keever et al. (1951), McVaugh (1943), and Oosting and Anderson (1939); but are not reported from sandstone in southern Illinois by Winterringer and Vestal (1956). The Sphagnum Community occurs at almost every outcrop, although infrequent on those studied and seldom sampled. Among the taxa that may occur are Sphagnum cyclophyllum, S. subsecundum, S. imbricatum, and S. compactum. Other non-vascular plants occur sporadically. Herbaceous associates, Panicum dichotomum, Viola primulifolia, and Lycopus virginicus, are also mesophytes. Axis 1 of the first ordination, then, is a moisture (seepage) gradient.

The Aulacomnium palustre Community is another mesophytic community. Its dominant is a characteristic moss of "wet soil and bogs" (Sharp 1939) and "moist rock ledges" (Conard and Redfearn 1979). Similar communities are reported on granite from the edges of pools or in moist soil pits (Oosting and Anderson 1939, McVaugh 1943, Burbanck and Platt 1964, Berg 1974). Although this community was sampled on the deepest soils of the zone (Table 6), it was also observed on shallow soil, often in shade. Seepage moisture and protection from extreme insolation are probably more important environmental factors than soil depth in its distribution.

Axis 2 of the first ordination, like axis 1, appears to be a moisture gradient. Deletion of Sphagnum and Aulacomnium dominated plots did not change the order in which the other communities occurred on that axis 2 (their arrangement was repeated on axis 1 of the

second ordination). Axis 1 of the second ordination, then, is also a moisture gradient.

Closest to the origin on axis 1 of the second ordination (Figure 8) is the Campylopus pilifer Community. Campylopus pilifer is a true outcrop species, occurring on "open sandstone rocks and rock ledges" (Conard and Redfearn 1979). That C. pilifer is a mesophyte, as its position on axis 1 suggests, is supported by its occurrence in "moist hollows" on granite (Oosting and Anderson 1939). It occurs in full sunlight, however (Table 6), and survives desiccation.

Adjacent on ordination axis 1 (Figure 8) are the communities in which Polytrichum commune and Cladonia caroliniana dominate, then the C. dimorphoclada and C. stepsilis-Campylopus flexuosus Communities. Polytrichum commune occurs "on soil in moist areas" (Conard and Redfearn 1979). Campylopus flexuosus is also moderately mesophytic, occurring in vernal wet shallow soil mats with the winter annual herb, Sedum smallii, and the succulent, Talinum teretifolium, on granite in North Carolina (Keever et al. 1951). The C. flexuosus community is virtually unshaded (Table 6), however, and often desiccated. Farther from the origin (Figure 8), the even more drought tolerant P. juniperinum is dominant, a species of "dry, exposed to partially shaded places" (Conard and Redfearn 1979). The Reindeer Lichens are also drought-tolerant; they include Cladonia subtenuis, C. rangiferina, and C. arbuscula.

At the driest end of axis 1 (Figure 8), receiving very little seepage moisture, are the Cladonia leporina (a branched fruticose

lichen) and C. squamosa (a squamulose podetiate lichen) Communities. Cladonia leporina was only observed at the two Lookout Mountain sites; there it occurs with C. squamosa, which also occurs farther north. Cladonia leporina is also reported as a dominant colonizer of moss mats on granite outcrops from Virginia south (Berg 1974, Oosting and Anderson 1939, McVaugh 1943, Keever et al. 1951, Burbanck and Platt 1964). These communities have slightly deeper soil on the average than most of the others (Table 6), but this factor is not necessarily correlated with available moisture to lichens, which absorb atmospheric moisture (Schofield and Yarman 1943). Lack of seepage moisture may be compensated by the northerly aspects (Table 6).

Shrub-Herb Zone

Eleven communities were delineated in the Shrub-Herb Zone. The most vegetationally distinct were outliers in the first ordination (not illustrated): a Leucobryum albidum Community (one sample plot) segregated on axis 1, and a Campylopus flexuosus Community segregated on axis 2 (two sample plots). Other communities were apparent in the accompanying data matrix, and clarified through repetition of the ordination with outliers deleted (Figures 9 and 10). In the second ordination, Cladonia chlorophaea and Dicranum condensatum Communities were distinct on axis 2 (Figure 9). An Aulacomnium palustre-Polytrichum commune Community was segregated on axis 3 (Figure 10); C. caroliniana-P. juniperinum and C. caroliniana Communities overlap; and C. caroliniana-P. commune, P. commune, Reindeer Lichen-P. commune, and Reindeer Lichen Communities are fairly distinct. Compositions of

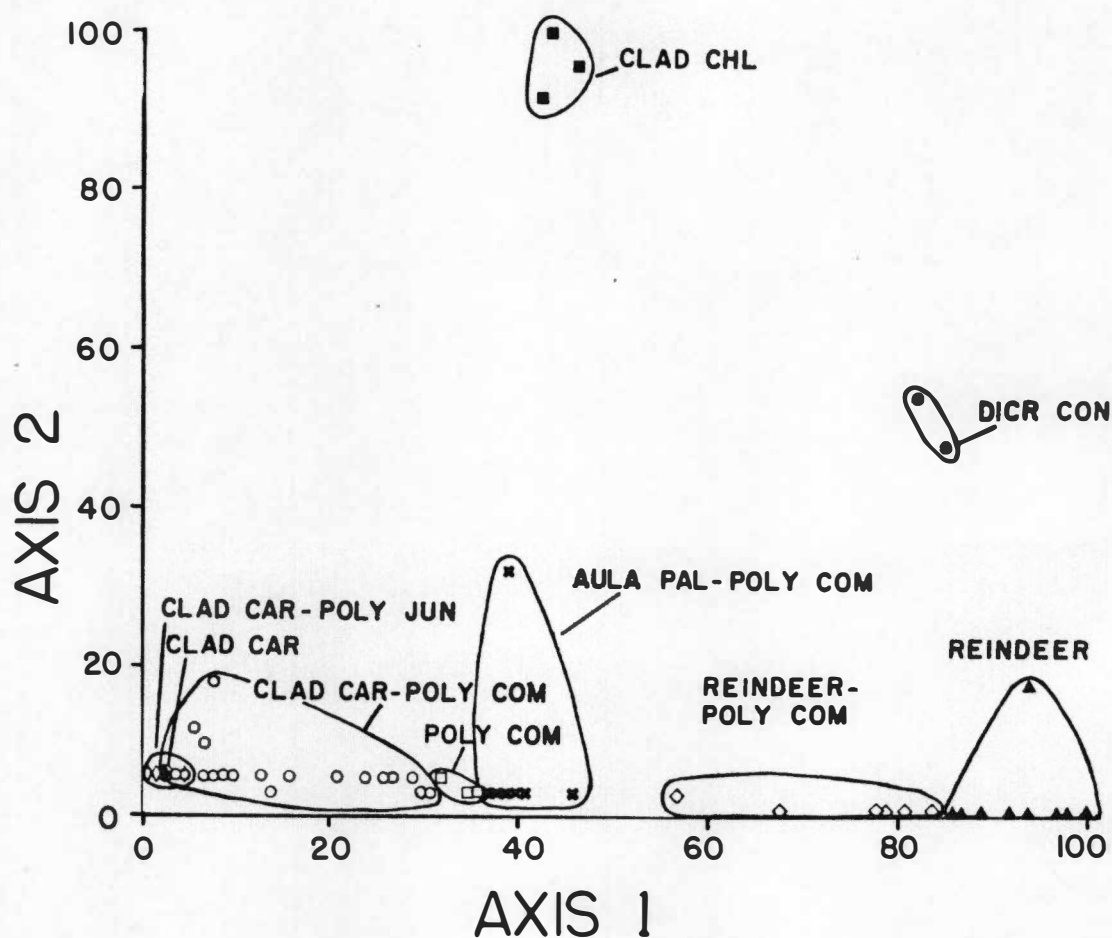


Figure 9. Relative location of Shrub-Herb Zone non-vascular plant sample plots on the first two Reciprocal Averaging Ordination axes, outlier plots dominated by Leucobryum albidum or Campylopus flexuosus having been deleted. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 1 is inferred to be a shading gradient, and possibly a soil depth gradient, both factors increasing away from the origin.

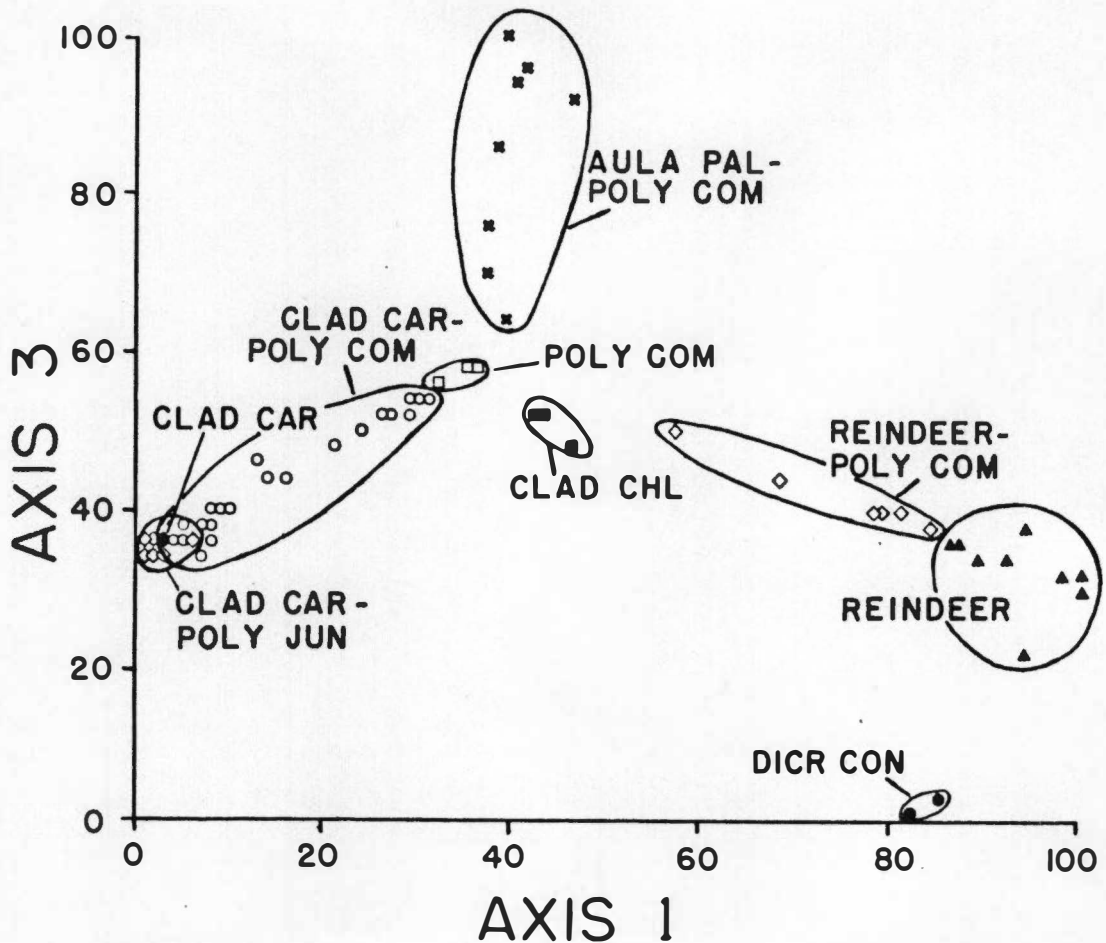


Figure 10. Relative location of Shrub-Herb Zone non-vascular plant sample plots on the first and third Reciprocal Averaging Ordination axes, outlier plots dominated by Leucobryum albidum or Campylopus flexuosus having been deleted. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 1 is inferred to be a shading gradient, and possibly a soil depth gradient, both factors increasing away from the origin. Moisture is inferred to increase away from the origin on axis 3.

communities are included in Table 7. Discriminant analysis (without the outlier Leucobryum sample plot) reveals a significant difference between communities ($F=17.0$ at 144/1311 df; $p<0.001$). Classification was 66.1% successful, 62.4% in jackknifed classification.

Segregation of outlier communities on the first ordination axis--not illustrated here--is of interest. Leucobryum is common on rotting wood, a sporadic habitat on these outcrops. In the single sample in which it occurred, it covered only 7cm^2 . The species also occurred in similar habitats in other life form zones but was usually infrequent. Occasionally it is a dominant, especially in shaded areas, as at an outcrop on the Old Stagecoach Road at Savage Gulf State Natural Area, Grundy County, Tennessee. Leucobryum glaucum rather than L. albidum is reported from sandstone in Illinois (Winterringer and Vestal 1956), and granite (Oosting and Anderson 1937 and 1939, McVaugh 1943, Keever et al. 1951).

The Campylopus flexuosus Community, the second outlier community, was also rare in this zone, but cover was greater--50% of the plots. This species was much more important in the Cryptogam-Herb Zone. It is characteristic of "bare, exposed rock, usually sandstone" (Conard and Redfearn 1979), but also occurs on granite (Keever et al. 1951) on thin soil.

Examination of the mean environmental characteristics of the communities (Table 8) and their placement along axis 1 (Figure 9) reveals that soil depth and shading increase away from the origin on axis 1. Thus Reindeer Lichen dominated communities, Aulacomnium,

Table 7. Mean cover (cm^2/dm^2) and standard error of species in the Shrub-Herb Zone non-vascular plant communities.

Species ^a	Community											ALL SAMPLE PLOTS
	LEUC ALB	CAMP FLE	CLAD CAR- POLY JUN	CLAD CAR	CLAD CAR- POLY COM	POLY COM	AULA PAL- POLY COM	CLAD CHL	REIN- DEER- POLY COM	DICR CON	REIN- DEER	
AULA PAL	X				0.6		39.7				0.2	1.8
	SE				0.6		15.8				0.2	0.6
CAMP FLE	X	52.5										0.6
	SE	27.5										0.2
CAMP PIL	X		1.0	0.2								0.3
	SE		0.7	0.2								0.2
CLAD CAR	X		49.6	70.2	42.0		1.0				0.2	28.9
	SE		5.4	6.9	5.8		0.7				0.2	1.9
CLAD CHL	X				0.4		0.5	38.6				1.1
	SE				0.3		0.5	14.3				0.3
CLAD CRY	X		0.1				0.4					^{pb}
	SE		0.1				2.0					0.03
CLAD LEP	X										0.2	P
	SE										0.2	0.03
CLAD SQU	X									0.8	0.3	0.1
	SE									0.8	0.3	0.04
CLAD STR	X		4.8	0.2	2.4	0.2						1.7
	SE		2.0	0.2	1.7	0.2						0.6
DICR CON	X				0.2			1.6		23.2	0.5	0.6
	SE				0.2			1.6		8.1	0.5	0.2
LEUC ALB	X	7.0										P
	SE	---										---
POLY COM	X		0.2		21.6	26.5	14.6	1.0	18.7		2.0	9.6
	SE		0.1		5.3	5.3	10.9	1.0	1.3		0.8	1.3
POLY JUN	X	3.0	27.5		2.7							7.5
	SE	0.0	4.0		1.7							1.1
REINDEER	X		P				0.4		30.3	0.7	59.5	9.5
	SE		0.01				0.4		2.8	0.7	5.7	0.9
SPHA SPP	X						3.6					0.1
	SE						2.0					0.1
SQUAMULE	X				0.4	0.1						0.1
	SE				0.3	0.1						0.05
Total No. Plots	1	2	48	25	31	32	8	5	6	4	27	189

^aSpecies abbreviations are explained in Appendix, Table 22.

^bPresent but less than 0.05cm^2 .

Table 8. Average environmental conditions of the Shrub-Herb Zone non-vascular plant communities.

Variable ¹		Community											ALL SAMPLE PLOTS
		LEUC ² ALB	CAMP FLE	CLAD CAR- POLY JUN	CLAD CAR	CLAD CAR- POLY COM	POLY COM	AULA PAL- POLY COM	CLAD CHL	REIN- DEER- POLY COM	DICR CON	REIN- DEER	
Aspect	$\bar{X}$	--- ³	0.64	0.47	0.26	0.65	0.46	0.55	0.29	0.29	0.64	1.33	0.53
	SE s ⁴	---	----	0.07 a	0.06 a	0.12 a	0.20 a	0.31 a	0.00	----	0.35 a	0.26 b	0.05
Slope angle (°)	$\bar{X}$	0.0	1.5	5.8	3.2	8.1	3.3	4.9	6.4	1.8	7.0	0.7	4.2
	SE s	---	1.5 abc	1.1 bc	1.0 ab	1.4 c	0.8 abc	2.6 ab	2.4 abc	1.8 ab	1.8 abc	0.4 a	0.4
Micro- topo- graphy	$\bar{X}$	2.0	2.0	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.0
	SE M ⁵ s	---	0.0 2 a	0.06 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.0 2 a	0.1 2 a	0.02
Shading	$\bar{X}$	----	4.0	3.3	2.0	2.5	4.4	4.7	---	7.0	7.0	4.8	4.1
	SE M s	---	0.0 5.5 ab	0.4 4 ab	1.0 2 ab	0.6 1 a	0.6 6 ab	0.6 4 ab	---	---	0.0 7 b	0.7 6 ab	0.2
Soil depth (cm)	$\bar{X}$	18.0	5.0	8.4	11.5	13.1	18.9	15.5	15.7	22.5	14.0	13.6	12.8
	SE s	----	3.0 abc	0.9 a	1.8 ab	1.8 b	2.0 ce	1.7 abcd	5.9 abcd	4.8 de	5.3 abcd	1.8 bd	0.7
Thickness O ₁ soil horizon (cm)	$\bar{X}$	8.0	1.8	1.1	2.5	1.8	2.4	1.4	2.0	2.8	1.5	2.4	1.9
	SE s	---	1.3	0.2	0.5	0.3	0.2	0.2	0.3	0.6	0.6	0.2	0.1
Thickness O ₂ soil horizon (cm)	$\bar{X}$	2.0	1.7	3.6	2.5	5.1	2.5	1.3	4.1	2.2	2.0	2.2	2.9
	SE s	---	0.3	0.6	0.3	0.5	0.3	0.2	1.0	0.4	0.7	0.2	0.2
Thickness A soil horizon (cm)	$\bar{X}$	8.0	1.5	3.4	4.5	4.5	10.6	9.9	6.0	10.0	6.0	6.4	6.2
	SE s	---	1.5	0.7	1.0	1.2	0.8	1.4	3.7	3.1	3.2	1.2	0.4
Thickness B soil horizon (cm)	$\bar{X}$	0.0	0.0	0.4	1.9	2.0	5.1	0.0	6.0	10.0	3.8	3.3	2.7
	SE s	---	0.0	0.3	1.0	1.0	1.3	0.0	3.7	3.1	3.7	1.2	0.4
pH A soil horizon	$\bar{X}$	3.60	---	4.08	3.57	4.16	3.99	4.19	---	4.06	---	3.96	3.96
	SE s	----	---	0.08 b	0.08 a	0.10 b	0.04 b	0.03 b	---	0.04 b	---	0.07 b	0.03

¹Scales for variables appear in Table 2, page 21.²Species abbreviations are explained in Appendix, Table 22.³Dashed lines indicate missing or insufficient data.⁴Results of multiple mean or median comparison tests. Communities which share a letter are not significantly different ($p=0.05$).⁵Median.

Cladonia chlorophaea, and Dicranum Communities usually occur in areas of greater shade and deeper soil; while C. caroliniana and Polytrichum juniperinum dominated communities usually are in less shade and shallower soil. Note, however, the wide range of samples in which P. commune is important on this axis.

From knowledge of species environmental preferences (Hale 1979, Conard and Redfearn 1979, Sharp 1939), moisture increases away from the origin on axis 3 (Figure 10). This axis is similar to axis 2 of the Cryptogam-Herb Zone (Figure 8, page 40) ordination. Again, Aulacomnium palustre dominates the moist end of the axis (the two Aulacomnium dominated communities are 56.8% similar with Sørensen's (1948) quantitative index of similarity). Again, P. commune is dominant toward the moist end of the axis, and P. juniperinum and Reindeer Lichens important where drier. Most of the Cladonia caroliniana may actually be C. dimorphoclada (narrow podetia), which is apparently more drought and shade tolerant than C. caroliniana. The position of Dicranum condensatum at the dry end of the axis may be an artifact; it occurs on "light, open to shaded soil" (Conard and Redfearn 1979). McVaugh (1943) reported D. condensatum from moist marginal zones in partial shade on granite.

In summary, C. caroliniana (C. dimorphoclada) occurs mostly on shallow soil of rather seepy, open areas of the zone. Polytrichum juniperinum becomes an important associate in drier situations. In shaded areas, P. commune becomes important; while Reindeer Lichens enter and become dominant in dry, shaded areas. Drought stress in the

latter sites may be partially relieved by a northerly aspect, however (Table 8).

Vascular plants also affect distribution of non-vascular plant communities. The m^2 plots dominated by heath shrubs (Kalmia latifolia, Vaccinium vacillans, and V. arboreum) had a lower moss-lichen cover than expected. Shrubs provide extra shade, and leaf litter which may be physically and/or chemically limiting. Of the three heaths, only V. vacillans had considerable non-vascular plant cover, and that was mostly Reindeer Lichen Type. Vaccinium vacillans is deciduous (as opposed to evergreen Kalmia and semi-evergreen V. arboreum), smallest, and shared dominance with other vascular taxa, notably, Smilax rotundifolia. Non-vascular plants also occurred with Pinus virginiana subsaplings and seedlings; these were mainly the Polytrichum commune and Cladonia caroliniana-P. commune Communities. Greatest variety and highest cover of non-vascular plants occurred where herbs dominated. At the Clear Creek-Lilly Bridge site, Gaylussacia baccata (a heath shrub), and C. caroliniana (inflated podetia) Communities usually occur together.

Tree Zone

Fourteen communities were delineated by ordination of Tree Zone non-vascular plant sample plots. Four communities dominated by mesophytes were derived (Figure 11): Sphagnum, Thuidium delicatulum, Hypnum curvifolium, and Aulacomnium palustre Communities. Slightly less mesic was the Polytrichum commune Community (species characteristics from Conard and Redfearn 1979). Others were Reindeer Lichen,

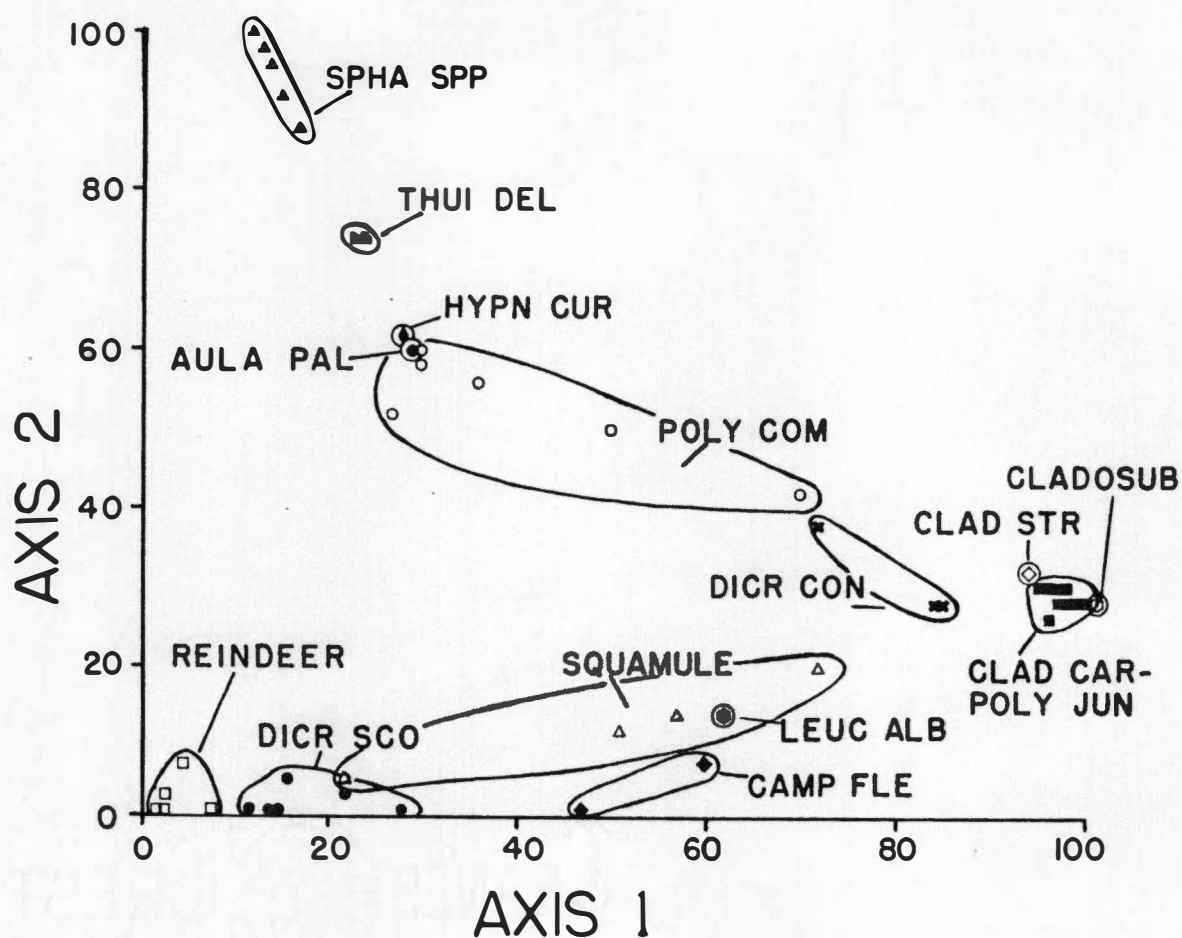


Figure 11. Relative location of Tree Zone non-vascular plants on the first two Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 1 is inferred to be a shading gradient, light intensity decreasing toward the origin. Moisture is inferred to increase away from the origin on axis 2.

Dicranum scoparium, Squamulose Cladonias, Leucobryum albidum, and Campylopus flexuosus Communities. Farthest from the origin (Figure 11) were D. condensatum, Cladonia strepsilis, C. caroliniana-Polytrichum juniperinum, and C. subcariosa Communities. Dicranum Community plots were outliers on axis 3 (not shown). Compositions of communities are included in Table 9. The communities were significantly distinct, as shown by discriminant analysis ($F=43$ at 273/1468 df, $p<0.001$). Classification was 89.9% successful, 81.0% successful in jackknifed classification.

High classification success in this zone, an indicator of community distinctiveness, may be due in part to low density of non-vascular plants. Of 290 dm² plots examined, only 163 (43%) had non-vascular vegetation. This figure is much higher than that for the Shrub-Herb Zone, 17%, Cryptogam-Herb, 1%, or Lithophyte Zone, 1%.

In moist, shaded areas, mesophytes dominate the Sphagnum spp. (mostly S. recurvum, unlike the Sphagnum spp. of the Cryptogam-Herb Zone), Aulacomnium palustre, Hypnum curvifolium, and Thuidium delicatulum Communities. The Aulacomnium Community was infrequent. Hypnum occurs on "rocks, soil, logs and tree bases" (Conard and Redfearn 1979), while Thuidium is on "soil, humus, decaying wood, rocks, or tree bases, in moist areas" (Conard and Redfearn 1979). These four communities are the most mesophytic of the zone and their position on axis 2 (Figure 11), farthest from the origin, suggests a moisture gradient. The P. commune Community, then, occurs at a moderately moist position on the axis, similar to the position of

Table 9. Mean cover (cm^2/dm^2) and standard error of species in the Tree Zone non-vascular plant communities.

Species ^a	Community														ALL SAMPLE PLOTS
	SPHA SPP	THUI DEL	HYPN CUR	AULA PAL	POLY COM	REIN- DEER	OICR SCO	OICR CON	CLAD STR	CLAD- OSUB	CLAD CAR- POLY JUN	SQUA- MULE	LEUC ALB	CAMP FLE	
AULA PAL	X			12.0	0.3										0.1
	SE			----	0.3										0.1
CAMP FLE	X						0.2							6.7	0.1
	SE						0.2							2.0	0.03
CAMP PIL	X												16.0		0.1
	SE										0.1		----		0.03
CLAD CAR	X				0.7			1.2		7.0	49.8	2.5		0.3	14.4
	SE				0.6			1.2		---	4.8	2.5		0.3	1.4
CLAD CRY	X					1.1									0.2
	SE					0.8									0.2
CLAD GRA	X							1.6							pb
	SE							1.3							0.04
CLAD LEP	X					P		0.4							P
	SE					0.02		0.4							0.02
CLAD SQU	X						0.3								P
	SE						0.2								0.01
CLAD STR	X				0.6			0.4	6.0		3.8				1.3
	SE				0.6			0.4	---		1.9				0.6
CLAD OSUB	X									15.0					0.1
	SE									----					----
OICR CON	X							25.8							0.8
	SE							13.1							0.4
OICR SCO	X					0.1	41.9					0.7			2.1
	SE					0.05	9.0					0.7			0.4
HYPN CUR	X		99.0		0.4										0.7
	SE		----		0.3										0.1
LEUC ALB	X					P							25.0		0.2
	SE					0.02							----		0.2
POLY COM	X	0.9	2.5	10.0	58.7	0.7	0.2	1.0							14.4
	SE	0.4	2.5	----	6.2	0.4	0.2	1.0							1.5
POLY JUN	X										23.4	1.5			6.6
	SE										3.9	1.5			1.1
REINDEER	X				0.3	65.0	4.9	0.2				1.0	2.0		13.6
	SE				0.3	5.5	2.6	0.2				0.7	---		1.1
SCAP UNO	X	0.8	0.5												0.1
	SE	0.6	0.5												0.1
SPHA SPP	X	33.4													3.7
	SE	8.6													3.7
SQUAMULE	X					0.3	2.0				0.3	20.5			0.8
	SE					0.3	2.5				0.2	11.1			0.3
THUI DEL	X	1.2	17.5		0.9										0.6
	SE	0.6	7.5		0.5										0.2
USNEA SP	X					0.2									P
	SE					0.2									0.04
Total No. Plots	18	2	1	1	39	33	8	5	1	1	46	4	1	3	163

^aSpecies abbreviations are explained in Appendix, Table 22.^bPresent but less than 0.05cm^2 .

P. commune dominated communities on ordination axes of zones discussed previously (Figure 8, page 40; Figure 10, page 47).

Communities are arranged by shade-tolerance along axis 1 (Figure 11), as demonstrated by graphing percent canopy closure along that axis (Figure 12), or by arranging the mean canopy closure of each community as communities were ranked on axis 1 (Table 10). Axis 1 appears, therefore, to be a non-linear shading gradient; that factor increases toward the origin.

Further evidence that axes 1 and 2 are shading and moisture gradients, respectively, is provided by known environmental preferences of many other dominants. Polytrichum commune occurs over a wide range of soil moisture and shading but remains a mesophyte (Conard and Redfearn 1979). The Reindeer Lichen Community occurs in heavily shaded, dry sites, as it did in the Shrub-Herb Zone (the two types are 92.4% similar). Griggs (1914) and Braun (1935) cite reindeer lichens as important beneath pines on shallow soil over sandstone. Dicranum scoparium is also shade-tolerant, occurring on "soil, humus, soil over rocks, rotten wood, and tree bases" (Conard and Redfearn 1979). It also grows in partial shade (McVaugh 1943) and beneath trees (Keever et al. 1951) on granite, and in protected recesses on sandstone in Illinois (Winterringer and Vestal 1956). Leucobryum albidum also grows in shade (Conard and Redfearn 1979), as can some squamulose Cladonias (Hale 1979) and D. scoparium (Conard and Redfearn 1979). Drought tolerance of D. scoparium and Leucobryum is not documented, nor are shade and moisture specificities for Campylopus flexuosus. The latter

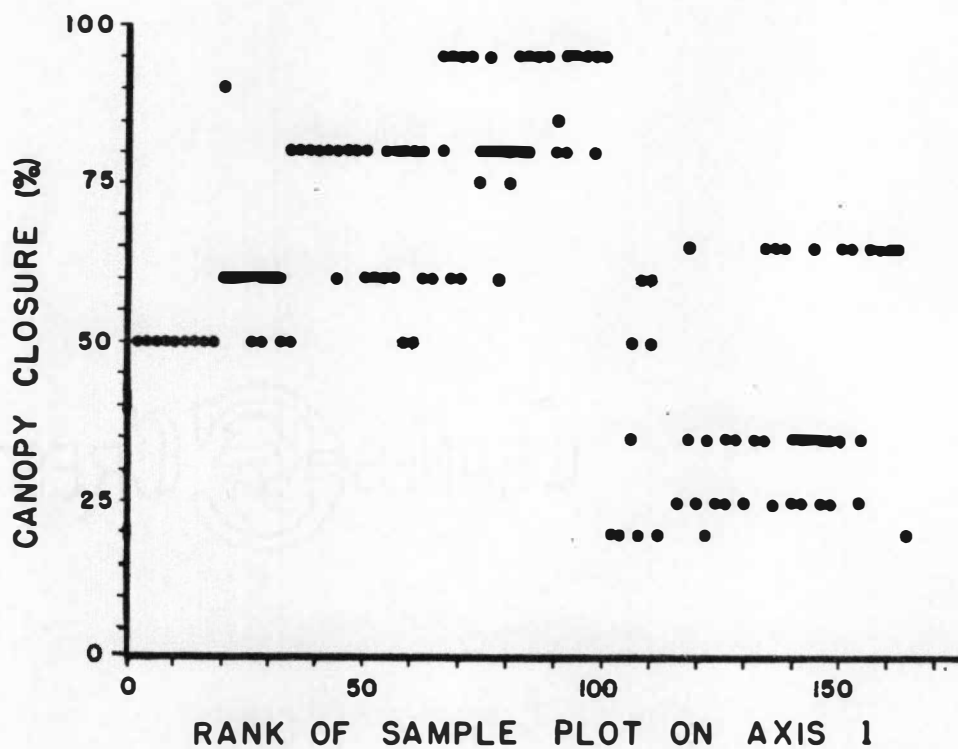


Figure 12. Percent canopy closure of the Tree Zone non-vascular plant sample plots as they were arranged along axis 1 of the Reciprocal Averaging Ordination. Sample plots are ranked in the order they occurred on the axis.

Table 10. Average environmental conditions of the Tree Zone non-vascular plant communities.

Variable ¹		Community														
		SPHA ² SPP	THUI DEL	HYPN CUR	AULA PAL	POLY COM	REIN- DEER	DICR SCO	DICR CON	CLAD STR	CLAD- OSUB	CLAD CAR POLY JUN	SQUA- MULE	LEUC ALB	CAMP FLE	ALL SAMPLE PLOTS
Aspect	$\bar{X}$	0.84	----- ³	1.71	1.00	0.93	1.18	1.65	0.85	0.29	1.71	0.43	0.67	1.92	0.89	0.87
	SE	0.28	-----	-----	-----	0.15	0.21	0.17	0.42	-----	-----	0.06	0.53	-----	0.25	0.07
Slope angle (°)	$\bar{X}$	5.3	0.0	12.0	7.0	6.8	5.1	11.9	16.0	36.0	5.0	7.9	14.3	7.0	26.3	7.8
	SE	2.0	0.0	-----	-----	1.5	1.6	2.3	6.8	-----	-----	1.4	7.6	-----	4.9	0.8
Micro- topo- graphy	$\bar{X}$	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	SE	0.05	0.0	-----	-----	0.03	0.03	0.0	0.2	-----	-----	0.0	0.0	-----	0.0	0.02
Shading	$\bar{X}$	6.0	6.0	6.0	7.0	6.0	5.5	6.6	6.4	4.0	6.0	4.4	-----	6.0	5.7	5.8
	SE	0.0	0.0	-----	-----	0.2	0.2	0.2	0.6	-----	-----	0.3	-----	-----	0.3	0.1
Percent canopy closure	$\bar{X}$	80.0	80.0	60.0	95.0	81.5	54.4	58.8	20.0	25.0	20.0	42.8	46.2	60.0	20.0	60.8
	SE	0.0	0.0	-----	-----	3.0	1.4	1.2	-----	-----	-----	2.6	3.7	-----	-----	1.8
Canopy height (m)	$\bar{X}$	7.0	7.0	7.0	10.0	8.2	5.0	6.6	3.0	3.0	3.0	3.5	4.0	7.0	3.0	5.7
	SE	0.0	0.0	-----	-----	0.3	0.2	0.4	-----	-----	-----	0.1	0.0	-----	-----	0.2
Soil depth (cm)	$\bar{X}$	16.4	-----	26.0	18.5	14.9	8.3	5.7	6.2	2.0	10.0	5.6	11.4	4.0	9.3	9.9
	SE	2.9	-----	-----	-----	2.1	1.4	2.3	1.3	-----	-----	0.5	5.0	-----	0.3	0.8
Thickness O ₁ soil horizon (cm)	$\bar{X}$	3.8	-----	3.0	6.0	3.7	1.9	2.2	1.6	2.0	2.0	0.7	0.6	2.0	4.0	2.0
	SE	0.2	-----	-----	-----	0.3	0.3	0.3	0.4	-----	-----	0.1	0.5	-----	2.1	0.1
Thickness O ₂ soil horizon (cm)	$\bar{X}$	1.1	-----	1.0	12.0	6.3	1.9	0.8	4.6	0.0	8.0	3.0	0.8	2.0	5.3	3.1
	SE	0.3	-----	-----	-----	1.0	0.3	0.4	1.0	-----	-----	0.4	0.4	-----	1.7	0.3
Thickness A soil horizon (cm)	$\bar{X}$	18.2	-----	-----	0.0	4.4	1.3	0.0	0.0	0.0	0.0	1.1	-----	0.0	1.8	3.1
	SE	0.6	-----	-----	-----	1.4	0.7	0.0	0.0	-----	-----	0.3	-----	-----	1.8	0.5
Thickness B soil horizon (cm)	$\bar{X}$	1.3	-----	-----	0.0	3.1	1.0	0.0	0.0	0.0	0.0	0.0	-----	0.0	0.0	0.9
	SE	1.2	-----	-----	-----	1.3	0.7	0.0	0.0	-----	-----	0.0	-----	-----	0.0	3.5
pH A soil horizon	$\bar{X}$	4.10	-----	3.80	-----	3.95	3.60	-----	-----	-----	-----	-----	-----	-----	-----	3.94
	SE	0.00	-----	-----	-----	0.06	0.00	-----	-----	-----	-----	-----	-----	-----	-----	0.05

¹Scales for environmental variables appear in Table 2, page 21.²Species abbreviations are explained in Appendix, Table 22.³Dashed lines indicate missing or insufficient data.⁴Results of multiple mean or median comparison tests. Communities which share a letter are not significantly different ($p=0.05$).⁵Median.

occurs in full sunlight and often dries out completely in the Cryptogam-Herb Zone.

The Cladonia strepsilis and C. subcariosa Communities, both dominated by squamulose Cladonias, along with the C. caroliniana-Polytrichum juniperinum Community, are appropriately ordinated in a sunny, moderately xeric position on the axes (Figure 11). The C. caroliniana-P. juniperinum Community, 95.8% similar to that of the Shrub-Herb Zone, is similarly ordinated there (Figure 10, page 47). Nearby the D. condensatum Type (84.6% similar to that of the Shrub-Herb Zone), is appropriately positioned as a moss of "light, open to shaded soils" (Conard and Redfearn 1979).

Composition of the sample plots was affected by the tree overstory (as reflected in percent canopy closure) and understory. Vascular plants produce shade and leaf litter. Few non-vascular plants were beneath large shrubs or subsaplings. Vaccinium arboreum and V. vacillans dominated areas exhibited especially few non-vascular plants, as in the Shrub-Herb Zone. Braun (1935) also noted that importance of lichens and mosses decreased where heath shrubs (Kalmia latifolia, Gaylussacia baccata and V. vacillans) grew on Pine Mountain, Kentucky, in forests on shallow soil over sandstone. In the present study, areas dominated by Pinus virginiana subsaplings and seedlings, or by herbs, had a relatively high non-vascular plant cover, probably in response to a relatively high light intensity.

Comparison of Non-Vascular Plant Communities Across Zones

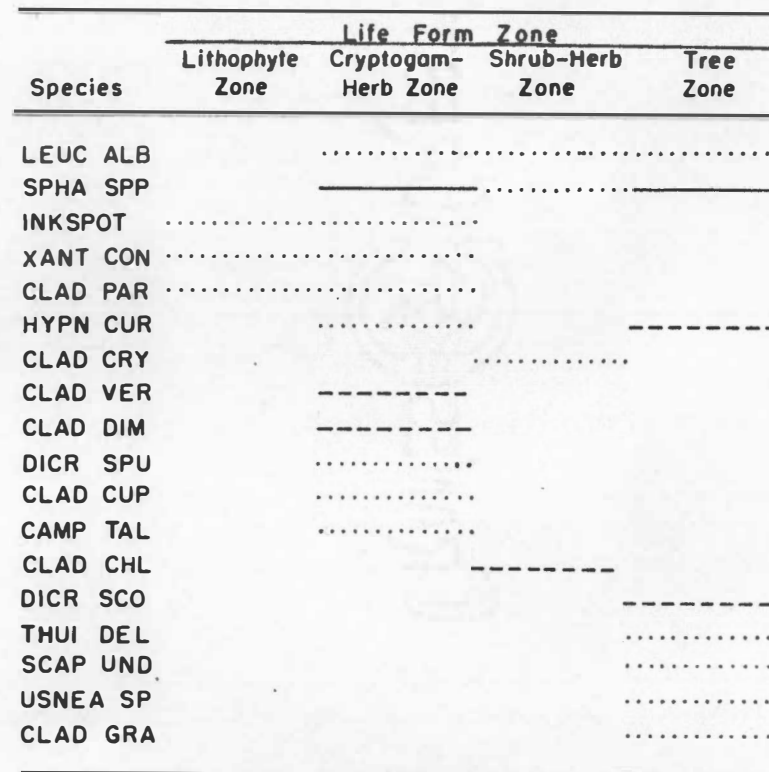
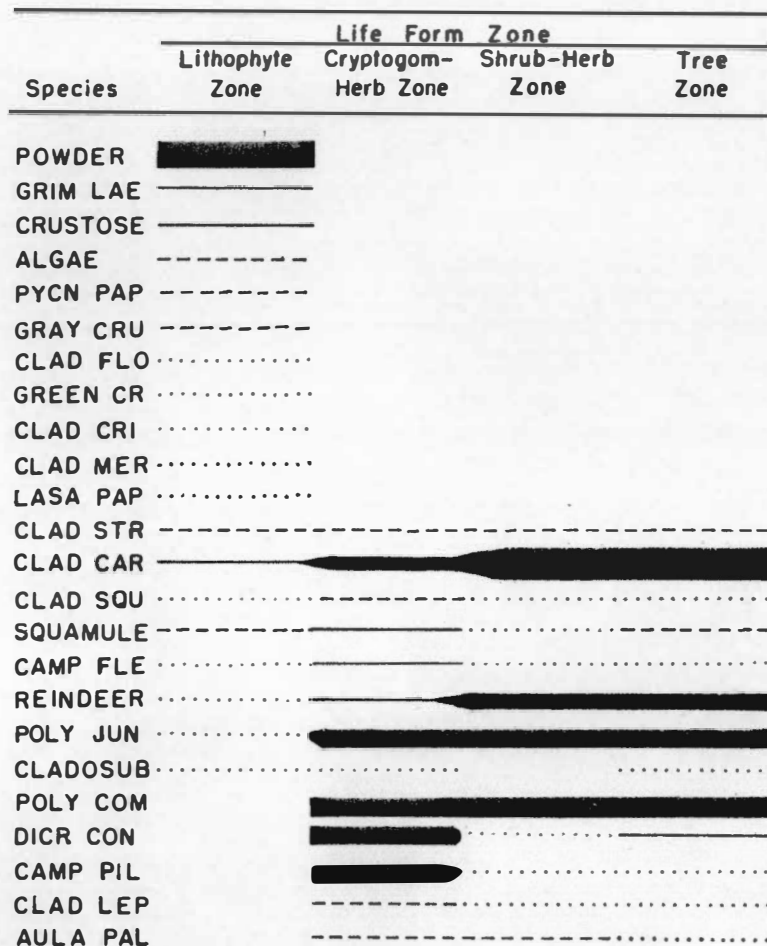
Environment. Life form zones were tested for overall environmental distinctiveness. Mean soil depth increased significantly ($p=0.05$) from the Lithophyte, to the Cryptogam-Herb, to the Shrub-Herb Zone (and actually decreasing slightly from the Shrub-Herb to the Tree Zone). Soil depth is probably most important in establishing availability of seepage moisture to mosses and lichens. Moisture seeping through soil from upslope at the bedrock surface moves to surface-dwelling non-vascular plants through capillary action. Since there is a shorter distance from seepage water to the surface of shallow soils than deep soils, seepage moisture is most available to non-vascular plants in shallow soil, i.e., the Cryptogam-Herb Zone. The soil of this zone is also mostly organic (no A horizon) and can therefore hold much water. Seepage is also important near the edge of the vegetation mat in the Lithophyte Zone, but is prone to evaporation. Many non-vascular plants of the Cryptogam-Herb Zone are virtually without soil and can soak up seepage directly, but are also prone to desiccation. Actual monitoring of moisture levels in plants relative to soil and atmospheric moisture would be informative.

Light intensity is greatest in the Lithophyte and Cryptogam-Herb Zones, decreasing significantly ($p=0.20$) in the Shrub-Herb Zone, and again in the Tree Zone. Vascular plants, especially trees, are responsible for the differences. Vascular plants also alter the substrate with litter and decaying wood, habitats of some mosses and lichens.

Flora. To compare life form zones floristically, the taxa present in sample plots were compared (Figure 13). The Lithophyte Zone was most distinct (50% of its taxa were unique). The Cryptogam-Herb Zone had 21% unique taxa; the Shrub-Herb Zone, 6%; and the Tree Zone, 23%. Sørensen's (1948) index of floristic similarity also supports the uniqueness of the Lithophyte Zone (Table 11).

Species importance values. To further compare the zones vegetationally, the percent cover of individual taxa within each zone was also compiled (Figure 13). Of seven taxa that occurred in every zone, only one was important in each zone--Cladonia caroliniana (which includes the taxon, C. dimorpha). Cladonia strepsilis and squamulose Cladonias also occurred as more than a trace in each zone.

Fourteen taxa occurred in each of the three zones with soil, but their importance varied between zones (Figure 13). Unidentified squamulose Cladonias and Sphagnum spp. each have bimodal importance, one peak in the Cryptogam-Herb and one in the Tree Zone; taxonomic differences may explain their distributions. The bimodal importance of Dicranum condensatum is unexplained by species differences, however. Several taxa peak in the Cryptogam-Herb Zone, e.g., Campylopus flexuosus, C. pilifer, and Cladonia leporina. Aulacomnium palustre was prevalent in both Cryptogam-Herb and Shrub-Herb Zones. Cladonia caroliniana appears to peak in the Shrub-Herb Zone but actually represents two species: C. caroliniana peaks in the Cryptogam-Herb Zone and C. dimorpha in the Shrub-Herb and Tree Zones. Reindeer lichens also peak in the Shrub-Herb Zone and are as important in the Tree Zone,



Key:

.....	0% < x ≤ 1%
-----	1% < x ≤ 5%
_____	5% < x ≤ 10%
██████████	10% < x ≤ 25%
██████████	25% < x ≤ 50%

Figure 13. Relative cover (%) of each non-vascular plant species in each life form zone. Species abbreviations are explained in Appendix, Table 22.

Table 11. Sørensen's (1948) floristic index of similarity of non-vascular plants between life form zones.

Life Form Zone	Life Form Zone			
	Lithophyte Zone	Cryptogam-Herb Zone	Shrub-Herb Zone	Tree Zone
Lithophyte	100.0	47.8	36.8	31.8
Cryptogam-Herb		100.0	70.0	65.2
Shrub-Herb			100.0	78.9
Tree				100.0

but their density actually decreased in the Tree Zone (where non-vascular plants are less frequent). Similarly, Polytrichum commune and P. juniperinum, equally important in each zone, were less frequent in the Tree Zone than the Shrub-Herb Zone.

Communities. To test whether communities occur in more than one zone, Sørensen's (1948) index of similarity was calculated between each pair. Mean cover per dm² was used as the attribute of each taxon. Types with a high percent similarity may represent the same community.

Several pairs of communities are 75% or more similar. The Cladonia caroliniana Community of the Lithophyte Zone is 78.6% similar to the C. caroliniana Community of the Shrub-Herb Zone (and 72.6% similar to the C. caroliniana-Polytrichum juniperinum Community of the Tree Zone). Taxonomic problems previously discussed may disavow these relationships, however. The Cryptogam-Herb and Shrub-Herb Zones share one additional community, dominated by C. caroliniana and P. commune. The Shrub-Herb and Tree Zones share three communities, dominated by Reindeer Lichens (92.4% similar), Dicranum condensatum (84.6% similar), and C. caroliniana and P. juniperinum (95.8% similar). The Cryptogam-Herb and Tree Zones have no communities 75% or more similar.

If 50% similarity is taken as the threshold of community identity, then other communities also cross zones (Table 12). Distribution of communities is similar to the distribution of their dominants as reflected in their percent cover between zones (Figure 13).

Table 12. Non-vascular plant communities at least 50% similar with Sørensen's (1948) quantitative index of similarity (based on the mean cover of each species).

Community ^a	Zone ^b	Community	Zone	% S ^c
CLAD CAR	L	CLAD CAR-POLY COM	C-H	57.7
CLAD CAR	L	CLAD CAR-POLY JUN	S-H	69.5
CLAD CAR	L	CLAD CAR	S-H	78.6
CLAD CAR	L	CLAD CAR-POLY COM	S-H	65.0
CLAD CAR	L	CLAD CAR-POLY JUN	T	72.6
SPHA SPP	C-H	SPHA SPP	T	59.3
AULA PAL	C-H	AULA PAL-POLY COM	S-H	56.8
POLY COM-CLAD CAR	C-H	CLAD CAR-POLY COM	C-H	62.6
POLY COM-CLAD CAR	C-H	CLAD CAR-POLY COM	S-H	75.4
POLY COM-CLAD CAR	C-H	POLY COM	T	65.2
CLAD CAR-POLY COM	C-H	CLAD CAR-POLY JUN	S-H	56.9
CLAD CAR-POLY COM	C-H	CLAD CAR	S-H	53.2
CLAD CAR-POLY COM	C-H	CLAD CAR-POLY COM	S-H	78.4
CLAD CAR-POLY COM	C-H	CLAD CAR-POLY JUN	T	59.8
REINDEER	C-H	REINDEER-POLY COM	S-H	58.1
SQUAMULE-POLY JUN- CLAD CAR	C-H	SQUAMULE	T	56.2
CLAD-CAR-POLY JUN	S-H	CLAD CAR	S-H	65.0
CLAD CAR-POLY JUN	S-H	CLAD CAR-POLY COM	S-H	61.6
CLAD CAR-POLY JUN	S-H	CLAD CAR-POLY JUN	T	95.8
CLAD CAR	S-H	CLAD CAR-POLY COM	S-H	59.9
CLAD CAR	S-H	CLAD CAR-POLY JUN	T	67.7
CLAD CAR-POLY COM	S-H	CLAD CAR-POLY JUN	T	64.2
POLY COM	S-H	POLY COM	T	60.2
REINDEER-POLY COM	S-H	REINDEER	T	53.2
DICR CON	S-H	DICR CON	T	84.6
REINDEER	S-H	REINDEER	T	92.4

^aSpecies abbreviations are explained in Appendix, Table 22.

^bLife form zones: Lithophyte Zone (L), Cryptogam-Herb Zone (C-H), Shrub-Herb Zone (S-H), and Tree Zone (T).

^cPercent similarity.

II. VASCULAR PLANT COMMUNITIES

Cryptogam-Herb Zone

Ordination of Cryptogam-Herb Sample plots that actually contained herbs (78 of 265) produced four communities, dominated, respectively, by: (1) Talinum teretifolium, Andropogon virginicus, Danthonia sericea, and three annual forbs--a Talinum-Grass-Annual Forb Community; (2) Bigelowia nuttallii; (3) Aster surculosus and Liatris microcephala; and (4) Panicum dichotomum (Figures 14 and 15). Compositions of the communities are included in Table 13. The communities correspond well to field observations and are significantly different according to discriminant analysis ($F=8.7$ at 39/184 df; $p<0.001$). Classification was 91.0% successful; jackknifed, 88.5% successful.

The Talinum-Grass-Annual Forb Community was observed at edges of vegetation mats or in small vegetation islands, the latter often in shallow rock basins. Its soil is shallow to undetectable. Such habitats are common on large outcrops but rare on others, e.g., narrow cliff-edges.

Taxa of the Talinum-Grass-Annual Forb Community vary between outcrops. The only ubiquitous taxa are annual forbs--Hypericum gentianoides and Crotonopsis elliptica--and grasses--Andropogon virginicus or Schizachyrium scoparium, and Danthonia sericea. A perennial succulent, T. teretifolium (actually morphologically intermediate between T. teretifolium and T. mengesii (Ware 1967) at the Clear Creek-Lilly Bridge site) is not common, especially in

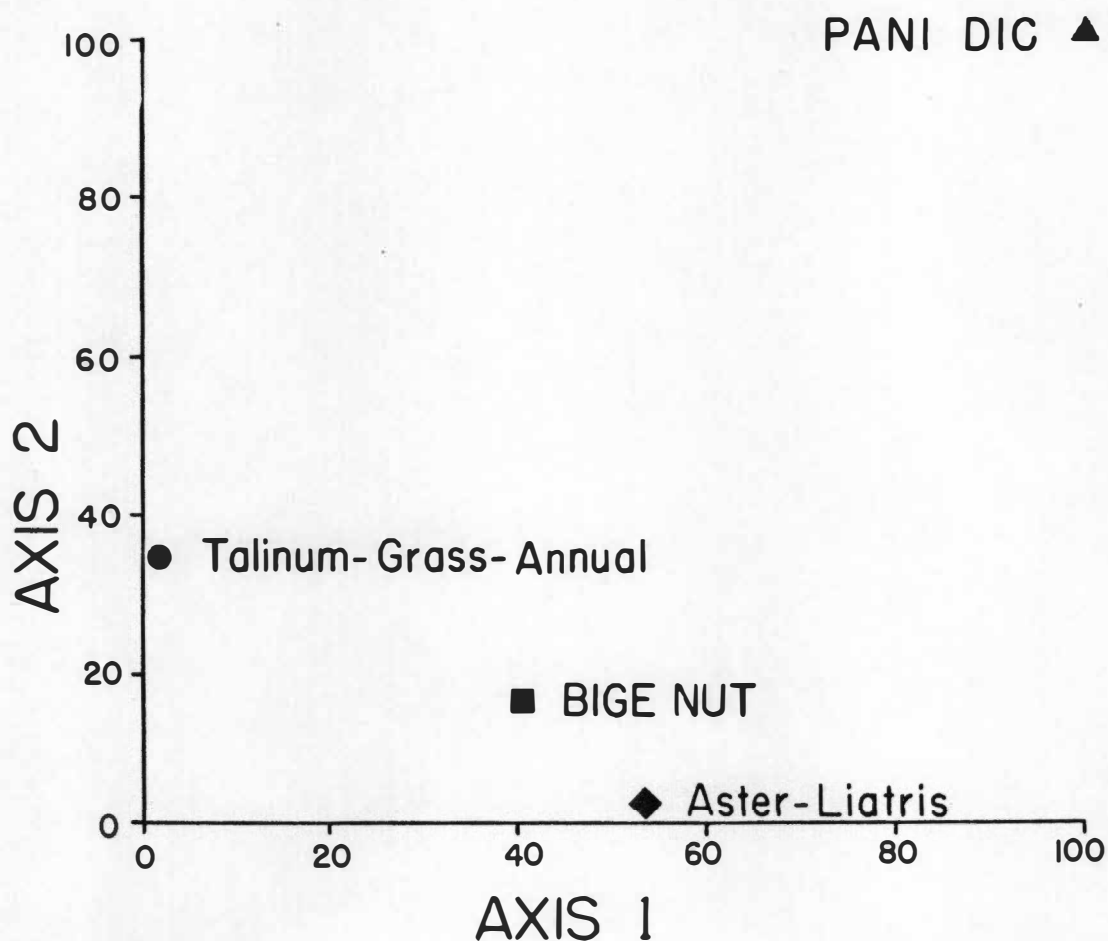


Figure 14. Relative location of Cryptogam-Herb Zone vascular plant sample plots on the first two Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol. Species abbreviations are explained in Appendix, Table 22.

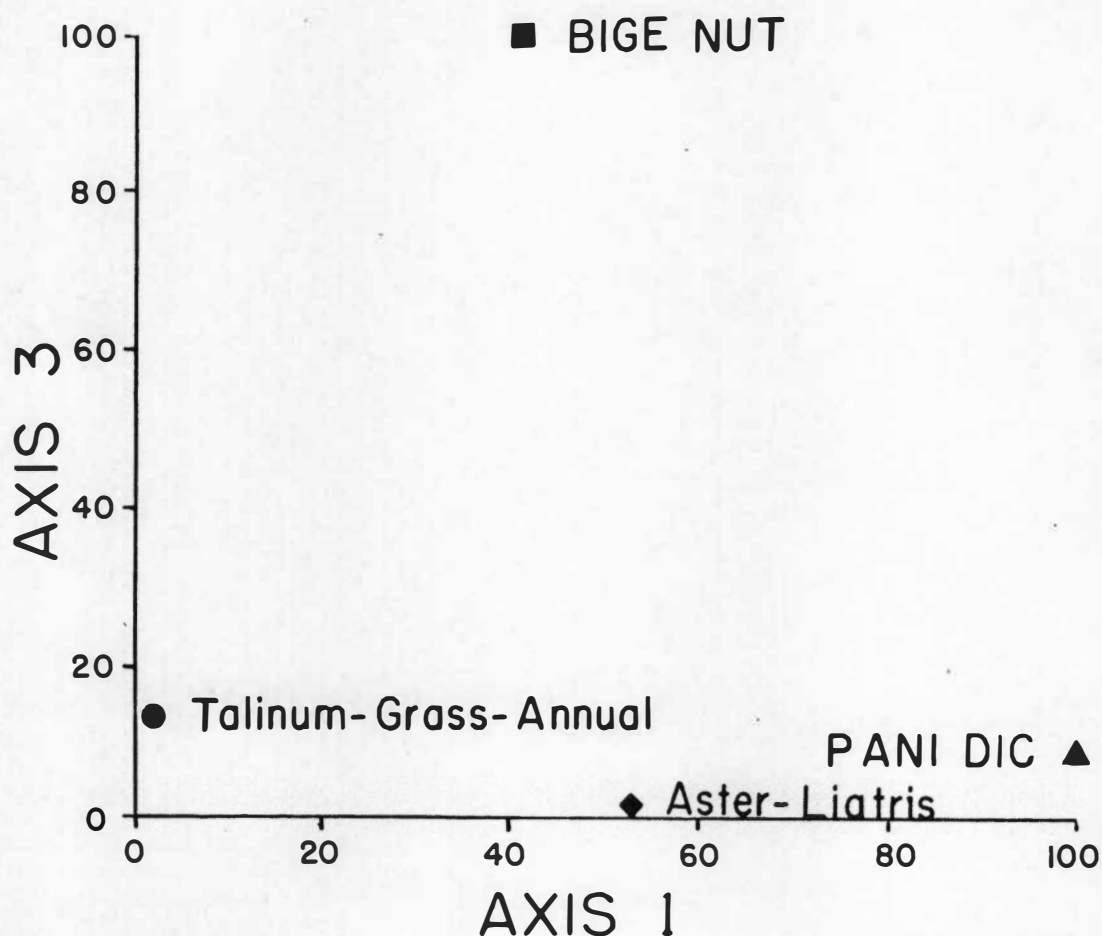


Figure 15. Relative location of Cryptogam-Herb Zone vascular plant sample plots on the first and third Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol. Species abbreviations are explained in Appendix, Table 22.

Table 13. Mean cover (cm^2/dm^2) and standard error of species in the Cryptogam-Herb Zone vascular plant communities.

Species ^a		Community				ALL SAMPLE PLOTS
		TALI TER- Grass- Annual	BIGE NUT	ASTE SUR- LIAT MIC	PANI DIC	
ANDR VIR	$\bar{X}$	6.6				2.9
	SE	2.9				1.3
AREN GLA	$\bar{X}$	0.5				0.2
	SE	0.3				0.1
ASTE SUR	$\bar{X}$			16.5		5.5
	SE			5.0		1.7
BIGE NUT	$\bar{X}$		19.2			3.2
	SE		3.9			0.6
CROT ELL	$\bar{X}$	0.7				0.3
	SE	0.5				0.2
DANT SER	$\bar{X}$	5.4				2.3
	SE	3.3				1.5
DANT SPI	$\bar{X}$			0.2		0.1
	SE			0.2		0.1
HYPE GEN	$\bar{X}$	3.0				1.3
	SE	1.8				0.8
LIAT MIC	$\bar{X}$			8.4		2.8
	SE			1.9		0.6
LYCO VIR	$\bar{X}$				2.4	0.2
	SE				1.7	0.1
PANI DIC	$\bar{X}$				16.0	1.0
	SE				9.1	0.5
PANI SPH	$\bar{X}$			0.4		0.1
	SE			0.4		0.1
TALI TER	$\bar{X}$	8.0				3.5
	SE	2.0				0.9
VIOL PRI	$\bar{X}$				3.4	0.2
	SE				2.9	0.2
Total No. Plots		34	13	26	5	78

^aSpecies abbreviations are explained in Appendix, Table 22.

Tennessee, but often locally important. Arenaria glabra is another infrequent associate, an annual, that may be locally abundant. On some unsampled outcrops, Diodia teres, Agrostis eliottiana, Krigia dandelion, Rumex acetosella, and Plantago aristata are also associates.

Depending on which species are present and type and size of available habitat, individual taxa may also occupy bands within the Talinum-Grass-Annual Community. Grasses may be concentrated in the deeper soil, Talinum in soil of intermediate depth, and Arenaria in the shallowest soil. Bands are usually less than 10cm in width and therefore not recordable with dm² quadrats. Bands may also be absent and the taxa more-or-less uniformly distributed within the community.

Communities similar to the Talinum-Grass-Annual Community have been described on many outcrops in the southeastern United States. Oosting and Anderson (1937 and 1939), Keever et al. (1951), Burbank and Platt (1964), Berg (1974), and McVaugh (1943) reported similar communities on granite outcrops, including one with T. teretifolium, Sedum smallii, H. gentianoides, C. elliptica, and Danthonia spicata (Keever et al. 1951). Sandstone outcrops in southern Illinois (Winter-ringer and Vestal 1956) have shallow soil communities with T. parviflorum rather than T. teretifolium, Sedum pulchellum (a limestone outcrop plant in Tennessee (Quarterman 1950)), Opuntia compressa (on sandstone and limestone outcrops in Tennessee (Baskin and Baskin 1977, personal observation), D. spicata, Agrostis eliottiana, K. biflora, and K. dandelion, H. gentianoides, and C. elliptica.

At Little River Canyon, Talinum was present only in crevices. Bigelowia nuttallii, "the rayless goldenrod," instead occupied

basins, small vegetation islands, and edges of vegetation mats. This herb is a linear-leaved, caespitose, perennial composite (Small 1933, Cronquist 1980). Bigelowia was often the only herb in the samples where it occurred. It is also on granite outcrops (McVaugh 1943), and on sandy soil and sandstone outcrops of the Coastal Plain (Harper 1906, Small 1933, Cronquist 1980). Sometimes parasitizing Bigelowia was the rare dodder, Cuscuta harperi.

Sedum smallii also forms a monospecific community at Little River Canyon. Sedum smallii is a winter annual (Radford et al. 1968) that had senesced by my summer sampling period and therefore was not sampled. It dominates shallow soil in basins, even those often inundated. It is rare in Tennessee (Committee for Tennessee Rare Plants 1978), but common on granite outcrops in other areas (Keever et al. 1951, Burbanck and Platt 1964, Berg 1974, Wyatt and Fowler 1977). Its autecology has been studied (Wiggs and Platt 1962, McCormick and Platt 1964, Sharitz and McCormick 1973): it is apparently the only herb on the outcrops studied that is able to persist in very shallow, vernaly inundated outcrop soils. This habitat is unvegetated where the species does not occur (Berg 1974), and during late summer.

Another sandstone outcrop community not sampled is dominated by Selaginella rupestris. This fern ally was observed on shallow sandy soil over sandstone at Flat Rock in DeKalb County, Alabama, but occurred at none of the research sites. It invades Grimmia mats on granite outcrops (Oosting and Anderson 1937 and 1939, McVaugh 1943, Keever et al. 1951) and occurs on the Appalachian shale barrens (Platt 1951). It is common on granite in Virginia (Berg 1974), but McVaugh

(1943) reported it to be infrequent on granite further south except near the mountains.

The Aster surculosus-Liatris microcephala Community is common on significantly deeper soils than the other communities (Table 14). Both dominants are relatively xerophytic. Liatris is characteristic of "exposed, rocky places, glades, open woods, and sandy shores" (Cronquist 1980). Aster grows in rock or sandy, open habitats (Radford et al. 1968). Liatris probably requires deeper soil than taxa of other communities, since it produces a swollen underground stem. Both Aster and Liatris were present at every Plateau sandstone outcrop examined for this study, but neither species is common on granite (McVaugh 1943).

The Panicum dichotomum Community is dominated by mesophytes. Panicum dichotomum is a species of "bogs, ditches, savannas and low pinelands" (Radford et al. 1968). Its associates are equally mesophytic, Lycopus virginicus and Viola primulifolia (Radford et al. 1968). Sphagnum is a frequent non-vascular associate.

The P. dichotomum Community occurs at the edge of vegetation mats (mean soil depth was 0.4cm) where seepage from upslope keeps it moist much of the growing season. A low slope angle (Table 14) contributes to retention of moisture. Mean shading is also highest of any community in the zone (Table 14). Isolation of this community on axes 1 and 2 (Figure 14) of the ordination is another indication of its environmental distinctiveness.

Table 14. Average environmental conditions of the Cryptogam-Herb Zone vascular plant communities.

Variable ¹		Community				ALL SAMPLE PLOTS
		TALI ² TER- Grass- Annual	BIGE NUT	ASTE SUR- LIAT MIC	PANI DIC	
Aspect	$\bar{X}$	0.46	0.98	0.35	0.64	0.48
	SE	0.22	0.37	0.11	----- ³	0.11
	s ⁴	a	a	a	a	
Slope angle (°)	$\bar{X}$	2.9	3.1	5.1	2.8	3.6
	SE	1.5	1.8	1.0	2.8	1.3
	s	a	a	a	a	
Micro- topo- graphy	$\bar{X}$	2.2	2.0	2.0	2.0	2.1
	SE	0.1	0.0	0.0	0.0	0.1
	M ⁵	2	2	2	2	
Shading	s	a	a	a	a	
	$\bar{X}$	3.4	1.9	2.7	4.4	3.0
	SE	0.4	0.4	0.3	0.2	0.3
Soil depth (cm)	M	3.5	1	3	4	
	s	c	a	ab	b	
	$\bar{X}$	2.6	0.5	10.9	0.4	4.9
	SE	0.7	0.1	1.3	0.3	0.7
	s	a	a	b	a	

¹Scales for variables appear in Table 2, page 21.

²Species abbreviations are explained in Appendix, Table 22.

³Dashed lines indicate missing or insufficient data.

⁴Results of multiple mean or median comparison tests.
Communities which share a letter are not significantly different
(p=0.05).

⁵Median.

Shrub-Herb Zone

Seven communities occur in the Shrub-Herb Zone. The first ordination attempt (not illustrated here) resulted in segregation of four outlier sample plots dominated by Gaylussacia baccata--the Gaylussacia Community. Other communities were derived in a second ordination without outliers (Figures 16 and 17). The communities derived by ordination are similar to those derived by Hierarchical Agglomeration (Figure 5, page 25), so the latter were accepted as valid. They include Grass-Forb, Pinus virginiana (seedlings and subsaplins), G. baccata, Vaccinium arboreum, V. vacillans-Smilax rotundifolia, Kalmia latifolia, and Helianthus longifolius-Danthonia sericea Communities. Compositions of communities are included in Table 15. The communities are significantly distinct according to discriminant analysis ($F=35.5$ at $234/62$ df; $p<0.001$). Classification was 100% successful; jackknifed, 70.4% successful.

Two communities are dominated by herbs, five by woody taxa. This result reflects the two subzones often noted within the Shrub-Herb Zone, a band next to the Cryptogam-Herb Zone dominated by herbs and a band near the Tree Zone dominated by woody species. Woody species were always present since their presence was used to distinguish Cryptogam-Herb from Shrub-Herb Zone.

One herb-dominated community, the Helianthus longifolius-Danthonia sericea Community, was only sampled at Little River Canyon. Helianthus longifolius is a vigorous, rosette-forming perennial forb of "dry, rocky soil" (Heiser et al. 1969) ranging from Lookout and

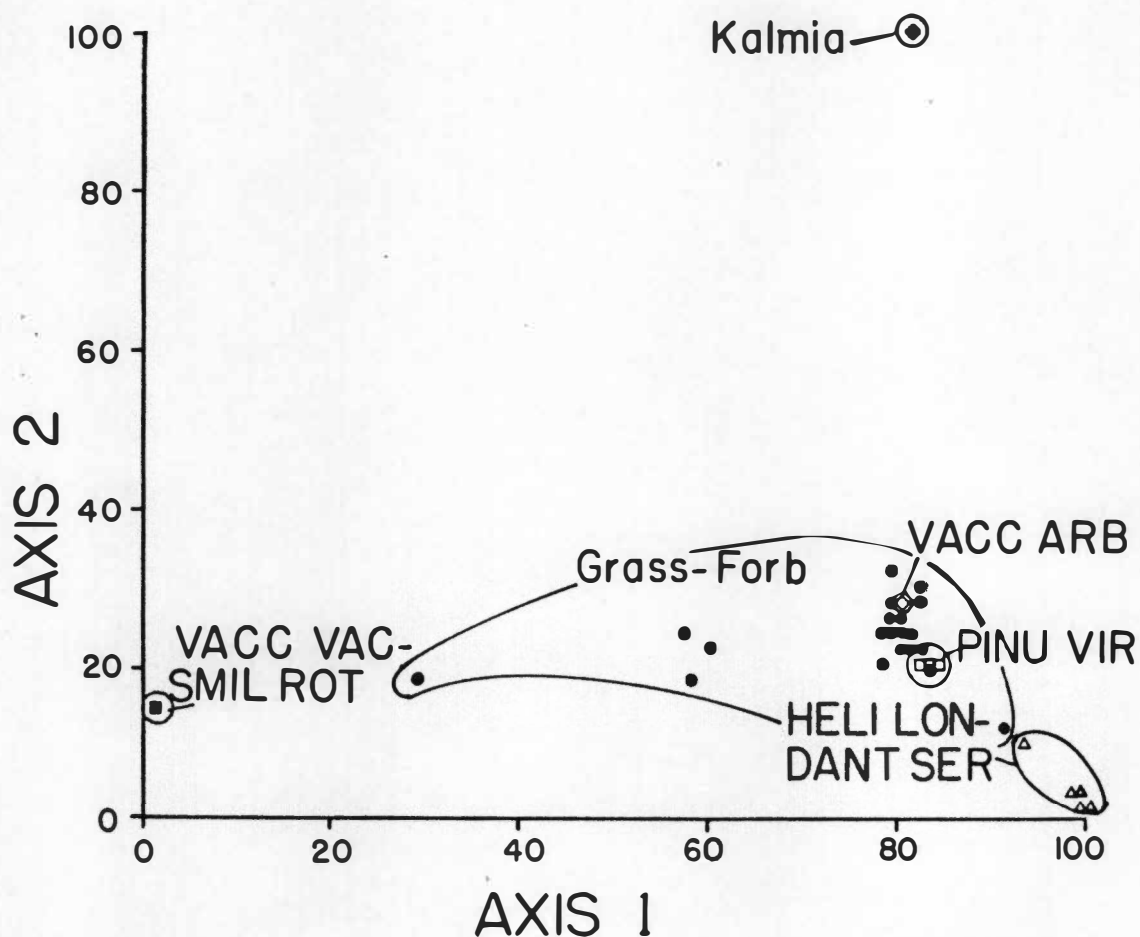


Figure 16. Relative location of the Shrub-Herb Zone vascular plant sample plots on the first two Reciprocal Averaging Ordination axes, outlier plots dominated by *Gaylussacia baccata* having been deleted. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22.

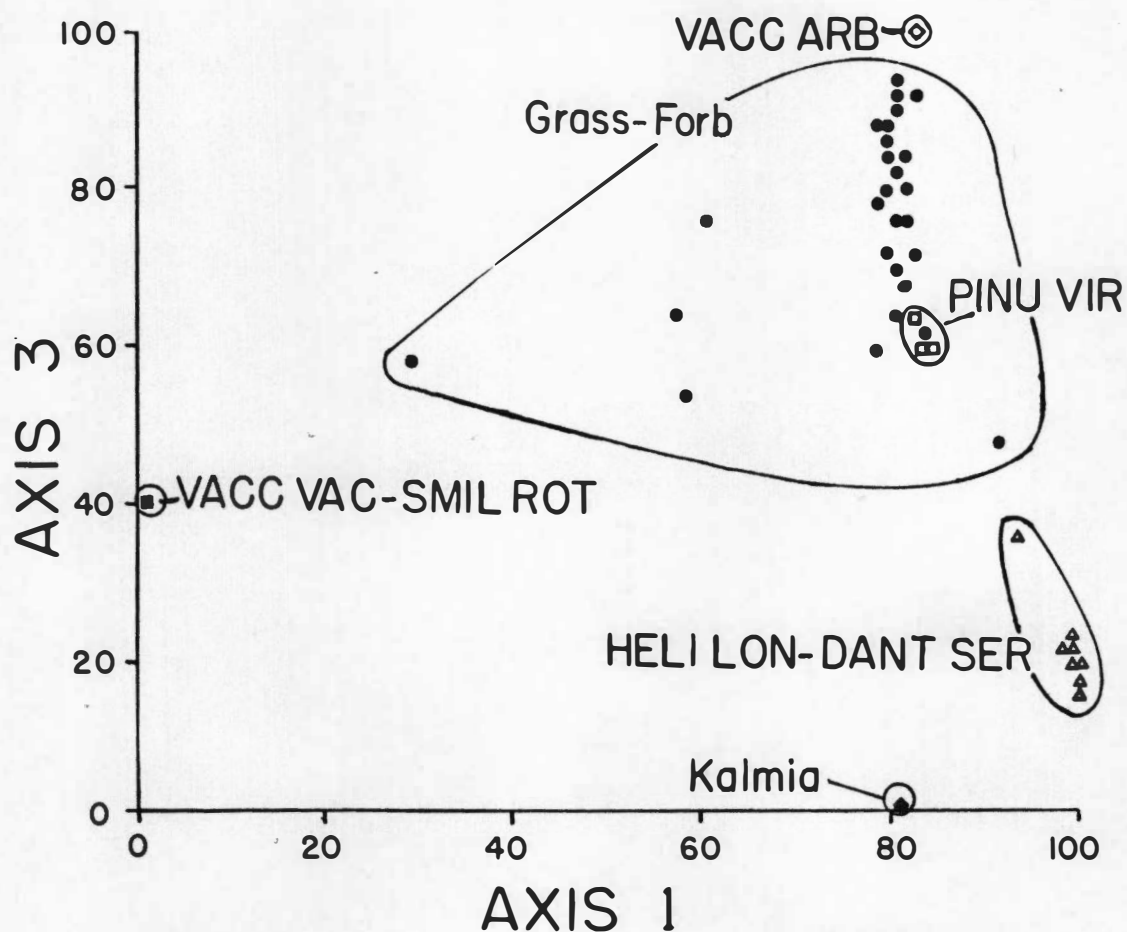


Figure 17. Relative location of the Shrub-Herb Zone vascular plant sample plots on the first and third Reciprocal Averaging Ordination axes, outlier plots dominated by *Gaylussacia baccata* having been deleted. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22.

Table 15. Mean cover (cm^2/m^2) and standard error of species in the Shrub-Herb Zone vascular plant communities.

Species ^a	Community						HELI LON- DANT SER	ALL SAMPLE PLOTS
	GAYL BAC	VACC VAC- SMIL ROT	KALM LAT	VACC ARB	Grass- Forb	PINU VIR		
ACER RUB	X				3.7			2.4
	SE				2.6			1.8
AGRO PER	X				20.0	16.7		13.9
	SE				15.2	16.7		10.5
AMEL ARB	X	8.5			14.6			9.8
	SE	8.5			14.3			9.8
ANDR VIR	X		250.0		225.0	301.1		167.2
	SE		-----C		69.8	299.5		49.9
ANIS CAP	X	100.0			14.3			13.0
	SE	100.0			14.3			10.2
AREN GLA	X				0.3			0.2
	SE				0.2			0.1
ARIS LON	X				0.1			0.1
	SE				0.1			0.1
ASTE DUM	X				6.0			3.9
	SE				4.3			2.9
ASTER SP	X			20.0	89.7			58.5
	SE			-----	85.6			58.6
ASTE SUR	X		125.0	25.0	258.7	1666.7		263.0
	SE		-----	-----	109.7	1666.7		110.5
BIGE NUT	X				3.0	3.3	49.5	9.5
	SE				2.1	3.3	31.2	4.9
CARY PAL	X				30.0			19.4
	SE				28.6			19.5
CHIO VIR	X						0.5	0.1
	SE						0.5	0.1
CLIT MAR	X				34.3			22.2
	SE				27.9			19.1
CORE MAJ	X			5.0	16.0			10.5
	SE			---	7.3			5.0
CORE PUL	X					100.0		5.6
	SE					100.0		4.9
CROT ELL	X				5.7	102.0	0.1	9.4
	SE				5.7	99.0	0.1	6.2
CUSC HAR	X					0.7		pb
	SE					0.7		0.03
DANT SER	X				247.1		1033.9	313.4
	SE				185.7		404.8	140.7
DANT SPI	X				62.1	850.0	0.2	87.5
	SE				37.6	825.1	0.2	47.7
GAYL BAC	X	9125.0						675.9
	SE	554.3						38.1
HELI LON	X						2868.8	425.0
	SE						379.6	56.4
HETE NER	X			35.0	21.7			14.7
	SE			-----	7.6			5.2
HIER GRO	X				0.3			0.2
	SE				0.3			0.2
HYPE GEN	X				17.6	4.4	0.1	11.6
	SE				17.1	4.4	0.1	11.7
ILEX OPA	X						2.1	0.3
	SE						2.1	0.3
KALM LAT	X		10000.0					185.2
	SE		-----					-----
LECH RAC	X			12.0	0.6		8.8	1.9
	SE			-----	0.6		8.7	1.4
LESP PRO	X				1.4			0.9
	SE				1.4			1.0
LIAT MIC	X	5.7			432.9		1.4	281.2
	SE	4.3			108.8		1.2	74.5
MALA UNI	X						187.5	27.8
	SE						187.5	27.8
OPUN COM	X				20.6			13.4
	SE				10.2			7.0
PANI COM	X				0.7			0.5
	SE				0.7			0.5
PANI DIC	X						7.6	1.1
	SE						7.6	1.1
PANI LAN	X				6.3	25.0	0.3	5.5
	SE				5.2	25.0	0.2	3.8

Table 15 (Continued)

Species ^a	Community						HELI LON- DANT SER	ALL SAMPLE PLOTS
	GAYL BAC	VACC VAC- SMIL ROT	KALM LAT	VACC ARB	Grass- Forb	PINU VIR		
PANI SPH	X				1.3			0.8
	SE				1.3			0.9
PANI VIL	X				4.5			2.9
	SE				3.0			2.1
PINU VIR	X		25.0		187.9	9768.9	309.5	710.9
	SE		----		125.9	1718.1	246.4	125.5
POLY CUR	X						0.1	P
	SE						0.1	0.01
POTE CAN	X				0.7		1.1	0.6
	SE				0.5		1.1	0.4
QUER FAL	X			43.0	11.7			8.4
	SE			----	7.4			5.1
QUER STE	X				5.7			3.7
	SE				5.7			3.9
RHUS COP	X				3.6			2.3
	SE				3.6			2.4
RHYN SPP	X						0.4	0.1
	SE						0.2	0.04
RUBU FLA	X				7.1			4.6
	SE				5.8			4.0
SCHI SCO	X			1210.0	576.6			396.1
	SE			-----	127.8			87.5
SENE SMA	X				4.0			2.6
	SE				3.0			2.1
SMIL GLA	X		210.0		7.6			8.8
	SE		-----		4.5			3.1
SMIL ROT	X	3000.0			21.4			125.0
	SE	-----			15.8			10.8
SORB ARB	X	250.0						9.2
	SE	249.8						7.8
STIP AVE	X			350.0	114.3			80.5
	SE			-----	53.8			36.8
STYL BIF	X						0.7	0.1
	SE						0.7	0.1
TALI TER	X							P
	SE							0.03
TEPH VIR	X		400.0	1800.0	218.6			182.4
	SE		-----	-----	148.1			101.4
UNK HERB	X						43.7	6.5
	SE						25.3	3.8
VACC ARB	X			17500.0	225.7		14.6	472.5
	SE			-----	158.9		12.4	108.8
VACC STA	X				4.3			2.8
	SE				4.3			2.9
VACC VAC	X	7327.5			34.3			293.6
	SE	2702.5			31.7			78.9
Total No. Plots	4	2	1	1	35	3	8	54

^aSpecies abbreviations are explained in Appendix, Table 22.^bPresent but less than 0.05cm².

Sand Mountains onto granite outcrops near the Georgia-Alabama State Line. A population was introduced into North Carolina (Heiser et al. 1969, McVaugh 1943, Cronquist 1980). The community often occurs between the Cryptogam-Herb Zone and other Shrub-Herb Zone communities. Its soil pH is relatively high (4.25) (Table 16).

The other herb dominated community, the Grass-Forb Community, is both the most diverse and common (Table 15) of any sampled in the zone. It occurred at every area sampled. Dominants include Liatris microcephala, Aster surculosus, Danthonia sericea, and Andropogon virginicus; with seedlings or subsaplings of Pinus virginiana, Smilax glauca, and S. rotundifolia. Less frequent but characteristic species include Lechea racemulosa, Heterotheca nervosa, and Polygala curtisii. Opuntia compressa, characteristic of disturbed limestone outcrops (Baskin and Baskin 1977), is an important local associate at the Jamestown Barrens and several unsampled outcrops.

A community similar to the Grass-Forb Type, the Aster surculosus-Liatris microcephala Community of the Cryptogam-Herb Zone, may be an extension of the Grass-Forb Community into that zone. Environmentally, the two communities are not significantly different. According to Sørensen's (1948) index of similarity based on mean species cover, they are 25.9% similar in vegetation.

Communities similar to the Grass-Forb Community are on sandstone outcrops in Ohio (Griggs 1914) and southern Illinois (Winterringer and Vestal 1956). Diverse stands of herbs with some of the same taxa (especially grasses) are also reported from granite outcrops in the

Table 16. Average environmental conditions of the Shrub-Herb Zone vascular plant communities.

Variable ¹	Community							ALL SAMPLE PLOTS
	GAYL ² BAC	VACC VAC- SMIL ROT	KALM LAT	VACC ARB	Grass- Forb	PINU VIR	HELI LON- DANT SER	
Aspect	$\bar{X}$ ---- ³ SE ---- s ⁴	----	----	0.00 ----	0.64 0.12 a	1.00 ----	1.09 0.25 a	0.73 0.10
Slope angle (°)	$\bar{X}$ 0.0 SE 0.0 s	0.0 0.0	0.0 ---	5.0 ---	5.8 0.7 a	3.5 3.5 a	6.6 2.7 a	5.0 0.6
Micro- topo- graphy	$\bar{X}$ 2.0 SE 0.0 M ⁵ s	2.0 0.0 2 a	2.0 --- 2 a	2.0 --- 2 a	2.2 0.1 2 a	2.0 0.0 2 a	2.0 0.0 2 a	2.1 0.1
Shading	$\bar{X}$ --- SE --- M s	6.5 0.5 6.5 a	7.0 --- 7 a	--- ---	4.1 0.8 5 a	2.0 1.0 2 a	5.1 0.3 5.5 a	4.6 0.4
Soil depth (cm)	$\bar{X}$ 10.7 SE 2.7 s	9.5 0.5 a	30.0 ----	30.0 ----	13.8 1.9 a	10.7 3.5 a	12.3 0.8 a	13.6 1.3
Thickness O ₁ soil horizon (cm)	$\bar{X}$ 3.7 SE 1.4	2.0 1.0	2.0 ---	4.0 ---	1.7 0.2	2.7 1.7	1.5 0.2	1.9 0.2
Thickness O ₂ soil horizon (cm)	$\bar{X}$ 2.2 SE 0.3	3.0 0.0	2.0 ---	3.0 ---	3.3 0.4	7.3 3.3	1.1 0.3	3.0 0.4
Thickness A soil horizon (cm)	$\bar{X}$ 4.8 SE 1.7	4.5 1.5	--- ---	10.0 ----	3.2 0.9	0.7 0.7	9.0 0.9	4.2 0.7
Thickness B soil horizon (cm)	$\bar{X}$ 0.0 SE 0.0	0.0 0.0	--- ---	--- ---	1.4 0.9	0.0 0.0	--- ---	0.9 0.6
pH A soil horizon	$\bar{X}$ 3.47 SE 0.06 s	---- ---- a	3.55 ----	3.60 ----	3.99 0.06 b	4.25 0.15 bc	4.25 0.05 c	3.96 0.06

¹Scales for variables appear in Table 2, page 21.²Species abbreviations are explained in Appendix, Table 22.³Dashed lines indicate missing or insufficient data.⁴Results of multiple mean or median comparison tests.
Communities which share a letter are not significantly different
(p=0.05).⁵Median.

Southeast (Whitehouse 1933, Oosting and Anderson 1939, McVaugh 1943, Keever et al. 1951, Burbanck and Platt 1964, Berg 1974).

Pinus virginiana subsaplings and seedlings are important in many Shrub-Herb Zone communities (Table 15) and dominate three plots--the P. virginiana Community. Occasionally young pines form a band bordering the Tree Zone, but are most often found in the center of small vegetation islands. The community was too infrequent to infer much about its habitat.

The remaining communities are mostly dominated by heath shrubs. Of these communities, the Gaylussacia baccata Community is the most environmentally unusual, occurring on the most acid soils sampled (Table 16), a pH averaging 3.47. This community is also so vegetationally distinct that its sample plots are outliers in the first ordination. Gaylussacia occurred in the samples as a subshrub (less than 30cm tall) with a very shallow-soil herb, Talinum teretifolium, and the non-vascular Cladonia caroliniana Community. Talinum and C. caroliniana (inflated podetia) are taxa more characteristic of the Cryptogam-Herb than the Shrub-Herb Zone. The Gaylussacia Community was only observed at the Clear Creek-Lilly Bridge site but also invades moss-lichen mats on extremely shallow soil over sandstone in the Cumberland Mountains (Braun 1935). It occurs on sandstone in Ohio (Griggs 1914), too, and on granite in the Blue Ridge (Weakley 1979).

Five other sample plots were dominated by woody taxa--the Vaccinium arboreum, V. vacillans with Smilax rotundifolia, and Kalmia latifolia Communities. Vaccinium stamineum, V. corymbosum, and Sorbus

spp. were also important on unsampled areas. The Kalmia and V. arboreum Communities had the deepest soils of the zone, over 30cm (Table 16). Their soil pH was low (mean of 3.55 and 3.60, respectively). The V. vacillans-Smilax Community sample plots had shallower soil (9.5cm). Significant differences among these variables could not be measured with so few samples, however. These shrubs often form a zone bordering the tree-dominated areas, with scattered, usually smaller individuals in the forest understory.

Other outcrop researchers have also cited the importance of the taxa enumerated above. Griggs (1914) included V. vacillans, V. stamineum, G. baccata, Smilax rotundifolia, and Kalmia as dominants in his "transitional shrub zone" on Ohio sandstone cliff edges. Braun (1935) also mentioned G. baccata and V. vacillans in a shrub zone over sandstone in the Cumberland Mountains. Of these taxa, only V. arboreum is reported from sandstone in southern Illinois (Winterringer and Vestal 1956). Vaccinium arboreum is also common on granite in the Southeast; Kalmia and G. baccata are less frequent (Oosting and Anderson 1939, McVaugh 1943, Keever et al. 1951, Burbank and Platt 1964).

In contrast, Juniperus virginiana is consistently mentioned as the important Shrub-Herb Zone invader on sandstone outcrops in southern Illinois (Winterringer and Vestal 1956). On granite outcrops, Juniperus is also important (Oosting and Anderson 1937, McVaugh 1943). Juniperus is not mentioned, though, by Braun (1935) nor Griggs (1914) on other sandstones of the Appalachian Plateau. Even seedlings of the

species were rarely sampled in the present study, although Juniperus trees were often scattered in the bordering forest. It is the dominant tree on limestone outcrops in Tennessee (Quarterman 1950).

Several environmental variables within the zone appeared to be correlated when Pearson's r was calculated between them. Soil pH and shading were negatively linearly correlated ($r=-0.74$, $p<0.006$). Possibly acid litter from shading trees accounts for this trend, or perhaps heath litter is responsible. Shading also varied negatively with thickness of the O₂ soil horizon ($r=-0.71$, $p<0.001$).

Tree Zone: Canopy

Community delineation. Pinus virginiana dominated all but one Tree Zone canopy sample plot. Neither cluster analysis nor ordination revealed any other communities.

Tsuga canadensis dominated a single sample plot at the Clear Creek-Lilly Bridge site. Well-established Tsuga and Pinus strobus trees were perched near the cliff edge in soil averaging 4.5cm deep. Tsuga seedlings and saplings were also present. Since Tsuga is usually more mesophytic than other tree species sampled on these outcrops (Whittaker 1956, Little 1971), that particular site is presumably more mesic than the others, in part due to its northeast aspect. Tsuga was present but unimportant in forests bordering the Jamestown Barrens and Pickett State Forest sites. While Tsuga is a well-known dominant of stream banks and steep draws on the Plateau (Hinkle 1978), its occurrence on exposed sandstone has not often been

documented. Besides the Clear Creek site, it was observed by the author on exposed sandstone above waterfalls (Foster Falls, Marion County and Fall Creek Falls, Bledsoe County, Tennessee), the trees decreasing in abundance and stature with increasing distance from the falls.

The P. virginiana Community of the present study is similar to that described by Wade (1977) in a study of the xerophytic forests of the Plateau. His community occurred on "ridges, steep south and southwest-facing slopes and cliff edges" (Wade 1977). Wade concurred with Braun (1950) that this community is a physiographic climax on dry sites, although Wade concluded that it could be succeeded by a white oak type elsewhere. The composition of Wade's community and that of Hinkle (1978) is compared to that of this study in Table 17.

Hinkle (1978) also reported a P. virginiana community in his study of the Plateau forest communities of Tennessee. His community was mainly on south-facing cliff edges on the shallowest, most acidic soils of any he sampled. He noted that almost pure stands of P. virginiana occur on cliff edges and narrow ridges, but with an admixture of xerophytic hardwoods on upper slopes and disturbed areas, hardwoods becoming more important where soil is deeper. Hinkle considered his P. virginiana Community part of the Virginia Pine type (Cover Type 79) of the Society of American Foresters (1962).

Other studies have also noted the importance of P. virginiana on sandstone outcrops. Smalley (1979) reiterated its importance on shallow soils over sandstone on the Cumberland Plateau south of the

Table 17. Comparison of the composition of *Pinus virginiana* communities of the Cumberland Plateau as described in the present study, by Hinkle (1978), and by Wade (1977).

Species	Canopy (Relative Importance Value (%)) ^a			Saplings (Relative Density (%))		
	Present Study	Hinkle	Wade	Present Study	Hinkle	Wade
<i>Acer rubrum</i>	1.9	0.9	1.1	4.6	16.9	22.1
<i>Amelanchier arborea</i>	2.5			0.8	^{Pb}	0.5
<i>Carpinus caroliniana</i>					P	
<i>Carya glabra</i>	0.8	1.0	0.3		1.6	0.7
<i>Carya ovalis</i>					P	0.5
<i>Carya ovata</i>				1.1		
<i>Carya pallida</i>	0.1	1.4	0.4		1.3	1.4
<i>Carya tomentosa</i>		2.2	1.4	0.6	1.7	1.7
<i>Chionanthus virginicus</i>	1.2					
<i>Cornus florida</i>		P	0.4	0.2	13.2	12.1
<i>Crataegus</i> sp.					P	0.2
<i>Diospyros virginiana</i>	0.3			1.1		
<i>Fraxinus americana</i>				0.8		
<i>Ilex opaca</i>	1.1			1.3	P	0.2
<i>Juniperus virginiana</i>	0.9			0.2		
<i>Kalmia latifolia</i>				4.6	1.5	4.3
<i>Liquidambar styraciflua</i>				0.4		
<i>Nyssa sylvatica</i>	1.4	1.3	1.3	15.6	4.0	3.6
<i>Oxydendrum arboreum</i>	0.1	2.4	1.6	0.4	9.5	13.1
<i>Pinus echinata</i>		6.5	3.0		P	
<i>Pinus strobus</i>	0.4					
<i>Pinus taeda</i>	0.6					
<i>Pinus virginiana</i>	81.4	57.9	71.0	46.1	22.6	19.2
<i>Prunus serotina</i>	0.1			0.2		
<i>Quercus alba</i>	1.2	11.8	5.0		10.6	6.7
<i>Quercus coccinea</i>		4.7	4.4		1.9	2.1
<i>Quercus falcata</i>	0.2	P	0.3	1.1	P	0.2
<i>Quercus marilandica</i>	0.1	P			P	0.2
<i>Quercus prinus</i>	1.2	2.9	3.6	0.4	1.1	1.0
<i>Quercus rubra</i>			0.6		P	0.2
<i>Quercus stellata</i>	1.8	4.4	2.7	0.2	2.6	1.9
<i>Quercus velutina</i>	0.2	2.1	2.9	0.8	3.4	1.4
<i>Quercus</i> spp.		P	0.8		P	
<i>Rhododendron maximum</i>					P	
<i>Sassafras albidum</i>					3.0	4.5
<i>Sorbus</i> spp.				8.4		
<i>Stewartia ovata</i>					P	
<i>Tsuga canadensis</i>	2.0				P	1.9
<i>Vaccinium</i> spp.	0.4			8.9	P	0.2

^aRelative Importance Value =

$$\frac{\text{Relative Basal Area (\%)} + \text{Relative Density (\%)}}{200} \times 100.$$

^bPresent but less than 0.06%.

Tennessee River, where it occurs with Quercus alba, Q. stellata, Q. marilandica, Q. prinus, Q. coccinea, P. echinata, Carya spp., and Robinia pseudoacacia. Griggs (1914) and Braun (1935) reported that P. virginiana and P. rigida were dominant in shallow soil over sandstone in southern Ohio (with associates, Q. velutina, Castanea dentata, and Oxydendrum arboreum) and the Cumberland Mountains, respectively. Native pines are infrequent in southern Illinois (Mohlenbrock 1975); instead, Juniperus virginiana is the dominant tree on sandstone there (Winterringer and Vestal 1956). Quercus marilandica, Q. stellata, Ulmus alata, Vaccinium arboreum, Amelanchier arborea, Diospyros virginiana, and Carya glabra are associates.

Pinus virginiana occurs on most granite outcrops within its range but usually shares dominance or is a subdominant of other species, e.g., P. echinata (Oosting and Anderson 1939, McVaugh 1943), P. pungens (Keever et al. 1951), or P. taeda (McVaugh 1943, Burbank and Platt 1964, Berg 1974), depending on location. Juniperus virginiana may also be the dominant tree (McVaugh 1943). Tsuga and P. strobus can also dominate granite outcrops in the Blue Ridge (Oosting and Anderson 1939).

Size structure. Stem density per hectare in 2cm dbh size classes (Figure 18) was examined to gain insight into the age structure of the forest. Pinus virginiana was clearly the most important tree species in all size classes, but its importance varied among the classes. Other taxa were most abundant in size classes below about 9cm dbh. Their mortality is high, however, and most

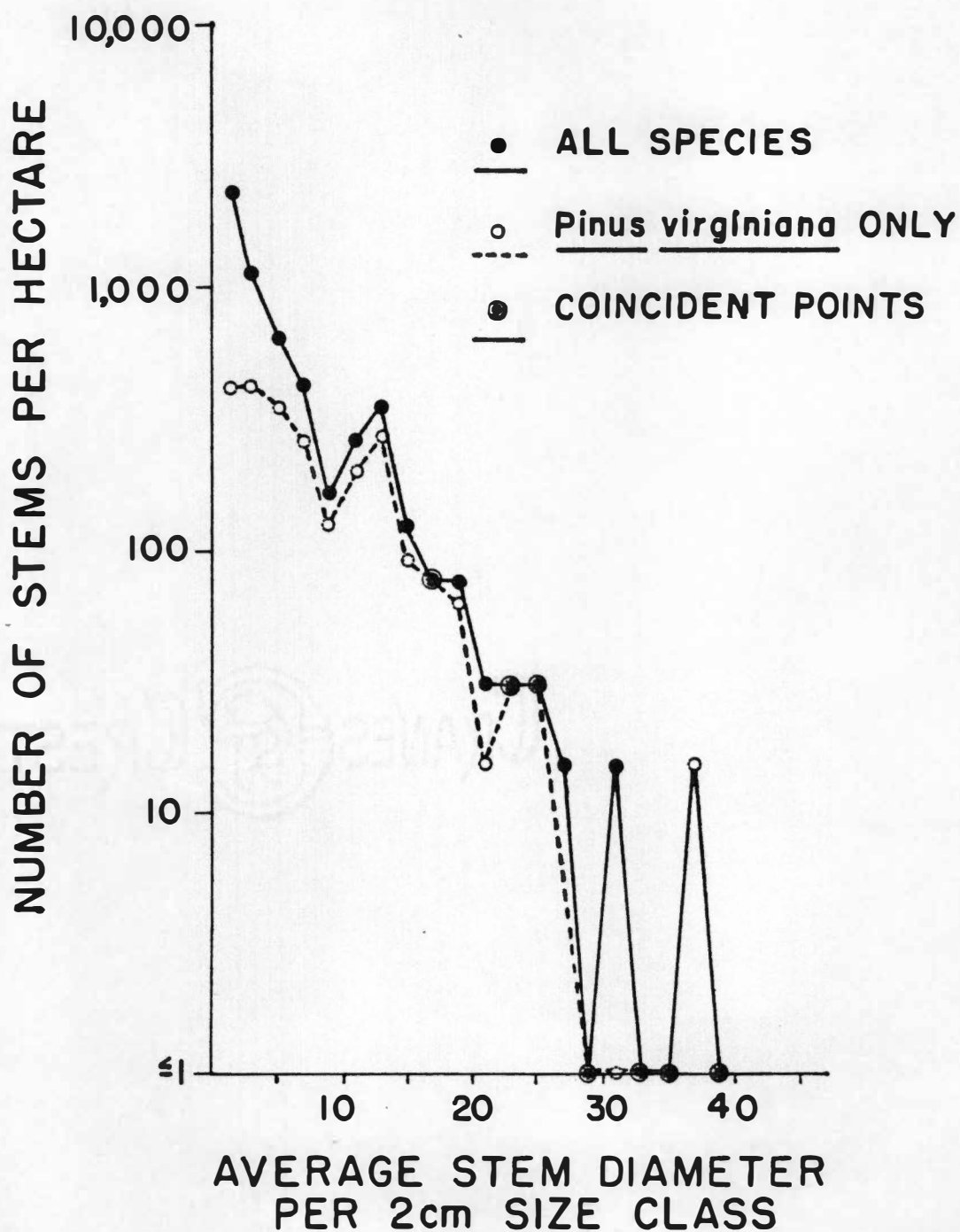


Figure 18. Stem density in 2cm dbh size classes for all species and for Pinus virginiana. Points are marked at midpoints of size classes, saplings at 1.5cm (saplings were from 1 to 2cm dbh). Note log scale of ordinate.

drop out rapidly. Pinus virginiana saplings have comparatively greater survivorship until they reach about 13cm dbh, when their decline also becomes rapid (or else growth becomes very slow). A few individuals of P. virginiana and other species survive and grow, however.

Diameter-age relationship. It was suspected that although stem diameter increases with tree age, harsher conditions in vegetation islands cause stunting of trees. This hypothesis was tested with tree cores taken from the largest trees in each canopy sample plot. Only Pinus virginiana cores are compared here.

The resulting curve of minimum tree age versus dbh (Figure 19) was almost linear for most points. A special sample of five trees in islands at the Clear Creek-Lilly Bridge site, however, did not fit the curve. These trees were about the oldest sampled (60 to 87 years) but were smaller than many younger trees (two were less than 10cm dbh). With these atypical trees deleted, age and dbh vary linearly ($r=0.74$ at $p<0.001$). The hypothesis that trees in islands are stunted is therefore accepted.

Environmental factors. A correlation matrix (Pearson's r) produced for environmental variables indicates that some are linearly correlated. Quadrat size (island size for those less than 60m^2) is correlated with percent canopy closure ($r=0.63$, $p<0.002$), canopy height ($r=0.70$, $p<0.002$), and soil depth ($r=0.53$, $p<0.011$). The larger the island, then, the deeper the soil and greater the canopy cover and height. Percent canopy closure is also correlated with canopy height

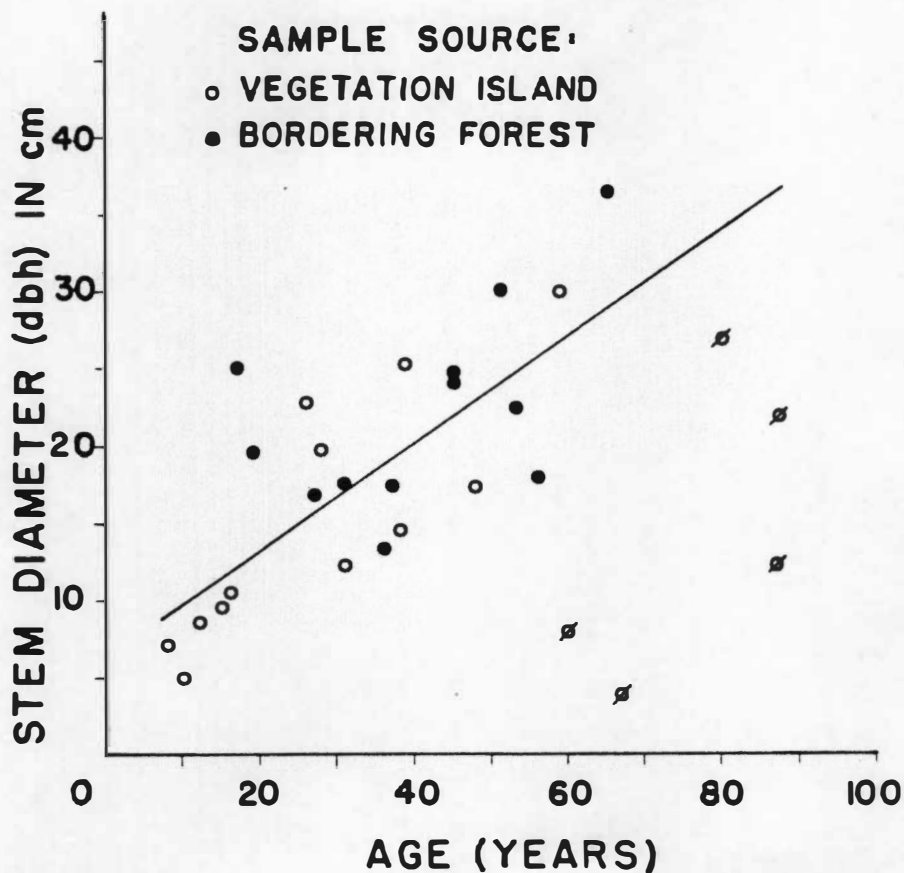


Figure 19. Diameter-age relationship of Pinus virginiana trees on sandstone outcrops and bordering forest. The regression line is plotted. ($Y=0.35X + 6.7$; $r=0.74$, $p<0.001$). Five anomalous samples (ø) from the Clear Creek-Lilly Bridge site were deleted from the calculation.

($r=0.74$, $p<0.001$); also with thickness of the O_1 ($r=0.39$, $p<0.071$), A ($r=0.59$, $p<0.004$), and B ($r=0.46$, $p<0.030$) soil horizons. Soil depth is also correlated with soil pH. Larger islands, then, are usually less acidic than smaller islands.

Canopy species diversity is also related to whether the sample came from an island or the forest bordering the outcrop (Figure 20). The nine sample plots in which Pinus virginiana was the only canopy species were all islands, usually small ones. To test a hypothesis that environmental conditions are harsher in small islands, thereby contributing to a low species diversity, sample plots were hand sorted into groups by species composition and stand location: (1) vegetation islands in which the canopy is exclusively P. virginiana, (2) other islands, (3) the bordering forest plot dominated by Tsuga canadensis, and (4) other bordering forest plots. Mean environmental conditions of the groups appear in Table 18.

Mean soil depth, percent canopy closure, and canopy height all increased from P. virginiana only islands, to other island plots, to border plots (Table 18). Measurements on P. virginiana islands were significantly lower than those of border plots. The single Tsuga plot was insufficient to characterize its habitat. In general, small islands are apparently more stressful to trees than areas bordering outcrops. Those with the shallowest soil and smallest physical area are usually occupied exclusively by P. virginiana, the canopy tree best able to survive these conditions.

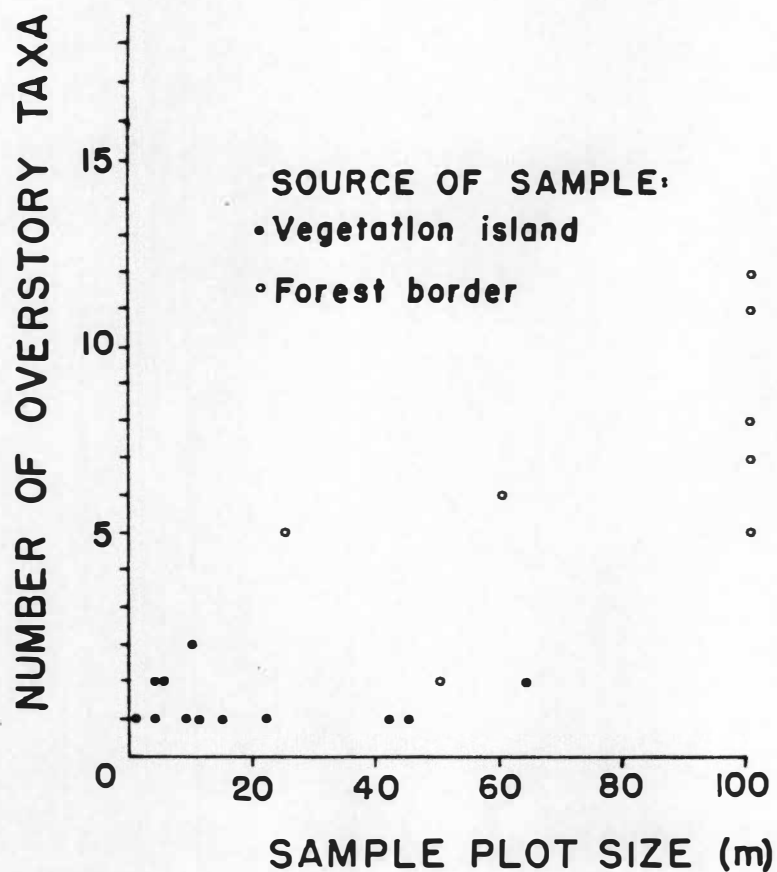


Figure 20. Canopy species diversity among sample plots of different sizes and sources.

Table 18. Average environmental conditions of four subsets of Tree Zone canopy sample plots.

Variable ¹		Location of Sample Plot				ALL SAMPLE PLOTS
		Islands		Forest Border		
		PINU ² VIR Only Taxon	Mixed Taxa	TSUG CAN Dom1- nates	Mixed Taxa	
Sample plot size (m ²)	$\bar{X}$ SE s ⁴	16.7 5.6 a	28.6 13.7 a	100.0 ----- ³	82.1 11.8 b	44.0 8.0
Aspect	$\bar{X}$ SE s	0.73 0.13 a	0.97 0.25 a	1.92 -----	0.74 0.26 a	0.84 0.17
Slope angle (°)	$\bar{X}$ SE s	6.4 2.0 a	5.7 4.1 a	7.0 ---	6.7 1.2 a	6.4 1.2
Percent canopy closure	$\bar{X}$ SE s	28.3 8.2 a	54.0 17.4 ab	60.0 -----	76.4 6.1 b	50.9 7.2
Canopy height (m)	$\bar{X}$ SE s	2.7 0.6 a	4.7 2.5 ab	7.0 ---	7.5 0.9 b	5.4 0.6
Soil depth (cm)	$\bar{X}$ SE s	6.2 5.2 a	15.3 5.5 ab	4.5 ---	21.6 3.6 b	13.8 2.7
Thickness O ₁ soil horizon (cm)	$\bar{X}$ SE s	2.4 0.8 a	2.5 0.4 a	2.4 ---	3.2 0.4 a	2.4 0.3
Thickness O ₂ soil horizon (cm)	$\bar{X}$ SE s	4.5 1.0 a	2.0 0.4 a	1.0 ---	3.9 1.0 a	3.0 0.5
Thickness A soil horizon (cm)	$\bar{X}$ SE s	2.7 1.5 a	6.4 3.1 a	0.0 ---	5.7 2.0 a	4.0 1.0
Thickness B soil horizon (cm)	$\bar{X}$ SE s	0.0 0.0 a	4.6 3.9 a	0.0 ---	9.4 3.1 a	3.7 1.6
pH A soil horizon	$\bar{X}$ SE s	3.85 0.25 a	3.78 0.32 a	----- -----	3.94 0.12 a	3.89 0.09
Total No. Plots		9	5	1	7	22

¹Scales for variables appear in Table 2, page 21.

²Species abbreviations are explained in Appendix, Table 22.

³Dashed lines indicate missing or insufficient data.

⁴Results of multiple mean comparison tests. Communities which share a letter are not significantly different (p=0.05).

Tree Zone: Understory

Ordination (Figure 21) of Tree Zone understory sample plots produced 10 communities: Acer rubrum, Liquidambar styraciflua, Grass-Forb, Pinus virginiana, Prunus serotina, Vaccinium vacillans-Smilax rotundifolia, V. arboreum, Vitis rotundifolia, Quercus prinus, and Diospyros virginiana Communities. The V. arboreum Community plots were outliers on axis 2 (not illustrated). Compositions of the communities appear in Table 19. Discriminant analysis revealed that classification was 91.0% successful, 57% successful in jackknifed classification, and types were significantly different ($F=8.7$ at 384/208 df; $p<0.001$) (the Q. prinus dominated plot had to be deleted from analysis).

The Grass-Forb Community is 48.6% similar to that of the Shrub-Herb Zone, and 25.6% similar to the Aster surculosus-Liatris microcephala Community of the Cryptogam-Herb Zone, using Sørensen's (1948) quantitative index of similarity. There are no significant environmental differences between the three communities.

Dominants of the Grass-Forb Community include Liatris microcephala, Danthonia spp., Schizachyrium scoparium, and various woody seedlings. This community has the lowest canopy closure (Table 20) of any Tree Zone understory community, as expected for species of "open" habitats (Radford et al. 1968).

Pinus virginiana seedlings and subsaplings dominated areas with a mean of 9.3cm of soil and 74% canopy closure (Table 20). Mean soil pH was the lowest of any understory community, but not significantly so. Although there were no significant environmental differences between

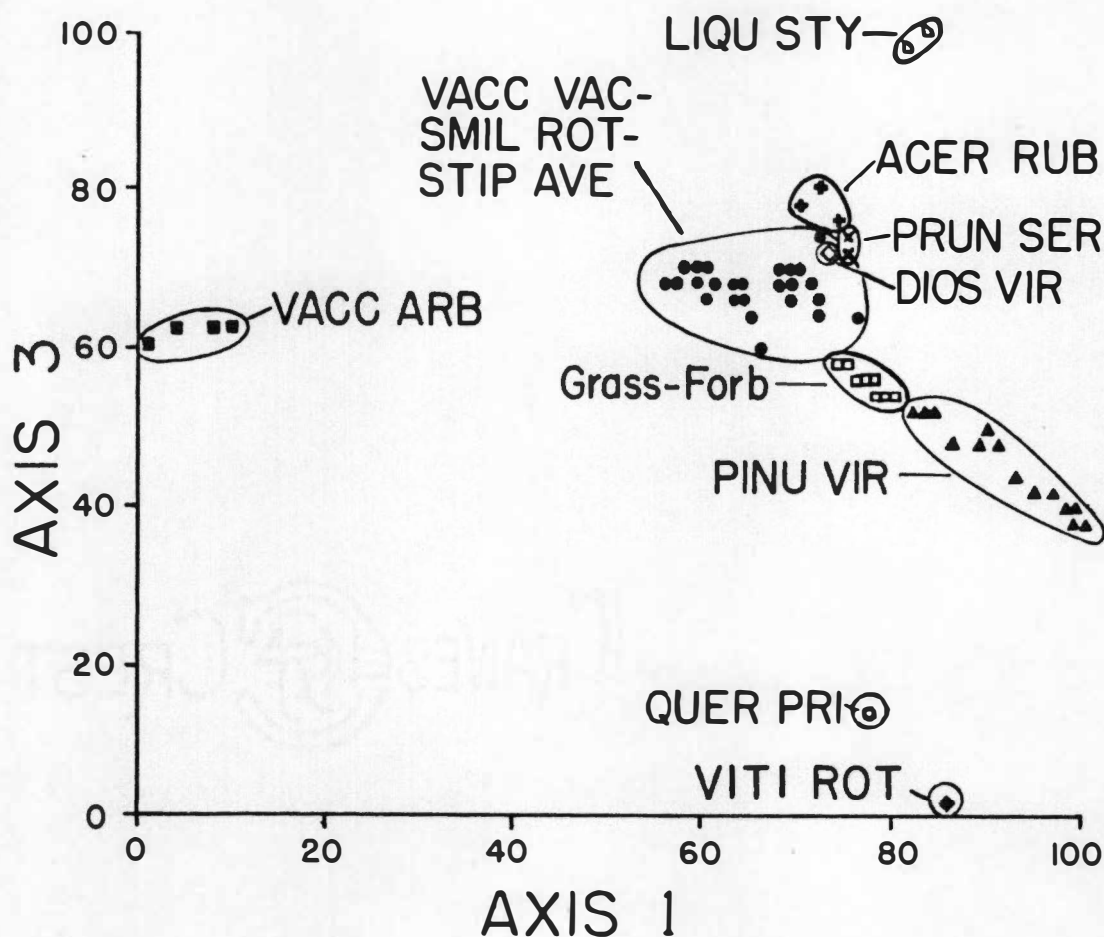


Figure 21. Relative location of Tree Zone understory sample plots on the first and third Reciprocal Averaging Ordination axes. Those plots within each community are marked with a different symbol and circled. Species abbreviations are explained in Appendix, Table 22. Axis 1 is inferred to be an aspect and shading gradient. Aspect and light intensity increase away from the origin. Aspect is scaled to increase with increasing moisture.

Table 19. Mean cover (cm^2/m^2) and standard error of species in the Tree Zone understory communities.

Species ¹	Community										ALL SAMPLE PLOTS
	VACC ARB	VACC- VACC- SMIL ROT	ACER RUB	DIOS VIR	PRUN SER	Grass- Forb	QUER PRI	LIQU STY	PINU VIR	VITI ROT	
ACER RUB	7.9	66.0	4223.7			0.8		1253.0	9.8	48.0	223.6
SE	5.1	47.4	4133.5			0.7		1253.0	8.2	-----	140.8
AGRO HYE		0.1									0.1
SE		0.2									0.1
AGRO STO									0.9		0.2
SE									0.6		0.1
AGROSTIS									9.1		2.0
SE									6.0		1.3
AMEL ARB		11.8									4.9
SE		9.9									4.3
ANDR VIR		7.6				85.6					16.2
SE		5.4				44.2					7.3
ANIS CAP		5.4	6.3						129.6		30.4
SE		2.7	6.3						74.3		16.6
AREN GLA						0.3					0.03
SE						0.3					0.5
ASTE DUM		0.9							0.5		0.3
SE		0.7							0.5		12.0
ASTE SLUR		4.5				71.7					4.8
SE		3.2				30.0					182.7
ASTE SPP	2.1	9.2	33.3		200.0	2.9			798.8		92.4
SE	2.1	4.9	33.3		200.0	2.9			413.3		0.1
BIDE FRO									0.4		0.1
SE									0.4		1.3
BIGE MUT									5.9		1.3
SE									5.9		4.7
CARY PAL		0.8		350.0							0.3
SE		0.7		-----							1.5
CAST PUM		3.6									1.4
SE		3.1									0.9
CHIM MAC		1.9							0.4		0.8
SE		1.7							0.4		27.5
CORE MAJ		13.0		100.0	50.0	3.8			88.2		17.2
SE		4.3		-----	50.0	3.3			76.2		0.1
CRATA SP					4.0						0.1
SE					4.0						0.2
CROT ELL						1.1					0.2
SE						1.0					56.5
DANTH SP	5.4	9.8	33.3			112.1		6.0	155.7		33.5
SE	4.2	5.1	33.3			41.8		6.0	146.7		0.6
DESM LAE		1.4									0.6
SE		1.4									38.0
DIOS VIR				3000.0							-----
SE				-----							7.0
EUOMY SP		16.4							0.7		6.4
SE		14.5							0.7		2.5
EUPA SES					100.0						1.9
SE					100.0						P
EUPH COR									0.2		0.1
SE									0.2		0.1
FRA X AME	0.7										0.1
SE	0.7										0.1
GAUL PRO		10.6									4.4
SE		7.7									3.4
HETE MAR		1.5									0.6
SE		1.5									0.7
HETE NER		2.1									0.9
SE		1.2									0.5
HYPE GEN						9.3					1.4
SE						8.3					1.3
HYPER SP									20.6		4.4
SE									15.5		3.5
ILEX OPA	11.4	38.2					5.0		0.1		17.0
SE	11.4	31.1					---		0.05		13.7
KALM LAT		35.6									14.9
SE		30.6									13.5
LECHE SP		0.9									0.4
SE		0.9									0.4
LEGUME 1		P									P
SE		0.03									0.01
LEGUME 2											0.3
SE											---
LEGUME 3											0.2
SE											---
LEGUME 5		1.8									0.6
SE		1.5									0.7
LESP HIR		1.5									0.6
SE		1.5									0.7
LESP PRO		3.0									1.3
SE		3.0									1.3
LIAT MIC						370.4			3.2		57.0
SE						108.0			1.8		16.8
LIQU STY		1.2						9512.5			241.3
SE		1.2						487.5			9.3
LYCO VIR									0.1		P
SE									0.1		0.02
MALA UNI	2.0		3.0								0.4
SE	1.3		3.0								0.1
MITC REP	564.3	27.7	20.0				2.0	4.0	0.1	12.0	62.5
SE	230.1	24.3	20.0				---	4.0	0.1	---	22.9
NYSS SYL	79.3	383.2			500.0				7.1		181.3
SE	70.5	378.6			500.0				7.1		167.1

Table 19. (Continued)

Species ¹	Community										ALL SAMPLE PLOTS
	VACC ARB	VACC- VAC- ROT	ACER ARB	OLOS VIR	PRUN SER	Bross- Fors	QUER PRI	LIQU STY	PINU VIR	VITI ROT	
OPUN COM	X					3.1					0.5
	SE					2.1					0.3
PANI DIC	X	2.3									0.9
	SE	1.6									0.7
PANI DIC	X	0.7			50.0				289.7		63.9
	SE	0.4			50.0				119.6		26.7
PANI LAN	X	3.0	1.3			2.9			0.9		1.9
	SE	3.0	1.3			2.2			0.9		1.4
PANI SPP	X	0.5			5.0				17.1		4.0
	SE	0.5			5.0				8.1		1.8
PART QUI	X	1.2									0.5
	SE	1.2									0.5
PINU VIR	X	2.8		2.0		68.3			912.6		208.0
	SE	1.6		---		62.1			621.1		139.1
POLY CUR	X				7.5				0.2		0.2
	SE				7.5				0.2		0.1
POTE CAM	X	0.8							17.3		4.0
	SE	0.6							11.5		2.6
PRUN SER	X	15.0	1100.0		10025.0						297.1
	SE	14.2	1100.0		9975.0						194.3
PTER AQU	X	0.4									0.2
	SE	0.4									0.2
QUER ALB	X	40.9		100.0							10.3
	SE	39.4		---							17.3
QUER FAL	X	41.4	154.1			68.4			1.5		78.8
	SE	16.9	151.4			22.4			1.5		66.8
QUER MAR	X		0.2								0.1
	SE		0.2								0.1
QUER PRI	X						75.0			90.0	2.1
	SE						---			---	---
QUER RUB	X	7.1									0.6
	SE	7.1									0.6
QUER STE	X		3.0								1.3
	SE		3.0								1.3
QUER VEL	X	25.6		100.0							12.0
	SE	24.2		---							10.7
RHEXI SP	X					1.7			47.1		10.4
	SE					1.7			31.0		6.9
RHUS COP	X	9.1		500.0							10.1
	SE	9.1		---							4.0
RHUS RAD	X	28.5									11.9
	SE	20.0									8.8
RUBU FLA	X	5.3	6.8		150.0	5.7			41.4		16.9
	SE	5.3	3.5		150.0	5.7			31.0		7.7
SASS ALB	X		5.0			1.2					2.3
	SE		4.5			1.2					2.0
SCHI SCO	X		3.0			185.4					29.4
	SE		3.0			79.0					12.4
SCUT ELL	X								1.0		0.2
	SE								0.6		0.1
SENE SMA	X	2.4				1.3					1.1
	SE	2.4				1.2					23.8
SMIL GLA	X	14.3	44.9			25.2					9.6
	SE	14.3	19.7			25.2					291.1
SMIL ROT	X	36.9	685.8	33.3			9.0		0.2		202.3
	SE	28.0	459.6	33.3			---		0.2		1.5
SOLI CAE	X				10.0				5.9		1.3
	SE				10.0				5.9		7.6
SOLI ERE	X								35.3		6.6
	SE								29.6		0.6
SOLI ODO	X		1.4								0.6
	SE		1.4								0.6
SOMC ASP	X		1.1					4.0			0.4
	SE		1.0					2.8			10.6
SORB SPP	X		13.9						22.1		6.0
	SE		10.9						22.0		141.6
STIP AVE	X	19.7	291.9	1400.0		2.1			0.9		39.2
	SE	8.6	89.0	---		2.1			0.6		0.9
TALI TER	X								4.4		1.0
	SE								4.4		9.6
TSUG CAN	X									760.0	---
	SE									---	---
UNK HERB	X			30.0							0.7
	SE			---							0.2
UNKHERB1	X		3.6								1.5
	SE		3.6								1.6
UNKHERB4	X	0.7	0.3								0.2
	SE	0.7	0.2								0.1
UNKHERB6	X	0.9	1.4								0.7
	SE	0.8	1.0								0.4
VACC ARB	X	10098.1	304.0	166.7							1080.7
	SE	2467.5	193.0	166.7							294.4
VACC STA	X		24.2		350.0			500.0			27.2
	SE		21.3		---			500.0			13.6
VACC VAC	X	124.3	1395.4			40.4					600.1
	SE	95.2	802.5			40.4					353.4
VERO OFF	X		0.5								0.2
	SE		0.4								0.2
VIOL PRI	X				10.0				4.3		1.2
	SE				10.0				2.8		9.6
VITI ROT	X									8.0	0.1
	SE									---	---
Total No. Plots	7	33	3	1	2	12	1	2	17	1	79

¹Species abbreviations are explained in Appendix, Table 22.²Present but less than 0.05 cm².

Table 20. Average environmental conditions of the Tree Zone understory communities.

Variable ¹		Community										ALL SAMPLE PLOTS
		VACC ² ARB	VACC- SMIL ROT	ACER RUB	DIOS VIR	PRUN SER	Grass- Forb	QUER PRI	LIQU STY	PINU VIR	VITI ROT	
Aspect	$\bar{X}$	0.29	0.55	0.29	----- ³	0.64	0.73	0.64	0.82	1.18	1.92	0.71
	SE	0.00	0.12	-----	-----	-----	0.26	-----	0.18	0.18	-----	0.09
	s		a				ab		ab	b		
Slope	$\bar{X}$	4.0	7.3	4.0	0.0	3.5	4.7	9.0	17.0	6.0	7.0	6.3
angle	SE	3.0	1.3	4.0	-----	3.5	1.3	-----	12.0	2.5	-----	0.9
(°)	s	a	a	a		a	a		a	a		
Micro-	$\bar{X}$	2.5	2.1	1.7	2.0	2.0	1.9	2.0	2.0	2.2	2.0	2.1
topo-	SE	0.7	0.1	3.5	-----	0.0	0.0	-----	0.0	0.2	-----	0.1
graphy	M ⁵	2	2	2	2	2	2	2	2	2	2	
	s	a	a	a	a	a	a	a	a	a	a	
Shading	$\bar{X}$	6.6	6.3	6.5	-----	6.5	5.8	6.0	5.0	6.1	7.0	6.2
	SE	0.2	0.2	0.5	-----	0.5	2.9	-----	0.0	0.1	-----	0.1
	M	7	6	6.5		6.5	6	6	5	6	7	
	s	a	a	a		a	a	a	a	a	a	
Percent	$\bar{X}$	86.4	77.5	73.3	75.0	80.0	13.4	80.0	95.0	74.3	60.0	73.1
canopy	SE	1.4	2.6	9.3	-----	-----	3.1	-----	-----	5.2	-----	2.2
closure	s	b	b	ab			a			b		
Canopy	$\bar{X}$	7.6	7.3	7.0	6.8	7.0	4.5	11.0	10.0	7.5	7.0	7.0
height	SE	0.8	0.4	4.0	-----	-----	0.4	-----	-----	0.6	-----	0.3
(m)	s	b	b	b			a			b		
Soil	$\bar{X}$	16.9	13.0	10.0	17.5	20.0	13.4	-----	5.0	9.3	3.0	12.2
depth	SE	6.0	2.1	10.0	-----	16.0	3.1	-----	5.0	2.6	-----	1.3
(cm)	s	a	a	a		a	a		a	a		
Thickness	$\bar{X}$	2.5	3.3	2.0	1.0	3.0	1.7	-----	8.0	2.9	3.0	2.8
O ₁ soil	SE	0.5	0.4	-----	-----	2.0	0.4	-----	-----	0.3	-----	0.2
horizon (cm)	s	ab	b			ab	a			ab		
Thickness	$\bar{X}$	3.0	3.5	1.0	4.0	2.5	3.8	-----	2.0	4.3	0.0	3.5
O ₂ soil	SE	0.7	0.5	-----	-----	0.5	0.7	-----	-----	1.4	-----	0.4
horizon (cm)	s	a	a			a	a			a		
Thickness	$\bar{X}$	13.5	4.6	15.0	13.0	7.5	5.8	-----	0.0	7.4	0.0	6.3
A soil	SE	5.0	1.3	-----	-----	7.5	1.8	-----	-----	2.9	-----	1.0
horizon (cm)	s	b	a			ab	ab			ab		
Thickness	$\bar{X}$	7.5	2.5	15.0	0.0	7.5	3.8	-----	0.0	1.5	0.0	3.2
B soil	SE	4.3	1.2	-----	-----	7.5	2.0	-----	-----	1.5	-----	0.8
horizon (cm)	s	a	a			a	a			a		
pH A soil	$\bar{X}$	4.25	4.01	-----	3.90	-----	3.81	-----	-----	3.70	-----	3.94
horizon	SE	-----	0.07	-----	-----	-----	0.11	-----	-----	0.40	-----	0.06
	s		a				a			a		

¹Scales for variables appear in Table 2, page 21.²Species abbreviations are explained in Appendix, Table 22.³Dashed lines indicate missing or insufficient data.⁴Results of multiple mean or median comparison tests. Communities which share a letter are not significantly different ($p=0.05$).⁵Median.

this community and the P. virginiana Community of the Shrub-Herb Zone, the two are only 14% similar in vegetation (Sørensen's (1948) quantitative index of similarity).

Vaccinium arboreum dominated areas with relatively deep soil (mean of 16.9cm) (Table 20), and high canopy closure (86.4%). Vegetationally, the V. arboreum Communities of the Shrub-Herb and Tree Zones are 66% similar.

Many taxa are important in the V. vacillans-Smilax rotundifolia Community. Associates include V. arboreum, Nyssa sylvatica, and Stipa avenacea (Table 19). Stipa forms a sward beneath trees at the Jamestown Barrens. This community is 29% similar in vegetation to the V. vacillans-Smilax rotundifolia Community of the Shrub-Herb Zone, and not significantly different environmentally.

Other communities were too infrequent to be adequately documented. All but one--the Vitis rotundifolia Community--were dominated by tree seedlings or subsaplings: Acer rubrum, Liquidambar styraciflua, Prunus serotina, Diospyros virginiana, or Quercus prinus. That these subsaplings were important in only 13% of the understory sample plots substantiates the high mortality rate postulated for deciduous saplings noted previously (pages 86-88).

Dominants of some forest understory communities are similar to those of the Shrub-Herb Zone, but proportions of taxa differ, and a somewhat different flora is encountered. Young trees become an important element, too, in the Tree Zone understory. The Shrub-Herb Zone, then, is not simply an extension of the Tree Zone understory, or vice versa. The two must be regarded separately.

Other studies have noted the prominence of the dominant understory shrubs. Vaccinium vacillans, V. stamineum, Gaylussacia baccata, and Kalmia latifolia are all important understory taxa on sandstone in southern Ohio (Griggs 1914), and Braun (1935) cited all but V. stamineum on sandstone in the Cumberland Mountains, too. Rhododendron catawbiense, Kalmia, V. arboreum, Gaylussacia, and Sorbus melanocarpa were cited in forest understory over granite in the Blue Ridge by Oosting and Anderson (1937). Another species in the understory of xeric forests of the northern Cumberland Plateau, as at Pickett State Forest, is G. brachycera, the "box huckleberry."

Measured environmental variables that best differentiate the communities are shading (percent canopy closure) and aspect (Table 20). Aspect generally increases away from the origin on axis 1 (Figure 22) of the ordination, while canopy closure decreases (Figure 23). These two variables are negatively correlated ($r=-0.33$ at $p<0.025$). Aspect is also negatively correlated with soil pH ($r=-0.47$, $p<0.068$). Thus more southwesterly aspects have higher canopy cover and less acid soils than less exposed aspects. Soil depth also increases with higher percent canopy closure ($r=0.56$, $p<0.001$). However, a more thorough study of the interrelationship of aspect, shading, and soil depth with soil moisture levels is desirable.

Comparison of Vascular Plant Communities Across Zones

Environment. Vegetation differences between life form zones can be explained as a consequence of environmental differences.

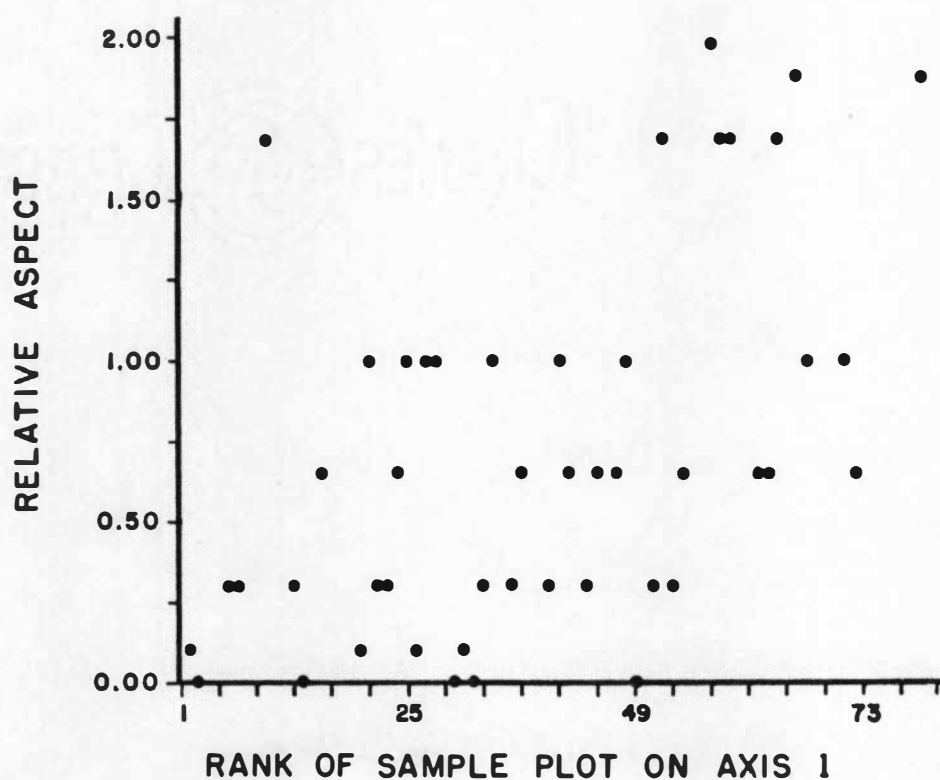


Figure 22. Aspect of Tree Zone understory sample plots as they were arranged along axis 1 of the Reciprocal Averaging Ordination. Sample plots were ranked in the order they occurred on axis 1. Scaling for aspect is in Table 2, page 21.

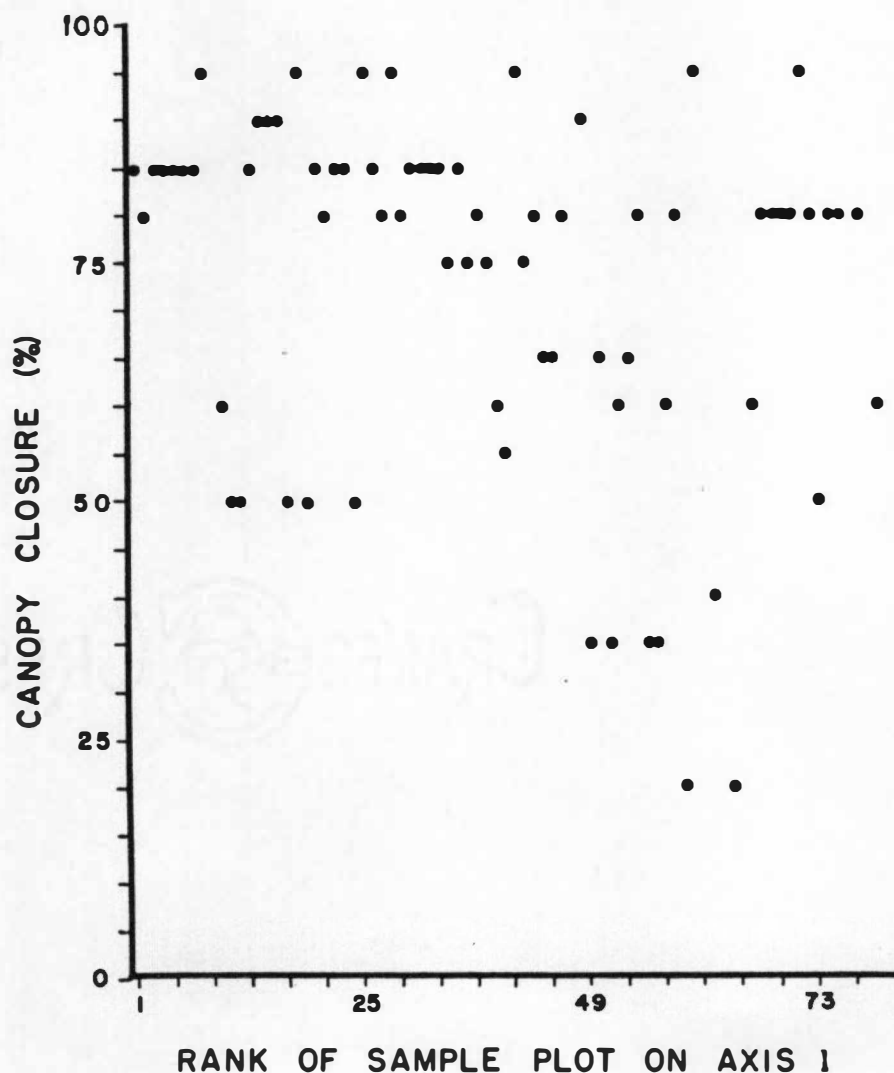


Figure 23. Percent canopy closure of Tree Zone understory sample plots as they were arranged along axis 1 of the Reciprocal Averaging Ordination. Sample plots were ranked in the order they occurred on axis 1.

With respect to vascular plants, shading (understory) varied significantly between zones ($p < 0.20$), increasing from the Cryptogam-Herb to the Shrub-Herb to the Tree Zone. Soil depth increased significantly from the Cryptogam-Herb to the Shrub-Herb Zone ($p < 0.05$) but not between the Shrub-Herb and Tree Zones.

Flora. Occurrence of vascular taxa was compared across life form zones. The Tree Zone was most diverse, with 92 taxa, 51% of which were limited to that zone. Next in diversity was the Shrub-Herb Zone, with 58 taxa of which 21% were unique. The Cryptogam-Herb Zone had only 13 taxa, all of which occurred with at least low frequency in other zones.

Adjacent zones were more floristically similar than non-adjacent zones, as expected. Sørensen's (1948) floristic index of similarity was 31.0% between the Cryptogam-Herb and Shrub-Herb Zone, 58.9% between the Shrub-Herb and Tree Zone, and 24.8% between the Cryptogam-Herb and Tree Zone.

The harsh environment of the Cryptogam-Herb Zone with its shallow soil and full exposure to insolation may restrict the number of species able to inhabit it. Most communities of the Shrub-Herb Zone also receive intense insolation, although drought stress is ameliorated by deeper soil. The species most tolerant of these conditions are the outcrop endemics or near-endemics, e.g., Talinum teretifolium, Arenaria glabra, Bigelovia nuttallii, Sedum smallii, and Helianthus longifolius, which occur predominantly in the Cryptogam-Herb and Shrub-Herb Zones.

Species importance values. Importance (relative cover) of species in several broad life form categories was compared between zones in Figure 24. Generally, these differences reflect the zonation that initiated delineation of life form zones. Herbs made up 100% of the Cryptogam-Herb Zone vascular plants, but were half as important in the Shrub-Herb Zone, and only slightly important in the Tree Zone. Shrubs were also important in the Shrub-Herb Zone, and even more important in the Tree Zone understory. Note also the differing compositions of the Tree Zone canopy, saplings, and understory strata.

Certain species act as indicators of environmental differences between the zones. The shade-tolerant Mitchella repens and Chimaphila maculata were only sampled in the Tree Zone. Heliophiles such as Andropogon virginicus, Liatris microcephala, and Schizachyrium scoparium, although not confined to the Cryptogam-Herb and Shrub-Herb Zones, were most important there.

Communities. Sørensen's (1948) quantitative index of similarity was calculated between each pair of communities. As discussed in text, only a few communities were very similar. The Vaccinium arboreum Communities of the Shrub-Herb and Tree Zone understory were 65.9% similar. The Grass-Forb Communities of the Shrub-Herb and Tree Zone understory were 48.6% similar. Other pairs of communities were less vegetationally similar. The life form zones are therefore vegetationally distinct, each with its own communities.

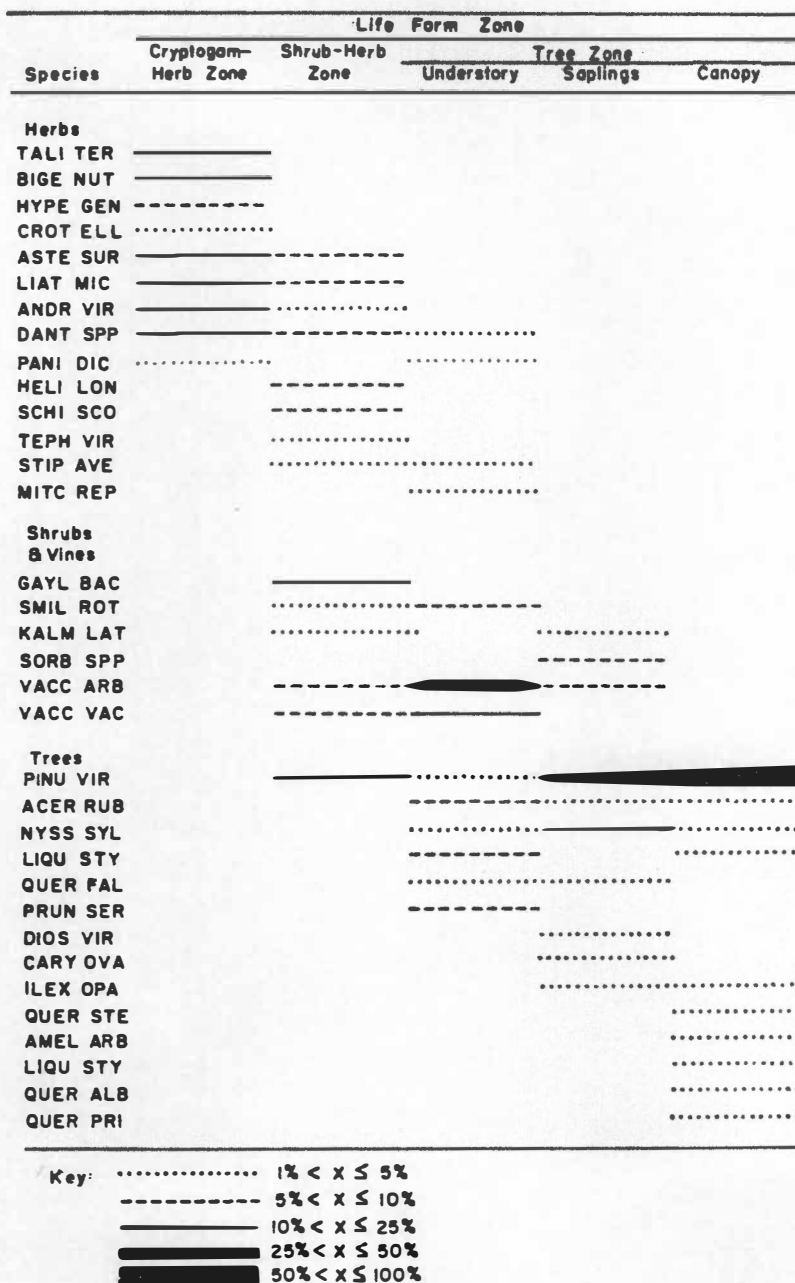


Figure 24. Percent importance of vascular plant species in each life form zone. Importance is based on relative cover (%) in Cryptogam-Herb Zone, Shrub-Herb Zone, and Tree Zone understory; percent relative density of Tree Zone saplings; and percent importance (basal area + relative density) of canopy trees. Species abbreviations are explained in Appendix, Table 22.

III. COMPARISON OF SOIL CHARACTERISTICS WITH THOSE OF SIMILAR STUDIES

Other Outcrops

Few studies have dealt with soil characteristics of sandstone outcrops. Braun (1935) measured soil pH in water on two outcrops on Pine Mountain, Kentucky: soil pH of the first outcrop varied from 3.9 to 3.98; pH of the A horizon of the second was 3.9, but that of the sand layer beneath was 4.57. These figures are close to the averages of soil pH of the A horizons of the Shrub-Herb and Tree Zones of the present study--3.96 and 3.94.

Of other kinds of rock outcrops studied in the southeastern United States, granitic outcrops are most environmentally like sandstone outcrops. Limestone differs because of higher pH of the rock, different sorts of habitats available (including gravel, or "pavement") (Quarterman 1950), and a different moisture regime (Quarterman 1950). Shale barrens (Platt 1951) are also different since plants grow through a layer of rock fragments. Granitic outcrops are massive rocks, as are the Plateau sandstones, and have low pH.

Shure and Ragsdale (1977) measured soil pH in three island communities on open granitic rock on the Georgia Piedmont. Soil pH was about 4.3 in Sedum smallii dominated islands, 4.4 in Lichen-Annual Herb islands, and 4.7 in Annual-Perennial Herb islands. Weakley (1979) found comparable soil pH's on a granitic outcrop in the North Carolina Blue Ridge: grass-herb mats had pH 4.7; islands of Hypericum gentianoides averaged 4.6; one vegetation mat with a small shrub had a

soil pH of 5.1. In the present study, soil pH was much lower: 3.99 in the Grass-Forb Community and 4.25 in the Helianthus longifolius-Danthonia sericea Community of the Shrub-Herb Zone. Some of the communities of the present study were not islands, however. From these studies, sandstone outcrop soils on the Cumberland Plateau are more acid than those of granite, possibly because of different composition of the two rock types: the sandstones studied are almost pure quartz, while the granitic rocks are a mixture of minerals, including basic feldspars.

Soil is also apparently deeper on granitic outcrops. Shure and Ragsdale (1977) reported mean mineral soil depths of about 3cm in Sedum smallii mats, 5cm in Lichen-Annual Herb mats, and 22cm from Annual-Perennial Herb mats. Weakley (1979) reported soils to 14cm deep beneath a Hypericum gentianoides-Polygala curtisii community. However, a Danthonia spicata-Schizachyrium scoparium-Solidago bicolor community was on only 4.5cm of soil. In the present study, in contrast, average mineral soil depth was 2.6cm in Talinum-Grass-Annual Forb communities, 0.5cm in Bigelowia communities, 0.4cm for the Panicum dichotomum Community, and 10.6cm for the Aster-Liatris Type of the Cryptogam-Herb Zone. Annual-perennial herb communities of the Shrub-Herb Zone, the Grass-Forb and Helianthus-Danthonia Communities, had 13.8 and 12.2cm of soil, respectively.

Similar Tree Communities

Values of soil characteristics measured from the Pinus virginiana Community (Tree Zone canopy) in the present study are

comparable to those determined by Hinkle (1978) for his P. virginiana Community. He did not sample shallow soils, however (his averaged 66.6cm deep as opposed to 12.2cm in the Tree Zone of the present study). Organic horizons are apparently thicker on sandstone outcrops than his forests (5.4cm compared to 1.39cm), but the A and B horizons were far thicker in Hinkle's (1978) study. Hinkle also recorded soil pH in water (1:1), 3.75 in the A and 4.03 in the B horizon, the most acidic of any community he sampled on the Plateau. Soil pH of the A horizon averaged 3.94 in the present study.

Hinkle (1978) also measured soil characteristics not measured in the present study. He found 2.04ppm phosphorus in the A and 1.00ppm in the B horizon; 36.33ppm potassium in the A and 31.22ppm in the B horizon. These mineral concentrations were some of the lowest figures obtained for xeric upland Plateau forests, especially in the B horizon. Available water holding capacity was not unusual for the uplands, however, 0.21 in the A and 0.18 in the B horizon. The texture of the A horizon ranged from sandy loams to loam/silt loams, but most were sandy loams or loams; other upland forest soils usually had more clay. The B horizons ranged from loams to silty clay loams, but most were between sandy loams and loam/silt loams, also low in clay.

Wade (1977) also measured soil characteristics of his P. virginiana Community on the Plateau. His soils were even closer to those of the present study since they ranged from 20 to 80cm deep (mean of 43cm). Textures were mostly silty loams to sandy loams. Soil pH was strongly to extremely acid. Wade noted that surface stone made up to 30% of the soil of his cliff-edge plots.

Smalley (1979) used data from soil surveys to describe soils of "sandstone glades, rock outcrops, and Plateau edges" on the Cumberland Plateau south of the Tennessee River. He described the soils as fine sandy loams, sandy loams, and loams; to 20 inches deep; well to excessively drained; with low soil fertility. He noted that dark brown or gray soils around the outcrop had a large percentage of organic matter, as noted in the present study.

CHAPTER VI

FLORISTIC COMPARISON OF RESEARCH AREAS

I. HYPOTHESES

Sandstone outcrops offer a harsh microenvironment markedly different from the prevailing environment of the region. Vegetation is restricted to those species able to withstand the stresses of desiccation, shallow soil, great temperature extremes, and high insolation. Outcrops within the region should share many taxa, then, since only a small percentage of the total flora of the region can survive there.

The Cumberland Plateau sandstone outcrops, while similar in habitat, are discontinuous in space and can therefore be regarded as islands in the landscape. Colonization by new species must take place by long-distance dispersal or by speciation (including the selection of ecotypes). Two tenets of island biogeography (MacArthur and Wilson 1967) can be easily tested with the present data: first, that diversity increases with island size; and second, that the closer islands are, the greater their floristic similarity.

II. NUMBER OF TAXA VERSUS OUTCROP SIZE

The number of taxa collected in sampling each research area increased almost linearly with the area in plots (Figure 25), a factor that is related to outcrop size. When number of taxa was

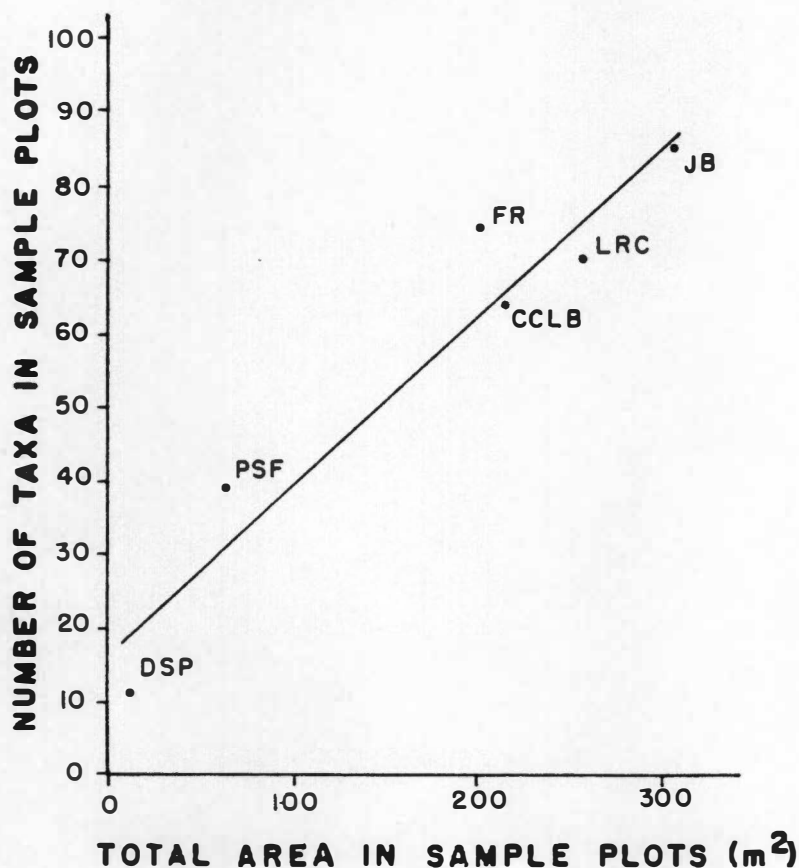


Figure 25. Number of species versus the area sampled at each research area. The linear regression line is plotted ($Y=16.6 + 0.23X$; $r=0.96$, $p<0.001$). Research areas are Little River Canyon (LRC), DeSoto State Resort Park (DSP), Clear Creek at Lilly Bridge (CCLB), Flat Rock (FR), the Jamestown Barrens (JB), and Pickett State Forest (PSF).

plotted opposite relative size of the outcrop, a curvilinear relationship was revealed (Figure 26). The hypothesis that smaller outcrops, or islands, have fewer taxa than larger outcrops is therefore accepted.

III. FLORISTIC SIMILARITY VERSUS DISTANCE

Sørensen's (1948) index of similarity, based on species presence, was calculated between each pair of research areas. Indices were plotted by distance between the areas in Figure 27. Except for the DeSoto State Resort Park site, which was undersampled due to its sensitive location in the park, similarities were roughly the same between sites, regardless of distance between them. Instead, large outcrops were most similar to one another. The results contradict the predictions of island biogeography (MacArthur and Wilson 1967), but an explanation for the conflict is not readily apparent.

IV. LIFE FORM PERCENTAGES

Another means of comparing research areas is by percentage of their total flora in each life form (Table 21). The largest outcrops, Little River Canyon, Flat Rock, the Jamestown Barrens, and Clear Creek-Lilly Bridge, were most similar. Overall, herbs predominated (48%) followed by woody taxa (26%) and lichens (16%). Lichens became more important on a small cliff-edge outcrop at Pickett State Forest (28%). Herb percentages also vary. The Clear Creek-Lilly Bridge area has a smaller herb zone than most outcrops examined.

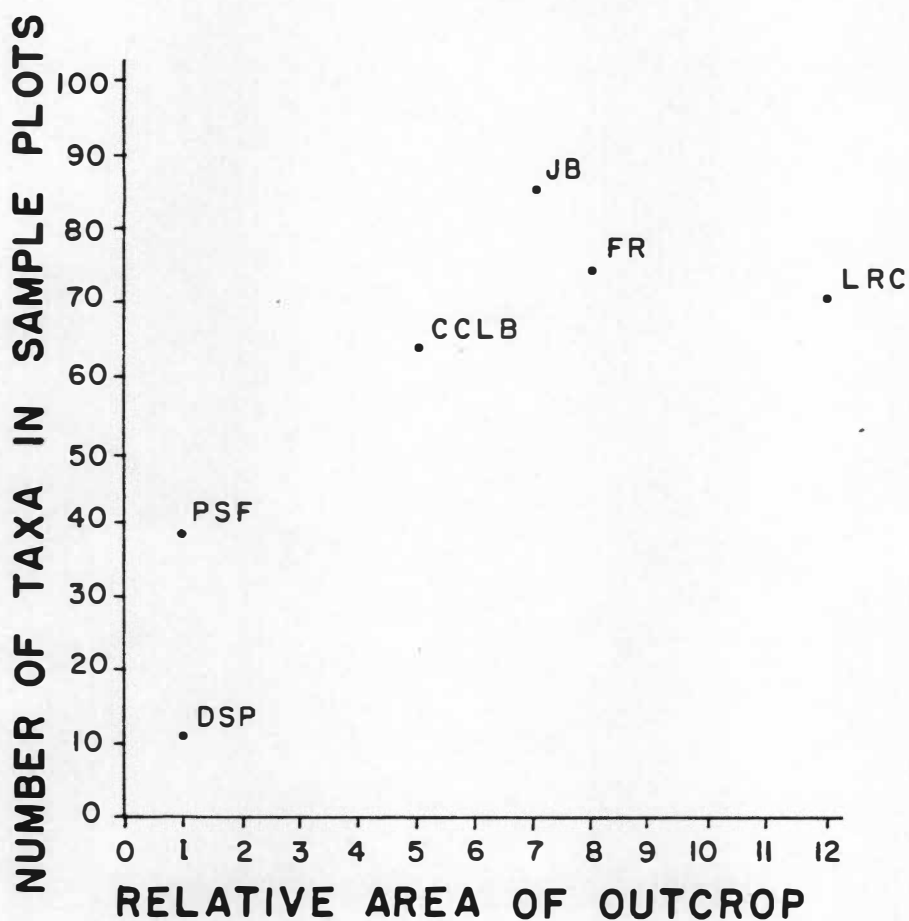


Figure 26. Number of species collected in sampling each research area relative to the area of exposed rock. Research areas are Little River Canyon (LRC), DeSoto State Resort Park (DSP), Clear Creek at Lilly Bridge (CCLB), Flat Rock (FR), the Jamestown Barrens (JB), and Pickett State Forest (PSF).

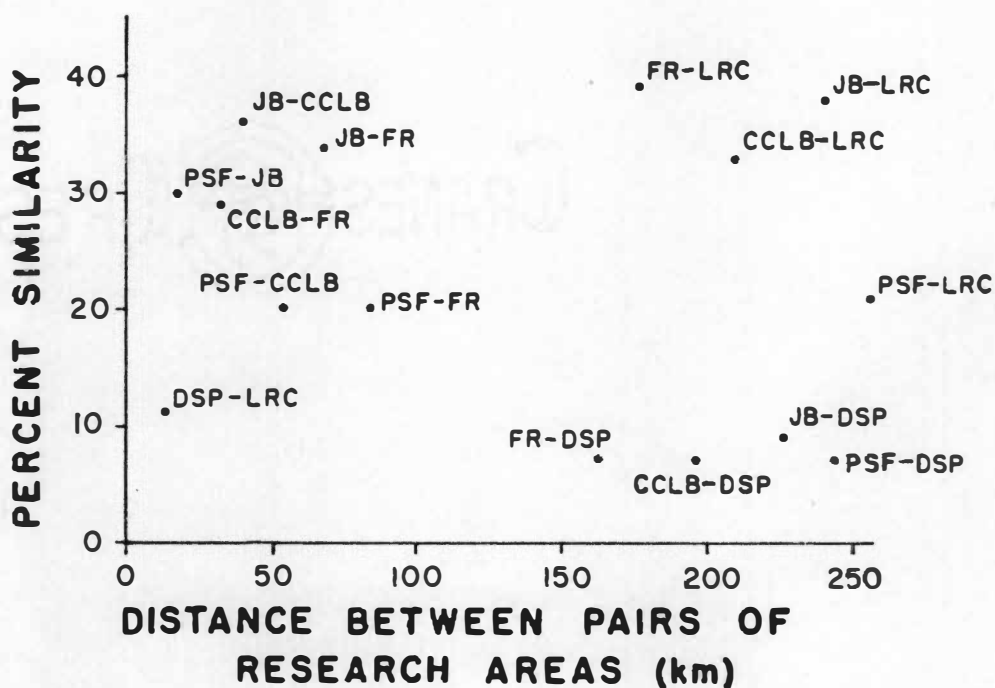


Figure 27. Sørensen's (1948) index of similarity between research areas based on species presence relative to distance between research areas. Research areas are Little River Canyon (LRC), DeSoto State Resort Park (DSP), Clear Creek at Lilly Bridge (CCLB), the Jamestown Barrens (JB), and Pickett State Forest (PSF).

Table 21. Number of species of each life form at each research area both in ("In") and in or near ("Out") sample plots.

Life Form	Research Area ^a											
	LRC		DSP		FR		CCLB		JB		PSF	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Algae	0	1	0	0	0	1	0	1	1	1	1	1
% of total taxa	0	1	0	0	0	1	0	1	1	1	3	2
Bryophytes												
Mosses	6	7	3	3	9	9	8	8	4	4	4	5
Liverworts	0	0	0	0	1	1	0	0	0	0	0	0
% of total taxa	8	8	27	10	13	10	13	11	5	4	10	8
Lichens												
Branched	4	4	3	4	4	4	3	3	1	4	4	5
Podetiate	1	1	0	1	0	2	3	3	4	4	0	2
Squamulose	2	2	0	0	2	2	3	4	3	3	2	2
Podetiate-squamulose	1	1	0	1	1	1	1	1	4	4	1	1
Crustose	3	3	0	0	4	4	4	5	6	6	4	5
Foliose	1	1	0	1	1	1	2	2	1	1	1	1
Umbilicate	0	0	0	0	0	0	2	2	0	0	0	1
% of total taxa	17	14	27	24	16	14	29	27	22	20	32	28
Pteridophytes	0	0	0	0	0	1	1	1	0	1	0	0
% of total taxa	0	0	0	0	0	1	2	1	0	1	0	0
Herbs												
Graminoids	7	10	2	3	9	16	3	5	9	14	5	7
Small herbs	6	9	0	3	6	6	3	5	3	8	0	1
Succulents	1	2	0	1	0	0	1	1	0	0	0	0
Trailing	2	2	0	0	2	3	1	1	3	3	1	1
Forbs	10	15	0	4	11	17	2	5	20	29	7	8
% of total taxa	37	44	18	38	37	43	16	23	40	49	34	28
Woody Plants												
Woody vines	3	4	0	1	5	5	3	3	3	3	1	2
Small shrubs	1	1	0	0	0	0	2	2	1	2	1	3
Medium shrubs	4	4	0	1	2	4	3	4	2	2	0	0
Large shrubs	1	1	0	1	1	1	2	2	3	3	1	2
Succulents	0	0	0	0	0	0	0	0	1	1	0	0
Trailing	2	2	0	1	2	2	1	2	2	2	0	1
Trees	15	16	3	4	15	18	15	15	14	16	5	12
% of total taxa	37	33	27	28	33	31	43	37	32	26	21	33
Area sampled (m²)	257		11		200		213		305		61	
											1047	

^aThe research areas are as follows: LRC=Little River Canyon, DSP=DeSoto State Resort Park, FR=Flat Rock, CCLB=Clear Creek at Lilly Bridge, JB=Jamestown Barrens, PSF=Pickett State Forest.

CHAPTER VII

SUCCESSION

Life form zones probably represent stages in plant succession from rock to forest, but as a ready means of dating the zones was unavailable, this hypothesis was not tested. If the zones are successional, then the variety of communities and microhabitats observed within zones indicates that succession on these outcrops is complex.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Various communities were discerned within each stratum (canopy trees, other vascular plants, non-vascular plants) of each life form zone -- (A) Lithophyte, (B) Cryptogam-Herb, (C) Shrub-Herb, and (D) Tree Zones--on Cumberland Plateau sandstone outcrops. Communities were delineated among plot samples with Reciprocal Averaging Ordination and/or Hierarchical Agglomeration.

The most environmentally and vegetationally distinct zone is the (A) Lithophyte Zone, with plants growing on bare rock. Most of this zone is exposed to intense insolation and irregularly available moisture. Basins and drains may be periodically or seasonally inundated, however.

The most common Lithophyte Zone community is composed of (1) various crustose lichens and the foliose lichen, Xanthoparmelia conspersa. This community usually covers most of the unshaded rock, especially where inundation is rare or absent. Basins, though, may be vegetated by the (2) Powder Crustose Lichen Community, or, if inundated for long periods of time, a (3) Filamentous Algae Community. Somewhat shaded rock is often covered by a community composed of (4) filamentous algae and inkspot crustose lichen. Two communities are mat-forming: dominated by the moss, (5) Grimmia laevigata, or the branched lichen, (6) Cladonia caroliniana. These communities are not important at every outcrop examined. Tiny cracks and crevices are usually filled with the

(7) Squamulose Cladonias Community, which occasionally forms mats.

In contrast to the Lithophyte Zone, the Cryptogam-Herb, Shrub-Herb, and Tree Zones usually possess soil. Of these zones, the (B) Cryptogam-Herb Zone is the most exposed to insolation and has the least soil to buffer its vegetation from desiccation. Non-vascular plants predominate, as in the Lithophyte Zone, but a few vascular plants are able to flourish under these conditions as well.

Among the non-vascular plant communities of the Cryptogam-Herb Zone, the (1) Sphagnum spp. Community occupies the areas that receive the most regular seepage moisture. The (2) Aulacomnium palustre Type also prefers moist sites, but is less common. Other communities are the (3) Campylopus pilifer (moss), (4) C. flexuosus-Cladonia strepsilis (squamulose lichen), (5) C. dimorphoclada (branched lichen), (6) C. caroliniana-Polytrichum commune (moss), (7) P. juniperinum, (8) Reindeer Lichen (Cladina spp.), (9) Cladonia squamosa (squamulose, podetiate lichen), (10) Squamulose Cladonias (mixture of species), and (11) C. caroliniana-P. juniperinum Communities. On Lookout Mountain, a (12) C. leporina Community also occurred. Seepage moisture, shading, and perhaps soil depth, are important factors in community distribution.

While many non-vascular plant dominants of the Cryptogam-Herb Zone are important in other life form zones, the vascular plant vegetation is unique. At the southernmost site (Little River Canyon), (1) Bigelowia nuttallii forms a monospecific community on shallow soil

among moss mats in full sun. At other sites, the (2) Talinum teretifolium-Grass-Annual Forb Community occupies these habitats. Hypericum gentianoides, Crotonopsis elliptica, Danthonia sericea, and Andropogon virginicus or Schizachyrium scoparium are virtually ubiquitous members of this community, while Talinum and Arenaria glabra are conspicuous members at some sites. On slightly deeper soil, a (3) Liatris microcephala-Aster surculosus Community may predominate. Seepy Sphagnum mats are occupied by another community dominated by (4) Panicum dichotomum, with Viola primulifolia and Lycopus virginicus as associates. Two communities were observed but not sampled: the winter annual, (5) Sedum smallii, often covers shallow soil on sites in Alabama and southern Tennessee in the spring; and (6) Selaginella rupestris may also cover shallow soil in Alabama (not on any outcrops sampled, however). Moisture, soil depth, and shading are probably important factors in this zone.

The (C) Shrub-Herb Zone is in many ways a transition from Cryptogam-Herb to Tree Zone understory. Soil depth is greater than in the former, and light intensity is lower, but insolation is greater than beneath the forest canopy. Non-vascular plants are also influenced by vascular plants present, through shading and litter. Many dominants are also important in other zones.

Moist areas of the Shrub-Herb Zone are occupied by the (1) Aulacomnium palustre Community; P. commune is a co-dominant. The latter is an important species over a wide range of environmental conditions in the zone. Sunny, moderately moist areas are dominated

by the (2) Cladonia caroliniana and (3) C. caroliniana-P. commune Communities. Polytrichum juniperinum replaces P. commune as moisture decreases, forming a (4) C. caroliniana-P. juniperinum Community. Moist, shaded areas are occupied mostly by a (5) P. commune Community, grading into a (6) Reindeer Lichen-P. commune Community to a (7) Reindeer Lichen Community as moisture decreases. A (8) Dicranum condensatum moss community also occurs in dry shaded situations. Finally, (9) Cladonia chlorophaea, (10) Leucobryum albidum, and (11) Campylopus flexuosus Communities are occasional.

Vascular plant communities of the Shrub-Herb Zone are dominated either by herbs or woody plants, the latter usually dominating an area near the Tree Zone. Of the two herb-dominated types, the (1) Helianthus longifolius-Danthonia sericea Community was found only on Lookout Mountain. The (2) Grass-Forb Community was ubiquitous. Dominants of the latter include Liatris microcephala, Aster surculosus, Danthonia sericea, and Andropogon virginicus (seedling Pinus virginiana, Smilax rotundifolia, and S. glauca are also common). Other communities are dominated by (3) Vaccinium arboreum, (4) V. vacillans and S. rotundifolia, (5) Kalmia latifolia, (6) P. virginiana subsaplings, or (7) Gaylussacia baccata. The latter was dominant on shallow acid soils at the Clear Creek-Lilly Bridge research area.

The (D) Tree Zone canopy is vegetated by the Pinus virginiana Community. A single plot was dominated by Tsuga canadensis, however, at a site probably more mesic than normal, in part due to a northerly aspect. Usually sites were xeric, however.

Pinus virginiana was important in the canopy in all size classes. Other species were also important in size classes below about 9cm dbh. Large trees of any species were rare. Samples taken from forests bordering the outcrops usually were more diverse than those from vegetation islands on the rock, reflecting the more extreme environmental conditions of the latter (shallower soil, greater insolation from reflected light, less seepage moisture). Tree cores indicate that island trees may be stunted.

The Tree Zone non-vascular plant stratum is similar to that of the Shrub-Herb Zone but sparser. Again, (1) Reindeer Lichen and (2) Dicranum scoparium Communities dominate dry, shaded sites. The (3) Cladonia caroliniana-Polytrichum juniperinum, (4) C. strepsilis, and (5) C. subcariosa Communities occur in more open, dry areas. In intermediate sites, (6) D. condensatum, (7) Mixed Squamulose Cladonias, (8) L. albidum, and (9) Campylopus flexuosus Communities predominate. A (10) Polytrichum commune Community is common in more moist sites. Several communities occur in moist, shaded sites in the Tree Zone: the (11) Sphagnum spp. (not the same taxa as in the Cryptogam-Herb Zone), (12) Thuidium delicatulum, (13) Hypnum curvifolium, and (14) Aulacomnium palustre communities.

The Tree Zone vascular plant understory is similar to the Shrub-Herb Zone, too. (1) Vaccinium vacillans-Smilax rotundifolia, (2) V. arboreum, (3) Pinus virginiana subsaplings, and (4) Grass-Forb Communities all occur. Communities dominated by subsaplings of (5) Acer rubrum, (6) Diospyros virginiana, (7) Prunus serotina, (8) Quercus

pinus, (9) Liquidambar styraciflua, and (10) Vitis rotundifolia (vine) each occupy a few sample plots, too, however. Composition of the communities is usually different from those of the Shrub-Herb Zone, and environmentally the plants are much more shaded.

A floristic comparison of research areas revealed that no two sandstone outcrops studied were alike. Nevertheless these outcrops are also very similar when examined with reference to the predominant vegetation of the region. Some communities were observed at only one or two areas, as discussed, but most were ubiquitous. The research areas were also similar floristically when Sørensen's (1948) index of similarity was calculated between each pair. The major factor affecting diversity and similarity appeared to be outcrop size: large outcrops have the most species and are similar to one another regardless of distance between them. Small outcrops are often floristically unique. Similar percentages of different life forms occurred at each research area.

Sandstone outcrops represent a unique habitat with their peculiar assemblage of plant communities. Many species are not common elsewhere on the Cumberland Plateau, e.g., Liatris microcephala. Others are outcrop endemics, not necessarily restricted to sandstone (an example is Talinum teretifolium). Still others, such as Coreopsis pulchra (cited from samples in the Tree and Shrub-Herb Zones), are narrow endemics, in this case restricted to Lookout Mountain.

Relatively undisturbed Plateau sandstone outcrops deserve protection as unique habitats. They also offer unlimited possibilities for research on drought stress physiology, ecotypes, island biogeography and succession.

LITERATURE CITED

LITERATURE CITED

- Ashton, D. H., and R. N. Webb. 1977. The ecology of granite outcrops at Wilson's Promontory, Victoria. *Australian Journal of Ecology* 2:269-296.
- Baskin, C. C., and J. M. Baskin. 1975. Additions to the herbaceous flora of the Middle Tennessee cedar glades. *Journal of the Tennessee Academy of Science* 50:25-26.
- _____. 1977. Seed and seedling ecology of *Opuntia compressa* in Tennessee cedar glades. *Journal of the Tennessee Academy of Science* 52:118-122.
- _____. 1978. Plant ecology of cedar glades in the Big Barren Region of Kentucky. *Rhodora* 80:545-557.
- Baskin, J. M., E. Quarterman, and C. Caudle. 1968. Preliminary checklist of the herbaceous vascular plants of cedar glades. *Journal of the Tennessee Academy of Science* 43:65-71.
- Beers, J. W., P. E. Dress, and L. C. Wensel. 1966. Aspect transformation in site productivity research. *Journal of Forestry* 64:691-692.
- Berg, J. D. 1974. Vegetation and succession on Piedmont granitic outcrops of Virginia. Master's thesis. College of William and Mary, Williamsburg, Virginia, USA.
- _____. 1981, in press. Terrestrial microcosms--A state of the art review. Pages 1-16. In Working papers prepared as background for testing for effects of chemicals on ecosystems. National Research Council Committee to Review Methods for Ecotoxicology. National Academy Press, Washington, District of Columbia, USA.
- Braun, E. L. 1935. The vegetation of Pine Mountain, Kentucky. *American Midland Naturalist* 16:517-565.
- _____. 1950. Deciduous forests of eastern North America. Hafner Publishing Company, New York, New York, USA.
- Burbanck, M. P., and R. B. Platt. 1964. Granite outcrop communities of the Piedmont Plateau in Georgia. *Ecology* 45:292-306.
- Cain, S. 1938. The species-area curve. *American Midland Naturalist* 19:578-581.

- Committee for Tennessee Rare Plants. 1978. The rare vascular plants of Tennessee. *Journal of the Tennessee Academy of Science* 53: 128-133.
- Conard, H. S. and P. L. Redfearn, Jr. 1979. How to know the mosses and liverworts. 2nd edition. William C. Brown Company Publishers, Dubuque, Iowa, USA.
- Cooper, W. S. 1913. The climax forest of Isle Royale, Lake Superior, and its development. II. The successions. *Botanical Gazette* 55:115-140.
- Core, E. L. 1966. Vegetation in West Virginia. McClain Printing Company, Persons, West Virginia, USA.
- Cronquist, A. 1980. Vascular flora of the southeastern United States. I. Asteraceae. University of North Carolina Press, Chapel Hill, North Carolina, USA.
- Crum, H. 1976. Mosses of the Great Lakes Forest. University of Michigan Press, Ann Arbor, Michigan, USA.
- Culberson, C. F. 1969. Chemical and botanical guide to lichen products. University of North Carolina Press, Chapel Hill, North Carolina, USA.
- _____. 1970. Chemical and botanical guide to lichen products. Supplement. *Bryologist* 73:177-377.
- _____. 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. *Journal of Chromatography* 72:113-125.
- _____. 1974. Conditions for the use of Merck silica gel 60 F254 plates in the standardized thin-layer chromatographic technique for lichen products. *Journal of Chromatography* 97:1-108.
- Culberson, C. F., W. L. Culberson, and A. Johnson. 1977. Chemical and botanical guide to lichen products. Second supplement. American Bryological and Lichenological Society, Missouri Botanical Garden, St. Louis, Missouri, USA.
- Culberson, C. F. and H. Kristinsson. 1970. A standardized method for the identification of lichen products. *Journal of Chromatography* 46:85-93.
- Delcourt, P. A., and H. R. Delcourt. 1979. Late Pleistocene and Holocene distributional history of the deciduous forest in the

southeastern United States. Veröffentlichungen des Geobotanischen Institutes der ETH, Stiftung Rübel (Zürich) 68:79-107.

- DeSelm, H. R. In press. Characterization of some Southeastern barrens. In Proceedings of the Sixth North American Prairie Conference. Ohio State University, Columbus, Ohio, USA.
- Dey, J. P. 1978. Fruticose and foliose lichens of the high-mountain areas of the Southern Appalachians. Bryologist 81:1-93.
- Dixon, W. J., and M. B. Brown, editors. 1977. BMDP-77: Biomedical computer programs P-series. University of California Press, Berkeley, California, USA.
- Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.
- Dunn, O. J. 1964. Multiple comparisons using rank sums. Technometrics 6:241-252.
- Ebinger, J. E. 1979. Vascular flora of sandstone outcrops in Clark County, Illinois. Castanea 44:38-44.
- Erickson, R. O., L. G. Brenner, and J. Wraight. 1942. Dolomitic glades of east-central Missouri. Annals of the Missouri Botanical Garden 29:89-101.
- Fenneman, N. M. 1938. Physiography of the eastern United States. McGraw-Hill Book Company, New York, New York, USA.
- Fink, B. 1935. The lichen flora of the United States. 2nd (1960) edition. University of Michigan Press, Ann Arbor, Michigan, USA.
- Finn, L. L. 1968. Vegetation of a cedar glade area near Mascot, Tennessee, and observations on the autecology of three Arenaria taxa. Master's thesis. The University of Tennessee, Knoxville, Tennessee, USA.
- Francis, J. K., and N. S. Loftus. 1977. Chemical and physical properties of Cumberland Plateau and Highland Rim forest soils. United States Department of Agriculture, Forest Service Research Paper SO-138, Southern Forest Experiment Station, Government Printing Office, Washington, District of Columbia, USA.
- Freeman, C. P. 1933. Ecology of the cedar glade vegetation near Nashville, Tennessee. Journal of the Tennessee Academy of Science 8:143-228.
- Friedmann, I., Y. Lipkin, and R. Ocampo-Paus. 1967. Desert algae of the Negev (Israel). Phycologia 6:185-196.

- Fritts, H. C. 1976. Tree rings and climate. Academic Press, New York, New York, USA.
- Gattinger, A. 1901. The flora of Tennessee. Gospel Advocate Printing Company, Nashville, Tennessee, USA.
- Gauch, H. G. 1977. ORDIFLEX--A flexible computer program for four ordination techniques; weighted averages, polar ordination, principal components analysis, and reciprocal averaging. Release B. Cornell University, Ithaca, New York, USA.
- Gauch, H. G., Jr., R. H. Whittaker, and T. R. Wentworth. 1977. A comparative study of reciprocal averaging and other ordination techniques. *Journal of Ecology* 65:157-174.
- Griggs, R. F. 1914. A botanical survey of the Sugar Grove Region. The Ohio State University Bulletin 18:248-340.
- Grout, A. J. 1903. Mosses with hand-lens and microscope. Published by author, New York, New York, USA.
- Hack, J. T. 1966. Interpretation of Cumberland escarpment and Highland Rim, south-central Tennessee and northeast Alabama. Geological Survey Professional Paper 524-C. United States Government Printing Office, Washington, District of Columbia, USA.
- Hale, M. E. 1969. How to know the lichens. William C. Brown Company Publishers, Dubuque, Iowa, USA.
- _____. 1979. How to know the lichens. 2nd edition. William C. Brown Company Publishers, Dubuque, Iowa, USA.
- Harper, R. M. 1906. A phytogeographical sketch of the Altamaha Grit Region of the Coastal Plain of Georgia. *Annals of the New York Academy of Science* 42:1-415.
- Heiser, C. B., Jr., D. M. Smith, S. B. Clevenger, and W. C. Martin, Jr. 1969. The North American sunflowers (*Helianthus*). *Memoirs of the Torrey Botanical Club* 22:1-218.
- Hill, M. O. 1973. Reciprocal averaging: An eigenvector method of ordination. *Journal of Ecology* 61:237-249.
- Hinkle, C. R. 1978. The relationship of forest communities and selected species to edaphic and topographic factors on the Cumberland Plateau of Tennessee. Doctoral thesis. The University of Tennessee, Knoxville, Tennessee, USA.
- Keener, C. S. 1970. The natural history of the mid-Appalachian shale barren flora. Pages 215-248 in P. C. Holt, editor. The

- distributional history of the biota of the Southern Appalachians. II. Flora. Research Division Monograph 2, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.
- Keever, C. 1957. Establishment of Grimmia laevigata on bare granite. Ecology 38:422-429.
- Keever, C., H. J. Oosting, and L. E. Anderson. 1951. Plant succession on exposed granite of Rocky Face Mountain, Alexander County, North Carolina. Bulletin of the Torrey Botanical Club 78: 401-421.
- Kruskal, W. H. and W. A. Wallis. 1952. Use of ranks in one-criterion analysis of variance. Journal of the American Statistical Association 47:585-621.
- _____. 1953. Use of ranks in one-criterion analysis of variance. Errata. Journal of the American Statistical Association 48: 905-911.
- Lipmaa, T. 1939. The unistratal concept of plant communities (the unions). American Midland Naturalist 21:111-145.
- Little, E. L., Jr. 1971. Atlas of United States trees. I. Conifers and important hardwoods. United States Department of Agriculture, Forest Service Miscellaneous Publication 1146, Washington, District of Columbia, USA.
- MacArthur, R. H. and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey, USA.
- McCormick, J. F., A. E. Lugo, and R. R. Sharitz. 1974. Experimental analysis of ecosystems. Pages 151-179 in B. B. Strain and W. D. Billings, editors. Handbook of vegetation science. VI. Vegetation and environment. Dr. W. Junk B. V., Publishers, The Hague, Netherlands.
- McCormick, J. F., and R. B. Platt. 1964. Ecotypic differentiation in Diamorpha cymosa. Botanical Gazette 125:271-279.
- McVaugh, R. 1943. The vegetation of the granitic flat-rocks of the southeastern United States. Ecological Monographs 13:119-165.
- Miller, R. A. 1974. The geologic history of Tennessee. State of Tennessee, Department of Conservation, Division of Geology, Nashville, Tennessee, USA.
- Mohlenbrock, R. H. 1975. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale, Illinois, USA.
- Mohr, C. 1901. Plant life of Alabama. Government Printing Office, Washington, District of Columbia, USA.

- Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, New York, USA.
- Murdy, W. H. 1968. Plant speciation associated with granite outcrop communities of the southeastern Piedmont. *Rhodora* 70:394-407.
- Murdy, W. H., T. M. Johnson, and V. K. Wraight. 1970. Competitive replacement of Talinum mengesii by Talinum teretifolium in granite outcrop communities of Georgia. *Botanical Gazette* 131:186-192.
- Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical package for the social sciences. McGraw-Hill Book Company, New York, New York, USA.
- Oosting, H. J., and L. E. Anderson. 1937. Vegetation of a barefaced cliff in western North Carolina. *Ecology* 18:280-292.
- _____. 1939. Plant succession on granite rock in eastern North Carolina. *Botanical Gazette* 100:750-768.
- Ozment, J. E. 1967. The vegetation of limestone ledges of southern Illinois. *Transactions of the Illinois Academy of Science* 60:135-171.
- Peech, M. 1965. Hydrogen ion activity. Pages 914-925 in C. A. Black, editor. *Methods of soil analysis. II. Chemical and microbiological properties*. Agronomy Series 9, American Society of Agronomy, Incorporated, Madison, Wisconsin, USA.
- Peterson, W. 1979. A revision of the genera Dicranum and Orthodicranum (Musci) in North America north of Mexico. *Doctoral thesis*. University of Alberta, Edmonton, Alberta, Canada.
- Platt, R. B. 1951. An ecological study of the mid-Appalachian shale barrens and of the plants endemic to them. *Ecological Monographs* 21:269-300.
- Post, W. M., and J. D. Shepherd. 1974. Hierarchical agglomeration. Processed report. The University of Tennessee, Knoxville, Tennessee, USA.
- Quartermann, E. 1950. Major plant communities of Tennessee cedar glades. *Ecology* 31:234-254.
- Radford, A. E., H. E. Ahles, and C. R. Bell. 1968. *Manual of the vascular flora of the Carolinas*. University of North Carolina Press, Chapel Hill, North Carolina, USA.

- Raunkiaer, C. 1934. The life forms of plants and statistical plant geography. Clarendon Press, Oxford, England.
- SAS Institute. 1979. SAS user's guide. 1979 edition. SAS Institute, Incorporated, Raleigh, North Carolina, USA.
- Sawyer, J. O., Jr., and A. A. Lindsay. 1963. The Holdridge bioclimatic formation of the eastern and central United States. *Proceedings of the Indiana Academy of Science* 72:105-112.
- Schofield, H. T., and L. E. Yarman. 1943. Some investigations of the water relations of lichens. *Ohio Journal of Science* 43:139-146.
- Schuster, R. M. 1966. The Hepaticae and Anthocerotae of North America. I. Columbia University Press, New York, New York, USA.
- Sharitz, R. R., and J. F. McCormick. 1973. Population dynamics of two competing annual plant species. *Ecology* 54:723-740.
- Sharp, A. J. 1939. Taxonomic and ecological studies of eastern Tennessee bryophytes. *American Midland Naturalist* 21:267-361.
- Shure, D. J., and H. L. Ragsdale. 1977. Patterns of primary succession on granite outcrop surfaces. *Ecology* 58:993-1006.
- Skorepa, A. 1973. Taxonomic and ecological studies on the lichens of southern Illinois. Doctoral thesis. The University of Tennessee, Knoxville, Tennessee, USA.
- Small, J. K. 1933. Manual of the Southeastern flora. Published by author, New York, New York, USA.
- Smalley, G. W. 1979. Classification and evaluation of forest sites on the southern Cumberland Plateau. United States Department of Agriculture, Forest Service General Technical Report SO-23. United States Government Printing Office, Washington, District of Columbia, USA.
- Society of American Foresters. 1962. Forest cover types of North America. Society of American Foresters, Washington, District of Columbia, USA.
- Sørensen, T. A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. *Det Kongelige Danske Videnskabernes Selskab, Copenhagen, Biologiske Skrifter* 5:1-34.
- Stotler, R. E. 1976. Saxicolous bryophyte and macrolichen associations in southern Illinois. I. Little Grand Canyon, Jackson County. *Bryologist* 79:1-15.
- Thomson, J. W., G. W. Scotter, and T. Ahti. 1969. Lichens of the Great Slave Lake Region, Northwest Territories, Canada. *Bryologist* 72:137-177.

- Thornbury, W. D. 1965. Regional geomorphology of the United States. Wiley and Sons, Incorporated, New York, New York, USA.
- Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. *Geographic Review* 38:55-94.
- United States Department of Agriculture, Soil Conservation Service. 1975. Soil taxonomy. Agriculture Handbook 436. United States Government Printing Office, Washington, District of Columbia, USA.
- United States Department of Commerce, Weather Bureau. 1957. Climatic summary of the United States. Section 77: Eastern Tennessee. United States Government Printing Office, Washington, District of Columbia, USA.
- _____. 1974. Climate of the states. I. Eastern states plus Puerto Rico and the United States Virgin Islands. Water Information Center, Incorporated, Manhasset Isle, Port Washington, New York, USA.
- Wade, G. L. 1977. Dry phase vegetation of the uplands of the Cumberland Plateau of Tennessee. Master's thesis. The University of Tennessee, Knoxville, Tennessee, USA.
- Ward, J. H. 1963. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association* 58: 236-244.
- Ware, S. 1967. A new *Talinum* (Portulacaceae) from the cedar glades of Middle Tennessee. *Rhodora* 69:466-475.
- Weakley, A. S. 1979. Natural area inventory--Master plan for Bluff Mountain, Ashe County, North Carolina. North Carolina Nature Conservancy, Chapel Hill, North Carolina, USA.
- West, V. and R. Stotler. 1977. Saxicolous bryophyte and macrolichen associations in southern Illinois. II. Panther's Den, Union County. *Bryologist* 80:612-618.
- Wetmore, C. 1968. Lichens of the Black Hills of South Dakota and Wyoming. Publications of the Museum, Michigan State University Biological Series 3:209-464.
- Wharton, C. H. 1977. The natural environments of Georgia. Georgia Department of Natural Resources, Atlanta, Georgia, USA.
- Wherry, E. T. 1930. Plants of the Appalachian shale barrens. *Journal of the Washington Academy of Science* 20:43-52.

- Whitehouse, E. 1933. Plant succession on central Texas granite. Ecology 14:391-401.
- Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26:1-80.
- Wiggs, D. N., and R. B. Platt. 1962. Ecology of Diamorpha cymosa. Ecology 43:654-670.
- Wilson, C. W., J. W. Jewell, and E. T. Luther. 1956. Pennsylvanian geology of the Cumberland Plateau. Tennessee Division of Geology, Nashville, Tennessee, USA.
- Winterringer, G. S., and A. G. Vestal. 1956. Rock-ledge vegetation in southern Illinois. Ecological Monographs 26:105-130.
- Wyatt, R., and N. Fowler. 1977. The vascular flora and vegetation of the North Carolina granite outcrops. Bulletin of the Torrey Botanical Club 104:245-253.

APPENDIX

APPENDIX

Table 22. Species of sandstone outcrops of the Cumberland Plateau.

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
ACER RUB	<u>Acer rubrum</u> L.	T	xx ^d		XX	XX	XX	XX	
AGRO ELL	<u>Agrostis elliottiana</u> Schultes	G							X
AGRO HYE	<u>A. hyemalis</u> (Walter) BSP.	G			XX				
AGRO PER	<u>A. perennans</u> (Walter) Tuck.	G					XX		
AGRO STO	<u>A. stolonifera</u> L.	G			XX				
AGROSTIS	<u>Agrostis</u> sp.	G			XX				
ALGAE	Algae, blue-green and green filamentous species	A			X		XX	XX	X
AMEL ARB	<u>Amelanchier arborea</u> (Michaux f.) Fernald	T	XX		XX	XX	XX	XX	
ANDR TER	<u>Andropogon ternarius</u> Michaux	G			X				
ANDR VIR	<u>A. virginicus</u> L.	G	XX	XX	XX	X	XX	XX	X
ANIS CAP	<u>Anisostichus capreolata</u> (L.) Bureau	V	XX		XX		XX	X	
AREN GLA	<u>Arenaria glabra</u> Michaux	H-		X		XX	XX		X
ARIS LON	<u>Aristida longespica</u> Poiret	G	X				X		
ASPL PLA	<u>Asplenium platyneuron</u> (L.) Oakes	F					X		
ASTE DUM	<u>Aster dumosus</u> L.	Hf			XX	X	XX		
ASTE HEM	<u>A. hemisphericus</u> E. J. Alex.	Hf						XX	
ASTE SPP	<u>Aster</u> spp.	Hf	XX			XX	XX		
ASTE SUR	<u>A. surculosus</u> Michaux	Hf	X	X	XX		XX	XX	X
AULA PAL	<u>Aulacomnium palustre</u> (Hedw.) Schwaegr.	Bm	XX		XX				X
BIDE FRO	<u>Bidens frondosa</u> L.	Hf			XX		X		
BIGE NUT	<u>Bigelovia nuttallii</u> L. C. Anderson (=Chondrophora virgata (Nuttall) Greene)	Hf	XX						
BULB CAP	<u>Bulbostylis capillaris</u> (L.) Clarke	G			X				
CAMP FLE	<u>Campylopus flexuosus</u> (Hedw.) Brid.	Bm	XX		XX	XX			
CAMP PIL	<u>C. pilifer</u> Brid.	Bm	XX						
CAMP TAL	<u>C. tallulensis</u> Sull. & Lesq.	Bm			XX				

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
CARE COM	<u>Carex complanata</u> Torrey & Hooker	G					X		
CAREX SP	<u>Carex</u> spp.	G			X				
CARY GLA	<u>Carya glabra</u> (Miller) Sweet	T	XX						
CARY OVA	<u>C. ovata</u> (Miller) K. Koch	T				XX			
CARY PAL	<u>C. pallida</u> (Ashe) Engler & Graebner	T	XX				XX		
CARYA SP	<u>Carya</u> sp.	T			X				
CARY TOM	<u>C. tomentosa</u> (Poiret) Nuttall	T				XX	XX		
CAST PUM	<u>Castanea pumila</u> (L.) Miller	S+					XX		
CHAS SES	<u>Chasmanthium sessiliflorum</u> (Poiret) H. O. Yates	G				X			
CHIM MAC	<u>Chimaphila maculata</u> (L.) Pursh	H-	XX		XX				
CHIO VIR	<u>Chionanthus virginicus</u> L.	T	XX						
CLAD ARB	<u>Cladina arbuscula</u> (Wallr.) Hale & Culb.	Lb				X			
CLAD CAE	<u>Cladonia caespiticia</u> (Pers.) Flk.	Ls				XX			
CLAD CAP	<u>C. capitata</u> (Michx.) Spreng.	Lp					XX		
CLAD CAR	<u>C. caroliniana</u> (Schwein.) Tuck. (= <u>C. dimorphoclada</u> Robbins when podetia are little inflated)	Lb	XX	XX	XX	XX	XX	XX	
CLAD CHL	<u>C. chlorophaea</u> (Flk.) Spreng., s.T.	Lp				X	XX	X	
CLAD CON	<u>C. coniocraea</u> (Flk.) Spreng.	Lps					XX		
CLAD CRI	<u>C. cristatella</u> Tuck.	Lps					XX		
CLAD CRY	<u>C. cryptochlorophaea</u> Asah.	Lp				XX		X	
CLAD DIM	<u>C. dimorphoclada</u> Robbins	Lb			XX				
CLAD FLO	<u>C. floerkeana</u> (Fr.) Somm.	Lp					XX		
CLAD FUR	<u>C. furcata</u> (Huds.) Schrad.	Lb						XX	
CLAD GRA	<u>C. grayi</u> Merr.	Lp	XX	X		XX	XX		
CLAD LEP	<u>C. leporina</u> Fr.	Lb	XX	XX					
CLAD MER	<u>C. merochlorophaea</u> Asah.	Lp			X				
CLAD PAR	<u>C. parasitica</u> (Hoffm.) Hoffm.	Ls				XX	XX	XX	
CLAD PIE	<u>C. piedmontensis</u> Merr.	Lps					XX		
CLAD RAN	<u>Cladina rangiferina</u> (L.) Harm.	Lb	XX	XX	XX	XX	X	XX	X

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b							
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O	
CLAD SQU	<u>Cladonia squamosa</u> (Scop.) Hoffm.	Lps	XX	X	XX	XX	XX	XX	X	
CLAD STR	<u>C. strepsilis</u> (Ach.) Vain.	Ls	XX		XX	X	XX	XX	X	
CLADOSUB	<u>C. subcariosa</u> Nyl. (=C. polycarpoides Nyl.)	Ls	XX		XX					
CLAD SUB	<u>Cladonia subtenuis</u> (Abb.) Hale & Culb.	Lb	XX	X	XX	XX	X	X	X	
CLAD UNC	<u>Cladonia uncialis</u> (L.) Wigg.	Lb					X	XX	X	
CLAD VER	<u>C. verticillata</u> (Hoffm.) Schaer.	Lb					X	XX	X	
CLIT MAR	<u>Clitoria mariana</u> L.	Ht					XX			
CORE MAJ	<u>Coreopsis major</u> Walter	Hf	XX		XX		XX	XX	X	
CORE PUL	<u>C. pulchra</u> F. E. Boynton	Hf	XX	X						
CORN FLO	<u>Cornus florida</u> L.	T			XX					
CRATA SP	<u>Crataegus</u> sp.	T			XX					
CROT ELL	<u>Crotonopsis elliptica</u> Willd.	H-	XX	X	XX	XX	XX			
CRUSTOSE	Unidentified crustose lichens	Lc				XX	XX			
CUNI ORI	<u>Cunila origanoides</u> (L.) Britton	Hf								X
CUSC HAR	<u>Cuscuta harperi</u> Small	Ht	XX							
CYPR ACA	<u>Cypripedium acaule</u> Aiton	Hf			X					
DANT SER	<u>Danthonia sericea</u> Nuttall	G	XX		XX		XX		X	
DANT SPI	<u>D. spicata</u> (L.) Beauvois ex R. & S.	G	XX	XX		XX	XX	XX		
DANT SPP	Vegetative and poor specimens of <u>D. sericea</u> and <u>D. spicata</u>	G	XX							
DESM CIL	<u>Desmodium ciliare</u> (Muhl. ex Willd.) DC	Hf					X			
DESM LAE	<u>D. laevigatum</u> (Nuttall) DC.	Bm	XX							
DICR CON	<u>Dicranum condensatum</u> Hedw.	Bm	XX	XX		XX	XX		X	
DICR SCO	<u>D. scoparium</u> Hedw.	Bm			XX	XX				
DICR SPU	<u>D. spurium</u> Hedw.	Bm				XX				
DIME ORE	<u>Dimelaena oreina</u> (Ach.) Norm.	Lf				XX				
DIOS VIR	<u>Diospyros virginiana</u> L.	T				XX	XX			
ELYM VIR	<u>Elymus virginicus</u> L.	G			X					
EPIG REP	<u>Epigaea repens</u> L.	St							X	
ERAG SPE	<u>Eragrostis spectabilis</u> (Pursh) Steudel	G					X			

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
ERIG CAN	<u>Erigeron canadensis</u> L.	Hf					X		
EUONY SP	<u>Euonymus</u> sp.	S	XX		XX	XX			
EUPA ROT	<u>E. rotundifolium</u> L.	Hf			X				
EUPA SES	<u>E. sessilifolium</u> L.	Hf			XX				
EUPH COR	<u>Euphorbia corollata</u> L.	Hf	XX						
FIMB DIC	<u>Fimbristylis dichotoma</u> (L.) Vahl	G	X						
FRAX AME	<u>Fraxinus americana</u> L.	T			XX				
GAUL PRO	<u>Gaultheria procumbens</u> L.	S-				XX			X
GAYL BAC	<u>Gaylussacia baccata</u> (Wang.) K. Koch	S				XX			
GAYL BRA	<u>G. brachycera</u> (Michaux) Gray	S-					X	X	X
GELS SEM	<u>Gelsemium sempervirens</u> (L.) Aiton	V	X	X					
GILL TRI	<u>Gillenia trifoliata</u> (L.) Moench	Hf					X		
GNAP OBT	<u>Gnaphalium obtusifolium</u> L.	Hf					X		
GRAY CRU	Unidentified gray crustose lichen (possibly <u>Lecidea</u> <u>macrocarpa</u> (DC) Steud.)	Lc					XX		
GREEN CR	Unidentified olive-green crustose lichen	Lc			XX			XX	
GRIM LAE	<u>Grimmia laevigata</u> (Brid.) Brid.	Bm	X				XX	XX	X
HELI LON	<u>Helianthus longifolius</u> Pursh	Hf	XX	X					
HETE NER	<u>Heterotheca nervosa</u> (Willd.) Shinners var. <u>nervosa</u>	Hf					XX	XX	
HEXA CON	<u>Hexastylis contracta</u> Blomquist	H-					X	X	
HIER GRO	<u>Hieracium gronovii</u> L.	Hf					XX		
HIER VEN	<u>H. venosum</u> L.	Hf					XX		
HOUS CAE	<u>Houstonia caerulea</u> L.	H-	X				X		
HYPE DEN	<u>Hypericum denticulatum</u> HBK. var. <u>recognitum</u> Fernald & Schubert	Hf			X				
HYPE GEN	<u>H. gentianoides</u> (L.) BSP.	H-	XX	X	XX	X	XX		
HYPE STR	<u>H. stragalum</u> P. Adams & Robson	St				X			
HYPER SP	<u>Hypericum</u> sp.	Hf			XX				

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
HYPN CUR	<u>Hypnum curvifolium</u> Hedw.	Bm						XX	
HYPO HIR	<u>Hypoxis hirsuta</u> (L.) Coville var. <u>hirsuta</u>	G						X	
ILEX OPA	<u>Ilex opaca</u> Aiton	T	XX		XX	XX		X	X
INKSPOT	Inkspot-like crustose lichen, probably <u>Sarcogyne simplex</u> (Dav.) Nyl.	Lc	XX		XX	XX	XX	XX	
JUNCU SP	<u>Juncus</u> sp.	G		X	X				
JUNI VIR	<u>Juniperus virginiana</u> L.	T	X		XX			X	
KALM LAT	<u>Kalmia latifolia</u> L.	S+				XX	XX	XX	
KRIG DAN	<u>Krigia dandelion</u> (L.) Nuttall	H-					X		X
LASA PAP	<u>Lasallia papulosa</u> (Ach.) Llano	Lu				XX		X	X
LECHE SP	<u>Lechea</u> sp., probably <u>L. racemulosa</u> Michaux	Hf	XX				XX	XX	
LEGUME1	Unidentified legume	Hf					XX		
LEGUME2	Unidentified legume	Hf					XX		
LEGUME3	Unidentified legume	Hf					XX		
LEGUME5	Unidentified legume	Hf					XX		
LESP HIR	<u>Lespedeza hirta</u> (L.) Hornemann	Hf					XX		
LESP PRO	<u>L. procumbens</u> Michaux	Ht			XX				
LESP REP	<u>L. repens</u> (L.) Barton	Ht					XX		
LEUC ALB	<u>Leucobryum albidum</u> (Brid. ex P.-Beauv.) Lindb.	Bm				XX		X	X
LIAT MIC	<u>Liatris microcephala</u> (Small) K. Schumann	Hf	XX	X	XX	XX	XX	XX	X
LIQU STY	<u>Liquidambar styraciflua</u> L.	T	XX		XX				
LOBE NUT	<u>Lobelia nuttallii</u> R. & S.	Hf	X						
LYCO OBS	<u>Lycopodium obscurum</u> L.	F						X	X
LYCO VIR	<u>Lycopus virginicus</u> L.	Hf			XX				
LYGO PAL	<u>Lygodium palmatum</u> (Bernh.) Swartz	F			X				
MALA UNI	<u>Malaxis unifolia</u> Michaux	H-	XX			XX			
MITC REP	<u>Mitchella repens</u> L.	Ht	XX		XX	XX		XX	X
MNIUM SP	<u>Mnium</u> sp.	Bm							X
NYSS SYL	<u>Nyssa sylvatica</u> Marshall	T	XX		XX	XX	XX		X
OPUN COM	<u>Opuntia compressa</u> (Salisbury) Macbride	Ss					XX		X

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
OXYD ARB	<u>Oxydendrum arboreum</u> (L.) DC.	T		X	X	XX		X	X
PANI BIC	<u>Panicum bicknellii</u> Nash	G					XX		
PANI COM	<u>P. commutatum</u> Schultes	G					XX		
PANI DIC	<u>P. dichotomum</u> L.	G	XX		XX				
PANI LAN	<u>P. lanuginosum</u> Ell.	G	XX		XX		XX	XX	X
PANIC SP	<u>Panicum</u> sp., probably <u>P. lanuginosum</u> or <u>P. villosissimum</u>	G			XX				
PANI SPH	<u>P. sphaerocarpon</u> Ell.	G						XX	
PANI VIL	<u>P. villosissimum</u> Nash	G					X		
PART QUI	<u>Parthenocissus quinquefolia</u> (L.) Planchon	V			XX				X
PINU STR	<u>Pinus strobus</u> L.	T				XX			
PINU TAE	<u>P. taeda</u> L.	T	XX						
PINU VIR	<u>P. virginiana</u> Miller	T	XX	XX	XX	XX	XX	XX	X
PLAN ARI	<u>Plantago aristata</u> Michaux	Hf							X
POLY BIF	<u>Polygonatum biflorum</u> (Walter) Ell.	Hf							X
POLY COM	<u>Polytrichum commune</u> Hedw.	Bm	XX	XX	XX	XX	XX	XX	X
POLY CUR	<u>Polygala curtisii</u> Gray	H-	XX		XX	X			
POLY JUN	<u>Polytrichum juniperinum</u> Hedw.	Bm	XX	XX	XX	XX	XX	XX	X
POLY VIR	<u>Polypodium virginianum</u> L.	F							X
POTE CAN	<u>Potentilla canadensis</u> L.	St.	XX		XX		XX		
POWDER	Powder-like crustose lichen, possibly <u>Sarcogyne simplex</u> (Dav.) Nyl.	Lc	XX		XX	XX	XX	XX	X
PRUN SER	<u>Prunus serotina</u> Ehrhart	T	XX	XX	XX		XX		
PTER AQU	<u>Pteridium aquilinum</u> (L.) Kuhn	F				XX			
PYCN INC	<u>Pycnanthemum incanum</u> (L.) Michaux	Hf					X		
PYCN MUT	<u>P. muticum</u> (Michaux) Persoon	Hf							X
PYCN PAP	<u>Pycnothelia papillaria</u> (Erhr.) Duf.	Lc					XX	XX	
PYRUS SP	<u>Pyrus</u> sp.	T					X		
QUER ALB	<u>Quercus alba</u> L.	T			XX		XX		X
QUER COC	<u>Q. coccinea</u> Muenchh.	T						X	X
QUER FAL	<u>Q. falcata</u> Michaux	T	XX		XX	XX	XX		
QUER MAR	<u>Q. marilandica</u> Muenchh.	T	XX	XX			XX		X

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
QUER PRI	<u>Q. prinus</u> L.	T	XX		X	XX		X	X
QUER RUB	<u>Q. rubra</u> L.	T			XX			X	X
QUER STE	<u>Q. stellata</u> Wang.	T	XX		XX	XX	XX		X
QUER VEL	<u>Q. velutina</u> Lam.	T				XX	XX	XX	X
RANU REC	<u>Ranunculus recurvatus</u> Poiret	Hf			X				
REINDEER	Reindeer lichens, predom- inantly <u>Cladonia rangiferina</u> and <u>C. subtenuis</u> with some <u>C. arbuscula</u> and <u>Cladonia uncialis</u>	Lb	XX	XX	XX	XX	XX	XX	X
RHEX MAR	<u>Rhexia mariana</u> L.	Hf	X		X				
RHEXI SP	<u>Rhexia</u> sp.	Hf			XX				
RHEX VIR	<u>R. virginica</u> L.	Hf			X				
RHOD MAX	<u>Rhododendron maximum</u> L.	S+							X
RHUS COP	<u>Rhus copallina</u> L.	S			X		XX		X
RHUS RAD	<u>R. radicans</u> L.	V	XX						
RHYN GLO	<u>Rhynchospora globularis</u> (Chapman) Small	G	X		X	X			
RHYNC SP	<u>Rhynchospora</u> sp.	G	XX						
RUBU FLA	<u>Rubus flagellaris</u> Willd.	St	XX	X	XX	XX	XX		X
RUME ACE	<u>Rumex acetosella</u> L.	H-					X		X
SASS ALB	<u>Sassafras albidum</u> (Nuttall) Nees	T					XX	XX	
SCAP UND	<u>Scapania undulata</u> (L.) Dum.	B1			XX				
SCHI SCO	<u>Schizachyrium scoparium</u> (Michaux) Nash (= <u>Andropogon scoparius</u> Michaux)	G			XX	XX	XX	X	X
SCHO CRO	<u>Schoenolirion croceum</u> (Michaux) Gray	Hf							X
SCUT ELL	<u>Scutellaria elliptica</u> Muhl.	H-			XX				
SEDU SMA	<u>Sedum smallii</u> (Britton) Ahles (= <u>Diamorpha cymosa</u> (Nuttall) Britton = <u>D.</u> <u>smallii</u> Britton)	H-	XX	X					
SELA RUP	<u>Selaginella rupestris</u> (L.) Spring	F							X
SENE SMA	<u>Senecio smallii</u> Britton	Hf					XX	X	X
SEYM CAS	<u>Seymeria cassioides</u> (J. F. Gmelin) Blake	Hf	X						
SMIL GLA	<u>Smilax glauca</u> Walter	V			XX	XX	XX	XX	X

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L T0 ^c	D T0	F T0	C T0	J T0	P T0	O T0
SMIL ROT	<u>S. rotundifolia</u> L.	V	XX		XX	XX	XX		
SOLI CAE	<u>Solidago caesia</u> L.	Hf			XX				
SOLI ERE	<u>S. erecta</u> Pursh	Hf			XX				
SOLI NEM	<u>S. nemoralis</u> Aiton	Hf					X		
SOLI ODO	<u>S. odora</u> Aiton	Hf					XX		
SONC ASP	<u>Sonchus asper</u> (L.) Hill	Hf			XX				
SORB SPP	<u>Sorbus arbutifolia</u> (L.) Heynhold var. <u>arbutifolia</u> and var. <u>melanocarpa</u> (Michaux) Schneider	S	XX		X	XX			X
SPHA SPP	<u>Sphagnum</u> spp., including <u>S.</u> <u>subsecundum</u> Nees ex Strum, <u>S. cyclophyllum</u> Sull. & <u>Lesq. ex Sull. S.</u> <u>compactum</u> DC. ex Lam. & DC., <u>S. imbricatum</u> Hornsch. ex Russ., and <u>S. recurvum</u> P.- Beauv.	Bm	X		XX	XX		X	
SPIR GRA	<u>Spiranthes gracilis</u> (Bigelow) Beck	H- G	X						X
SPORO SP	<u>Sporobolus</u> sp.	G			X				
SQUAMULE	Unidentified squamulose <u>Cladonia</u> spp.	Ls				XX	XX		
STEL MED	<u>Stellaria media</u> (L.) Cyrillo	H- G					X		
STIP AVE	<u>Stipa avenacea</u> L.	G	XX			XX	XX	XX	X
STYL BIF	<u>Stylosanthes biflora</u> (L.) BSP.	H-	XX						
TALI TER	<u>Talinum teretifolium</u> Pursh, intermediate between <u>T.</u> <u>mengesii</u> W. Wolf and <u>T. teretifolium</u>	Hs	X			XX			X
TEPH VIR	<u>Tephrosia virginiana</u> (L.) Persoon	Hf				X	XX	XX	X
THUI DEL	<u>Thuidium delicatulum</u> (Hedw.) BSG.	Bm			XX				
TRIC DIC	<u>Trichostema dichotomum</u> L.	Hf	X				X		
TSUG CAN	<u>Tsuga canadensis</u> (L.) Carr.	T				XX	X	X	
ULMU ALA	<u>Ulmus alata</u> Michaux	T			X				
UNK HERB	Unidentified herb	H	XX						
UNKHERB1	Unidentified herb	H					XX		
UNKHERB4	Unidentified herb	H					XX		
UNKHERB6	Unidentified herb	H					XX		

Table 22 (Continued)

Computer Code	Linnean Name	Life Form ^a	Research Site ^b						
			L IO ^c	D IO	F IO	C IO	J IO	P IO	O O
USNEA SP	<u>Usnea</u> sp. (sometimes persists after falling from trees)	Lu				XX			X
VACC ARB	<u>Vaccinium arboreum</u> Marshall	S+	XX	X	XX	XX	XX	X	X
VACC COR	<u>V. corymbosum</u> L.	S+	X						X
VACC STA	<u>V. stamineum</u> L.	S	XX		X				X
VACC VAC	<u>V. vacillans</u> Torrey	S-	XX			XX	XX	XX	X
VACCI SP	<u>Vaccinium</u> sp.	S	XX		X				X
VALE RAD	<u>Valerianella radiata</u> (L.) Dufr.	Hf					X		X
VERO ARV	<u>Veronica arvensis</u> L.	Ht			X				
VERO OFF	<u>V. officianalis</u> L.						XX		
VIOL PRI	<u>Viola primulifolia</u> L.	H-			XX				
VIOLA SP	<u>Viola</u> sp.	H-			XX				
VITI ROT	<u>Vitis rotundifolia</u> Michaux	V			X	XX			
WHITE CR	Unidentified white crustose lichen	Lc	XX		XX	XX	XX	X	X
XANT CON	<u>Xanthoparmelia conspersa</u> (Ach.) Hale	Lf	XX	X	XX	XX	XX	XX	X

^aLife forms are as follows: A=filamentous algae; Bm=moss; Bl=liverwort; Lb=branched lichen; Lp=podetiate, unbranched lichen; Ls=squamulose lichen; Lps=podetiate, squamulose lichen; Lc=crustose lichen; Lf=foliose lichen; Lu=umbilicate lichen; G=graminoid herb; Hf=forb; H-=small herb; Ht=trailing herb; Hs=succulent herb; S=medium shrub; S-=low shrub; S+=large shrub; Ss=succulent shrub; St=trailing shrub; V=woody vine; T=tree.

^bThe research sites are: L=Little River Canyon, D=DeSoto State Resort Park, F=Flat Rock, C=Clear Creek at Lilly Bridge, J=Jamestown Barrens, and P=Pickett State Forest; O=other Cumberland Plateau sandstone outcrops.

^cWhere the species was collected is indicated by: I=in sample plots; O=on outcrop but not in sample plots.

^dX=present.

VITA

Bretta Elaine Perkins came to The University of Tennessee, Knoxville, in September 1977, on a graduate assistantship which she fulfilled by working with the laboratories for General Botany, Plant Morphology, Winter Field Botany, Plant Ecology, and Spring Flora, and assisting in the greenhouse. She also received a research grant from the Aaron J. Sharp Fellowship.

Her undergraduate work at the University of Georgia, Athens, began in September 1973 with receipt of the Georgia Certificate of Merit and a Georgia Regents Scholarship. She received a fellowship from the National Science Foundation Undergraduate Research Program for the summer of 1972 at Georgia College, Milledgeville, where she studied C_3 and C_4 plants of the Georgia sand hills. She was an Honors student at the University of Georgia, and graduated Cum Laude with General Honors with a Bachelor of Science in Botany in June 1977. The following summer, she worked at the U.S. Forest Service Tree Seed Laboratory in Macon, Georgia.

She graduated in June 1973 from Southwest High School in Macon with top honors.

Bretta Elaine Perkins was born in Jacksonville, Florida on April 8, 1955. Her parents are Thomas M. Perkins, Jr. and Viola Brown Perkins.

She is a member of the Ecological Society of America, the Association of Southeastern Biologists, Tennessee Academy of Science, Tennessee Native Plant Society, and Georgia Nature Conservancy.