Characterization of Vascular Plant Species Composition and Relative Abundance in Southern Appalachian Mixed-Oak Forests

by

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(Abstract)

Eight study sites were established in mid-elevation, south aspect, mixed-oak forests in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia to address questions concerning the variability in species composition, richness, and relative abundance of vascular plant species in those communities. All forest strata were sampled using a nested plot design. Variability in species richness and species composition was found to be high. Total species richness values ranged from 84 to 273, and Sorrenson's Coefficient of Similarity index values indicated that approximately 46, 38, and 51 percent of the species in the overstory, mid-story, and herb stratum were the same among sites, respectively. However, despite differences in composition and richness, K-S tests revealed significant differences in the distribution of ranked relative abundance only in the mid-story at two sites. Differences did occur in the relative abundance of twelve growth form categories. While tree seedlings and perennial herbs dominated, on average, woody vines and fern species represented substantial coverage on sites in the Allegheny Mountains. Correlations among forest strata were weak. The greatest amount of variation in species richness was attributiable to the standard deviation of a forest site quality index (FSQI), which was thought to represent the variation in microtopography across each site. The lack of correlation and high variability in plant species richness and composition, despite similarities in topographic characteristics, reinforce the inherent weaknesses involved with using the chronosequence approach to studying ecological responses in the Southern Appalachian mixed-oak region. Future remeasurement and long term monitoring of these study sites, following the implementation of silvicultural manipulations, will provide the information needed to make inference on the effects of forest management practices on Southern Appalachian mixed-oak forests.

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DEDICATION

Dedicated to the memory of my mom, Gabrielle Hammond, whom was always supportive and encouraged me to achieve my dreams.

Preface

The conservation of biological diversity has become a major concern for much of society and for many governments and government agencies at all levels. The importance of biological diversity will never be fully known, but the reasons for its conservation are numerous. Humans have relied on the products of nature since the origin of the species. Plant compounds can be found in over two-thirds of modern medicines (Ehrlich 1990) and our reliance on plant taxa for possible agronomic cultivars is endless (McMinn 1991). Perhaps the best reason for conserving biological diversity is our lack of understanding of the complexity and interrelatedness of the ecosystem in which we live.

This study was part of a much larger undertaking titled "The impacts of Silviculture on Floral Diversity in the Southern Appalachians"; therefore, plot design and sampling protocol follow that of the parent study. Both studies originated from the need to further develop our understanding of natural systems and the effects that science based forest management practices have on non-target plant communities. With increasing pressures on our nations forests for both timber and non-timber forest resources, we must obtain quantitative evidence to demonstrate the long-term effects of forest management.

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CHAPTER 1: INTRODUCTION

Southern Appalachian Region

Geology and Vegetation

The Southern Appalachians represent the mountainous region of the Southeastern United States. The region has been divided into the Blue Ridge, Ridge and Valley, and Appalachian Mountain physiographic provinces. Their formation resulted from geologic activity in the late Paleozoic Era (Fenneman 1938). In the absence of any major uplifting since this time, the flora of the region has developed into what is considered the most complex taxa of North America (Braun 1950; Sharp 1970; Whittaker 1956). The flora of today's Appalachians show direct connection to the emergence of angiosperms in the late Mesozoic Era (Braun 1950).

The Blue Ridge differs from the Appalachian Mountain and Ridge and Valley in the drainage characteristics, general form of the mountains, and the geologic composition of the substrates. The much older metamorphic formations of the Blue Ridge contrast the sedimentary sandstones, shales, and limestones of all provinces west of the Blue Ridge. Ridges in the Blue Ridge range in elevation from 450 to nearly 1800 meters. Unlike the crescent ridges of the Appalachian Mountain and Ridge and Valley, mountains of the Blue Ridge are broad and domed (Daniels et al. 1973). The Ridge and Valley, located between the Blue Ridge and Appalachian Mountain, is composed of northeast to southwest oriented parallel ridges ranging in elevation from 600 to 1400 meters above sea level (Smith 1995), but generally more uniform in height than those of the Blue Ridge (Daniels et al. 1973). The orientation of these landforms creates a domination of northwestern and south-southeastern aspects throughout the region.

Ridges of the Appalachian Mountain province are more disected than those of the Ridge and Valley. Unlike the often broad, limestone valleys of the Ridge and Valley, the winding valleys of the Appalachian Mountain create a dendritic drainage pattern resulting in great variability in aspect and exposure over short distances. The massive sandstone beds of the region result in large upland flats (Daniels et al. 1973). Southern aspects in all three regions are dominated by mixed oak communities comprised primarily of *Quercus prinus*, *Q. coccinea*, *Q. alba*, *Carya* spp., *Acer rubrum*, and various other hardwood species. Mixed oak forests represent approximately seventy-five percent of the Ridge and Valley province in Virginia (Thompson 1992; Johnson 1992), and a major portion of the Appalachian Mountain province. Both timber and non-timber resources obtainable from these forests contribute greatly to local and regional economies.

Evolution of the National Forest System

Since original colonization of the region by European settlers, timber resources have played a major role in Appalachian society. Initial harvesting of these forests was limited to the highest quality *Quercus* spp., *Juglans nigra, Prunus serotina*, and *Liriodendron tulipifera* (Smith 1995), but as high quality growing stock continued to be depleted, more species were utilized. Around the turn of the century it became evident that our nations timber resources were in fact limited, and steps had to be taken to insure future wood supplies. As a result of the need for a continual supply of fiber, the National Forest system was established to conserve the forest landbase to guarantee that the nation's future timber and water needs would be met.

Recent decades have revealed changes in values demanded from our nations forests. Increasing concern over the apparent worldwide decline in biological diversity has placed non-timber values on an equal par with traditional National Forest management objectives. Legislation passed in 1976 formalized this change in management by mandating the maintenance of biological diversity on federal lands. The National Forest Management Act of 1976 (NFMA) states that:

> "Forest planning shall provide for diversity of plant and animal communities and tree species consistent with the overall multiple-use objectives of the planning area. Such diversity shall be considered throughout the planning process. Inventories shall include quantitative

> data making possible the evaluation of diversity in terms of its prior and present condition. For each planning alternative, the interdisciplinary team shall consider how diversity will be affected by various mixes of resource outputs and uses, including proposed management practices (36 CFR 219.26)."
>
> It continues to say that "Management prescriptions, where appropriate and to the extent practicable, shall preserve and enhance the diversity of plant and animal communities, including endemic and desirable naturalized plant and animal species, so that it is at least as great as that which would be expected in a natural forest and the diversity of tree species similar to that existing in the planning area. Reductions in diversity of plant and animal communities and tree species from that which would be expected in a natural forest, or from that similar to the existing diversity in the planning area, may be prescribed only where needed to meet overall multiple-use objectives. Planned type conversion shall be justified by an analysis showing biological, economic, social, and environmental design consequences, and the relation of such conversions to the process of natural change (36 CFR 219.27(g))."

The passage of the NFMA created a multitude of challenges for National Forest managers. Among these were the need to i) select a method for quantifying diversity, ii) implement that methodology in an inventory to determine the diversity of "natural forests" on federal lands, and iii) investigate the short- and long-term effects of various management practices on those communities. In the twenty-one years since the drafting of the NFMA, little progress has been made towards resolving these challenges.

Ecologists have debated the issue of diversity and its measurement since the 1940's (Gove et al. 1994). A lack of agreement on how diversity should be represented has resulted in nearly as many diversity indices as ecologists studying the issue (Odum et al

1960; Menhinick 1964; Fisher et al 1943; Preston 1948; and Whittaker 1965; Shannon and Weaver 1963; Simpson 1949). Many of these indices focus on various aspects of diversity thought to be most important by individual investigators in the regions where they studied. Comprehensive reviews of diversity indices are provided by Peet (1974), Kempton (1979), Patil and Taillie (1982), Maugurran (1988), Gove et al. (1994), and a brief discussion of the primary approaches and most widely applied indices is contained in the following chapter.

Considerable work has been done characterizing the species composition of many regions of the Southern Appalachians (Braun 1950; Keever 1953; Whittaker 1956; Hicks 1980; Travis 1982; Wendel 1987; Aulick 1993). However, these studies have focused primarily on tree species composition (Braun 1950; Keever 1953) and its relation to environmental gradients (Whittaker 1956; Travis 1982) in primary forests. Little emphasis has been placed on herbaceous community species composition (Bratton 1975) or overall species composition in second growth forests which currently dominate the Southern Appalachian landscape. In addition, many ecologists feel the need for evaluating community structure, represented by relative abundance, and irrespective of individual species identity (May 1975; McMinn 1991; Tillman 1996) . No treatment of this could be found in the literature for the Southern Appalachians.

Objectives

i) Create a checklist of plant species and their frequency in eight Southern Appalachian mixed-oak forests,

ii) Quantify the species composition and horizontal structure of the overstory and mid-story canopy layers of eight Southern Appalachian mixed-oak forests,

iii) Quantify overall species richness and Shannon's diversity of the herb layer for the eight mixed-oak forests, and

iv) Describe the variability in relative abundance of vascular plants occurring in the herbaceous layer of the eight mixed-oak forests.

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CHAPTER 2: LITERATURE REVIEW

Diversity

Definition

The debate over the concept of diversity and its measurement is not new. McMinn (1991) makes a distinction between biodiversity and diversity. He states that diversity is simply a synonym for variability, where as biodiversity encompasses all biotic components of ecosystems and includes "the diversity of genes, species, plant and animal communities, ecosystems, and the interaction of these elements." Diversity as a term is not limited to biological systems, but instead can be applied to any phenomenon subject to variation. The concept of diversity is well represented in linguistics, social, and physical sciences (Patil and Taillie 1982). Ecologists investigating terrestrial systems often focus on species diversity of plant communities since green plants usually account for an overwhelming proportion of the biomass in a given system. However, as Pielou (1975) points out, complexity of a community's plant species composition does not reflect the diversity of other taxonomic levels. For example, a community could exist which is limited to a few genera, but many species are represented within each genera. Applying the concepts of species diversity to the diversity of growth forms occurring in a community has been suggested as an alternative (Maugurran 1988). This approach may better illustrate the degree to which inter-specific competition is achieved through strongly contrasting life strategies.

Diversity Indices

The idea of diversity encompasses two concepts: numbers of species and eveness of species relative abundance. Species number was first introduced by Fisher et al. (1943), and is simply the number of species found in a given community. Due to the implication that the exact number of species could be determined for a boundless community, the concept was later referred to as species richness (Whittaker 1965). Evenness, on the other hand, refers to the degree to which dominance is distributed among the species in a community. Evenness is highest if all species in the community are equally represented. Evenness is usually represented by species relative abundance (Patil and Taillie 1982). Many measures of diversity exist and a complete review is beyond the scope of this text. Hurlbert (1971), Maugurran (1988), Patil and Taillie (1982), Peet (1974), and Pielou (1975) have given comprehensive treatment to the derivation of the many indices and the concerns associated with their application.

The concepts of diversity and most of the problems associated with its measurement can be seen in the most recognized indices. Species richness, Simpson's index (1949), and Shannon's (1963) index are the most notable of a wide array of indices which aim to narrow the broad concept of species diversity into a single number. As previously mentioned, species richness is a count. Ideally, a richness value would represent the number of species in a given community; however, most ecologists recognize that a community has no definitive bounds and therefore cannot contain a fixed number of species (Peet 1974). Hence, species richness must be estimated through sampling and the number of species expressed on an area basis. The obvious problem encountered when comparing richness values from various communities is the total area sampled must be equivalent. Most botanical studies express species richness as the number of species per square meter (Maugurran 1988); however, the equality of plot size does not eliminate the possible inequality of sample size, nor does it ensure equality in the numbers of individuals sampled. A number of methods have been proposed for transforming species richness to a value independent of sample size (Menhinick 1964; Odum et al. 1960); however, seldom are the conditions needed to satisfy these transformations met (Peet 1974).

Simpson's index and Shannon's index belong to a family of indices known as heterogeneity indices, which incorporate both richness and evenness (Peet 1974). These indices stem from information theory, and assign a diversity value based on the sum of each species contribution to an overall measure of abundance. Measures of abundance most commonly used include number of individuals per species, percent cover, and biomass. The selection of which measure to apply is entirely subjective and can promote bias in the index value (Peet 1974). Given that species vary greatly in size, the number of individuals is an inappropriate representation of dominance. Whittaker (1965) suggests that species relative net primary productivity is a direct result of resource partitioning, and therefore represents a species true dominance in a community. Instead of numbers of individuals, he suggests a direct measure of biomass. Since determining the biomass of all the species in a community can be time consuming and costly, dominance can also be represented by the crown cover of each species (Whittaker 1965).

Despite the bias associated with the variable used to represent abundance, two indices utilizing the same measure may nevertheless fail to agree on the rank of several communities (Hurlbert 1971, Patil and Taillie 1982, Peet 1974). The inability of the indices to concur results from unequal weighting of the individuals in the community by the index formulation itself. Mathematical theory shows that some indices are more affected by changes in relative abundance of dominant species while others are more sensitive to changes among rare species. To further complicate the issue, ecologists fail to agree on which indices are most sensitive to which species. For example, while Peet (1974) illustrates that Shannon's index is most sensitive to rare species, others believe it to be most sensitive to dominant species (Monk 1967, Sager and Hasler 1969). Still others consider Shannon's to respond greatest to changes in species of intermediate abundance (Fager 1972, Poole 1974, Whittaker 1965).

Diversity Orderings

The disagreement among diversity indices led to the development of the concept of intrinsic diversity orderings. Patil and Taillie (1982) introduce the concept which states that communities are intrinsically different if one of the following conditions can equate their diversity: i) introduction of species into community, ii) redistribution of abundance from more to less abundant species without changing species rank, or iii) relabeling species categories. The general idea is that if all indices of the relationship Δ_β [1] rank two or more communities the same, then they are considered to be intrinsically different. The foundation of the approach is nested in the mathematical relationship between the species count, Shannon, and Simpson indices (Patil and Taillie 1982). All three indices are special cases of the mathematical formula

$$\Delta_\beta = \Sigma^{s}_{i=1}\{(1-\pi_i^{\beta})/\beta\}\pi_i , \qquad [1]$$

where $\beta \geq -1$

s = number of species

π_i = relative abundance of the i^{th} species

Species count, Shannon (H’), and Simpson’s indices are obtained when β = -1, 0, and 1, respectively (Gove et al 1994). To determine if two communities are intrinsically different, Δ_β is plotted against β for each community being compared. If the profiles parallel, then the community with the greater Δ_β value at each β is said to be intrinsically more diverse. If the profiles cross, the β value at which they cross allows interpretation of what portions of the communities differ. The interpretation of intersecting profiles is based on the biases of the various indices for species of different relative abundance (i.e. dominant, common, or rare).

Although diversity profiles alleviate the problems associated with disagreement among indices, profiles are still a single dimensional representation of a complex concept. The mathematical conditioning used to determine intrinsic diversity does not necessarily impose ecological meaning onto the resultant values. Many researchers are skeptical of approaches which seek to quantify diversity with a single number (Gove et al. 1994; Hurlbert 1971; Maugurran 1988; Peet 1974).

Species Abundance Models

Species distributions or abundance models fit empirical community data to known mathematical distributions to quantify the partitioning of species relative abundance within a community. Maugurran (1988) states that “a species abundance distribution utilizes all the information gathered in a community and is the most complete mathematical description of the data.” Although many distributions have been applied to empirical data, the log series (Fisher et al. 1943), lognormal (Preston 1948), geometric series, and MacArthur's (1957) broken stick model have been the most widely applied (Maugurran 1988). Various data transformations are utilized to illustrate the community properties thought most important by the investigator (Maugurran 1988). It has been suggested that the high number of communities described by the log and lognormal distributions is simply a mathematical property of empirical data sets and is described by the Central Limit Theorem (May 1975). Others feel that the overwhelming good fit of biological data sets is such that the distributions must have ecological significance (Sugihara 1980).

The geometric series and broken stick models have their foundations in community ecology. The geometric series, which can be expected to fit data sets from communities where harsh conditions limit growth, represents a niche-preemption hypothesis where a few species dominate the community and each successive species occupies a constant fraction of its next more abundant species' niche space (Maugurran 1988). Given a constant relationship among species, the geometric series forms a straight line on a rank abundance plot. The broken stick model represents communities in which S number of species compete for and secure equal proportions of a given resource (Maugurran 1988). This results in a uniform distribution of abundance (i.e. maximum evenness) rarely seen in nature (Maugurran 1988).

Since more than one distribution may adequately describe a given data set, selection of a distribution becomes dependent on other factors. Taylor (1978), for example, advocates the application of the log series over that of the lognormal because it is a poorer fit to the portion of the community containing rare species. This attribute causes the under representation of those species, which he feels ensures only resident species will influence the fit of the curve (Maugurran 1988).

<u>Dominance Curves</u>

Despite the support of species abundance models, their acceptance is not universal. Whittaker (1965) points out that by fitting empirical data to a distribution, considerable resolution is lost. He contributes this to the fact that “relations are less lawful, orderly, and consistent than ecologists might wish...” and the fit is not always “...neat.” He, in turn, proposes dominance diversity curves as an alternative graphical technique for comparing species diversity. Dominance curves are a plot of the log abundance over species rank (Whittaker 1965). Curves take on shapes similar to those of the distributions discussed above. However, the data is plotted directly and no information is lost (Whittaker 1965). The spread of the curves (i.e. number of species ranks) represents the richness of the sample, while the degree of slope is an indication of dominance. Hence, both components of diversity are represented. Hurlbert (1971) addresses the need to distinguish between dominance and importance of a given species: two terms often used interchangeably. Dominance is a concept that can be construed as a species’ ability to capture growing space. However, a species’ importance is difficult, if not impossible, to determine, and may be completely independent of dominance. Hurlbert (1971) offers the example of the chestnut blight (*Endothia parasitica*). Although the absolute biomass of the fungus may represent only a small fraction of the community, its impacts on species composition and structure of the previous oak-chestnut forest are immense (Braun, 1950; Keever 1953; Hurlbert 1971; Whittaker 1956).

Although dominance curves do not quantify diversity into a measure easily and directly comparable among communities, it is the attribute of interpretation which provides the researcher with the opportunity to distinguish “general and exceptional phenomena” in the distributions of species abundance (Whittaker 1965). Given the temporal dynamics of plant communities, long-term monitoring is necessary regardless of the methodology used to represent species diversity. The impacts of various management practices may be transient, and therefore misrepresented by a snapshot evaluation. To determine the sustainability of current practices, the entire response pattern must be understood.

Evenness as a Community Attribute

While the statistical problems associated with diversity indices have been discussed, there also exists conceptual short comings in the theories of diversity. Attributable to information theory origins, diversity indices associate high diversity with high evenness. The very definition of diversity contradicts this relationship. For example, if community X is composed of species whose relative abundance's are nearly equal, indices will indicate that this community is more diverse than community Y whose species all have very *different* relative abundance. Based on the previous definition of diversity (i.e. variable or different), community Y with its high degree of difference among species should be considered more diverse. Patil and Taillie (1982) elude to this problem in their discussion of rarity. Along with Hurlbert (1971), they make reference to a nineteenth century essay describing a tropical forest (Wallace 1875). The author notes that one has great difficulties finding multiple specimens of the same species. Most any ecologist or layman would consider such a forest to be very diverse. Therefore, Patil and Taillie (1982) suggested that it is the aspect of rarity, not evenness, which contributes to high diversity. Natural communities are seldom comprised of equally abundant species, and the concept of competitive exclusion is entirely based on a few species abilities to dominate community resources. While those few dominating species will be present in most communities, a truly diverse community will have a breadth of species with low relative abundance that are capable of self maintenance and reproduction at a level sufficient to remain in the community.

The contradictions apparent in the conceptual relationship between evenness and diversity are reason to shift the focus of ecological research off of "diversity" and towards a fundamental understanding of species relative abundance. This understanding should include the determination of factors which influence species relative abundance and the temporal scale on which changes in the distribution of species relative abundance in a community become cyclic.

Diversity and Community Stability

Methods which attempt to preserve information on the relative abundance of species have been formulated, and the importance of community structure has been widely accepted (Fisher et al. 1943; Kempton 1979; May 1975; Southwood 1978; Tillman 1996; Whittaker 1965). The importance of community structure is illustrated in the ongoing debate over community stability. The immense subject of stability could occupy several texts; however, to summarize, early theory proposed that diverse communities would be more stable over time than communities composed of only a few species (Goodman 1975). Ecologists supporting this theory cited a handful of experiments and observations as evidence. Goodman (1975) in a comprehensive review of the diversity-stability debate lists the following reasons as the foundation of the theory:

1. experimental one predator/ one prey systems have high degrees of fluctuation and usually go extinct,
2. island biota are vulnerable to invasion,
3. depauperate arctic and boreal populations have great fluctuations while tropical forests are seemingly stable, and
4. man made monocultures are subject to pest outbreaks.

Goodman (1975) provided rebuttals to each of these evidence to denounce the hypothesis and conclude that there was nothing to support the theory. One predator/ one prey systems, although highly oscillatory, are not countered by low fluctuations in many predatory/ many prey experiments. Secondly, the theory of island biogeography (MacArthur and Wilson 1967) has shown isolated populations to behave very differently from continental communities subjected to constant immigration and emigration of species. Thirdly, although empirical evidence does suggest a state of constancy in tropical forests, many researchers feel that the apparent stability is a function of sample intensity in which so few individuals of each species are present within a measurable sampling unit, that it is difficult to detect even considerable fluctuations (Goodman 1975). Finally, although it is undeniable that agronomic monocultures are highly susceptible to pathogens, Goodman (1975) notes that if given time, those systems could stabilize, but it is doubtful that it would be at economically desirable densities.

Goodman (1975) points out scales of disturbance which are important in viewing the diversity-stability debate: small and large scale. Interestingly, when viewed in response to large scale disturbance, diversity and stability seem to be inversely related. Considering the fact that highly diverse communities, such as the Southern Appalachians, evolve due to niche preemption and species specialization in the absence of large scale disturbance, those species which have highly specialized requirements will be greatly impacted by perturbations which drastically alter environmental conditions. In this respect, greater diversity results in lesser stability.

For small scale disturbances, Goodman (1975) points out that stability becomes more of an issue of population response to various types of disturbance. Frank (1968) poses that there either exists no reason for the stability of a community following small scall perterbations, or that the species within a community evolve life cycle patterns in response to cyclic changes in environmental conditions. Therefore, it is the life strategies of the species in the community which determine the communities degree of stability following disturbance, as well as the nature of the disturbance itself.

Tillman (1996), in a 13 year study, presented evidence that the distribution of species relative abundance was the factor most closely related to community stability. He showed that when subjected to nitrogen additions and drought, grassland communities remained stable with respect to the distribution of community biomass, but shifts in species dominance occurred due to differential response of individual species to nutrient and soil moisture alterations. Therefore, he concluded that it is a community's structure which remains stable and not the rank of specific species. Tillman's (1996) grassland communities are representative of most community response patterns. Some species will have the ability to increase their dominance under changing environmental conditions, while others may be forced to reduce their reproductive efforts and in turn focus on individual survival until conditions again become favorable. Holling (1973) defines species maintenance in a community under unfavorable conditions as ecosystem “resilience”.

Goodman (1975) indicates that some populations in fact induce instability as a defense mechanism. In predator-prey relationships where prey vulnerability is high only at certain stages of the life cycle, it may be beneficial for a species to reduce its reproductivity in order to reduce the predator population. Once the predator population is lowered, the prey species can again focus on increasing population size.

Although the examples above are not limited to plant communities, they illustrate that the degree of stability in a community is an intrinsic characteristic of the particular community and not a “passive reflection” of diversity (Goodman 1975).

Diversity as a Societal Value

In addition to the statistical concerns associated with the measurement of diversity and the conceptual discrepancies in ecological theory, is the aspect of diversity associated with sociological importance. Aside from the ecological interpretation of community diversity, land management issues dealing with diversity are heavily influenced by societal values. Since measurements of diversity are irrespective of species identity, one community may appear to be more diverse than another community based solely on its richness and evenness values. However, once societal values are included in the evaluation of diversity, indices may not reflect the attributes of a community which are deemed sociologically important. For example, community A has more species and those species are more evenly distributed than species occurring in community B. Based on the components of diversity previously discussed, indices should conclude that A is more diverse than B. However, suppose the dominant species in community B are relatively rare at the landscape level. The current outlook of society and federal management objectives mandated by the NFMA would place greater importance on the conservation of community B. It is for this reason that measures of diversity must be considered only as tools for the quantification of community attributes. Measurements should be combined with species lists, well established management objectives, and societal and ecological interpretation if communities are to be evaluated and ranked in order of *importance*. In addition, the quantification of diversity should maintain fundamental community information so that given changes in sociological values, previously collected data will continue to provide an informative basis for evaluation.

Appalachian Floral Characterizations

Braun (1950) characterized the region extending from the Hudson River Valley south to North Georgia as the oak-chestnut forest. She describes the vegetation of the region to be extremely complex and designates the Southern Appalachians as the center from which all deciduous forests of eastern North America formed. Following the introduction of the chestnut blight in 1904, the near total elimination of *Castanea dentata* took about thirty years (Keever 1953). Currently the chestnut exists only as rootstocks and associated sprouts restricted to suppressed canopy positions. The canopy gaps associated with its absence have resulted in shifts in dominance of several canopy species (Keever 1953; Whittaker 1956). Few studies have been conducted to quantify the vascular plant species composition of the Southern Appalachians. Of the existing research, most of the emphasis has been placed on identifying species associations along environmental gradients, with little effort aimed at intensively investigating the composition and structure of any single type. Braun (1950), Keever (1953), and Whittaker (1956) are among those to characterize the flora of the region; however, it must be noted that although their efforts were intensive, the timing of their research was such that the full effects of the disappearance of *Castanea dentata* on understory woody and herbaceous species composition and abundance may not have occurred.

Keever (1953) investigated the effects of the chestnut blight in mid-elevation stands of the Blue Ridge mountains near Highlands, NC. By the early 1950's, *Quercus rubra*, *Q. prinus, Q. alba,* and *Carya glabra* dominated the overstory of stands once occupied by *Castanea dentata*. *Acer rubrum, Cornus florida*, and *Carya glabra* were found to be the primary understory species. Although 22 species of woody seedlings were identified, ten species represented 96.7 percent of the individuals on the thirty 4 X 4m plots. Evaluation of herbaceous plants on thirty 2 X 2 m plots, occurring on southern aspects, revealed domination by *Dryopteris noveboracensis, Smilacina racemosa, Potentilla simplex,* and *Chimaphila maculata*. Twenty-nine additional herbaceous species where identified. Keever (1953) anticipated that community response to increased light transmission through canopy gaps was still occurring at the time of the study, and concluded that additional changes in herbaceous community composition should be expected.

Soon after Keever's description, Whittaker (1956) provided a comprehensive review of the community types occurring in the Great Smokey Mountains National Park, Tennessee. He expressed the difficulty in distinguishing among community types, and stated that any attempts to identify species aggregations in an assemblage so complex as that found in the Smokey Mountains would be based entirely on arbitrarily assigned measurement criteria. He did, however, identify several community types which were separable along an elevation gradient. Forests occurring at high elevations (> 1400 m above sea level) in the southern extent of the range were dominated by mesic, deciduous species such as *Fagus grandifolia, Betula allegheniensis, Aesculus octandra,* and *Acer spicatum.* The deciduous forests of the southern mountains were replaced at high elevations of the upper latitudes by boreal forests.

Consistent with Keever (1953), Whittaker characterized mid-elevation (750-1050 m above sea level) southern aspects as being dominated by mixed oaks and distinguished three dominant cover types: red oak-hickory, chestnut oak-chestnut, and chestnut oak-chestnut heath. Chestnut types were readily distinguishable from the red oak-hickory due to the near total domination of *Castanea dentata* and *Quercus prinus*. Whittaker also pointed out that these types were distinguishable at great distances due to the gray appearance of the dead and dying *Castanea dentata* stems. Understory and herbaceous species composition was similar among the oak types. Moderate to heavy crown coverage in the understory resulted from the occurrence of ericaceous species such as *Kalmia latifolia, Rhododendron maximum, Rhododendron calendulaceum,* and *Gaylussacia ursina*. Areas marked by the greatest losses of chestnut were developing dense midstories of *Acer rubrum, Oxydendrum arboreum, Cornus florida,* and *Smilax rotundifolia.* Herbaceous coverage was variable (1-30 percent), but tended to be lowest in the red oak type. Species dominating the herb stratum also varied between types, but species such as *Polystichum acrostichoides, Aster divaricatus, Aureolaria laevigata, Cimicifuga racemosa, Prenanthes trifoliata, Goodyera pubescens, Galax aphylla*, and *Viola spp* were common throughout. *Galax aphylla* was noted to be the dominant species on the most xeric sites.

Aulick (1993) provides one of the few herbaceous characterizations of the region in her description of three watersheds on the Fernow Experimental Forest (FEF) in north-central West Virginia. In contrast to the herbaceous species identified by Whittaker (1956) and Keever (1953) as dominants, Aulick (1993) found the herb stratum of FEF dominated by *Dryopteris marginalis*, *Laportea canadensis,* and *Viola* spp. Seedlings of *Acer pensylvanicum* also occupied considerable coverage. Percent cover, species richness, and Shannon's index were calculated for watersheds (WS) 3, 4, and 7. Few differences were found among variables tested. WS7 had significantly higher richness per m^2 (5.0 ± 0.3) and higher percent coverage (37.5 ± 2.7) than either WS3 or WS4 (3.7 ± 0.3, 19.3 ± 3.7 and 3.6 ± 0.2, 26.4 ± 4.3, respectively). No differences were found in H' between any of the watersheds sampled. Values of 1.9, 1.9, and 1.6 (Aulick 1993) were similiar to those reported by Gilliam and Turrill (1993) for the same watersheds and by Moriarty and McComb (1985) for mixed mesophytic forests in eastern Kentucky. It must be noted that although no appreciable differences surfaced from the FEF data (Aulick 1993), critical historical differences exist between the watersheds. Following clearcutting in 1970, WS3 was subjected to three applications per year of ammonium sulfate beginning in 1989. WS7 was clearcut in 1967, and herbicides were used to eliminate all vegetation for a period of two years. Considering the nature of the disturbances to which WS3 and WS7 had been subjected, results of comparisons between watersheds, irrespective of stand history, cannot be considered representative of other watersheds in the region. Although this in no way invalidates the intent of the study under review (Aulick 1993), which was to establish baseline characterization of the watersheds, it does limit its inference space.

Gilliam et al. (1995) in an evaluation of WS4 and an additional watershed, WS13, of the FEF, report equal proportions of herb stratum coverage between woody and herbaceous species. Variation in herb layer composition was shown to be significantly (α =0.05) correlated with the overstory of the mature stands in these watersheds. Hammond et al. (1997) report an increasing trend in herbaceous layer richness with decreases in mid-story coverage. In addition, they identified wide ranges of species richness (92 to 167 species/14 ha.) across mixed oak sites in Virginia and West Virginia. Gilliam et al. (1995) point out that variation in species composition on FEF was greater within watersheds than between.

Other's have investigated the linkage of forest strata with contradicting results. McCune and Anto's (1981) found that dissimilarity between stands for a given forest stratum explained little variation in the composition of other stratum in the Swan Valley of Montana. In contrast, Gagnon and Bradfield (1986) found significant correlation between all strata in *Abies amabilis* and *Psuedotsuga menziesii* stands on Vancouver Island, British Columbia. Gagnon and Bradfield (1986) report especially high correlation between the overstory and herb layers. Despite suggestions that linkages occur between forest strata (Gilliam et al 1995; Gagnon and Bradfield 1986), patterns of historical disturbance can be expected to shape species distributional patterns within and between forest stands (Braun 1950).

Whittaker (1956) cautions that the variability and extent of the Southern Appalachian range causes considerable shifts in dominance of community types on a regional basis. Orographic effects of the mountains reduce precipitation on eastern slopes of the Smokies, and along with reduced exposure to dry west winds, results in an expansion of oak types and loss of pine types relative to western slopes (Whittaker 1956). Similiar effects of climate on vegetation can be expected to occur with changes in latitude along the Appalachian chain.

Given the limited extent of investigation of Southern Appalachian herbaceous communities, and the relative instability of the regions forest (Braun 1950) during the period in which characterizations were done (Keever 1953; Whittaker 1956), additional research is needed to determine plant community characteristics in the region.

Consideration of the variability in species composition and relative abundance on similiar sites across the landscape is especially important. This study addresses these issues in a wide ranging baseline characterization of Southern Appalachian mixed-oak forests, specifically designed to include remeasurements over an extended period of time.

CHAPTER 3: METHODS

Study Site Description

Site Selection

Study sites were selected to represent mid-elevation, 600-1050 meters above sea level, mixed oak forests in the Southern Appalachian mountains. Selection criteria required relatively uniform canopy structure and diameter distribution across each site, and overstory species composition representative of mixed oak forests with white oak site $index_{50}$ 18 to 23 meters. Area requirements were such that each site be sufficiently large to accommodate seven square, two hectare treatment plots. In addition, all sites were located in mature stands, 50 to 100 years old, which displayed no indication of silvicultural manipulation within the past 15 to 25 years, and were capable of providing merchantable harvests at the time of site establishment.

Location

Eight study sites were located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia (Figure 1). Two study sites are located in the Blacksburg Ranger District of the Jefferson National Forest; Blacksburg 1 (BB1) and Blacksburg 2 (BB2), on Sinking Creek Mountain, Montgomery county, Virginia. A third site (NCL) was placed on Potts Mountain in the New Castle Ranger District, Craig county, VA. The remaining site in the Ridge and Valley province (WYT) is located on Walker Mountain in the Wythe Ranger District, Wythe county, VA. Four sites were established in the Allegheny Mountain province. Two sites, Clinch 1 (CL1) and Clinch 2 (CL2), are near High Knob on the Clinch Ranger District, Wise county, VA. The final two sites, WV1 and WV2, are on the Westvaco Wildlife and Ecosystem Research Forest near Cassity, Randolph county, WV.

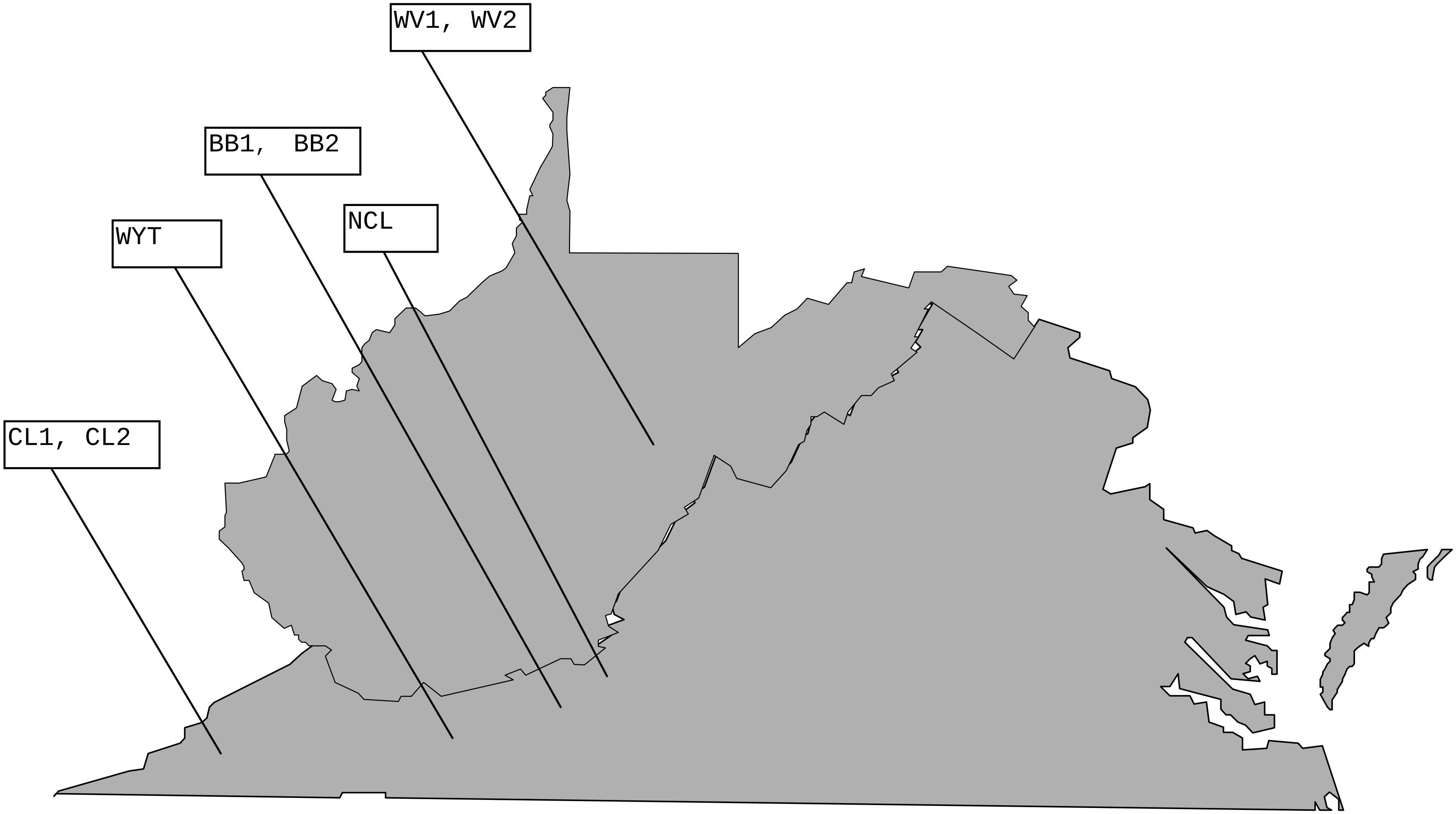

Figure 3.1. Location of eight study sites in the Ridge and Valley and Appalachian Mountain physiographic provinces in Southwestern Virginia and West Virginia.

Topography and Soils

These regions are characterized by steep ridges derived from sandstone and shale parent materials uplifted during the Appalachian Revolution in the late Paleozoic Era (Fenneman 1938). Due to the resistant sandstone caps, cliffs and rock outcrops are prevalent. Moderate slopes of 20 to 55 percent, coupled with shallow rocky soils, result in low moisture holding capacity. Soils on the BB1 and BB2 are of the Berks and Weikert series and are classified as Loamy-skeletal, mixed, mesic Typic Dystrochrepts and Loamy-skeletal, mixed mesic Lithic Dystrochrepts, respectively (Creggar et al. 1985). In addition to the Berks series, the Jefferson series is present on the NCL site. Depth of the Berks and Jefferson series are two fold that of soils in the Weikert series (Table 3.1). The Gilpin-Dekalb stony complex makes up the soils of WV1 and WV2. Similiar to the Berks and Weikert series in texture and classification, these soils occur on moderate slopes and range in thickness from 50.8 to 101.6 cm (Pyle et al. 1984). Soils of the Muskingum stony loam, steep phase series dominate CL1 and CL2 (Perry et al. 1954). All of the above mentioned series contain considerable rock fragments and have pH values of 3.5 to 6.

Climate

All Sites receive 106-124 cm of annual precipitation distributed evenly throughout the year (Perry et al. 1954; Creggar et al. 1985; Pyle et al. 1984). Mean daily July temperatures for WV, BB, and CL sites are 20.5, 21.6, 22.2 degrees C, respectively (Perry et al. 1954; Creggar et al. 1985; Pyle et al. 1984). Values for WYT and NCL sites are similiar to BB. Orographic effects of the Allegheny Plateau and Mountains reduce annual precipitation levels in the Ridge and Valley province to the lower end of the specified range, while milder winter temperatures reduce snowfall from approximately 122 to 163 cm to approximately 61 to 81 cm (Smith 1995) and increase the number of frost free days from 120 to 130 (Perry et al. 1954; Creggar et al. 1985; Pyle et al. 1984).

Table 3.1. Soils and climate information[a] for eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of Virginia and West Virginia.

Site	Soil Series and Classification	Soil Depth	Avg. Ann. Precip	Avg. Snow-fall	Mean Daily July Temp. (
			cm		
BB1/	Berks: Loamy-skeletal, mixed, mesic Typic	50-100	102.6	72.1	21.
BB2[b]	Dystrochrepts Weikert: Loamy-skeletal, mixed mesic Lithic Dystrochrepts	25-50			
CL1/ CL2[c]	Muskingum stony loam, steep phase:	7 -183	124.5	43.1	22.
NCL[d]	Berks: Loamy-skeletal, mixed, mesic Typic Dystrochrepts	50-100	102.6	72.1	21.
	Jefferson: Fine-Loamy, siliceous, mesic Typic Hapludults	150+			
WYT[d]			102.6	72.1	21.
WV1/	Gilpin-Dekalb stony complex:	50-100	106.7	148.6	20.
WV2[e]	Gilpin- Loamy-skeletal, mixed, mesic Typic Dystrochrepts Dekalb- Fine-Loamy, mixed, mesic Typic Hapludults				

a Climate data is for nearby towns at approximately 300 m lower elevations.

b Creggar et al. 1985

c Perry et al. 1954

d No soil identification on this site, climatic characteristics Creggar et al 1985.

e Pyle et al. 1984

Study Design

Treatment and Measurement Plot Establishment

All data for this study were collected as part of the study titled "The Impacts of Silviculture on Floral Diversity in the Southern Appalachians," further referred to as the Diversity study. The long-term goal of the diversity study is to determine the effects of seven regeneration alternatives on floral diversity. At each site, seven 2 ha treatment plots (141.4 X 141.4 m) were established using a hand compass, adjusted for declination, and cloth tape, according to a map previously prepared in the office. Plot boundaries were marked with double flagging tied to trees every 15 m. A tree nearest each corner was triple flagged. One of seven treatments: i) clearcut, ii) group selection, iii) shelterwood from above with 4.5 to 7 m^2*ha^{-1} residual basal area, iv) shelterwood from below with 11.5 to 14 m^2*ha^{-1} residual basal area, v) leave tree at 2 to 3.5 m^2*ha^{-1} residual basal area, vi) chemical understory vegetation control, or vii) control was randomly assigned to each plot following pre-treatment sampling. Due to area constraints, WV1 has only 5 treatment plots: the shelterwood from above and chemical control plots were not included.

Following establishment of the seven treatment plots, plot centers were located by taping 100 m along a diagonal line in each plot. A 35 cm, rebar reinforced, PVC stake was labeled with an aluminum tag bearing the appropriate treatment plot number and driven into the ground to permanently mark each location. From these points, three 24 X 24 m measurement (tree) plots were randomly located within each treatment (Figure 3.2). A random number generator design for numbers 0 to 360 was used to select an azimuth towards which to locate the first plot. The two remaining plots per treatment were located along azimuths 120 degrees and 240 degrees from the first. The center of each tree plot was established along the appropriate azimuth at a random distance, such that a 22.8 m buffer was maintained between measurement plots and treatment plot boundaries. Distances were controlled to eliminate tree plot overlap. From the center point, the four corners of the 24 X 24 m measurement (tree) plots were located using a declination adjusted staff compass and cloth tape. Plot boundaries were aligned with the cardinal directions. Beginning at plot center and working clockwise from the northwest corner, reinforced PVC stakes were driven into the ground and labeled with an aluminum tag bearing a unique number. Additional PVC stakes were placed at 5, 6, 12, 18, and 19 m along each boundary. All distances were adjusted for slope, which was estimated using the percent scale of a Sunto clinometer. The establishment of the non-corner PVC stakes, formed sixteen 6 X 6 m shrub plots and eight 1 X 1 m herbaceous plots in each tree plot (Figure 3.3). When sampling shrub plots, cloth tapes were run from each 6, 12, and 18 m stake to the corresponding stake on the opposing boundary line. The tapes identified the actual boundary of each shrub plot. Herbaceous plot boundaries were established by placing a 1 X 1 m PVC sampling frame inside the tree plot boundaries, such that two corners of the frame contacted the two PVC location stakes placed either side of each tree plot corner (Figure 3.3). Three out of sixteen shrub plots and six out of eight herbaceous plots were randomly selected for sampling in each tree plot. The same plots that were measured in the pre-treatment sampling will be measured in each post-treatment sampling.

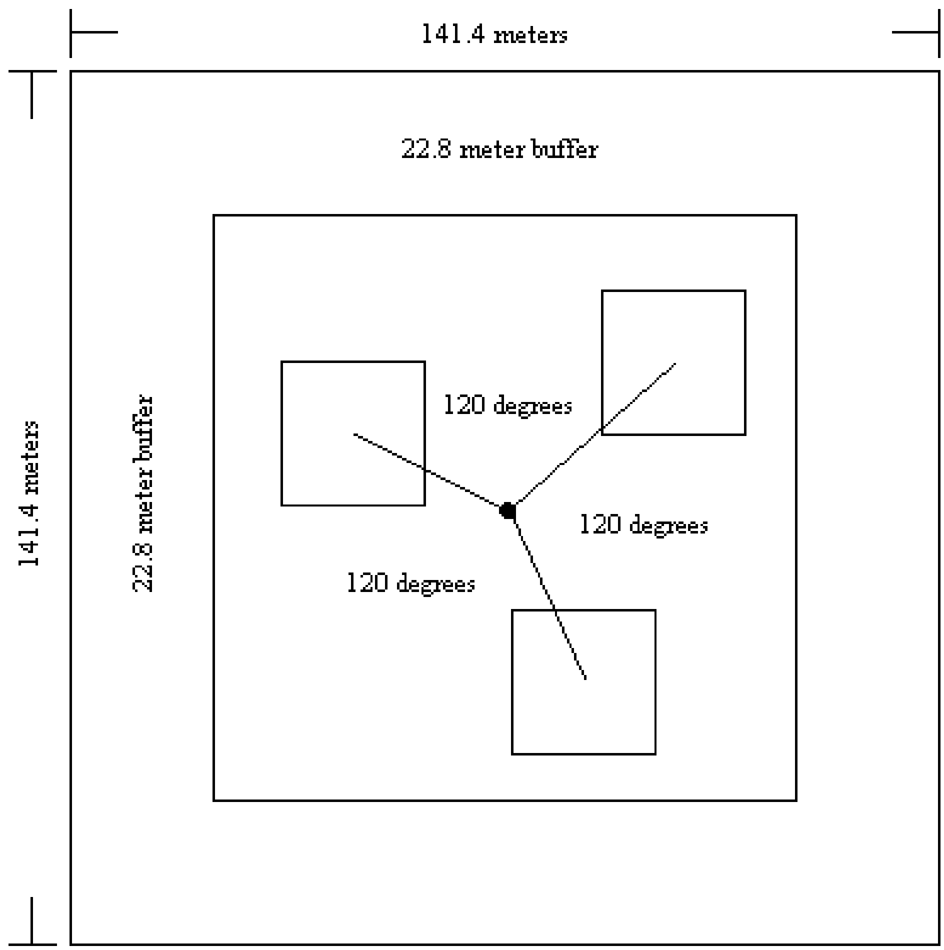

Figure 3.2. Plot schematic representing arrangement of three 576 m^2 tree plots within a two hectare treatment plot.

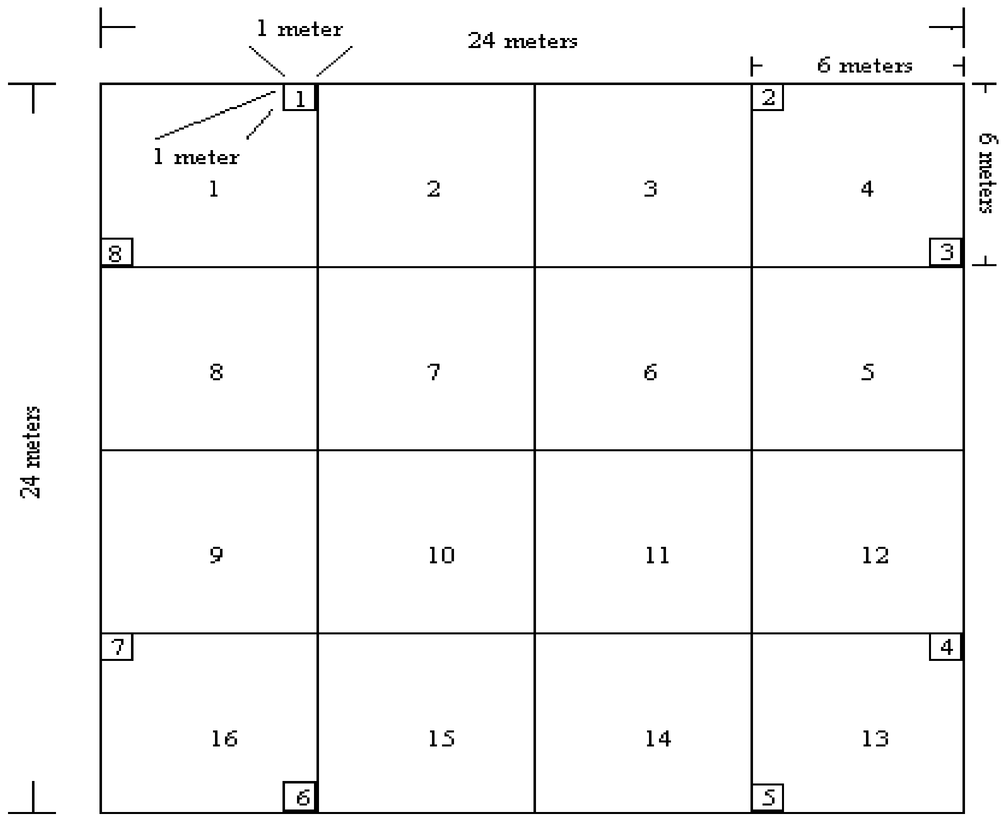

Figure. 3.3. Plot schematic representing eight nested 1 m^2 herbaceous plots and sixteen 36 m^2 shrub plots within a 576 m^2 tree plot.

Plot Measurements

Vegetation was divided into three strata. Trees were defined as woody stems greater that 5 m in height measured perpendicular from the ground to the tallest live or dead extremity. Shrubs were woody stems less that 5 m but greater that 1 m tall. Herbs were woody and herbaceous plants less than 1 m in height.

Stem diameter at 1.37 meters above ground (DBH) was measured to the nearest millimeter using a metal diameter tape for each tree on the 24 X 24 m tree plots. Each stem was identified to the species level and mapped using an X-Y coordinate system with the origin at the northwest corner. Therefore, the southwest corner has the coordinate 24:24. Species names were recorded using a four letter code consisting of the first two letters of each part of the trees latin name. Additional variables sampled for each tree include:

- live or dead status
- canopy class - defined as dominant, codominant, intermediate, or suppressed
- crown health - defined as one of three live classes and two dead classes based on percentage of crown volume containing foliage relative to other trees of the same species and canopy class, 90-100%, 50-89%, < 50%, recently dead, or dead

In order to ensure that future measurements correspond to the proper tree, an aluminum tag bearing a unique number was nailed to each tree, below stump height, using an aluminum nail. If a tree forked below DBH but above 30 cm, all stems were measured but were considered to be one tree. If a stem forked below 30 cm, each stem was counted as an individual tree and measured and tagged appropriately.

A cloth tape was used to measure crown diameter to the nearest 0.1 m along an axis corresponding to the greatest horizontal distance between live buds for each individual shrub occurring on the 6 X 6 m shrub plots. A second diameter was measured at the widest point, perpendicular to the first. Each shrub was identified to the species level and recorded using the appropriate four letter code. Stems originating from the same rootstock were counted as individuals if the stems separated below the surface of the A horizon.

All woody and herbaceous species were identified and counted on the 1 X 1 m herb plots. Species were categorized as woody or herbaceous and foliar coverage was visually estimated and placed in one of six categories defined using a pre-transformed scale (Little and Hills 1978).

In addition to measurements taken in each vegetation stratum, a walk through was performed on each 24 X 24 m tree plot and each 2 ha treatment plot. Each species was identified and recorded in an attempt to account for all species present. Taxonomic nomenclature follows Radford et. al. (1964). These lists will help to determine future treatment effects on species whose low numbers precluded their occurrence in the measurement plots.

Sampling Schedule

The data used in this study represent the pre-treatment data of the Diversity study. Walk-throughs and measurement of each stratum took place in mid-May to mid-June following spring leaf out. An additional sampling of the herb plots and walk-throughs occurred in early to mid-August of each year. Two herb samplings were necessary to include species of herbaceous plants which are present and identifiable during different portions of the growing season. Post treatment sampling of these sites for the Diversity study will take place one full growing season, three years, five years, and ten years following treatment. Additional sampling will occur at ten year intervals until a rotation age of 85 to 100 years.

DATA ANALYSIS

Based on preliminary analysis of species area relationships on the 126 herb plots at each site, the six herb plots and three shrub plots occurring within each tree plot were pooled to form one herb plot and one shrub plot per tree plot. The species area curve based on the 1 X 1 m herb plots failed to reach a plateau even at the treatment plot level (i.e. eighteen 1 X 1 m herb plots) (Figure 3.4a). The decision to group at the tree plot level was based on maintaining a degree of specificity with respect to topographical variables sampled. All such variables were collected at the tree plot level and a grouping of plots above that level would have precluded the ability to relate vegetative characteristics to site features. Additionally, pooling of shrub and herb plots to the tree plot level eliminated statistical concerns associated with their systematic establishment. Finally, equating the number of replications within each vegetation stratum, and hence degrees of freedom among the various ANOVA, created a more equal basis for comparisons.

Checklist

A species checklist was constructed from the compilation of treatment plot walk-throughs from all eight study sites. The checklist includes the species growth form category, and a ranking of species frequency based on the number of sites at which it was identified. The frequency categories are as follows:

Category	No. Sites
Very abundant	8
Abundant	6-7
Frequent	4-5
Infrequent	2-3
Rare	1

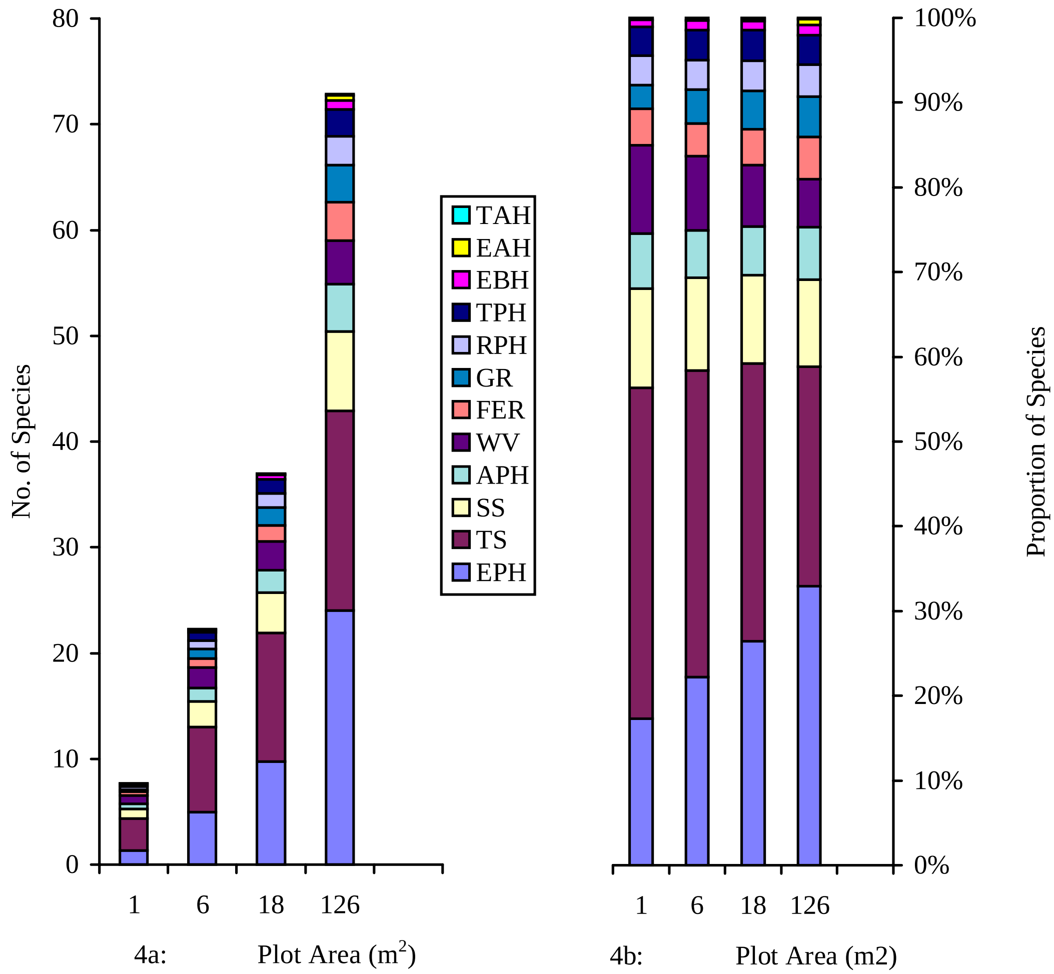

Figure 3.4a and b.. Species area relationships illustrating the numbers of vascular plant species per level of 1 x 1 m herb plot combination for eight mixed oak forests in the Southern Appalachians of Virginia and West Virginia. n = 972, (1 m^2); n = 162 (6 m^2); n = 54, (18 m^2); and n = 8, (126 m^2). Species were divided into the following twelve growth form categories: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species Richness

Herbaceous, shrub, and tree species richness values were calculated for each site based on herb, shrub, and tree plot data, respectively. Hypothesis tests were conducted using ANOVA and multiple comparison tests for a completely randomized design. The specific hypothesis tested was

Ho: no differences in species richness existed between study sites,

versus the alternative

Ha: differences do existed in species richness between study sites.

Species Composition

Differences in species composition between sites were evaluated by calculating Sorensen's (1948) coefficient of similarity (CS) for each pairwise combination of sites. Comparisons were made for each vegetation stratum, along with overall species composition. Coefficient of similarity was defined as:

CS = 2AB'/(A+B)

where:

A = the number of species in community a

B = the number of species in community b

AB' = the number of species in common between sites a and b

Distribution of Relative Abundance

The variability in community structure between communities sampled was investigated for each vegetation stratum by comparing dominance diversity curves. Comparisons of between site variability were made using a single curve from each site for each vegetation stratum. This curve was constructed by averaging the relative basal area or percent cover rank, depending on stratum, of each species across the corresponding 21 pooled plots at each site for the tree, shrub, and herb stratum, respectively. Averaging by rank, irrespective of species, created a curve limited in scale by the average number of species per 576 m^2, 108 m^2, and 6 m^2 tree, pooled shrub, and pooled herb plots, respectively. A Kolgomorov-Smirnoff test was used to test differences in curve shape for each of the 28 pairwise site comparisons:

Ho: no differences existed in the distribution of relative abundance among study sites,

versus the alternative

Ha: differences existed in the distribution of relative abundance among study sites.

In addition to site to site comparisons, within site comparisons were made for the herb layer. For within site comparisons, herb plots were pooled according to tree plot as previously described. Curves were then produced following the same methodolgy for site curves, but the number of plots averaged to produce the curves were limited to three in order to produce a single curve for each treatment plot. This resulted in seven curves per site. Again, a K-S test was used to test for differences in shape for each of the 21 pairwise comparisons at each site. The construction of dominance curves according to treatment plot provides baseline curves against which future post treatment comparisons of treatment induced changes in community structure can be made.

The results of the K-S tests for the curves described above showed any differences in curve shape between treatment plots within a site or between sites, depending on comparisons made, but did not provide a direct means of comparing the degree of difference attributable to each source of variability (i.e. within and between site). In order to determine which source of variability was greater, the number of pairwise comparisons resulting in significant differences was expressed as a percentage of the total number of comparisons made for each source of variability. The source of variability corresponding to the greatest percentage represented the largest source of variation in community structure. Since this index provided no means for statistical comparison, the differences required to make inference on the magnitude of within site variability relative to between site variability were large.

Total Basal Area per Hectare

Mean total basal area per ha was calculated for each site based on DBH measurements taken from the 21 tree plots established at each site. ANOVA and multiple comparison tests for a completely randomized design (CRD) were used to test the null hypothesis:

Ho: no differences existed in overstory basal area per ha between study locations,

versus the alternative hypothesis

Ha: differences existed in overstory basal area per ha between study locations.

Overstory Stem Density

Overstory stem density (number of stems per ha) was calculated for each site and comparisons between sites were made following the same procedures outlined for multiple comparisons of total basal area per ha. Specific hypothesis tested were

Ho: no differences existed between the number of overstory stems per ha at each study site,

versus the alternative

Ha: differences existed between the number of overstory stems per ha at each study site.

Overstory Diameter Distribution

To illustrate the size distribution of overstory stems in the communities sampled, quadratic mean diameter (QMD), defined as the diameter of the tree of mean basal area, was calculated for each study site. ANOVA and multiple comparison tests for a CRD were again used to test the null hypothesis

Ho: no differences existed between QMD at each study site,

versus the alternative

Ha: differences existed between QMD at each study site.

Shrub Cover and Density

Mean percent crown cover and rootstock density of the shrub layer were calculated for each study site based on crown diameter measurements and numbers of stems per plot. Site to site comparisons of total percent cover and rootstock density followed the procedures used for testing hypothesis on total basal area per ha and stems per ha previously described for the overstory. Sample units were as previously discussed. Hypothesis tested were

Ho: no differences existed in mean percent cover or rootstock density in the mid-story among study sites,

versus the alternative

Ha: differences existed in mean percent cover or rootstock density in the mid-story among study sites.

Herb Stratum Diversity

Shannon's index, $H' = -\Sigma p_i \ln(p_i)$, where p_i is the relative crown cover of the i^{th} species, total percent crown cover, and relative percent crown cover of the first species rank were calculated for each site from measurements taken on 126 herb plots per study site. Herb plots were pooled to the tree plot level as previously discussed. Relative percent cover was used to represent dominance (p_i). Although methods for computing the variance of H' and t-statistics have been developed (Whittaker 1972; Hutcheson 1970), the approximation of H' to the normal distribution (Taylor 1978) enabled the use of ANOVA. Taking advantage of the more powerful parametric procedures, ANOVA and multiple comparison tests for a CRD were used to test the null hypothesis

Ho: no differences existed in H', species richness, or percent cover among study sites,

versus the alternative

Ha: differences existed in H', species richness, or percent cover among study sites.

Relative Dominance of Growth Forms

To illustrate the distribution of relative abundance among various growth forms present in the herbaceous stratum of the communities studied, each species was placed into one of twelve categories: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid. Each species designation appears as the letters in bold in the species checklist. Site to site differences in the proportion of dominance in each category were tested using a chi-squared test for homogeneity.

Ho: no differences existed in the relative percent cover for twelve growth form categories among study sites,

versus the alternative

Ha: differences existed in the relative percent cover for twelve growth form categories among study sites.

RESULTS

Study Site Characteristics

Study sites were selected on the basis of aspect, elevation, site productivity, age, and overstory species composition and uniformity. All sites, with the exception of WV1, have predominately southeastern aspects (Table 4.1). Slopes range from 12 percent to 38 percent, on average, and remain consistent at a given site. Oak site $index_{50}$ ranged from 18 to 24 meters, and stand age was representative of mature mixed-oak stands.

Overstory

Horizontal Structure

Overstory horizontal structure was consistent among the eight study sites sampled (Table 4.2). Quadratic mean diameter ranged from 17.4 cm at NCL to 21.1 cm at CL1, with few significant differences. The small mean diameter at NCL resulted from a low basal area (24 m^2*ha^{-1}) coupled with a moderate stem density (1024 Stems*ha^{-1}). Note the large basal area values for the Allegheny Mountain sites when compared to BB1, BB2, NCL, and WYT in the Ridge and Valley. The Allegheny sites had 6 $m^{2*}ha^{-1}$ more basal area and 178 more stems per hectare.

Table 4.1. Mean topographical characteristics and associated 95 percent confidence intervals from 21, 576 m^2 tree plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Site	Aspect (degrees)	Slope (%)	FSQI [a]	Oak Site Index$_{50}$ (meters)	Age (years)
BB1	153 ± 19	16 ± 3 abc	11.0±4.3	n/a	n/a
BB2	151 ± 14	21 ± 3 c	10.9±3.6	22	99
CL1	149 ± 20	30 ± 3	10.5±3.8	18	111
CL2	108 ± 19	16 ± 3 abc	12.3±2.0	20	76
NCL	150 ± 16	12 ± 4 ab	12.4±2.8	18	62
WV1	270 ± 7	38 ± 3	7.5±2.6	23	73
WV2	129 ± 11	9 ± 4 a	10.6±1.8	24	63
WYT	163 ± 39	18 ± 4 bc	12.0±3.8	22	70

a Forest Site Quality Index

Table 4.2. Mean[a] horizontal structure characteristics of the overstory at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 576 m^2 tree plots.

Site	QMD[b] (cm)	Basal area ($m^2 * ha^{-1}$)	Stems*ha^{-1}
BB1	19.8 ab	25.5 cd	847.0 b
BB2	18.2 bc	26.8 cd	1045.0 b
CL1	21.1 a	29.2 bc	839.9 b
CL2	19.2 abc	29.1 bcd	1021.8 b
NCL	17.4 c	24.2 d	1024.3 b
WV1	17.8 bc	35.2 a	1518.5 a
WV2	18.2 bc	32.5 ab	1293.0 a
WYT	17.8 bc	25.3 cd	1045.8 b
mean	18.7	28.5	1063.0

a Values followed by the same letter were not significantly different at α=0.05
b Quadratic Mean Diameter

Species Composition

Oak species (*Quercus* spp.) dominated the canopies of these forests (Table 4.3), occupying, on average, 55.2 percent of the basal area in trees over 5 m tall. *Q. prinus, Q. rubra,* and *Q. alba* were most prevalent at each site, with the exception of the two West Virginia sites. WV1 was dominated by *Q. rubra* (28.4 percent), while soft hardwood species such as *Acer rubrum, L. tulipifera,* and *Magnolia fraserii* dominated WV2 and replaced *Q. prinus* and *Q. alba* as primary species at both locations. *Q. rubra, Q. prinus, A. rubrum,* and *Nyssa sylvatica* were the only species to occur in the canopy at all eight study sites. Unlike the first three, however, *Nyssa sylvatica* occupied low amounts of basal area and ranked tenth in overall abundance. Other less frequent species included *Carya* spp., *Amelanchier arborea, Acer pensylvanicum, Aralia spinosa, , Betula allegheniensis , B. lenta, Cornus florida, Fraxinus americana, F. pennsylvanica Hamamelis virginiana, Ilex ambigua, I. verticillata, Ostrya virginiana, Pinus echinata, P. pungens, P. rigida, P. strobus, Platanus occidentallis, Prunus avium, Robinia pseudo-acacia, Sassafras albidum,Tsuga canadensis* and others.

Sorenson's (1948) coefficient of similarity index values at each site revealed that, on average, for each pair-wise comparison, sites contained approximately 50 percent of the canopy species found on other study sites sampled (Table 4.4). While these values suggest a high degree of variability between sites, similar species dominated each site and the variation in species composition occurred among the less represented species. Furthermore, when adjacent sites are compared, i.e. CL1:CL2, BB1:BB2, and WV1:WV2, CS values, 54 percent, 55 percent, and 52 percent, respectively, were notably higher than average for the corresponding sites (Table 4.4).

Table 4.3. Basal area ($m^2 * ha^{-1}$) by species at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 576 m^2 tree plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT	Study Mean
	Basal area ($m^2 * ha^{-1}$)[a]								
Quercus prinus	4.3	11.2	3.7	4.1	6.6	4.7	0.5	5.7	5.1
Acer rubrum	1.1	1.8	4.2	6.6	0.8	7.5	6.8	1.7	3.7
Quercus rubra	0.5	1.0	8.6	6.2	<0.1	10.0	3.1	0.3	3.5
Quercus alba	7.8	2.9	3.8	3.3	2.5	np	np	3.4	3.1
Quercus velutina	3.3	3.3	0.5	1.4	1.6	np	np	5.0	2.0
Quercus coccinea	2.9	0.1	0.1	0.1	8.9	np	np	2.8	1.9
Oxydendrum arboreum	0.2	1.7	2.0	3.1	0.9	0.3	np	3.5	1.5
Liriodendron tulipifera	1.1	2.1	0.2	0.8	np	3.5	4.0	0.4	1.4
Magnolia fraseri	np	np	1.3	0.7	np	2.6	4.3	np	1.1
Nyssa sylvatica	0.3	1.0	1.8	0.5	0.7	0.5	np	0.2	0.6
Acer saccharum	<0.1	0.2	<0.1	np	np	0.3	3.9	<0.1	0.6
Fagus grandifolia	np	np	0.1	np	np	3.2	1.9	np	0.5
Prunus serotina	0.3	np	0.1	np	np	1.1	2.6	np	0.5
Magnolia acuminata	np	0.4	1.2	0.4	np	0.3	1.6	<0.1	0.5
Tilia americana	np	np	np	np	np	np	3.1	np	0.4
other	3.7	1.0	1.5	1.9	2.1	1.4	0.8	2.4	1.9

a np = species not present at that site

Table 4.4. Mean of Sorenson's Coefficient of Similarity by site for three vegetation strata[a] at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 576 m^2,108 m^2, and 6 m^2 tree, shrub, and herb plots, respectively. Means based on 28 pair-wise site comparisons for each stratum.

	Vegetation Strata		
Site	Tree	Shrub	Herb
	Coefficient of Similarity		
BB1	.49	.42	.50
BB2	.50	.41	.53
CL1	.50	.39	.57
CL2	.49	.39	.55
NCL	.42	.32	.49
WV1	.42	.40	.48
WV2	.39	.32	.40
WYT	.49	.38	.52
mean	.46	.38	.51

[a] overstory (woody vegetation < 5m); mid-story (woody vegetation 1m< >5m); herb stratum (woody and herbaceous vegetation < 1m)

The plot of ranked cumulative relative abundance illustrates the consistency with which basal area was distributed among species at each site (Figure 4.1). All sites were 85 to 90 percent dominated (relative basal area) by 5 species, mostly *Quercus* spp., with the remaining 10 to 15 percent of the basal area being distributed among 6 (at NCL) to 10 (at BB2 and CL2) species. Kolmogorov-Smirnoff tests (KS) revealed no statistically significant differences in the distributions at $\alpha = 0.1$.

Mid-story

Crown Cover and Rootstock Density

Moderate shrub coverage existed at all eight study sites. Percent cover of the midstory ranged from 34.8 percent at WV2 to a high of 73.7 percent at NCL (Table 4.5). WV2 and WYT, 34.8 and 44.1 percent respectively, were substantially lower than average. Comparing crown cover and rootstock density, demonstrates the differences in crown area of individual rootstocks. Although NCL had lower than average rootstock density, greater mean crown area per rootstock (3.8 m^2) resulted in high overall coverage. In contrast, mean crown area per rootstock at BB1 was equal to the overall mean (2.1 m^2), yet high rootstock density resulted in 72.2 percent coverage, nearly as high as NCL.

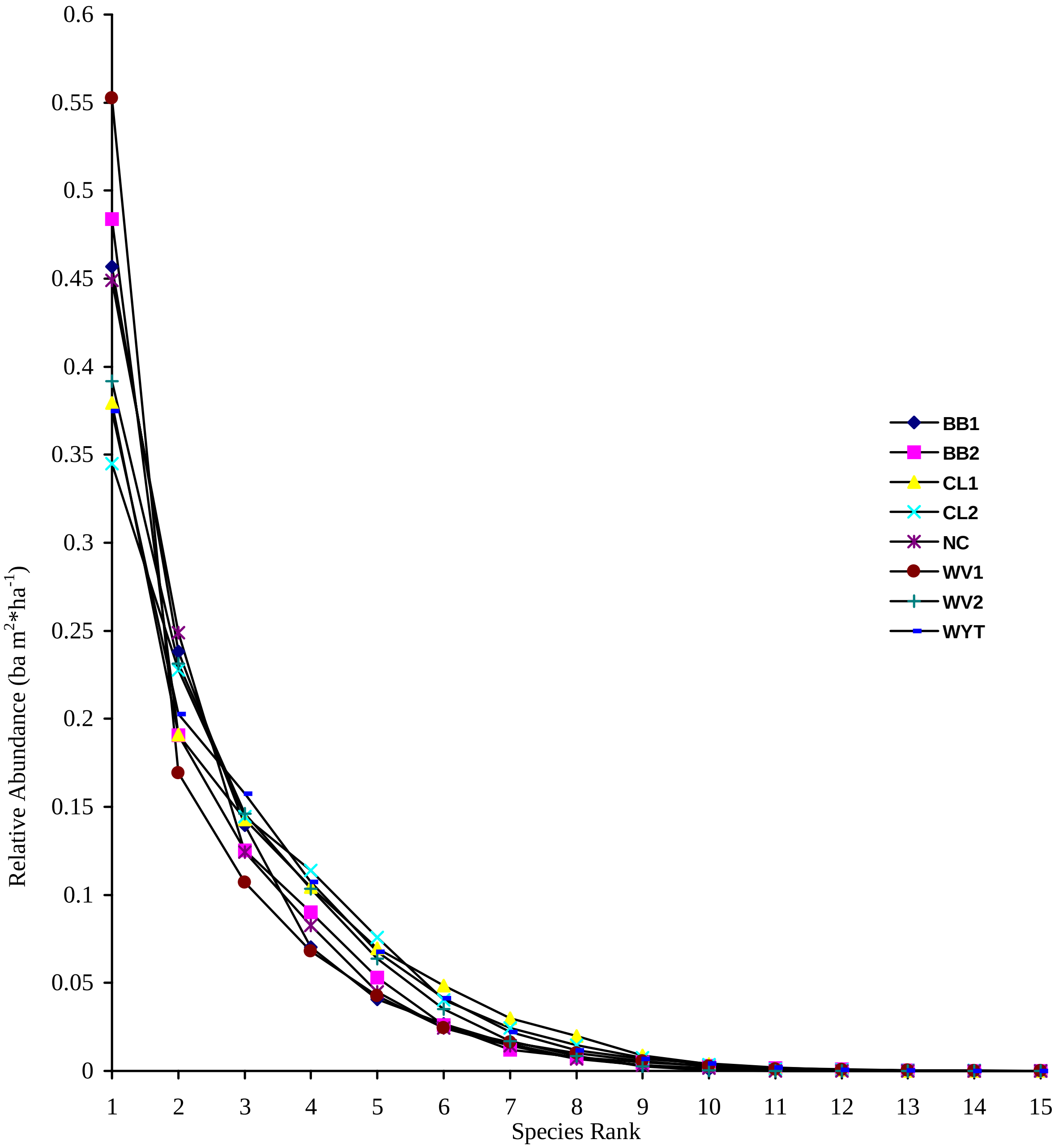

Figure 4.1. Ranked relative abundance (BA m^2*ha^{-1}) of overstory trees on 21, 576 m^2 tree plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia. The number of species ranks per site does not correspond to tree plot richness values, but is in fact the maximum number of species to occur on a plot at that site.

Table 4.5. Mean[a] horizontal structure characteristics of the mid-story at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 108 m^2 shrub plots.

Site	Crown Cover (%)	Rootstocks* ha^{-1}
BB1	72.2 a	3474 ab
BB2	63.9 ab	3197 abc
CL1	62.8 ab	3417 ab
CL2	50.5 abc	2434 bcd
NCL	73.7 a	1944 cd
WV1	59.1 abc	4154 a
WV2	34.8 c	1446 d
WYT	44.1 bc	2333 bcd
mean	57.6	2750

a Values followed by the same letter were not significantly different at α=0. 05

Species Composition

Nyssa sylvatica, *Acer rubrum*, and *Castanea dentata* were the dominant species in the midstory, accounting for 18.4, 15.0, and 8.1 percent of the mean relative cover, respectively (Table 4.6). Species dominance varied from site to site. While *Nyssa sylvatica* had 79.7 percent relative cover on NCL, it had minimal site occupation on WV1 (0.5 percent) and did not occur on WV2. In contrast, *Fagus grandifolia*, which occurred only on CL1, WV1, and WV2, clearly dominated WV1 (33.4 percent) and in conjunction with *Acer pensylvanicum* was a dominant species on WV2. *Oxydendrum arboreum*, although only highly represented at WYT, ranked fourth in overall dominance due to its occurrence on seven of the eight study sites. *Quercus* spp. accounted for approximately 4.5 percent of mid-story cover, and ranked ninth in overall coverage. The top 15 species occupied, on average, 85 percent of the mid-story cover. *Ilex ambigua, Liriodendron tulipifera, Kalmia latifolia, Rhododendron* spp., and *Sassafras albidum* were among the less represented species.

The extremely high dominance of *Nyssa sylvatica* at NCL resulted in a significantly different distribution of relative percent cover across species ranks (Figure 4.2). The distribution at NCL was significantly different from both BB1, BB2 and CL1 at $\alpha = 0.01$, and different from CL2 and WYT at $\alpha = 0.05$. The extent of *Fagus grandifolia* dominance at WV1 had a similar, yet not as large, an effect. WV1 differed significantly from CL1 at $\alpha = 0.05$ and BB2 at $\alpha = 0.1$. Maximum species richness per 108 m^2 shrub plot ranged from 12 at NCL to 15 at BB1 and BB2. Midstory species composition was more variable between study sites than in the overstory. Overall, site to site similarity in species composition was approximately 10 percent lower for the shrub layer. Coefficient of similarity ranged from 32 percent at NCL and WV2 to 42 percent at BB1 (Table 4.4). Consistent with results in the overstory, adjacent sites had considerably more species in common than sites widely separated on the landscape. The Blacksburg, Clinch, and West Virginia sites shared 57 percent, 44 percent, and 52 percent of the species present, respectively.

Table 4.6. Relative percent crown cover by species in the mid-story at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 108 m^2 shrub plots.

Species[a]	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT	Study Mean
	Relative Crown Cover[b]								
Nyssa sylvatica	14.3	12.6	1.2	1.1	79.7	0.5	np	7.6	18.4
Acer rubrum	27.0	21.8	14.9	16.3	1.3	13.3	10.7	12.2	15.0
Castanea dentata	0.6	1.5	16.5	24.5	4.7	0.2	np	18.6	8.1
Oxydendrum arboreum	0.5	9.8	3.0	10.7	4.1	1.1	np	27.3	6.6
Acer pensylvanicum	0.2	np	13.0	1.3	np	19.3	29.7	4.1	6.6
Cornus florida	17.3	9.8	np	0.1	5.4	np	np	3.6	5.5
Fagus grandifolia	np	np	0.1	np	np	33.4	21.5	np	4.9
Hamamelis virginiana	2.3	np	9.3	6.2	1.0	np	12.0	0.2	3.9
Magnolia fraseri	np	np	11.8	13.0	np	0.9	1.1	np	3.3
Amelanchier arborea	3.9	1.7	5.9	4.0	1.2	0.3	0.5	3.9	2.8
Acer saccharum	0.7	2.3	1.1	np	np	5.6	13.7	np	2.2
Pinus strobus	2.3	3.9	np	np	np	np	np	11.1	2.0
Magnolia acuminata	np	1.2	8.0	5.9	np	<0.1	0.7	np	1.9
Quercus prinus	4.1	6.4	0.1	np	0.6	<0.1	np	2.3	1.9
Betula lenta	np	0.8	3.3	0.7	np	9.6	1.0	0.5	1.7
other	26.8	28.2	11.8	16.2	2.0	15.8	9.1	8.6	14.9

a Species listed in order of descending dominance when averaged across all sites
b np = species not present at that site

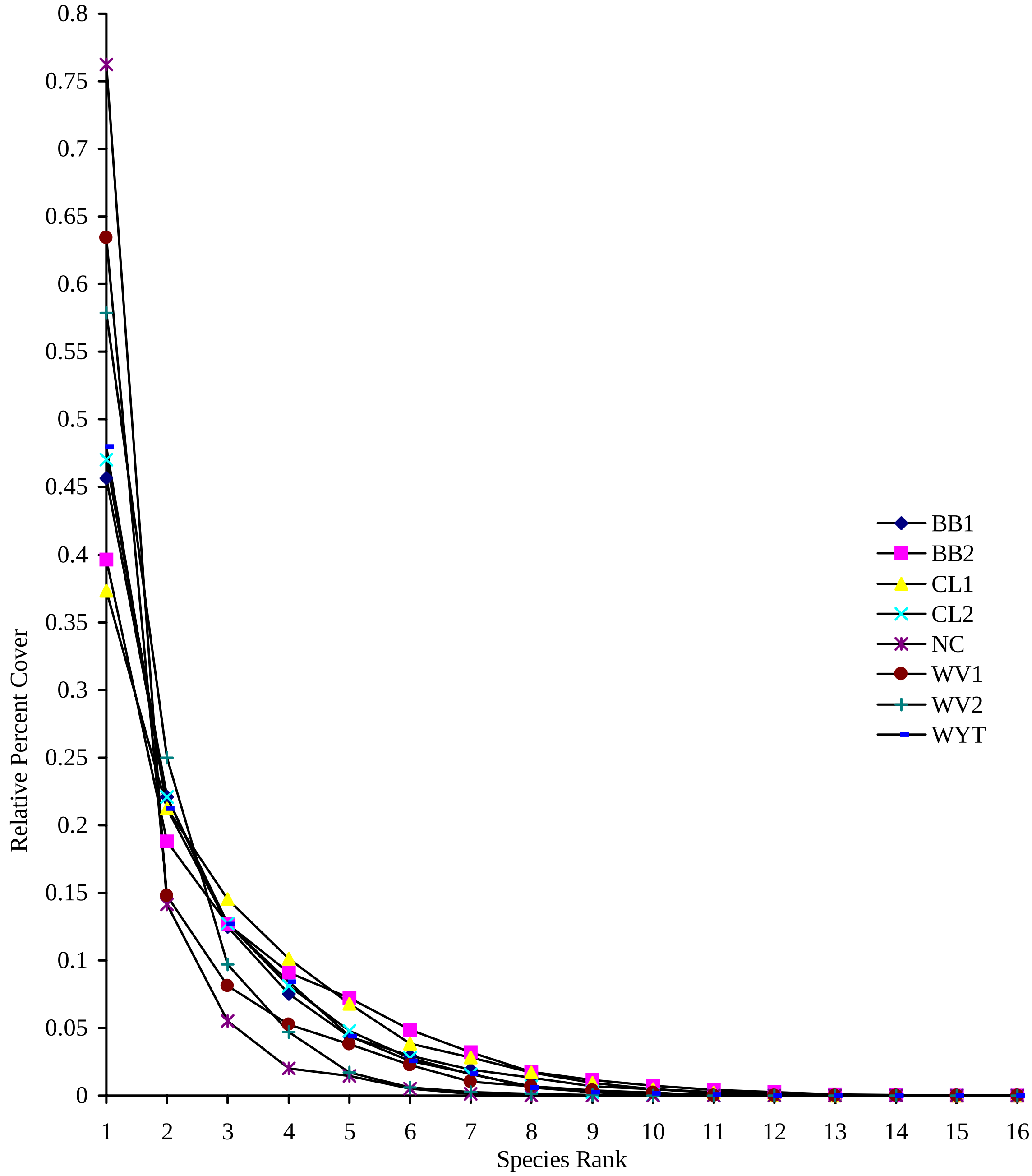

Figure 4.2. Ranked relative abundance (percent cover) of midstory shrubs and trees on 21, 108 m^2 shrub plots at each of eight study sites (n= 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia. The number of species ranks per site does not correspond to shrub plot richness values, but is in fact the maximum number of species to occur on a plot at that site.

Herbaceous Stratum

Percent Cover

Herbaceous stratum total percent cover was low to moderate, with large site to site variation (Table 4.7). While all sites had a combined average of 33.4 percent, total coverage ranged from 15.6 percent at WV2 to 46.4 percent at CL2, with WYT and CL1 close at 43.3 and 42.8 percent, respectively. Woody species dominated the stratum at all sites except CL2, where herbaceous species occupied 62 percent of the stratum cover. The degree of woody domination was highly variable among study sites ranging from 86.6 percent at NCL to the previously stated low at CL2. Only three pair-wise comparisons of the proportion of woody cover were not significantly different at $\alpha = 0.05$: BB1:WV1, WV1:WYT, and WV2:CL1. In contrast to large differences in the proportions of woody and herbaceous species cover, only one significant difference occurred in a comparison of the relative cover of the first ranked species class. The 44.7 percent dominance on WV2 was approximately 140 percent higher than at NCL (31.4), the second highest site domination.

Table 4.7. Herbaceous and woody percent crown cover and total percent crown cover of the herb stratum by site for 21, 6 m^2 herb plots at each of eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Site	Herbaceous	Woody	Total	1st Species Rank
	% Crown Cover[b]			
BB1	6.7	26.9	33.6 bc	20.3 a
BB2	8.4	18.6	27.0 cd	29.1 a
CL1	19.6	23.2	42.8 ab	24.3 a
CL2	28.6	17.8	46.4 a	30.8 a
NCL	4.8	30.8	35.6 abc	31.4 a
WV1	4.3	14.7	19.0 d	28.4 a
WV2	6.6	9.0	15.6 d	44.7
WYT	10.9	32.5	43.3 ab	20.4 a
mean[a]	11.2	22.2	33.4	28.7

a Totals may not sum correctly due to rounding

b Values followed by the same letter were not significantly different at α=0.05

Species Composition

Despite large differences in relative cover by the dominant species, no statistically significant differences were detected in the distribution of ranked relative cover at the eight sites sample (Figure 4.3). The top ten species ranks accounted for approximately 85 to 95 percent of herbaceous stratum cover at all sites. Although the distributions were not significantly different, WV1, WV2, and NCL had fewer species ranks and an apparent more rapid accumulation of relative cover, which suggests a higher degree of dominance on those sites. In addition to site to site comparisons, within site comparisons were made between treatment plot curves calculated at each site. One significant difference occurred at CL1. In that case and other cases where test results were nearly significant, comparisons were being made between curves with mean numbers of species ranks and a curve with a very low number of species ranks.

Coefficient of similarity values were higher for the herbaceous stratum than for either the tree or shrub strata. On average, sites shared 51 percent of the species, with WV1, WV2, and NCL again being the least similar. The abundance of each species varied dramatically from site to site. Sites located within the same physiographic region tended to have a greater degree of similarity in the species dominating the site. The Ridge and Valley sites, BB1, BB2, NCL, and WYT, had a larger component of *Quercus* spp. and ericaceous shrubs, such as *Gaylussacia baccata, Vaccinium pallidum,* and *V. stamineum,* than those located in the Allegheny Mountain region. *Viola* spp and ferns, such as *Dennstaedtia punctilobula* and *Thelypteris noveboracensis,* were most prolific on the latter sites. *Smilax rotundifolia,* although present on all eight sites, assumed a dominant position on both West Virginia sites, accounting for 16.7 and 26.0 percent of the cover on WV1 and WV2, respectively. Averaged across all sites, *Acer rubrum, Thelypteris noveboracensis, Vaccinium pallidum,* and *Smilax rotundifolia* account for 10.3, 9.0, 7.8, and 6.3 percent of herbaceous stratum cover, respectively (Table 4.8). The high overall ranking of *Thelypteris noveboracensis* is attributed to its extremely high coverage at CL1 and CL2, 22.3 and 28.0 percent relative cover, respectively, and not to an ever present strong component across all sites.

Family Dominance

The Ericaceae family accounted for 15.8 percent of the herbaceous stratum cover with the Liliacea, Fagacea, and Aceraceae accounting for 12.3, 12.3, and 12.1 percent respectively (Table 4.9). Twenty families account for over 97 percent of the herb stratum cover; however, an additional 38 families were sampled on the 162, 6 m^2 herb plots (Table 4.9). Some of the less common families include the Iridaceae, Fumariaceae, Asclepiadaceae, Araliaceae, Oxalidaceae, Saxifragaceae, Clusiaceae, and Eleagnaceae.

Abundance of Vegetative Growth Forms

The trend of variability in species dominance between sites continues even when species were placed into twelve growthform categories: woody vine , tree seedling, shrub seedling, erect annual herb, erect bienniel herb, erect perennial herb, acaulescent perennial herb, trailing annual herb, trailing perennial herb, reduced perennial herb, fern, or gramminoid. Chi-squared tests revealed site to site differences in the distribution of relative cover among growth forms (Figure 4.4). The most apparent differences became evident when BB1, BB2, and WYT were compared to the CL1, CL2, WV1, and WV2. While shrub species occupied 10 to 15 percent relative cover at the former three sites they constituted scarcely 5 percent on the CL1 and CL2 and were almost absent from WV1 and WV2. The majority of the shrub species cover was occupied by the same ericaceous species, such as *Vaccinium pallidum* and *Rhododendron* spp., at all sites; however, the absolute and relative abundance was substantially lower in the Allegheny province. The abundance of *Smilax* spp. at WV1 and WV2 was also evident in the woody vine category at those two sites. In addition, the Allegheny sites, except WV1, had an approximate 8 to 21 percent fern component, which was in turn absent from Ridge and Valley sites. *Dennstaedtia punctilobula* and *Thelypteris noveboracensis* were the primary species. A striking similarity among sites was the degree of herbaceous stratum domination by tree seedlings at every site, due primarily to *Acer rubrum, A. pensylvanicum, Amelanchier arborea*, *Quercus* spp., and *Sassafras albidum.* It should be noted that under the closed canopy conditions of these forests, graminoids and annual and biennial herbs combined made up less than one percent of the coverage across all sites, with graminoids comprising the majority of that value. Species of *Carex* and *Panicum* were most prevalent with occasionall occurences of *Juncus* spp., *Poa* spp. , and *Scirpus* spp. The most frequent annuals and biennials included *Galium aparine, Gnaphalium obtusifolium, Melampyrum lineare*, *Polygonum* spp., and *Prenanthes* spp.

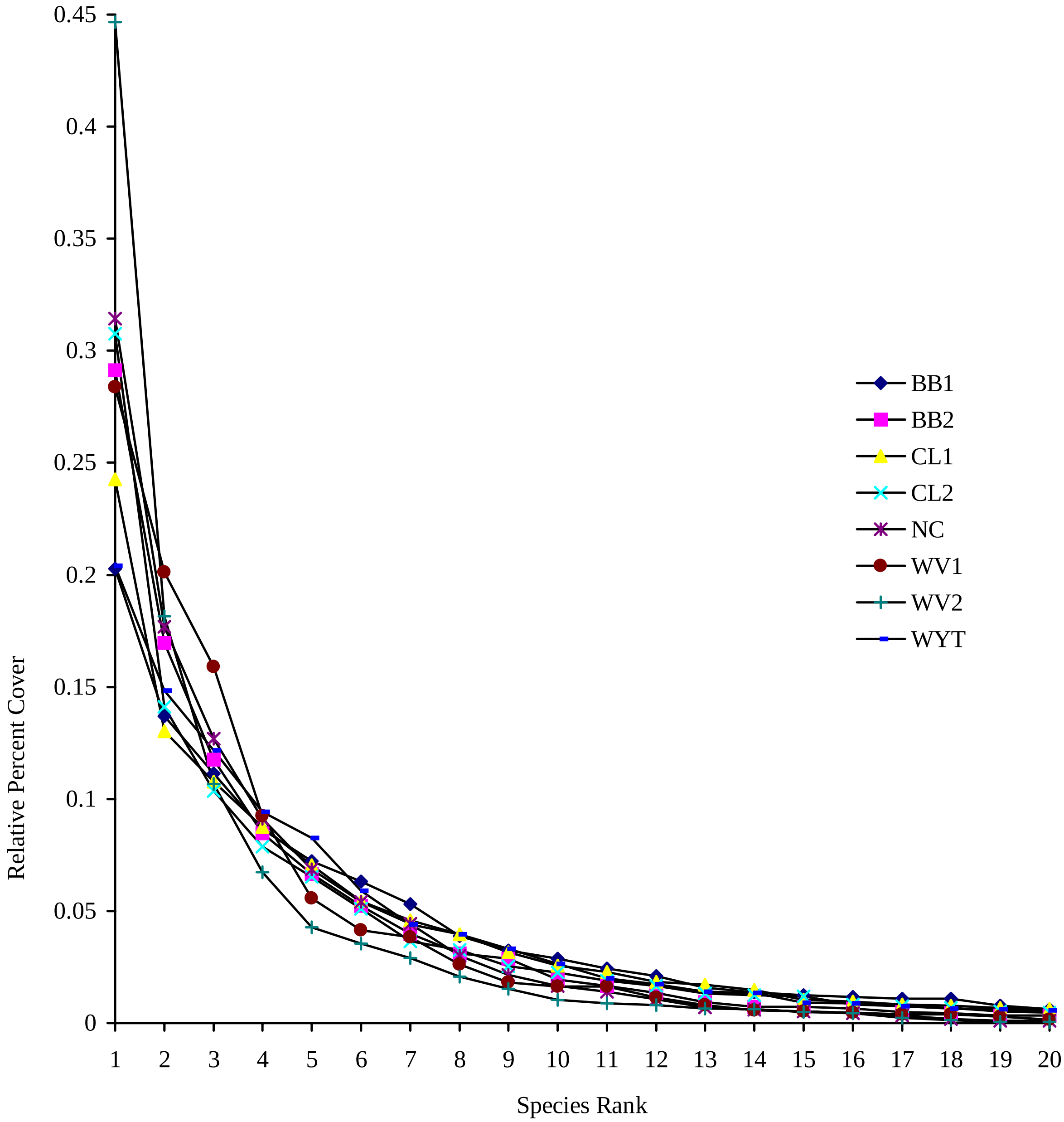

Figure 4.3. Ranked relative abundance (percent cover) of the herbaceous stratum on 21, 6 m^2 herb plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia. The number of species ranks per site does not correspond to shrub plot richness values, nor do they represent maximum number of species to occur on a plot at that site. The X-axis was truncated to increase chart resolution.

Table 4.8. Mean percent cover and mean relative percent cover for the twenty most abundant species in the herbaceous stratum at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on measurements taken on 162, 6 m^2 herb plots.

Species[a]	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT	StudyMean
	Relative Crown Cover[b]								
Acer rubrum	3.17	2.90	4.85	3.22	3.16	2.49	0.53	6.17	3.44
Thelypteris noveboracensis	np	np	9.77	12.97	np	0.05	0.14	0.32	3.01
Vaccinium pallidum	3.71	1.20	0.58	0.69	9.16	np	np	4.80	2.61
Smilax rotundifolia	1.48	0.13	3.23	3.36	0.02	3.18	4.06	0.76	2.10
Sassafras albidum	2.46	3.28	0.08	0.84	3.09	0.38	np	3.12	1.72
Viola spp.	0.60	0.49	3.48	3.90	0.05	0.16	3.52	0.31	1.62
Quercus prinus	1.84	3.68	0.35	0.35	0.63	0.05	np	3.47	1.34
Quercus coccinea	1.72	0.23	0.58	0.10	2.77	np	np	1.92	0.95
Gaylussacia baccata	0.05	0.26	np	np	4.75	np	np	2.23	0.94
Smilax glauca	1.61	0.96	0.20	0.35	2.14	np	np	1.38	0.86
Dioscorea villosa	1.25	2.29	0.50	0.64	0.17	0.05	0.01	1.55	0.84
Anemone quinquefolia	np	0.01	1.94	3.54	np	0.01	0.48	0.05	0.78
Quercus alba	2.20	0.69	0.60	0.51	0.05	0.01	np	1.65	0.74
Dennstaedtia punctilobula	np	np	0.82	3.91	np	0.04	0.30	1.43	0.66
Desmodium nudiflorum	np	3.00	np	0.07	0.11	np	np	np	0.60
Acer pensylvanicum	0.01	0.01	1.75	0.47	np	1.02	1.06	0.22	0.59
Rhododendron spp.	1.29	0.40	0.24	0.57	1.87	np	np	0.14	0.59
Amelanchier arborea	1.34	0.07	0.64	0.50	0.14	0.17	0.09	1.09	0.53
Quercus rubra	0.05	0.26	1.02	1.03	np	1.30	0.03	0.15	0.50
Magnolia acuminata	np	0.12	3.06	0.47	np	0.05	0.05	np	0.49
other	10.78	7.04	9.07	8.87	7.48	4.60	5.35	12.59	10.59
Total	33.55	27.02	42.77	46.36	35.60	13.56	15.61	43.32	33.40

a Species listed in order of descending dominance when averaged across all sites
b np = species not present at that site

Table 4.9. Percent cover of the top 20 Families present on 21, 6 m^2 herb plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia.

Family	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT	Study Mean
	Percent Crown Cover (%)								
Ericaceae	6.53	2.04	1.53	2.33	18.37	0.02	0.00	9.96	5.10
Liliaceae	3.96	1.94	4.93	5.98	2.66	3.50	4.33	4.37	3.96
Fagaceae	6.42	5.84	3.06	2.22	4.01	1.57	0.26	8.26	3.96
Aceraceae	3.18	2.92	6.63	3.70	3.16	3.53	1.62	6.39	3.89
Aspleniaceae	0.00	0.13	9.79	12.98	0.00	0.14	1.18	0.32	3.07
Violaceae	0.61	0.58	4.48	4.08	0.14	1.41	3.67	0.65	1.95
Lauraceae	2.53	3.36	0.08	0.84	3.09	0.38	0.00	3.12	1.67
Rosaceae	3.00	1.30	1.41	0.56	0.17	1.10	0.80	1.43	1.22
Magnoliaceae	0.45	0.27	3.76	1.15	0.01	0.27	1.16	0.85	0.99
Pteridiaceae	0.01	0.00	0.82	3.92	0.29	0.04	0.30	1.47	0.86
Dioscoreaceae	1.25	2.29	0.50	0.64	0.17	0.05	0.01	1.55	0.81
Ranunculaceae	0.02	0.04	1.94	3.54	0.00	0.01	0.48	0.05	0.76
Asteraceae	0.41	0.08	1.03	1.09	0.03	0.24	0.50	0.45	0.48
Fabaceae	0.43	3.00	0.00	0.11	0.11	0.00	0.00	0.04	0.46
Pyrolaceae	0.49	0.33	0.07	0.14	1.48	0.00	0.00	0.13	0.33
Cyperaceae	0.38	0.26	0.19	0.14	0.00	0.07	0.75	0.70	0.31
Juglandaceae	0.51	0.30	0.01	0.05	0.00	0.00	0.00	1.50	0.29
Nyssaceae	0.19	0.09	0.48	0.23	0.87	0.02	0.00	0.25	0.27
Vitaceae	1.04	0.61	0.00	0.01	0.02	0.01	0.00	0.14	0.23
Poaceae	0.37	0.04	0.60	0.39	0.02	0.01	0.04	0.29	0.22
other	4.89	4.42	7.98	5.80	4.16	4.73	1.99	7.80	5.22
Total	36.66	29.82	49.30	49.90	38.75	17.08	17.09	49.71	36.04

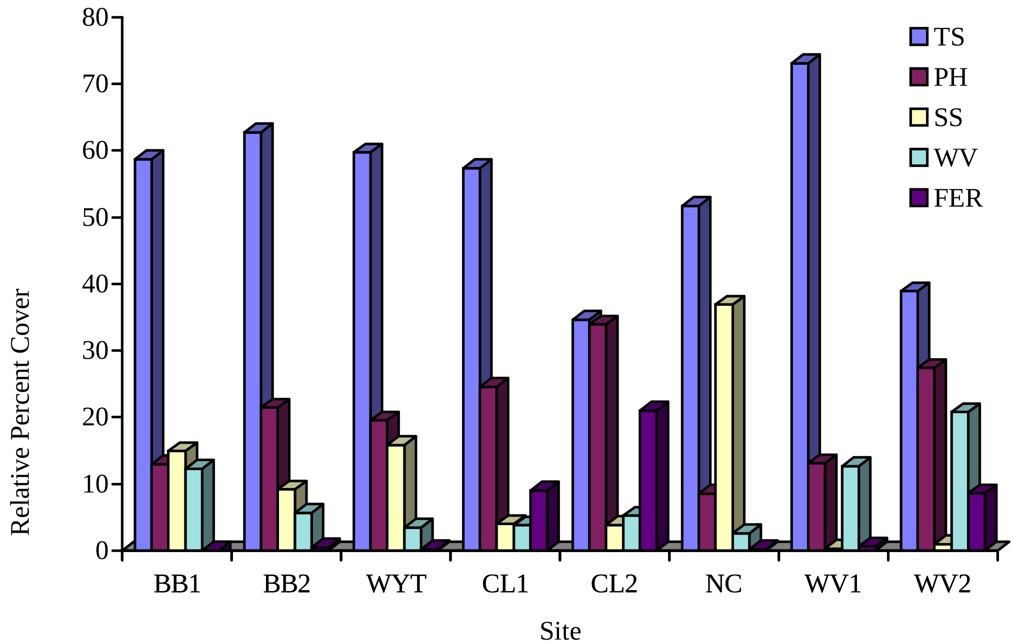

Figure 4.4. Distribution of relative percent cover among five growth form categories: TS, tree seedlings; PH, perennial herbs; SS, shrub seedlings; WV, woody vines; and FER, ferns (note: 7 of the original 12 categories were not included due to lack of substantial cover). Data taken from 162, 6 m^2 herb plots at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Species Diversity

Overall Species Frequency

Across all strata at the eight study sites sampled, 420 species were identified from among 81 families: 23 of the 81 families (28 percent) were only identified on the walkthrough census and were not present in the herbaceous plots. Of the 420 identified to the species level, 86 species were woody and 334 were herbaceous. Additional species were present that could not be identified beyond the Genus level, primarily due to the absence of reproductive parts. The majority of these species belonged to the *Aster, Carex, Poa, Rubus,* and *Viola* genera.

Approximately 46 percent of the species identified occurred at only one site. The majority of the species identified were infrequent or rare (Table 4.10). Only 21 species occurred at all eight study sites while 193 were unique to a single site. CL1 had a disproportionately low number of rare and infrequent species, with only 17 percent of the overall site richness occurring in those categories. In contrast, approximately 60 percent of the species at both WV2 and WYT were rare or infrequent.

The most frequent species were primarily those species which were shown to dominate the herbaceous stratum. However, there were a number of species which were frequent on the landscape that occupied, on average, less than half of one percent relative cover: examples include *Acer saccharum, Athyrium felix-femina, Betula lenta, Conopholis americana, Coreopsis major, Goodyera pubescens, Lysimachia quadrifolia, Monotropa uniflora, Osmunda cinnamomea, Polystichum acrostichoides, Robinia pseudo-acacia, Stellaria pubera,* and *Uvularia perfoliata*.

Table 4.10. Numbers of species occurring in each of eight frequency classes (numbers of site at which species occurred) at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia. Based on complete census of plant species at each study site. Frequency classes represent a gradient from rare to very abundant where rare species occurred on only one study site and very abundant species occurred on all eight study sites.

Site	Rare	Infrequent	Frequent	Abundant	Very Abundant
	(1)	(2-3)	(4-5)	(6-7)	(8)
			Numbers of Species		
BB1	22	36	39	37	21
BB2	12	28	33	38	21
CL1	4	13	22	37	21
CL2	13	22	36	38	21
NCL	8	22	11	22	21
WV1	15	69	28	30	21
WV2	36	55	23	21	21
WYT	83	86	45	38	21
mean	24.1	41.4	29.6	32.6	21.0
Total[a]	193	139	54	28	21

a Since the same species is represented in the values at more than one site, the infrequent, frequent, abundant, and very abundant columns due not sum to the total. The sum of the totals row includes some individuals identified only to the genus and does not equal the number of species identified to the species level.

Species Richness

As was suggested by the high variation in the numbers of rare and infrequent species between sites, there was a broad range of site wide species richness values. NCL and CL1 had by far the fewest species, with 84 and 97 respectively. Mean species richness across all 14 ha sites was 148.8. However, that value was as high as 273 on WYT. It must be noted that the 163 species identified on WV1, were from a total area of 10 ha not 14 ha as was the case for the remaining sites.

The majority of the variation in site wide richness values occurred among herbaceous species. Few differences in species richness occurred among either the tree or shrub strata on these sites (Table 4.11). Again, the areas sampled for each strata were unequal; therefore, richness values are not comparable between strata. Mean richness of the tree strata was 10 species per 576 m^2 plot, with a narrow range from 8.6 at NCL to 11.3 at BB2. Similar, yet slightly more variable results occurred in the mid-story. Mean richness was 7.3, but was as low as 4.0 at WV2. Approximately 22 species occurred, on average, per 6 m^2 plot in the herbaceous stratum. Approximately 60 percent of those were woody species (Table 4.12). Although overall site richness for WV2 was high, per plot values for each stratum fell well below average. In contrast, CL1 had very low overall site richness, yet ranked first in herbaceous stratum richness, and had higher than average tree and shrub strata values.

The erect perenial herb category, though second in percent cover, was represented by 159 species (Table 4.13). The second and third largest number of species occurred in the graminoid and tree seedling categories with 71 and 46 species, respectively. These values were based on species check lists developed from complete census walk throughs performed at each of the eight study sites. When smaller areas were considered, such as 6 m2 pooled herb plots or 1 m2 herb plots, the ranking of growth form categories changed (Figure 3.4a). The higher proportion of species which occurred in the tree seedling category when sampled on smaller areas indicates that a species area curve for the tree seedling category would plateau sooner than for categories such as erect perenial herbs or gramminoids (Figure 3.4b). However, at most levels of herb plot area combination, the ranking of growth form categories remained the same.

Shannon's Diversity

Shannon's diversity index (H') values for the herbaceous stratum followed the same trend as species richness (Table 4.14). H' was lowest at WV2, 1.73, and highest at BB1, 2.63. Since species richness and H' values had the same site to site patterns, linear regression was used to determine the degree to which the richness component of diversity was influencing H' values on these sites. Resultant R-squared values indicate that species richness explains 58.7 percent of the variation in H'. Considering the contradictory plot richness values and overall site richness values for the Clinch sites, regressions were also performed after excluding those sites from the data set. In the absence of CL1 and CL2, species richness explained 74.6 percent of the variation in H'.

Table 4.11. Mean[a] Species richness of three vegetation strata[b] at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia, based on walkthroughs and measurements taken on 162, 576 m^2,108 m^2, 6 m^2, tree, shrub, pooled herb plots, and unpooled herb plots, respectively.

	Vegetation Stratum (plot size)				
Site	Overstory	Mid-story	Herb Stratum		Total Richness
	(576m^2)	(108 m^2)	(6 m^2)	(1 m^2)	(14 ha)
	Numbers of Species				
BB1	9.6 ab	9.4 a	27.0 a	9.1	155
BB2	11.3 a	9.7 a	20.9 bc	7.0	132
CL1	10.3 ab	8.4 ab	29.1 a	9.8	97
CL2	10.6 ab	6.5 bc	26.0 ab	9.2	130
NCL	8.6 b	4.5 cd	16.7 cd	6.5	84
WV1	11.3 a	8.1 ab	16.3 cd	5.4	163
WV2	8.6 b	4.0 d	13.3 d	4.3	156
WYT	10.0 ab	7.8 ab	28.0 a	10.0	273
mean	10.0	7.3	22.2	7.7	148.8

a Values followed by the same letter were not significantly different at α=005.
b overstory (woody vegetation < 5m); mid-story (woody vegetation 1m< >5m); herb stratum (woody and herbaceous vegetation < 1m)

Table 4.12. Mean[a] ration of woody to herbaceous species richness in the herb stratum[b] on 21, 6 m^2 herb plots at each of eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

	Herbaceous Species	Woody Species
Site	Percent of Herb Stratum Richness	
BB1	33.9	64.1 ab
BB2	37.4	62.6 ab
CL1	46.8	53.2 bc
CL2	53.3	46.6 c
NCL	34.4	65.6 a
WV1	37.7	62.3 ab
WV2	46.4	53.6 abc
WYT	41.7	58.3 abc
mean	41.7	58.3

a Values followed by the same letter were not significantly different at α=005.
b overstory (woody vegetation < 5m); mid-story (woody vegetation 1m< >5m); herb stratum (woody and herbaceous vegetation < 1m)

Table 4.13. Number of species identified in each of twelve growth form categories at eight study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia. Values based on species checklist developed from complete census walk throughs performed at each site.

Growth Form Category	No. of Species
Erect perenial herb	159
Gramminoid	71
Tree Seedling	46
Acaulescent perenial herb	32
Shrub seedling	30
Fern	23
Erect annual herb	16
Trailing perenial herb	15
Woody vine	9
Erect bienniel herb	7
Reduced perenial herb	5
Trailing annual herb	4

Table 4.14. Shannon's diversity (H') of the herbaceous stratum from 21, 6 m^2 pooled herb plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Site	H'
BB1	2.63 a
BB2	2.26 bc
CL1	2.56 ab
CL2	2.35 abc
NCL	2.08 c
WV1	2.09 c
WV2	1.73
WYT	2.57 ab
mean	2.29

Correlation of Vegetative and Topographical Characteristics to Species Richness

Considering the large contribution of species richness to Shannon's diversity and the lack of significant differences in the distribution of relative abundance, species richness appeared to be the primary source of variation in diversity among the sites. For that reason, attempts were made to correlate vegetative and topographic parameters with plot richness values of the herbaceous stratum. As was the case with the correlation between richness and H', all correlations were stronger when CL1 and CL2 were excluded from the data set. R-square values from tests excluding CL1 and CL2 are presented (Table 4.15).

Very few vegetative variables explained a significant amount of variability in species richness (Table 4.15). Total herbaceous stratum cover was directly related to richness and explained 34 percent of the variability. In addition, there appeared to be a relationship between overstory horizontal structure and herbaceous stratum richness. Overstory stems per hectare explained nearly 19 percent of the variability in richness, and when coupled with QMD or basal area to better define the structure, r-square increased to 0.24.

The single best correlation came by comparing richness to the standard deviation of FSQI. The standard deviation was used to represent the variability in microtopography across the sites and resulted in an r-square value of 0.43. The lack of correlation illustrates the degree to which site history influences community composition and structural characteristics. While these study sites have always remained under forest cover, the effects of free range grazing, fire, wind and ice storms are undocumented and undoubtably confound stratum to stratum relationships as well as vegetation to site relationships.

Table 4.15. Correlation Coefficients for simple and multiple linear regressions performed with herb stratum species richness as the dependent variable, and various vegetative and topographic characteristics as independent variables from data taken in eight Southern Appalachian mixed-oak forests in Southwestern Virginia and West Virginia. Degrees of freedom = 161 for simple models and df = 160 for multiple parameter models with CL1 and CL2. Degrees of freedom = 119, and 118 respectively when CL1 and CL2 were excluded.

Variable	Correlation Coefficient (R^2)	
	w / CL1 and CL2	w / out CL1 and CL2
FSQI [a]	0.014	not tested
Standard Deviation of FSQI	0.177	0.431
Tree Species Richness	0.050	0.080
Overstory: stems*ha^{-1}	0.196	0.188
Overstory: basal area (m^2*ha^{-1})	0.054	0.130
Maximum Dbh^{-1}	0.006	0.001
Qaudratic Mean Diameter	0.048	0.011
Shrub Species Richness	0.060	0.080
Mid-story: rootstocks*ha^{-1}	0.014	0.008
Mid-story: percent crown cover	0.001	0.001
Herb Stratum: percent crown cover	0.274	0.340
Herb Stratum: percent woody cover/total cover	0.109	0.058
(BA) * (overstory stems*ha^{-1})	0.197	0.241
(QMD) * (overstory stems*ha^{-1})	0.191	0.245
(FSQI) * (herb stratum: percent crown cover)	0.396	0.519

a Forest Site Quality Index

CHAPTER 5: DISCUSSION

Comparison of Structural Characteristics and Species Composition to Other's Findings

Overstory

Structural characteristics of the mixed oak forests sampled were consistent with those previously investigated by others. Whittaker (1956) reported the mid-elevation southern aspects of the Great Smokey Mountains to be dominated by *Quercus* spp., *Carya* spp., *Castanea dentata*, *Nyssa sylvatica*, and *Liriodendron tulipifera*, with intermediate stems of *Acer rubrum*. It is hypothesized that the increase in dominance of *Acer rubrum* in the canopy on the sites in this study is the result of the absence of *Castanea dentata* from the overstory in this harvest rotation, and the absence of fire due to fire suppression campaigns. Travis (1982) also found *Acer rubrum* a strong component within the mixed oak type on sites in southwestern Virginia. Although the order of dominance among associated species on the Brumley Gap sites, *Oxydendrum arboreum, Magnolia acuminata,* and *Magnolia fraseri,* (Travis 198) did not coincide directly with these results, it is well within the degree of variation among the current sites. However, overall basal area and stems per hectare of Travis's sites were slightly higher at 22.2 m^2 and 1411 stems per hectare.

Mid-story

Mid-story composition was also similar to that found by Travis (1982), where *Acer rubrum, Amelanchier arborea, Cornus florida, Hamamelis virginiana,* and *Oxydendrum arboreum* were found to dominate the stems less than 10.2 cm. Although Whittaker (1956) found a greater proportion of ericaceous species, the ranges of midstory cover values (30 to 80 percent) in mixed-oak stands in Tennessee were consistent with the current findings.

Herbaceous Stratum

The herbaceous stratum represents a different degree of variation than that of the tree and shrub layers. As mentioned above, the eight study sites sampled varied widely in total cover, proportion of total cover occupied by woody species, species richness, and the degree of domination by different growth forms in the herbaceous stratum. This variability is not limited within these study sites but extends to the comparison of these results to those of Whittaker (1956), Aulick (1993), and Gilliam (1995). While these sites ranged in cover from 15.6 to 46.4 percent, Aulick (1993) found a slightly narrower range, 19.3, 26.4, and 37.5 percent, for watersheds 3, 4, and 7 on the Fernow Experimental Forest, Parsons, WV. Whittaker (1956) found slightly lower herb stratum cover (1 to 30 percent). Despite similarities in mean total cover values, the specific rank and cover for the dominant species were also different on the Fernow (Aulick 1993). While Aulick (1982) identified species such as *Caulophyllum thalictroides*, *Athyrium filix-femina, Laportea canadensis,* and *Viola* spp., as dominants, they occupied very low coverage in the current study. In addition, Gilliam (1995) showed equal proportions of woody and herbaceous species cover, while the current study indicates that woody species occupy twice the amount of cover as do herbaceous species.

Species composition also was shown to be less variable on the Fernow (Aulick 1982). Aulick found that 19.5 percent of the species identified were present at all three watersheds sampled, while only 5 percent occurred at all sites in the current study. These proportions should, however, be taken in context. The current study not only sampled a larger area, but sites were seperated by greater distances. As indicated by coefficient of similarity index values from this data, distance between sites has an inverse effect on species similarity. It should also be expected that the most common species in a community type would be disproportionately represented in a smaller sample. Therefore, as the number of species identified increases, an increasingly higher proportion of those would be the less common species.

Resulting values of meter square herbaceous stratum species richness appeared considerably larger for the current study. In fact, they were, on average, nearly twice those reported by Aulick (1982), 7.7 species per m^2 versus 4.1 species per m^2. However, richness values from WV1 and WV2 were approximately equal to those from the Fernow, suggesting regional differences in species richness. These results also suggest increasing variation in species richness within the same community type with increasing distance between locations.

Distribution of Relative Abundance

It was variation in species richness that had a dynamic effect on the distribution of relative abundance at the eight study sites sampled. Though differences in the distributions were not statistically different, the strength of the non-parametric KS test should be considered. Also, ecological differences are not limited to statistical differences and it is the threshold of ecological significance that is not fully understood. Consider first that as the number of species in the rank abundance plot decreased, the rate at which relative abundance accumulated with rank increased. Secondly, low species richness equated to lower total herbaceous stratum cover at WV1 and WV2, but did not have that effect on NCL. Therefore, the dominant species do not decrease in absolute cover even when species richness is low. With these facts, it becomes apparent that changes in the accumulation of relative abundance with rank occur due to less representation of species in the lower ranks. When fewer, infrequent species are present, the domination of the first ranked species increases, probably due to the exceptional abiltiy of those species to capture site resources. Hammond et al. (in Press) reported emigration from the lowest species ranks and immigration into the middle and upper ranks following canopy disturbance from different regeneration systems imposed on BB1. This suggests a greater sensitivity to change among less frequent species. In addition if most species invade into the middle ranks of the relative abundance plot (Hammond et al. in Press) following harvesting, it is likely to have an equalizing effect on species relative abundance. With few differences detected in the pre-treatment communities, any changes in the distribution of relative abundance should represent significant effects of treatment.

Apart from the fact that no differences occurred in ranked relative abundance among sites, relative abundance was distributed differently among growth forms at each site. These differences appeared to be distinguishable between physiographic locations.

Allegheny sites had considerably higher proportions of fern and woody vines than those in the Ridge and Valley. It is suspected, though not supported by data, that deer browse accounted for the increase. While not as evident on the Clinch sites, distinctive browse lines can be seen on WV1 and to a greater extent on WV2. It has been noted that forests heavily affected by deer browse develop dense coverage of fern species such as *Dennstaedtia punctilobula* and *Thelypteris noveboracensis.* This is also suspected to have led to the high degree of domination by *Smilax rotundifolia* and the low amount of shrub species coverage. It may also contribute to lower species richness per plot on WV1 and WV2, consequently selecting for species that are not preferential browse or which are persistent and able to sustain reproduction under such patterns of disturbance.

<u>Species Richness</u>

The West Virginia and Clinch sites had contradictory patterns in species richness per plot in the herb stratum relative to overall site richness. While Clinch 1 ranked seventh in overall richness it had the second highest herb plot richness of all sites. In order for fewer species to appear on measurement plots with more frequency, the spatial distribution of those species must be more even than on other sites. In contrast, the majority of the 10 hectares at WV1 and the 14 hectares at WV2 had relatively low herb stratum species richness. This was evident in the well below average herb plot richness values of 5.4 and 4.3, respectively. However, high site richness resulted from localized concentrations of species near perrenial drainages.

Two distinctive site groups were discernible when overall site richness values were compared. Those sites possessing perennial or intermittent streams, BB1, WV1, WV2 and WYT, had, on average, 76 more species per 14 hectare site than those with only ephemeral drainages, BB2, CL1, CL2, and NCL. That difference was reduced by nearly 30 percent when species dependent on wet habitat were removed from site species lists. High soil moisture and perhaps nutrient levels associated with creeks and drainages provide a highly productive environment for many species. Highly productive environments quite often posses more complex linkages and higher species diversity. In addition, distinct drainages on upland sites increase the number of microsites within the same unit area thereby allowing more species to persist. The distinction of the site groups was also evident in the proportions of species in each frequency category. Again sites with perrenial drainages had a disproportionately large number of rare and infrequent species compared to other sites.

CHAPTER 6: CONCLUSIONS AND SUMMARY

Mixed-oak forests of the Ridge and Valley and Allegheny Mountain physiographic provinces in the Southern Appalachians posses considerable variability in herbaceous stratum species richness, species composition, and the relative abundance of each species within a community. However, despite these differences, the distribution of ranked relative abundance remains somewhat less variable. Species richness values were considerably higher than had previously been reported for the region and appeared to be the most variable measure of species diversity. While the same variability in eveness was evident in both the shrub and herbaceous strata, differences were attributable to differences in species richness. This pattern was evident in several site comparisons in which differences were nearly significant.

Few community vegetation or topographic characteristics explain a notable portion of this variability. The variety of microsites on any given study site, represented by the standard deviation of FSQI, accounted for approximately forty percent of the variability in herbaceous stratum per-plot richness. Patterns of overall site richness and relative dominance of growth forms occurred that suggest sites within close proximity were more similar than those located at great distances, but over powering trends in dominance were apparent. Tree seedlings were clearly the dominant growth form, followed closely by perennial herbs. Annual herbs and graminoid species currently make up a very small proportion of herbaceous stratum cover. It is hypothesized that these categories will change significantly following canopy disturbance. If annual herbs do influence these sites in the wake of disturbance, it is unknown whether their invasive nature will increase the degree of community domination by a limited number of species, or if increases in species richness due to the reallocation of site resources will act to even out the ranked relative distribution of cover. With a community so variable in species composition and horizontal structure, it will be important to closely monitor year to year variation in control plots in order to detect actual effects of silviculturally mediated disturbance.

The degree of variation reinforces the significant inherent weaknesses involved with using the chronosequence approach to studying ecological responses in the Southern Appalachian mixed-oak forests. The number one assumption in that methodology entails that two sites of the same dominant community type and topographic location will develop similar species composition and community characteristics following the same disturbance. However, these data contradict this assumption and suggest that sites of similar aspect, elevation, slope, and dominant forest type will have considerable variation in herbaceous stratum plant communities.

Whittaker (1956) suggested that in light of the degree to which different forest strata affect the environment of other forest strata, they must be correlated. However, transect lines along moisture and elevational gradients failed to clearly identify boundaries and species assemblages in the Great Smokey Mountains National Park, Tennessee (Whittaker 1956). It appears that the variability along environmental gradients, and the consequent difficulty in assigning non-arbitrary bounds to communities along those gradients, is also present when a considerable number of sites are sampled within a single dominant community type.

Nonetheless with a baseline of community data, determining the effects of silvicultural manipulations will be a matter of time. Sound science-based management practices should be the goal of all research, but it is only through long term monitoring of a large number of treated stands that the true impacts of such practices can be evaluated. Remeasurements of this study are designed to provide this much needed science based information.

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Appendix A

Basal area (m^2*ha^{-1}) for woody stems greater than 5 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on measurements from 162, 576 m^2 tree plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Basal area (m^2*ha^{-1})							
Acer pensylvanicum	<0.1	<0.1	0.2	<0.1	np	0.1	0.3	np
Acer rubrum	1.1	1.8	4.2	6.6	0.8	7.5	6.8	1.7
Acer saccharum	<0.1	0.2	<0.1			0.3	3.9	<0.1
Amelanchier arborea	0.1	<0.1	0.8	0.8	<0.1	<0.1	<0.1	<0.1
Aralia spinosa	np	np	np	np	np	np	<0.1	np
Betula allegheniensis	np	np	np	np	np	<0.1	np	np
Betula lenta	0.2	<0.1	0.3	<0.1	np	0.6	0.3	<0.1
Carpinus caroliniana	<0.1	<0.1	<0.1	np	np	np	np	np
Castanea dentata	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	np	<0.1
Carya glabra	0.2	0.3	<0.1	0.7	<0.1	np	np	0.6
Carya tomentosa	1.0	0.5	<0.1	<0.1	0.1	np	np	0.6
Cornus florida	0.1	0.1	<0.1	<0.1	0.1	<0.1	np	0.2
Fagus grandifolia	np	np	0.1	np	np	3.2	1.9	np
Fraxinus americana	0.2	<0.01	<0.1	np	np	<0.1	<0.1	0.2
Fraxinus pennsylvanica	<0.1	np	np	np	np	np	np	np
Hamamelis virginiana	<0.1	np	<0.1	<0.1	np	<0.1	<0.1	np
Ilex ambigua	np	np	<0.1	np	np	<0.1	<0.1	np
Ilex verticillata	np	np	np	<0.1	np	np	np	np
Lindera benzoin	<0.1	np	np	np	np	np	np	np
Liriodendron tulipifera	1.1	2.1	0.2	0.8	np	3.5	4.0	0.4
Magnolia acuminata	np	0.4	1.2	0.4	np	0.3	1.6	<0.1
Magnolia fraseri	np	np	1.3	0.7	np	2.6	4.3	np
Nyssa sylvatica	0.3	1.0	1.8	0.5	0.7	0.5	<0.1	0.2
Ostrya virginiana	np	<0.1	np	np	np	np	<0.1	np
Oxydendrum arboreum	0.2	1.8	2.0	3.1	0.9	0.3	np	3.5

Appendix A (cont)

Basal area (m^2*ha^{-1}) for woody stems greater than 5 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on measurements from 162, 576 m^2 tree plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Basal area (m^2*ha^{-1})							
Pinus echinata	np	np	np	np	1.2	np	np	np
Pinus pungens	<0.1	np	np	np	0.1	np	np	np
Pinus rigida	0.8	np	np	np	0.6	np	np	0.4
Pinus strobus	0.5	0.2	np	np	np	np	np	0.4
Platanus occidentalis	0.4	np	np	np	np	np	np	np
Prunus avium	<0.1	np	np	np	np	np	np	np
Prunus pennsylvanica	np	np	np	np	np	<0.1	<0.1	np
Prunus serotina	0.3	np	0.1	np	np	1.1	2.6	np
Quercus alba	7.8	2.9	3.8	3.3	2.5	np	np	3.4
Quercus coccinea	2.9	0.1	0.1	0.1	8.9	np	np	2.8
Quercus prinus	4.3	11.2	3.7	4.1	6.6	4.7	0.5	5.7
Quercus rubra	0.5	1.0	8.6	6.2	<0.1	10.1	3.1	0.3
Quercus velutina	3.3	3.3	0.5	1.4	1.6	np	np	5.0
Rhododendron maximum	np	np	np	np	np	np	np	<0.1
Robinia pseudo-acacia	0.2	<0.1	<0.1	0.2	0.1	np	<0.1	<0.1
Sassafras albidum	0.1	<0.1	np	<0.1	<0.1	np	<0.1	<0.1
Tilia americana	np	np	np	np	np	np	3.1	np
Tsuga canadensis	np	np	np	np	np	0.5	np	np
Unkown Hardwood	np	np	np	<0.1	np	np	np	np
Viburnum prunifolium	<0.1	np	np	np	np	np	np	np
total	25.5	26.9	29.1	29.1	24.2	35.2	32.5	25.3

Appendix B

Percent shrub cover by species for woody stems between 1 m and 5 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 108 m^2 shrub plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Acer pensylvanicum	0.14	np	8.17	0.65	np	11.40	10.33	1.81
Acer rubrum	19.49	13.93	9.38	8.22	0.96	7.87	3.73	5.38
Acer saccharum	0.50	1.47	0.71	np	np	3.29	4.77	np
Amelanchier arborea	2.84	1.07	3.72	2.00	0.91	0.18	0.16	1.74
Betula lenta	np	0.49	2.05	0.34	np	5.68	0.36	0.23
Castanea dentata	0.40	0.96	10.38	12.36	3.47	0.12	np	8.23
Carya glabra	0.47	2.09	np	np	np	np	np	0.20
Castanea pumilla	np	np	np	np	np	np	np	0.71
Carya tomentosa	2.09	1.98	np	0.01	np	np	np	0.02
Cornus florida	12.51	6.26	np	0.03	3.98	np	np	1.60
Fagus grandifolia	np	np	0.09	np	np	19.71	7.47	np
Fraxinus americana	1.94	0.26	np	np	np	0.22	np	0.05
Fraxinus pennsylvanica	1.00	np	np	np	np	np	np	np
Gaylussacia baccata	np	np	np	np	0.01	np	np	0.02
Hamamelis virginiana	1.64	np	5.85	3.10	0.72	2.28	4.18	0.08
Ilex montana	np	np	1.43	0.43	np	0.06	np	np
Kalmia latifolia	1.70	2.55	np	np	0.24	0.51	np	0.15
Lindera benzoin	3.84	np	np	np	np	0.36	np	np
Liriodendron tulipifera	0.99	3.13	0.21	np	np	0.48	0.03	0.22
Magnolia acuminata	np	0.75	5.04	2.96	np	0.03	0.24	np
Magnolia fraseri	np	np	7.42	6.58	np	0.52	0.41	np
Nyssa sylvatica	10.32	8.01	0.77	0.55	58.72	0.29	np	3.34
Ostrya virginiana	np	0.09	np	np	np	np	np	np
Oxydendrum arboreum	0.37	6.27	1.86	5.41	3.06	0.67	np	12.06
Pinus rigida	np	2.51	np	np	0.02	np	np	np
Pinus strobus	1.65	np	np	np	np	np	np	4.90
Pinus virginianaI	np	np	np	np	np	np	np	0.02
Prunus pennsylvanica	np	np	np	np	np	0.10	0.33	np
Prunus serotina	0.60	np	np	np	np	4.37	2.51	np
Quercus alba	1.15	0.66	np	0.02	<0.01	np	np	0.08
Quercus coccinea	0.95	0.34	np	np	0.04	np	np	0.11
Quercus prinus	2.99	4.09	0.05	np	0.43	<0.01	np	1.03
Quercus rubra	0.18	1.04	0.07	0.05	np	0.54	0.31	0.05
Quercus velutina	0.48	1.06	np	0.09	0.02	np	np	<0.01
Rhododendron calendulaceum	np	np	0.51	2.25	np	np	np	0.47

Appendix B (cont)

Percent shrub cover by species for woody stems between 1 m and 5 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 108 m^2 shrub plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Rhododendron maximum	np	np	np	np	np	np	np	0.50
Rhododendron nudiflorum	0.29	np	0.45	np	np	np	np	0.25
Rhododendron spp.	0.15	1.86	0.05	np	np	np	np	<0.01
Robinia pseudo-acacia	np	np	np	np	0.37	np	np	0.04
Sassafras albidum	1.02	1.82	np	0.18	0.72	0.03	np	0.35
Tsuga canadensis	np	np	np	np	np	0.23	np	np
Vaccinium coryumbosum	np	np	np	5.24	0.02	np	np	np
Vaccinium pallidum	0.01	np	np	np	np	np	np	np
Vaccinium stamineum	0.18	0.24	4.41	np	np	np	np	0.50
Viburnum acerifolium	0.02	0.11	np	np	np	0.13	np	np
Viburnum prunifolium	1.99	0.11	np	np	np	np	np	np
Vitis spp.	0.12	0.58	np	np	np	np	np	np
total	72.18	63.85	62.84	50.46	73.68	59.06	34.82	44.12

Appendix C

Percent cover of woody and herbaceous species less than 1 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Acer spp.	np	np	0.02	np	np	np	np	np
Acer pensylvanicum	<0.01	<0.01	1.75	0.47	np	1.02	1.06	0.22
Acer rubrum	3.17	2.90	4.85	3.22	3.16	2.49	0.53	6.17
Acer saccharum	np	<0.01	<0.01	np	np	0.02	0.03	<0.01
Agrimonia spp.	np	<0.01	np	np	np	np	np	np
Agrostis alba	np	np	np	np	np	<0.01	np	np
Agrostis perennans	np	np	np	np	np	np	np	<0.01
Allium triccoccum	np	np	np	np	np	np	<0.01	np
Amelanchier arborea	1.34	0.07	0.64	0.50	0.14	0.17	0.09	1.09
Amphicarpa bracteata	np	np	np	np	np	np	np	<0.01
Anemone quinquefolia	np	<0.01	1.94	3.54	np	<0.01	0.48	0.05
Angelica venenosa	np	<0.01	np	np	<0.01	np	np	np
Antennana plantaginifolia	<0.01	np	np	np	np	np	np	np
Aralia nudicaulis	<0.01	np	np	np	np	np	np	np
Aristolochia macrophylla	0.13	np	np	np	np	np	np	np
Arisaema triphyllum	np	np	<0.01	np	np	<0.01	0.07	np
Asclepias quadrifolia	np	<0.01	np	np	np	np	np	np
Aster divaricatus	np	np	np	np	np	0.12	np	0.04
Aster sp	0.15	0.02	0.14	0.04	np	0.02	<0.01	0.07
Athyrium filix-femina	np	0.04	0.02	<0.01	np	np	np	np
Aureolaria flava	0.02	np	<0.01	<0.01	np	np	np	np
Baptisia tinctoria	np	np	np	np	np	np	np	<0.01
Betula lenta	np	np	0.04	np	np	0.25	0.03	<0.01
Botrychium spp.	<0.01	np	np	np	np	np	np	np
Botrychium virginianum	np	0.03	np	np	np	np	np	np
Castanea dentata	0.08	np	0.44	0.23	0.32	0.02	np	0.07
Carya glabra	0.26	0.10	<0.01	0.05	np	np	np	1.13
Calamagrostis porteri	0.04	np	np	np	np	np	np	np
Campanula divaricata	np	np	np	0.02	np	np	np	<0.01
Castanea pumila	np	np	np	np	np	np	np	0.04
Carex spp.	0.38	0.26	0.19	0.14	np	0.07	0.75	0.70
Carya spp.	np	np	np	np	np	np	np	<0.01
Cassia marilandica	<0.01	np	np	np	np	np	np	np
Carya tomentosa	0.24	0.20	np	np	np	np	np	0.36
Chimaphila maculata	0.49	0.33	0.07	0.14	1.48	np	np	0.13
Cimicifuga racemosa	0.02	0.02	np	np	np	np	np	np
Claytonia caroliniana	np	np	np	np	np	np	0.04	np
Clintonia spp.	np	np	np	0.05	np	np	np	np

Appendix C (cont)

Percent cover of woody and herbaceous species less than 1 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Clintonia umbellulata	np	np	0.05	np	np	np	<0.01	np
Cornus florida	0.14	<0.01	<0.01	np	0.21	np	np	0.09
Collinsonia canadensis	np	<0.01	np	0.02	np	np	np	np
Conopholis americana	np	np	0.18	0.23	np	<0.01	np	np
Convallaria montana	np	<0.01	np	np	np	np	np	0.11
Coreopsis major	0.06	np	<0.01	0.02	0.03	np	np	0.08
Crataegus spp	np	np	np	np	np	np	np	<0.01
Cypripedium acaule	np	<0.01	np	np	np	np	np	np
Danthonia spp.	np	np	np	np	np	np	np	0.17
Dennstaedtia punctilobula	np	np	0.82	3.91	np	0.04	0.30	np
Desmodium spp.	0.38	np	np	np	np	np	np	np
Desmodium nudiflorum	np	3.00	np	0.07	0.11	np	np	1.43
Dicentra cucullaria	np	np	np	np	np	np	<0.01	np
Dioscorea villosa	1.25	2.29	0.50	0.64	0.17	0.05	<0.01	1.55
Disporum lanuginosum	np	np	np	<0.01	np	<0.01	0.02	np
Dryopteris intermedia	np	np	np	np	np	0.08	0.94	np
Elaeagnus umbellata	<0.01	np	np	np	np	np	np	np
Epigaea repens	0.02	np	np	<0.01	0.26	np	np	0.02
Erechtites hieracifolia	np	np	np	np	np	np	np	0.02
Erythronium spp.	np	np	np	np	np	np	<0.01	np
Eupatorium spp.	0.05	<0.01	0.04	0.30	np	np	0.04	np
Euphorbia corollata	np	<0.01	np	np	np	np	np	np
Eupatorium purpureum	np	np	0.21	np	np	np	np	np
Fagus grandifolia	np	np	<0.01	np	np	0.19	0.24	np
Fraxinus americana	0.46	0.58	<0.01	np	<0.01	0.06	np	0.06
Gaylussacia baccata	0.05	0.26	np	np	4.75	np	np	2.23
Galax aphylla	0.03	0.03	0.12	0.53	0.44	np	np	0.43
Galium circaezans	0.05	0.35	np	<0.01	np	np	np	0.04
Galium spp.	0.03	np	0.02	np	np	np	<0.01	0.02
Galium lanceolatum	np	np	<0.01	np	np	np	np	np
Galium triflorum	<0.01	np	np	np	np	np	np	np
Galium urcifolia	np	np	np	np	np	np	np	0.04
Gaultheria procumbens	0.63	<0.01	np	np	1.06	np	np	1.80
Gentiana decora	np	<0.01	0.22	0.19	np	np	np	np
Geranium maculatum	0.09	0.11	np	np	np	np	np	<0.01
Gillenia trifoliata	<0.01	np	np	np	np	np	np	0.02
Glecoma hederacea	0.07	np	np	np	np	np	np	np
Goodyera pubescens	np	<0.01	np	<0.01	0.02	np	np	0.05
Goodyera repens	0.02	np	<0.01	np	np	np	np	np
Habenaria orbiculata	np	np	<0.01	np	np	np	np	np

Appendix C (cont)

Percent cover of woody and herbaceous species less than 1 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Hamamelis virginiana	0.05	<0.01	0.22	0.15	0.13	0.02	0.04	0.04
Heuchera americana	0.02	np	np	np	np	np	np	np
Hieracium paniculatum	np	np	<0.01	0.04	np	np	np	0.02
Hieracium spp.	np	np	np	0.02	np	np	np	0.02
Hieracium venosum	0.06	np	np	np	np	np	np	0.04
Houstonia longifolia	<0.01	np	np	np	np	np	np	0.03
Hypoxis hirsuta	np	np	np	np	np	np	np	0.02
Ilex spp.	np	np	np	np	np	np	0.02	np
Ilex montana	np	np	0.08	0.04	np	np	<0.01	np
Impatiens spp.	np	np	np	<0.01	np	np	np	np
Impatiens capensis	np	np	np	0.05	np	np	np	np
Ipomoea purpurea	np	0.07	np	np	0.07	np	np	np
Iris verna	np	np	np	np	<0.01	np	np	np
Isotria verticillata	np	np	np	0.05	0.07	np	np	np
Kalmia latifolia	0.05	0.05	np	np	<0.01	0.02	np	0.04
Leersia virginica	np	np	np	np	np	np	np	<0.01
Lespedeza intermedia	np	np	np	np	np	np	np	<0.01
Lespedeza procumbens	np	np	np	np	np	np	np	<0.01
Lindera benzoin	0.07	0.08	np	np	np	np	np	np
Lilium spp.	np	np	0.02	np	np	np	np	np
LIlium michauxii	np	np	np	np	np	np	np	0.07
Liriodendron tulipifera	0.45	0.15	0.27	0.07	<0.01	0.05	0.32	0.85
Lycopodium obscurum	np	np	0.08	np	np	np	np	np
Lycopus virginicus	np	np	np	np	np	np	np	<0.01
Lysimachia quadrifolia	0.10	0.02	0.12	0.08	np	<0.01	np	0.05
Magnolia acuminata	np	0.12	3.06	0.47	np	0.05	0.05	np
Magnolia fraseri	np	np	0.42	0.61	np	0.16	0.80	np
Magnolia spp.	np	np	<0.01	np	np	np	np	np
Medeola virginiana	np	0.05	0.85	1.14	np	0.13	0.04	np
Melampyrum lineare	np	np	np	np	np	np	np	0.13
Mitchella repens	np	np	np	np	np	0.79	0.04	np
Monotropa hypopithys	np	np	np	np	np	np	np	<0.01
Monotropa uniflora	np	np	<0.01	0.04	np	np	np	0.02
Nyssa sylvatica	0.19	0.09	0.48	0.23	0.87	0.02	np	0.25
Orchidaceae spp.	np	np	np	0.05	np	np	np	np
Osmunda cinnamomea	np	0.04	0.05	0.09	np	np	np	np
Osmunda claytoniana	np	0.07	np	0.31	np	np	np	np
Ostrya virginiana	np	0.02	np	np	np	np	np	np
Oxalis dillenii	np	np	np	np	np	np	np	<0.01

Appendix C (cont)

Percent cover of woody and herbaceous species less than 1 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Oxydendrum arboreum	np	0.05	0.03	0.19	0.43	np	np	np
Oxalis stricta	<0.01	np	np	np	np	np	np	np
Oxypolis rigidor	np	np	np	<0.01	np	np	np	np
Panicum commutatum	np	np	0.07	np	np	np	np	0.02
Panicum dichotomum	np	np	np	np	np	np	np	0.05
Panicum spp.	0.14	0.02	0.53	0.31	0.02	np	<0.01	0.03
Panicum latifolium	np	np	np	np	np	np	0.03	np
Panax trifolium	np	np	np	np	np	np	<0.01	np
Parthenocissus quinquefolia	0.81	0.12	np	np	np	np	np	0.02
Pinus spp.	np	np	np	np	<0.01	np	np	np
Pinus rigida	np	np	np	np	<0.01	np	np	np
Pinus strobus	0.05	<0.01	np	np	np	np	np	0.04
Poaceae spp.	0.19	0.02	np	0.03	np	np	np	np
Poa sp	np	np	np	0.05	np	np	np	np
Polystichum acrostichoides	np	0.09	np	np	np	np	0.09	np
Polygonatum biflorum	0.27	0.09	0.10	0.09	0.05	0.04	np	0.67
Potentila spp.	0.51	0.18	<0.01	np	<0.01	np	np	0.22
Prenanthes spp.	np	0.05	0.37	0.54	np	np	0.17	0.06
Prunus serotina	0.33	0.05	0.69	0.05	<0.01	0.56	0.24	0.03
Pteridium aquilinum	<0.01	np	np	<0.01	0.29	np	np	0.05
Pyrola rotundifolia	np	np	np	np	np	np	np	<0.01
Quercus alba	2.20	0.69	0.60	0.51	0.05	<0.01	np	1.65
Quercus coccinea	1.72	0.23	0.58	0.10	2.77	np	np	1.92
Quercus spp.	<0.01	np	0.05	np	np	np	np	np
Quercus prinus	1.84	3.68	0.35	0.35	0.63	0.05	np	3.47
Quercus rubra	0.05	0.26	1.02	1.03	np	1.30	0.03	0.15
Quercus velutina	0.52	0.98	0.02	0.02	0.23	np	np	0.96
Ranunculus recurvatus	np	np	np	np	np	np	np	<0.01
Rhododendron spp.	1.29	0.40	0.24	0.57	1.87	np	np	0.14
Rosa carolina	np	np	np	np	np	np	np	<0.01
Rosa multiflora	np	np	np	np	<0.01	np	np	np
Robinia pseudo-acacia	0.05	np	np	0.04	np	np	np	np
Rosa spp	0.16	0.28	np	np	np	np	np	np
Rubus spp	0.65	0.71	0.06	np	np	0.37	0.48	0.05
Sassafras albidum	2.46	3.28	0.08	0.84	3.09	0.38	np	3.12
Scuttelaria ellipitica	0.03	<0.01	np	np	np	np	np	0.05
Senecio aureus	np	np	np	np	np	np	np	<0.01
Smilax glauca	1.61	0.96	0.20	0.35	2.14	np	np	1.38
Smilax herbacea	0.05	<0.01	np	0.19	np	np	np	<0.01

Appendix C (cont)

Percent cover of woody and herbaceous species less than 1 m tall at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Species	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Percent Cover							
Smilax spp	np	np	0.03	np	np	np	np	np
Smilacina racemosa	0.30	0.17	0.17	0.09	0.11	np	0.04	0.68
Smilax rotundifolia	1.48	0.13	3.23	3.36	0.02	3.18	4.06	0.76
Solidago arguta	np	np	np	np	np	np	np	<0.01
Solidago bicolor	np	np	np	np	np	np	np	0.02
Solidago curtisii	np	np	np	np	np	0.06	np	0.07
Solidago spp	0.07	np	0.25	0.14	np	0.04	0.28	np
Stellaria pubera	<0.01	<0.01	0.13	0.23	np	np	0.11	0.05
Thalictrum spp	np	<0.01	np	np	np	np	np	np
Thelypteris hexagonoptera	np	np	np	np	np	np	<0.01	np
Thelypteris noveboracensis	np	np	9.77	12.97	np	0.05	0.14	0.32
Toxicodendron radicans	<0.01	np	np	np	np	np	np	0.05
Trillium erectum	np	np	np	np	np	np	<0.01	np
Trillium spp	np	np	0.05	0.02	np	np	0.10	np
Trillium undulatum	np	np	np	np	np	0.14	0.05	np
Unknown Herb	0.06	0.07	0.05	0.16	<0.01	<0.01	0.10	np
Uuknown Woody	<0.01	np	0.05	np	np	np	0.05	np
Uvularia perfoliata	0.12	0.20	0.02	<0.01	np	np	np	0.06
Uvularia pudica	0.14	0.31	0.22	0.67	0.28	np	np	0.64
Uvularia sessilifolia	np	0.02	np	np	0.06	np	np	np
Vaccinium spp	<0.01	np	<0.01	np	np	np	np	np
Vaccinium coryumbosum	np	np	np	0.84	np	np	np	np
Vaccinium pallidum	3.71	1.20	0.58	0.69	9.16	np	np	4.80
Vaccinium simulatum	np	0.12	0.47	np	np	np	np	np
Vaccinium stamineum	0.77	np	0.20	0.03	0.83	np	np	0.93
Viburnum acerifolium	0.19	0.07	np	np	<0.01	0.05	np	<0.01
Viburnum spp	<0.01	np	np	np	np	np	np	np
Viola cucullata	np	np	np	np	np	0.04	np	<0.01
Viola hastata	<0.01	np	0.74	0.14	0.09	0.47	0.11	0.12
Viola hirsutula	np	np	np	np	<0.01	0.38	np	0.18
Viola spp	0.60	0.49	3.48	3.90	0.05	0.16	3.52	0.31
Viola palmata	np	np	np	np	np	np	np	0.04
Viola pedata	np	np	np	0.04	np	np	np	np
Viola rotundifolia	np	np	0.25	np	np	0.37	0.05	np
Viola sororia	np	np	np	<0.01	np	np	np	np
Viola triloba	np	0.09	<0.01	np	np	np	np	np
Viburnum prunifolium	0.08	np	np	np	np	np	np	np
Vitis spp	0.23	0.50	np	<0.01	0.02	<0.01	np	0.12
Zizia trifoliata	0.08	<0.01	0.02	np	<0.01	np	np	0.17
total	33.55	27.02	42.77	46.36	35.60	13.56	15.61	43.32

Appendix D

Sorenson's (1948) coefficient of similarity values for 28 pair-wise site comparisons of overall species composition from eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on a complete species census of each 14 ha site.

	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
BB1	.	0.704	0.659	0.594	0.542	0.481	0.347	0.541
BB2	0.704	.	0.620	0.689	0.581	0.478	0.431	0.530
CL1	0.659	0.620	.	0.636	0.560	0.523	0.411	0.431
CL2	0.594	0.689	0.636	.	0.588	0.517	0.369	0.534
NCL	0.542	0.581	0.560	0.588	.	0.348	0.232	0.398
WV1	0.481	0.478	0.523	0.517	0.348	.	0.598	0.538
WV2	0.347	0.431	0.411	0.369	0.232	0.598	.	0.381
WYT	0.541	0.530	0.431	0.534	0.398	0.538	0.381	.
mean	0.553	0.576	0.549	0.561	0.464	0.498	0.396	0.479

Appendix E

Sorenson's (1948) coefficient of similarity values for 28 pair-wise site comparisons of overstory species composition from eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 576 m^2 tree plots.

	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
BB1	.	0.54	0.50	0.50	0.52	0.41	0.38	0.55
BB2	0.54	.	0.51	0.54	0.50	0.41	0.41	0.60
CL1	0.50	0.51	.	0.55	0.44	0.51	0.45	0.52
CL2	0.50	0.54	0.55	.	0.51	0.42	0.39	0.52
NCL	0.52	0.50	0.44	0.51	.	0.26	0.23	0.50
WV1	0.41	0.41	0.51	0.42	0.26	.	0.52	0.38
WV2	0.38	0.41	0.45	0.39	0.23	0.52	.	0.35
WYT	0.55	0.60	0.52	0.52	0.50	0.38	0.35	.
mean	0.49	0.50	0.50	0.49	0.42	0.42	0.39	0.49

Appendix F

Sorenson’s (1948) coefficient of similarity values for 28 pair-wise site comparisons of overstory species composition from eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 108 m^2 shrub plots.

	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
BB1	.	0.57	0.38	0.37	0.39	0.43	0.28	0.5
BB2	0.57	.	0.37	0.39	0.39	0.39	0.26	0.48
CL1	0.38	0.37	.	0.44	0.25	0.46	0.47	0.37
CL2	0.37	0.39	0.44	.	0.42	0.39	0.36	0.38
NCL	0.39	0.39	0.25	0.42	.	0.28	0.14	0.39
WV1	0.43	0.39	0.46	0.39	0.28	.	0.52	0.33
WV2	0.28	0.26	0.47	0.36	0.14	0.52	.	0.19
WYT	0.5	0.48	0.37	0.38	0.39	0.33	0.19	.
mean	0.42	0.41	0.39	0.39	0.32	0.40	0.32	0.38

Appendix G

Sorenson's (1948) Coefficient of Similarity values for 28 pair-wise site comparisons of overstory species composition from eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
BB1	.	0.45	0.60	0.56	0.57	0.40	0.30	0.64
BB2	0.45	.	0.60	0.63	0.61	0.43	0.36	0.60
CL1	0.60	0.60	.	0.68	0.50	0.55	0.54	0.54
CL2	0.56	0.63	0.68	.	0.54	0.48	0.44	0.55
NCL	0.57	0.61	0.50	0.54	.	0.42	0.23	0.54
WV1	0.40	0.43	0.55	0.48	0.42	.	0.61	0.44
WV2	0.30	0.36	0.54	0.44	0.23	0.61	.	0.30
WYT	0.64	0.60	0.54	0.55	0.54	0.44	0.30	.
mean	0.50	0.53	0.57	0.55	0.49	0.48	0.40	0.52

Appendix H

Percent cover of families present in the herbaceous stratum at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Family	BB1	BB2	CL1	CL2	NC	WV1	WV2	WYT	Study Mean
	Percent Cover (%)								
Aceraceae	3.18	2.92	6.63	3.70	3.16	3.53	1.62	6.39	3.89
Amaryllidaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Anacardiaceae	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01
Apiaceae	0.08	0.02	0.02	0.01	0.02	0.00	0.00	0.17	0.04
Aquifoliaceae	0.00	0.00	0.08	0.04	0.00	0.00	0.03	0.00	0.02
Araceae	0.00	0.00	0.01	0.00	0.00	0.01	0.07	0.00	0.01
Araliaceae	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Aristolochiaceae	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Asclepiadaceae	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aspleniaceae	0.00	0.13	9.79	12.98	0.00	0.14	1.18	0.32	3.07
Asteraceae	0.41	0.08	1.03	1.09	0.03	0.24	0.50	0.45	0.48
Balsaminaceae	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01
Betulaceae	0.00	0.02	0.04	0.00	0.00	0.25	0.03	0.01	0.04
Campanulaceae	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00
Caprifoliaceae	0.28	0.07	0.00	0.00	0.01	0.05	0.00	0.01	0.05
Caryophyllaceae	0.01	0.01	0.13	0.23	0.00	0.00	0.11	0.05	0.07
Convolvulaceae	0.00	0.07	0.00	0.00	0.07	0.00	0.00	0.00	0.02
Cornaceae	0.14	0.01	0.01	0.00	0.21	0.00	0.00	0.09	0.06
Cyperaceae	0.38	0.26	0.19	0.14	0.00	0.07	0.75	0.70	0.31
Diapensiaceae	0.03	0.03	0.12	0.53	0.44	0.00	0.00	0.43	0.20
Dioscoreaceae	1.25	2.29	0.50	0.64	0.17	0.05	0.01	1.55	0.81
Elaeagnaceae	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ericaceae	6.53	2.04	1.53	2.33	18.37	0.02	0.00	9.96	5.10
Fabaceae	0.43	3.00	0.00	0.11	0.11	0.00	0.00	0.04	0.46
Fagaceae	6.42	5.84	3.06	2.22	4.01	1.57	0.26	8.26	3.96
Fumariaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Gentianaceae	0.00	0.01	0.22	0.19	0.00	0.00	0.00	0.00	0.05
Geraniaceae	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.03
Hamamelidaceae	0.05	0.01	0.22	0.15	0.13	0.02	0.04	0.04	0.08
Iridaceae	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Juglandaceae	0.51	0.30	0.01	0.05	0.00	0.00	0.00	1.50	0.29
Lamiaceae	0.10	0.02	0.00	0.02	0.00	0.00	0.00	0.05	0.02
Lauraceae	2.53	3.36	0.08	0.84	3.09	0.38	0.00	3.12	1.67
Liliaceae	3.96	1.94	4.93	5.98	2.66	3.50	4.33	4.37	3.96
Lycopodiaceae	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.01
Magnoliaceae	0.45	0.27	3.76	1.15	0.01	0.27	1.16	0.85	0.99
Monotropaceae	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.03	0.01
Nyssaceae	0.19	0.09	0.48	0.23	0.87	0.02	0.00	0.25	0.27
Oleaceae	0.46	0.58	0.01	0.00	0.01	0.06	0.00	0.06	0.15

Appendix H (cont)

Percent cover of families present in the herbaceous stratum at each of eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Family	BB1	BB2	CL1	CL2	NC	WV1	WV2	WYT	Study Mean
	Percent Cover (%)								
Ophioglossaceae	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orchidaceae	0.02	0.02	0.02	0.11	0.09	0.00	0.00	0.05	0.04
Orobanchaceae	0.00	0.00	0.18	0.23	0.00	0.01	0.00	0.00	0.05
Osmundaceae	0.00	0.11	0.05	0.40	0.00	0.00	0.00	0.00	0.07
Oxalidaceae	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinaceae	0.05	0.01	0.00	0.00	0.02	0.00	0.00	0.04	0.01
Poaceae	0.37	0.04	0.60	0.39	0.02	0.01	0.04	0.29	0.22
Portulacaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
Primulaceae	0.10	0.02	0.12	0.08	0.00	0.01	0.00	0.05	0.05
Pteridiaceae	0.01	0.00	0.82	3.92	0.29	0.04	0.30	1.47	0.86
Pyrolaceae	0.49	0.33	0.07	0.14	1.48	0.00	0.00	0.13	0.33
Ranunculaceae	0.02	0.04	1.94	3.54	0.00	0.01	0.48	0.05	0.76
Rosaceae	3.00	1.30	1.41	0.56	0.17	1.10	0.80	1.43	1.22
Rubiaceae	0.10	0.35	0.03	0.01	0.00	0.79	0.05	0.12	0.18
Saxifragaceae	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scrophulariaceae	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.13	0.02
Violaceae	0.61	0.58	4.48	4.08	0.14	1.41	3.67	0.65	1.95
Vitaceae	1.04	0.61	0.00	0.01	0.02	0.01	0.00	0.14	0.23
Total	36.66	29.82	49.30	49.90	38.75	17.08	17.09	49.71	36.04

Appendix I

Percent relative cover of growth forms at eight study sites in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Based on 162, 6 m^2 herb plots.

Growth form	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT	Mean
Tree seedling	58.72	62.73	57.38	34.66	51.68	73.08	38.89	59.7	54.61
Erect perenial herb	8.68	16.44	20.18	27.57	2.59	6.46	13.18	14.98	13.76
Shrub seedling	14.94	9.19	3.99	3.86	36.9	0.31	0.98	15.81	10.75
Woody vine	12.32	5.7	3.81	5.23	2.6	12.65	20.76	3.48	8.32
Acaulescent perenial herb	0.59	0.77	4.02	5.33	0.63	4.41	13.99	1.3	3.88
Fern	0.02	0.5	9.05	21.03	0.24	0.65	8.62	0.23	5.04
Graminoid	1.04	0.36	0.9	0.86	0.02	0.18	2.72	1.09	0.90
Reduced perenial herb	1.62	0.95	0.07	0.17	4.99	2.1	0.16	1.92	1.50
Trailing perenial herb	2.07	3.3	0.32	0.83	0.35	0.15	0.05	1.33	1.05
Erect biennial herb	0	0.05	0.28	0.43	0	0	0.65	0.06	0.18
Erect annual herb	0	0	0	0.04	0	0	0	0.1	0.02
Trailing annual herb	0	0	0	0	0	0	0	0.01	0.00

Appendix J

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Acalypha rhomboidea	Euphorbiaceae	1	eah
Acer pensylvanicum	Aceraceae	8	ts
Acer rubrum	Aceraceae	8	ts
Acer saccharum	Aceraceae	7	ts
Achillea millefolium	Asteraceae	2	eph
Agrimonia sp	Rosaceae	2	eph
Agrostis alba	Poaceae	1	gr
Agrostis perennans	Poaceae	2	gr
Allium tricoccum	Liliaceae	1	aph
Allium vineale	Liliaceae	1	aph
Ambrosia sp	Asteraceae	1	eah
Amelanchier arborea	Rosaceae	8	ts
Amphicarpa bracteata	Fabaceae	1	tah
Andropogon virginicus	Poaceae	2	gr
Anemone lancifolia	Ranunculaceae	1	eph
Anemone quinquefolia	Ranunculaceae	8	eph
Angelica venenosa	Apiaceae	3	eph
Antennaria parlinii	Asteraceae	1	eph
Antennaria plantaginifolia	Asteraceae	3	eph
Anthoxanthum odoratum	Poaceae	1	gr
Aplectrum hyemale	Orchidaceae	1	eph
Apocynum androsaemifolium	Apocynaceae	1	eph
Arabis canadensis	Brassicaceae	1	ebh
Aralia nudicaulis	Araliaceae	4	eph
Aralia spinosa	Araliaceae	2	ss
Arisaema triphyllum	Araceae	4	eph
Aristolochia macrophylla	Aristolochiaceae	2	wv
Asarum canadense	Aristolochiaceae	1	aph
Asclepias amplexicaulis	Asclepiadaceae	1	eph
Asclepias quadrifolia	Asclepiadaceae	1	eph
Asclepias variegata	Asclepiadaceae	1	eph
Asplenium montanum	Aspleniaceae	1	fern
Asplenium platyneuron	Aspleniaceae	3	fern
Aster acuminatus	Asteraceae	2	eph
Aster arguta	Asteraceae	1	eph
Aster divaricatus	Asteraceae	5	eph
Aster infirmus	Asteraceae	2	eph

Appendix J (cont)

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Aster lateriflorus	Asteraceae	2	eph
Aster macrophyllus	Asteraceae	2	eph
Aster prenanthoides	Asteraceae	2	eph
Aster puniceus	Asteraceae	1	eph
Aster undulatus	Asteraceae	2	eph
Athyrium asplenioides	Aspleniaceae	1	fern
Athyrium filix-femina	Aspleniaceae	7	fern
Athyrium thelypterioides	Aspleniaceae	1	fern
Aureolaria flava	Scrophulariaceae	4	eph
Aureolaria laevigata	Scrophulariaceae	4	eph
Aureolaria virginica	Scrophulariaceae	1	eph
Baptisia tinctoria	Fabaceae	2	eph
Barbarea vulgaris	Brassicaceae	1	ebh
Betula allegheniensis	Betulaceae	2	ts
Betula lenta	Betulaceae	7	ts
Bidens sp	Asteraceae	1	eah
Botrychium dissectum	Ophioglossaceae	2	fer
Botrychium virginianum	Ophioglossaceae	6	fer
Boykinia sp	Saxifragaceae	1	eph
Brachyelytrum erectum	Poaceae	3	gr
Calamagrostis porteri	Poaceae	1	gr
Caltha palustris	Ranunculaceae	1	aph
Campanula divaricata	Campanulaceae	3	eph
Cardamine pensylvanica	Brassicaceae	1	ebh
Carduus acanthoides	Asteraceae	1	ebh
Carduus discolor	Asteraceae	1	ebh
Carex aestivalis	Cyperaceae	1	gr
Carex appalchia	Cyperaceae	1	gr
Carex baileyi	Cyperaceae	2	gr
Carex blanda	Cyperaceae	3	gr
Carex communis	Cyperaceae	2	gr
Carex crinita	Cyperaceae	2	gr
Carex debilis	Cyperaceae	2	gr
Carex digitalis	Cyperaceae	3	gr
Carex flaccosperma	Cyperaceae	1	gr
Carex gracillima	Cyperaceae	2	gr
Carex hirsutella	Cyperaceae	1	gr
Carex intumescens	Cyperaceae	2	gr
Carex laxiflora	Cyperaceae	5	gr

Appendix J (cont)

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Carex leptonervia	Cyperaceae	2	gr
Carex lurida	Cyperaceae	2	gr
Carex nigromarginata	Cyperaceae	1	gr
Carex ormostachya	Cyperaceae	1	gr
Carex pensylvanica	Cyperaceae	1	gr
Carex prasina	Cyperaceae	2	gr
Carex rosea	Cyperaceae	1	gr
Carex scabrata	Cyperaceae	3	gr
Carex scoparia	Cyperaceae	1	gr
Carex stipata	Cyperaceae	2	gr
Carex styloflexa	Cyperaceae	1	gr
Carex swanii	Cyperaceae	4	gr
Carex torta	Cyperaceae	1	gr
Carex umbellata	Cyperaceae	2	gr
Carex virescens	Cyperaceae	4	gr
Carex vulpinoidea	Cyperaceae	3	gr
Carex willdenowii	Cyperaceae	1	gr
Carpinus caroliniana	Betulaceae	1	ts
Carya glabra	Juglandaceae	7	ts
Carya ovata	Juglandaceae	1	ts
Carya tomentosa	Juglandaceae	6	ts
Cassia marilandica	Fabaceae	1	eph
Castanea dentata	Fagaceae	7	ts
Castanea pumila	Fagaceae	3	ss
Caulophyllum thalictoides	Berberidaceae	1	eph
Cercis canadensis	Fabaceae	1	ts
Chamaelirium luteum	Liliaceae	1	eph
Chelone glabra	Scrophulariaceae	3	eph
Chimaphila maculata	Pyrolaceae	6	rph
Chimaphila umbellata	Pyrolaceae	1	rph
Chrysanthemum leucanthemum	Asteraceae	1	eph
Chrysosplenium americanum	Saxifragaceae	2	tah
Cimicifuga racemosa	Ranunculaceae	3	eph
Cinna arundinacea	Poaceae	1	gr
Claytonia caroliniana	Portulacaceae	1	eph
Clematis virginiana	Ranunculaceae	1	tph
Clintonia umbellulata	Liliaceae	6	aph
Clitoria mariana	Fabaceae	1	tph
Collinsonia canadensis	Lamiaceae	4	eph

Appendix J (cont)

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Commelina diffusa	Commelinaceae	1	eah
Conopholis americana	Orobanchaceae	7	eph
Convallaria montana	Liliaceae	5	eph
Corallorhiza maculata	Orchidaceae	1	eph
Corallorhiza odontorhiza	Orchidaceae	1	eph
Coreopsis major	Asteraceae	7	eph
Cornus florida	Cornaceae	7	ts
Coronilla varia	Fabaceae	1	tph
Corylus cornuta	Betulaceae	3	ss
Crataegus sp	Rosaceae	4	ss
Crepis capillaris	Asteraceae	1	eph
Cunila origanoides	Lamiaceae	1	eph
Cypripedium acaule	Orchidaceae	6	eph
Cystopteris fragilis	Aspleniaceae	1	fern
Dactylis glomerata	Poaceae	5	gr
Danthonia compressa	Poaceae	3	gr
Danthonia spicata	Poaceae	3	gr
Dennstaedtia punctilobula	Pteridiaceae	6	fer
Dentaria diphylla	Brassicaceae	1	eph
Desmodium glabellum	Fabaceae	1	eph
Desmodium nudiflorum	Fabaceae	6	eph
Desmodium paniculatum	Fabaceae	1	eph
Dicentra cucullaria	Fumariaceae	1	eph
Dioscorea villosa	Dioscoreaceae	8	tph
Disporum lanuginosum	Liliaceae	4	eph
Dryopteris intermedia	Aspleniaceae	3	fern
Dryopteris marginalis	Aspleniaceae	1	fern
Elaeagnus umbellata	Elaeagnaceae	2	ss
Eleocharis tenuis	Cyperaceae	2	gr
Epifagus virginiana	Orobanchaceae	2	eph
Epigaea repens	Ericaceae	5	rph
Epilobium coloratum	Onagraceae	1	eph
Epilobium leptophyllum	Onagraceae	1	eph
Equisetum arvense	Equisetaceae	1	eah
Erechtites hieracifolia	Asteraceae	2	eah
Erigeron annuus	Asteraceae	2	eah
Erigeron pulchellus	Asteraceae	1	eph
Erythronium sp	Liliaceae	1	aph
Eupatorium perfoliatum	Asteraceae	1	eph

Appendix J (cont)

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Eupatorium purpureum	Asteraceae	5	eph
Eupatorium rugosum	Asteraceae	2	eph
Eupatorium steeleii	Asteraceae	1	eph
Euphorbia corollata	Euphorbiaceae	2	eph
Fagus grandifolia	Fagaceae	6	ts
Festuca elatior	Poaceae	3	gr
Festuca rubra	Poaceae	1	gr
Fraxinus americana	Oleaceae	6	ts
Fraxinus pennsylvanica	Oleaceae	2	ts
Galax aphylla	Diapensiaceae	6	aph
Galium aparine	Rubiaceae	3	tah
Galium circaezans	Rubiaceae	4	eph
Galium latifolium	Rubiaceae	4	eph
Galium lanceolatum	Rubiaceae	1	eph
Galium triflorum	Rubiaceae	4	eph
Gaultheria procumbens	Ericaceae	6	rph
Gaylussacia baccata	Ericaceae	5	ss
Gentiana decora	Gentianaceae	5	eph
Geranium maculatum	Geraniaceae	5	eph
Geum canadense	Rosaceae	1	eph
Geum laciniatum	Rosaceae	2	eph
Geum virginianum	Rosaceae	1	eph
Gillenia trifoliata	Rosaceae	2	eph
Glecoma hederacea	Lamiaceae	1	eph
Glyceria striata	Poaceae	3	gr
Glyceria melicaria	Poaceae	1	gr
Gnaphalium obtusifolium	Asteraceae	2	eah
Goodyera pubescens	Orchidaceae	7	eph
Goodyera repens	Orchidaceae	2	eph
Gratiola neglecta	Scrophulariaceae	1	eah
Habenaria ciliaris	Orchidaceae	1	eph
Habenaria clavellata	Orchidaceae	4	eph
Habenaria orbiculata	Orchidaceae	4	eph
Hamamelis virginiana	Hamamelidaceae	7	ss
Heuchera americana	Saxifragaceae	2	aph
Hieracium paniculatum	Asteraceae	4	eph
Hieracium pilosella	Asteraceae	2	eph
Hieracium pratense	Asteraceae	2	eph
Hieracium venosum	Asteraceae	4	eph
Holcus lanatus	Poaceae	3	gr

Appendix J (cont)

Vascular plants identified to the species level on eight, 14 ha, study sites located in the Ridge and Valley and Allegheny Mountain physiographic provinces of southwest Virginia and West Virginia. Frequency categories represent the number of sites at which the species was identified. Growth form categories are as follows: **w**oody **v**ine , **t**ree **s**eedling, **s**hrub **s**eedling, **e**rect **a**nnual **h**erb, **e**rect **b**ienniel **h**erb, **e**rect **p**erennial **h**erb, **a**caulescent **p**erennial **h**erb, **t**railing **a**nnual **h**erb, **t**railing **p**erennial **h**erb, **r**educed **p**erennial **h**erb, **fer**n, or **gr**amminoid.

Species	Family	Frequency	Growth Form
Houstonia longifolia	Rubiaceae	4	eph
Houstonia purpurea	Rubiaceae	1	eph
Hydrangea arborescens	Hydrangeaceae	5	ss
Hydrophyllum canadense	Hydrophyllaceae	1	eph
Hydrophyllum virginianum	Hydrophyllaceae	1	eph
Hypericum canadense	Clusiaceae	1	ep
Hypericum hypericoides	Clusiaceae	1	ss
Hypericum mutilum	Clusiaceae	1	eph
Hypericum punctatum	Clusiaceae	4	eph
Hypochoeris radicata	Asteraceae	1	aph
Hypoxis hirsuta	Amaryllidaceae	6	aph
Ilex ambigua var. ambigua	Aquifoliaceae	2	ss
Ilex decidua	Aquifoliaceae	1	ss
Ilex ambigua var. montana	Aquifoliaceae	3	ss
Ilex verticillata	Aquifoliaceae	3	ss
Impatiens capensis	Balsaminaceae	1	eah
Ipomoea pandurata	Convolvulaceae	1	tph
Ipomoea purpurea	Convolvulaceae	1	tah
Iris verna	Iridaceae	2	eph
Isoetes engelmannii	Isoetaceae	1	eph
Isotria verticillata	Orchidaceae	3	eph
Juncus effusus	Juncaceae	4	gr
Juncus subcaudatus	Juncaceae	3	gr
Juncus tenuis	Juncaceae	3	gr
Juniperus virginiana	Cupressaceae	5	ts
Kalmia latifolia	Ericaceae	6	ss
Laportea canadensis	Urticaceae	1	eph
Leersia oryzoides	Poaceae	1	gr
Leersia virginica	Poaceae	2	gr
Lespedeza hirta	Fabaceae	3	eph
Lespedeza intermedia	Fabaceae	1	eph
Lespedeza procumbens	Fabaceae	1	tph
Lespedeza repens	Fabaceae	1	tph
Lilium michauxii	Liliaceae	3	eph
Lilium philadelphicum	Liliaceae	1	eph
Lindera benzoin	Lauraceae	5	ss
Linum virginianum	Linaceae	1	eph
Liriodendron tulipifera	Magnoliaceae	8	ts
Lobelia cardinalis	campanulacea	1	eph
Lobelia inflata	campanulacea	3	eah

Appendix J (cont)

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Species	Family	Frequency	Growth Form
Luzula multiflora	Juncaceae	2	gr
Lycopodium obscurum	Lycopodiaceae	2	eph
Lycopus virginicus	Lamiaceae	2	eph
Lysimachia quadrifolia	Primulaceae	8	eph
Magnolia acuminata	Magnoliaceae	6	ts
Magnolia fraseri	Magnoliaceae	4	ts
Maianthemum canadense	Liliaceae	4	eph
Malus sp	Rosaceae	1	ts
Medeola virginiana	Liliaceae	7	eph
Meehania cordata	Lamiacea	1	tph
Melampyrum lineare	Scrophulariaceae	1	eah
Microstegium vimineum	Poaceae	1	gr
Mimulus ringens	Scrophulariaceae	1	eph
Mitchella repens	Rubiaceae	6	rph
Monarda clinopodia	Lamiaceae	1	eph
Monotropa hypopithys	Monotropaceae	4	eph
Monotropa uniflora	Monotropaceae	8	eph
Morus rubra	Moraceae	1	ts
Nyssa sylvatica	Nyssaceae	8	ts
Onoclea sensibilis	Onocleaceae	2	fer
Orchis spectabilis	Orchidaceae	3	aph
Osmunda cinnamomea	Osmundaceae	7	fer
Osmunda claytoniana	Osmundaceae	4	fer
Osmunda regalis	Osmundaceae	4	fer
Ostrya virginiana	Betulaceae	5	ts
Oxalis acetosella	Oxalidaceae	1	aph
Oxalis dillenii	Oxalidaceae	1	eph
Oxalis stricta	Oxalidaceae	1	eph
Oxydendrum arboreum	Ericaceae	7	ts
Oxypolis rigidior	Apiaceae	2	eph
Panax trifolium	Araliaceae	1	eph
Panicum acuminatum	Poaceae	3	gr
Panicum boscii	Poaceae	2	gr
Panicum clandestinum	Poaceae	3	gr
Panicum commutatum	Poaceae	5	gr
Panicum dichotomum	Poaceae	4	gr
Panicum latifolium	Poaceae	3	gr
Panicum longifolia	Poaceae	1	gr
Panicum sphaerocarpon	Poaceae	1	gr
Panicum tenue	Poaceae	1	gr

Appendix J (cont)

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Species	Family	Frequency	Growth Form
Parnassia glauca	Saxifragaceae	1	aph
Parthenocissus quinquefolia	Vitaceae	5	wv
Penthorum sedoides	Saxifragaceae	1	eph
Pilea pumila	Urticaceae	1	eah
Pinus echinata	Pinaceae	1	ts
Pinus pungens	Pinaceae	3	ts
Pinus rigida	Pinaceae	4	ts
Pinus strobus	Pinaceae	4	ts
Pinus virginiana	Pinaceae	2	ts
Plantago rugelii	Plantaginaceae	1	aph
Platanus occidentalis	Platanaceae	1	ts
Poa alsodes	Poaceae	1	gr
Poa cuspidata	Poaceae	4	gr
Podophyllum peltatum	Berberidaceae	4	eph
Polygala senega	Polygalaceae	2	eph
Polygonatum biflorum	Liliaceae	8	eph
Polygonum cespitosum	Polygonaceae	1	eah
Polygonum punctatum	Polygonaceae	1	eah
Polygonum sagittatum	Polygonaceae	1	eah
Polypodium appalachiam	Polypodiaceae	1	fer
Polypodium virginianum	Polypodiacea	2	fer
Polystichum acrostichoides	Aspleniaceae	7	fern
Polystichum hydropiper	Aspleniaceae	1	fern
Populus grandidentata	Salicaceae	1	ts
Potentilla canadensis	Rosaceae	2	tph
Potentilla simplex	Rosaceae	8	tph
Potentilla tridentata	Rosaceae	2	tph
Prenanthes trifoliata	Asteraceae	7	ebh
Prunella vulgaris	Lamiaceae	2	eph
Prunus avium	Rosaceae	1	ts
Prunus pensylvanica	Rosaceae	2	ts
Prunus serotina	Rosaceae	8	ts
Pteridium aquilinum	Pteridiaceae	5	fer
Pyrola americana	Ericaceae	1	aph
Pyrola rotundifolia	Ericaceae	4	aph
Quercus alba	Fagaceae	7	ts
Quercus coccinea	Fagaceae	7	ts
Quercus ilicifolia	Fagaceae	1	ts
Quercus prinus	Fagaceae	8	ts
Quercus rubra	Fagaceae	7	ts

Appendix J (cont)

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Species	Family	Frequency	Growth Form
Quercus velutina	Fagaceae	6	ts
Ranunculus hispidus	Ranunculaceae	1	eph
Ranunculus recurvatus	Ranunculaceae	5	eph
Rhododendron calendulaceum	Ericaceae	5	ss
Rhododendron maximum	Ericaceae	6	ss
Rhododendron nudiflorum	Ericaceae	1	ss
Rhus toxicodendron	Anacardiaceae	4	wv
Rhynchospora capitellata	Cyperaceae	1	gr
Robinia pseudo-acacia	Fabaceae	8	ts
Rosa carolina	Rosaceae	1	ss
Rosa multiflora	Rosaceae	3	ss
Rubus allegheniensis	Rosaceae	3	wv
Rubus canadensis	Rosaceae	2	wv
Rubus flagellaris	Rosaceae	4	wv
Rumex obtusifolius	Polygonaceae	2	ebh
Sambucus canadensis	caprifoliaceae	1	ss
Sanicula sp	Apiaceae	1	eph
Sassafras albidum	Lauraceae	8	ts
Satureja vulgaria	Lamiaceae	1	eph
Saxifraga michauxii	Saxifragaceae	2	aph
Scirpus atrovirens	Cyperaceae	2	gr
Scirpus cyperinus	Cyperaceae	3	gr
Scirpus polyphyllus	Cyperaceae	1	gr
Scutellaria elliptica	Lamiaceae	2	eph
Scutellaria lateriflora	Lamiaceae	1	eph
Senecio anonymous	Asteraceae	1	eph
Senecio aureus	Asteraceae	3	eph
Senecio obovatus	Asteraceae	1	eph
Senecio pauperculus	Asteraceae	1	eph
Silene stellata	Caryophyllaceae	1	eph
Silene pubera	Caryophyllaceae	1	eph
Silene virginica	Caryophyllaceae	2	eph
Sisyrinchium angustifolium	Iridaceae	1	eph
Smilacena trifolia	Liliaceae	1	eph
Smilacina racemosa	Liliaceae	8	eph
Smilax glauca	Liliaceae	8	wv
Smilax herbacea	Liliaceae	5	tph
Smilax rotundifolia	Liliaceae	8	wv
Solidago arguta	Asteraceae	1	eph
Solidago bicolor	Asteraceae	1	eph

Appendix J (cont)

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Species	Family	Frequency	Growth Form
Solidago caesia	Asteraceae	2	eph
Solidago curtisii	Asteraceae	3	eph
Solidago flexicaulis	Asteraceae	2	eph
Solidago graminifolia	Asteraceae	1	eph
Solidago odora	Asteraceae	1	eph
Solidago puberula	Asteraceae	1	eph
Solidago roanensis	Asteraceae	1	eph
Solidago rugosa	Asteraceae	3	eph
Sphenophilis americana	Poaceae	1	gr
Sphenophilis pensylvanica	Poaceae	1	gr
Sphenopholis nitida	Poaceae	2	gr
Spiraea japonica	Rosaceae	2	ss
Spiranthes sp	Orchidaceae	1	eph
Stellaria pubera	Caryophyllaceae	7	eph
Taraxacum officinale	Asteraceae	3	aph
Thalictrum dioicum	Ranunculaceae	1	eph
Thalictrum thalictroides	Ranunculaceae	1	eph
Thelypteris asplenioides	Aspleniaceae	1	fern
Thelypteris hexagonoptera	Aspleniaceae	2	fern
Thelypteris noveboracensis	Aspleniaceae	7	fern
Tiarella cordifollia	Saxifragaceae	1	aph
Tilia americana	Tiliaceae	3	ts
Tipularia discolor	Orchidaceae	1	eph
Trifolium pratense	Fabaceae	2	eph
Trifolium repens	Fabaceae	1	tph
Trillium erectum	Liliaceae	1	eph
Trillium undulatum	Liliaceae	2	eph
Trillum grandiflorum	Liliaceae	1	eph
Tsuga canadensis	Pinaceae	5	ts
Tussilago farfara	Asteraceae	1	aph
Ulmus rubra	Ulmaceae	1	ts
Uvularia perfoliata	Liliaceae	7	eph
Uvularia pudica	Liliaceae	6	eph
Uvularia sessilifolia	Liliaceae	3	eph
Vaccinium corymbosum	Ericaceae	1	ss
Vaccinium pallidum	Ericaceae	8	ss
Vaccinium simulatum	Ericaceae	1	ss
Vaccinium stamineum	Ericaceae	6	ss
Veratrum viride	Liliaceae	1	eph

Appendix J (cont)

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Species	Family	Frequency	Growth Form
Veronica officinalis	Scrophulariaceae	1	tph
Viburnum acerifolium	Caprifoliaceae	7	ss
Viburnum alnifolium	Caprifoliaceae	2	ss
Viburnum cassinoides	Caprifoliaceae	1	ss
Viburnum prunifolium	Caprifoliaceae	2	ss
Vicia caroliniana	Fabaceae	1	tph
Viola affinis	Violaceae	1	aph
Viola aphylla	Violaceae	1	aph
Viola blanda	Violaceae	2	aph
Viola canadensis	Violaceae	1	eph
Viola cucullata	Violaceae	3	aph
Viola eriocarpa	Violaceae	1	eph
Viola fimbriatula	Violaceae	1	aph
Viola hastata	Violaceae	8	eph
Viola hirsutula	Violaceae	3	aph
Viola palmata	Violaceae	4	aph
Viola pedata	Violaceae	3	aph
Viola rotundifolia	Violaceae	4	aph
Viola septemloba	Violaceae	1	aph
Viola sororia	Violaceae	2	aph
Viola triloba	Violaceae	3	aph
Vitis aestivalis	Vitaceae	2	wv
Zizia aptera	Apiaceae	2	eph
Zizia trifoliata	Apiaceae	3	eph

Appendix K

Ranked relative basal area (m^2*ha^{-1}) of overstory trees on 21, 576 m^2 tree plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Rank	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Relative Basal Area (m^2*ha^{-1}) (%)							
1	45.672	48.383	37.93	34.484	44.896	55.244	39.169	37.498
2	23.825	19.08	19.09	22.79	24.88	16.924	23.134	20.285
3	13.953	12.512	14.28	14.436	12.433	10.711	14.617	15.746
4	7.043	9.006	10.442	11.388	8.261	6.812	10.342	10.738
5	4.069	5.305	6.961	7.577	4.474	4.261	6.366	6.778
6	2.677	2.601	4.863	4.047	2.439	2.442	3.51	4.14
7	1.527	1.207	2.998	2.436	1.419	1.613	1.691	2.205
8	0.7	0.788	1.989	1.467	0.698	1.016	0.852	1.182
9	0.33	0.49	0.863	0.753	0.327	0.548	0.264	0.673
10	0.106	0.309	0.385	0.368	0.163	0.245	0.042	0.437
11	0.064	0.168	0.142	0.109	0.01	0.091	0.009	0.2
12	0.022	0.093	0.049	0.065	0	0.055	0.004	0.078
13	0.01	0.045	0.008	0.038	0	0.029	0	0.032
14	0.002	0.01	0	0.026	0	0.009	0	0.008
15	0	0.003	0	0.016	0	0	0	0

Appendix L

Ranked relative crown cover (percent) of midstory trees and shrubs on 21, 108 m^2 shrub plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

RANK	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
				Relative Crown Cover (percent)				
1	45.677	39.645	37.311	47.035	76.248	63.418	57.895	47.971
2	22.093	18.789	21.227	22.067	14.142	14.775	24.982	21.228
3	12.468	12.668	14.539	12.73	5.514	8.128	9.716	12.69
4	7.531	9.077	10.106	8.095	2.016	5.254	4.683	8.405
5	4.351	7.229	6.789	4.792	1.441	3.81	1.712	4.41
6	2.956	4.883	3.846	2.768	0.496	2.266	0.596	2.549
7	1.911	3.216	2.825	1.56	0.143	1.024	0.249	1.627
8	1.343	1.749	1.692	0.664	0	0.671	0.121	0.615
9	0.667	1.164	0.936	0.24	0	0.403	0.046	0.272
10	0.482	0.722	0.464	0.049	0	0.228	0	0.168
11	0.263	0.438	0.201	0	0	0.021	0	0.065
12	0.148	0.257	0.06	0	0	0.002	0	0
13	0.06	0.088	0.004	0	0	0	0	0
14	0.03	0.05	-100	0	0	0	0	0
15	0.011	0.019	0	0	0	0	0	0
16	0.009	0.006	0	0	0	0	0	0

Appendix M

Ranked relative crown cover (percent) of woody and herbaceous plant species (< 1 m tall) on 21, 6 m^2 herb plots at each of eight study sites (n = 15 at WV1) located in the Ridge and Valley and Allegheny Mountain physiographic provinces of Southwestern Virginia and West Virginia.

Rank	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Relative Crown Cover (%)							
1	20.273	29.119	24.254	30.755	31.427	28.388	44.654	20.395
2	13.702	16.959	13.03	14.099	17.69	20.127	18.151	14.845
3	11.126	11.758	10.772	10.359	12.696	15.892	10.659	12.171
4	8.647	8.47	8.75	7.872	9.103	9.247	6.724	9.435
5	7.218	6.665	7.049	6.521	6.87	5.575	4.281	8.247
6	6.308	5.231	5.436	5.113	5.419	4.144	3.547	5.897
7	5.311	3.993	4.573	3.645	4.429	3.834	2.89	4.393
8	3.89	3.118	3.96	3.251	3.009	2.619	2.079	3.952
9	3.247	2.874	3.148	2.533	2.145	1.815	1.518	3.304
10	2.876	1.936	2.556	2.249	1.646	1.625	1.024	2.651
11	2.428	1.652	2.28	1.888	1.391	1.625	0.89	2.003
12	2.102	1.353	1.851	1.649	1.069	1.15	0.812	1.726
13	1.578	0.934	1.721	1.333	0.688	0.809	0.638	1.411
14	1.378	0.732	1.477	1.236	0.596	0.571	0.617	1.345
15	1.255	0.731	1.039	1.19	0.506	0.524	0.497	0.9
16	1.173	0.637	0.964	0.822	0.437	0.461	0.431	0.878
17	1.09	0.501	0.822	0.748	0.343	0.396	0.226	0.76
18	1.09	0.438	0.784	0.664	0.193	0.397	0.131	0.639
19	0.766	0.348	0.677	0.505	0.092	0.276	0.046	0.614
20	0.623	0.348	0.616	0.474	0.092	0.167	0.046	0.568
21	0.564	0.317	0.53	0.453	0.058	0.12	0.047	0.508
22	0.434	0.232	0.472	0.383	0.033	0.06	0.046	0.444
23	0.337	0.232	0.471	0.354	0.034	0.059	0.046	0.336
24	0.338	0.232	0.444	0.354	0.034	0.06	0	0.337
25	0.294	0.232	0.393	0.309	0	0.059	0	0.337
26	0.294	0.233	0.394	0.291	0	-100	0	0.268
27	0.294	0.232	0.291	0.249	0	0	0	0.245
28	0.294	0.232	0.292	0.116	0	0	0	0.219
29	0.227	0.173	0.187	0.094	0	0	0	0.196
30	0.186	0.088	0.167	0.093	0	0	0	0.17

Appendix M (cont)

Rank	BB1	BB2	CL1	CL2	NCL	WV1	WV2	WYT
	Relative Crown Cover (%)							
31	0.185	0	0.109	0.093	0	0	0	0.149
32	0.158	0	0.09	0.093	0	0	0	0.133
33	0.124	0	0.07	0.093	0	0	0	0.094
34	0.074	0	0.07	0.049	0	0	0	0.094
35	0.073	0	0.07	0.024	0	0	0	0.081
36	0.021	0	0.07	0.023	0	0	0	0.056
37	0.022	0	0.057	0.023	0	0	0	0.035
38	0	0	0.047	0	0	0	0	0.035
39	0	0	0.017	0	0	0	0	0.034
40	0	0	0	0	0	0	0	0.035
41	0	0	0	0	0	0	0	0.015
42	0	0	0	0	0	0	0	0.015
43	0	0	0	0	0	0	0	0.015
44	0	0	0	0	0	0	0	0.015

VITA

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