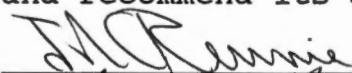
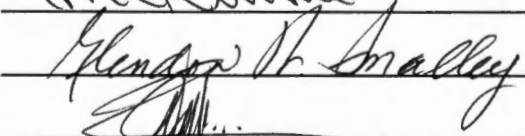


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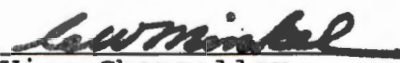
I am submitting herewith a thesis written by David H. Arnold entitled "Distinctness of Forest Communities within Landtypes in the Prentice Cooper State Forest, Marion County Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.


Edward R. Buckner, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
and Dean of The Graduate School

DISTINCTNESS OF FOREST COMMUNITIES
WITHIN LANDTYPES IN
THE PRENTICE COOPER STATE FOREST,
MARION COUNTY TENNESSEE

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

David H. Arnold
December 1990

Ag-VetMed

THESIS

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Dedication

I would like to dedicate this work to my father, John William Arnold. He passed away before this project was finished. Dad introduced me to the wonders of the forest when I was very young. The buckeye was probably his favorite tree. I can still remember us picking up buckeyes from underneath the tree beside Neal's Creek. The last thing we did together before his death was measure a sassafras tree for nomination into the Tennessee State Register of Big Trees. Even though the tree was over 100 feet tall, it did not make the register.

Since Dad first introduced me to the forest, I learned his buckeye tree is known by the scientific community as Hippocastanaceae Aesculus octandra Marshall. I am grateful he introduced me to the forest and supported me in my endeavors to understand it more closely.

Dad's buckeye tree by Neal's Creek has long been cut down but his memory will be with me forever--Thanks Dad, I Love You!

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Any time a project of this magnitude is undertaken the people that provide help or encouragement are too numerous to mention. Dr. George Weaver was the first person I met within the Department of Forestry, Wildlife and Fisheries. I am indebted to him for leading me in the right direction from the start. My committee members were invaluable for giving me guidance, direction and support. Dr. Ed Buckner served as committee head. His help and quick action in dealing with any administrative or technical problems allowed me to remain focused on the details involved with thesis research. Dr. Glenn Smalley provided many "front porch" discussions dealing with different approaches and applications of land classification. Dr. John Rennie provided information on the pros and cons of different forest sampling techniques, bridging the gap between theory and applied forest sampling. Dr. Esteben Walker served as statistician and helped me to understand how multivariate statistics (parametric or non-parametric) should be interpreted with a "real world" data set.

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not pertinent to the research at hand.

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I am very grateful to Joe "Moon Pie" Gipson. He helped me to become computer literate, provided many distractions when thesis work became overbearing and gave of his time and resources unselfishly during document finalization. If I became too involved with my work he would sit on me until I gave in and loosened up.

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find employment near the completion of school.

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Lastly, I would like to thank my wife, Cindy Arnold, for standing by my side during the happy and sad times. She is my sunshine and I am grateful the Lord brought her into my life. I would be lost without her love, companionship and understanding. Cindy, I love you!

This project was partially funded through a Graduate Research Assistantship provided by the Department of Forestry, Wildlife and Fisheries. I would also like to thank Bob Brooks of TVA for providing employment when the GRA expired.

Abstract

A land classification system has been developed for the Interior Uplands of Tennessee, Kentucky, Alabama, Georgia and Virginia (Smalley 1984b). The system utilizes information from geology, soils, and physiography to divide the landscape into units with homogeneous forest site potential. No detailed vegetation studies were made during the development of the system, raising questions as to its applicability for predicting forest cover within each landtype. The scope of this study was to 1) determine if distinct forest cover occurs within and between landtypes, 2) identify and describe the forest cover types occurring within landtypes and 3) investigate underlying factors controlling spatial arrangement of forest cover on the landscape. If distinct forest spatial patterns can be correlated to landtype descriptions, Smalley's system would be a valuable tool to efficiently characterize and map forest communities.

This study was conducted in two compartments of Prentice Cooper State Forest located on the southern tip of Walden Ridge on the Cumberland Plateau west of Chattanooga, TN. Rectangular, 0.10-acre plots were used to describe sub-plots for sampling vegetation from the overstory, understory, sapling/shrub and seedling/herbaceous forest strata as well as measure selected physical site characteristics. Sample plots were allocated by landtype using a random start with

subsequent systematic location. Final statistical analyses used the information from 139 plots situated on four major landtypes.

Variable distribution and variance structure was evaluated for each data set to determine appropriate multivariate techniques. Parametric discriminant analysis was used to investigate the distinctness of forest cover within landtypes. Farthest neighbor cluster analysis was used to document forest cover within landtypes. Principal factor analysis was used to investigate underlying factors controlling forest community variation.

Discriminant analysis revealed sampled landtypes had relatively distinct forest cover. The overstory misclassification matrix had the highest percent of correctly classified sampling plots of all single forest stratum data sets. As the information from successively subordinate forest strata was included in the analysis, the percentage of correctly classified plots approached 100.

Farthest neighbor cluster analysis revealed common communities occurring within different landtypes: chestnut oak (Quercus prinus L.), white oak (Quercus alba L.) and shortleaf pine (Pinus echinata Miller) communities occurred on all four sampled landtypes. A scarlet oak (Quercus coccinia Muenchh.) community occurred on landtypes 5, 6, and 17. A black oak (Quercus velutina Lam.) community occurred on landtypes 3 and 5. Landtype 17 contained three

communities not found on the other landtypes: yellow-poplar (Liriodendron tulipifera L.), northern red oak (Quercus rubra L.), and eastern hemlock (Tsuga canadensis (L.) Carr.).

Principal factor analysis revealed that an ecosystem element or element complex varying along an elevational gradient was the dominant factor in controlling forest community variation. Microenvironmental ecosystem elements appear to be secondary controllers of forest community variation. Site variables characterized physical aspects of the landscape. At best, these variables were indirect measures of ecosystem elements responsible for forest community variation, resulting in speculation as to the actual factors contributing to the majority of forest community variation.

This study examined the utility of a landtype classification system for efficiently characterizing forest cover on the landscape. The statistical techniques involved proved adequate to describe the forest resources within specific landtypes. Parametric discriminant analysis revealed forest cover within landtypes was relatively distinct. Contradictory to these results, farthest neighbor cluster analysis revealed common communities occurring within different landtypes. The discrepancy between the two techniques arises from the function of discriminant and cluster analysis. Discriminant analysis pools vegetation

information within landtypes to develop discriminating criteria while cluster analysis agglomerates vegetation information within landtypes into similar clusters. The differences between similar communities in conjunction with differences attributable to communities not common to all landtypes was significant enough to reveal relatively distinct forest cover within the sampled landtypes. Species Relative Importance Values of overstory species might be inadequate to determine if similar communities from different landtypes are distinct. Future research should focus on developing an appropriate variable(s) that incorporates bole height or quality to aid in distinguishing between similar communities that occur on different landtypes.

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CHAPTER I

JUSTIFICATION

I. INTRODUCTION

Natural resource managers are under pressure from an increasing number of user groups to provide competent guidance in the use of the resources under their charge. To complicate matters, not all user groups envision the same utilization of specific resources. For example, the timber industry and wilderness groups are polarized relative to what constitutes competent guidance and subsequent use. Also, resource managers are being held increasingly accountable if management practices they endorse or implement are perceived to be environmentally unsound.

Faced with these pressures, managers need efficient, reliable methods to locate, describe, inventory and interpret resources entrusted to them. Such information eases and validates the task of pursuing or rejecting the wants or needs of specific user groups, resulting in a more complete planning process when addressing options for resource utilization.

This study examines landtype influences on forest spatial patterns. Knowledge of landtype influences on forest patterns will provide resource managers with a tool to efficiently characterize, and subsequently manage, the forest

resources entrusted to them.

II. SPATIAL ARRANGEMENT OF FOREST COMMUNITIES

Before investigating forest cover/landtype relationships, a review of existing forest community theory was in order. Historically, two schools of thought have been formulated to explain the spatial arrangement of plant communities--the discrete community concept and the continuum community concept.

Discrete Community Concept

The discrete community concept was developed in Europe and is commonly called the association-unit community concept (Spurr and Barnes 1980). According to Daubenmire (1968),

The concept of community necessarily presumes a degree of biologic homogeneity in structure and species composition that is associated with area having boundaries. As two communities come into contact they intergrade, and the zone of integration, whether narrow or wide, is called an ecotone.

Ecotonal variations can be the result of three phenomena: 1) an abrupt discontinuity in environmental conditions, 2) an abrupt transition due to plant interactions and competition or 3) a gradual blending of two distinct factor complexes.

This approach to phytosociological arrangement is

discussed by several authors including Braun-Blanquet et al. 1932, Braun 1950, Weaver and Clements 1938, Oosting 1956, Daubenmire 1966, 1968 and Whittaker 1978a.

Continuum Community Concept

Many English and American ecologists claimed the discrete community concept was too rigid and inadequately described plant associations. In reaction to these weaknesses, the continuum concept was proposed and was introduced into the United States by Curtis and co-workers at the University of Wisconsin (Curtis and McIntosh 1951). Whittaker (1975) discussed continuum theory as follows:

The broad overlap and scattered centers of species populations along a gradient imply that most communities intergrade continuously along environmental gradients, rather than forming distinct, clearly separated zones. (Either environmental discontinuity or disturbance by fire, logging, and so on, can of course produce discontinuities between communities.)

Discrete and continuum community theory have been used simultaneously to explain forest community variation. Causton (1988) states community structure depends on the scale or forest stratum an investigator is examining. Distinct communities may be recognized with large scale surveys incorporating upper vegetation strata; small-scale surveys focusing on lower vegetation strata reveal vegetation

arranged as a continuum. Hinkle (1978) reports a regional vegetation cover exhibits both discontinua and continua occurring in a mosaic pattern over the region and both theories should be integrated to completely understand vegetation.

The discrete/continuum dichotomy of thought raised questions as to the most appropriate techniques to describe and validate community structure, i.e., classification or ordination. Classification involves grouping similar observations into clusters while ordination involves representation of sample and species relationships in a low-dimension space (Gauch 1986). These definitions can incorrectly lead to the conclusion that classification is appropriate when vegetation exhibits a discrete structure and ordination is appropriate when vegetation exhibits a continuous structure. In practice, selection of a specific technique for any plant community study should correspond to the research question asked (Causton 1988). The use of both ordination and classification are required to adequately address the objectives of this study.

III. FOREST LAND CLASSIFICATION

Forest land classification can be defined as a grouping of individual forest sites into aggregates whose members are relatively similar in overall site characteristics. The classification developed depends on the characteristics used

and upon the intended use of the classification (Radlof and Betters 1978). Land classifications are intended to provide basic information on the biological and physical characteristics of the landscape, to simplify interpretations of forest productivity and characterize likely responses to disturbances (Rowe and Sheard 1981).

Several approaches to forest land classification have been developed. Bailey et al. (1978), Barnes (1986), Spurr and Barnes (1980) and Barnes et al. (1982) outline and discuss different approaches to forest land classification. This discussion will focus on three approaches to forest land classification: 1) single factor classifications, 2) multi-factor component classifications and 3) multi-factor ecological classifications.

Single Factor Classifications

Single factor classifications focus on one ecosystem element--either vegetation, soils, physiography, or climate--as a classifying criterion. As developed by Daubenmire (1968), the habitat-type approach to site classification is a vegetation based single-factor classification system. The system uses late successional overstory and understory vegetation as an integrator of the environmental complex of climate, physiography and soil of a site. The grouping of habitat-types effectively integrates site characteristics. This technique is difficult to implement in areas of

disturbed vegetation unless successional pathways leading to the probable habitat-type can be identified.

The National Cooperative Soil Survey (NCSS) is the most extensive single-factor classification system for many areas of the United States. Soils are mapped according to soil taxonomy. In soil surveys, soils are treated separate from their environment, often resulting in poor correlation between forest types or productivity and soil mapping units. The taxonomic interpretation applied to NCSS groups soils together that are morphologically and chemically similar, yet occurring in different landscapes, ignoring the influence of landform in defining microenvironmental characteristics of a specific site (Grigal 1984 and Kotar 1988). This methodology has limited the utility of NCSS as a means of classifying the landscape into homogeneous forest sites.

Multi-factor Component Classifications

Multi-factor component classifications integrate ecosystem components (vegetation, soils and physiography) through the combination of individual component classifications. Descriptions of each component are visually overlaid, one on top of the other, to produce areas of similar vegetation, soils and physiography.

In 1976, the U.S. Forest Service, cooperating with several Federal agencies, initiated an effort to develop a comprehensive national land classification system. In 1979,

a tentative agreement was reached to use a component system integrating soil, vegetation, landform and water. The approach was found too rigid and did not explain the linkage among the components used to describe ecosystems (Larson and Schlatterer 1984). Component classification systems may also result in complexity too great for ease of mapping homogeneous ecosystem units.

Multi-factor Ecological Classifications

Recognition of the interactive characteristics of the biotic and abiotic ecosystem components has lead to the concept that land can be classified into homogeneous ecosystems (Rowe and Sheard 1981). An ecological classification expresses the interrelationships between ecosystem components. Jurdant et al. (1975) describe the ecological classification process as follows:

The basic bio-physical classification is derived from a priori integration of the knowledge of climate, geology, geomorphology, soils and vegetation collected by a team of specialists in various disciplines working together in the field and in the office. The a priori integration is preferred to an a posteriori integration commonly obtained by superimposing sectorial maps (geomorphology, soil, vegetation, etc.) which are not only more expensive to produce, but create complications due to minor variations in unit boundaries developed independently by each discipline.

This technique has been used extensively in the German

state of Baden-Wurttemberg (Spurr and Barnes 1980) and Canada (Jurdant et al. 1975). Within the United States, multifactor ecological classifications have been developed for the Sylvanian Recreation Area in the upper peninsula of Michigan (Spies and Barnes 1985), the McCormick Experimental Forest in Michigan (Barnes et. al. 1982) and the forests of the Savannah River Plant in South Carolina (Van Lear and Jones 1987).

IV. LAND CLASSIFICATION FOR THE INTERIOR UPLANDS

Description

A hierarchical land classification system has been developed for the Interior Uplands in Kentucky, Tennessee, Alabama, Virginia and Georgia (Smalley 1979, 1980, 1982, 1983, 1984a, 1986a and 1986b). The rationale, description and use of the system have appeared in several papers (Sims 1987, Smalley 1984a, 1985). The system incorporates existing knowledge on geology, physiography, soils and site productivity to describe logical segments (landtypes) of the landscape with similar productivity. Vegetation was relegated to a minor role as a site descriptor because the forests of the Interior Uplands have a long history of indiscriminate cutting, burning, grazing and clearing for agriculture (Smalley 1990).

Smalley's site classification system was adopted from Wertz and Arnold's (1975) Land System Inventory.

Physiographic province is the broadest level in the hierarchical arrangement of Smalley's system, followed by region, subregion, landtype association and landtype, which is the smallest unit of the landscape recognized by the system. Landtypes are characterized by geographic setting, dominant soils, bedrock, depth to bedrock, soil drainage, relative soil water supply, soil fertility and vegetation; they are also evaluated for productivity, management problems and species desirability (Figure 1).

Application

In practice, the system is a regionalization: portions of the landscape are recognized as having homogeneous characteristics identified by the elements used to develop the system. Once these subdivisions are recognized, lines can be drawn on maps or aerial photos to delineate landtypes (Bailey and Pfister 1978). Ground checking should be an integral part of developing a working classification. Some of the landtypes, due to their extent, are readily identifiable from a topographic map or aerial photos (landtypes 1,2,3,5, and 6). Others need to be evaluated on the ground unless criteria can be developed to identify them from topographic maps or aerial photos (landtypes 4,7,13 and 15) (Figure 2). Once a classification for a specific area is developed, landtypes are intended to be used as the basic units of management.

Description of Landtype 3:
Broad Sandstone Ridges--
South Aspect

Geographic setting--Moderately deep to deep. loamy soils on nearly level to steep south-facing portions of broad ridgetops and adjoining convex upper slopes in all subregions. This landtype extends from the ridge crest down to where the slope becomes linear or nearly so. At this point gradient usually increases noticeably. Slope ranges from 2 to 35 percent and is dominantly greater than 6 percent. Soils developed in loamy residuum from sandstone or from interbedded sandstone and shale. In some places a 2-to 3-foot silty mantle (presumably loess) occurs over the residuum. Rock fragments occur on the surface in places. South-facing ridges tend to be somewhat steeper and have shallower soils with a higher rock content than north-facing ridges. This landtype may occur below broad undulating uplands (Landtype 1) while south midslopes (landtype 6) occur below it. This landtype may lie adjacent to Landtypes 14 and 15 in the heads of hollows.

Dominant soils--Hartsells, Linker, Lonewood, Crossville, and Lily are more common in Subregions 1 and 2, while Albertville, Enders, and Nauvoo are more common in Subregion 3.

Bedrock--Sandstone and conglomerate with thin strata of shale and siltstone in places.

Depth to bedrock--20 to 72 inches.

Texture--Loam, fine sandy loam, and silt loam: sometimes gravelly, stony, or flaggy. Volume of sandstone, and in places, shale fragments in the solum is 35 percent or less, but deeper horizons may contain more.

Soil drainage--Well drained.

Relative soil water supply--Medium.

Soil fertility--Moderately low.

Vegetation--White oak, chestnut oak, southern red oak, hickories, black oak, post oak, blackgum, red maple, Virginia pine, shortleaf pine, and loblolly pine; occasional black locust, eastern redcedar, eastern white pine, and yellow-poplar. Dogwood, sassafras, sourwood, persimmon, vacciniums, sumac, viburnums, serviceberry, and smilax are common understory species

FIGURE 1.- SMALLEY'S LANDTYPES INCLUDED FOR EVALUATION.

Source: Smalley, G. W. 1982. Classification and Evaluation of Forest Sites on the Mid-Cumberland Plateau. USDA For. Ser. Gen. Tech. Rep. SO-30, 120 pp.

Description of Landtype 5:
North Sandstone Slopes

Geographic setting--Shallow to moderately deep, loamy and clayey soils with a wide range of coarse fragments on sloping to very steep north-facing linear to concave midslopes in all subregions. This landtype lies between narrow ridges, broad uplands, or broad ridges and convex upper slopes (landtypes 1, 2, and 3) and concave footslopes, terraces, and streambottoms (Landtypes 14 and 15). Slope ranges from 6 to 70 percent. Rock fragments are common on the surface.

Dominant soils--Hartsells, Mountainburg, Hector, Townley, and Montevallo are common in Subregion 3: Lily, Alticrest, Dekalb, Gilpin, and Ramsey are more common in Subregions 1 and 2.

Bedrock--Sandstone, conglomerate, sandstone interbedded with thin strata of siltstone and shale, interbedded shale and sandstone, and siltstone interbedded with sandstone and silty shale.

Depth to bedrock--40 inches and less.

Texture--Loam, fine sandy loam, sandy loam, and silt loam: may be stony, gravelly, shaly, channery, or flaggy. Coarse fragment content ranges from 5 to 65 percent in the solum and generally increases with depth.

Soil drainage--Well drained to somewhat excessively drained.

Relative soil water supply--Medium to high. Irrigated by subsurface flow.

Soil fertility--Moderately low to low.

Vegetation--White oak, black oak, yellow-poplar, hickories, blackgum, southern red oak, red maple, and chestnut oak; occasional northern red oak, American beech, shortleaf pine, Virginia pine, eastern redcedar, eastern hemlock, and black locust. Dogwood, sassafras, sourwood, serviceberry, laurel, vacciniums, viburnums, azaleas, sumac, persimmon, American holly, and smilax are common understory species.

Description of Landtype 6: South Sandstone Slopes

Geographic setting--Shallow to moderately deep, loamy and clayey soils with a wide range of coarse fragments on sloping to very steep south-facing linear concave midslopes in all subregions. This landtype lies between narrow ridges, broad uplands, or broad ridges and convex upper slopes (Landtypes 1, 3, and 4) and concave footslopes, terraces, and streambottoms (Landtypes 14 and 15). Slope ranges from 6 to 70 percent. Rock fragments are common on the surface. South-facing slopes tend to be steeper and have shallower soils with higher contents of coarse fragments than north-facing slopes.

Dominant soils--Hartsells, Mountainburg, Hector, Townley, and Montevallo are more common in Subregion 3: Lily, Alticrest, Dekalb, Gilpin, and Ramsey are more common in Subregions 1 and 2.

Bedrock--Sandstone, conglomerate, sandstone interbedded with thin strata of siltstone and shale, interbedded shale and sandstone, and siltstone interbedded with sandstone and silty shale.

Depth to bedrock--40 inches and less.

Texture--Loam, fine sandy loam, sandy loam, and silt loam: may be stony, gravelly, shaly, channery, or flaggy. Coarse fragment content ranges from 5 to 65 percent in the solum and generally increases with depth.

Soil drainage--Well drained to somewhat excessively drained.

Relative soil water supply--Medium to high. Irrigated by subsurface flow.

Soil fertility--Moderately low to low.

Vegetation--White oak, chestnut oak, scarlet oak, southern red oak, post oak, hickories, blackjack oak, black oak, red maple and blackgum; occasional Virginia pine, shortleaf pine, black locust, eastern redcedar, and loblolly pine. Dogwood, sassafras, sourwood, vacciniums, persimmon, smilax, sumac, and viburnums are common understory species.

Description of Landtype 17:
Plateau Escarpment and Upper
Sandstone Slopes and Benches--
South Aspect

Geographic setting--Deep to very deep. loamy soils formed in colluvium from sandstone, siltstone, and shale, and underlain by sandstone, siltstone, or shale in all subregions. Occupies the gently sloping to very steep upper one-third to one-half of southerly slopes that extend from the Plateau escarpment to the adjacent limestone valleys. Slope ranges from 5 to 70 percent. Much of the surface is covered with sandstone boulders and fragments. At the Plateau exterior, particularly in the Sequatchie Valley, this landtype may be absent if escarpment development has progressed down to limestone. In gorges of the Plateau interior, primarily in Subregion 1, where stream cutting has not carved through the sandstone caprock, this landtype occurs between the escarpment and larger streams and rivers and landtype 19 is absent. In narrow gorges the lower one-fourth to one-half of these slopes should be included in Landtype 16 because shading mollifies the normal warm microclimate. This landtype is not as productive as Landtype 16, and forests lack the preponderance of mesic species found on north aspects.

Dominant soils--Grimsley, Ramsey, Jefferson. Formerly mapped as sandstone rockland or bouldery colluvial land.

Bedrock--Sandstone, siltstone, and shale.

Depth to bedrock--40 to 60 inches or more.

Texture--Gravelly or cobbly loam, silt loam, sandy clay loam, or clay loam.

Soil drainage--Well drained.

Relative soil water supply--Medium to low. Irrigated by subsurface flow and seepage. This landtype is not as moist as Landtype 16.

Soil fertility--Moderately low to low.

Vegetation--White oak, chestnut oak, northern red oak, hickories, black oak, red maple, yellow-poplar, and black locust; occasional blackgum, elms, eastern white pine, white ash, black cherry, black walnut, sugar maple, southern red oak, shortleaf pine, Virginia pine, loblolly pine, and American beech. Dogwood, viburnums, eastern redbud, sourwood, azaleas, and grape are common understory species.

FIGURE 1.- CONTINUED.

1. Broad undulating sandstone uplands
2. Broad sandstone ridges--north aspect
3. Broad sandstone ridges--south aspect
4. Narrow sandstone ridges and convex upper slopes
5. North sandstone slopes
6. South sandstone slopes
7. Sandstone outcrops and shallow soils
8. Broad shale ridges--north aspect
9. Broad shale ridges--south aspect
10. Upper shale slopes--north aspect
11. Upper shale slopes--south aspect
12. Lower shale slopes--north aspect
13. Lower shale slopes--south aspects
14. Footslopes, terraces, and streambottoms with good drainage
15. Terraces, streambottoms and depressions with poor drainage
16. Plateau escarpment and upper sandstone slopes and benches--north aspect
17. Plateau escarpment and upper sandstone slopes and benches--south aspect
18. Lower limestone slopes, benches, and spur ridges--north aspect
19. Lower limestone slopes, benches, and spur ridges--south aspect
20. Limestone outcrops and shallow soils

FIGURE 2.- SMALLEY'S LANDTYPES OCCURRING ON THE WALDEN RIDGE SUBREGION OF THE CUMBERLAND PLATEAU.

Source: Smalley, G. W. 1982. Classification and Evaluation of Forest Sites on the Mid-Cumberland Plateau. USDA For. Ser. Gen. Tech. Rep. SO-30, 120 pp.

Ecosystem Integration

The land classification system is based on the premise that in rugged terrain, landforms have as much as, or even greater significance, than soils in influencing forest growth and productivity (Smalley 1984b). Landform influences on the ecosystem can be divided into four categories (Swanson et al. 1988).

- 1) Landforms -- due to elevation, aspect, parent materials and slope steepness -- influence air and ground temperature, moisture, nutrients and other materials (e.g., pollutants) available at sites within a landscape.
- 2) Landforms influence the movement of organisms, propagules, energy and material through a landscape.
- 3) Landforms influence the frequency and spatial patterns of nongeomorphically induced disturbances from fire, wind, grazing and anthropogenic activity.
- 4) Landforms influence the spatial pattern and frequency of geomorphic processes that alter biotic features and processes.

In nature, landform influences do not act in isolation from each other. They integrate to form multifaceted unique environments as determined by the physical characteristics of associated landforms. Smalley's classification utilizes landform influence on the environment to facilitate practical identification of complex ecosystem interactions, theoretically resulting in homogeneous units for forest development and productivity.

Smalley's system is theoretically sound. To make the system more useful, verification of the spatial arrangement of ecosystem components within and between landtypes is required. Quantification of the uniqueness of environment and forest cover within landtypes has already begun.

Hammer (1986) examined physical and chemical soil characteristics within four major landtypes on the Mid-Cumberland Plateau. Discriminant analysis correctly classified all 132 plots into their respective landtype. Maximum likelihood factor analysis suggested subsurface cations, A horizon properties, soil texture, drainage and thickness as the underlying factors accounting for variation in soil physical and chemical properties.

Wheat (1986) documented and described forest cover occurring on six landtypes on the Western Highland Rim. Cluster analysis identified eight different communities on the study area. Discriminant analysis of principal component scores from 15 overstory and 29 understory species resulted in 45% misclassification of plots from their respective landtypes, 64% of the misclassified plots were associated with two ridge landtypes.

Clatterbuck (1988) utilized synthesis tables, factor analysis, canonical discriminant analysis and several cluster analyses to document and describe the forest vegetation on the Cheatham Wildlife Management Area situated on the Western Highland Rim of Tennessee. Although his methodology varied

from Wheat's, Clatterbuck also concluded that ridge landtypes had the least distinct vegetation.

V. STUDY OBJECTIVES

The scope of the present study is to examine and validate the forest communities occurring within several landtypes located on the Prentice Cooper State Forest, located on the southern end of Walden Ridge west of Chattanooga, TN. Specific objectives are defined by the following questions:

- 1) Are forest communities within landtypes distinct ?
- 2) What is the nature of forest communities within landtypes?
- 3) What are possible underlying factors influencing forest communities within landtypes?

Question one is examined with discriminant analysis (classification). Question two is examined with cluster analysis (classification). Question three is examined with factor analysis (ordination). These techniques are more thoroughly discussed under SAMPLING METHODS AND MATERIALS.

CHAPTER II

STUDY SITE DESCRIPTION

I. LOCATION

This study required a site that met several criteria:

- 1) Location on the Cumberland Plateau
- 2) Homogeneous forest disturbance history
- 3) Accessibility, and
- 4) "Natural" forest recovery after disturbance.

The Prentice Cooper State Forest (PCSF) contains forested areas extensive enough to meet these criteria. The forest is located on the southern tip of Walden Ridge northwest of Chattanooga, TN (Figure 3).

The Forest has been divided into 18 compartments averaging 1,319 acres in size (Tenn. Dep. of Conservation 1989). Through the use of general reconnaissance, record examination and informal conversations, sections of compartments 8 and 9 were selected for this study, hereafter called the Mullins Cove area (Figure 4).

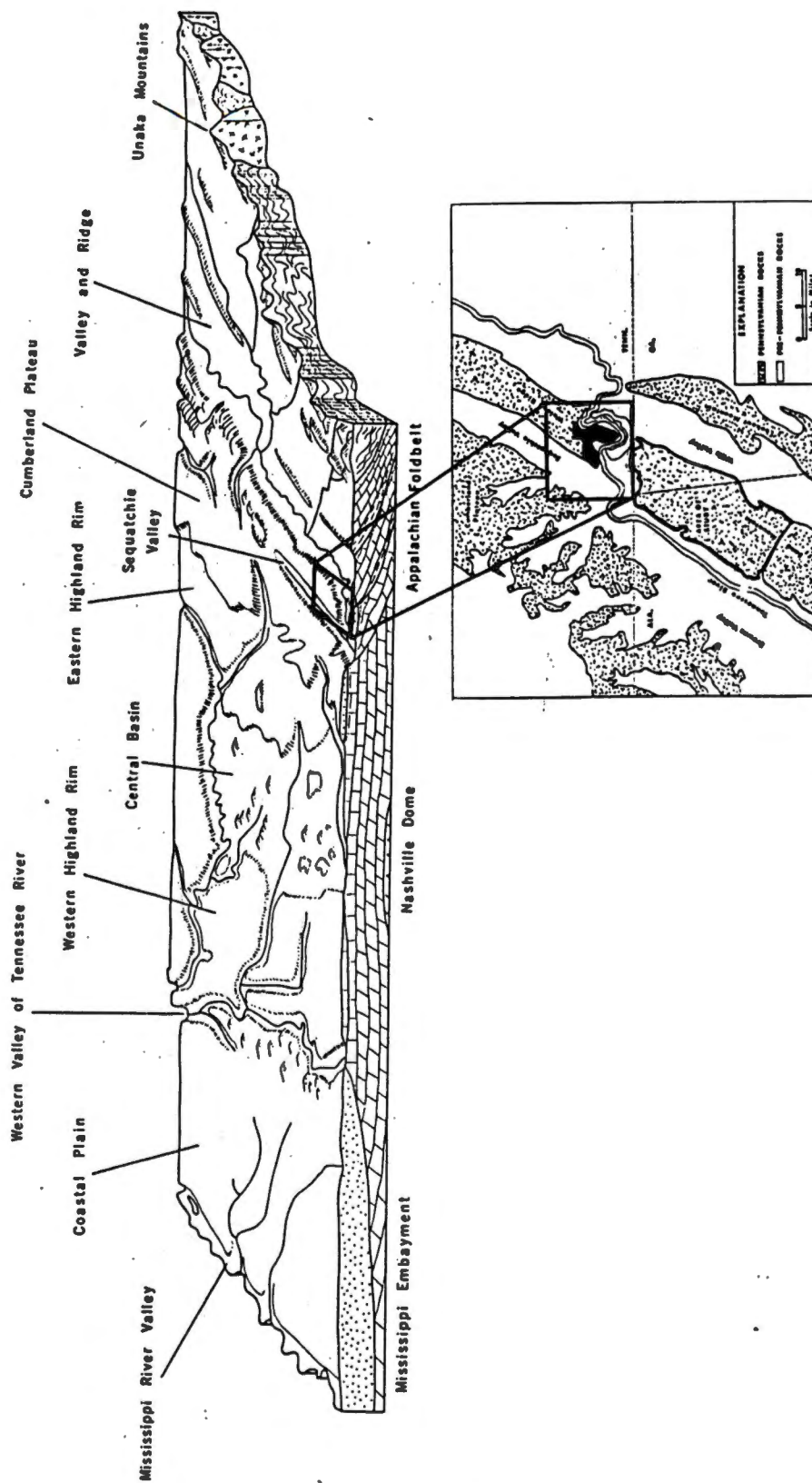


FIGURE 3.- LOCATION OF PRENTICE COOPER STATE FOREST.

Source: Miller, R. A. 1974. The Geologic History of Tennessee. Tenn. Div. Geology Bull. 74. 63 pp.

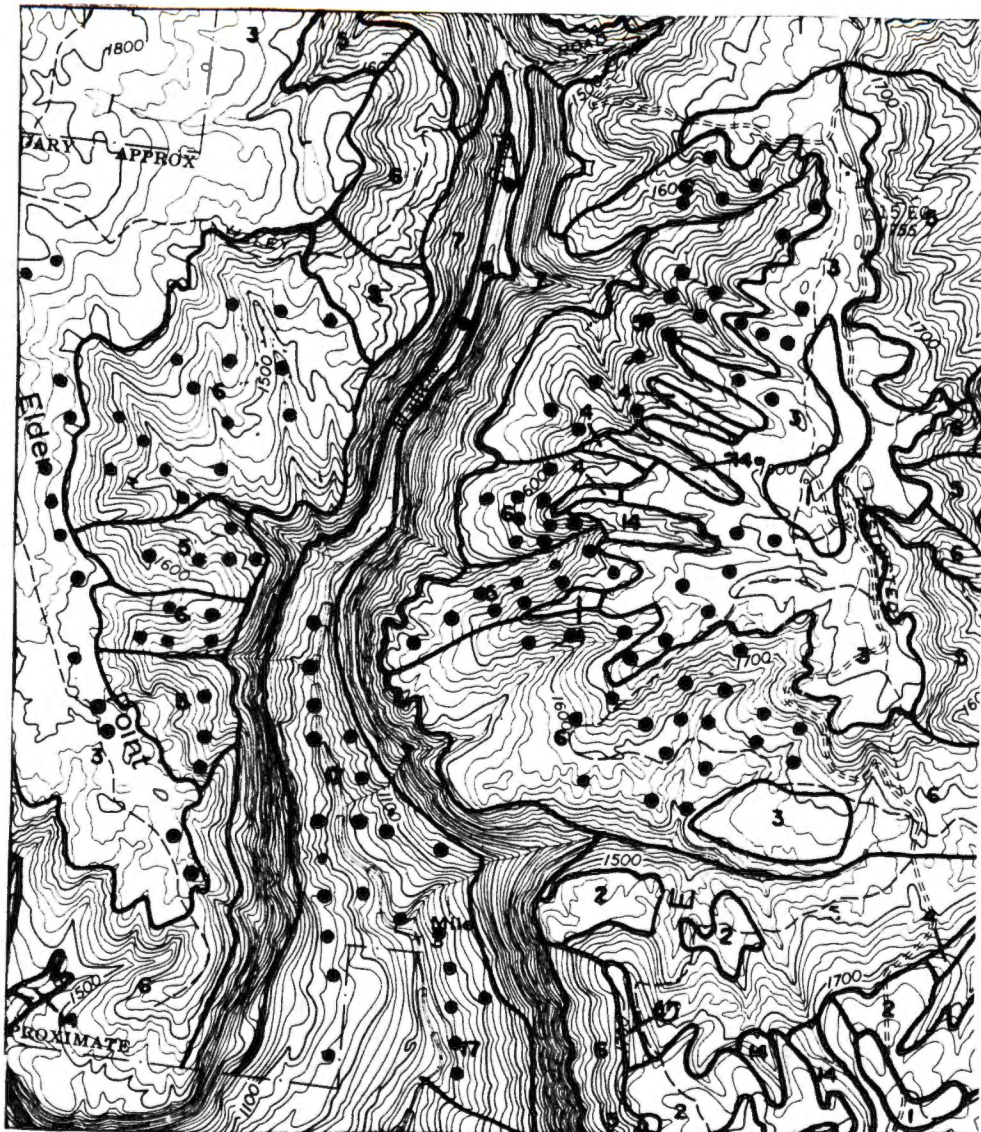


FIGURE 4.- MULLINS COVE PLOT LOCATIONS AND LANDTYPE DESIGNATIONS.

II. CLIMATE

The Cumberland Plateau has lower average temperatures than the adjacent Ridge and Valley and Eastern Highland Rim provinces with an approximate 3° F decrease for every 1,000 foot increase in elevation (Dickson 1960). The average January and July temperatures for Crossville are 32.6° F and 76.2° F, respectively (U.S. Dept. Comm. 1988). Higher average temperatures can be assumed for PCSF.

Length of frost-free growing period is similarly influenced by elevation. Most of the state is included in the range of 180 to 220 days. Shorter growing seasons are associated with higher elevations, with a 50 percent probability of a 165 day frost-free growing period (temperatures above 32° F) near Crossville (Fribourg and Ingram 1977). A longer frost-free growing period can be assumed for PCSF.

The Gulf of Mexico is the principal source of moist air for the area. Moisture-laden air forced to ascend the western slopes of the Cumberland Plateau is cooled, resulting in release of a portion of its moisture charge. This phenomena is responsible for higher average annual precipitation on the Plateau (50 to 55 inches/year) than in the Ridge and Valley Province (40 to 50 inches/year). Greatest precipitation occurs during the winter and early spring. Another precipitation maximum occurs in midsummer in response to convective shower and thunderstorm activity

(Dickson 1960). These rain events are characterized by sudden occurrence of violent thunderstorms and numerous lightning strikes.

Precipitation in Tennessee is the lowest in the fall and is caused by the occurrence of slow moving, rain suppressing high pressure systems. On the average, one or more prolonged dry-spells occur each year during the summer and/or fall (Dickson 1960). Due to the orographic nature of precipitation on the Plateau, the area sometimes receives more precipitation during dry spells than adjacent physiographic provinces.

III. DISTURBANCE

The Tennessee River Gorge forms the south border of PCSF. This area has a long history of disturbances that have influenced forest growth. A few of the more colorful events are described below (Raulston and Livingood 1974).

In 1777, over a dispute caused from selling land in Middle Tennessee to the white man, a group of Cherokee Indians broke from the Cherokee Nation and formed another tribe, the Chickamaugas. The Chickamaugas, lead by Dragging Canoe, settled near the narrows of the Tennessee River Gorge. From this strategic location, the Chickamaugas terrorized settlers traveling from East Tennessee to the new frontier in Middle Tennessee

In February, 1828, the Atlas became the first steamboat

to successfully travel through the Gorge on its way to Knoxville. Steamboat travel became more frequent along with the practice of cutting wood from the surrounding forests to provide fuel.

On March 11, 1867, the biggest flood in the recorded history of the upper Tennessee River resulted in river levels seventy to one hundred feet above normal in the narrows of the Tennessee River Gorge. The steamboat Cherokee traveled through the gorge during the flood "backing with all power on her wheel, but the current was carrying her on at almost railroad speed". A crew member on the Cherokee discussed the journey through the gorge:

Streams pitching from cliffs and sparkling in the sunlight, the great river rushing headlong against mighty cliffs of rock and its waters rebounding in great columns and waves, great trees ramming and crashing the stone walls,-- all this was indescribably thrilling and awe-inspiring.

The illegal art of moonshining has influenced the forests of the Tennessee River Gorge since white man first settled in the area. Numerous large stills destroyed by federal agents were encountered on the PCSF study site. The area bordering Walden Ridge and Raccoon Mountain has been described by federal revenue officers as one of the greatest areas of moonshine production in the nation.

In 1938, land acquisition for PCSF was initiated in Marion, Hamilton and Sequatchie Counties. By the early

1940's, most of the 25,759 acres presently contained in the forest was acquired. Before this time, the entire area was repeatedly high-graded, burned and grazed (Tenn. Dep. of Conservation 1989). Since state acquisition, disturbances have either been minimized or eliminated.

Due to fire suppression efforts, wildfires have been drastically reduced on the forest. Even so, the steep terrain and large number of people visiting and living near the forest ensure that fire is an ever-present factor influencing forest development.

Insect and disease damage still affect forest stands. Southern pine beetle (Dendroctonus frontalis Zimm.) outbreaks occur in shortleaf (Pinus echinata Miller) and Virginia pine (Pinus virginiana Miller) stands. Infested trees are usually salvaged (Tenn. Dep. of Conservation 1989).

Ice storms, floods, tornadoes and other natural disturbances occasionally influence forest development (Tenn. Dep. of Conservation 1989).

IV. FORESTS

The structure and composition of Cumberland Plateau forests have been extensively documented (Hinkle 1978, Schmalzer 1978, Smith 1977, Wade 1977 and Caplenor 1979). Both Braun (1950) and Vankat (1979) have proposed similar classifications of Cumberland Plateau forests. Braun places PCSF in the Deciduous Forest formation, the Mixed Mesophytic

Forest region, the Cumberland Plateau section, "the Cliff Section" subsection and the Southern District.

The majority of this sub-maturely dissected upland is covered with secondary mixed oak, oak-hickory and oak-pine forest types. Red maple (Acer rubrum L.) are found on poorly drained, swampy areas of the uplands, while post oak (Quercus stellata Wang.) and blackjack oak (Quercus marilandica Muenchh.) are found on very dry shallow soils. Pine-heath communities occur along the edge of plateau gorges (Braun 1950). Gorge communities are composed of mesic species and are usually very distinct from communities on the plateau surface.

The present age class structure of PCSF is a result of past land use prior to State acquisition. Previously high-graded stands, 70 to 100 years old, occupied 21,742 acres (91.4%). Of the remaining 1,544 forested acres (8.6 %), 840 acres support stands less than 10 years old, 107 acres support 30 to 40-year-old pine plantations established on abandoned fields after State acquisition and 597 acres support old-growth hardwood stands over 100 years old (Tenn. Dep. of Conservation 1989).

V. PHYSIOGRAPHY AND GEOLOGY

The Cumberland Plateau is the southern portion of the structural province known as the Appalachian Plateau. The Appalachian Plateau extends in a southwesterly direction from

southern New York to central Alabama. The Plateau's characteristics vary considerably.

Within Tennessee, the Plateau is a tableland of approximately 4,300 square miles (Luther 1977). The Plateau rises 800 to 2,000 feet above the Ridge and Valley Province on the east and 800 to 1,000 feet above the Eastern Highland Rim on the west (Fullerton and Bernard 1977). The Plateau varies in width from about 55 miles at the Kentucky border to about 35 miles along the Alabama border (Luther 1977). Elevation of the Plateau surface averages about 2,000 feet, with the Cumberland Mountains rising to 3,000 feet or more. The eastern boundary is a steep sandstone escarpment that is only slightly dissected by streams. The western boundary is much more dissected and is characterized by deep, steep-walled gorges, spurs and outliers. The Plateau gradually decreases in elevation from north to south.

The topography of the Plateau is due in part to the erosion-resistant Pennsylvanian sandstones that act as a protective cap for the underlying, more easily eroded Mississippian shales and limestones (Figure 5). These differential erosion rates combined with the presence or absence of late Paleozoic mountain-building forces have resulted in the present topography of the Plateau.

The top most Pennsylvanian aged rocks represent the last known depositional history in Tennessee during the Paleozoic Era. Any younger rocks formed during this time have since

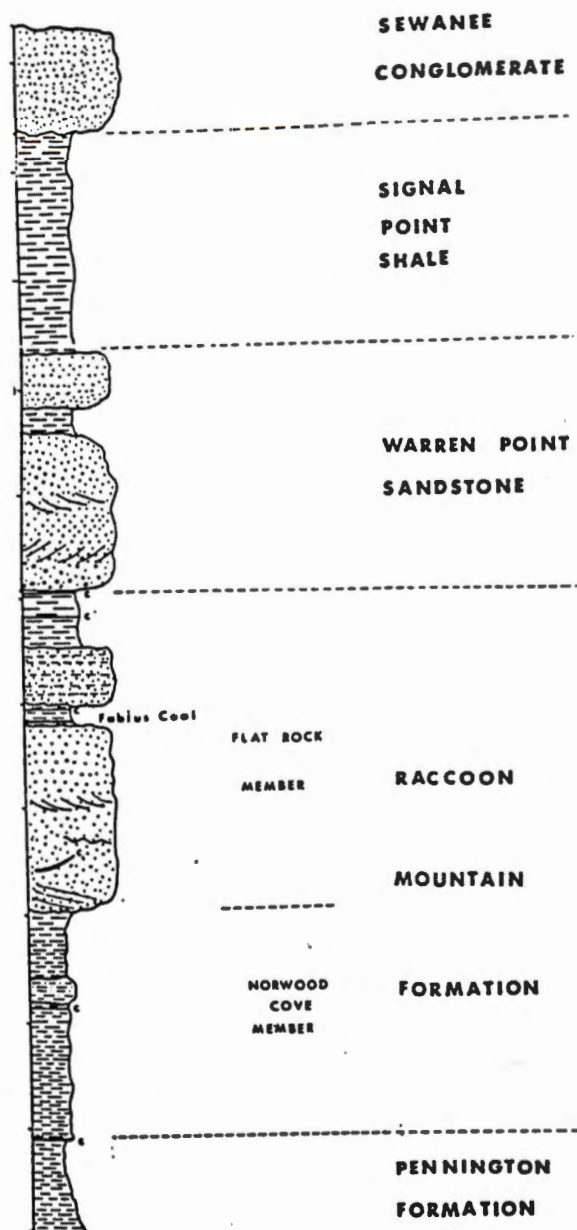


FIGURE 5.- GENERALIZED STRATIGRAPHIC SECTION OF MULLINS COVE STUDY SITE.

Source: Wilson, R. L. 1975. Lower Pennsylvanian strata of the northern part of Sand Mountain, Alabama, Georgia, and Tennessee. *Journal of the Tennessee Academy of Science* 50(1):20-24.

been removed by erosion (Miller 1974).

Toward the end of Paleozoic time, strong forces were exerted on the sediments that were deposited on the eastern edge of North America. The rock layers were buckled and fractured into long, high ranges of mountains. The western most deformations associated with this mountain building episode (Allegheny Orogeny) occur as thrust faults and bedding plane faults along the eastern side of the Cumberland Plateau in Tennessee. These geologic events are responsible for the major structural features associated with the eastern Cumberland Plateau: including the Cumberland Plateau overthrust fault, Cumberland Block, Sequatchie and Elk Valley, Grassy Cove, Crab Orchard Mountains and Walden Ridge (Luther 1977 and Miller 1974).

Other features associated with the Cumberland Plateau include the Tennessee River Gorge at the southern end of Walden Ridge; Lookout, Lone, and Powell Mountains east of the Plateau; and Raccoon and Sand Mountains south of the plateau. Numerous outliers occur west of the Plateau, the largest being Short Mountain. These features were formed by erosional dissection of the main Plateau mass (Luther 1977 and Miller 1974).

VI. SOILS

The soils of the Plateau are for the most part highly leached Utilisols in siliceous, mesic families. Nitrogen,

phosphorous and calcium content is usually insufficient for good tree growth (Francis et al. 1977). Soil characteristics are dependent on underlying bedrock and/or overlying colluvium.

Physical and chemical properties of Plateau soils have been shown to vary along aspect and slope position gradients (Franzmeier et al. 1969). A general classification of the PCSF soils by landtypes is given below (Jackson 1982):

<u>Landtype</u>	<u>General Soil Classification</u>
3	Lily-Lonewood-Ramsey: Gently sloping to steep, well-drained loamy soils that are less than 6 feet deep over sandstone and shales.
5 and 6	Ramsey-Rock Outcrop-Lily: Gently sloping to steep, well-drained loamy soils that are less than 4 feet deep over sandstone bedrock. Rock outcrops are common.
17	Bouldin-Gilpin-Allen: Gently sloping to steep, well-drained loamy soils that range from 2 feet to more than 5 feet deep over sandstone or shale on mountain sides or foot slopes. Boulders are numerous.

VII. LANDTYPES

Twenty different landtypes occur throughout Walden Ridge (Figure 2). Landtypes occurring on limestone or shale formations are not present in the Mullins Cove area. The most

extensive landtypes on the study site were LT-3, LT-5, LT-6 and LT-17.

Landtype 3 consists of broad sandstone ridges with a southern aspect. On PCSF study site this landtype is closely associated with the Sewanee Conglomerate Sandstone formation. The strata composing this formation are erosion resistant sandstones, resulting in an area of level to moderate slopes with alternating ridges and swales.

Landtype 5 consists of north-facing sandstone slopes. This landtype is closely associated with the Signal Point Shale formation. The Signal Point Shale formation, composed of alternating layers of shale and sandstone, is less erosion resistant than predominantly sandstone strata on the study site. The more erodible shale strata result in steeper slopes and greater dissection than in LT-3.

The influence of shale on site properties within LT-5 is manifest as it determines topography. Colluvial material from the younger Sewanee Conglomerate Sandstone formation overlying the Signal Point Shale formation control soil physical and chemical properties within LT-5.

Landtype-6 consists of south facing sandstone slopes. Aspect is the major difference between LT-5 and LT-6. The same site factors as discussed under LT-5 characterize sites within LT-6.

Landtype 17 consists of the plateau escarpment and upper sandstone slopes and benches with a southern aspect. Two

physiographic features caused by erosional processes influence the local topographic relief within LT-17:

1) massive sandstone boulders partially buried by smaller colluvial and/or alluvial material and 2) underlying horizontal bedrock strata with differential erosive resistance. These processes result in a "cup and mound" topography that create variable microsite conditions for forest growth and development.

CHAPTER III

SAMPLING METHODS AND MATERIALS

I. SAMPLE PLOT ALLOCATION

Two schools of thought prevail on the location of sample plots for vegetation analysis. Proponents of R. A. Fisher claim complete or restricted randomization is necessary to maintain statistical integrity, resulting in valid sampling errors. Followers of W. S. Gosset ("Student") believe systematic sampling is usually unbiased, gives greater accuracy for the same number of plots and that biometric techniques are validly applied although they tend to overestimate error statistics. When using systematic sampling care must be taken to insure vegetation or landscape patterns do not coincide with the grid interval used to locate plots (Daubenmire 1968).

The pros and cons of random versus systematic plot location are discussed in many works dealing with quantitative vegetation analysis (Causton 1988; Daubenmire 1968; Freese 1962; Hush, Miller and Beers 1982; Lund and Thomas 1989; Orloci 1978). Advantages attributed to systematic location include representative sampling throughout the population under question and ease of plot location in the field (Freese 1962). These advantages were the primary reasons for using systematic location in this

study, realizing any variance structure calculated for subsequent analyses could be overestimated (conservative).

A landtype overlay drawn by Tennessee Division of Forestry personnel was used to stratify the landscape into operational landtype units. A dot grid representing 6 X 6 chains (396 X 396 ft.) was used to locate sampling plots within each landtype, resulting in a stratified systematic sampling design with random starts for each landtype. The grid dots represented the lower-slope left corner of a 0.10-acre rectangular plot used to sample overstory vegetation (this and subsequent plot positions were located facing down slope). Each grid dot was located in the field by compass and pacing and evaluated for the following conditions:

- 1) minimal localized disturbances to insure homogeneous forest recovery
- 2) homogeneous physiographic features to simplify vegetation/landform relationships
- 3) significant distance away from landtype boundaries to prevent sampling of ecotones.

If one of these conditions was severely violated, a new plot was established within a 0.5 chain distance either parallel to the initial plot's major or minor axis (Figure 6).

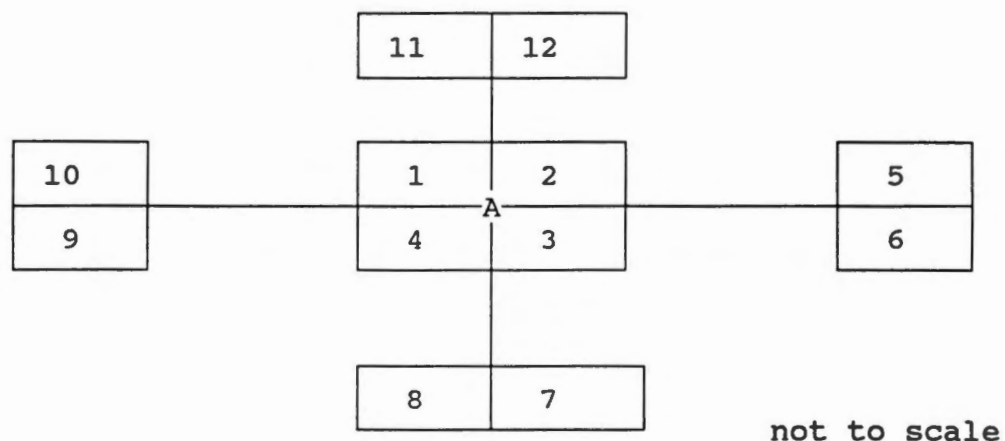


FIGURE 6.- SYSTEMATIC MOVEMENT OF OVERSTORY PLOT WHEN PLOT ACCEPTANCE CRITERIA WERE NOT MET.

Point A represents the original location of the lower-slope left corner (facing down slope) of the original overstory plot. Plots 1 through 4 represent 0.10-acre plots formed by four quadrants with A as the origin. The first of the plots described by points 1, 2, 3, or 4 to fulfill plot acceptance criteria will be used for data collection. If none of these plots meet the acceptance criteria, the "wing plots" (plots 5-12) defined by 1/2 chain displacements of the origin are successively examined until a plot meets the acceptance criteria. If plot acceptance criteria are not met after examination of all described plot locations, the area will be deemed unsuitable for sampling.

This sampling scheme resulted in 149 overstory plots allocated as followed:

<u>Landtype</u>	<u>No. of plots sampled</u>
2	1
3	33
4	1
5	36
6	43
7	2
14	4
15	2
17	27

Due to small sample size, plots sampled as LT-2, LT-4, LT-7, LT-14 and LT-15 were discarded from subsequent analyses. Data was compiled from the 139 remaining plots to create the working data sets.

II. SAMPLE PLOT DESIGN

Overstory Vegetation

Overstory vegetation (5.5 in. diameter breast height (d.b.h.) and larger) was collected from 0.10-acre (100x43.56 ft.) rectangular plots. The major axis of the plot was aligned parallel to the contour to facilitate ease of plot establishment and minimize vegetational variance associated with elevation. Overstory data included tree species, d.b.h. (1 in. diameter class) and crown class (dominant, co-dominant, intermediate, suppressed).

Understory Vegetation

Understory vegetation (1.5 in. to 5.5 in. d.b.h.) was collected from 0.05-acre subplots. Understory plots were defined by bisecting overstory plots perpendicular to the major axis, using the half containing the down slope left hand corner for data collection. Understory data included species, d.b.h. (1 in. diameter classes) and coverage class. Coverage class¹ was defined for this and subsequent subplots as the percent of plot area covered by the vertical projection of plant crowns to the ground surface. The coverage classes were represented as 0 to 5 percent, 5 to 25 percent, 25 to 50 percent, 50 to 75 percent, 75 to 95 percent and 95 to 100 percent (Daubenmire 1954).

Sapling and Shrub Vegetation

Sapling and shrub vegetation (greater than 2 ft. high, less than 1.5 in. d.b.h.) was sampled using one 0.01-acre (20.9 x 20.9 ft.) square plot bounded by and including the lower-slope, left corner of the overstory plot. Data collected for shrub vegetation included plant species and coverage class.

¹Only coverage class of seedling/herbaceous species was used in subsequent statistical analyses.

Seedling and Herb Vegetation

Seedling and herb vegetation (less than 2 ft. high) was sampled using two mil acre (radius=3 ft. 8.7 in.) circular plots; one each located at the lower-slope left corner and upper-slope right corner of the overstory plot. Data collected for understory vegetation included plant species and coverage class.

Physiographic data

The following physiographic data were collected for each plot (measurement variables were evaluated from the center of the overstory plot's up-slope boundary): landtype; elevation; position; angle; aspect; shape; bedrock and degree of protection.

Landtype was coded according to the numbers assigned by Smalley (1982). Elevation was in feet as determined from topographic maps in the field. Slope position was coded as 1=ridge crowns and convex shoulders, 2=upper slope, 3=lower slope and 4=bottoms and footslopes. Slope angle was determined with a clinometer. Plot aspect was measured to the nearest degree with a compass in the field. Slope shape was coded as 1=concave slope, 2=linear slope (no surface curvature) and 3=convex slope. Underlying bedrock was coded from an unpublished geologic map acquired from the Tennessee Division of Geology; 1=Pennington Formation, 2=Raccoon Mountain Formation, 3=Warren Point Sandstone Formation,

4=Signal Point Shale Formation and 5=Sewanee Conglomerate Formation.

Protection was a value representing an index of topographic shading from surrounding landforms. The concept consisted of finding the mean value of the ratio between elevation difference and distance to the nearest surrounding landform evaluated at 0, 45, 90, 135, 180, 225, 270 and 315 degrees of azimuth (Callaway 1987). The formula is:

$$(ER - EP)/D$$

where: ER = elevation of sheltering landform

EP = elevation of plot

D = horizontal distance from plot to sheltering landform

The southern azimuths were weighted by 1.5 because exposure to the sun is greater on the southern aspects and this has been shown to affect tree growth (Beers et al. 1966).

Users of Calloway's protection index have had problems with objectively defining adjacent landforms to evaluate elevation/distance ratios (Pyle 1988). To make the decision more objective, I defined a circle of 5-inch map radius (10,000 ft.) around each sampling point to identify adjacent landforms as candidates for measurement. Selection of 10,000 ft. was subjective, but this distance allowed inclusion of

the dominant landforms surrounding the study area and permitted evaluating protection from any sample point. The point of elevation that formed the greatest vertical angle, with the sampling point as the vertex, along an elevation profile described by the predetermined cut off radii and the associated azimuth was used to determine elevation/distance ratios.

III. STATISTICAL ANALYSES

Five data sets were analyzed:

- 1) samples X overstory species matrix containing species relative importance values as cell entries
- 2) samples X midstory species matrix containing species relative importance values as cell entries
- 3) samples X sapling/shrub species matrix containing species relative frequencies as cell entries
- 4) samples X seedling/herbaceous species matrix containing species mean cover index as cell entries
- 5) samples X physical site parameter matrix containing quantitative site variables as cell entries.

Species relative importance value (RIV) is intended to represent the relative dominance of specific species. Species RIV is derived from the sum of relative basal area

and relative frequency. For each species, RIV is:

$$RIV = sba/pba + sf/pf$$

where sba = species basal area
 pba = plot basal area
 sf = species frequency
 pf = plot frequency

The sum of all species relative importance values for a single plot equals 200.

Multivariate statistical techniques were used to analyze the data. Plant ecologists have developed ordination techniques with few underlying statistical assumptions. These techniques are limited to descriptive interpretations achieved through ordering plant species and communities along hypothetical environmental gradients. Other multivariate techniques developed from classical statistical inference theory have the potential to predict characteristics of the forest environment (Shugart 1981). Even if violation of model assumptions render classical statistical inference invalid, these techniques can serve quite adequately to illustrate ecological relationships. Multivariate techniques developed from classical statistical inference were used in this study to evaluate the potential of ecological data sets to predict forest characteristics. If the model assumptions were severely violated the same techniques could also be used descriptively.

Discriminant analysis was performed to determine distinctiveness of landtype characteristics. Cluster analysis of overstory data set was performed to document and describe forest communities occurring within each landtype. Factor analysis of the vegetation/forest site data was performed to determine possible underlying factors influencing forest community spatial relationships.

Discriminant Analysis

For a set of observations containing one or more quantitative variables and a classification variable defining groups of observations, discriminant analysis techniques develop criterion permitting classification of each observation into one of several groups.

Both parametric and non-parametric discriminant techniques are available. Non-parametric techniques give valid posterior probabilities for data sets without making assumptions about the underlying distribution. Numerous non-parametric techniques exist, deriving posterior probabilities based on 1) density estimates (k^{th} -nearest-neighbor, kernel method), 2) parametric discriminant analysis performed on ranked variables, 3) logit models based on the cumulative logistic probability function and 4) several linear programming based approaches (SAS Institute 1987, Mahomood and Lawrence 1987, Joachimsthaler and Stam 1988).

Parametric discriminant techniques give valid

probabilities when the underlying data structure follows a multivariate normal distribution. The classification criterion can be based on either the individual within group covariance matrix (yielding a quadratic function) or the pooled within class covariance matrix (yielding a linear function) (SAS Institute 1987).

For this study, two assessments were made before selecting a specific discriminant technique: 1) within group variable distribution and 2) within group variance structure.

Normality. The Shapiro-Wilk test for normality was used to evaluate the variable distribution within landtypes as follows:

A) from the physical land characteristics data set

- 1) aspect
- 2) slope percent
- 3) elevation
- 4) protection

B) from the overstory vegetation data set
(species with highest frequency of occurrence)

- 1) chestnut oak IV
- 2) white oak IV
- 3) black oak IV
- 4) red maple IV

The results of the Shapiro-Wilk test indicated a high probability that the within group distributions were not multivariate normal (Table 1).

TABLE 1.- P-VALUES FROM THE SHAPIRO-WILK TEST TO ASSESS
NORMALITY OF SELECTED OVERSTORY AND PHYSICAL LAND
VARIABLES.

VARIABLE	LANDTYPE			
	3	5	6	17
	P-VALUE ¹			
CHESTNUT OAK RIV	0.01	0.09	0.01	0.01
WHITE OAK RIV	0.01	0.01	0.01	0.01
BLACK OAK RIV	0.01	0.01	0.01	0.01
RED MAPLE RIV	0.01	0.01	0.01	0.01
ASPECT	0.18	0.01	0.47	0.01
SLOPE PERCENT	0.35	0.02	0.45	0.19
ELEVATION	0.01	0.01	0.36	0.39
PROTECTION	0.01	0.73	0.06	0.02

1. P-value is the probability of a variable being sampled from a normal distribution.

Both non-parametric and parametric discriminant techniques were evaluated for this study. Even though violation of multivariate normality renders any classical statistical inference invalid for this analysis, parametric discriminant techniques appear most appropriate to illustrate relative relationships between forest cover occurring within specific landtypes.

Future studies are needed to assess the distributions in forest ecology data sets. Once distributions are documented, the performance of parametric or non-parametric discriminant techniques or both must be evaluated to develop preferred methods for specific research goals. Attempts have been made to develop robust techniques having the potential to elevate discriminant analyses to more than just a descriptive technique (McDonald 1981).

Variance Structure. Within group variance structure determines if a classification criterion should be based on a linear discriminant function or a quadratic discriminant function. The squared distance from an observation (plot) to group t (landtype) is given by:

$$d_{t2}(\mathbf{x}) = (\mathbf{x} - \mathbf{m}_t)' \mathbf{V}_t^{-1} (\mathbf{x} - \mathbf{m}_t)$$

If within group covariance matrices can be assumed equal, $\mathbf{V}_t$ equals the pooled covariance matrix. If within group

covariance matrices cannot be assumed equal, V_t equals individual covariance matrices. The posterior probability of an observation belonging to group t is equal to:

$$p(t|x) = \frac{e^{-0.5(d_t^2 + \ln|S_t|)}}{\sum_u e^{-0.5(d_u^2 + \ln|S_u|)}}$$

If the pooled covariance matrix is used then $\ln|S_t| = 0$, resulting in a linear discriminant function as opposed to a quadratic discriminant function. An observation is then classified into the group with the largest posterior probability (SAS Institute 1987).

Equality of within group covariance matrices can be tested with SAS by using the POOL=TEST option in PROC DISCRIM. These steps implement Bartlett's modification of the likelihood ratio test. The test is not robust with non-normal distributions. Bartlett's test, combined with visual examination of within group covariance matrices of selected data sets, was sufficient to determine that individual covariance matrices should be used to calculate posterior probabilities.

One physical site characteristics data set and six vegetation data sets were used to evaluate the discreteness of landtype characteristics. Landtype was used as the classification variable for all data sets. Aspect, slope

percent, elevation and protection were used as discriminating variables for the physical site characteristics data set. The RIV² of overstory species, RIV of understory species, relative frequency of sapling/shrub species occurring in five percent or more plots and the mean cover index of seedling/herbaceous species occurring in 20 percent or more plots were used as discriminating variables for individual forest stratum data sets. Two composite data sets were also analyzed by successively combining the understory and sapling/shrub data sets to the overstory data set.

Cluster Analysis

Cluster analysis is used to group similar observations. Input consists of data vectors characterizing observations to be clustered. Distance measures are calculated from the characterization vectors to determine similar observations. Choice of a distance measure, as well as a clustering technique, depends on the nature of the research question and underlying data structure.

Numerous clustering techniques and distance measures are available. Clustering techniques can be hierarchical or non-hierarchical, polythetic or monothetic and agglomerative or divisive. Hierarchical techniques successively join

² eastern hemlock and sweet birch occurred in less than five percent of the plots but were included for analysis due to their local dominance.

similar clusters in a hierarchy, illustrating the relationships between observations; non-hierarchical techniques provide no clustering history. Polythetic techniques utilize all information gathered on an observation to determine similarity; monothetic techniques utilize information from one observation characteristic to determine similarity. Agglomerative techniques begin clustering procedures by successively agglomerating individual observations into similar groups; divisive techniques begin clustering procedures by successively dividing pooled observations into similar groups. A clustering method can simultaneously be hierarchical, polythetic, and agglomerative, as well as any combination of the three discussed attribute pairs. Hierarchical, polythetic, agglomerative and/or divisive techniques are recommended to investigate plant community structure (Gauch 1982).

Numerous methods are available to evaluate similarity (distance or density) between observations. Since multivariate normal data structure is questionable for the data sets involved in this study, two clustering techniques not dependent on multivariate normal distributions were evaluated to investigate forest community structure: complete-linkage and k^{th} -nearest neighbors clustering.

Complete-linkage, or farthest neighbor clustering begins by combining the two closest observations to form a cluster. Once this initial step is performed, the farthest neighbor

technique defines distance as the largest pairwise distance between an observation in one entity and an observation in another entity (an entity being a cluster or a single observation) (Jackson 1983). A new cluster is formed by joining entities that are closest to each other. The farthest neighbor clustering technique was implemented with SAS using PROC CLUSTER and the METHOD=COMPLETE options. This algorithm uses Euclidian distance to calculate similarity between two observations. The Euclidian distance between two observations is defined as the square root of the sum of squared differences between respective observation characteristics:

$$d_{ij} = \sqrt{\sum (x_{ij} - x_{i',j})^2}$$

Both farthest neighbor and k^{th} -nearest neighbor clustering techniques were performed on the overstory X species data matrix with species RIV's as input variables. The results were evaluated using Gauch's (1986) list of criteria for judging the appropriateness of clustering techniques. A specific technique should be computationally feasible, robust, effective and concise.

Results from the farthest neighbor clustering technique were easier to interpret and produced clusters that strengthened subjective community observations made in the field. Therefore, this technique was used to document and

describe plant communities by landtype. Overstory species RIV's were used to define distances between plots and clusters. Community clusters were defined from landtype dendrograms using levels of dispersion that best represented field observations. Community names were derived from the species with the greatest mean importance value within a cluster.

Factor Analysis

The goal of factor analysis is to summarize the interrelationships among variables in a concise but accurate manner as an aid to conceptualization. Most factor analysis techniques begin with product-moment correlations among variables, introduce certain restrictions, then solve for weights (factor pattern) that signify a variable's correlation with a set of underlying, unobservable factors (Gorsuch 1983).

The common factor model assumes that observed variables are linear combinations of underlying, unobservable factors.

The equation for the common factor model is given by:

$$x_{ij} = f_{i1}b_{1j} + f_{i2}b_{2j} + \dots + f_{iq}b_{qj} + e_{ij}$$

where

x_{ij} is the value of the i^{th} observation on the j^{th} variable

f_{ik} is the value of the i^{th} observation on the k^{th} common factor (factor score)

b_{kj} is the regression coefficient of the k^{th} common factor for predicting the j^{th} variable (pattern element)

e_{ij} is the value of the i^{th} observation on the unique factor

q is the number of common factors.

(Kim 1978, Bernstein 1988 and SAS 1985)

The " q " common factors are assumed to be "common" to two or more variables and contribute to the covariation between variables. The unique factor contains variable specific variation unexplained by the common factors; this could include random errors of measurement, inherent variable variation and all other sources of error and bias (Gorsuch 1983).

Factor matrices are estimated through the decomposition of a partial correlation matrix containing communalities in the diagonals. A variable's communality is the portion of variance accounted for by the common factors (Gorsuch 1983).

The reduced correlation matrix can be represented by (Bernstein 1988):

$$R = B \Phi B' + U$$

where

R is the full correlation matrix

$B \Phi B'$ is the partial or common factor correlation matrix with elements

B = pattern matrix

$\Phi = (1/N) (F'F)$ = factor correlation matrix

The communalities occurring within the diagonals of the common factor correlation matrix must be estimated before the common factor matrix can be decomposed into factor scores and pattern elements. Once correlation matrix elements are estimated, the reference axes can be rotated to improve factor interpretation. There are numerous methods to estimate communalities, decompose common factor matrices and rotate reference axes. It is beyond the scope of this study to provide details for the intricacies of these operations. Gorsuch (1983) devotes a whole chapter to communality estimation and the other works cited in this section should provide a good starting point to evaluate different factor and rotation methods.

Principal factor analysis is a commonly used technique to estimate the elements of R . The technique is computationally efficient and easy to implement. Several circumstances made

principal factor analysis appealing for the specific question posed for this study: 1) the investigation of forest community/landtype relationships was purely exploratory in the sense that no preconceived factor pattern was trying to be reproduced, 2) anomalies with the data sets involved prohibited sound implementation of maximum-likelihood factor analysis (a technique that is preferred by many statisticians) and 3) less computer time was required to analyze the four vegetation data sets involved with this study.

For these reasons, principal factor analysis, as implemented by SAS PROC FACTOR, was used in this study. Prior communality estimates were provided by using a variable's maximum correlation with any other variable. Due to ease of interpretation, the non-rotated factor pattern was used to describe underlying factors.

Subjective examination of scree plots and eigen values was used to determine the number of factors to extract. Four factors seemed appropriate to explain the variation within the overstory data set (eigen values > 1). For comparison between strata, four factors were extracted from the other single stratum data sets even though fewer factors appear appropriate to explain variation within these data sets.

Principal factor analysis was performed on four data sets: 1) overstory data set, 2) understory data set, 3) sapling/shrub layer data set and 4) seedling/herbaceous layer

data set. Each data set included information from the respectively mentioned forest stratum plus physical site data.

CHAPTER IV

RESULTS AND DISCUSSION

As previously discussed, multivariate normal distribution cannot be assumed for the variable groups involved with the following analyses. Because of this, any probabilities or classification percentages presented in subsequent discussions should be viewed from a descriptive rather than an inferential stand point.

I. DISCRIMINANT ANALYSIS

Results

Landtype Environments. The physical site characteristics classification matrix revealed greater than 87 percent correct classification of observations within each landtype (Table 2).

Overstory Vegetation. The overstory vegetation classification matrix revealed more than 85 percent correct classification for all landtypes except landtype 5 (44.44 percent) (Table 3).

Understory Vegetation. The understory vegetation classification matrix revealed high misclassification rates

TABLE 2.- PHYSICAL SITE CHARACTERISTICS CLASSIFICATION MATRIX.

Number of Observations and Percent Classified into LT:					
From LT	3	5	6	17	TOTAL
3	29 87.88	0 0.00	4 12.12	0 0.00	33 100.00
5	0 0	32 88.88	4 11.11	0 0.00	36 100.00
6	0 0.00	5 11.90	37 88.10	0 0.00	42 100.00
17	0 0.00	0 0.00	0 0.00	27 100.00	27 100.00
Total	33	38	40	27	138 ¹
Percent	23.91	27.54	28.99	19.57	100.00

1. One plot was dropped due to missing values.

TABLE 3.- OVERSTORY CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT: FROM					
LT	3	5	6	17	TOTAL
3	30 90.91	1 3.03	2 6.06	0 0.00	33 100.00
5	4 11.11	16 44.44	14 38.89	2 5.56	36 100.00
6	3 6.98	1 2.33	39 90.70	0 0.00	43 100.00
17	0 0.00	4 14.81	0 0.00	23 85.19	27 100.00
TOTAL	37	22	55	25	139
PERCENT	26.62	15.83	39.57	17.99	100.00

for all landtypes except landtype 3 (87.88 percent correct classification) (Table 4).

Sapling and shrub vegetation. The sapling and shrub vegetation classification matrix revealed high misclassification rates for all landtypes except landtype 17 (70.39 percent correct classification) (Table 5).

Seedling and herb vegetation. The seedling and herb vegetation classification matrix revealed relatively low misclassification rates for all landtypes; correctly classified plots were greater than 69 percent for all sampled landtypes (Table 6).

Combined forest vegetation. The correct classification rate for LT-5 in the two stratum data set was 83.33 percent, with the majority of misclassified plots being classified into LT-6. All remaining plots in both two stratum and three stratum data sets were correctly classified (Tables 7 & 8).

Discussion

Landtype environments. Due to the high correct classification rates for all landtypes, physical conditions controlling forest growth within landtypes can be assumed more or less homogeneous and distinct. All plots sampled as LT-17 were classified as such and no plots sampled as LT-

TABLE 4.- UNDERSTORY CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT: FROM					
LT	3	5	6	17	TOTAL
3	29 87.88	2 6.06	2 6.06	0 0.00	33 100.00
5	8 22.22	21 58.33	3 8.33	4 11.11	36 100.00
6	14 32.56	12 27.91	15 34.88	2 4.65	43 100.00
17	3 11.11	9 33.33	1 3.70	14 51.85	27 100.00
TOTAL	54	44	21	20	139
PERCENT	38.85	31.65	15.11	14.39	100.00

TABLE 5.- SAPLING AND SHRUB CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT: FROM					
LT	3	5	6	17	TOTAL
3	16 48.48	4 12.12	13 39.39	0 0.00	33 100.00
5	3 9.09	16 48.48	12 36.36	2 6.06	33 100.00
6	8 20.00	9 22.50	23 57.50	0 0.00	40 100.00
17	4 14.81	2 7.41	2 7.41	19 70.37	27 100.00
TOTAL	31	31	50	21	133 ¹
PERCENT	23.31	23.31	37.59	15.79	100.00

1. Six plots were dropped due to missing values.

TABLE 6.- SEEDLING AND HERB CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT: FROM					
LT	3	5	6	17	TOTAL
3	23 69.70	1 3.03	9 27.27	0 0.00	33 100.00
5	0 0.00	27 75.00	7 19.44	2 5.56	36 100.00
6	6 13.95	2 4.65	35 81.40	0 0.00	43 100.00
17	1 3.70	0 0.00	3 11.11	23 85.19	27 100.00
TOTAL	30	30	54	25	139
PERCENT	21.58	21.58	38.85	17.99	100.00

TABLE 7.- TWO STRATA (OVERSTORY AND UNDERSTORY)
CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT:					
FROM LT	3	5	6	17	TOTAL
3	33 100.00	0 0.00	0 0.00	0 0.00	33 100.00
5	1 2.78	30 83.33	5 13.89	0 0.00	36 100.00
6	0 0.00	0 0.00	43 100.00	0 0.00	43 100.00
17	0 0.00	0 0.00	0 0.00	27 100.00	27 100.00
TOTAL PERCENT	34 24.46	30 21.58	48 34.53	27 19.42	139 100.00

TABLE 8.- THREE STRATA (OVERSTORY, UNDERSTORY AND
SAPLING/SHRUB) CLASSIFICATION MATRIX.

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO LT: FROM					
LT	3	5	6	17	TOTAL
3	33 100.00	0 0.00	0 0.00	0 0.00	33 100.00
5	0 0.00	33 100.00	0 0.00	0 0.00	33 100.00
6	0 0.00	0 0.00	40 100.00	0 0.00	40 100.00
17	0 0.00	0 0.00	0 0.00	27 100.00	27 100.00
TOTAL	33	33	40	27	133
PERCENT	24.81	24.81	30.08	20.30	100.00

3,LT-5 or LT-6 were misclassified as LT-17. This pattern illustrates the distinctness of forest environments above and below the plateau escarpment; LT-3, LT-5 and LT-6 were located above the plateau escarpment and LT-17 was located below the plateau escarpment. Landtypes 3 and 6 have common aspects while LT-5 and LT-6 have common elevations and slope percents, possibly explaining the misclassification patterns.

Vegetation. The misclassification pattern for the overstory data set was similar to that expressed in the physical land characteristics data set. With the exception of LT-5 (north-facing sandstone slopes), overstory vegetation appears to be relatively distinct. The pattern of misclassified plots also suggests vegetation varies along an elevation gradient from LT-3 through LT-17.

Discriminant analyses performed on the understory, sapling/shrub layer and seedling/herbaceous layer sets were less successful in revealing vegetation discreteness within landtypes. Even so, elements of the misclassification pattern illustrated by the overstory analysis can be found throughout the other strata. For all subordinate forest strata, the majority of misclassified plots sampled as landtypes above the escarpment were reclassified into another landtype above the escarpment. Misclassified plots sampled as LT-17 were reclassified into all three above escarpment landtypes. With the exception of the understory data set,

misclassification rates for LT-17 were relatively low. Nine plots from the understory data set sampled as LT-17 were reclassified as LT-5.

These relationships reveal similarity of vegetation among landtypes above the escarpment. Vegetation on LT-5 is most similar to vegetation below the escarpment.

Misclassification rates for the two and three stratum data sets were very low, suggesting that inclusion of all forest layers provided better information than any single strata.

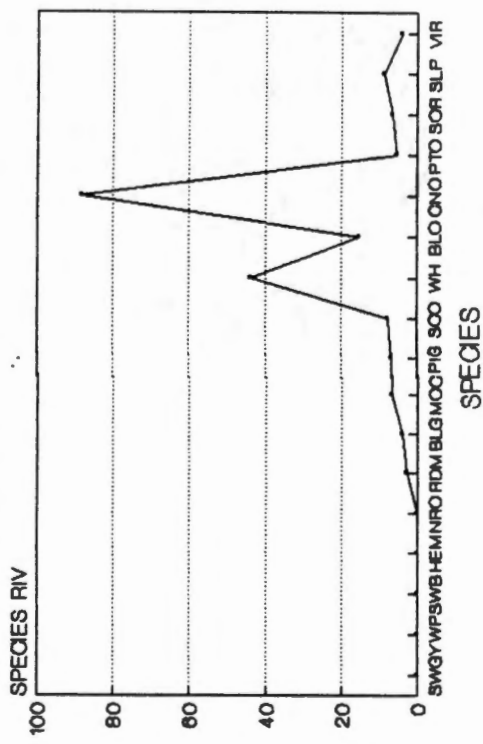
III. CLUSTER ANALYSIS

Results

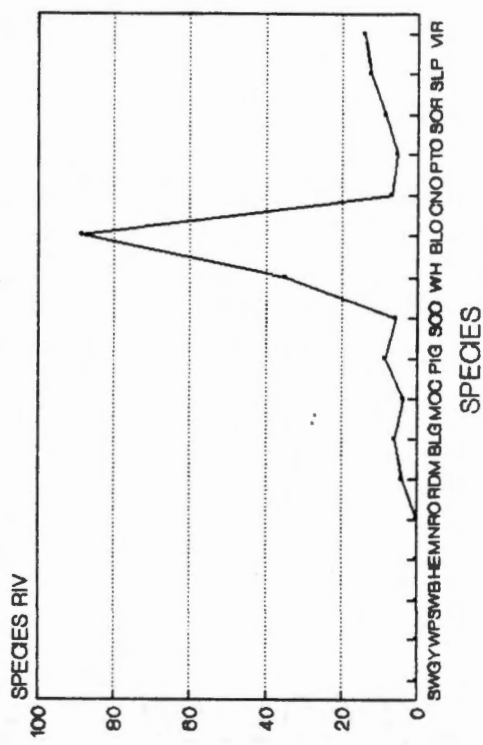
Landtype 3. Farthest neighbor cluster analysis identified four forest communities within LT-3--chestnut oak (Quercus prinus L.), black oak (Quercus velutina Lam.), shortleaf pine and white oak (Quercus alba L.) (Figures 7 through 10) .

Chestnut Oak Community. This was the predominant forest community sampled in LT-3 east of Mullins Creek (12 plots). The plots classified as chestnut oak community were generally located on ridgetops and convex upper slopes. White oak was the major overstory associate with black oak as a secondary associate. Dogwood (Cornus florida L.), chestnut oak and sourwood (Oxydendrum arboreum (L.) DC.) were dominant understory associates with red maple (Acer rubrum L.) and

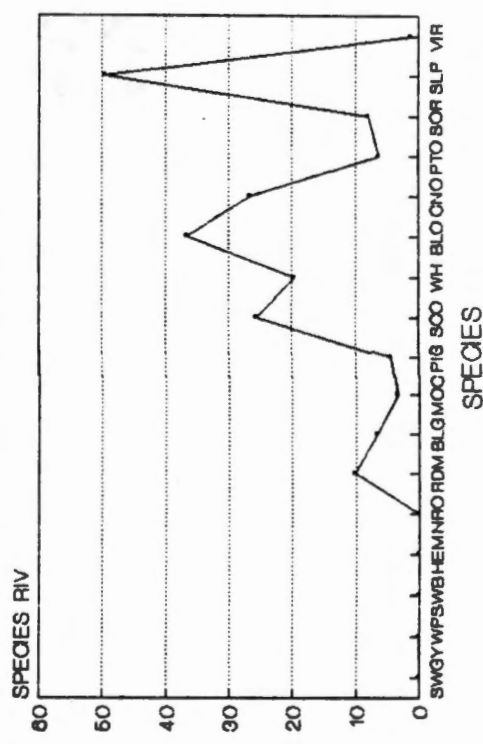
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BLACK OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



WHITE OAK COMMUNITY

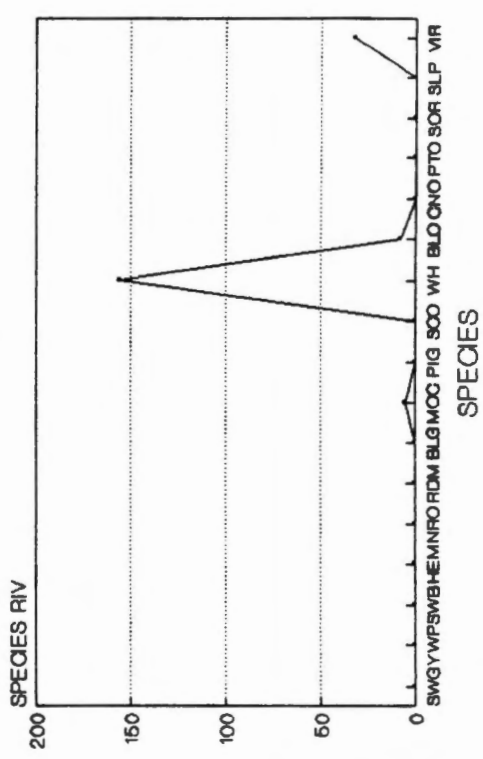
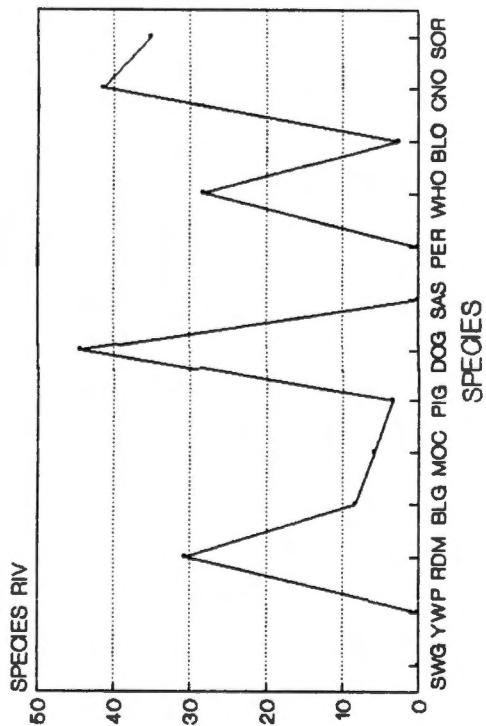
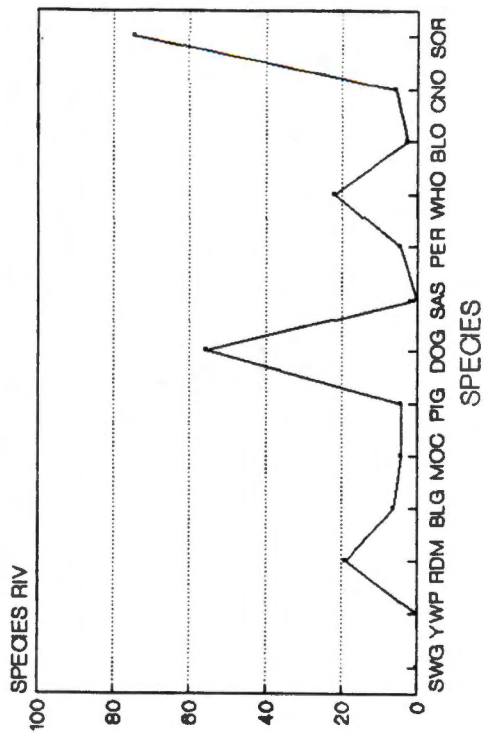


FIGURE 7.- LANDTYPE 3 OVERSTORY SPECIES COMMUNITY PROFILES.

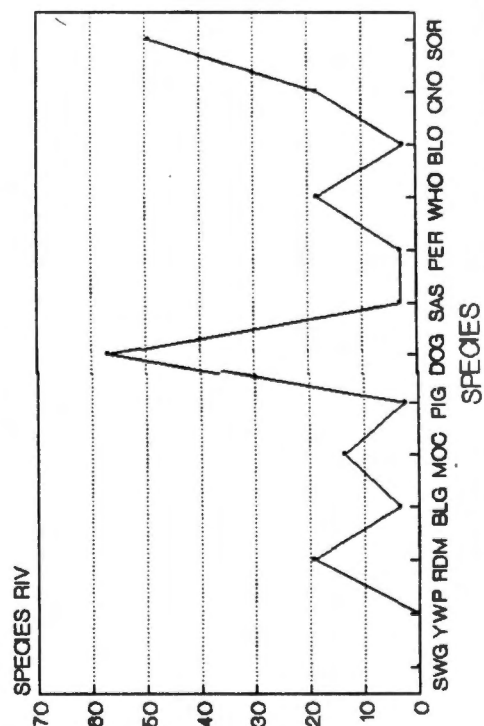
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BLACK OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



WHITE OAK COMMUNITY

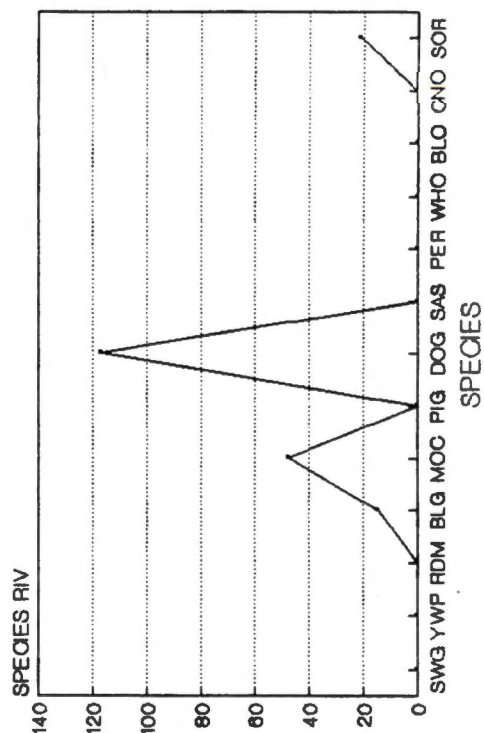


FIGURE 8.- LANDTYPE 3 UNDERSTORY SPECIES COMMUNITY PROFILES.

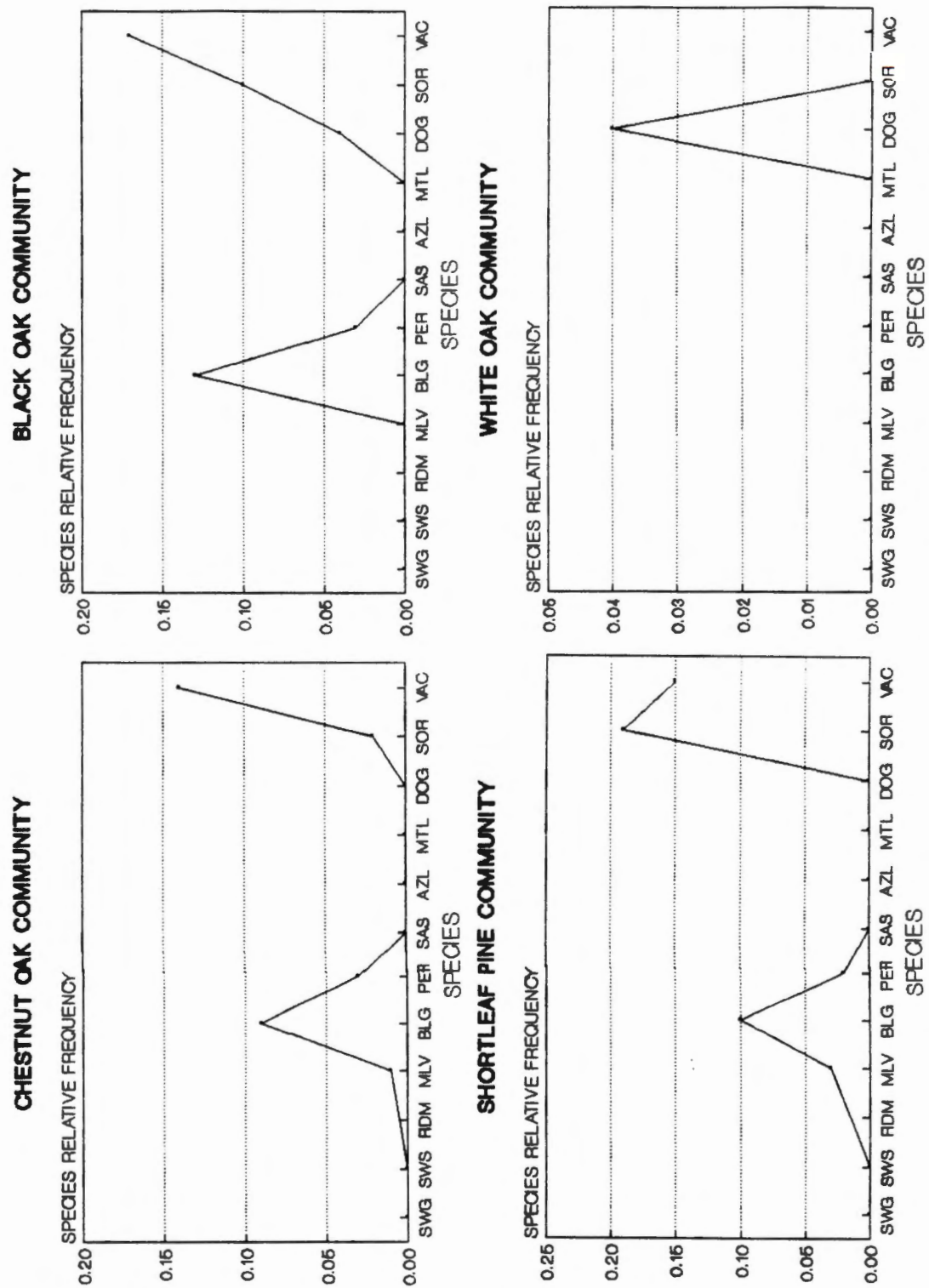
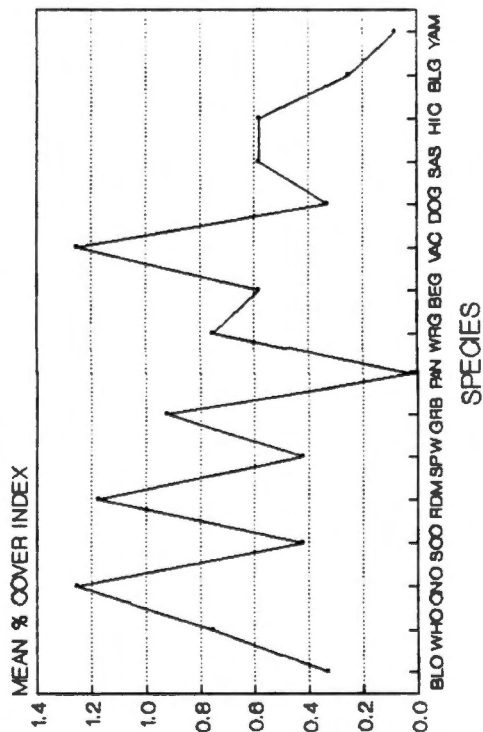
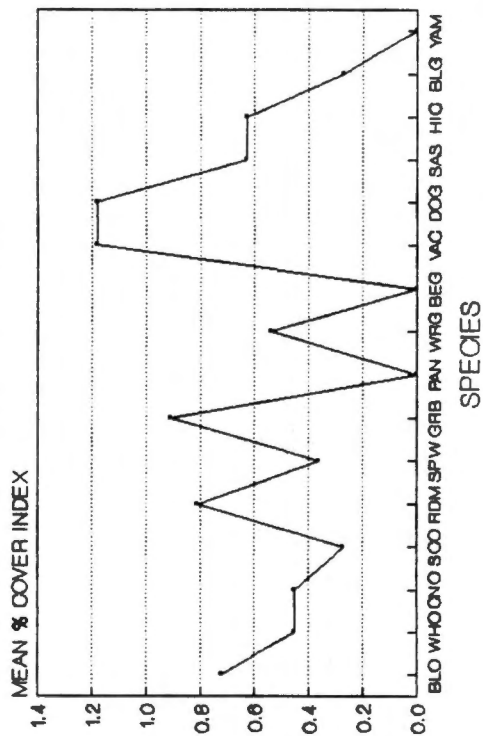


FIGURE 9.- LANDTYPE 3 SAPLING/SHRUB SPECIES COMMUNITY PROFILES.

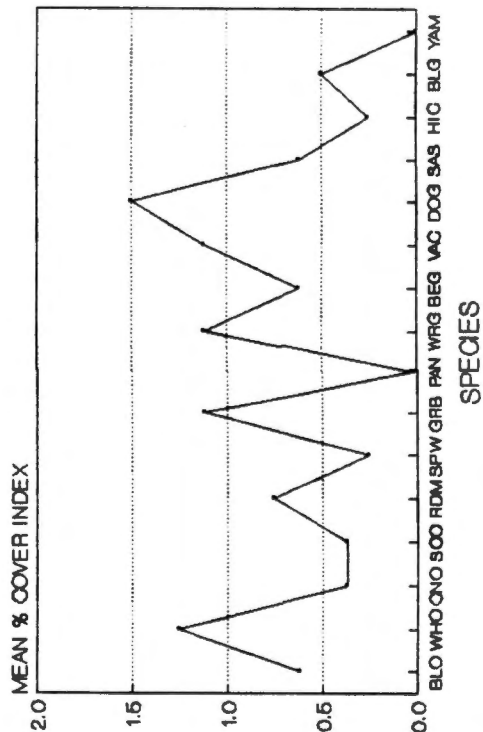
CHESTNUT OAK COMMUNITY



BLACK OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



WHITE OAK COMMUNITY

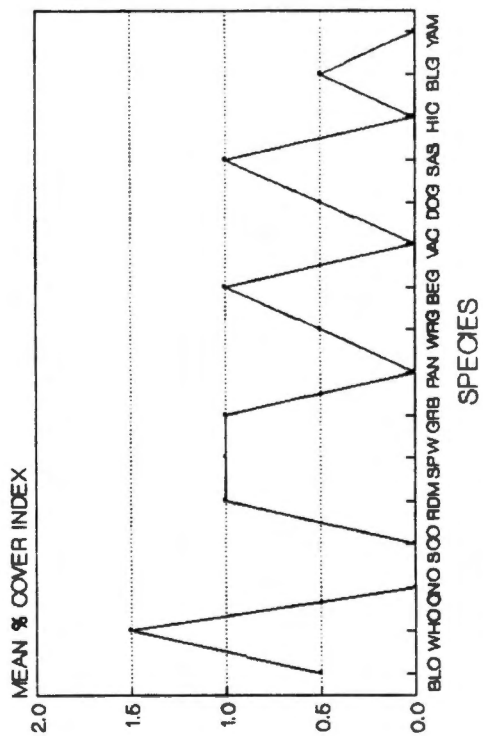


FIGURE 10.- LANDTYPE 3 SEEDLING/HERB SPECIES COMMUNITY PROFILES.

white oak as secondary associates. Vaccinium (Vaccinium spp. L.) and black gum (Nyssa sylvatica Marshall) were dominant species in the sapling/shrub layer. Chestnut oak, Vaccinium spp. L., red maple, Smilax spp. L., white oak, needle grass (Stipa avenacea L.), sassafras (Sassafras albidum (Nuttall) Nees.) and hickories (Carya spp. Nuttall) were dominant seedling/herbaceous layer species.

Black Oak Community. Black oak was the predominant forest community sampled in LT-3 west of Mullins Creek (11 plots). The plots classified in the black oak community were in similar locations as the chestnut oak plots, on ridgetops and convex upper slopes. White oak was the major overstory associate. Sourwood and dogwood were dominant understory associates with chestnut oak, white oak and red maple as secondary associates. Vaccinium spp. L., sourwood and black gum were dominant species in the sapling/shrub layer. Vaccinium spp. L., dogwood, black oak, sassafras, hickories, needle grass, and beggar lice (Desmodium spp. Desvaux) were dominant species in the seedling/herbaceous layer.

Except for dominant overstory species, the black oak and chestnut oak communities within LT-3 are very similar. Both communities are located on similar sites but predominate on different ridges within the study area: the black oak community occurring west of Mullins Creek and the chestnut oak community occurring east of Mullins Creek. Species

dominance is possibly controlled by inherent site differences related to ridge physiography, the eastern ridge being broader and more protected than the western ridge.

Shortleaf Pine Community. Most plots within LT-3 classified as shortleaf pine were located west of Mullins Creek (8 plots). The plots classified in the shortleaf pine community were also located on ridgetops and convex upper slopes. Black oak, chestnut oak, scarlet oak and white oak were major overstory associates. Dogwood and sourwood were dominant understory associates with red maple, white oak and chestnut oak species as secondary associates. Sourwood, Vaccinium spp. L. and blackgum were dominant species in the sapling/shrub layer. White oak, Smilax spp. L., needle grass, vaccinium spp. L., red maple, black oak, beggar lice and sassafras were dominant in the seedling/herbaceous layer.

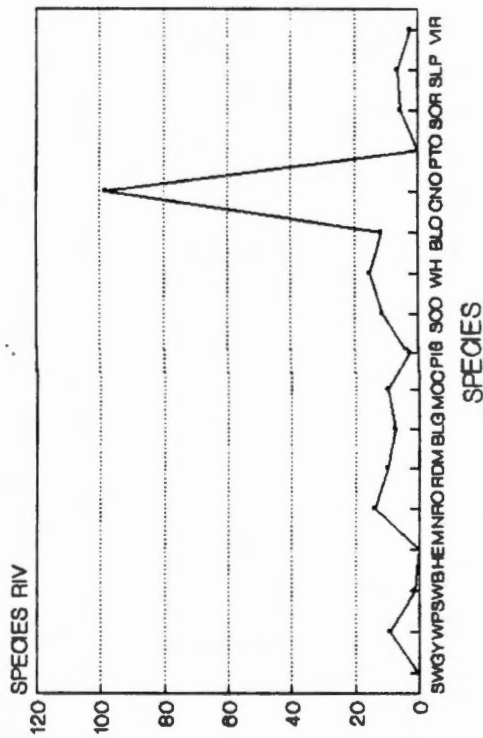
White Oak Community. Two plots east of Mullins Creek were classified as a white oak community. White oak was dominant with Virginia pine as a minor overstory associate. Dogwood was the dominant understory species with mockernut hickory (Carya tomentosa (Poiret) Nuttall) and sourwood as secondary understory associates. The sapling/shrub layer was dominated by dogwood. White oak, red maple, spotted wintergreen (Chimaphila maculata (L.) Pursh), beggar lice and sassafras were dominate in the seedling/herbaceous layer.

Landtype 5. Farthest neighbor cluster analysis resulted in four forest communities within LT-5--chestnut oak, scarlet oak (Quercus coccinea Muenchh.), white oak and shortleaf pine (Figures 11 through 14).

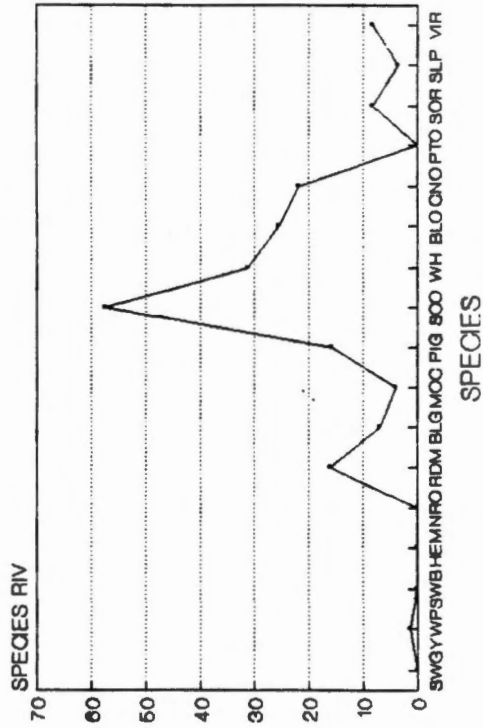
Chestnut Oak Community. The farthest neighbor clustering algorithm produced two chestnut oak clusters within LT-5. Except for the magnitude of chestnut oak RIV, the overstory structure for both chestnut oak clusters were very similar. Subordinate forest strata for both chestnut oak clusters were very similar and no consistent pattern was noticed between the two clusters on the landscape. These conclusions lead to combining both chestnut oak clusters for describing the chestnut oak community within LT-5.

Most of the plots classified into the chestnut oak community within LT-5 were located on linear to concave mid-slopes. Six plots occurred on more exposed ridgetops and convex upper slopes. White oak, red maple, northern red oak (Quercus rubra L.) and yellow-poplar (Liriodendron tulipifera L.) were minor overstory associates. Red maple, dogwood, sourwood were dominant understory species with chestnut oak and blackgum as secondary associates. Vaccinium spp. L. was the dominant sapling/shrub layer species with maple leaf viburnum, mountain laurel and sassafras as secondary associates. Vaccinium spp. L., red maple, sassafras, chestnut oak and greenbrier were seedling/herbaceous layer associates.

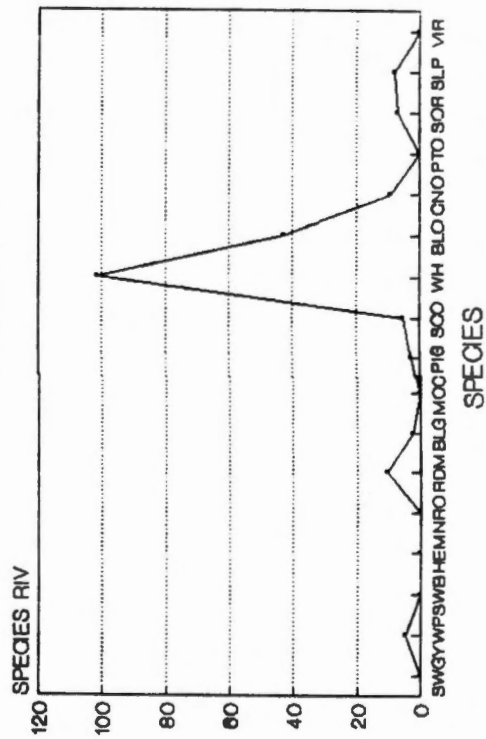
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

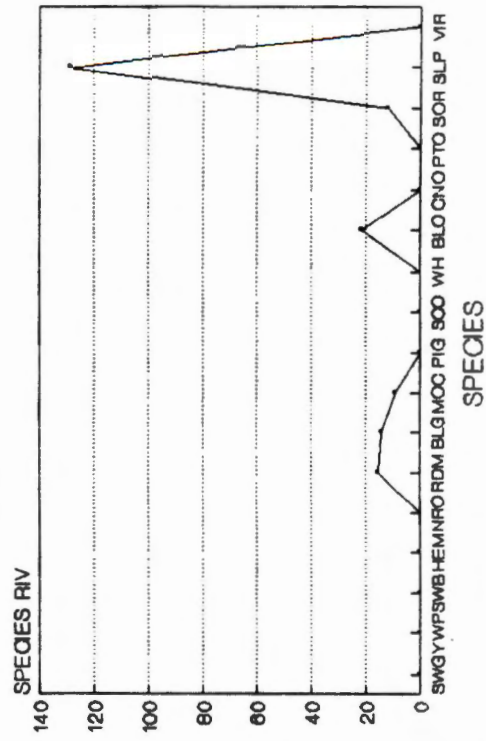
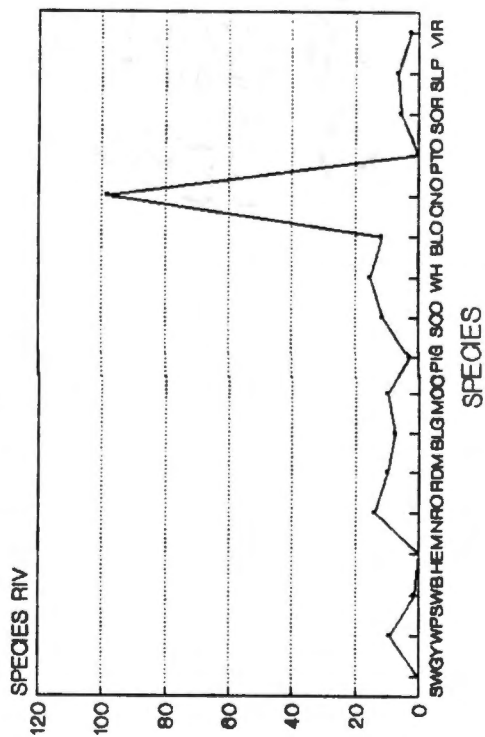
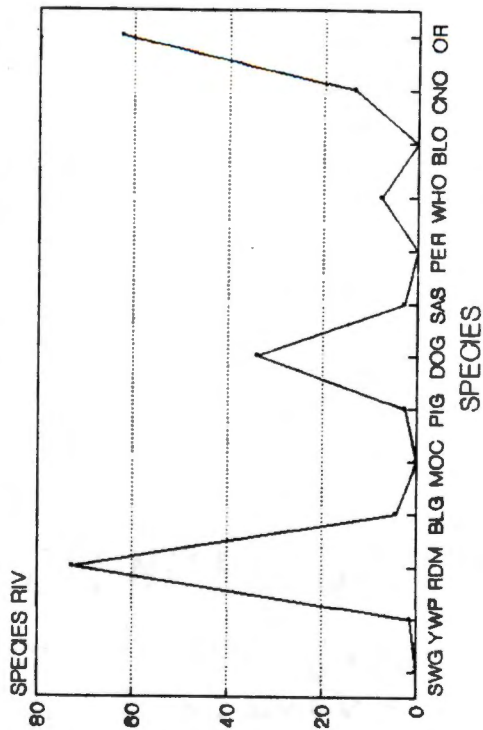


FIGURE 11.- LANDTYPE 5 OVERSTORY SPECIES COMMUNITY PROFILES.

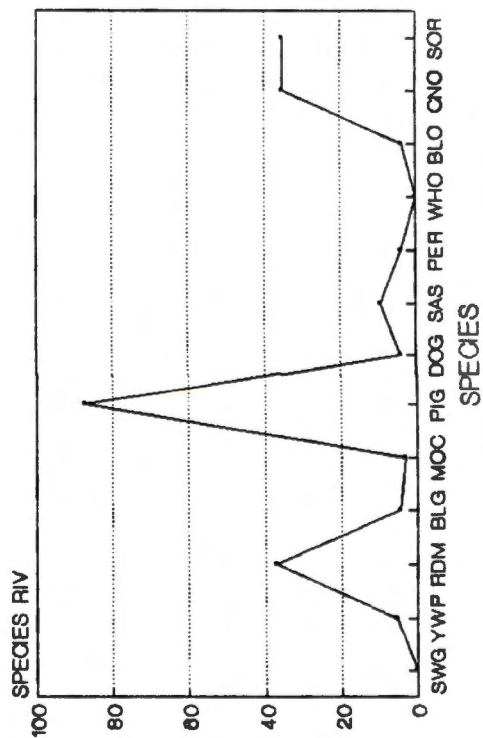
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

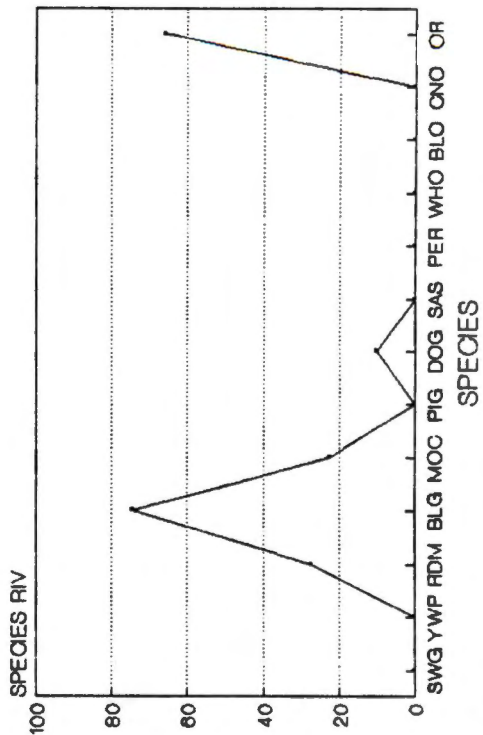
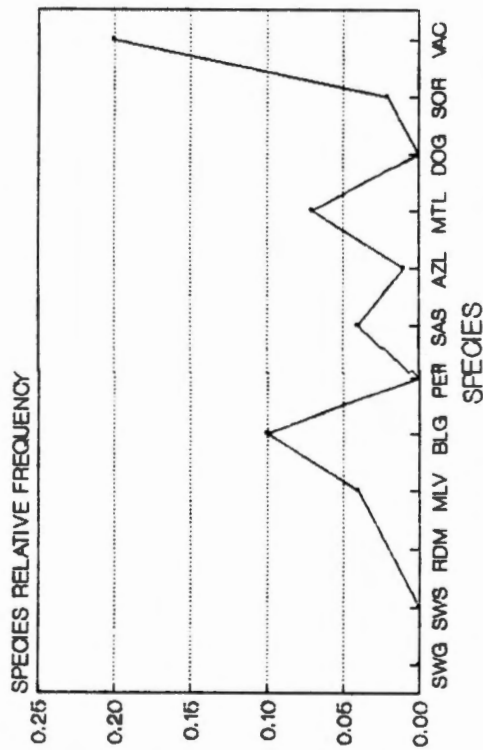
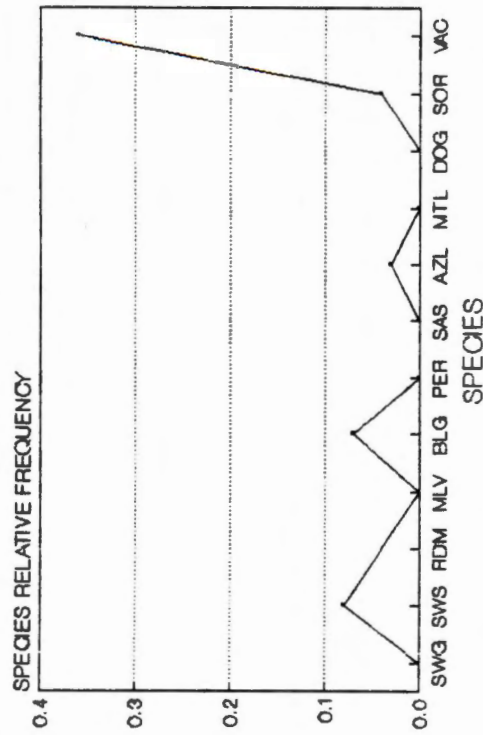


FIGURE 12.- LANDTYPE 5 UNDERSTORY SPECIES COMMUNITY PROFILES.

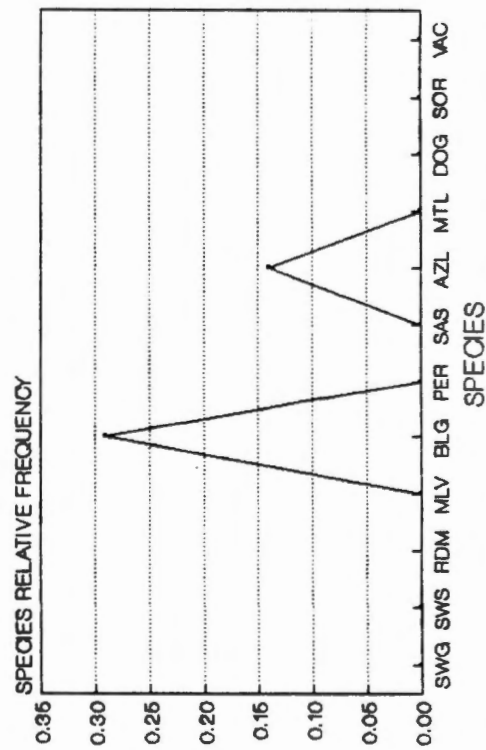
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SCARLET OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



WHITE OAK COMMUNITY

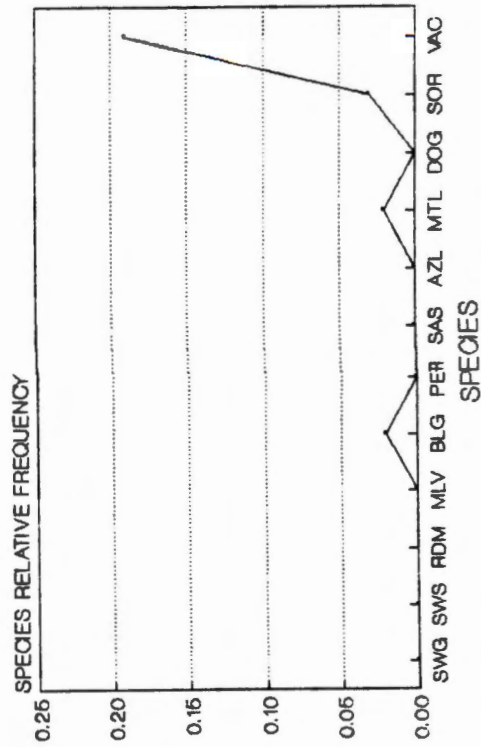
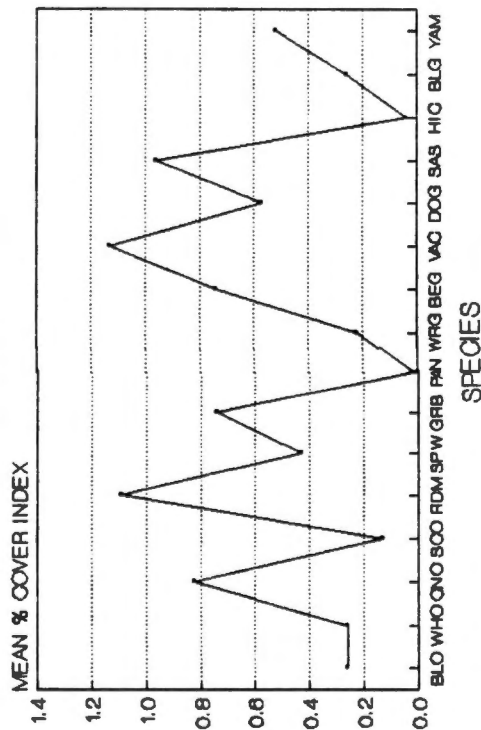
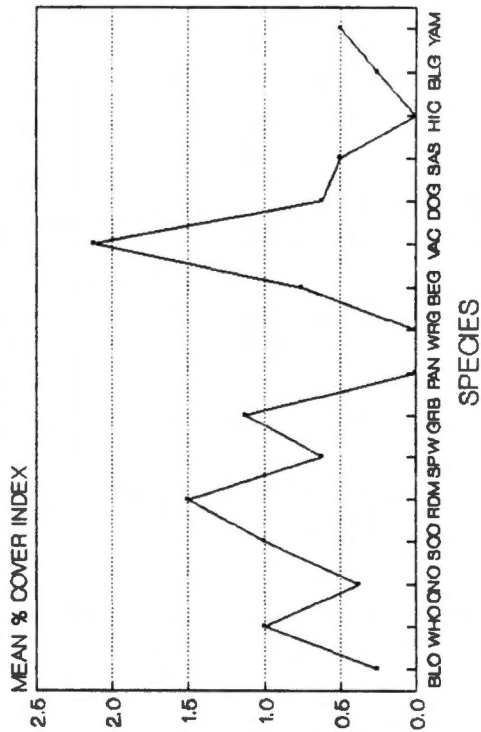


FIGURE 13.- LANDTYPE 5 SAPLING/SHRUB SPECIES COMMUNITY PROFILES.

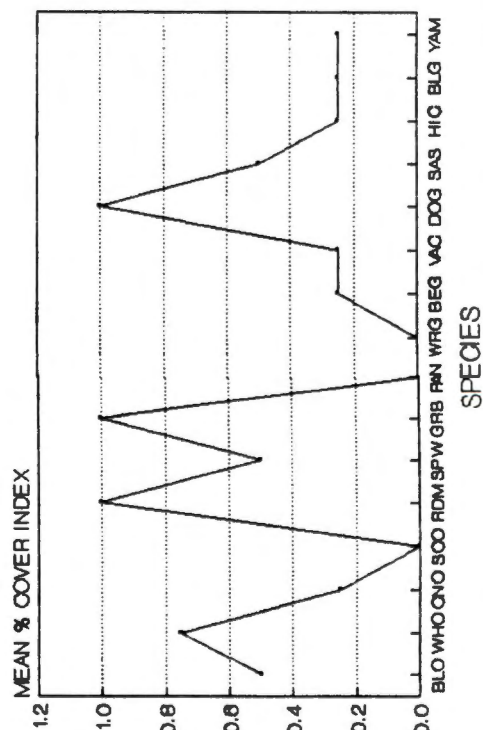
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

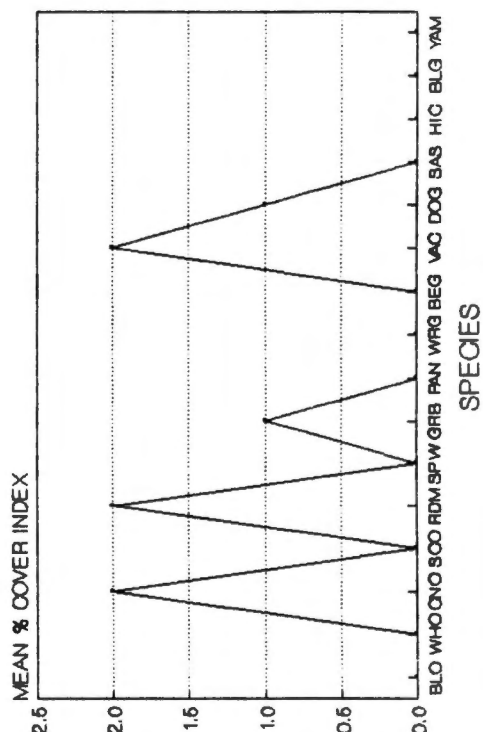


FIGURE 14.- LANDTYPE 5 SEEDLING/HERB SPECIES COMMUNITY PROFILES.

Scarlet Oak Community. Eighteen plots within LT-5 were classified into a scarlet oak community. These plots were restricted to ridgetops and convex upper slopes. White oak, chestnut oak, pignut hickory (Carya glabra (Miller) Sweet) and red maple were secondary overstory associates. Red maple, sourwood and dogwood were dominant understory associates with chestnut oak of secondary importance. Vaccinium spp. L. was the dominant sapling/shrub layer species with sweetshrub, blackgum and sourwood as secondary associates. Vaccinium spp. L., red maple, Smilax spp. L., chestnut oak, scarlet oak, sweetshrub, beggar lice and spotted wintergreen were seedling/herbaceous layer associates.

White Oak Community. Four plots within LT-5 were classified into a white oak community. This community is very similar to the chestnut oak community, the major difference being the local dominance of white oak. Black oak was a major overstory associate with chestnut oak and red maple as secondary associates. Dogwood was a dominant understory associate with red maple and sourwood as secondary associates. The sapling/shrub layer was dominated by Vaccinium spp. L. Red maple, Smilax spp. L., dogwood and white oak were seedling/herbaceous layer associates.

Shortleaf Pine Community. One plot within LT-5 was classified as shortleaf pine. Black oak was a minor overstory associate. Blackgum and sourwood were dominant

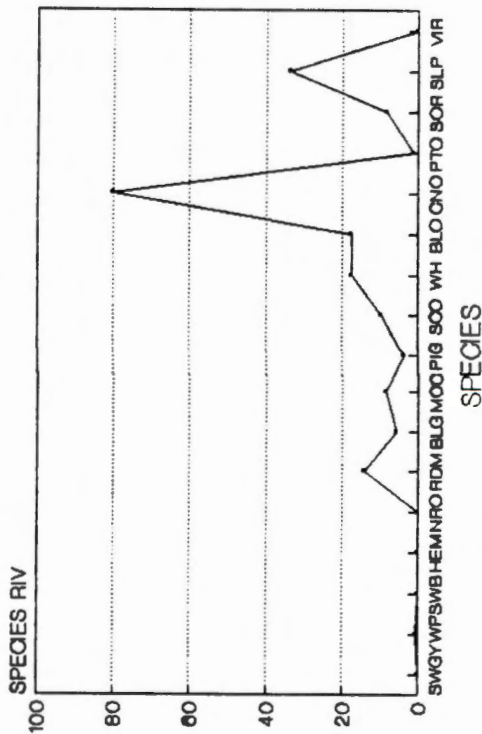
understory associates with yellow-poplar and mockernut hickory as secondary associates. Blackgum was the dominant sapling/shrub layer associate with Azalea spp. as a secondary associate. Chestnut oak, red maple, Vaccinium spp. L., Smilax spp. L. and dogwood were seedling/herbaceous layer associates.

Landtype 6. Farthest neighbor cluster analysis resulted in four forest communities within LT-6--chestnut oak, shortleaf pine, scarlet oak white oak (Figures 15 through 18).

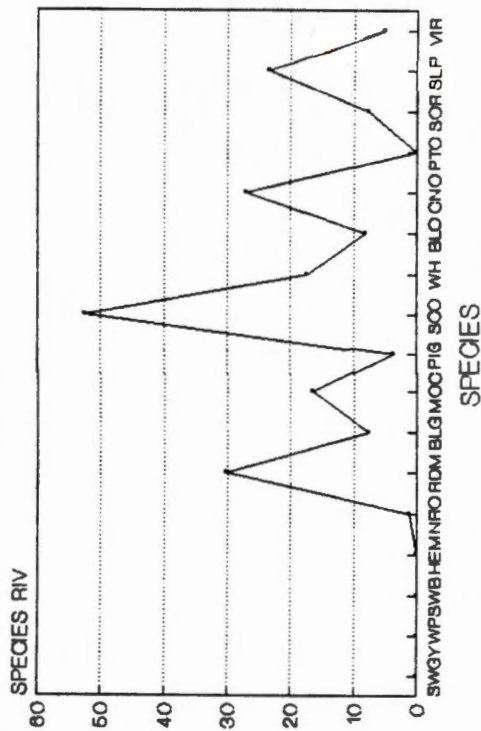
Chestnut Oak Community. Sixteen plots within LT-6 were classified into a chestnut oak community. These plots were located on the more protected sites within LT-6, mid- to lower slopes. Shortleaf pine was a major overstory associate with white oak, black oak and red maple as secondary associates. Red maple, sourwood and dogwood were dominant understory associates with chestnut oak as a secondary associate. Vaccinium spp. L. was dominant in the sapling/shrub layer with maple leaf viburnum (Viburnum acerfolium L.) and persimmon (Diospyrus virginiana L.) as secondary associates. Red maple, Vaccinium spp. L., dogwood, needle grass, chestnut oak, spotted wintergreen, sassafras and beggar lice were seedling/herbaceous layer associates.

Shortleaf Pine Community. Twelve plots within LT-6

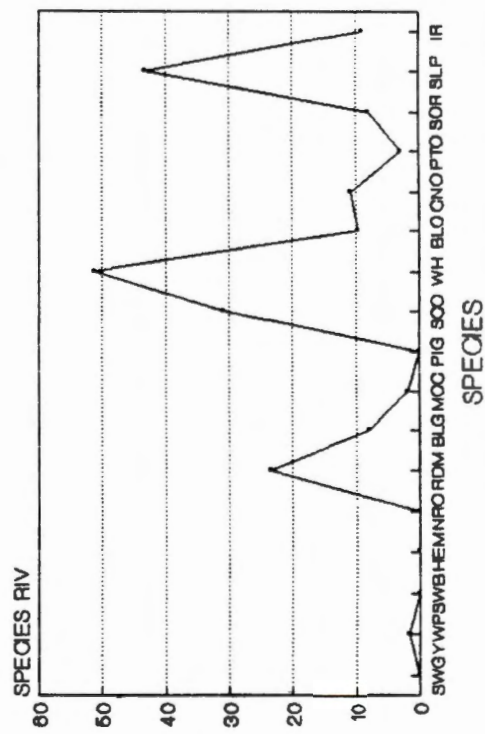
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

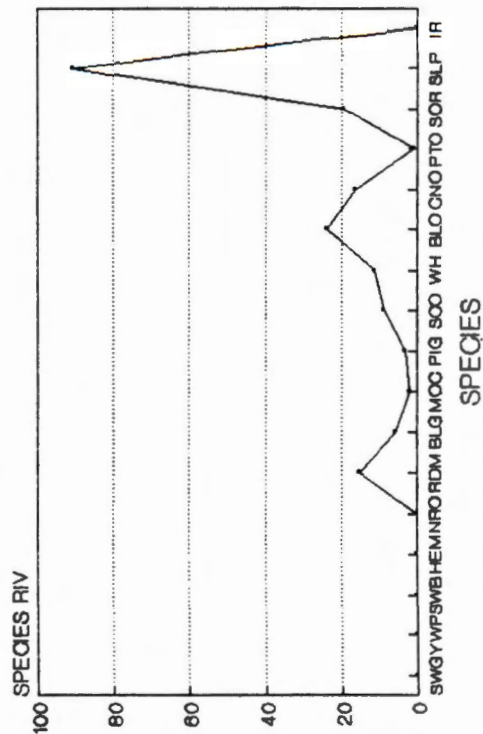
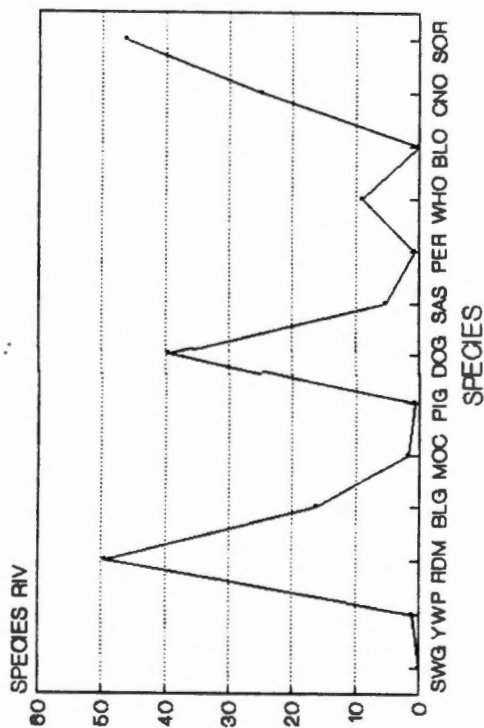
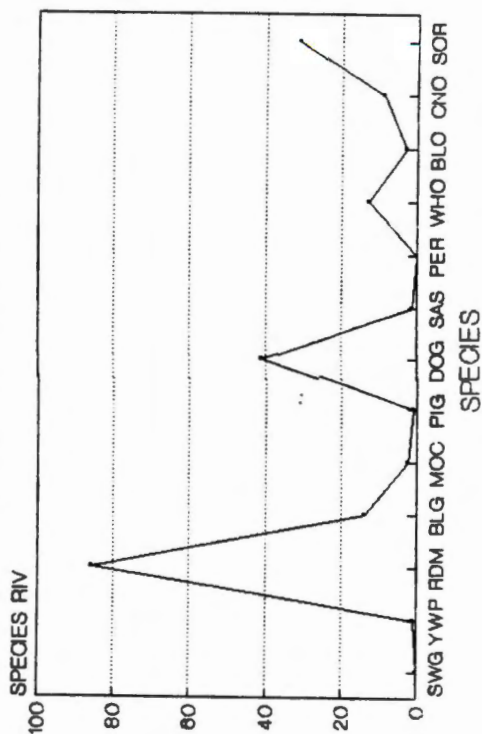


FIGURE 15.- LANDTYPE 6 OVERSTORY SPECIES COMMUNITY PROFILES.

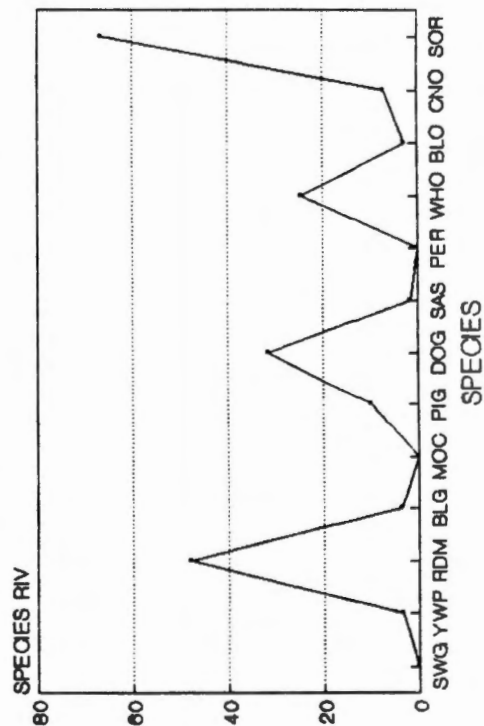
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

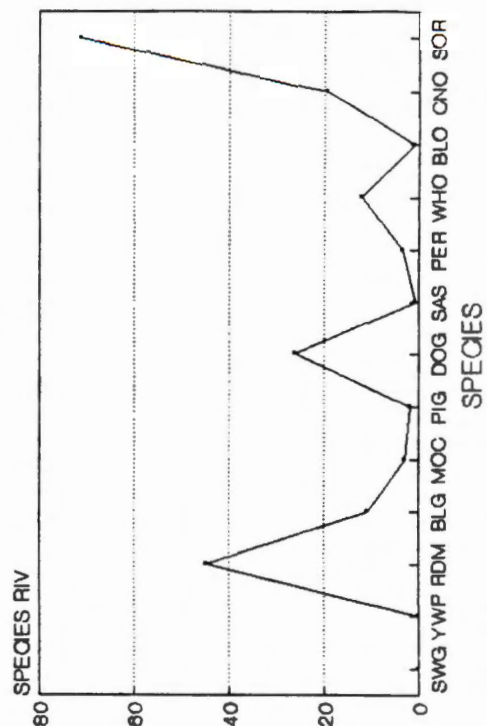
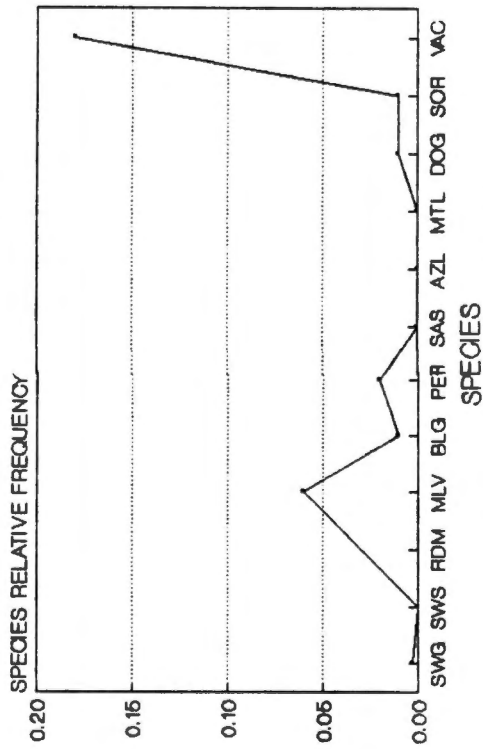
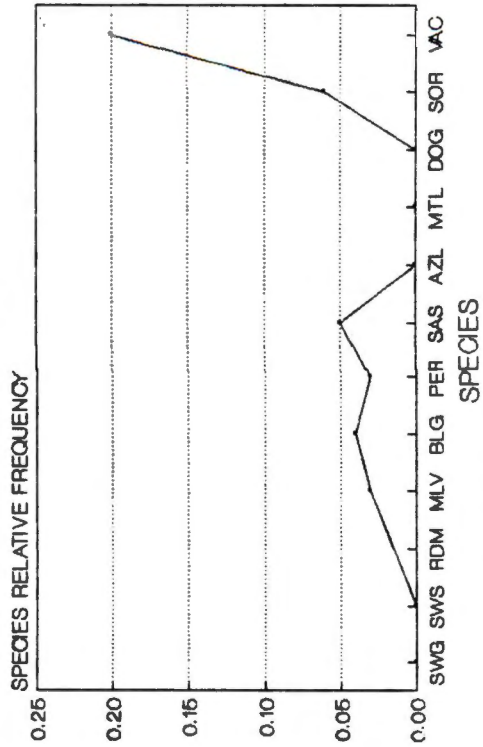


FIGURE 16.- LANDTYPE 6 UNDERSTORY SPECIES COMMUNITY PROFILES.

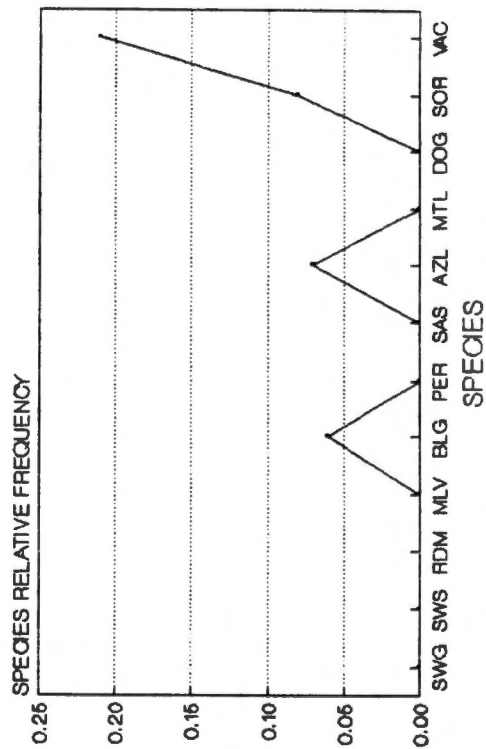
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

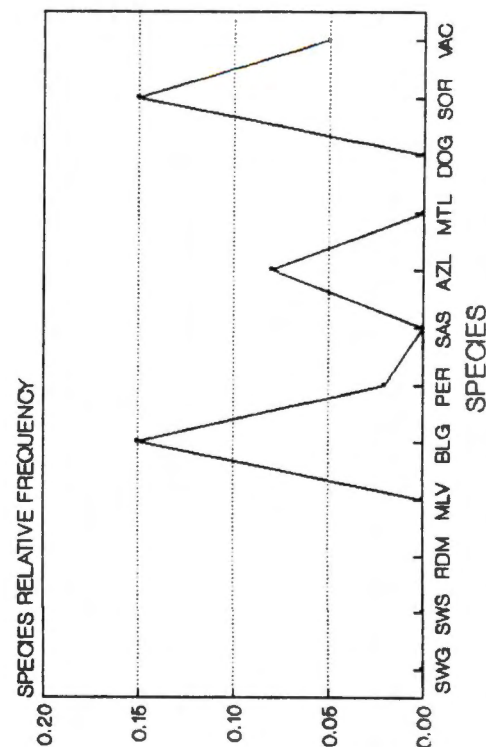
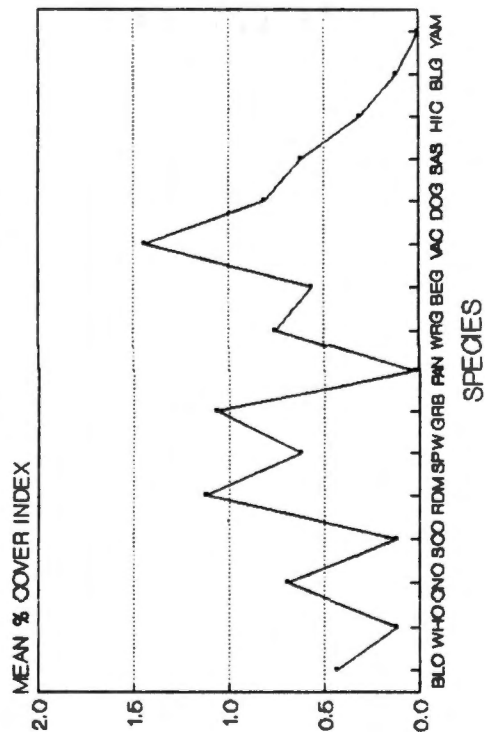
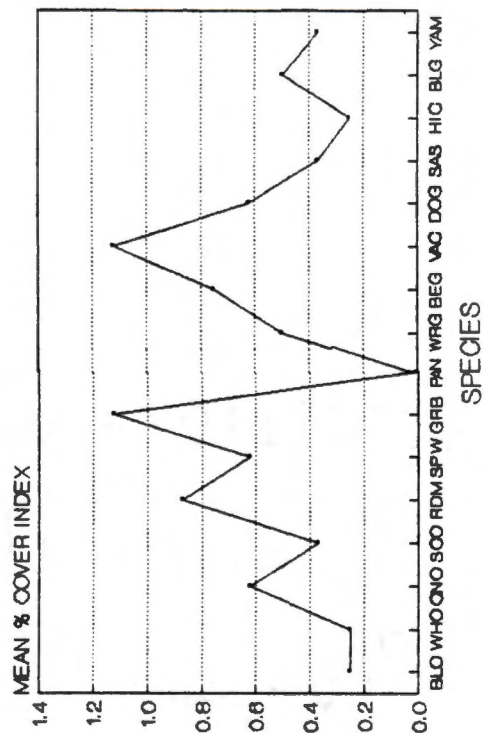


FIGURE 17.- LANDTYPE 6 SAPLING/SHRUB SPECIES COMMUNITY PROFILES.

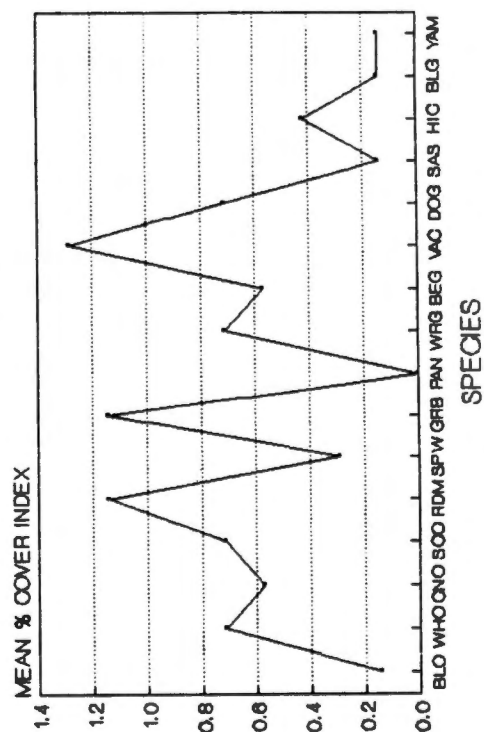
CHESTNUT OAK COMMUNITY



SCARLET OAK COMMUNITY



WHITE OAK COMMUNITY



SHORTLEAF PINE COMMUNITY

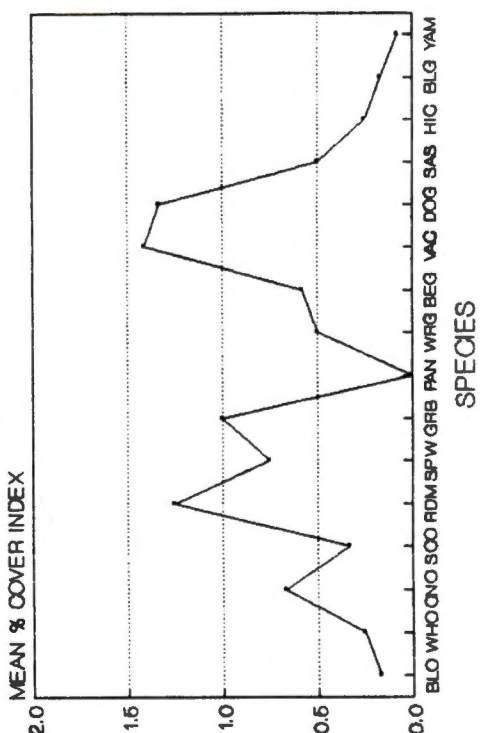


FIGURE 18.- LANDTYPE 6 SEEDLING/HERB SPECIES COMMUNITY PROFILES.

were classified into a shortleaf pine community. These plots were generally located on upper to mid-slopes. Black oak, sourwood, chestnut oak, red maple and white oak were minor overstory associates. Sourwood and red maple were dominant understory associates with dogwood and white oak as secondary associates. Blackgum and sourwood were dominant sapling/shrub layer associates with Azalea spp. and Vaccinium spp. L. as secondary associates. Vaccinium spp. L., dogwood, red maple, greenbrier, spotted wintergreen and beggar lice were seedling/herbaceous layer associates.

Scarlet Oak Community. Nine plots within LT-6 were classified as a scarlet oak community. These plots were located on more exposed sites near ridgetops and convex upper slopes. Red maple, chestnut oak and shortleaf pine were major overstory associates with mockernut hickory, black oak and blackgum as secondary associates. Red maple was dominant in the understory with dogwood and sourwood as secondary associates. Vaccinium spp. L., sourwood, sassafras, blackgum, persimmon and maple leaf viburnum were sapling/shrub layer associates. Greenbrier, Vaccinium spp. L., red maple, beggar lice, dogwood, spotted wintergreen and chestnut oak were seedling/herbaceous associates.

White Oak Community. Six plots within LT-6 were classified as a white oak community. These plots were located on mid-slope positions. Shortleaf pine was the dominant overstory associate, almost equal in dominance as

white oak. Scarlet oak, red maple, blackgum and chestnut oak were secondary overstory associates. Sourwood and red maple were dominant understory associates with dogwood and white oak as secondary associates. Vaccinium spp. L., sourwood, azalea and blackgum were sapling/seedling associates. Vaccinium spp. L., red maple, greenbrier, white oak, scarlet oak, dogwood, needle grass, chestnut oak, Azalea spp. and beggar lice are seedling/herbaceous associates.

Landtype 17. The forest cover within landtype 17 was the most variable encountered on the study site. As a result, farthest neighbor cluster analysis was unable to produce a dendrogram that could adequately describe forest communities at a single level of dispersion. Due to a similarity in associated overstory species, the most appropriate single level of dispersion resulted in classifying plots dominated by yellow-poplar, eastern hemlock (Tsuga canadensis (L.) Carr.) and northern red oak into one cluster. A second level of dispersion within this cluster was used to recognize separate communities that would otherwise have been combined into one cluster.

Farthest neighbor cluster analysis resulted in eight forest communities within LT-17--chestnut oak, white oak, black oak, eastern hemlock, yellow-poplar, northern red oak, shortleaf pine and scarlet oak (Figures 19 through 22).

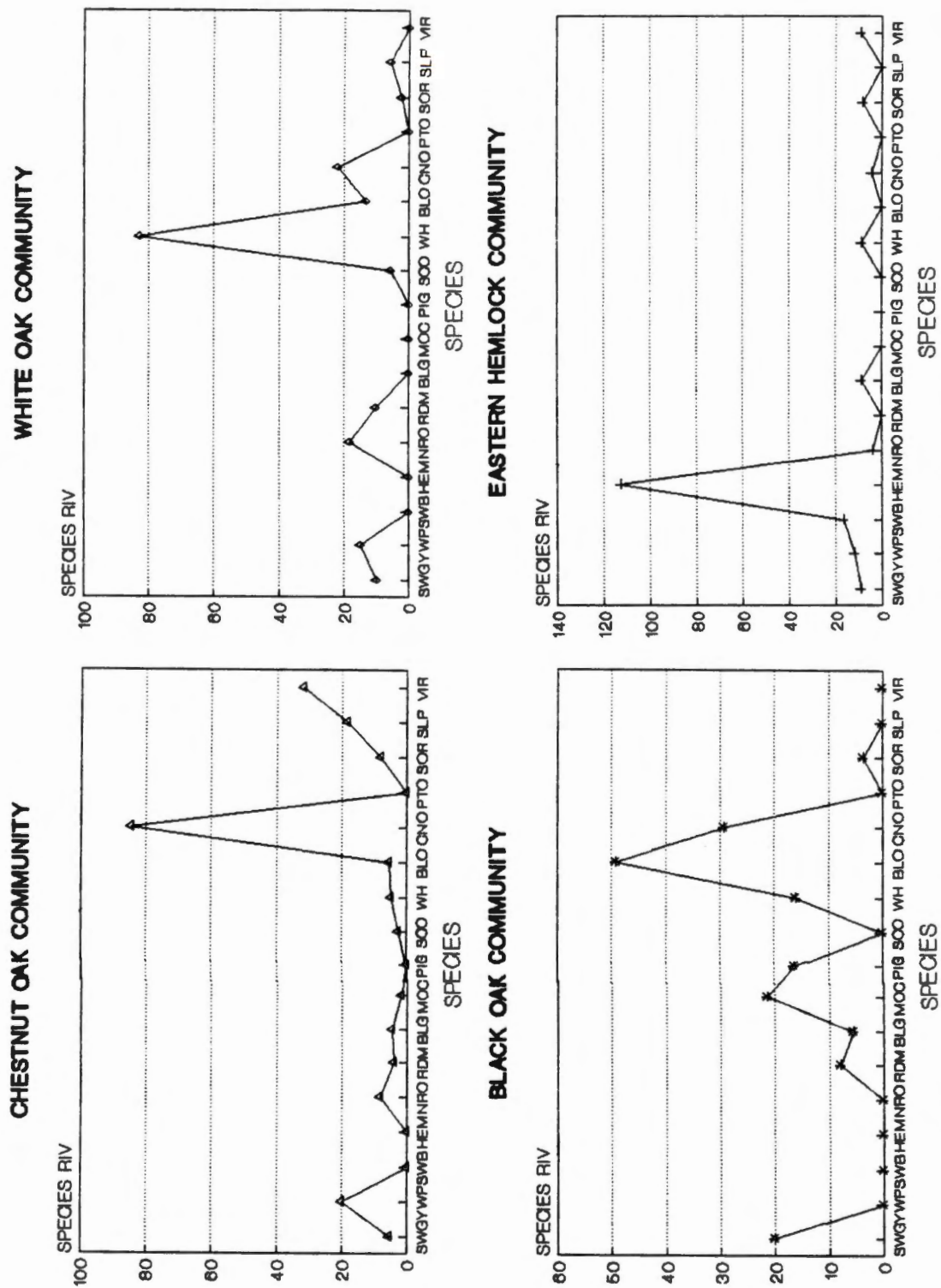
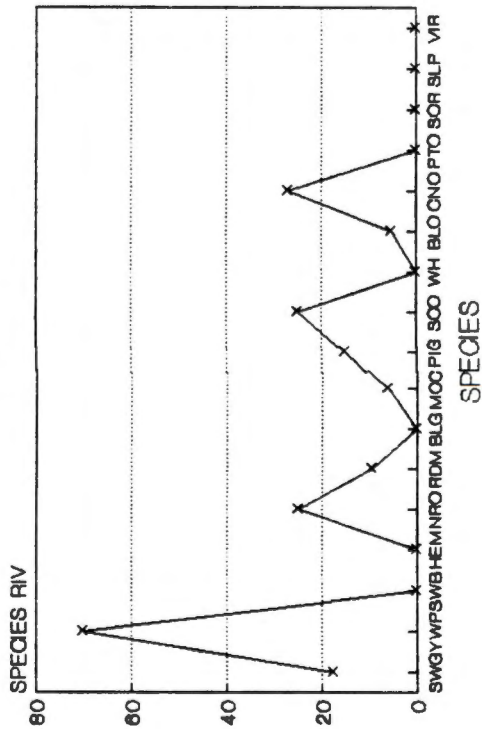
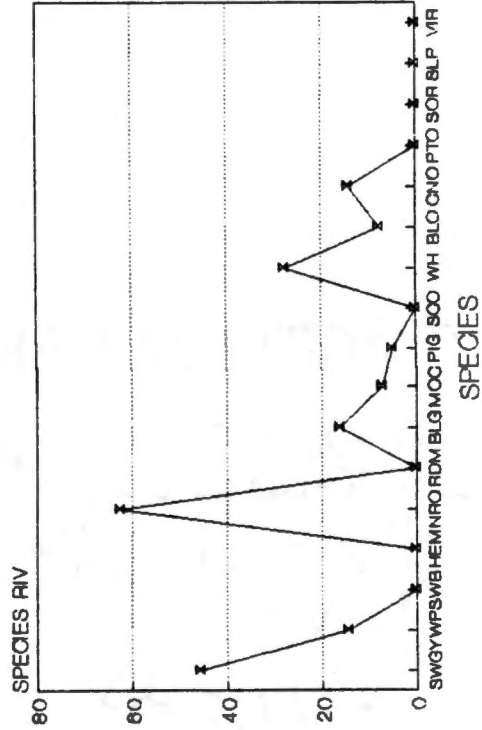


FIGURE 19.- LANDTYPE 17 OVERSTORY SPECIES COMMUNITY PROFILES.

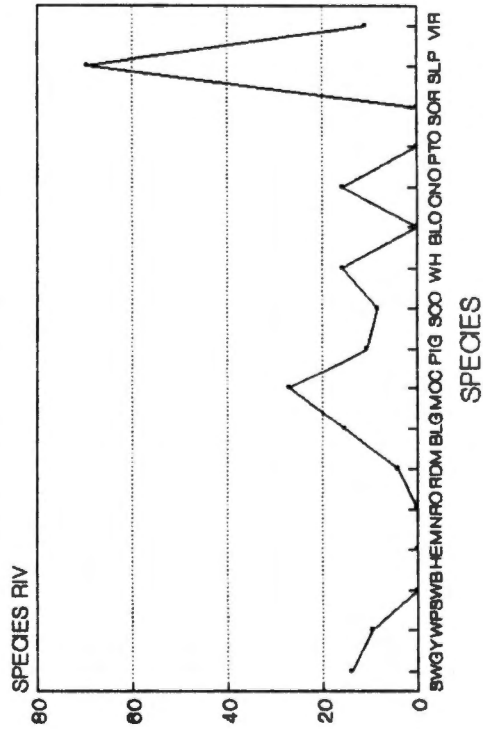
YELLOW-POPLAR COMMUNITY



NORTHERN RED OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



SCARLET OAK COMMUNITY

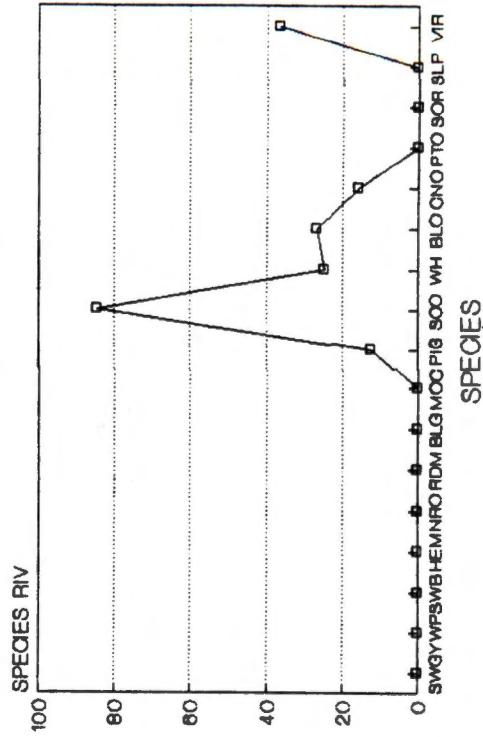
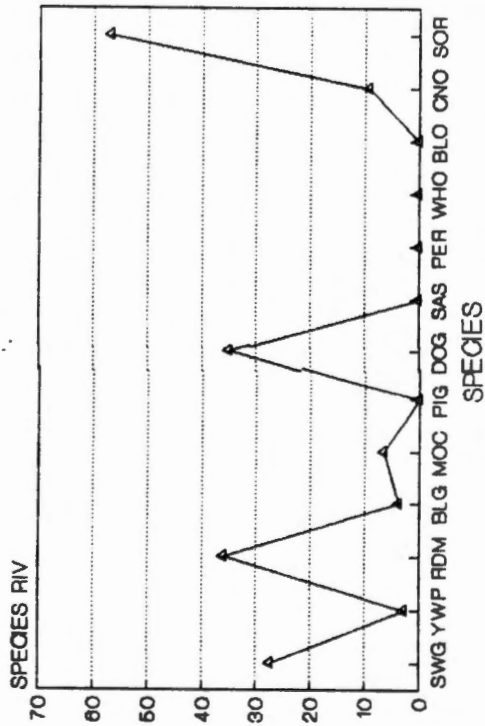
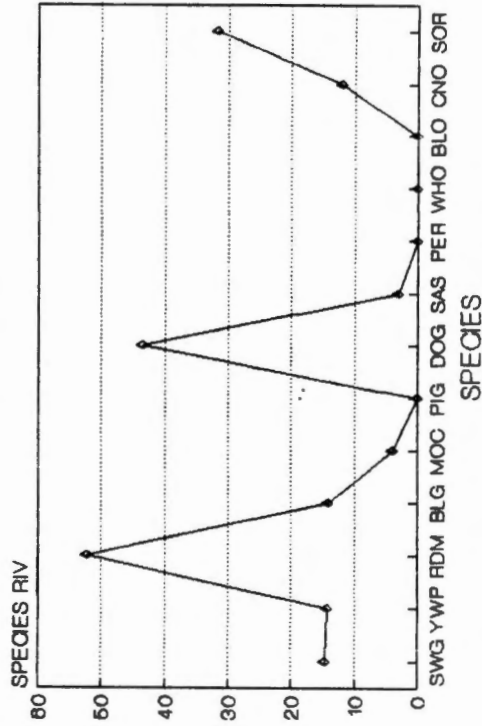


FIGURE 19.- CONTINUED.

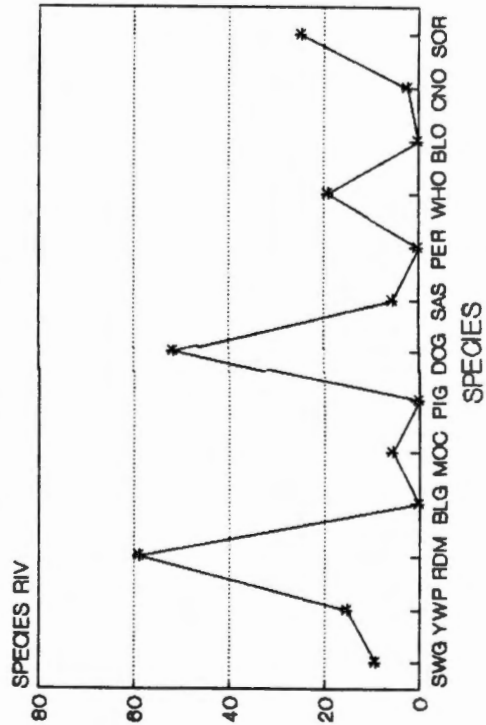
CHESTNUT OAK COMMUNITY



WHITE OAK COMMUNITY



BLACK OAK COMMUNITY



EASTERN HEMLOCK COMMUNITY

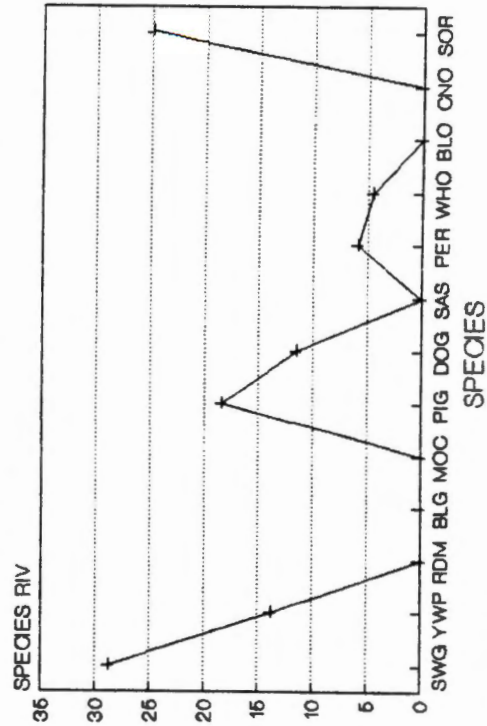
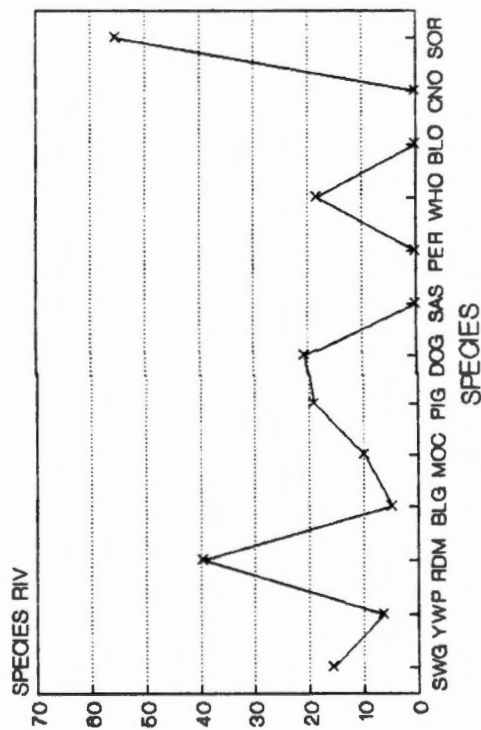
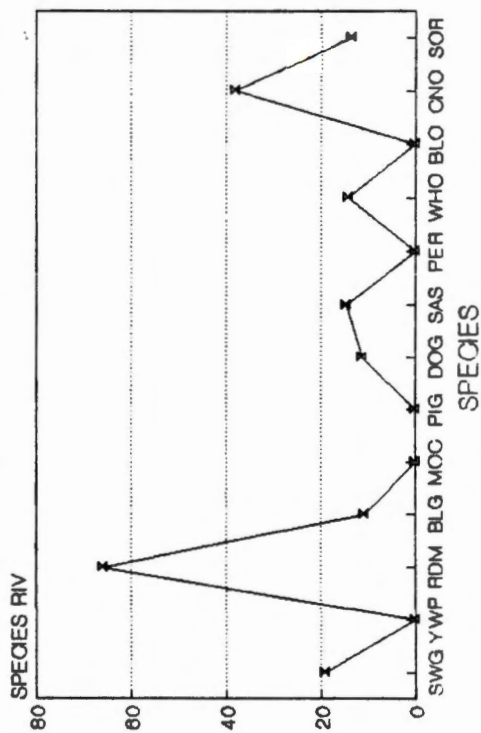


FIGURE 20.- LANDTYPE 17 UNDERSTORY SPECIES COMMUNITY PROFILES.

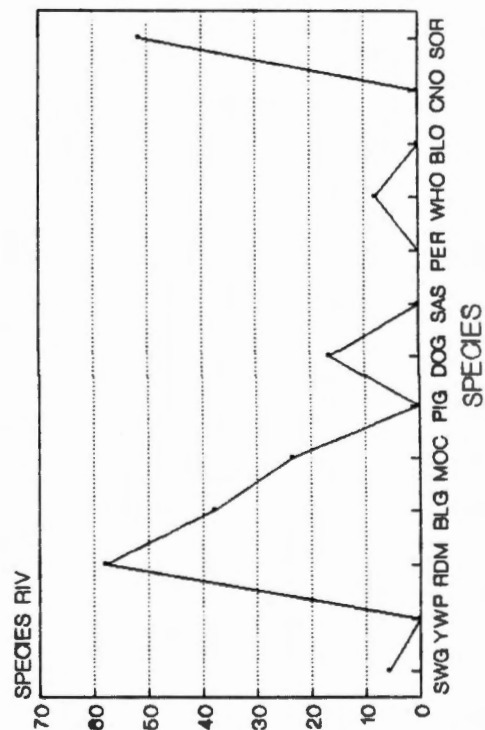
YELLOW-POPLAR COMMUNITY



NORTHERN RED OAK COMMUNITY



SHORTLEAF PINE COMMUNITY



SCARLET OAK COMMUNITY

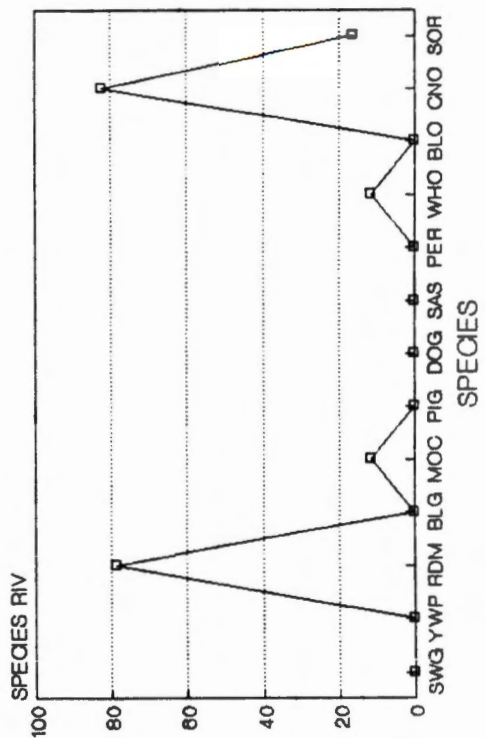
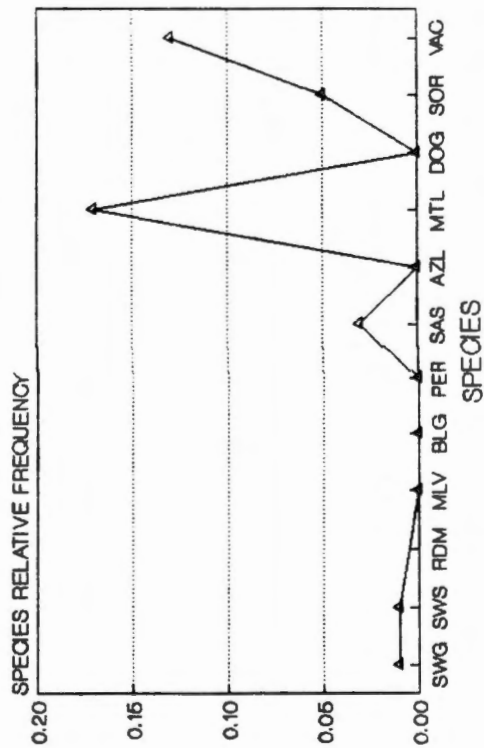
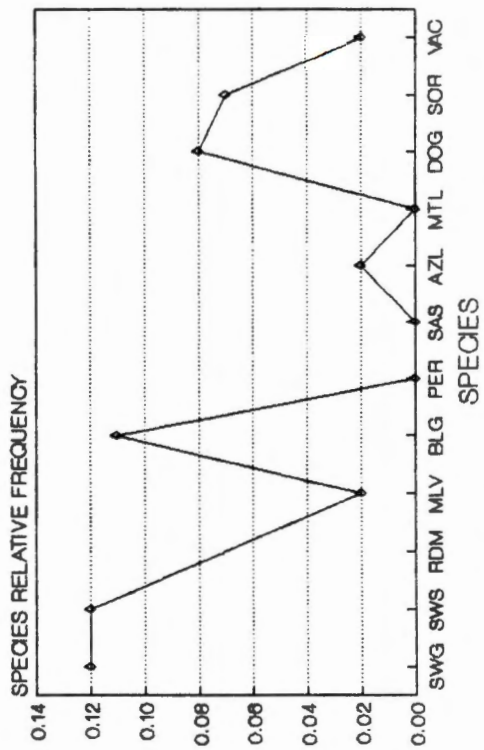


FIGURE 20.- CONTINUED.

CHESTNUT OAK COMMUNITY

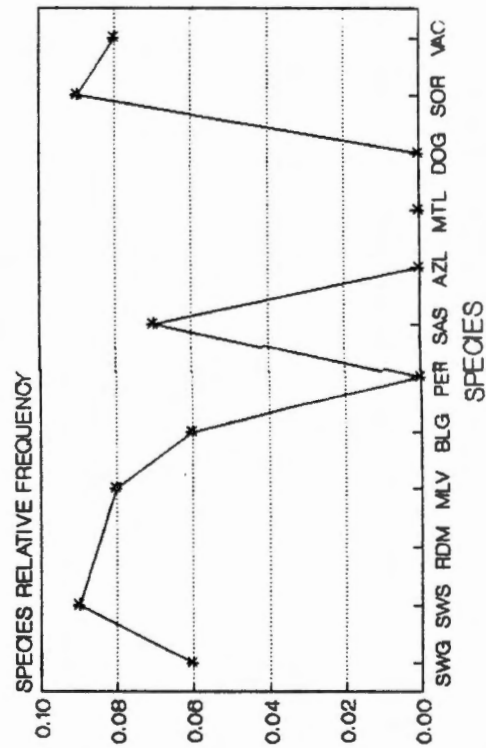


WHITE OAK COMMUNITY



88

BLACK OAK COMMUNITY



EASTERN HEMLOCK COMMUNITY

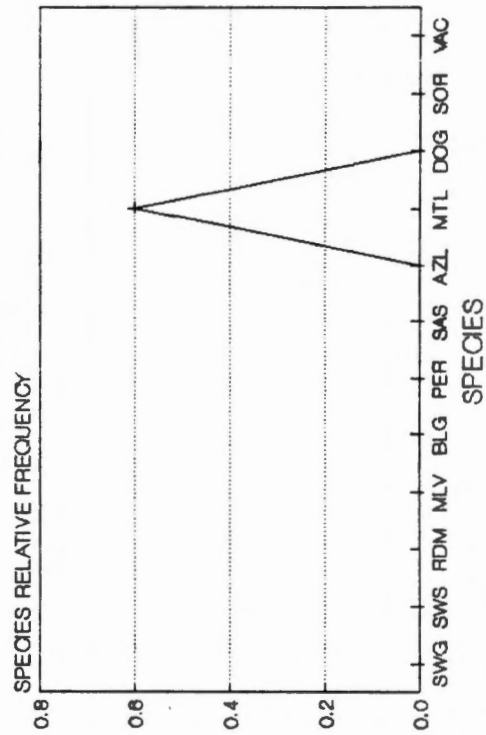
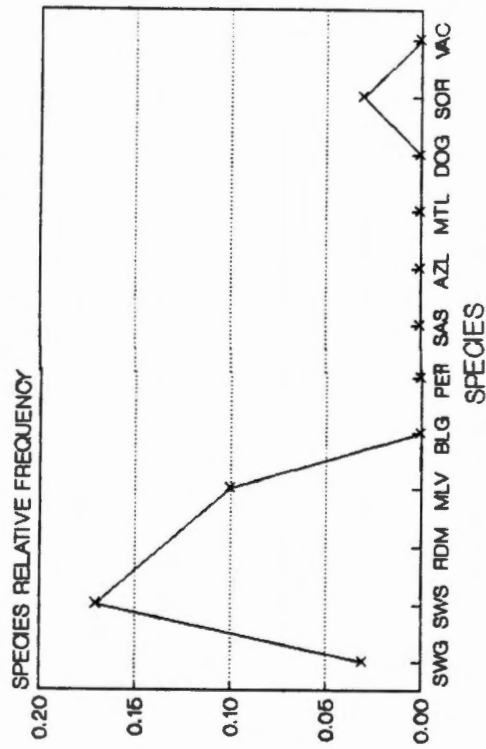
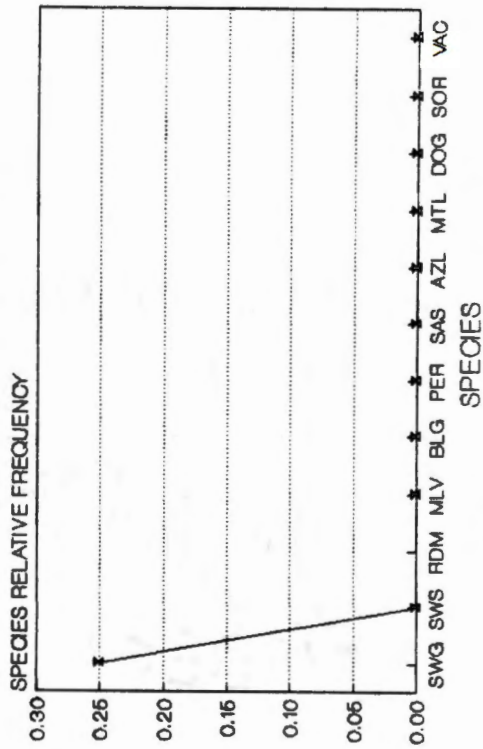


FIGURE 21.- LANDTYPE 17 SAPLING/SHRUB SPECIES COMMUNITY PROFILES.

YELLOW-POPLAR COMMUNITY

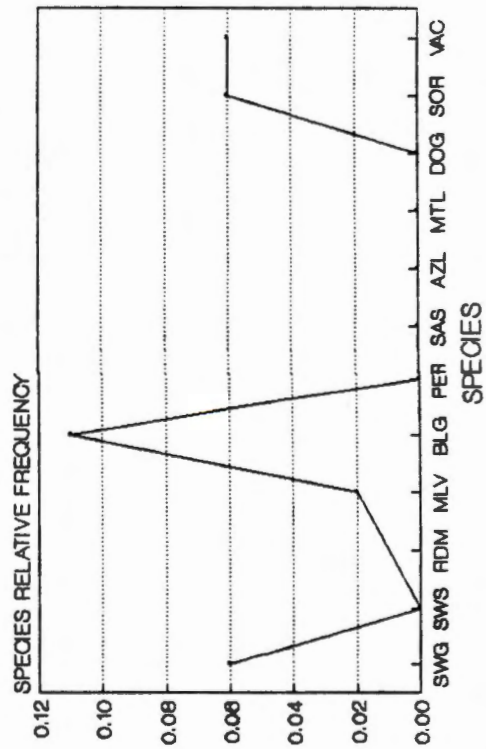


NORTHERN RED OAK COMMUNITY



88

SHORTLEAF PINE COMMUNITY



SCARLET OAK COMMUNITY

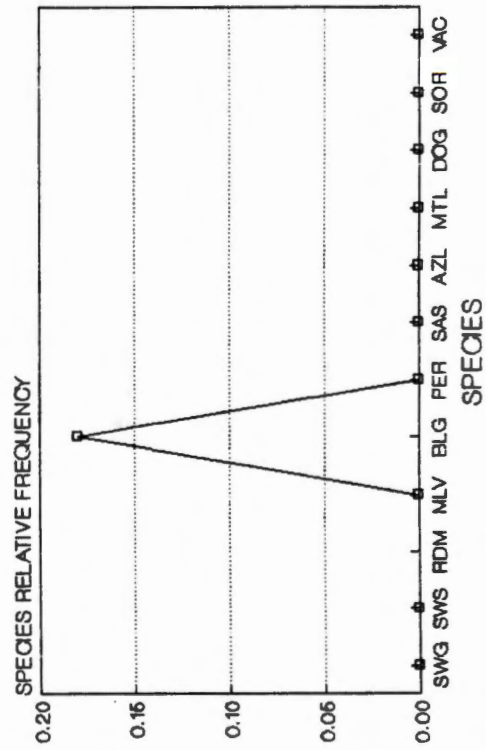
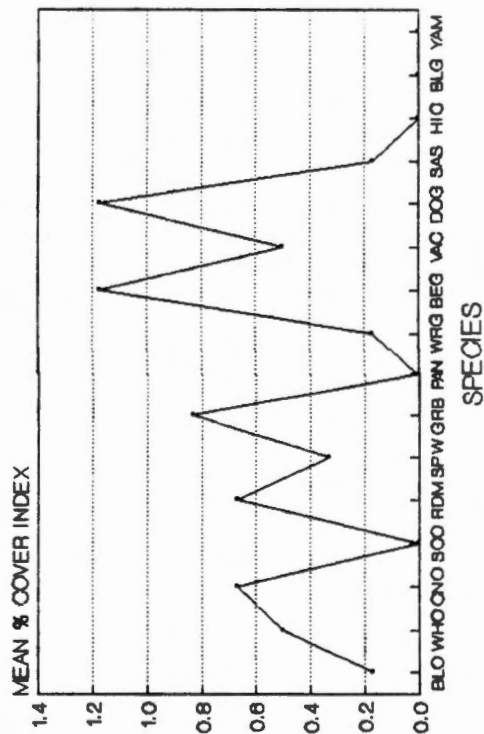
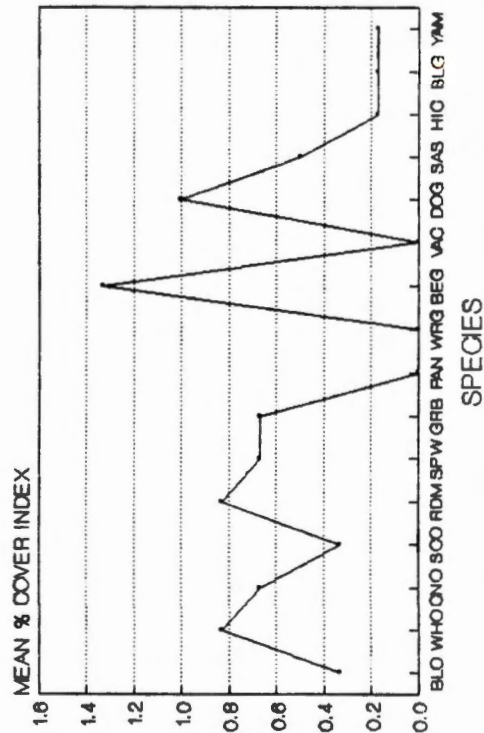


FIGURE 21.- CONTINUED.

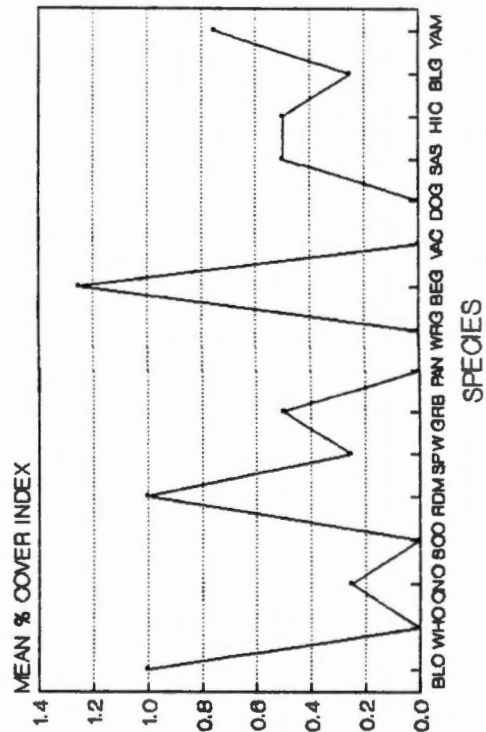
CHESTNUT OAK COMMUNITY



WHITE OAK COMMUNITY



BLACK OAK COMMUNITY



EASTERN HEMLOCK COMMUNITY

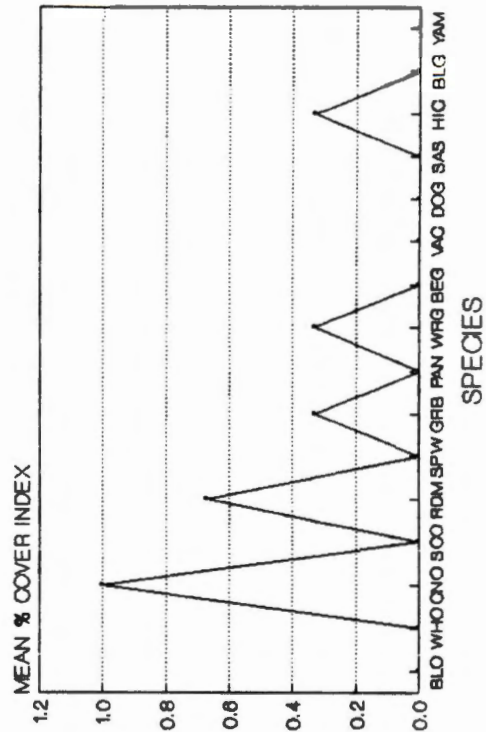
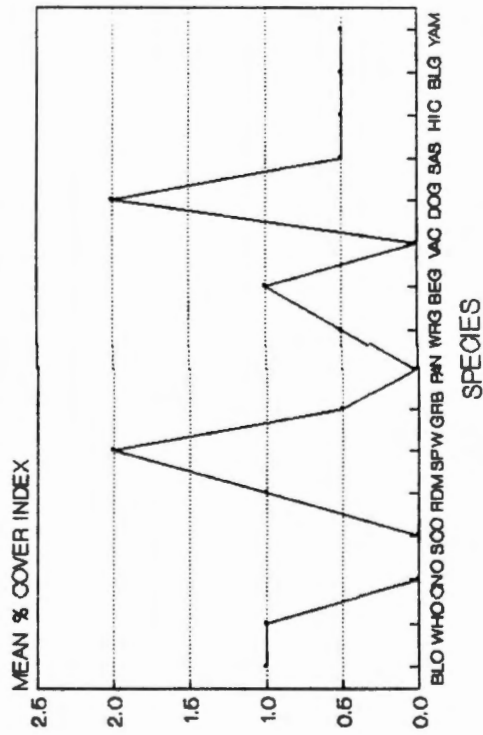
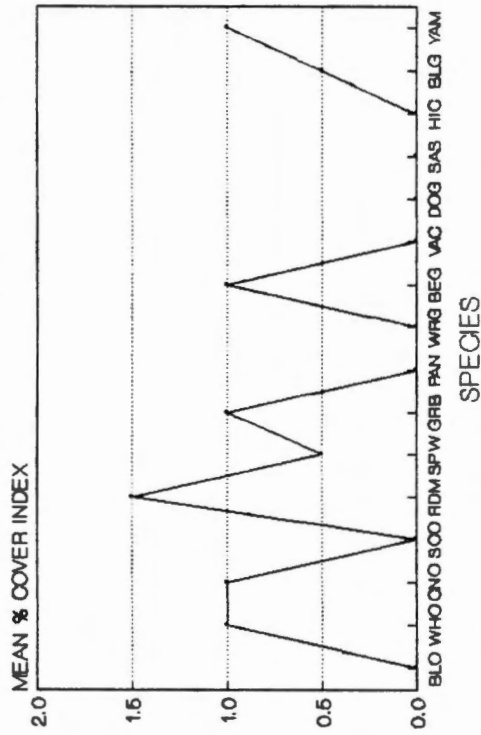


FIGURE 22.- LANDTYPE 17 SEEDLING/HERB SPECIES COMMUNITY PROFILES.

YELLOW-POPLAR COMMUNITY

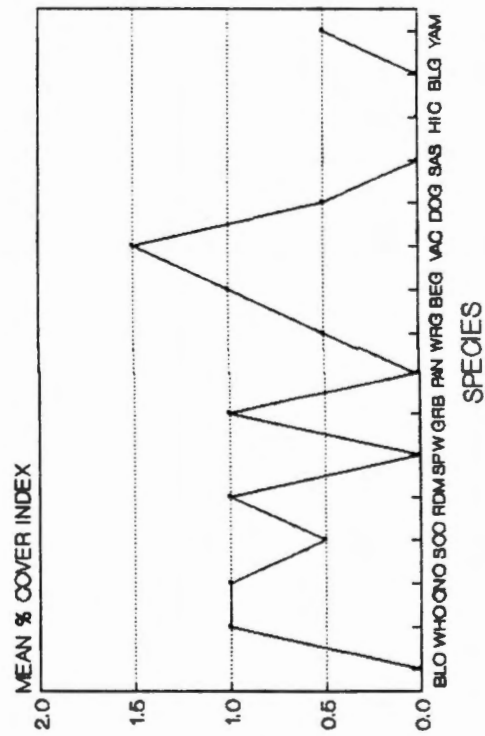


NORTHERN RED OAK COMMUNITY



91

SHORTLEAF PINE COMMUNITY



SCARLET OAK COMMUNITY

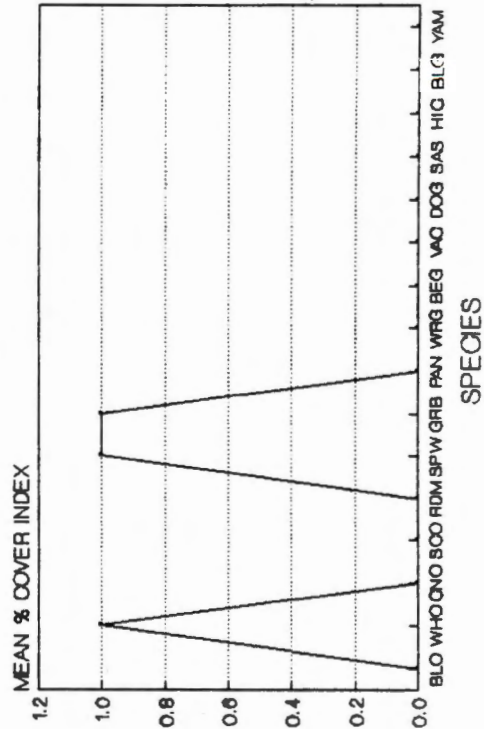


FIGURE 22.- CONTINUED

Chestnut Oak Community. Six plots within LT-17 were classified as a chestnut oak community. These plots were located adjacent to Mullins Creek on the more protected sites within landtype 17. As the width of Mullins Cove Gorge increased, chestnut oak plots were located on mid-slopes. Virginia pine, shortleaf pine and yellow-poplar were overstory associates. Sourwood and red maple were dominant understory associates with dogwood, pignut hickory, white oak and sweetgum (Liquidambar styraciflua L.) as secondary associates. Mountain laurel (Kalmia latifolia L.), Vaccinium spp. L. and sourwood were sapling/shrub layer associates. Dogwood, beggar lice, greenbrier, red maple, Virginia creeper (Parthenocissus quinquefolia (L.) Planchon), poison ivy (Toxicodendron radicans (L.) Kuntze) and maple-leaf viburnum were seedling/herbaceous layer associates.

White Oak Community. Six plots within LT-17 were classified into a white oak community. These plots were located on mid- to lower slope positions. Chestnut oak, northern red oak, yellow-poplar and sweetgum were overstory associates. Red maple, dogwood, sourwood, sweetgum, yellow-poplar, blackgum and chestnut oak were understory associates. Sweetgum, sweetshrub, blackgum, dogwood and sourwood were sapling/shrub layer associates. Poison-ivy, Virginia creeper, beggar lice, sweetshrub, Christmas fern (Polystichum acrostichoides (Michaux) Schott), dogwood, red maple,

chestnut oak and spotted wintergreen were seedling/herbaceous layer associates.

Black Oak Community. Four plots within LT-17 were classified as a black oak community. These plots were located on mid- to upper slopes. Chestnut oak was the dominant overstory associate with mockernut hickory, sweetgum, pignut hickory and white oak as secondary associates. Red maple and dogwood were dominant understory associates with sourwood, white oak and yellow-poplar as secondary associates. Sourwood and sweetshrub were dominant sapling/shrub layer associates with Vaccinium spp. L., maple-leaf viburnum, sassafras, sweetgum and blackgum as secondary associates. Beggar lice, poison-ivy, black oak, red maple, Virginia creeper, Christmas fern and wild yam (Dioscorea spp. L.) were seedling/herbaceous layer associates.

Eastern Hemlock Community. Three plots within landtype 17 were classified as an eastern hemlock community. This community was the most site specific community sampled on the study site, being restricted to the narrowest section of Mullins Creek gorge. Eastern hemlock dominated the overstory with Sweet birch (Betula lenta L.) and yellow-poplar as minor overstory associates. Sweetgum and sourwood were dominant understory associates with pignut hickory, yellow-poplar and dogwood as secondary associates. Mountain laurel and Azalea spp. were dominant sapling/shrub layer associates. Chestnut oak, poison-ivy, sweetshrub and red

maple were dominant seedling/herbaceous layer associates.

Yellow-poplar Community. Two plots within LT-17 were classified into a yellow-poplar community. One plot was located adjacent to the colluvial slope below the plateau escarpment, the other plot was located on a lower slope near Mullins Creek. Chestnut oak, scarlet oak and northern red oak were dominant overstory associates with pignut hickory as a secondary associate. Sourwood, red maple, dogwood, pignut hickory, white oak and sweetgum were understory associates. Sweetshrub, maple-leaf viburnum, sweetgum and sourwood were sapling/shrub layer associates. Dogwood, spotted wintergreen, black oak, white oak, red maple, Virginia creeper, sweetshrub and beggar lice were seedling/herbaceous layer associates.

Northern Red Oak Community. Two plots within LT-17 were classified as a northern red oak community. Both plots were located on the lower slope east of Mullins Creek. Sweetgum was the dominant overstory associate with white oak, chestnut oak, blackgum and yellow-poplar as secondary associates. Red maple was the dominant species in the understory with chestnut oak, sweetgum, sassafras, white oak and sourwood as secondary associates. Sweetgum was the only species sampled in the sapling/shrub layer. Red maple, black oak, white oak, pignut hickory, greenbrier, maple-leaf viburnum, sweetshrub, Christmas fern, beggar lice, Prunus

spp. L. and wild yam were seedling/herbaceous layer associates.

Shortleaf Pine Community. Two plots within LT-17 were classified as a shortleaf pine community. Both plots were located east of Mullins Creek, one adjacent to the colluvial slope at the base of the plateau escarpment and the other adjacent the confluence of Mullins Creek and Hemlock Branch. Shortleaf pine was dominant in the overstory with mockernut hickory, blackgum, white oak, chestnut oak, sweetgum and virginia pine as minor overstory associates. Red maple, sourwood, blackgum, mockernut hickory and dogwood were understory associates. Blackgum, sweetgum, sourwood and Vaccinium spp. L. were sapling/shrub layer associates. White oak, chestnut oak, red maple, Virginia creeper, greenbrier, beggar lice and Vaccinium spp. L. were seedling/herbaceous layer associates.

Scarlet Oak Community. One plot within LT-17 was classified as a scarlet oak community. The plot was located on a mid-slope position. Virginia pine, black oak, white oak and chestnut oak are secondary overstory associates. Chestnut oak and red maple were dominant understory associates with sourwood as a secondary associate. Blackgum was the dominant sapling/shrub layer associate. Sweetshrub, white oak, spotted wintergreen, greenbrier, black cherry and morning glory were seedling/herbaceous layer associates.

Discussion

Cluster analysis revealed similar communities occurred within different landtypes: chestnut oak, white oak and shortleaf pine communities were recognized in all sampled landtypes; scarlet oak communities were present in LT-5, LT-6 and LT-17; and black oak communities were present in LT-3 and LT-17.

The number of common communities within landtypes raises question to the validity of results obtained from discriminant analysis. The discrepancy stems from discriminating criteria being developed from vegetation information pooled by landtype. This included information from communities specific to a single landtype as well as differences exhibited between communities common to several landtypes (Figure 23 through 27). Consequently, forest vegetation pooled by landtype is relatively distinct. Forest communities occur at a smaller scale than landtypes.

V. FACTOR ANALYSIS

Results

Factor interpretation. Elements of the environment seldom operate individually to influence the spatial arrangement of forest communities. This is evident by the high factor loadings of highly correlated variables on the same factor. Also, the categorical variables used to evaluate some site conditions did not provide enough

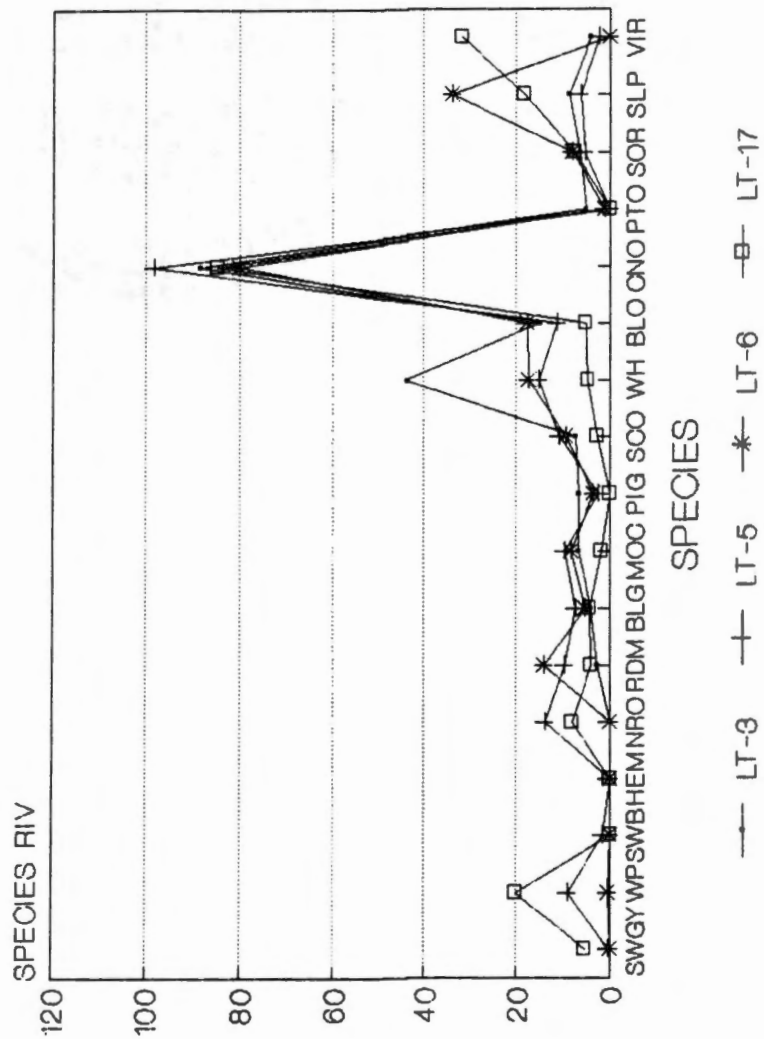


FIGURE 23.- CHESTNUT OAK COMMUNITY OVERSTORY PROFILES.

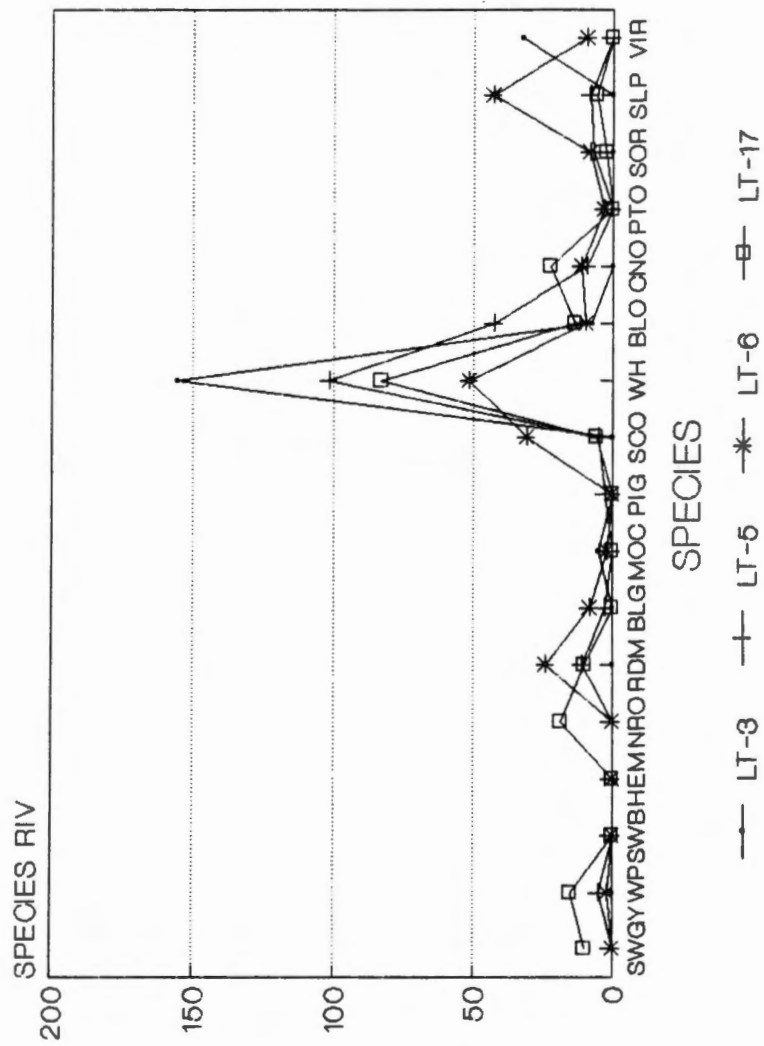


FIGURE 24.- WHITE OAK COMMUNITY OVERSTORY PROFILES.

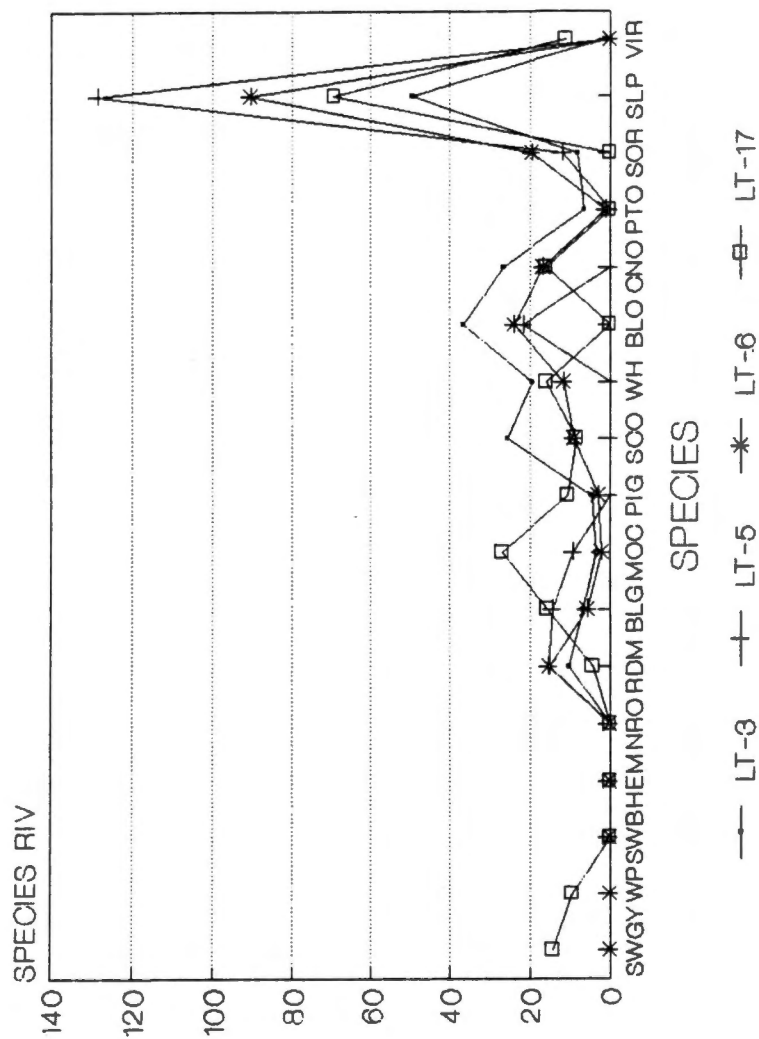


FIGURE 25.- SHORTLEAF PINE COMMUNITY OVERSTORY PROFILES.

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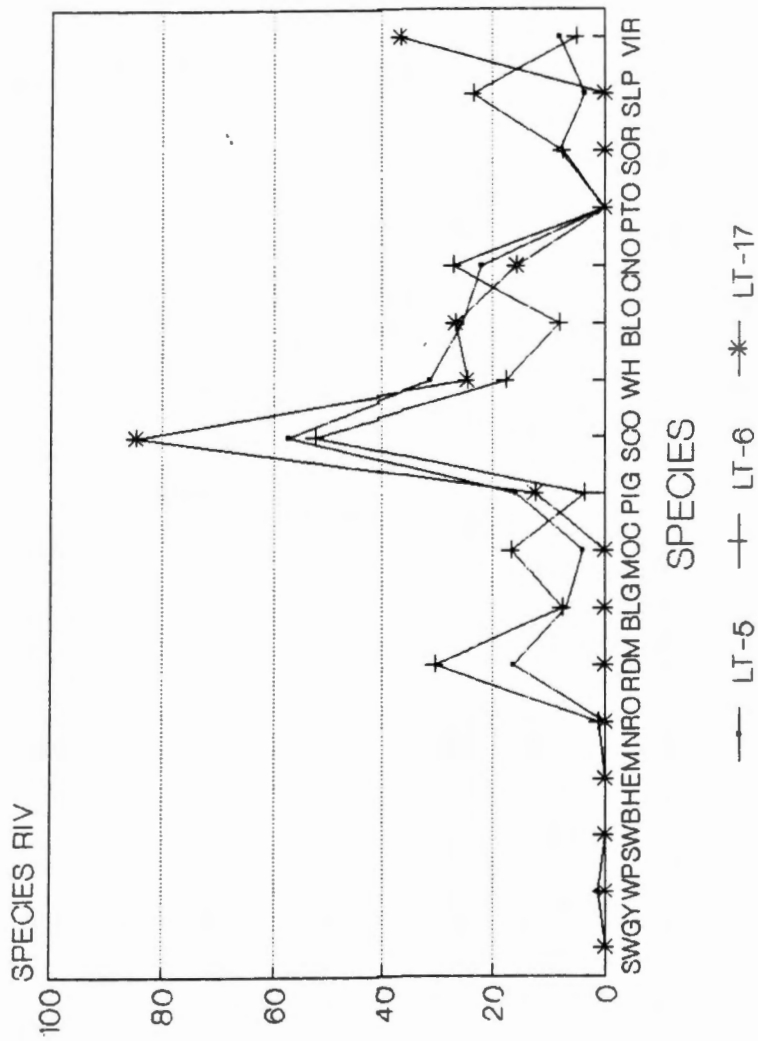


FIGURE 26.- SCARLET OAK COMMUNITY OVERSTORY PROFILES.

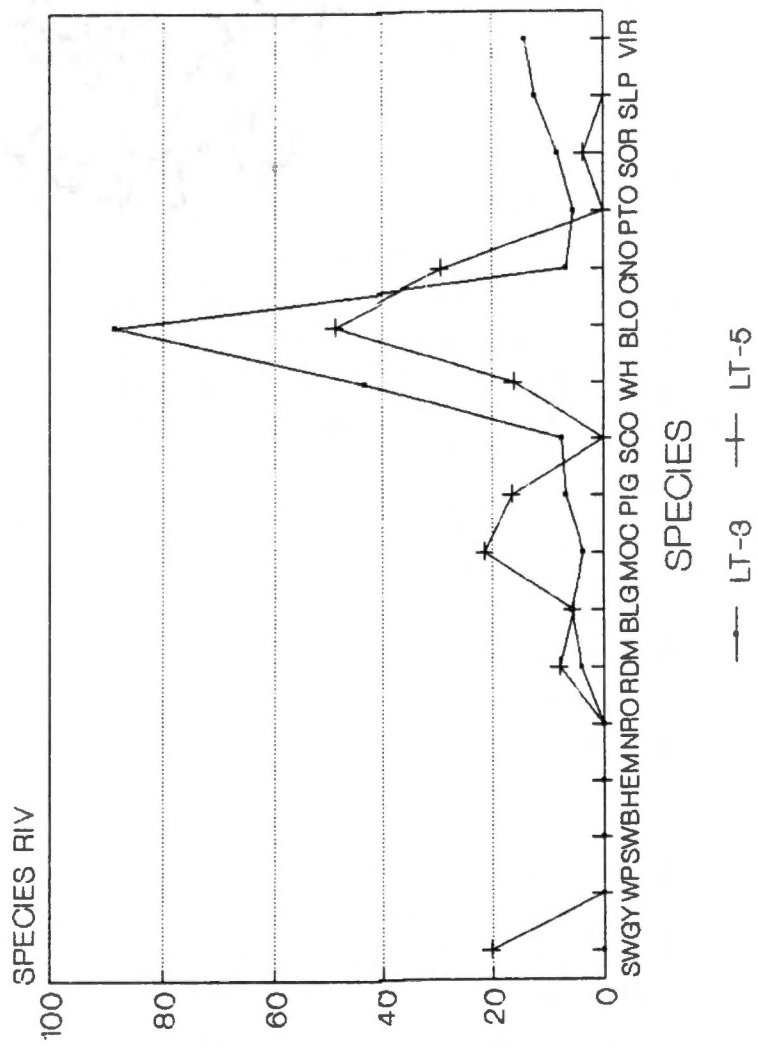


FIGURE 27.- BLACK OAK COMMUNITY OVERSTORY PROFILES.

information to hypothesize a relationship between a specific ecosystem element and forest development. For these reasons, the nature of factors is described without being named for specific ecosystem elements.

Factor one - elevational gradient. Factor one accounted for 47%, 52%, 56% and 51% of the explainable variation in the overstory, understory, sapling/shrub layer and seedling/herbaceous layer data sets respectively (Tables 9 through 12). Primary loadings for physical site variables are very consistent for all four data sets. Landtype, protection and slope location had positive primary loading scores while geology and elevation had negative primary loading scores for the overstory, understory and sapling/shrub data sets. The same variables primarily loaded on factor one within the seedling/herbaceous layer data set but with opposite signs (this does not change factor interpretation because the basic relationship between variables is the same).

Factors Two, Three and Four - Microsite gradients. A sizable gap in explained variance exists between factor one and factor two for all four data sets. The magnitude and subsequent decrease in explained variation from factor two through factor four indicates these factors are subordinate in explaining forest community variation. Also, factors two

TABLE 9.- EIGENVALUES AND FACTOR PATTERN FOR THE OVERSTORY DATA SET.

EIGENVALUES OF THE REDUCED CORRELATION MATRIX				
FACTOR	1	2	3	4
EIGENVALUE	5.331880	1.683637	1.277691	1.124246
DIFFERENCE	3.648243	0.405947	0.153445	0.352328
PROPORTION	0.4725	0.1492	0.1132	0.0996
CUMULATIVE	0.4725	0.6218	0.7350	0.8346

FACTOR PATTERN				
	FACTOR1	FACTOR2	FACTOR3	FACTOR4
LT ¹	0.94208	-0.07840	-0.15108	-0.11029
PROT2	0.93772	-0.01296	0.02337	-0.11189
SWG	0.64214	-0.18059	-0.20939	0.14495
SLOL	0.52839	0.23831	0.18104	-0.14600
YWP	0.52183	-0.08688	0.10450	0.14438
NRO	0.40840	-0.17980	0.13544	0.37182
AXISMIN	0.26946	0.26090	0.03503	0.03995
AXISMAJ	0.26373	-0.18712	-0.01946	0.11872
PTO	-0.21669	0.10809	-0.20865	-0.01148
GEOL	-0.92332	0.12652	0.14086	0.20846
ELEV	-0.94560	0.12106	0.15388	0.13899
HEM	0.35967	0.75811	0.07847	0.14552
SWB	0.32490	0.74122	0.20548	0.21681
MOC	0.05981	-0.14425	-0.03540	-0.10161
ASPT	-0.02874	-0.31150	0.09717	0.30764
SLOP	0.17417	-0.18587	0.51686	-0.14647
CNO	-0.06936	-0.18230	0.47749	0.23429
PIG	-0.00355	0.01632	-0.15757	0.00569
VIR	0.10936	0.01665	-0.18740	-0.05602
BLO	-0.29780	0.15022	-0.51539	0.00227
WHO	-0.09393	-0.14314	-0.27647	0.30999
BLG	-0.01112	0.04197	0.00543	0.07001
SCO	-0.13257	-0.03504	0.07040	-0.24819
SOR	-0.22453	0.16735	-0.09688	-0.26079
RDM	-0.09971	-0.11385	0.28861	-0.32861
SLP	-0.19137	0.07282	0.07668	-0.47779

1. See appendix A for meaning of acronyms

TABLE 10.- EIGENVALUES AND FACTOR PATTERN FOR THE UNDERSTORY DATA SET.

EIGENVALUES OF THE REDUCED CORRELATION MATRIX				
FACTOR	1	2	3	4
EIGENVALUE	4.763937	1.238858	0.943896	0.692814
DIFFERENCE	3.525079	0.294962	0.251082	0.088296
PROPORTION	0.5235	0.1361	0.1037	0.0761
CUMULATIVE	0.5235	0.6597	0.7634	0.8395

FACTOR PATTERN				
	FACTOR1	FACTOR2	FACTOR3	FACTOR4
LT	0.95830	0.06641	-0.11114	0.00646
PROT2	0.94557	-0.02440	-0.04721	0.01118
SWG	0.61417	0.10838	0.10798	-0.09920
SLOL	0.51341	-0.10730	0.27794	-0.10036
YWPU	0.36082	0.19770	-0.01347	0.26650
GEOL	-0.95288	-0.04923	0.08266	0.05575
ELEV	-0.96423	-0.02386	0.08093	0.03930
PIGU	0.04671	0.41396	0.10715	0.21674
PERSU	-0.10503	0.40003	0.14899	-0.02896
WHOU	-0.19162	0.32357	-0.24962	0.26444
BLGU	-0.10471	-0.15289	-0.11720	-0.08660
SLOP	0.17264	-0.42202	0.21526	0.02707
RDMU	0.10323	-0.52424	-0.29515	0.14138
AXISMIN	0.26427	0.06153	0.39004	-0.02315
SASU	0.08627	-0.12052	0.17705	-0.00398
MOCU	-0.03715	0.23075	-0.33918	-0.16195
ASPT	-0.06272	-0.08057	-0.41464	-0.10511
SORU	-0.14952	-0.10835	0.28108	0.29484
AXISMAJ	0.26651	0.12166	-0.12281	0.28535
BLOU	-0.14658	0.02835	0.08139	0.21025
CNOU	-0.14295	-0.09336	0.09510	-0.24208
DOGU	-0.15340	0.37685	0.05888	-0.37697

TABLE 11.- EIGENVALUES AND FACTOR PATTERN FOR THE
SAPLING/SHRUB DATA SET.

EIGENVALUES OF THE REDUCED CORRELATION MATRIX				
FACTOR	1	2	3	4
EIGENVALUE	4.595595	0.922682	0.676112	0.581143
DIFFERENCE	3.672913	0.246571	0.094969	0.143116
PROPORTION	0.5973	0.1199	0.0879	0.0755
CUMULATIVE	0.5973	0.7173	0.8052	0.8807

FACTOR PATTERN				
	FACTOR1	FACTOR2	FACTOR3	FACTOR4
LT	0.95799	-0.07839	-0.08540	0.00640
PROT2	0.94714	0.03895	0.03310	0.03971
SLOL	0.53508	0.26879	0.38989	-0.09690
SWG	0.52085	-0.38849	-0.06641	-0.04872
SAS	0.05457	-0.02693	0.01050	0.03893
PER	-0.17234	-0.03601	-0.00236	-0.14263
GEOL	-0.95396	0.07100	-0.01410	0.08687
ELEV	-0.96916	0.09266	-0.00328	0.05229
MTL	0.31036	0.50168	-0.03387	-0.03369
AXISMIN	0.26178	0.39882	-0.12735	0.12738
SWS	0.15365	-0.24311	0.09406	0.16320
ASPT	-0.05927	-0.40376	0.16034	0.17402
VAC	-0.13357	-0.06068	0.23862	-0.01289
BLG	-0.10508	0.01039	-0.22871	0.09017
MLV	0.12581	0.10527	-0.32547	0.09460
AXISMAJ	0.25544	-0.10211	-0.37355	0.24341
SLOP	0.17399	0.08863	0.22962	0.40679
AZL	-0.06030	0.05060	0.11125	0.36438
DOG	0.07257	-0.04170	0.13661	-0.14127
SOR	0.00855	-0.07673	-0.14340	-0.25816

FIGURE 12.- EIGENVALUES AND FACTOR PATTERN FOR THE
SEEDLING/HERB DATA SET.

EIGENVALUES OF THE REDUCED CORRELATION MATRIX

FACTOR	1	2	3	4
EIGENVALUE	4.544006	1.162386	1.051569	0.762731
DIFFERENCE	3.381620	0.110817	0.288838	0.177206
PROPORTION	0.5144	0.1316	0.1191	0.0864
CUMULATIVE	0.5144	0.6460	0.7651	0.8515

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3	FACTOR4
ELEV	0.96199	0.02755	0.09051	-0.11940
GEOL	0.95006	0.07699	0.10983	-0.09487
VAC	0.34546	-0.27960	0.26356	0.13379
WRG	0.29929	-0.19090	-0.16926	-0.18192
GRB	0.28682	-0.22871	-0.02946	0.17387
SLOL	-0.49436	-0.36162	0.05982	0.02917
PROT2	-0.94273	-0.05737	0.02750	0.07123
LT	-0.95801	0.04670	-0.08937	0.03744
BEG	-0.18662	0.49229	0.07006	-0.10541
SAS	0.14924	0.37688	0.10456	0.02184
AXISMAJ	-0.29068	0.36189	0.09565	-0.26223
SPW	0.00911	0.17024	-0.03511	0.10150
DOG	0.07018	-0.15167	-0.10010	0.03372
SLOP	-0.19832	-0.04693	0.46487	-0.09508
CNO	0.07462	0.11262	0.30066	-0.14319
YAM	-0.17957	0.09600	0.19863	0.06966
RDM	0.13003	-0.14590	0.16914	0.14015
HIC	0.12869	-0.01073	-0.28639	-0.03795
BLG	0.14611	0.25388	-0.35823	0.10760
BLO	0.07912	0.06387	-0.41109	-0.20687
WHO	0.08452	0.18946	-0.24147	0.35380
ASPT	0.04770	0.30588	0.26000	0.35363
SCO	0.11779	-0.11876	-0.06288	0.26549
PAN	0.00000	0.00000	-0.00000	-0.00000
AXISMIN	-0.25643	-0.16611	0.00115	-0.35856

through four do not exhibit a consistent loading pattern for physical site variables between forest strata, resulting in difficulty of factor interpretation.

Discussion

The loading scores for factor one strongly suggest that an elevational factor complex accounts for the majority of the explainable variation associated with the sampled forest communities. Factor one loading scores suggests that as elevation decreases, protection increases, importance of mesic site species increases and importance of xeric site species decreases.

Many ecosystem elements vary along an elevational gradient, including but not limited to water availability and dynamics, air temperature, propagule dissemination, shade intensity and duration, soil physical and chemical properties and anthropogenic and natural disturbances. The variables measured to evaluate site conditions for this study do not provide enough evidence to relate the majority of forest community variation to a specific ecosystem element. Due to the interactions and covariation of ecosystem elements, it is doubtful that a study constructed to quantitatively measure individual elevation gradients could attribute forest community variation to a single ecosystem elements.

In general, loadings for factors two, three and four illustrate negative correlations between mesic plant species

and xeric plant species. Physical site variables loading on these factors suggest microsite gradients are important in explaining forest strata variation but are unable to specify the mechanisms causing this variation.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study examined relationships between forest cover and Smalley's landtype classification system as applied on Prentice Cooper State Forest. Knowledge of the spatial relationships of forest communities within landtypes could provide natural resource managers with a way to evaluate and classify forest resources in an efficient manner. Three questions were posed to investigate forest community/landtype relationships within Smalley's system:

- 1) Do distinct forest communities occur within specific landtypes ?
- 2) What is the nature of forest communities occurring within specific landtypes?
- 3) What are possible underlying factors influencing forest communities?

The results of this study illustrated the framework in which multivariate statistics based on classical inference theory should be used when investigating forest cover/landtype relationships. Previous studies using the same techniques interpreted the results without evaluating variable distributions or variance structure. Without knowing or testing for variable distribution and variance

structure, resulting probability levels could be grossly inappropriate.

The question arises--what is the appropriate context in which to apply multivariate statistical models developed from classical statistical inference theory to data sets that do not meet model assumptions? Johnson (1981) states two possibilities for the appealing results obtained from application of such techniques to wildlife habitat studies when model assumptions are not met:

- 1) ... biologists might be reporting the results of sophisticated multivariate techniques only when they are in accord with their biological intuition, previous knowledge, or results of simpler univariate analysis. A technique that produces conclusions in conflict with other knowledge may be rejected as inappropriate.
- 2) Statisticians could be looking at finer detail than biologists do when they evaluate multivariate methods. A technique can be biased, of low power, inefficient, and defective in other statistical ways, but still provide invaluable insight into the biological problem.

This study adopted the philosophy in explanation 2: violation of model assumptions preclude predictive statements about the location of forest communities. Even so, valuable insights were gained about the relative distinctiveness, composition and variation of forest communities within landtypes.

Do Landtypes Have Distinct Vegetation?

Discriminant analysis revealed the four sampled landtypes possessed relatively distinct vegetation. Landtype 17, located below the plateau escarpment, had more in common with LT-5 than any other landtype located above the escarpment. LT-3, LT-5 and LT-6 had similar vegetation, resulting in misclassifications among these landtypes.

What is the Nature of Forest Communities within Landtypes ?

Farthest neighbor cluster analysis revealed vegetation exists in definable communities that occur on the landscape at a smaller scale than landtypes. Some communities occurred in only one landtype while others occurred in all four landtypes. This pattern suggests that landtypes are adequate to define operational constraints but an additional hierarchy below landtype is needed to distinguish forest communities.

A problem is now made evident when trying to use species RIV's to discriminate between forest communities dominated by the same species occurring in several landtypes. A 0.10-acre plot containing 25 trees 12 inches d.b.h., 20 of which are chestnut oak and five miscellaneous species, has the same RIV's as a plot with five trees 12 inches d.b.h., four of which are chestnut oak and one miscellaneous species. The range of values exhibited in this example are highly artificial for undisturbed stands, but they demonstrate the inadequacy of species RIV's for comparing communities of

different productivity. Forest communities can also vary in form and quality of tree stems. This vertical variation is not measured by RIV.

These conclusions suggest absolute measurements of species characteristics, including bole height or quality, would be better discriminators of forest communities dominated by the same species but occurring in different landtypes.

Establishing landtype relationships between dominant and secondary associates throughout all sampled forest strata is another possibility to distinguish between similar communities occurring in different landtypes. Associated species may be more site specific than common dominant species. Identification of associate species/landtype relationships would also be easier to apply in the field than volume/quality differences.

What Underlying Factors Influence Community Variation?

Principal factor analysis revealed the primary source of forest community variation occurs along an elevational gradient. Many ecosystem elements vary along an elevational gradient, including water availability and dynamics, atmospheric temperature, propagule dissemination, shade intensity and duration, soil physical and chemical properties, anthropogenic and natural disturbances. There was also evidence that these elements influence forest

community variation at a microenvironmental scale. The nature of this study attempted to indirectly measure the influence of ecosystem elements by physically characterizing the landscape, resulting in speculation as to the importance of individual ecosystem elements in accounting for forest community variation.

To be successful in establishing the significance of ecosystem elements within landtypes, future studies in forest community/landtype relationships should attempt to measure ecosystem elements directly. Due to the many interactions existing between ecosystem elements and their environment, such a study will be a difficult and time consuming process.

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APPENDICES

APPENDIX A
VARIABLE ACRONYMS

TREE SPECIES

<u>ACRONYM</u>	<u>VARIABLE</u>
BLG*	black gum (<u>Nyssa sylvatica</u> Marshall)
BLO	black oak (<u>Quercus velutina</u> Lam.)
CNO	chestnut oak (<u>Quercus prinus</u> L.)
DOG	dogwood (<u>Cornus florida</u> L.)
HEM	eastern hemlock (<u>Tsuga canadensis</u> (L.) Carr.)
HIC	hickory spp. (<u>Carya</u> Nuttall)
MOC	mockernut hickory (<u>Carya tomentosa</u> (Poiret) Nuttall)
NRO	northern red oak (<u>Quercus rubra</u> L.)
PER	persimmon (<u>Diospyros virginiana</u> L.)
PIG	pignut hickory (<u>Carya glabra</u> (Miller) Sweet)
PTO	post oak (<u>Quercus stellata</u> Wang.)
RDM	red maple (<u>Acer rubrum</u> L.)
SAS	sassafras (<u>Sassafras albidum</u> (Nuttall) Nees.0
SCO	scarlet oak (<u>Quercus coccinea</u> Muenchh.)
SLP	shortleaf pine (<u>Pinus echinata</u> Miller)
SOR	sourwood (<u>Oxydendrum arboreum</u> (L.) DC.)
SWB	sweet birch (<u>Betula lenta</u> L.)
SWG	sweetgum (<u>Liquidambar styraciflua</u> L.)
VIR	Virginia pine (<u>Pinus virginiana</u> Miller)
WHO	white oak (<u>Quercus alba</u> L.)
YWP	yellow-poplar (<u>Liriodendron tulipifera</u> L.)

* tree acronyms with a preceding U denote understory stratum

SHRUB SPECIES

<u>ACRONYM</u>	<u>VARIABLE</u>
AZL	azalea (<u>Azalea</u> spp. L.)
MLV	maple leaf viburnum (<u>Viburnum acerifolium</u> L.)
MTL	mountain laurel (<u>Kalmia latifolia</u> L.)
SWS	sweet-shrub (<u>Calycanthus floridus</u> L.)
VAC	vaccinium (<u>Vaccinium</u> spp. L.)

HERB SPECIES

<u>ACRONYM</u>	<u>VARIABLE</u>
BEG	beggar lice (<u>Desmodium</u> spp. Desvaux)
GRB	greenbrier (<u>Smilax</u> L.)
PAN	panicum (<u>Panicum</u> L.)
SPW	spotted wintergreen (<u>Chimaphila maculata</u> L.)
WRG	wire grass (<u>Stipa avenacea</u> L.)
YAM	wild yam (<u>Dioscorea</u> spp. L.)

LANDTYPE CHARACTERISTIC

ACRONYM

VARIABLE

ASPT	plot aspect
AXISMAJ	plot shape-major axis
AXISMIN	plot shape-minor axis
ELEV	elevation
GEOL	underlying geologic formation
LT	landtype
PROT2	protection index
SLOL	slope location
SLOP	slope percent

O B S	B L O	W H O	C N O	S C O	N R O	P I G
1	30.6895	51.861	55.563	0.000	0.0000	0.0000
2	9.5709	10.436	139.524	0.000	0.0000	0.0000
3	0.0000	12.873	94.767	11.659	0.0000	36.4427
4	11.6007	50.987	61.904	0.000	0.0000	0.0000
5	70.3890	77.886	21.342	21.255	0.0000	0.0000
6	0.0000	126.061	0.000	0.000	0.0000	0.0000
7	32.2553	65.585	50.430	19.243	0.0000	0.0000
8	0.0000	73.729	77.191	21.357	0.0000	0.0000
9	13.0712	27.001	17.218	49.809	0.0000	0.0000
10	81.9700	83.872	0.000	22.138	0.0000	0.0000
11	15.4088	184.591	0.000	0.000	0.0000	0.0000
12	20.1180	60.931	67.144	10.011	0.0000	0.0000
13	0.0000	7.449	165.014	13.462	0.0000	0.0000
14	0.0000	33.580	0.000	81.626	0.0000	7.9401
15	44.3746	22.289	71.756	34.799	0.0000	0.0000
16	0.0000	0.000	134.820	0.000	25.8513	0.0000
17	25.8712	43.196	12.923	63.047	0.0000	0.0000
18	0.0000	24.776	107.991	45.481	0.0000	0.0000
19	0.0000	19.759	155.670	0.000	0.0000	0.0000
20	22.4153	63.050	34.659	28.539	0.0000	12.8221
21	17.6316	17.632	109.035	10.614	0.0000	0.0000

O B S	M O C	R D M	S L P	V I R	S O R	P T O
1	37.3096	0.0000	0.000	24.5770	0.0000	0.0000
2	32.3556	0.0000	0.000	0.0000	0.0000	0.0000
3	11.6594	16.6752	0.000	0.0000	15.9242	0.0000
4	0.0000	0.0000	28.091	15.1451	0.0000	32.2723
5	0.0000	0.0000	0.000	0.0000	9.1274	0.0000
6	9.6364	0.0000	0.000	64.3030	0.0000	0.0000
7	0.0000	0.0000	0.000	0.0000	24.1821	8.3037
8	0.0000	0.0000	13.861	0.0000	13.8613	0.0000
9	9.7831	0.0000	36.813	0.0000	24.6521	21.6539
10	0.0000	12.0200	0.000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.000	0.0000	0.0000	0.0000
12	0.0000	16.0819	0.000	8.3021	0.0000	0.0000
13	0.0000	0.0000	0.000	0.0000	14.0754	0.0000
14	10.0528	20.1056	0.000	0.0000	33.6854	0.0000
15	0.0000	9.8538	0.000	0.0000	0.0000	0.0000
16	0.0000	11.4628	0.000	0.0000	0.0000	0.0000
17	9.2238	33.9141	11.825	0.0000	0.0000	0.0000
18	0.0000	10.6029	0.000	0.0000	11.1489	0.0000
19	0.0000	16.8564	0.000	0.0000	7.7153	0.0000

O B S	B L G	Y W P	S W G	H E M	S W B	S L T	L T	P L O T
1	0.0000	0.000	0.0000	0	0	1	3	1
2	0.0000	0.000	0.0000	0	0	1	3	2
3	0.0000	0.000	0.0000	0	0	1	3	3
4	0.0000	0.000	0.0000	0	0	1	3	4
5	0.0000	0.000	0.0000	0	0	1	3	5
6	0.0000	0.000	0.0000	0	0	1	3	6
7	0.0000	0.000	0.0000	0	0	1	3	7
8	0.0000	0.000	0.0000	0	0	1	3	8
9	0.0000	0.000	0.0000	0	0	1	3	9
10	0.0000	0.000	0.0000	0	0	1	3	10
11	0.0000	0.000	0.0000	0	0	1	3	11
12	17.4114	0.000	0.0000	0	0	1	3	12
13	0.0000	0.000	0.0000	0	0	1	3	13
14	13.0106	0.000	0.0000	0	0	1	5	14
15	16.9275	0.000	0.0000	0	0	1	5	15
16	9.7362	8.393	9.7362	0	0	1	5	16
17	0.0000	0.000	0.0000	0	0	1	5	17
18	0.0000	0.000	0.0000	0	0	1	5	18
19	0.0000	0.000	0.0000	0	0	1	5	19

VITA

David Arnold was born on October 16, 1961, in Winchester, Tennessee. He graduated from Franklin County High School in 1980. Following graduation he enrolled at Middle Tennessee State University. In the summer of 1983 he finished the pre-forestry curriculum at M.T.S.U. and transferred to Auburn University. In 1985 he received his Bachelor of Science (High Honors) from Auburn University. Immediately after graduation he began work as propagation manager at Tennessee Valley Nursery in Winchester, Tennessee. In January of 1988, he received a Graduate Research Assistantship with the Department of Forestry, Wildlife and Fisheries at the University of Tennessee, Knoxville. Requirements for a Master of Science in Forestry were completed in December of 1990. David married Cynthia Dianne Baker in December of 1989.