
**Impacts of Seven Silvicultural Alternatives on Vascular Plant Community
Composition, Structure, and Diversity in the Southern Appalachians**

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*Keywords—Appalachian hardwoods, clearcut, exotic species, floral community, forest
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Abstract—The effects of seven silvicultural prescriptions were examined one full growing season post-treatment on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Prescriptions were (1) control, (2) understory control with herbicide, (3) group selection, (4) high-leave shelterwood, (5) low-leave shelterwood, (6) leave tree, and (7) clearcut. The effects of each treatment on the vascular plant community were characterized by changes in species diversity, species composition, exotic species richness, Raunkiaer's life-forms, and growth-forms. Pre-treatment, baseline data, and a randomized block design ensured the precision of post-treatment comparisons. High-disturbance treatments (i.e., low-leave shelterwood, leave tree, clearcut) exhibited lower tree-stratum species richness than unharvested treatments. Prescriptions had no effect on shrub-stratum richness. Compared to the control, woody, herb-stratum richness was higher in harvested treatments. Non-woody herb-stratum richness was unaffected. No differences in herb-stratum species diversity were detected using Shannon's ($\exp H'$) or Simpson's ($1/D$) indices. Non-woody species richness per 2-ha treatment plot was significantly higher than the control for high-disturbance treatments. Pre- vs. post-treatment species composition was least similar for high-disturbance treatments, as measured by qualitative and quantitative community similarity indices. Exotic woody species richness was unaffected by treatment; however, non-woody exotic species were more prevalent in high-disturbance treatments. Hemicryptophytes replaced phanerophytes as the most important life-form for harvested treatments. Therophytes were more important in harvested treatments, while the proportion of cryptophytes and chamaephytes did not change in response to treatments. Tree and shrub growth-forms were less dominant in harvested treatments, while graminoids and annual/biennial forbs were more important for high-disturbance treatments. These data represent only the initial results of a long-term study designed to examine plant-community response to silviculture for one harvest rotation length. Long-term results will aid in devising management strategies that address concerns for biodiversity without devaluing traditional resource demands.

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I. INTRODUCTION

Justification

Concern over the global loss of biological diversity (Wilson 1988, Ehrlich and Wilson 1991) and the inferred impacts of such a loss on ecosystem function (Grime 1997) warrants increased consideration in land management regimes for measures that conserve species and maintain ecosystem integrity. Existing preserves are, by themselves, inadequate for long-term species conservation (Harris 1984). Consequently, lands traditionally managed as multiple-use, or exclusively for natural resources, are being solicited—both by the public and the scientific community—to include biodiversity maintenance as a management objective (Hansen et al. 1991, Probst and Crow 1991). As the issues of biodiversity and ecosystem integrity become more prominent in the conscience of the public, resource managers will be obligated to provide for those values. Kennedy (1985) cites an increasingly urban society that devalues traditional resource management objectives—most notably timber harvesting—in favor of more non-utilitarian values, as an influencing factor on future management decisions. The demand for forest products and the impression of environmentalism on the political mainstream will likely persist into the near future (Burton et al. 1992). In the United States, resource managers will be increasingly pressed to establish a balance between changing public values and the concomitant need for natural resources.

The framework for achieving this end is in various stages of implementation, particularly on federal lands (Salwasser 1990, Rauscher 1999). The National Forest Management Act of 1976 mandates the initiation of Forest Plans that include measures for

preserving biodiversity on all National Forests. The potential effects of plans on biodiversity must be evaluated prior to implementation, and monitored thereafter (Probst and Crow 1991). The USDA Forest Service, USDI National Park Service, USDI Bureau of Land Management, and the USDI Fish and Wildlife Service are all working toward the adoption of ecosystem management strategies (FEMAT 1993). Professional forestry organizations have similarly recognized the importance of maintaining biodiversity on private lands. A task force assembled by the Society of American Foresters (1991) recommends that all professional foresters endeavor to maintain, and where appropriate enhance, biodiversity. The effective implementation of a holistic management regime is, however, a complex task (Rauscher 1999). While addressing concerns for the maintenance of biodiversity and ecosystem integrity, managers must take care not to devalue traditional resource demands.

Research that contributes to an understanding of how management practices affect ecosystem attributes is the key to developing holistic management strategies. There are several ecosystems that are inherently more biologically diverse, which subsequently have attracted more research interest than others. The most obvious of these ecosystems are the tropical rain forests (Myers 1988, Wilson 1988). Temperate zones, however, should be given equal attention, because these are the landscapes that historically have been most affected by anthropogenic activity (Franklin 1988). In North America, the southern Appalachian Mountain region is notable for its high biological diversity despite a storied disturbance history (e.g., Clarkson 1964). Because of the continued prominence of timber harvesting, the southern Appalachians are ideal for investigations that demonstrate how species composition, forest structure, and ecological processes are affected by forest

management. Much effort has been made to quantify the effects of harvesting on species diversity in the southern Appalachians; however, experimental data are still lacking (Roberts and Gilliam 1995). In order to understand how a range of silvicultural prescriptions affects spatial and temporal diversity patterns, additional research is necessary. Forest managers must know, on a site-specific basis, which silvicultural treatments are most appropriate for providing resources and maintaining ecological attributes (Miller and Kochenderfer 1998).

Recognizing the need for data on the relationship between ecosystem attributes and forest management, a long-term, collaborative research project, “The Impacts of Silviculture on Biodiversity in the Southern Appalachians” (hereafter referred to as the Diversity Study), was initiated in May 1993. Participants in the study include Virginia Polytechnic Institute and State University, College of Natural Resources; the USDA Forest Service, Southern Research Station; the Jefferson National Forest; and Westvaco Corporation. Silvicultural treatments examined include, (1) undisturbed control, (2) understory control with herbicide, (3) group selection, (4) high-leave shelterwood, (5) low-leave shelterwood, (6) leave-tree, and (7) clearcut. Originally designed to quantify changes in plant, bird, and salamander community attributes over time (> 50 yrs), the scope has since been narrowed to plants and salamanders due to resource limitations. The short-term impact of harvest disturbance on salamanders has been reported elsewhere (see Harpole and Haas 1999, Knapp 1999). The short-term changes in the composition and structure of the vascular plant community in response to the seven silvicultural treatments will be reported and discussed herein.

Previous studies have sought to quantify the effects of timber harvesting on vascular plants in the Appalachians. Most of these studies have observed only the initial impacts of disturbance, and few have pre-disturbance, baseline data. The Diversity Study differs by

intending to monitor changes throughout the successional development of the plant community, for a period at least equal to the harvest rotation typical of the southern Appalachians. Pre-treatment reference data for all measurement plots enable the comparison of changes from a baseline condition. The many studies that have used a chronosequence approach lack baseline data on pre-disturbance community attributes. Chronosequence studies cannot, therefore, conclusively separate disturbance effect from inherent site variability and pre-disturbance conditions. This study also intends to be more comprehensive than previous studies. Many studies have focused on the effects of clearcuts on species diversity. The response to other silvicultural practices has received far less attention. Similarly, the structural and functional attributes of diversity have often been overlooked in favor of compositional diversity. Compositional diversity alone is a valid research objective; however, it is insufficient for making inferences about ecosystem processes. Furthermore, few studies have observed the effects of harvest on the entire vascular plant community; rather, they report on a single species, guild, or stratum (e.g., understory, midstory, overstory). In particular, the herbaceous stratum is often overlooked as a component of the plant community.

Objectives

The purpose of this paper is to present and discuss the initial effects of seven silvicultural treatments on five southern Appalachian forest communities. Compositional and structural attributes are compared for pre- vs. post-treatment vascular plant communities. Post-treatment results represent data collected one full growing season after treatments were implemented. Specifically, this paper seeks to

- i) quantify initial changes in species diversity in the herbaceous, shrub, and tree strata in response to seven silvicultural alternatives,
- ii) quantify initial changes in species composition in the herbaceous, shrub, and tree strata in response to seven silvicultural alternatives,
- iii) characterize initial community response to seven silvicultural alternatives in terms of functional species groups,
- iv) identify silvicultural alternatives that are predisposed to invasion by exotic species, and
- iv) quantify initial changes in stand structure in response to seven silvicultural alternatives.

II. LITERATURE REVIEW

Pivotal to understanding the results of this investigation is some level of familiarity with (1) the broad concepts of biodiversity, (2) methods of measuring species diversity, (3) species diversity hypotheses, and (4) diversity and ecosystem development, particularly in the southern Appalachians.

Defining biodiversity

A review of the literature reveals various—and often contradictory—definitions of biodiversity. Magurran (1988) attributes the resemblance of biodiversity to an optical illusion as the source of discrepancy: “The more [biodiversity] is looked at, the less clearly defined it appears to be, and viewing it from different angles can lead to different perceptions of what is involved.” Biodiversity, in the most basic sense, is the variety of life. The simplicity of this definition, however, belies the true complexity of the concept. Biodiversity is often considered synonymous with species diversity, but species diversity, too, is a contentious issue. In a frequently cited paper, Hurlbert (1971) suggests that the abundance of “semantic, conceptual, and technical problems” in species diversity literature has reduced species diversity to a “nonconcept”. One of the more significant problems is the absence of a consistent, ecologically meaningful approach to measuring species diversity. A more comprehensive definition recognizes that biodiversity is not only the variety of species and life-forms, but it also is the variety of organizational levels at which life exists (Hunter 1990). Commonly recognized levels of organization include the genetic, species, community, and landscape level (Noss 1990).

Biodiversity can also be characterized from a perspective of spatial scale, categorized by Whittaker (1972) as alpha, beta, and gamma diversity. Alpha diversity describes within-habitat diversity, and is sometimes referred to as local diversity. The variation between adjacent habitats or along an environmental gradient represents beta diversity. Variety associated with geographical separation is gamma diversity, or regional diversity. Alpha and beta diversity can be considered components of gamma diversity (Peet 1974).

Noss (1990) recognizes three principal components of biodiversity. Compositional, structural, and functional diversity exist at all organizational levels. Compositional diversity refers to the variety of elements in a community, including species and alleles (Noss 1990). Structural diversity is a primary determinant of compositional and functional community attributes. Structure involves the horizontal pattern and vertical complexity of plants, woody debris, and other community elements. Functional attributes include many of the processes (e.g., nutrient cycling, energy flow) associated with an ecosystem or its constituents. Functional diversity is often difficult to quantify; subsequently, compositional and structural diversity are the predominant focus of most research (Franklin 1988).

From a land management perspective, ecosystem processes may be of greater interest than species diversity, per se. Angermeier and Karr (1994) argue for the use of biological integrity, rather than diversity, as a primary management objective. Biological integrity, in the context of ecosystems, is used to describe a state where the elements, functions, and processes of an ecosystem are maintained at some desirable level. Biological integrity is considered inclusive of biotic processes, a notable distinction from most definitions of biodiversity. Furthermore, the authors contend that altered communities may

lack biological integrity without necessarily being less diverse than natural communities. All species do not exhibit the same functional value (Tilman et al. 1997). Consequently, change in species composition—such as the exchange of an exotic species for a native—may prove more disruptive to ecosystem processes than loss of species diversity.

Goldstein (1999), however, cautions against addressing the definitional shortcomings of biodiversity by replacing it with equally ambiguous buzzwords, such as “biological integrity” or “ecosystem health” that are more suggestive of ecosystem processes. Management strategies that aim to protect ecosystem processes without consideration for species and their respective life-history requirements are of little merit, according to Goldstein.

The question of definition is important because the way biodiversity is defined is reflected in the way it is assessed. A more universally accepted definition of biodiversity would contribute to increased consistency in its measurement. The myriad of approaches used to evaluate biodiversity make interpretation cumbersome, and in many cases preclude the comparison of data sets. A standardization of definition and measurement may broaden the applicability of biodiversity research.

Measuring species diversity

Ecologists have devised innumerable means of quantifying the diversity of elements at each organizational level. In particular, species diversity appears to be the element of greatest interest and is usually examined at the community level (Hunter 1990). Techniques for characterizing species diversity within or among communities are abundant in the ecological literature. These measures can be broadly grouped into (1) alpha-diversity indices, (2) species abundance models/plots, (3) comparative diversity profiles, and (4)

community-similarity indices. The following is not intended to be an exhaustive review of species diversity measurements, but rather a superficial explanation of their respective uses, merits, and shortcomings. For a more complete discussion of these measures—including their mathematical derivations—see Whittaker (1972), May (1975), Pielou (1975), and Magurran (1988).

Alpha-diversity indices

The most intuitive diversity indices require only a count of species, and are referred to as species richness indices. Species richness (S) is simply the number of species in a sample. Two species richness measures are recognized: (1) species density, or the number of species per sample area (Hurlbert 1971), and (2) numerical richness, which is the number of species for a given number of individuals or amount of biomass (Kempton 1979).

Although appealing because of its simple calculation and interpretation, species richness has limitations. Natural communities are open systems without a fixed species assemblage; therefore, determining absolute species richness is not possible. Richness values cannot be compared across unequal sample sizes without additional manipulation and loss of information. An assumption of equal sampling intensity among samples is also necessary (Magurran 1988). Species richness also provides no indication of evenness, or the way in which the abundance of species is distributed. The relative abundance of species may change due to disturbance without a corresponding response in species richness (Kempton 1979). Consequently, ecologists have derived more complex diversity indices that combine elements of species richness and evenness into a single number that is comparable between communities. Peet (1974) termed indices of this type, heterogeneity indices.

Two popular heterogeneity indices are Simpson's index and Shannon's index.

Simpson's index measures the probability that two individuals randomly selected from a sample will belong to the same species:

$$\text{Simpson's index: } D = \sum \pi_i^2$$

where π_i is the proportion of individuals belonging to the i^{th} species. Simpson's, therefore, is an index of dominance concentration. Because the original form of Simpson's index is inversely related to diversity, a more commonly used form subtracts D from its maximum value of one (Magurran 1988). The value of this form ($1-D$) increases as diversity increases. Another alternative form uses the reciprocal of D , where the value of $1/D$ is interpreted as the number of equally dominant species required to produce the same diversity as the given sample (Peet 1974). Kempton (1979) notes that $1/D$ is more effective than D in discriminating between communities with similar abundance distributions.

Shannon's index was adopted from information theory. The index measures rarity as the uncertainty of encounter of an individual randomly selected from an infinite population:

$$\text{Shannon's index: } H' = - \sum \pi_i \ln \pi_i$$

where π_i is the proportion of individuals belonging to the i^{th} species. The antilogarithmic transformation of H' is sometimes used to aid in interpretation. Similar to the inverse of Simpson's index, the value of $\exp H'$ is interpreted as the number of equally abundant species that would produce the same diversity as the given sample (Peet 1974). $\exp H'$ also provides better discrimination between communities than the untransformed index (Kempton 1979).

Neither heterogeneity index is without limitations. The inherent drawbacks to these measures become evident by observing the response of an index to changes in the species

abundance distribution (Peet 1974). Peet (1974) demonstrates Shannon's index to be sensitive to changes in the importance of rare species. Because Simpson's index is a measure of dominance, it is weighted toward the abundance of the most common species in the sample (Magurran 1988). Indices weighted toward either the most abundant or the rarest species may not provide an accurate description of community pattern (Kempton 1979). Additionally, because the Shannon and Simpson indices are not weighted toward the same region of the species abundance distribution, they may produce conflicting results when ordering the diversity of a set of communities (Hurlbert 1971, Swindel et al. 1987).

Heterogeneity indices are intended to facilitate diversity comparisons between communities by combining complex data into a single number. By reducing data, however, these single-number indices obscure the information contained in the original data sets. The biological relevance—particularly of indices derived from information theory—has also been challenged (Hurlbert 1971). While richness and evenness are, by themselves, meaningful attributes, the utility of combining them is arguable. Descriptors more meaningful and intuitive than single-number indices are available for evaluating compositional and structural differences between communities.

Species abundance models/plots

Among available measures, the most complete mathematical descriptor of species diversity is the species abundance distribution (Magurran 1988). Abundance distributions provide richness and evenness data without combining the elements into a single ambiguous value. Four general models are used to characterize the most commonly observed patterns of species abundance distributions. Whittaker (1972), May (1975), Pielou (1975), and

Magurran (1988) detail the geometric, logarithmic, log-normal, and broken-stick abundance models.

The geometric series describes a community that develops from an unsaturated habitat where colonization requires preemption of available niche space. The characteristic distribution is formed when the dominant species claims a fraction of total niche space, the second species claims a fraction of the remaining available space, and so on, until all species occupy some portion of the niche space (Whittaker 1972, May 1975). This distribution is observed in species-poor communities (e.g., harsh or early successional) where species dominance is governed by a predominant resource requirement (Whittaker 1965, 1972). Abundance of a species is proportional to its respective niche fraction, or resource utilization (Magurran 1988). According to the model, the few very abundant species must occupy a majority of the niche space while the many rare species occupy relatively small niche fractions. The species abundance distributions of plant communities in the southern Appalachians are clearly controlled by a complex interaction of multiple factors, rather than the single controlling resource required for this model. The applicability of the geometric series to the typical southern Appalachian plant community is doubtful.

Similar to the geometric series, the log series describes relatively simple, species-poor communities. Magurran (1988) suggests a progression of geometric to logarithmic distributions as early successional communities develop, or as resources become less limiting. Unlike the geometric series, however, the log series is not based on any biological assumptions (Whittaker 1972). Pielou (1975) explains that the log series is not a biological model, but rather a statistical model, or mathematical fit of empirical data without inference of ecological relationships. Statistical models lack biological explanations, meaning the

models make no predictions about the biological mechanisms (e.g., resource-partitioning) responsible for the observed abundance pattern. Nonetheless, abundance distributions have been demonstrated to follow the log series model (Magurran 1988) validating its suitability as a mathematical description of some communities.

The log-normal model describes the abundance distribution of a species-rich community with variable resource requirements (Whittaker 1972). In such a community, high species richness coupled with a wide range of resource requirements result in a subsequently high number of factors controlling the relative abundance distribution. A normal distribution is a consequence of the multiplicative nature of these many, controlling variables (May 1975). Arguably, this distribution is governed more so by the Central Limit Theorem and the mathematical tendencies of large sets of numbers than by any biological justification (May 1975, Magurran 1988). According to the Central Limit Theorem, a distribution will be normal when a large number of factors cause random variation in the value of the given variable (Magurran 1988). In the case of a species abundance distribution from a large, heterogeneous community, the large number of factors controlling species dominance will generate a normal distribution. When species abundance is plotted on a logarithmic, rather than linear scale, the distribution is subsequently log-normal (Whittaker 1972). Several authors have proposed biological mechanisms—rather than the aforementioned statistical mechanisms—to account for the frequent fit of the log-normal model to observed abundance distributions (Magurran 1988). Whether considered to be a statistical, biological, or hybrid model, the log-normal distribution is the most ubiquitous of existing models (May 1975) and may be applicable to southern Appalachian plant communities.

In relatively homogeneous habitats, communities whose competitors are all taxonomically similar may exhibit the species abundance distribution characterized by the broken-stick, or random niche boundary hypothesis (Whittaker 1972, May 1975). The broken-stick model suggests that a single controlling resource is randomly, but somewhat evenly, partitioned among species in a given community. Accordingly, the available niche space is analogous to a stick that is randomly broken into S divisions, where S equals the number of species in the community (Magurran 1988). This model is, therefore, driven only by the species richness parameter (May 1975). Reasonable fits to the model have been achieved for communities of birds, lake sediment crustaceans, and other taxonomically similar communities, but are unlikely for the large, heterogeneous plant communities of the southern Appalachians.

Whittaker (1972) proposes viewing the described species abundance models not as independent cases, but rather as an inter-gradation of forms. The geometric series describes a species abundance distribution where a few species are dominant, but most species are rare. The log and log-normal models predict greater numbers of species with intermediate dominance. At the opposite extreme from the geometric series, the broken-stick model predicts high evenness (equal abundance) among species.

The relationship between these four models is best demonstrated by constructing a rank-abundance plot for the respective hypothetical species abundance distributions. Rank-abundance plots are a common graphical means of representing species abundance data (Magurran 1988). Graphical representations simplify data sets while preserving much of the information obscured by single-number indices. Rank-abundance plots are constructed by ranking abundance from greatest to least for all species in a sample. Abundance is plotted

on a logarithmic scale against species rank and can be represented as frequency, density, importance value, percent cover, or biomass, although the shape of the curve will differ according to the abundance variable selected. The resulting curve reveals the relationship between species richness and evenness for a given community. Curves with near vertical slopes represent communities dominated by only a few species. Horizontal slopes indicate a more equitable distribution of species. Although relatively easy to construct, the interpretation of dominance-diversity curves is not always intuitive, particularly when comparing the curves derived from two communities. Whittaker (1972) warns that inference of the ecological processes responsible for the characteristic patterns of abundance is controversial, as conflicting mechanisms have been offered as explanation of a single form. Nonetheless, the utility of species abundance models and rank-abundance plots is clearly in their ability to distinguish deviations of a community from a characteristic form, or to note dissimilarities between communities (Whittaker 1972).

There are seemingly countless approaches to graphically displaying species abundance data. Rank-abundance plots are variously presented on a logarithmic or linear scale for both abundance (y-axis) and species rank (x-axis). Frequency histograms present numbers of species that fall into specified abundance classes (e.g., number of individuals). Cumulative abundance percentage may be plotted against the log species rank to produce a k-dominance plot. The approaches are too many to describe, but the important point argued by May (1975) is that most of these methods are only superficially different variants of the same concept. Regardless of form, each approach remains a graphical descriptor of the same species abundance distribution. Although various authors have argued for the use of a

particular technique for a given scenario, the standardization of graphical forms would greatly facilitate the comparison of data sets (May 1975).

Comparative diversity profiles

One graphical technique that differs from the conventional forms of presenting abundance data is the comparative diversity profile adapted by Swindel et al. (1987) from the concept of intrinsic diversity orderings proposed by Patil and Taillie (1982). According to that concept, if each of the k most abundant species of community A are more dominant than the k most abundant species of community B, then community B is said to be intrinsically more diverse (Swindel and Grosenbaugh 1988). Swindel et al. (1987) have devised a graphical representation of Patil and Taillie's (1982) intrinsic diversity ordering concept. Rather than presenting the species abundance distribution of a single community, as is conventional with most graphical depictions of abundance data, comparative diversity profiles plot one community versus another community according to their ranked cumulative abundance vectors. The resultant curve provides an ordering of the intrinsic diversity of the two communities. To construct the comparative profile, cumulative ranked sums of abundance for each community are plotted against each other. The resulting curve is compared to the diagonal line where $y = x$. When the curve plots above the reference line, the x-axis community is considered intrinsically more diverse. When the curve plots below the reference line, the y-axis community is considered more diverse. There is no intrinsic diversity ordering between two communities whose curve crosses the diagonal reference. When two communities are intrinsically ordered, as in the above example, that ordering is index-free. That is, when a comparative profile indicates an intrinsic ordering between

communities, that ordering will be confirmed by any index, without dispute (Swindel and Grosenbaugh 1988).

Because comparative profiles present raw data, the loss of information associated with single-number indices is avoided. Consequently, additional information concerning the composition and structure of each community can be inferred from a comparative profile. Inferences that are particularly notable include the contribution of rare species to the distribution of each community. This information is especially applicable when the phenomenon of interest is the impact of disturbance on a temporal, rather than spatial community pair.

Because comparative diversity profiles are essentially derived from an index of evenness, they are subject to many of the same limitations that exist for other assessments of diversity. The level of information provided by comparative profiles may, however, make them a preferable alternative to other available diversity measures. Furthermore, the interpretation of comparative profiles is relatively intuitive; evaluating the profiles requires little understanding of complex mathematical functions or ecological principles.

Community similarity indices

A variety of measures exist for quantifying the similarity (or dissimilarity) of two communities (Huhta 1979, Wolda 1981, Magurran 1988). Typically used for measuring beta diversity of spatial site pairs, Philippi et al. (1998) note that similarity coefficients can also be applied to temporal pairs (same site, different time). A number of authors have compared similarity indices based on mathematical or biological soundness (e.g., Huhta 1979, Wolda 1981), but their conclusions often differ, perhaps dependent on the data set(s) examined. Similarity indices are either qualitative or quantitative. Qualitative measures are

based on presence/absence data, without consideration of the abundance or rarity (Magurran 1988). Jaccard's index (Jaccard 1912) is among the earliest qualitative similarity coefficients and is still in common use because of its simplicity (Magurran 1988).

$$\text{Jaccard's index: } C_J = j / (a+b-j)$$

where j = the number of species shared by the two communities, a , b = the number of species in site A and B, respectively (notation follows Magurran 1988). A similar index was developed by Czekanowski, but is more commonly known as the Sorensen index (Wolda 1981).

$$\text{Sorensen index: } C_S = 2j / (a+b)$$

where notation is as above.

Quantitative measures account for species abundance, and are generally preferred over qualitative indices (Huhta 1979). Among the simplest quantitative indices is a modification of the above Sorensen index by Bray and Curtis (Magurran 1988).

$$\text{Sorensen quantitative index: } C_N = (2jN) / (aN + bN)$$

where jN = the sum of the lower abundance of a species between sites A and B; and aN = the total number of individuals at sites A. Like many quantitative indices, Sorensen's quantitative index has been criticized for being influenced by sample size and species richness (Wolda 1981). An index that minimizes these pitfalls is the Morisita index, as modified by Horn (Wolda 1981). In an evaluation of several similarity indices, Wolda (1981) confirmed that the Morisita-Horn index is nearly independent of richness and sample size.

$$\text{Morisita-Horn index: } C_{MH} = (2\sum a_i b_i) / ((da + db) aN bN) \text{ and}$$

$$da = (\sum a_i^2) / aN^2$$

where a_n = number of individuals in the i th species of site A, and a_N = total individuals in site A. The obvious limitation of this index is the cumbersome calculation involved.

Conceptual limitations of diversity measures

All measures of diversity, whether single-number indices or more descriptive graphical representations, are subject to certain limitations. A notable conceptual limitation to species diversity measures is their association of high diversity to high evenness.

Maximum diversity is theorized to exist when abundance is equal among all species in a community. The equation of evenness with diversity contradicts the very definition of diversity, which implies difference, not evenness. Consider dominance-weighted diversity indices, which assign near-maximum values to equitable communities, with little sensitivity to the number of species in the community. Consider a hypothetical example (follows Hurlbert 1971) using Simpson's index (1-D), where for two communities with 50 and 100 evenly distributed species, the respective diversity values are .98 and .99 (with negligible fluctuation due to sample size). In this case, the large increase in species richness is masked by the contribution of evenness.

Another conceptual problem with diversity measures can be illustrated with the value judgements placed on high diversity. Presumably, to label a community as diverse is to confer upon it an associated high social, economic, or biological value. It follows that because high evenness contributes to high diversity, evenness must also be highly valued. The concept of rarity—a concept largely overlooked by diversity measures—confounds such a value judgement. Rare species are often defined as species that are narrowly endemic or limited in geographic range (Falk 1990); however, this discussion is limited to species that are locally rare in terms of abundance. May (1975) notes that a typical community will

be comprised of some common species, some rare species, and many species intermediate in abundance. Traditionally, the field of conservation biology has focused on species in the rare spectrum of a community's relative abundance distribution. A major concern is the fate of rare species following anthropogenic disturbance, including habitat fragmentation.

Consider again, two natural communities, A and B, each with the same number of species, but community A has a greater proportion of rare species, while community B has a more even abundance distribution. According to the conventional richness-evenness definition of species diversity, community B is more diverse. Community A, however, is likely to be assigned a higher priority from a species conservation perspective. Although most measures of diversity would dispute the presumption, the community with many rare species seems intuitively more diverse.

Selecting an appropriate measure

From the previous discussion of available diversity measures follows the problem of selecting the most appropriate measure for a given data set. Of course, the measures selected will, to a large degree, depend on the nature of the data set and the questions being asked. Clearly, limited options are available for a data set comprised only of species presence/absence counts. The lack of abundance data, in such a case, precludes the use of many useful measures. When species diversity is a primary theme of interest, and species abundance data are available, a good starting point is to construct a rank-abundance plot and formally test the fit of the four main abundance models. Selection of the appropriate diversity indices may depend on the pattern of abundance (Magurran 1988). For example, a given species abundance distribution may favor selection of a dominance-weighted index over a richness-weighted index. Sensitivity of an index to sample size may also be a

consideration. Aside from the mathematical or statistical concerns, the biological validity of an index should be given considerable weight. Ultimately, however, the choice to use an index may be dependent on factors unrelated to theoretical or biological concerns (Magurran 1988). Often an investigator wishes to compare a given data set to the results of comparable studies. In this case, consistency of diversity indices between studies is required for meaningful comparisons (Magurran 1988).

Alternatives to diversity measures

Few ecological investigations are initiated with the exclusive intent to examine the species diversity of a community or community set. A more plausible scenario involves the use of species diversity measures as tools to characterize more pertinent community attributes. The Diversity Study, for example, seeks to examine the general response of a vascular plant community to various levels of tree canopy disturbance. To examine that response solely using diversity measures would not only provide an incomplete characterization, but potentially could be a mischaracterization of community response. Powerful descriptors of community attributes are available in addition to diversity measures. Especially in the case of single-number indices, diversity measures associated with a reduction of data should be used judiciously as supplements to more complete descriptors. Even the utility of raw data should not be underestimated. A wealth of information is available from a simple species presence/absence list or ranked relative abundance distribution.

Taxonomic classifications

When species presence/absence lists are collected, arrangement of species into higher taxonomic levels may reveal some pattern in a community's disturbance response. Disturbance-induced increases or decreases in the members of particular families, for example, are useful observations for characterizing a disturbance response. The obvious problem with taxonomic classifications is that they are based on a subjective evaluation of form and presumed developmental origins. Traditional groupings are subject to constant rearrangement, particularly with the advent of new molecular techniques. Furthermore, taxonomic relationships do not beget functional relationships. The functional tendencies of species within a family, or even a genus, may be entirely unrelated. For example, there is no reason to assume that two closely related species will respond in a consistent direction to environmental perturbation.

Functional vegetation classifications

A more effective way to assay community response to disturbance is to examine the response in terms of plant functional groups (McIntyre et al. 1995). A classic functional grouping that remains popular is the life-form classification of Raunkiaer (1934). Raunkiaer's system is based on the position of a plant's perennating buds during harsh seasons. Perennating buds are responsible for plant regeneration following a period of dormancy. In the southern Appalachians, the shortened days and colder temperatures of winter are the primary cause of dormancy, although in some years drought may be a factor. In its simplest form, Raunkiaer's classification consists of five main life-forms:

- i) Therophytes: Annual plants, which survive the unfavorable season via seeds, rather than persistent buds.

ii) Cryptophytes: Plants whose perennating buds are buried below the soil surface as bulbs, tubers, or rhizomes. Subdivisions include terrestrial geophytes and palustrine (wetland) helophytes.

iii) Hemicryptophytes: Plants whose exposed aerial portions die back during the unfavorable season. Perennating buds persist in the upper mineral or organic soil horizon.

iv) Chamaephytes: Plants whose perennating buds persist < 25 cm above the soil surface and are protected during unfavorable seasons by leaf litter.

v) Phanerophytes: Woody plants, including vines, whose perennating buds persist > 25 cm above the soil surface.

Raunkiaer (1934) developed “normal” life-form spectrums for what he considered the four major global phytoclimates. Middle latitude deciduous and needle-leaved forest regions are included in the hemicryptophytic phytoclimate. Accordingly, hemicryptophytes should exhibit dominance for the life-form spectra of the eastern United States. Numerous authors have created life-form spectra for specific geographic regions, such as by state (McDonald 1937, Gibson 1961) or for specific ecosystems (Allard 1944, Gara and Stuckey 1992). Most studies have confirmed the inclusion of the eastern United States into the hemicryptophytic phytoclimate (Gara and Stuckey 1992). In addition to characterizing deviations of regional or local life-form proportions from the normal spectrum, community response to perturbation can be assessed by observing temporal changes in life-form spectra. McIntyre et al. (1995) examined life form spectra across different disturbance intensities for three disturbance types in Australian grasslands. Patterns of deviation in life-form spectra were correlated with intensity of grazing and soil disturbance. Although most life-form

spectra are constructed from species presence/absence lists, spectra weighted for species abundance have more ecological significance (Gara and Stuckey 1992).

Similar studies can be conducted using growth-form (Belsky 1992, Boyd et al. 1995). Growth-form, unlike life-form, is a classification based primarily on plant morphological characters and is not necessarily related to functional attributes. Shuggart (1997), however, details the effects of plant form on function, supporting the use of growth-form as a functional type. In addition to classifications based on physiognomic characters, plant functional groups could also be categorized according to pollination mechanisms, seed dispersal mechanisms, photosynthetic pathways, nutrient requirements, shade tolerance, stress tolerance, etc. (Shuggart 1997).

Species of concern

A community's response to disturbance may be monitored by quantifying the impact of perturbation on specific species, rather than on functional species groups. The most prominent of such species are obviously those officially listed as threatened and endangered on a state or federal level. Endangered species are often assumed to differ from common species in some aspect of their biology, such as resource requirements or tolerance to stress (Falk 1990). For that same reason, species that are locally rare, but not the designees of "special" status, may also be good indicators of perturbation or environmental stress. Similarly, some species are known to exhibit sensitivity to specific environmental conditions (Hunter 1990). Because these indicator species have small ecological tolerances, they serve as predictors of environmental change that may not be apparent at a community level.

Other species of concern are exotic and invasive species. Unlike rare or indicator species, the trend of interest with exotic and invasive species is their increased presence or

abundance, rather than their decline. The influx of exotic species to a native plant community is a hypothesized result of altered environmental conditions (Stohlgren et al. 1999). Hobbs and Huenneke (1992), for example, suggest that deviations from natural disturbance patterns may facilitate the replacement of native species with exotics. Although the invasion of a community by exotic species may initially enhance species diversity, the subsequent increased dominance of exotics will ultimately reduce diversity (Stohlgren et al. 1999).

Species diversity hypotheses

Numerous hypotheses have been advanced that attempt to explain the mechanisms responsible for differences in species composition and abundance distributions among communities. The most prominent species diversity models emphasize the importance of local biotic and abiotic processes as the deterministic factors of local diversity (Ricklefs 1987). Two general categories of species diversity model exist: equilibrium and non-equilibrium. The primary distinction between the two categories is the question of whether the species in a community achieve a state of competitive equilibrium (Connell 1978, Pickett 1980, Roberts and Gilliam 1995).

Equilibrium models

The equilibrium state exists when a community exhibits only minor or transient fluctuation in its species composition and abundance distribution. Although periodic disturbance may cause deviation from equilibrium, the community eventually returns to the original, stable equilibrium. The primary mechanism predicted to maintain high diversity at

equilibrium is niche diversification. Alternative or secondary models include the circular-networks hypothesis and compensatory-mortality hypothesis.

Niche-diversification hypothesis

Equilibrium models predict that species in a community coexist through extreme specialization and subsequent partitioning of the available niche space. Niche specialization minimizes competition for resources, allowing for high species diversity without direct competition pressure. Species that are not sufficiently specialized are outcompeted by competitively dominant species (Pickett 1980). Equilibrium communities are stable, co-evolved assemblages of species, each of which occupies the niche to which it is the most specialized (Connell 1978). A community persists in a stable condition until a perturbation temporarily disrupts the equilibrium species composition or abundance structure. Disturbance intervals are not frequent enough to prevent a return to the original equilibrium condition.

Circular-networks hypothesis

Rather than the linear hierarchy of competition traditionally assumed to exist in a community, this hypothesis suggests that competitive relationships among species are circular (Connell 1978). Each species has a limited arsenal of competitive interference mechanisms that allow it to eliminate some species, but succumb to others (Roberts and Gilliam 1995). No single species is competitively superior to all other species. Minimal competitive exclusion ensures equilibrium and maintains diversity.

Compensatory-mortality hypothesis

Species diversity is maintained at the equilibrium state through selective, density-dependent mortality. That is, the species that is most abundant is also subject to the highest mortality resulting from predation or other disturbances (Connell 1978). Disturbance thereby perpetuates equilibrium by preventing the competitive elimination of rare species. In forested ecosystems, a tree species that primarily holds the dominant canopy position may be more susceptible to wind, ice, and insect mortality than less dominant species. The resulting canopy gaps preclude the establishment of pure stands by encouraging the regeneration of gap-specialized species. Connell (1978) offers an example in which preferential predation of seeds or seedlings selects against common species, allowing rare species to persist in tropical rainforests. Compensatory mortality, however, has not been observed as a major contributor to species diversity maintenance, and likely acts only as a secondary mechanism, working in conjunction with more primary mechanisms (Connell 1978).

Non-equilibrium models

In contrast to the equilibrium hypotheses, several prominent models predict the maintenance of species diversity as a consequence of constant shifts in species composition and abundance that preclude equilibrium. The various mechanisms that might explain the non-equilibrium coexistence of species are detailed by the gradual-change, equal-chance, intermediate-disturbance, and dynamic-equilibrium hypotheses.

Gradual-change hypothesis

When rates of environmental change are higher than rates of competitive exclusion, shifts in species dominance could occur (Connell 1978). A dominant species exhibits a greater capacity to exploit the resources for a given set of environmental conditions. Gradual changes in that environment allow inferior competitors to persist or flourish as superior competitors lose their competitive advantage. No species is capable of establishing dominance because of high rates of environmental change. The gradual-change model has not been demonstrated in forested ecosystems, at least during an ecological time scale. Long-term environmental perturbations, such as climate change, have obviously been instrumental in determining species distributions from a geological time scale.

Equal-chance hypothesis

According to this hypothesis, all species are assumed to have equal competitive ability and resistance to disturbance or environmental change (Connell 1978). Local diversity is a function of chance colonization and the number of species available in the regional species assemblage. This hypothesis has little merit in temperate forest ecosystems, where response to disturbance and environmental stress is clearly species-specific. In the southern Appalachians, observable differences in the competitive abilities of species are responsible for species distributions along elevational, topological, and nutrient gradients (McEvoy et al. 1980, Stephenson 1982).

Intermediate-disturbance hypothesis

Random perturbations at various frequencies and intensities prevent one species from establishing dominance (Connell 1978, Petraitis et al. 1989). Perturbations may be in

the form of biotic processes (e.g., predation, disease) or abiotic disturbance (e.g., fire, wind-throw). The opportunistic response to perturbation by otherwise inferior competitors promotes their coexistence with competitive dominants (Pickett 1980). In the case of plants, because of evolved specialization in the regeneration niche, species diversity is highest when disturbance is intermediate in size, frequency, and intensity. High frequencies select against species that are slow in growing or reaching sexual maturity, or that disperse seed only periodically. Therefore, diversity will be low at high frequencies of perturbation. Less frequent perturbations allow for superior competitors to establish dominance, thereby eliminating rare species and reducing species diversity. Similarly, when the area disturbed is large, species with long-lived seeds that were dormant in the soil prior to disturbance, or species that produce abundant, wind-dispersed seeds, will colonize the gap most effectively. In contrast, small gap colonizers must be tolerant of shade and more resistant to predators. At either extreme (large vs. small disturbance) species diversity does not reflect the entire pool of potential colonizers. At intermediate sizes, a greater number of species have an equal opportunity to colonize. At intermediate intensities, where all plants are not necessarily killed, but may be damaged, both vegetative reproduction and propagule colonization are possible. This model may be applicable to the southern Appalachians where the historic disturbance regime is predominately characterized by perturbations of intermediate frequency, size, and intensity. Denslow (1980) predicts that for a given community, native species diversity is highest for the historic disturbance regime under which that community has developed and to which native species have adapted.

Dynamic-equilibrium hypothesis

Huston's (1979) model of dynamic equilibrium is a variation of the theme proposed in the intermediate-disturbance hypothesis. Accordingly, plant communities have the potential to achieve competitive equilibrium, but seldom do because of periodic perturbation. Diversity, however, is maintained not through mechanisms of specialization among species, but through differential rates of population growth. For example, if all the species' populations in a community exhibit a slow growth rate, then any species with a potential competitive advantage will be slow to establish dominance over species lacking such an advantage. The subsequent low rate of competitive displacement allows for longer intervals of species coexistence, thereby maintaining diversity. The rate of approach to equilibrium is a function of the rate of competitive displacement. Equilibrium, however, is rarely achieved because of random perturbations that reshuffle species populations into a reorganization phase. High species diversity is maintained by the interaction of low population growth rates with low to intermediate disturbance frequencies. Huston (1979) views the interaction of these conditions as a dynamic equilibrium.

An alternative model

Petraitis et al. (1989) have proposed a *general model of diversity* to explain—for equilibrium and non-equilibrium models alike—why high species diversity is most often observed at intermediate size, frequency, and intensity of disturbance. The processes that control equilibrium and non-equilibrium models are the same; only differences in the perceived spatial and temporal scales of disturbance separate the models. Species diversity is a function of species immigration and extinction. Immigration and extinction are affected

by species' life-history attributes; a species exhibits resistance to either competition or disturbance, but not both. Superior competitors are more susceptible to disturbance and experience greater mortality than poor competitors. Inferior competitors compensate by resisting or quickly recovering from disturbance. Intermediate disturbance levels maximize diversity by accommodating both species that compensate for disturbance and those that compensate for competition.

Applicability of models to the Appalachians

There is a lack of empirical evidence demonstrating the applicability of a particular model to the southern Appalachians, or temperate forests in general. Roberts and Gilliam (1995) question the feasibility of formally testing species diversity hypotheses, given the inconsistency among observed diversity patterns for seemingly similar plant communities. Furthermore, the matrix of local variables that influence the distribution and abundance of species may be too complex for a single model to describe. Another conceptual shortcoming of most current species diversity models is the failure to recognize the extent to which regional processes influence local diversity (Ricklefs 1987). Recent insights into the relationship between local and regional diversity suggest that local processes are secondary to more important regional determinants of species diversity (Cornell and Lawton 1992, Caley and Schluter 1997). While competition, predation, and local disturbance regimes influence species diversity, the ultimate driving factors may be larger-scale biogeographic and historic processes. Although elements of some species diversity models may be applicable to Appalachian plant communities, existing models have limited utility for explaining differences in species composition and abundance among communities.

Appalachian diversity and ecosystem development

Overstory response to timber harvesting

The USDA Forest Service, Coweeta Hydrologic Laboratory in Franklin, NC has been the site of a large body of work relating silviculture to vascular plant species diversity and forest development. Of particular note is the examination of successional patterns following successive clearcuts on watershed 13 (WS 13). The northeast-facing watershed was clearcut without timber removal in 1939 and again in 1952. Woody vegetation was inventoried prior to harvest in 1934, post-treatment in 1952, and again in 1977. Parker and Swank (1982) examined the responses of tree species composition, density, and richness to each clearcut. Following the 1939 treatment, *Liriodendron tulipifera*, *Acer rubrum*, and *Quercus prinus* increased in relative density. Species response varied by slope or landform position. *Acer rubrum* increased on mid to upper slopes. The increase in *Liriodendron tulipifera* was not restricted by slope or landform. *Liriodendron tulipifera* and *Acer rubrum* again increased following the second clearcut. The increase in *Quercus prinus* exhibited after the first clearcut persisted only on the upper, south-facing slopes following the second clearcut. Relative density remained stable for other *Quercus* species. Minor species (e.g., *Acer saccharum*, *Nyssa sylvatica*) declined in relative density in response to both clearcuts. Tree species richness was unaffected by successive clearcuts.

Leopold et al. (1985) further examined forest development on WS 13 by resampling woody vegetation in 1984. Successive clearcuts did not appear detrimental to stand productivity. By 1984, the watershed had attained 80% of its pre-treatment basal area, presumably due to the contribution of rapid coppice growth. The importance of stump sprouts over seeds as a regeneration mechanism was enhanced by successive clearcuts. As a

consequence of vigorous sprouting, *Acer rubrum*, *Quercus prinus*, and *Q. coccinea* also increased moderately in importance. Nonetheless, the rapid germination and height growth following release of buried seed is assumed to have contributed to the increased importance of *Liriodendron tulipifera* and *Betula lenta*. *Quercus rubra*, *Q. alba*, and many minor species decreased in importance, suggesting slower sprout growth or lower shade tolerance than in the more aggressive competitors.

Elliot and Swank (1994) examined changes in tree species diversity in WS 13 from 1934 to 1991. Species diversity, as measured by Shannon's index (H') and dominance-diversity curves, decreased over that time span following shifts in evenness. Although total basal area recovered to pre-treatment level, *Liriodendron tulipifera* comprised over 35% of that basal area. Lower diversity estimates, therefore, reflect the increased dominance of *Liriodendron tulipifera* following successive clearcuts. This is consistent with the aforementioned diversity models—particularly the intermediate-disturbance hypothesis—that predict lower species diversity at high disturbance frequencies.

Leopold et al. (1985) urge precaution in interpreting WS 13 results. Although baseline, pre-treatment data were collected for comparison to post-clearcut conditions, measurements were not consistently taken from the same sampling plots for all inventory years. Also, because all cut stems were left onsite after each clearcut, the subsequent forest development on WS 13 is not necessarily representative of operational clearcuts.

The lack of permanent sampling plots was amended as Elliot et al. (1997) evaluated temporal changes in species composition and diversity on watershed 7 (WS 7). Permanent plots were inventoried prior to a 1974 clearcut. The same plots were sampled periodically, post-harvest, from 1977 to 1993. Responses of tree species composition and diversity were

compared for three plant communities: cove-hardwood, mixed-oak hardwood, and pine-hardwood. The cumulative response of woody species confirms that clearcuts favor the early regeneration of shade-intolerant species. *Rhododendron maximum* and *Kalmia latifolia* shrubs, although shade-tolerant, also responded favorably to harvest. Woody species richness increased or remained constant across all community types. As on WS 13, *Liriodendron tulipifera* increased in dominance for the entire watershed on WS 7. Significant declines in dominance were observed for *Quercus coccinea*, *Q. velutina*, and *Carya* species.

Gilliam et al. (1995) also investigated the effects of clearcutting on overstory composition and diversity on the mixed-hardwood Fernow Experimental Forest near Parsons, West Virginia in the Allegheny Plateau. Two 20-year-old clearcut watersheds were compared to two mature (70 years old), uneven-aged stands. Basal area of the mature stands was twice that of clearcut stands, while the opposite trend was observed for stem density. Total watershed overstory species richness did not differ between clearcut and mature stands. Clearcut stands, however, exhibited significantly higher species richness per 0.04-ha sampling plot, suggesting a more even distribution for overstory species in clearcuts than in mature, uneven-aged stands. Although *Acer saccharum*, *Liriodendron tulipifera*, *Prunus serotina*, and *Quercus rubra* were the most important overstory species in all stands, the relative importance of species differed between the two stand ages. Shade intolerant *Liriodendron tulipifera* and *Prunus serotina* were relatively more important than the more tolerant *Acer saccharum* and *Quercus rubra* that dominated the mature stands. Overstory species diversity (H') was not significantly different between clearcut and mature stands.

At the Bent Creek Experimental Forest near Asheville, NC, Beck and Hooper (1986) followed the development of a clearcut hardwood stand for 20 years. Prior to harvest in 1965, the stand was dominated *Acer rubrum*, *Liriodendron tulipifera*, and *Quercus* species. The same species comprised the majority of advanced regeneration, with *Acer rubrum* seedlings being the most abundant. Two growing seasons post-harvest, *Liriodendron tulipifera* was the most dominant component of the regenerating stand. *Betula lenta*, *Robinia pseudoacacia*, *Acer rubrum*, and *Quercus* species were also important, although *Acer rubrum* and *Quercus* seedlings declined from their pre-harvest numbers. Following stand closure at year 10 was a five-year period of severe woody stem mortality resulting from intense between-stem competition. By year 20, *Betula lenta*, *Liriodendron tulipifera*, *Acer rubrum*, and *Robinia pseudoacacia* dominated the stand. *Quercus* species appear to have assumed a less important role in the developing stand than was observed in the pre-harvest stand.

From the above studies on stand development and overstory diversity following clearcutting, some general trends are apparent:

i) Shortly after harvest, biomass begins to accrue, until after some time it approaches pre-harvest levels.

Although succession models disagree on the eventual point of maximum biomass accumulation, they do agree that biomass continues to accrue as a stand approaches maturity. According to Odum's (1969) "energetics of succession", biomass accrues over time along an asymptotic curve as long as primary productivity exceeds community respiration. Biomass approaches its peak near "climax", as respiration of senescent trees

exceeds ecosystem productivity. Bormann and Likens (1979) propose an alternative model where biomass peaks prior to the “steady state”. By this model, biomass accumulates during the “aggradation phase” of forest development. As the even-aged stems of an aggrading stand increase in girth and height, biomass accumulates nearly linearly. The peak of aggradation corresponds to the point of maximum biomass accumulation; however, the increased susceptibility of the large trees to endogenous disturbance results in individual or multiple treefall gaps. This “transition phase” marks the change to an uneven-age structure and subsequent decline in biomass. Biomass should level off and fluctuate around some average value as the stand enters a hypothetical steady state. The steady state does not imply an absence of disturbance, as endogenous disturbances continually alter stand structure, particularly in the disturbance-prone Appalachians. In cases where the steady state is interrupted, or never achieved because of severe exogenous disturbances, the stand will return to a “reorganization phase” and the beginning of the stand development cycle.

ii) Stem density increases immediately after harvest to a level that greatly exceeds pre-harvest density. Density eventually levels off before declining rapidly following stand closure.

The aggradation phase of Bormann and Likens (1979) is marked not only by biomass accumulation, but also by the thinning of stems and reduced density, particularly of dominants. This phenomenon is also consistent with Oliver’s (1981) “general pattern of stand development” following a major exogenous disturbance (e.g., a clearcut). After an initial period of colonization, or “initiation stage”, stem density is reduced during the “stem exclusion stage”. Exclusion occurs when existing stems expand to occupy the available

growing space until resources become limiting (e.g., reduced light at crown closure). As a result, new stems are prevented from colonizing because of lack of growing space. Intense between-stem competition for limiting resources also promotes suppression or mortality of stems with less aggressive growth strategies.

iii) Certain species appear predisposed to initial colonization; however, these species do not necessarily persist, as seemingly less aggressive species eventually reclaim dominance at later stages of stand development.

Woody species are frequently labeled as either being pioneer or late successional species according to their regeneration and growth strategies. Similar to the trend observed at Coweeta, Bent Creek, and the Fernow, Oliver (1981) has observed, in a northern hardwood forest, the initial colonization of the stand by *Betula* and *Acer* species. *Quercus rubra*, however, eventually overtopped the pioneer *Acer* and *Betula* species to become the dominant stand component, despite low initial abundance. Two models that might account for the eventual dominance of *Quercus*, or similar late successional species, are presented by Connell and Slatyer (1977).

By the “tolerance” model, late successional species do not possess the aggressive regeneration or growth strategies that are conducive to early stand dominance. Although they grow more slowly, late successional species, because of their tolerance to limited resources, are able to survive and even grow while in inferior canopy positions. The superior ability to exploit resources allows late successional species to eventually out-compete pioneer species.

The “inhibition” model, however, suggests that a late successional species eventually gains dominance through a greater resistance to endogenous disturbance (e.g., disease, insects, ice, wind), not a tolerance to limiting resources. Once pioneer species become established, they inhibit the invasion of new species and the growth of late successional species already present. Late successional species can only gain dominance as pioneer species are eliminated through senescence or other endogenous disturbances. Without the removal of the prohibitive pioneer canopy, late successional species will remain in a suppressed position.

iv) Clearcutting results in little change in overall overstory species richness. Species diversity is high immediately following harvest, but declines following stand closure because of decreased evenness.

Odum (1969) posits that species richness and evenness should increase throughout the course of succession. The empirical data from Coweeta and the Fernow contradict Odum’s general model, instead suggesting a peak in diversity prior to stand closure. Species diversity patterns may be specific to a given ecosystem and/or disturbance history (Halpern and Spies 1995); and the complex of variables that drive species diversity is not well understood, as previously discussed. The long-term data produced by the Diversity Study may prove instrumental in elucidating the patterns of diversity that occur under various disturbance levels in the southern Appalachians.

Understory response to timber harvesting

As it has become apparent that the consequences of forest management on biological diversity are of serious concern, forest researchers have been challenged to recognize the

less heralded component of the forest community: the herbaceous understory. Conventional forest management research has long concentrated on the overstory canopy, woody regeneration, and other aspects of the plant community related to commercial forestry. Not until the early 1990s did the plant community as a whole begin to receive serious consideration in the forest management literature. In particular, an abundance of recent literature addresses the effects of silviculture on floral composition and diversity in eastern deciduous forests, where timber harvesting remains an important form of disturbance on public and private lands.

One of the most infamous attempts to assess the recovery of herbaceous understory plants from clearcutting was conducted by Duffy and Meier (1992) in the mixed-mesophytic forest region of the southern Appalachians. Herbaceous understory species richness and cover of nine primary stands were compared to nine second-growth stands in various stages of recovery from clearcutting. Secondary stands varied in age from 45-87 years. Primary stands were believed to be historically free of major anthropogenic disturbance. Only vernal herbs were sampled; late-season species were not considered. Herbaceous species richness, measured in 1-m² plots, was significantly higher in primary stands than in secondary stands. Herb cover, visually estimated using a cover-scale, was also significantly higher in primary stands. There was no positive correlation between secondary stand age and cover or richness, suggesting no trend toward recovery. These results led the authors to the contentious conclusion that current logging rotation lengths are of insufficient length to maintain herbaceous understory diversity. The results of this study, however, were subject to serious criticism concerning potential methodological errors and bias (Elliot and Loftis 1993, Steinbeck, 1993).

Elliot et al. (1997) also evaluated successional changes in understory composition and diversity on WS7 at the Coweeta Hydrologic Laboratory in North Carolina. As in the WS7 overstory study, vegetation response was compared for cove-hardwood, mixed-oak hardwood, and pine-hardwood communities. Following a clearcut in 1974, all herbaceous vegetation from 1-m² subplots was harvested in 1977, 1979, 1984, and 1993. Plants were separated by species and oven-dried to provide dry-weight biomass measurements. Species richness and Shannon's index (H') were used as estimates of diversity. Pielou's evenness index (J') was also calculated to separate the effect of evenness on species diversity. Measured values were tested for differences over time and between community types. Understory biomass was greatest in 1979; by 1993 biomass averaged $\leq 8.0\%$ of 1979 levels for each community type. Understory species diversity declined from 1977 to 1993, except in the pine-hardwood community, where no significant change was observed. Evenness tended to decline with time after clearcutting. Crown closure is assumed to have contributed to the reduction in understory biomass and richness observed in 1993. Fewer early-successional species (e.g., *Solidago*, *Aster*, *Panicum*) were able to persist following crown closure, presumably because of diminished light and resource levels. By 1993, however, forest-interior herbs (e.g., *Viola*, *Galium*, *Uvularia*) had not re-established to levels typical of mature stands in Coweeta.

In addition to examining the effects of clearcutting on overstory composition and diversity on the Fernow Experimental Forest in West Virginia, Gilliam et al. (1995) compared the same clearcut vs. mature watersheds to assess the differences in the understory. The understory of each watershed was systematically sampled in 1-m² subplots. All species ≤ 1 m tall were identified and cover was visually estimated for each species.

Species diversity was measured as species richness, and Shannon's index (H') based on natural log transformed importance values (sum of relative cover and relative frequency). The results present no conclusive differences in cover, biomass, richness, or H' between clearcut and mature watersheds. Although one clearcut watershed exhibited higher dominance by fern species, in general, species composition was similar among watersheds.

Other studies have also characterized differences between the understories of young clearcut and mature secondary forest stands. Yorks and Dabydeen (1999) examined seasonal and successional trends in understory species diversity for 17 clearcut stands vs. three mature stands, in the Allegheny Plateau of western Maryland. The age of clearcuts ranged from 1 to 26 years. Stands were selected to represent either northwest or southeast aspects. Measurement plots were established and sampled three times during the growing season to account for seasonal cover and composition differences. Presence and cover of understory species were collected in 1-m² subplots from which Shannon's index (H') was calculated using the base-2 logarithm of percent cover as the abundance measure. Species richness was calculated per 1-m² subplot and per 0.1-ha quadrat. Richness and H' were significantly higher in June and August than in October. Understory cover was significantly higher in June than in other months. No significant differences of any diversity measures were observed between northwest or southeast slopes. Stand age was not significantly correlated with any of the diversity measures.

Fredericksen et al. (1999) examined the initial understory response to various harvest intensities in oak-hickory and northern hardwood stands in Pennsylvania. Forty non-industrial, private forest stands were sampled throughout the Allegheny Plateau of northeastern Pennsylvania. Harvest intensity ranged from uncut to clearcut; most stands

were selectively harvested at differing levels. Harvested stand ages were predominately 2-8 years, while some uncut stands were free of major disturbance for over 75 years. Residual basal area served as an index for harvest intensity. The understory plant community was separated into summer and vernal categories. Harvest intensity was not correlated to species richness or diversity (H') for summer or vernal species in oak-hickory or northern hardwood stands. Summer ground and shrub cover were negatively correlated to harvest intensity in both forest types. Species composition in the vernal herb group did not differ by harvesting intensity, but summer herb composition differed for northern hardwood stands.

A similar study in the central hardwood region of Indiana compared the effects of clearcutting, group selection, and single-tree selection on understory composition and diversity (Jenkins and Parker 1999). Measurement plots were established in 37 clearcut, 45 group-selection, 44 single-tree selection, and 24 uncut stands. Species composition, richness, evenness ($H' / \ln S$), and diversity (H') were evaluated for mesic and dry-mesic slopes across various sizes and ages of silvicultural openings. No differences in species richness, evenness, or diversity were exhibited among silvicultural treatments for dry-mesic slopes. Species richness of clearcut and group selection stands was significantly higher than uncut reference stands. For mesic slopes, richness, evenness, and diversity were not correlated with opening size or age for either stand type. Percent cover was not significantly correlated with opening size or age for most species. Species composition of harvested stands generally deviated little from the species assemblages characteristic of mesic or dry-mesic stands.

In contrast to the relative consistency in overstory response to harvesting, the most predictable trend in understory response is the lack of any consistent pattern among different

communities. In part, contrasting results may be a consequence of differing methodologies. Duffy and Meier (1992), for example, examined only vernal herbs, while Elliot et al. (1997) captured late-summer species by sampling only in August. Other studies make no mention of the timing of sampling (e.g., Gilliam et al. 1995). Yorks and Dabydeen (1999) demonstrated that seasonal differences exist for both herbaceous cover and species diversity, reconfirming the importance of sampling throughout the growing season.

Another impediment to identifying a consistent pattern of understory response to disturbance is the irresolute role of community and site characteristics in determining plant species composition and diversity. The creation of predictive diversity models hinges on the ability to resolve a complex equation of causal factors that include potential unknowns such as disturbance history. Distinguishing the variables most important in determining plant species composition and diversity requires additional research of initial and long-term community response to disturbance (Halpern and Spies 1995) for a wide range of ecosystems and disturbance types (Roberts and Gilliam 1995).

III. METHODS

Study Area

Eight Diversity Study sites were originally established in the Ridge and Valley and the Cumberland Plateau of physiographic provinces of southwest Virginia, and the Allegheny Plateau of central West Virginia (*figure 3.1*). Because post-treatment data have yet to be collected on two sites and harvesting has been postponed indefinitely on a third, the current sub-study is concerned with the five sites (BB1, BB2, CL2, NC, WV1)¹ on which post-treatment data have been collected. Two of these study sites, BB1 and BB2, are located in Montgomery County, Virginia within the Blacksburg Ranger District of the Jefferson National Forest. The other two Jefferson National Forest sites, CL2 and NC, are respectively located in Wise County, Virginia, within the Clinch Ranger District, and in Craig County, Virginia, within the Newcastle Ranger District. The fifth site, WV1, is part of Westvaco Corporation's Wildlife and Ecosystem Research Forest in Randolph County, West Virginia. Sites were selected according to predetermined criteria that included aspect, elevation, percent slope, site quality, forest type, and stand age (*table 3.1*). Sites were intended to be positioned on generally south-facing, mid-elevational (600-1200 m abs), moderate slopes (10-40 %). Selected sites were moderately-productive and dominated by a mixed-hardwood forest type, age 62-100 years. Additionally, sites were stocked relatively uniformly with trees of merchantable size and form. Only sites that appeared to be free of silvicultural disturbance 15 years prior to establishment were selected.

¹ Blacksburg 1 (BB1); Blacksburg 2 (BB2); Clinch 2 (CL2); Newcastle (NC); West Virginia 1 (WV1).

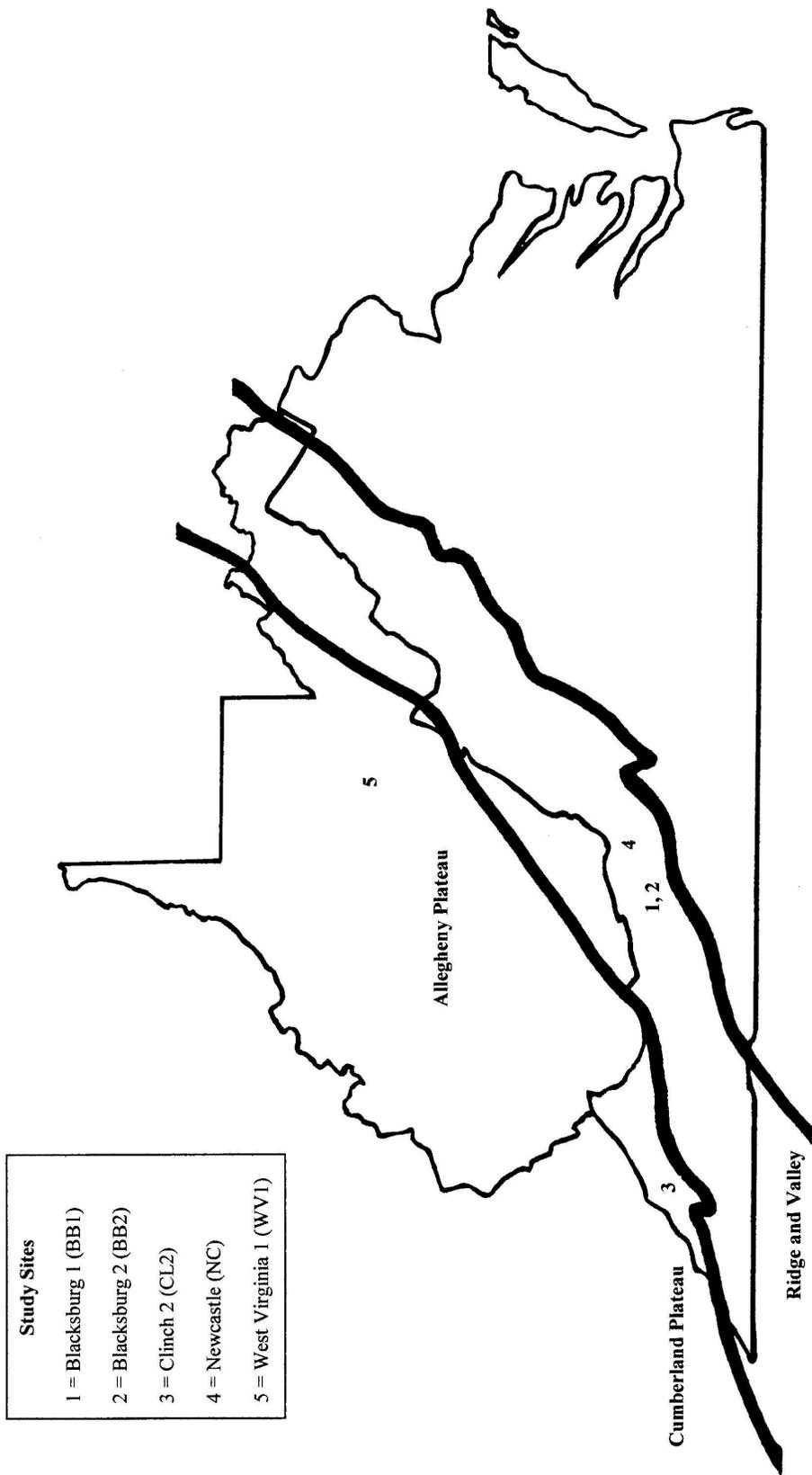


Figure 3.1. Location of five Diversity Study sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia

TABLE 3.1. Mean topographic and stand attributes at time of harvest for five study sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Site	¹ Elevation	² Aspect	² Slope	³ Age	⁴ Site Index ₅₀
BB1	710 m	153°	16%	100 yrs	23 m
BB2	730 m	151°	21%	99 yrs	22 m
CL2	1040 m	108°	30%	76 yrs	20 m
NC	670 m	150°	12%	62 yrs	18 m
WV1	880 m	270°	38%	73 yrs	23 m

¹Elevation determined from median topographic map contour line that bisects site

²Aspect and percent slope represent the means of all tree plots for the given site

³Increment cores sampled and rings counted for dominant and codominant trees

⁴Heights of cored trees measured with a clinometer; site index standardized for *Quercus alba*

Soils and Geology

The soils of all five sites are derived from sandstone and shale residuum and colluvium. Soils tend to overlie the parent sandstone or shale bedrock at depths of 40-100 cm. As is typical of most Appalachian forests, the soils are rocky, well-drained, and acidic, without exceptional moisture-holding capacity. The representative soil series on all five sites are predisposed only to slight or moderate erosion. All study sites fall within the Mesic soil temperature class, meaning the winter to summer range of soil temperature at 50 cm is 8-15 °C (Daniels et al. 1973). Soils at BB1 and BB2 are classified as (1) loamy-skeletal, mixed, mesic Typic Dystrachrepts in the Berks series, (2) loamy-skeletal, mixed, mesic Lithic Dystrachrepts in the Weikert series, and (3) fine-loamy, siliceous, mesic Typic Hapludults in the Jefferson series (Creggar et al. 1985). The Berks-Weikert complex is dominant, while the Jefferson series is only sparsely present on footslopes. A soil survey of Craig County, Virginia has not been completed as part of the National Cooperative Soil Survey; therefore, published soil data are not available for the NC site. Examination of soils at NC, however, suggests a predominance of shale- and sandstone-derived Weikert and Berks soils. Characteristics of the soils at NC are likely to be similar to those of BB1 and BB2. Soils at CL2 belong almost entirely to the stony, fine, sandy-loam phase of the Muskingum series (Perry et al. 1954). Of all the sites, soil at CL2 may be the deepest to bedrock, with a solum of up to 150 cm. Soils at WV1 belong to the Gilpin-Dekalb stony complex, and are classified as (1) loamy-skeletal, mixed, mesic Typic Dystrachrepts and (2) fine-loamy, mixed, mesic Typic Hapludults (Pyle et al. 1982).

Climate

The Ridge and Valley and Allegheny Plateau physiographic provinces are characterized by a moderately moist, temperate, mesothermal climate. Precipitation is distributed throughout the year, without a distinct dry season, although the spring is consistently wettest. Temperature and precipitation for both regions can exhibit considerable local variation because of differences in relief, aspect, and vegetation patterns. Mean annual precipitation for BB1, BB2, and NC is approximately 105 cm (NOAA 1995). Annual precipitation is slightly higher at WV1 (107 cm), due in part to higher winter snowfall (Pyle et al. 1982). The annual precipitation at CL2 (124 cm) is higher than the other Ridge and Valley sites (NOAA 1995), and is more typical of the annual average for the nearby Cumberland Plateau. The annual, mean daily temperature is also highest at CL2 (12.5 °C), ranging from a January average of 0 °C to a July average of 21.5 °C (NOAA 1995). Mean daily temperature for the other Ridge and Valley sites is approximately 10.8 °C, with annual January and July temperatures of -1.0 °C and 20.5 °C, respectively (NOAA 1995). WV1 exhibits the coldest average January temperature (-1.6 °C), but is similar to BB1, BB2, and NC in July (20.5 °C). The WV1 annual, mean daily temperature (9.7 °C) is the lowest of all sites (Pyle et al. 1982).

Woody Vegetation

The study sites are contained within Braun's (1950) Oak-Chestnut Forest region of the eastern deciduous forest, although CL2 is strongly influenced by the Mixed Mesophytic Forest region, and WV1 exhibits characteristics of the Northern Hardwood region. The "mixed-hardwood" region may be an equally appropriate and more inclusive name that

obviates the delimitation of Braun's more specific forest regions. Following the introduction of *Cryphonectria parasitica* (chestnut blight), and subsequent elimination of its primary host, *Castanea dentata*, species of *Quercus*, *Acer*, and *Carya* were among the species to assume dominance in mixed-hardwood stands. *Liriodendron tulipifera*, *Prunus serotina*, *Tilia americana*, *Fagus grandifolia*, and species of *Fraxinus*, *Betula*, and *Magnolia* are other common dominants that may be very important, locally. *Nyssa sylvatica*, *Oxydendrum arboreum*, *Cornus florida*, *Acer pensylvanicum*, *Amelanchier arborea*, and *Ilex* species are frequent in the intermediate or suppressed canopy positions. Important shrub species include *Kalmia latifolia* and species of *Vaccinium*, *Rhododendron*, and *Viburnum*.

Hammond (1998) characterized the pre-treatment vascular plant community for all eight Diversity Study sites. As anticipated, *Quercus* species were the dominant overstory component of all sites (table 3.2). BB1 and BB2 were dominated by *Quercus alba*, *Q. prinus*, *Q. velutina*, *Acer rubrum*, and *Liriodendron tulipifera*. *Quercus rubra*, *Acer rubrum*, *Q. prinus*, *Q. alba*, and *Oxydendrum arboreum* were major components at CL2. The overstory of NC is suggestive of a low-quality site: *Quercus coccinea*, *Q. prinus*, *Q. alba*, *Q. velutina*, and *Nyssa sylvatica* dominate the NC canopy. In contrast, the dominance of WV1 by *Quercus rubra*, *Acer rubrum*, *Liriodendron tulipifera*, *Fagus grandifolia* and *Magnolia fraseri* indicates a more productive, mesic site.

Examination of the pre-treatment midstory (stems 1-5 m in height) of each site suggests that in the absence of major disturbance, the overstory canopy would eventually shift away from the current dominance by *Quercus* species. When measured by relative percent of crown cover, *Quercus prinus* was the only species of oak to comprise more than one percent of the midstory crown for any site (table 3.3). Major components of the BB1

TABLE 3.2. Pre-treatment basal area¹ by species, as measured in 576-m² tree plots² and expanded to a per-ha basis. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	-----Basal area (m ² /ha)-----				
	BB1	BB2	CL2	NC	WV1
<i>Acer rubrum</i>	1.1	1.8	6.6	0.8	7.5
<i>Fagus grandifolia</i>	np	np	np	np	3.2
<i>Liriodendron tulipifera</i>	1.1	2.1	0.8	np	3.5
<i>Magnolia acuminata</i>	np	0.4	0.4	np	0.3
<i>Magnolia fraseri</i>	np	np	0.7	np	2.6
<i>Nyssa sylvatica</i>	0.3	1.0	0.5	0.7	0.5
<i>Oxydendrum arboreum</i>	0.2	1.7	3.1	0.9	0.3
<i>Prunus serotina</i>	0.3	np	np	np	1.1
<i>Quercus alba</i>	7.8	2.9	3.3	2.5	np
<i>Quercus coccinea</i>	2.9	0.1	0.1	8.9	np
<i>Quercus prinus</i>	4.3	11.2	4.1	6.6	4.7
<i>Quercus rubra</i>	0.5	1.0	6.2	0.1	10.0
<i>Quercus velutina</i>	3.3	3.3	1.4	1.6	np
Miscellaneous	3.8	1.2	1.9	2.1	1.7
TOTAL	25.6	26.7	29.1	24.2	35.4

¹Basal area estimates from Hammond (1997)

²n = 21 for all sites except WV1, where n = 15

and BB2 midstory included *Acer rubrum*, *Nyssa sylvatica*, and *Cornus florida*. CL2 was the only site where the midstory was dominated by *Castanea dentata* (24.5%). *Acer rubrum*, *Magnolia fraseri*, and *Oxydendrum arboreum* were also important at CL2. *Nyssa sylvatica* was overwhelmingly abundant (79.7%) at NC. *Fagus grandifolia*, *Acer pensylvanicum*, *Acer rubrum*, and *Betula lenta* were the most important midstory species at WV1.

Although variable by site, general trends were observed across sites in their pre-treatment, woody understories. The Ericaceae family was dominant, particularly species of *Vaccinium* and *Rhododendron* in the Ridge and Valley sites. Seedlings of *Quercus* species and *Acer* species were important across all sites. *Sassafras albidum* was abundant at BB1, BB2, and NC. *Smilax* species were also abundant across all sites.

Land-use history

Beginning in the late 1800s and extending through the 1930s, the majority of primeval Appalachian forest in Virginia and West Virginia was extensively logged (Clarkson 1964, Sarvis 1995). In 1900, Virginia and West Virginia are estimated to have produced 30% of the nation's hardwood lumber (Sarvis 1995). The advent of the Shay locomotive, incline logging, and the band saw facilitated the rapid removal of timber from previously inaccessible stands (Clarkson 1964). Consequently, most of the region's forestland, today, is second-growth, except for scattered acreage that was non-merchantable, inaccessible, or overlooked.

U.S. Forest Service documents, as well as the work of Forest Service historians and archaeologists, confirm the logging history of the four Jefferson National Forest sites. The Weeks Act of 1911 authorized the federal purchase or condemnation of private lands for inclusion in the National Forest system. BB1, BB2, NC, and CL2 were all included in large

TABLE 3.3. Pre-treatment relative crown cover¹ by midstory species as measured in 36-m² shrub plots². Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Relative crown cover (%)				
	BB1	BB2	CL2	NC	WV1
<i>Acer pensylvanicum</i>	0.2	np	1.3	np	19.3
<i>Acer rubrum</i>	27.0	21.8	16.3	1.3	13.3
<i>Acer saccharum</i>	0.7	2.3	np	np	5.6
<i>Amelanchier arborea</i>	3.9	1.7	4.0	1.2	0.3
<i>Betula lenta</i>	np	0.8	0.7	np	9.6
<i>Castanea dentata</i>	0.6	1.5	24.5	4.7	0.2
<i>Cornus florida</i>	17.3	9.8	0.1	5.4	np
<i>Fagus grandifolia</i>	np	np	np	np	33.4
<i>Hamamelis virginiana</i>	2.3	np	6.2	1.0	np
<i>Magnolia acuminata</i>	np	1.2	5.9	np	0.1
<i>Magnolia fraseri</i>	np	np	13.0	np	0.9
<i>Nyssa sylvatica</i>	14.3	12.6	1.1	79.7	0.5
<i>Oxydendrum arboreum</i>	0.5	9.8	10.7	4.1	1.1
<i>Pinus strobus</i>	2.3	3.9	np	np	np
<i>Quercus prinus</i>	4.1	6.4	np	0.6	0.1
Miscellaneous	26.8	28.2	16.2	2.0	15.8

¹Crown cover estimates from Hammond (1997)

²n = 63 for all sites except WV1, where n = 45 (from 5 treatment plots)

tracts purchased between 1930 and 1940. Prior to purchasing these tracts, the Forest Service conducted surveys and appraisals of each tract, the results of which were reported in Acquisition Examination Reports (AERs). Summarized in the AERs were often detailed site descriptions, natural resource appraisals, and land-use histories.

BB1 and BB2 were included in a 1430-ha tract purchased from a private estate in 1940. The AER indicates that in 1940, sawtimber-size stems were absent from the tract. Pole-timber accounted for 694 ha, while the remainder of the tract was in young saplings or early reproduction. Aerial photographs taken in 1935 suggest that parts of the tract were subject to hot fires shortly before 1935 (Ed Leonard, Blacksburg Ranger District, pers. comm.). Fire-suppression policies on federal lands would have contained fires on the tract after its acquisition in 1940.

CL2 was acquired as part of a direct purchase of 8255 ha from the Virginia Coal and Iron Company in 1936. According to the AER, the entire tract was logged or culled at least once prior to purchase. The portion of the tract that contains CL2 was purportedly logged 1926-27 by the Clinch Valley Lumber Company. At the time of examination in 1934, 6255 ha of the tract were in saplings, early reproduction, or expected reproduction. For a period of 10 years beyond the purchase date, Virginia Coal and Iron Company retained the right to harvest the 347 ha of virgin timber remaining on the tract.

In 1935, the Forest Service purchased a 16000-ha tract from the Craig-Giles Iron Company. A large portion of the tract, including the current location of the NC site, lies within John's Creek Valley, an area whose logging history is well-documented (see Sarvis 1995). In 1912, Tri-State Lumber Company, from Pennsylvania, purchased timber rights to the Craig-Giles Iron Company holdings in John's Creek Valley. In 1915, Tri-State began to

extract the estimated 100-150 million board feet of lumber purportedly growing on 11250 ha, within the valley. By 1921, Tri-State had extracted nearly all of the valuable *Quercus alba*, *Q. rubra*, *Q. prinus*, *Liriodendron tulipifera*, *Tsuga canadensis*, and *Carya* species. In addition to nearly 25 portable saw mills, Tri-State erected a large band mill at the confluence of Oregon Creek and John's Creek, not more than two miles from the NC site. Because there was not a railroad in John's Creek Valley, Tri-State also constructed an incline rail system to haul lumber north, over Potts Mountain, to a shipping point for the Potts Valley Branch of the Norfolk and Western Railway, in Waitesville, West Virginia.

Logging was not the only major disturbance on lands surrounding NC. The Forest Service AER for the Craig-Giles Iron Company tract reports the occurrence of intermittent fires that "have not only damaged and destroyed large quantities of reproduction and mature timber, but also have seriously depleted the productive capacity of the soil." A primary cause of fires at the time was sparks from the railway system. Local residents also started fires to encourage vegetative sprouting on which their cattle could graze (Ed Leonard, Blacksburg Ranger District, pers. comm.). By the time the Forest Service purchased the 16000-ha tract in 1935, only 2076 ha were in pole-size timber. The remainder of the forest was in saplings, early regeneration, or barren.

Although extensive records of the logging and land-use history are not available for the WV1 study site, it can be safely assumed that similar events occurred. In the book *Tumult on the Mountain*, Clarkson (1964) details the logging and railroad industry of West Virginia, including Randolph County and the lands surrounding WV1. In addition to the loss of the American chestnut, extensive logging and intermittent fires are the most influential disturbance events to shape southern Appalachian forests.

Study Design

Experimental design

A randomized incomplete block design with sub-sampling was established in which five, 14-ha sites were treated as blocks. The block design was selected to reduce the error associated with inherent site variability in order to improve the precision of treatment comparisons. Within each block, seven silvicultural prescriptions were randomly assigned to adjacent 2-ha treatment plots (*figure 3.2*). Area constraints at WV1 allowed for placement of only five, rather than seven, treatment plots. The herbicide and low-leave shelterwood prescriptions were not applied. Nested within each treatment plot are three levels of subplots: tree plots, shrub plots, and herb plots (*figure 3.3*).

Treatments

The seven silvicultural prescriptions were intended to represent regeneration alternatives that are currently used, or being considered for use, in the Appalachian hardwood region. The study was designed to observe the effects of operational silviculture practices, rather than just experimental effects of treatments. Buffers were not established between treatment plots. Skid trail design and placement was at the discretion of the logger. Consequently, post-treatment results reflect edge and skid-trail effects, in addition to treatment effect. Commercial loggers using chainsaws and skidders typical of the region's moderate slopes conducted all harvesting. Loggers were encouraged to adhere to Best Management Practices in accordance with state and local guidelines and regulations. An 80-year rotation length is intended. Prescriptions include a variable range of canopy manipulation and stand structure, and consequently represent a full range of light

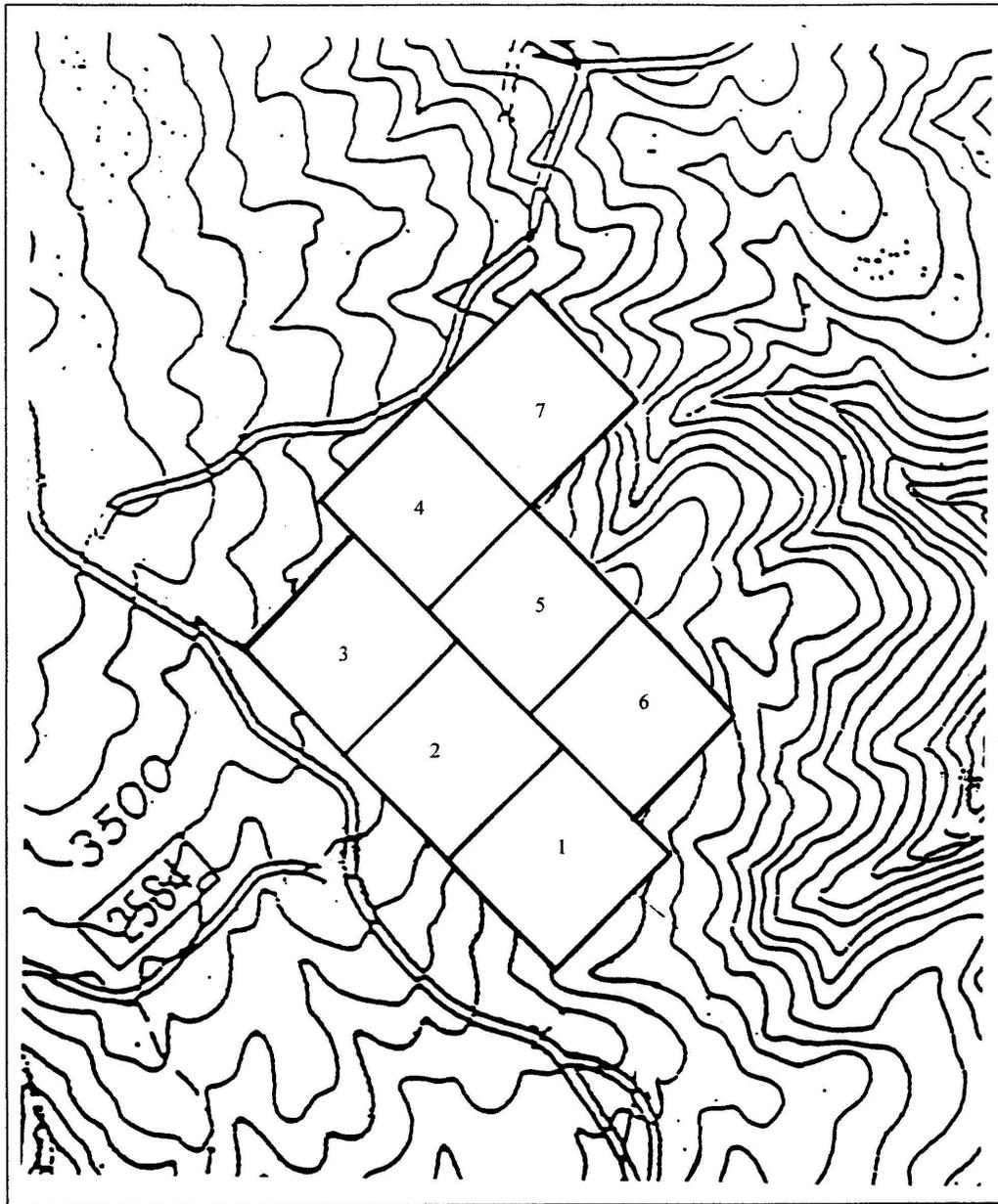


Figure 3.2. The random arrangement of 2-ha treatment plots at CL2, one of five Diversity Study sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment Plots	
1	= Clearcut
2	= Group selection
3	= Control
4	= Leave tree
5	= Understory herbicide
6	= Low-leave shelterwood
7	= High-leave shelterwood



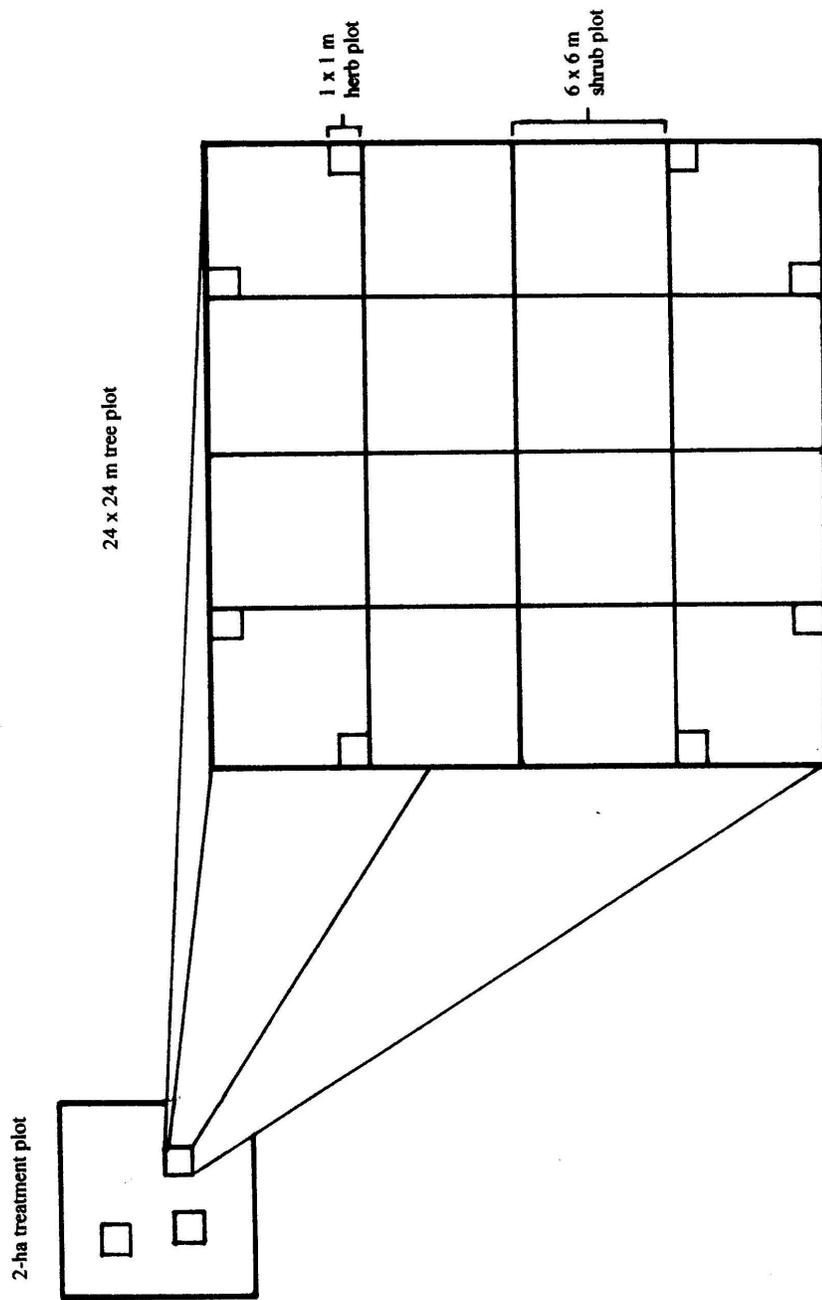


Figure 3.3. Nested-plot design for sampling the herb, shrub, and tree strata at five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia

conditions on the forest floor. Prescription application was completed in March 1995 for BB1, June 1996 for BB2 and NC, September 1997 for WV1, and March 1998 for CL1 (table 3.4).

Control

Control plots were not silviculturally manipulated in order to maintain a basis of comparison for treatment effects. Buffers were not maintained between the control and adjacent treatments. Skid-trails were not necessarily excluded from entering control plots.

Understory control with herbicide

Streamline basal herbicide applications were used to selectively treat woody understory vegetation (1-5 m). Woody competition was controlled to encourage regeneration of 14 preferred species (Appendix A). Preferred species were selected according to merchantability, wildlife value, longevity, and resistance to *Lymantria dispar* (gypsy moth). Stems were individually treated on the lower 15-30 cm to the point of runoff with an oil-herbicide solution. Methylated seed oil was used as the herbicide carrier. Initially, the selected active ingredient (a.i.) was triclopyr ester (13.6% a.i. Garlon 4[®]), applied via backpack sprayers fitted with jet-fan nozzles. Some species (e.g., *Nyssa sylvatica*) proved resistant to Garlon 4[®] alone. Following the recommendation of Dr. S. M. Zedaker (pers. comm.), Virginia Tech Department of Forestry, a cocktail of triclopyr and imazapyr (27.6% a.i. Stalker[®]) was used and found to be more successful in controlling resistant species.

TABLE 3.4. Current and projected status of treatment application and vegetation sampling of five Diversity Study sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Site	Pre-treatment inventory	1 st Post-treatment inventory	2 nd Post-treatment inventory	Harvest start	Harvest completion
BB1	1993	1996	1999	Nov-94	Mar-95
BB2	1995	1998	2001	Nov-95	Jun-96
CL2	1995	1999	2002	Aug-97	Mar-98
NC	1995	1998	2001	Nov-95	Jun-96
WV1	1996	1999	2002	May-97	Sep-97

Group selection

Within the 2-ha treatment plot, all stems > 2.5 cm were removed from 0.5 ha, divided into 2-3 circular groups. Diameters of groups were to be 1.5-2 times the height of adjacent trees. Subsequent 20-year cutting cycles will each remove an additional 0.5 ha. Timber stand improvement (TSI) was implemented between groups in order to encourage preferred species regeneration and improve tree growth and quality in the residual stand. Target residual basal area (b.a.) following TSI was 15-20 m²/ha.

High-leave shelterwood

A partial harvest was conducted, retaining 12-15 m² b.a./ha, distributed evenly over the 2-ha treatment plot. The residual shelter was to consist of dominant and codominant stems, favoring members of the preferred species list. Residuals were to be of good form with a target diameter at breast height (d.b.h., 1.37 m from ground) of 25-40 cm. Removal of the residual overstory is contingent on the successful establishment and growth of desirable regeneration. Regeneration release should normally occur 5-10 years following the initial partial harvest. Herbicide or mechanical control of unwanted regeneration may be applied as deemed necessary to meet species composition objectives.

Low-leave shelterwood

A partial harvest was conducted, retaining 4-7 m² b.a./ha, distributed evenly. Poletimber trees, 5-25 cm d.b.h., were to compose the residual canopy. Because of the dubious merchantability of the residual stand, tree form received less consideration than in other prescriptions. Upon attaining a sufficient establishment and growth of regeneration, a release harvest may be desirable. Alternatively, the residual shelter may be retained as a

component of the regenerating stand. Again, herbicide or mechanical control of undesirable competition may be applied.

Leave tree (deferment)

A single, partial harvest was conducted, retaining 3-4 m² b.a./ha, distributed evenly. A maximum of 45 dominant and codominant stems, ≥ 30 cm d.b.h., were retained per hectare. Sawtimber in larger diameter classes is preferred, thereby reducing the number of stems/ha. Residual basal area was not to exceed 4-5 m²/ha. This prescription is not a shelterwood; residual trees are retained through the next rotation, rather than harvested as a regeneration release. Residuals are left primarily for aesthetic reasons and provide no functional role for the regenerating stand. Wildlife may benefit from residuals that produce mast or are suitable as perches for avifauna. Residual trees were selected for good form and potential to live 60-80 years, until the next rotation. Mast-producing species were preferred.

Clearcut

All merchantable stems were removed as part of a single commercial harvest. Non-merchantable stems to a 5 cm d.b.h. lower limit were felled in a subsequent site preparation. Mast, snag, or cull trees could be retained for wildlife purposes, but could not exceed 10 stems/ha.

Plot establishment

Treatment plots

Treatment plot boundaries were delineated using a hand compass and fiberglass tape. Flagged trees marked boundaries at 15 m intervals. Treatment plot corners were triple flagged at the nearest tree. Following prescription application, treatment plot corners were

permanently marked with reinforcement bars and labeled with aluminum tags. Permanent measurement plots are nested within treatment plots (*figure 3.3*).

Tree plots

A random systematic procedure was used to locate three 24 m x 24 m tree plots within each treatment plot. Tree plot centers were located at a random distance from the treatment plot center using a random distance generator whose maximum distance was 36.9 m, to ensure a 23 m buffer between tree plot perimeters and the treatment plot boundary. The first tree plot center was also located at a random direction from the treatment plot center, using a random azimuth generator. The directions of the two remaining tree plot centers were determined by adding 120° and 240°, respectively to the azimuth of the first randomly located tree plot center. The distances from tree plot centers to the treatment plot center were extended in the case of overlapping tree plots. Tree plot centers were permanently marked with rebar inside a PVC pipe.

Tree plot corners were located from a tree plot center using a staff compass and fiberglass tape, such that plot boundaries were aligned in cardinal directions. Corners were also permanently marked with rebar inside PVC pipes. Plot centers and corners were labeled with unique numbers. PVC pipes were also driven into the ground at 5, 6, 12, 18, and 19 horizontal meters along each side of the plot boundaries. Plot boundary markers were driven into the ground prior to harvest operations to avoid damage by logging machinery. Markers were relocated and missing PVC or rebar replaced prior to post-treatment sampling.

Subplots

Tree plots were further divided into sixteen 6 m x 6 m quadrants used to sample shrub stratum attributes. PVC pipes at the 6, 12, and 18 m positions of the four tree-plot boundaries were used to create a 4 x 4 grid of shrub subplots. Six tapes were used to delineate temporary interior grid boundaries at the time of sampling. Additionally, eight 1 m x 1 m herb subplots were nested interior to the perimeter of each tree plot. Two herb subplots for each side of the tree plot were located at the paired 5, 6 m and 18, 19 m PVC pipes. Herb subplots were numbered from 1-8, starting at the northwest tree plot corner, and incrementing in a clockwise direction.

Plot measurement

Treatment plots

A presence/absence inventory (walk-through) was conducted for each 2-ha treatment plot. Crewmembers were spaced at 2-4 m intervals from a plot corner along a treatment plot boundary. Maintaining an equal distance between crewmembers, the crew proceeded toward the opposite treatment plot boundary, recording on data sheets all woody and non-woody vascular plant species. Repeated passes were made until a 100% inventory was complete. Species were recorded only once, regardless of the frequency encountered. Strausbaugh and Core's, Flora of West Virginia (1978) was favored as the primary floral guide and taxonomic key to aid in species identification. Samples of unknown species were collected and identified using reference collections at the Massey Herbarium at Virginia Tech. The expertise of Tom Wieboldt, botanist and associate herbarium curator, was invaluable in both the field and herbarium.

Tree plots

Tree plots were used to measure attributes of all stems within the tree stratum, delineated by a minimum height of 5 m. The same cloth tape grid system used to delineate shrub subplots was used as an X-Y coordinate system for determining the spatial location of all trees within the tree plot boundaries. Each tree was permanently tagged below stump height with an aluminum tag imprinted with a unique number. Tree attributes assessed include species, d.b.h., live/dead status, canopy position, and canopy health. Canopy positions were identified as dominant, codominant, intermediate, or suppressed. Trees were assigned a canopy health from 1-5, ranging from 90-100 % healthy to dead. Additional codes were recorded in case of insect damage, animal damage, mechanical damage, ice damage, disease, lightning strike, excessive lean, tree throw, or broken top. Tagged trees that were harvested during prescription application were assigned codes for harvest, and where applicable, stump sprouting. Tree plot data were recorded on an electronic, hand-held data recorder. A presence/absence walk-through was also conducted in each tree plot, using the same procedure outlined for treatment plots.

Shrub subplots

Three of the 16 shrub subplots were randomly selected for the measurement of shrub stratum attributes. The shrub stratum was defined as all stems 1-5 vertical meters from the ground. The same subplots measured during pre-treatment sampling were re-measured in post-treatment sampling. Crown diameter and number of rootstocks were recorded by species. Crowns were measured with a cloth tape in two perpendicular directions, and the average used to calculate crown cover. Shrub subplot data were also recorded on an electronic, hand-held data recorder.

Herb subplots

Six of eight herb subplots were randomly selected for sampling herbaceous stratum attributes. The same subplots measured in the pre-treatment sampling were re-measured post-treatment. A portable, 1-m², PVC frame was aligned interior to the tree plot boundary to delineate each selected herb subplot. Number of individuals was counted and foliage cover estimated by species for all woody and non-woody stems rooted within the sampling frame. All stems < 1 m in vertical height were considered components of the herbaceous stratum. The method used for identifying an “individual” varied by growth patterns. Using ferns as an example, members of the genera *Osmunda*, *Dryopteris* and *Polystichum* grow in clumps, and each clump was, therefore, identified as an individual. Members of the genera *Athyrium*, *Dennstaedtia* and *Thelypteris*, however, spread via underground rhizomes, and do not form tight clumps. Each leaf, rather than clump, was tallied as an individual for these genera. Foliage cover was visually estimated as a percentage of 1 m², using a cover scale where class 1 = 0-7%, 2 = 8-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-93%, and 6 = 94-100% cover. All data were recorded on hand-held data recorders.

Sampling schedule

Pre-treatment sampling was conducted on each site the growing season immediately prior to prescription application (*table 3.4*). Post-treatment sampling was conducted the second growing season following application. Walk-through inventories and herb-plot sampling were performed in mid-May to early June and again in early August. An early and late season sampling was necessary to account for seasonal differences in species

assemblages or timing of flowering. Flower characters are the most reliable for identifying to species level, particularly with problematic genera such as *Solidago*, *Aster*, *Carex*, and *Panicum*. Walk-through species composition lists were combined for the early and late sampling periods. The shrub and tree strata were sampled only once each season.

A second post-treatment sampling was conducted on BB1 in the summer of 1999. The remaining sites are also scheduled for re-sampling the fourth growing season after prescription application. Thereafter, sites will likely be re-measured in ten-year intervals beginning with the tenth growing season.

Hypotheses and Data Analysis

Five general hypotheses were tested to assess the response of the vascular plant community to seven silvicultural alternatives. The response was characterized in terms of species diversity, community similarity, functional plant classifications, exotic species, and stand structure.

Species diversity

Species diversity indices and graphical diversity profiles were used to evaluate initial changes in species diversity. The null hypothesis tested was

(1) H_0 : No changes in species diversity occur in response to seven silvicultural prescriptions.

Species richness

Species richness was measured as the number of species per unit of area sampled. Number of species was counted for herb subplots, shrub subplots, tree plots, and treatment plots. Changes in species richness by prescription were tested for

- i) herb stratum: the numbers of woody and non-woody, herb-stratum (≤ 1 m in height) species were separately tallied for each of 18, 1-m² herb subplots per treatment plot.
- ii) shrub stratum: the numbers of woody, shrub-stratum (1-5 m in height) species were tallied for each of nine, 36-m² shrub subplots per treatment plot.
- iii) tree stratum: the numbers of tree stratum (> 5 m in height) species were calculated for each of three, 576-m² tree plots per treatment plot.
- iv) tree-plot richness: the numbers of woody and non-woody species, regardless of stratum, were separately tallied for each of three tree plots per treatment plot.

v) treatment-plot richness: the numbers of woody and non-woody species, regardless of stratum position, were separately tallied for each 2-ha treatment plot

Heterogeneity indices

To account for species evenness in addition to richness, species diversity was also measured using Simpson's index and Shannon's index. Data from herb subplots were pooled and tested at the tree-plot level. Species abundance was measured as number of individuals. Simpson's index was calculated and transformed to $1/D$ because of its greater ability to discriminate between similar communities. Shannon's index values were transformed to $\exp H'$ to better discriminate between communities and to facilitate comparison with Simpson's index values.

Comparative diversity profiles

Comparative diversity profiles were constructed to compare pre- vs. post-treatment communities for each silvicultural alternative. Pre-treatment, herb-plot abundance data were separately pooled for each prescription across all five sites. The same was done for post-treatment data. The cumulative ranked abundance vector of each of the resulting seven pre-treatment communities was plotted against its respective post-treatment community. Stated differently, the five-site, post-treatment community was plotted against the five-site, pre-treatment community for each silvicultural alternative. The result was seven curves, each curve representing one of the seven silvicultural prescriptions. The curves were evaluated, as previously discussed, to determine if there is an intrinsic ordering of the pre- vs. post-treatment communities. Statistical testing of this graphical approach is not possible.

In constructing abundance vectors, species were lumped into respective genera when plant identification to species level was dependent on inflorescence (e.g., *Solidago*, *Aster*, *Carex*, *Poa*). Consequently, diversity profiles are approximate and should be considered conservative, particularly for post-treatment communities where such species were prolific colonizers.

Community similarity

Two qualitative and two quantitative similarity indices were selected to test the hypothesis,

(2) H₀: No changes in species composition occurred in response to seven silvicultural prescriptions.

Qualitative similarity indices

Jaccard's index and Sorensen's index were selected to evaluate post-treatment differences in species composition, based only on species presence data. Indices were calculated at two scales, using species presence data from treatment plot walk-throughs and from herb plots pooled to the tree-plot level.

Quantitative similarity indices

Post-treatment community composition differences were also evaluated using the Morisita-Horn index and modified Sorensen quantitative index. Calculations were based on species abundance data (number of individuals) pooled from herb plots to the tree-plot level. The quantitative indices are, therefore, comparable to the qualitative indices calculated from pooled herb plots.

Functional plant groups

Two functional plant classifications were used to characterize the initial community response to silviculture. The null hypothesis tested was

(3) H_0 : Implementation of seven silvicultural prescriptions causes no deviation in the normal southern Appalachian plant community life-form spectrum or growth-form spectrum.

Raunkiaer's life-form

For each treatment plot, species were weighed by their frequency of occurrence in the three tree plots (assigned a value of 1, 2, or 3), using presence data from tree-plot walkthroughs. Species were then grouped and their frequency counts summed into Raunkiaer's five main life-forms classes: therophytes, cryptophytes, hemicryptophytes, chamaephytes, and phanerophytes. The sum total of frequency counts in all classes was used to calculate the relative importance of each class. Abundance data from herb plots would have provided a more accurate measure of importance; however, herb plots would produce an inadequate life-form spectrum, because they capture less than 50% of the total species in a treatment plot.

Growth-form

For each treatment plot, a growth-form spectrum based on relative importance was produced in the same manner as the life-form spectra. Species were grouped into seven growth-form classes: annual/biennial forbs, perennial forbs, graminoids, pteridophytes, shrubs, woody vines, and trees.

Exotic species

Pre- and post-treatment counts of exotic species by prescription were used to test the hypothesis,

(4) H₀: Implementation of seven silvicultural prescriptions does not increase a community's susceptibility to exotic plant species invasion.

Woody and non-woody exotic species counts were tallied from tree-plot and treatment-plot walkthrough data. Statistical analysis followed the same ANOVA procedure as used for species richness, and other diversity indices.

Stand structure

Structural attributes of the tree and shrub strata were measured to confirm that the implemented silvicultural prescriptions represent a range of disturbance intensities as a consequence of various levels of canopy and midstory manipulation. The hypothesis tested was

(5) H₀: No changes in midstory and overstory structural characteristics occur between stands following implementation of seven silvicultural alternatives.

Basal area and mean d.b.h.

D.b.h. was measured for all stems >5 m in height within tree plots. D.b.h values were used to calculate basal area, which was expanded to a per-ha basis for each tree plot.

Shrub cover

Shrub crown diameters were used to estimate shrub crown area. Crowns were assumed to be circular. Crown areas were summed for each sampled shrub plot. Shrub cover of each plot was expanded to a per-ha basis.

Statistical analysis

The objectives of the statistical analysis were to (1) detect differences in measured attributes among the seven prescriptions, and (2) detect differences between pre- and post-treatment attributes for each prescription. All data were tested for normality using a Shapiro-Wilkes test in PROC UNIVARIATE, option NORMAL (SAS Institute 1996). Because data were not found to be non-normal, data were not transformed prior to testing. Student's paired t-tests were used to detect pre- to post-treatment changes in measured attributes for each prescription. Differences were significant when P was less than $\alpha = 0.10$.

For all single-variable measures (species diversity, species composition, exotic species counts, stand structure), differences among prescriptions were tested with a one-way analysis of variance (ANOVA) using PROC GLM (SAS Institute 1996). Pre-treatment attributes were tested to determine the need for a covariate in post-treatment testing. Because pre-treatment differences were not detected, covariates were not used in testing for post-treatment differences among prescriptions. Unbalanced data required the use of LSMEANS, option PDIFF (SAS Institute 1996) as a post-hoc separation of treatment means. Differences were considered significant when P was less than $\alpha = 0.10$.

Multivariate analysis of variance was performed to test for differences among prescriptions for multiple-variable classes (life-form, growth-form). Tests were conducted using the MANOVA statement within PROC GLM (SAS Institute 1997). MANOVA produced a univariate analysis-of-variance table for each dependent variable specified. Correlation between variables was examined in the partial correlation matrix associated with the error effect matrix. Wilk's Lambda statistic was used as a test of overall treatment effect at $\alpha = 0.10$.

IV. RESULTS

The response of the plant community to disturbance is presented in two general ways: (1) the combined community response (all silvicultural prescriptions combined), and (2) the effects of each of the seven silvicultural prescriptions. The latter is further described by examining the pre- to post-treatment changes in attributes for each prescription as well as the comparative differences in attributes among post-treatment prescriptions. Because the primary purpose of the Diversity Study is to observe community response to specific prescriptions, the response to the overall silvicultural operation was not formally tested. The greater part of the results is devoted to presenting the individual effects of each silvicultural prescription on various plant community attributes.

Combined community response

The overall community response is characterized by considering the silvicultural manipulations as one single disturbance event, rather than seven separate prescriptions. As such, the pre-disturbance “community” is comprised of the pre-treatment species assemblages of all five sites, compiled into a single assemblage of unique species. The post-disturbance “community” is constructed in the same way, so that the two overall communities can be compared. Comparison of the pre- and post-treatment lists of unique species, compiled from all five sites (*Appendix B*), reveals notable changes in the pre-disturbance community’s species composition in response to the disturbance event (*table 4.1*). In the pre-disturbance community, there were a combined 286 species belonging to 71 families. By the second post-treatment growing season, overall species richness had increased 72%, to 494 species belonging to 86 families. Herbaceous species accounted for a

Table 4.1. Comparison of pre- vs. post-treatment vascular plant communities based on compiled species lists from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

	Pre-treatment	Post-treatment
No. of families	71	86
No. of genera	176	253
No. of species	286	494
Native (% of total)	272 (95%)	431 (87%)
Exotic (% of total)	14 (5%)	63 (13%)
Woody (% of total)	79 (28%)	85 (17%)
Herbaceous (% of total)	207 (72%)	409 (83%)

majority of new species in the post-treatment community. Woody species increased only by a count of six, while herbaceous species nearly doubled from 207 to 409. In the pre-treatment community, native species outnumbered exotics nearly 20 to 1. In contrast, the 63 exotics surveyed in the post-treatment community accounted for 13% of all species. Twenty-four percent of pre-treatment species belonged to the Asteraceae, Cyperaceae, and Poaceae families (*table 4.2*). The same families were even more important, in terms of numbers of species, following treatment application. The Asteraceae family accounted for 16.4% of species, while an additional 17.6% of species were members of the Cyperaceae and Poaceae families. The Liliaceae and Orchidaceae were among the families that were relatively less important in the post-treatment community; however, that decline reflects an increase in the importance of other families, rather than a loss of Liliaceae or Orchidaceae species. Similarly, important pre-treatment families predominated by woody species (e.g., Ericaceae, Fagaceae) were relatively less important after treatment application as a result of the influx of herbaceous species.

Table 4.2. Pre- vs. post-treatment distribution of species by family, compiled from species presence lists on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau, of Virginia and West Virginia.

Family	-----Pre-treatment-----			-----Post-treatment-----		
	No. species	Relative %	Rank	No. species	Relative %	Rank
Aspleniaceae	6	2.1	12	7	1.4	17
Asteraceae	28	9.8	1	81	16.4	1
Cyperaceae	22	7.7	2	42	8.5	3
Ericaceae	13	4.5	6	12	2.4	8
Fabaceae	9	3.1	8	27	5.5	4
Fagaceae	9	3.1	8	8	1.6	15
Lamiaceae	4	1.4	17	11	2.2	9
Liliaceae	18	6.3	4	17	3.4	6
Orchidaceae	10	3.5	7	10	2.0	11
Poaceae	19	6.6	3	45	9.1	2
Ranunculaceae	5	1.7	14	11	2.2	9
Rosaceae	17	5.9	5	22	4.5	5
Rubiaceae	7	2.4	11	10	2.0	11
Scrophulariaceae	3	1.0	22	13	2.6	7
Violaceae	8	2.8	10	10	2.0	11
Others	108	37.7	---	193	39.0	---

Treatment effect

Stand structure

Basal area

The seven silvicultural prescriptions represent different levels of canopy manipulation, and effectively created the desired variation in stand structural characteristics among treatments. Prior to treatment application, mean basal area across all sites was ~30 m²/ha. Following treatment application, only the control and understory herbicide remained at pre-harvest basal area levels (*table 4.3*); all other prescriptions exhibited a significant decline in basal area. The group selection and high-leave shelterwood retained a mean of 16.8 and 12.9 m²/ha, respectively. The high-disturbance prescriptions—leave tree, low-leave shelterwood, and clearcut—respectively retained 7.6, 4.9, and 1.5 m²/ha. Using residual basal area as an index of disturbance intensity, the prescriptions were ranked from least to greatest disturbance in this order: (1) control, (2) understory herbicide, (3) group selection, (4) high-leave shelterwood, (5) leave tree, (6) low-leave shelterwood, (7) clearcut. Post-hoc means separation confirmed this ranking.

Tree diameter

No significant changes in d.b.h. were observed in the control, understory herbicide, or group selection in response to treatment application (*table 4.3*). Mean d.b.h. increased from pre- to post-treatment for the high-leave shelterwood and leave tree. D.b.h. decreased for the low-leave shelterwood and clearcut. Post-treatment differences in the mean diameter of residual trees were also expected among prescriptions. Across sites, the mean pre-treatment d.b.h. of all stems > 5 m in height was 14.3 cm. Pre-treatment d.b.h. did not differ

TABLE 4.3. Pre- vs. post-treatment d.b.h. and basal area, measured from 576-m² tree plots and expanded to a per-ha basis for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Mean DBH (cm)		Basal area (m ² /ha)	
		Pre ¹	Post ¹	Pre ¹	Post
Control	15	14.5	14.7	28.5	27.9 a
Understory herbicide	12	14.0	15.1	28.1	29.3 a
Group selection	15	14.8	17.4	31.8	16.8 * b
Shelterwood (11-14 m ² /ha)	15	13.5	18.3 *	30.5	12.9 * bc
Shelterwood (4-7 m ² /ha)	12	14.9	13.4 *	32.3	4.9 * d
Leave tree	15	13.9	21.2 *	28.5	7.6 * cd
Clearcut	15	14.2	9.9 *	33.2	1.5 * d

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

among prescriptions. Despite pre- to post-treatment changes in d.b.h., no statistically significant differences among post-treatment levels were detected.

Shrub cover

For all prescriptions, including the control, cover was significantly lower following treatment application (*table 4.4*). The decline in cover was generally uniform for all prescriptions. No post-treatment differences in cover were detected among prescriptions.

Community similarity

All strata

Jaccard's and Sorensen's qualitative similarity coefficients both indicated pre- to post-treatment changes in composition for all prescriptions, although for a given prescription, the two indices did not agree on the degree of change. Jaccard's low index values suggested weak similarity between pre- and post-treatment communities for each prescription, while Sorensen's values were consistently higher (*table 4.5*). The two indices did, however, provide a generally consistent ordering of relative similarity among prescriptions. For both indices, pre- vs. post treatment similarity was highest for the control and understory herbicide. The high-leave shelterwood, group selection, and leave tree exhibited intermediate similarity, while the low-leave shelterwood and clearcut were the least similar.

TABLE 4.4. Pre- vs. post-treatment shrub cover, measured from 36-m² shrub plots and expanded to a per-ha basis for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	-----Shrub cover (m ² /ha)-----	
		Pre ¹	Post ¹
Control	45	7995.1	5517.3 *
Understory herbicide	36	5855.4	2730.7 *
Group selection	45	5441.1	3099.4 *
Shelterwood (11-14 m ² /ha)	45	7733.1	2744.6 *
Shelterwood (4-7 m ² /ha)	36	6525.3	3895.5 *
Leave tree	45	6363.2	3716.7 *
Clearcut	45	7694.8	3327.9 *

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.5. Mean Jaccard and Sorensen community similarity coefficients as calculated from species presence lists for each 2-ha treatment plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Jaccard qualitative index	Sorensen qualitative index
Control	5	0.55 a	0.70 ab
Understory herbicide	4	0.55 a	0.71 a
Group selection	5	0.46 b	0.63 cd
Shelterwood (11-14 m ² /ha)	5	0.47 ab	0.64 bc
Shelterwood (4-7 m ² /ha)	4	0.37 c	0.54 e
Leave tree	5	0.38 bc	0.55 de
Clearcut	5	0.37 c	0.54 e

Herbaceous stratum

Because abundance data were available only for 1-m² herb plots, quantitative similarity coefficients were calculated only for the herbaceous stratum. Qualitative indices were also calculated for comparative purposes. The Morisita-Horn qualitative index provided the highest level of mean separation between prescriptions (*table 4.6*).

Herb-stratum similarity values were highest for the control (0.88) and the understory herbicide (0.87), but were not significantly higher than the group selection (0.70), or high-leave shelterwood (0.72). Similarity for the low-leave shelterwood (0.58), leave tree (0.47), and clearcut (0.59) was significantly weaker than for the control or understory herbicide. The modified Sorensen quantitative index differed from the Morisita-Horn in that only the similarity value for the control (0.73) was significantly higher than the low-leave shelterwood (0.50), leave tree (0.45), and clearcut (0.59). Jaccard's and Sorensen's qualitative indices were less effective in discriminating between pre- and post-treatment communities and among prescriptions. According to both indices, only the clearcut (0.62) was significantly different from the control (0.78) and understory herbicide (0.77), in terms of herbaceous stratum similarity.

Species diversity

Tree-stratum richness

Post-treatment tree stratum (stems >5 m in height) richness was significantly lower than the control value for all prescriptions involving canopy removal (*table 4.7*). Pre-treatment mean number of tree species ranged from 10.2-11.7 species per 576 m², across prescriptions. Post-treatment richness was significantly lower than the control (10.1 species) for all prescriptions except the understory herbicide and group selection, which respectively

TABLE 4.6. Mean herb stratum similarity, as measured by four community similarity coefficients. Values calculated from herb-plot abundance and/or species presence data, pooled to the tree plot level for each of seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Morisita-Horn ¹ quantitative index	Sorensen ¹ quantitative index	Jaccard ² qualitative index	Sorensen ² qualitative index
Control	15	0.88 a	0.73 a	0.65 a	0.78 a
Understory herbicide	12	0.87 ab	0.68 ab	0.64 a	0.77 a
Group selection	15	0.70 ac	0.57 ab	0.53 ab	0.69 ab
Shelterwood (11-14 m ² /ha)	15	0.72 ac	0.59 ab	0.53 ab	0.69 ab
Shelterwood (4-7 m ² /ha)	12	0.58 c	0.50 b	0.51 ab	0.67 ab
Leave tree	15	0.47 c	0.45 b	0.50 ab	0.65 ab
Clearcut	15	0.59 bc	0.51 b	0.45 b	0.62 b

¹ Abundance measured as number of individuals and pooled from six, 1-m² herb plots for each tree plot.

² Index based only on species presence list pooled from six, 1-m² herb plots for each tree plot.

TABLE 4.7. Pre- vs. post-treatment tree stratum richness per 576-m² tree plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	---Species richness (spp/576 m ²)---	
		Pre ¹	Post
Control	15	10.2	10.1 a
Understory herbicide	12	11.3	10.1 * a
Group selection	15	11.3	8.5 * ab
Shelterwood (11-14 m ² /ha)	15	10.4	6.1 * b
Shelterwood (4-7 m ² /ha)	12	11.7	5.4 * bc
Leave tree	15	10.4	4.3 * bc
Clearcut	15	10.7	2.7 * c

¹ No significant treatment effects within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

retained 10.1 and 8.5 species. Tree stratum richness was lowest in the clearcut, which retained only 2.7 species.

Shrub-stratum richness

In the pre-treatment community, the mean number of woody shrubs (1-5 m in height) per 36-m² shrub plot, ranged from 3.5-5.5 species, across prescriptions (*table 4.8*). Shrub species richness significantly declined in response to the understory herbicide, group selection, and both shelterwood prescriptions. Among post-treatment prescriptions, however, there were no significant differences.

Herbaceous-stratum richness

Herb stratum species richness was separately tallied for woody and non-woody stems. Pre- to post-treatment woody richness increased for all prescriptions involving canopy removal, but decreased for the control (*table 4.9*). Prior to treatment, 4.4-5.4 woody species per 1-m² plot were surveyed across prescriptions. Post-treatment woody richness was significantly higher than the control (4.5 species) for the group selection (5.9 species), low-leave shelterwood (6.6 species), leave tree (5.8 species) and clearcut (6.0 species). Pre-treatment non-woody richness ranged from 2.5-4.0 species per 1-m² plot (*table 4.10*). Following treatment, non-woody richness increased for all prescriptions except the control and understory herbicide. Although richness increased following high-disturbance treatments, no significant post-treatment differences were observed among prescriptions for non-woody species at the herb-plot level

TABLE 4.8. Pre- vs. post-treatment shrub stratum richness per 36-m² shrub plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	---Species richness (spp/36 m ²)---	
		Pre ¹	Post ¹
Control	45	5.0	4.6
Understory herbicide	36	5.0	3.3 *
Group selection	45	4.1	3.4 *
Shelterwood (11-14 m ² /ha)	45	5.5	4.2 *
Shelterwood (4-7 m ² /ha)	36	3.9	3.5 *
Leave tree	45	3.5	3.4
Clearcut	45	4.5	4.4

¹ No significant treatment effects within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.9. Pre- vs. post-treatment total woody species richness per 1-m² herb plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	----Species richness (spp/m ²)----	
		Pre ¹	Post
Control	90	5.4	4.8 * ab
Understory herbicide	72	5.0	4.6 a
Group selection	90	5.2	6.0 * c
Shelterwood (11-14 m ² /ha)	90	4.9	5.9 * bc
Shelterwood (4-7 m ² /ha)	72	5.4	6.7 * c
Leave tree	90	4.5	5.8 * bc
Clearcut	90	4.8	6.4 * c

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.10. Pre- vs. post-treatment total non-woody species richness per 1-m² herb plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

TREATMENT	n	----Species richness (spp/m ²)----	
		Pre ¹	Post ¹
Control	90	2.9	2.6
Understory herbicide	72	3.2	2.7
Group selection	90	3.1	4.6 *
Shelterwood (11-14 m ² /ha)	90	2.5	3.1 *
Shelterwood (4-7 m ² /ha)	72	3.5	5.9 *
Leave tree	90	3.3	5.0 *
Clearcut	90	2.6	5.8 *

¹ No significant treatment effects within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

All-strata richness

Species richness of all three combined strata was surveyed in 576-m² tree plots and 2-ha treatment plots. In pre-treatment tree plots, the mean number of woody species ranged from 20.5-23.1 per plot, among the seven prescriptions (*table 4.11*). Post-treatment richness increased for all prescriptions, excluding the control; however, there were no significant differences in woody richness among post-treatment prescriptions. Less than one exotic woody species per tree plot was observed for all prescriptions in both the pre- and post-treatment plots. A more substantial tree-plot level response was observed for non-woody species. Prior to treatment, mean total non-woody richness ranged from 19.7-24.9 species per 576-m² plot (*table 4.12*). Following treatment, non-woody richness increased significantly for all prescriptions involving canopy manipulation. Post treatment non-woody richness was significantly higher than the control (25.5 species) for the group selection (43.3 species), low-leave shelterwood (53.6 species), leave tree (42.5 species), and clearcut (47.5 species). Exotic non-woody species were nearly absent (<1 species) before treatment. Significantly more exotic non-woody species were observed for the group selection, low-leave shelterwood, leave tree, and clearcut following treatment. Post-treatment exotic richness was significantly higher than the control (0.1 species) for the low-leave shelterwood (4.4 species), leave tree (3.3 species), and clearcut (4.0 species).

At the 2-ha, treatment-plot level, differences in woody species richness were observed that were not detected at the tree-plot level. Post-treatment exotic richness was significantly higher than pre-treatment values for the group selection (1.2 species) and clearcut (1.8 species) (*table 4.13*). Few post-treatment differences were detected for exotic richness among prescriptions. Total post-treatment woody richness, however, was higher in

TABLE 4.11. Pre- vs. post-treatment exotic and total woody species richness from all vegetation strata per 576-m² tree plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	N	Exotic richness (spp/576 m ²)		Total richness (spp/576 m ²)	
		Pre ¹	Post ¹	Pre ¹	Post ¹
Control	15	0.0	0.0	22.2	24.1
Understory herbicide	12	0.2	0.1	21.7	24.0 *
Group selection	15	0.3	0.3	23.1	27.3 *
Shelterwood (11-14 m ² /ha)	15	0.0	0.5	20.6	24.6 *
Shelterwood (4-7 m ² /ha)	12	0.0	0.7	22.8	27.4 *
Leave tree	15	0.0	0.5	20.5	26.1 *
Clearcut	15	0.1	0.3	22.6	26.5 *

¹ No significant treatment effects within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.12. Pre- vs. post-treatment exotic and total non-woody species richness from all vegetation strata per 576-m² tree plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Exotic richness (spp/576 m ²)		Total richness (spp/576 m ²)	
		Pre ¹	Post	Pre ¹	Post
Control	15	0.0	0.1 a	23.0	25.5 a
Understory herbicide	12	0.3	0.4 a	22.1	25.2 a
Group selection	15	0.1	2.3 * ab	24.9	43.3 * b
Shelterwood (11-14 m ² /ha)	15	0.0	0.9 ab	19.7	26.7 * a
Shelterwood (4-7 m ² /ha)	12	0.1	4.4 * c	23.7	53.6 * b
Leave tree	15	0.0	3.3 * bc	21.1	42.5 * b
Clearcut	15	0.1	4.0 * c	21.0	47.5 * b

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.13. Pre- vs. post-treatment exotic and total woody species richness from all vegetation strata per 2-ha treatment plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Exotic richness (spp/2 ha)		Total richness (spp/2 ha)	
		Pre ¹	Post	Pre ¹	Post
Control	5	0.6	0.4 ab	34.6	34.8 a
Understory herbicide	4	0.0	0.0 a	33.5	35.0 a
Group selection	5	0.4	1.2 * ab	37.4	40.4 ab
Shelterwood (11-14 m ² /ha)	5	0.2	1.0 ab	33.4	40.0 * ab
Shelterwood (4-7 m ² /ha)	4	0.3	1.5 ab	34.8	41.3 ab
Leave tree	5	0.4	1.2 ab	33.8	40.0 * ab
Clearcut	5	0.2	1.8 * b	34.0	41.6 * b

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

the clearcut (41.6 species) than the control (34.8 species) and understory herbicide (35.0 species). Again, the treatment-plot level response of non-woody species was greater than the woody species response. All prescriptions, excluding the control and understory herbicide, exhibited a mean pre- to post-treatment increase in exotic and total non-woody species (*table 4.14*). Post-treatment exotic non-woody richness was significantly higher for the group selection (12.8 species), low-leave shelterwood (14.3 species), leave tree (15.6 species), and clearcut (17.6 species), when compared to the control (4.2 species) and understory herbicide (1.8 species). A similar trend was observed for the total non-woody richness, where the 128.0, 110.8, and 118.6 species per treatment plot, surveyed on the low-leave shelterwood, leave tree, and clearcut, respectively, were significantly higher than the control (72.4 species).

Heterogeneity indices

Because species abundance data were available only from herb plots, species diversity was calculated for the herbaceous stratum, only. Pre- to post-treatment differences were observed only for the clearcut and high-leave shelterwood using Shannon's index; Simpson's index exhibited no significant pre- to post-treatment difference for any prescription (*table 4.15*). Neither Shannon's nor Simpson's index detected significant differences in species diversity between the control and manipulated treatments.

TABLE 4.14. Pre- vs. post-treatment exotic and total non-woody species richness from all vegetation strata per 2-ha treatment plot for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Values followed by the same letter are not significantly different within columns ($p < 0.10$).

Treatment	n	Exotic richness (spp/2 ha)		Total richness (spp/2 ha)	
		Pre ¹	Post	Pre ¹	Post
Control	5	1.0	4.2 a	50.6	72.4 ab
Understory herbicide	4	0.5	1.8 a	45.0	68.3 a
Group selection	5	0.8	12.8 * b	49.2	108.8 * bc
Shelterwood (11-14 m ² /ha)	5	0.6	9.6 * ab	45.2	85.8 * abc
Shelterwood (4-7 m ² /ha)	4	0.5	14.3 * b	48.3	128.0 * c
Leave tree	5	0.6	15.6 * b	43.4	110.8 * bc
Clearcut	5	0.8	17.6 * b	47.0	118.6 * c

¹ No significant treatment effect within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

TABLE 4.15. Pre- vs. post-treatment herb stratum species diversity as measured by Shannon's and Simpson's indices. Values calculated from herb-plot abundance¹, pooled to tree-plot level for seven silvicultural prescriptions. Mean of five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	Shannon's index (exp H')		Simpson's index (1/D)	
		Pre ¹	Post ¹	Pre ¹	Post ¹
Control	5	10.2	10.1	7.3	7.5
Understory herbicide	4	11.0	11.1	8.3	8.5
Group selection	5	10.1	11.4	7.3	7.7
Shelterwood (11-14 m ² /ha)	5	9.5	11.7 *	7.4	8.8
Shelterwood (4-7 m ² /ha)	4	11.8	12.8	8.5	8.4
Leave tree	5	9.9	9.6	7.0	5.9
Clearcut	5	9.7	11.9 *	7.4	7.5

¹ No significant treatment effects within columns ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

Comparative diversity profiles

Ranked abundance vectors for pre- and post-treatment communities were compiled for each prescription (*Appendix C*). The subsequent graphical diversity profiles confirmed the pre- to post-treatment species diversity ordering, or lack thereof, for each prescription (*figure 4.1 a-g*). In no case was the post-treatment community intrinsically less diverse than the pre-treatment community, contrary to Shannon's and Simpson's index values. The plotted curves crossed the diagonal reference line for the control, low-leave shelterwood, and leave tree, indicating no definitive diversity ordering of their respective pre- vs. post-treatment communities. In contrast, the curves each plotted below the reference line for the understory herbicide, group selection, high-leave shelterwood, and clearcut, indicating that the post-treatment community was, in all cases, intrinsically more diverse than the pre-treatment community.

In addition to diversity ordering, the cumulative abundance curves are useful descriptors of the abundance structure of each community being compared. The left-hand tails, for example, clearly depict the distribution of abundance among the most common species. The right-hand tails are useful for comparing the abundance of rare species, although the resolution of the curve may be poor due to species clustering. For high-disturbance prescriptions, the distribution of abundance tended to be more even in the post-treatment community. The number of rare species also increased dramatically for high-disturbance, post-treatment communities. In the control, 23 species comprised 90% of the total pre-treatment abundance, while 24 species comprised 90% of the post-treatment abundance. Similarly, little change was observed in the far right-hand portion of the control curve: 32 and 31 rare species accounted for the last two percent of total abundance in the

pre- and post-treatment communities, respectively. Most prescriptions were not dramatically different from the control with respect to the left-hand tails. The clearcut, for example, distributed 90% of total pre-treatment abundance among 27 species. The same percentage was distributed among 33 species in the post-treatment community. The more notable difference between the control and high-disturbance prescriptions occurred in the right-hand tails. Again, in the pre-treatment clearcut community, the last two percent of total abundance was distributed among only 29 species. In the post-treatment clearcut, however, 57 species accounted for the same two percent of abundance. Similar trends were observed for the low-leave shelterwood and leave tree, and to a lesser degree in the group selection and high-leave shelterwood.

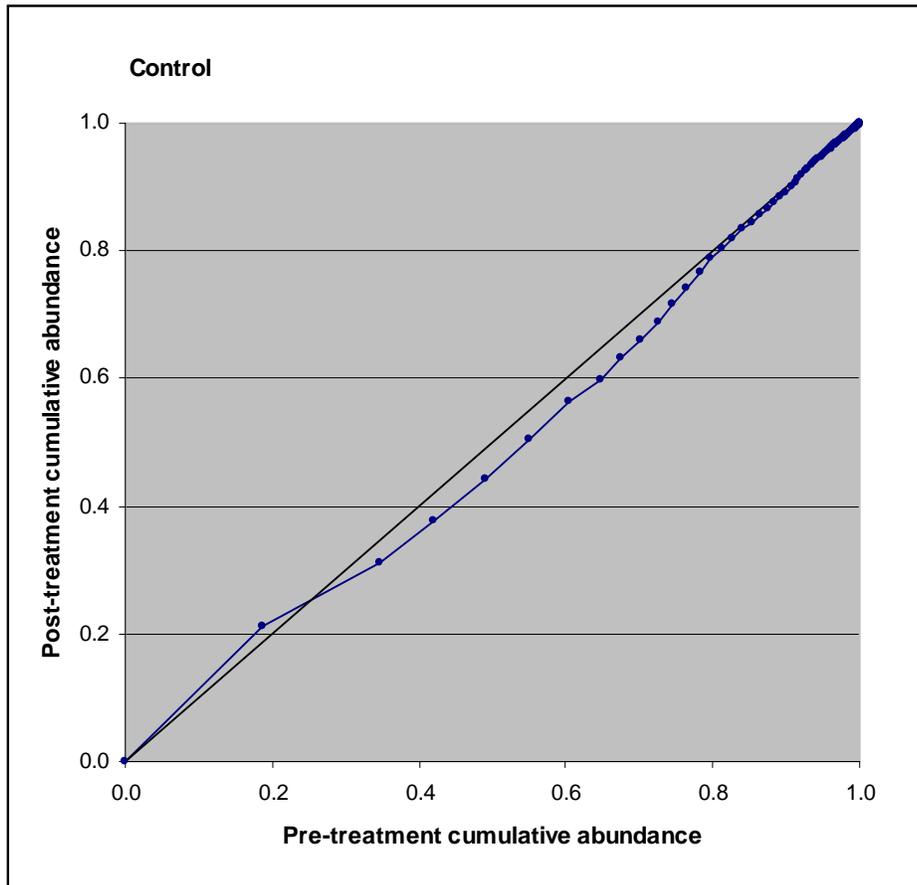


Figure 4.1a. Comparative diversity profile for the control treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

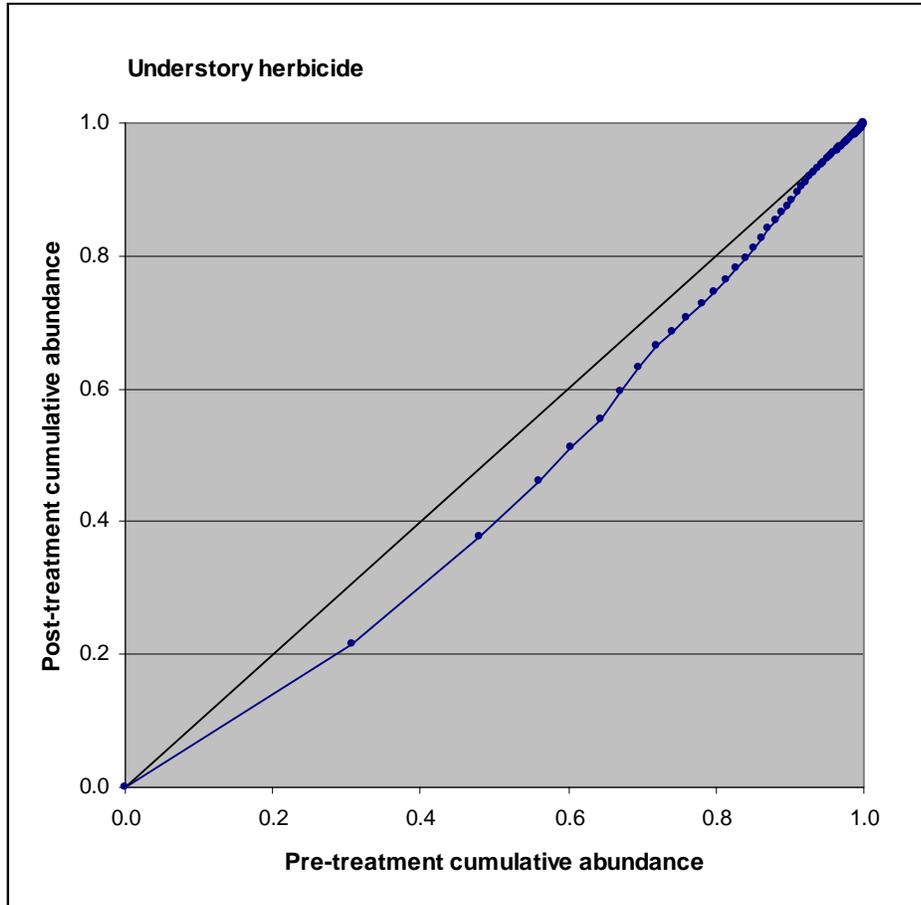


Figure 4.1b. Comparative diversity profile for the understory herbicide treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

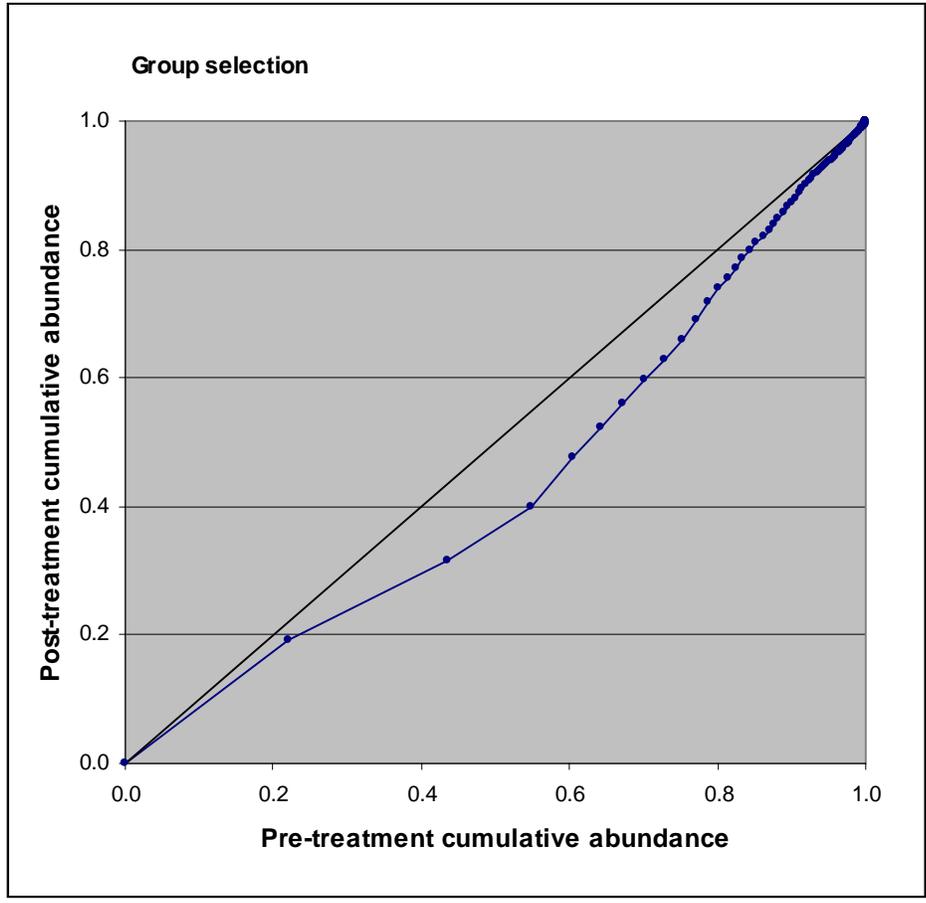


Figure 4.1c. Comparative diversity profile for the group selection treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

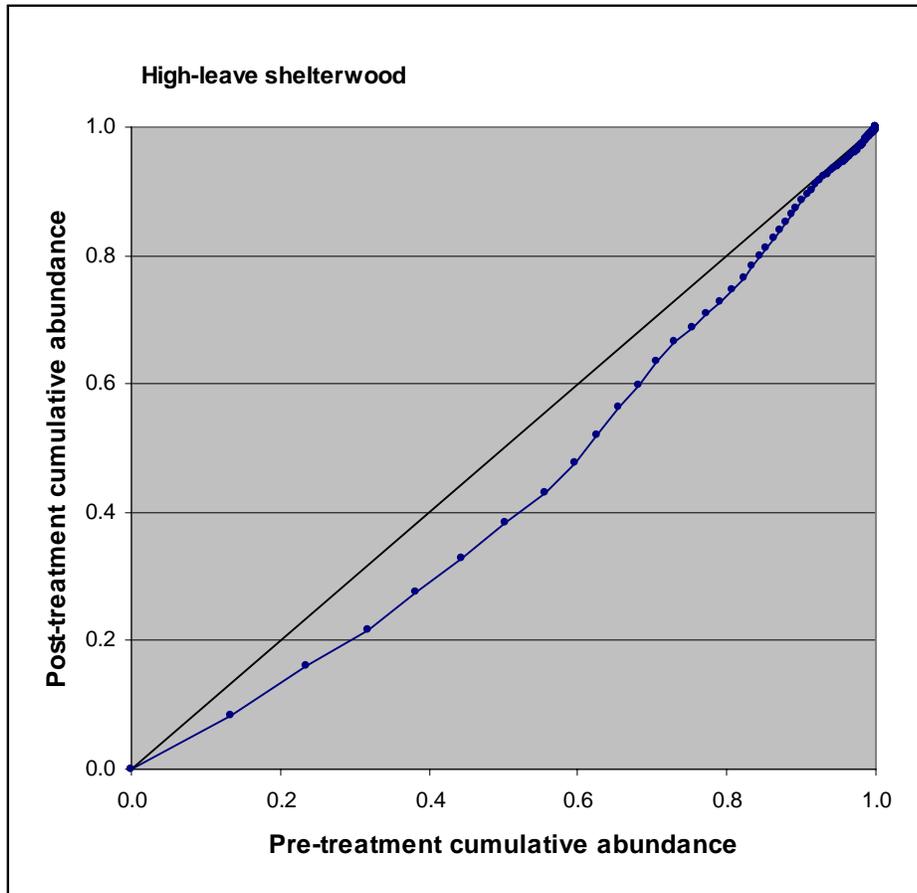


Figure 4.1d. Comparative diversity profile for the high-leave shelterwood treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

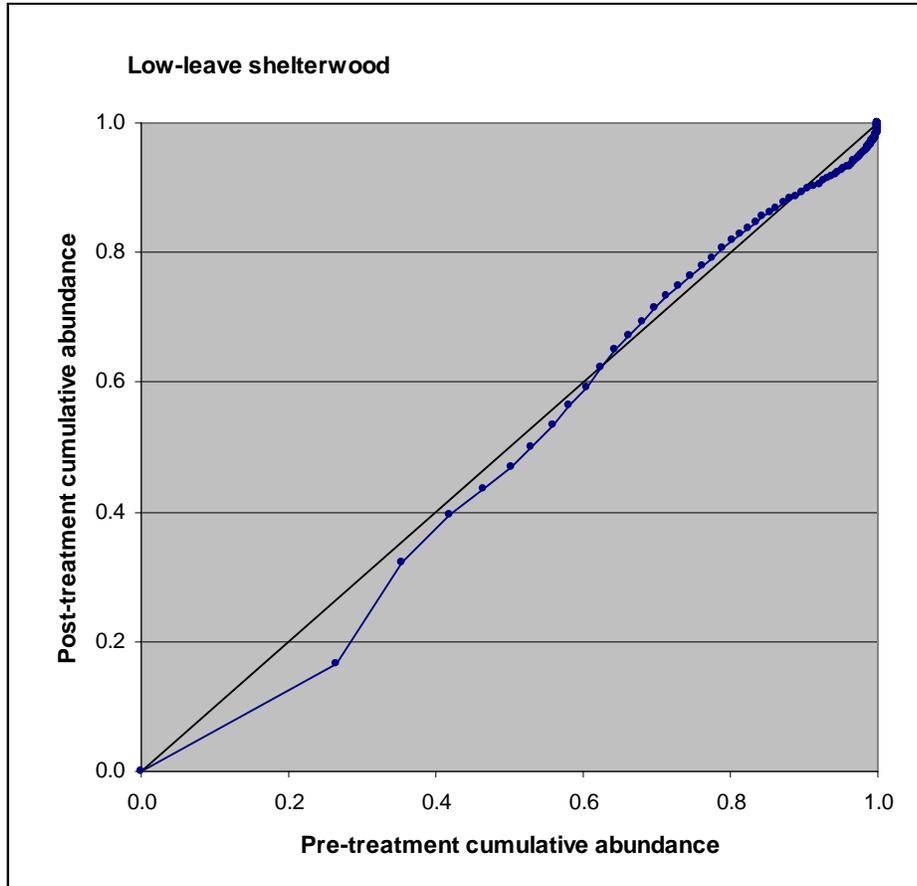


Figure 4.1e. Comparative diversity profile for the low-leave shelterwood treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

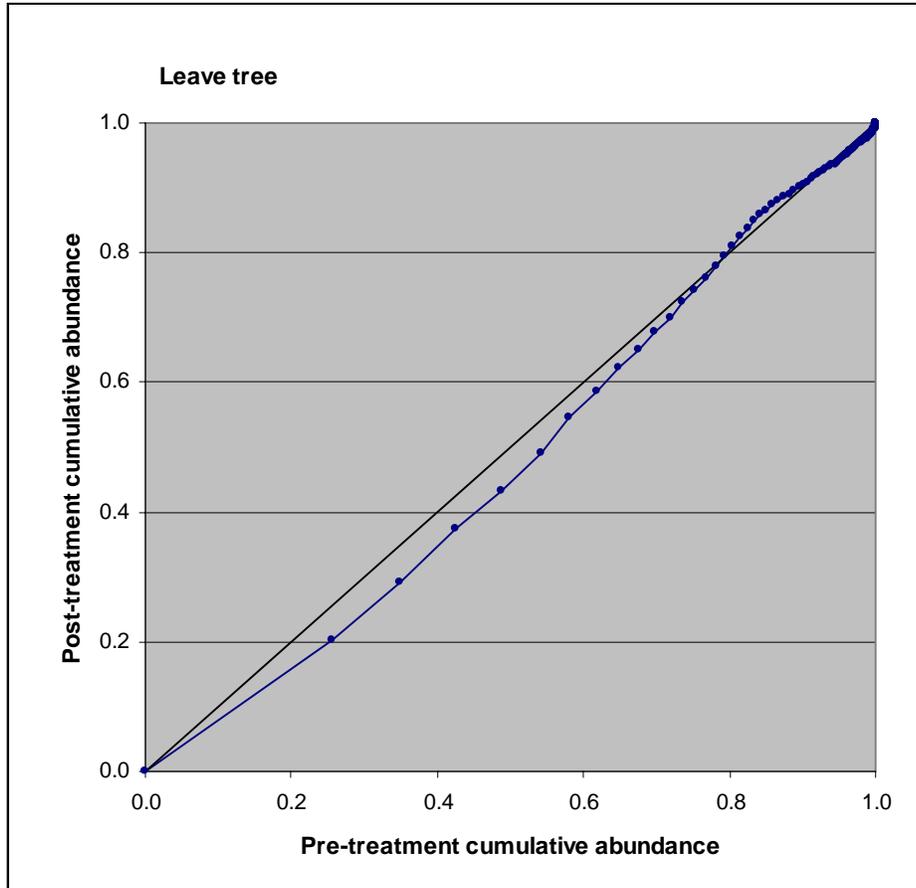


Figure 4.1f. Comparative diversity profile for the leave tree treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

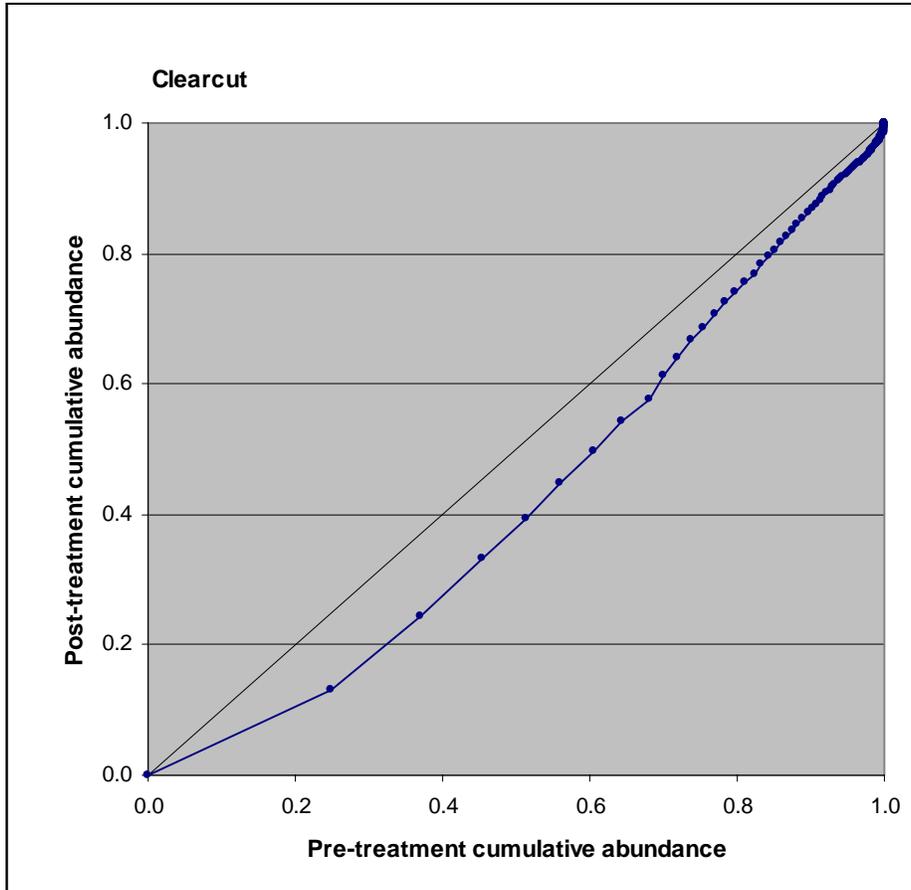


Figure 4.1g. Comparative diversity profile for the clearcut treatment. Based on pre- vs. post-treatment cumulative ranked abundance (no. of individuals) pooled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Plant functional groups

Raunkiaer life-forms

Using species frequency in tree plots to weight for importance, pre-treatment life-form spectra were constant across all prescriptions (*table 4.16*). Phanerophytes were most abundant, and accounted for 55% of species. Hemicryptophytes and cryptophytes comprised 27% and 16% of species, respectively. Less than three percent of species were chamaephytes and therophytes, combined. Prescription implementation had a significant effect on the relative importance of all life-forms except chamaephytes (*table 4.17*). Compared to the control, the relative importance of phanerophytes declined with increasing prescription disturbance intensity (*figure 4.2a*). The same trend occurred in cryptophytes (*figure 4.2b*). Hemicryptophytes increased with increasing disturbance intensity (*figure 4.2c*), as did therophytes (*figure 4.3d*). In all harvested stands except the high-leave shelterwood, hemicryptophytes replaced phanerophytes as the most important life-form. Multivariate analysis results indicate a strong negative correlation ($r = -0.91$) between the two life-forms, meaning that as one form increases, the other will decrease. Weighted spectra were compared to regional spectra and Raunkiaer's normal spectrum for the hemicryptophyte region (*table 4.18*). Among post-treatment communities, the clearcut and low-leave shelterwood communities most closely resembled Raunkiaer's normal spectrum and other regional spectra. Because only forested ecosystems were evaluated in the Diversity Study, phanerophytes were obviously more important than in other more comprehensive spectra that include species across a range of vegetation types. Unweighted spectra were also derived from the five site, unique species lists (*Appendix B*) for overall

TABLE 4.16. Pre-treatment life-form spectra¹ for seven silvicultural alternatives implemented on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	PH	CH	HE	CR	TH
Control	15	0.54	0.02	0.29	0.14	0.01
Understory herbicide	12	0.55	0.01	0.29	0.14	0.01
Group selection	15	0.54	0.02	0.27	0.16	0.01
Shelterwood (11-14 m ² /ha)	15	0.56	0.02	0.26	0.16	0.01
Shelterwood (4-7 m ² /ha)	12	0.55	0.02	0.28	0.15	0.01
Leave tree	15	0.54	0.02	0.26	0.17	0.01
Clearcut	15	0.56	0.02	0.24	0.17	0.01
<i>MEAN SPECTRUM</i>		0.55	0.02	0.27	0.16	0.01

¹ No significant treatment effect within columns for any dependent variable ($p < 0.10$).

PH = Phanerophytes

CH = Chamaephytes

HE = Hemicryptophytes

CR = Cryptophytes

TH = Therophytes

TABLE 4.17. Post-treatment life-form spectra¹ for seven silvicultural alternatives implemented on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	PH	CH	HE	CR	TH
Control	15	0.50	0.02	0.31	0.14	0.01
Understory herbicide	12	0.50	0.01	0.33	0.17 *	0.00
Group selection	15	0.39 *	0.01	0.45 *	0.12 *	0.03 *
Shelterwood (11-14 m ² /ha)	15	0.48 *	0.01	0.36 *	0.14	0.02
Shelterwood (4-7 m ² /ha)	12	0.33 *	0.02	0.49 *	0.12 *	0.05 *
Leave tree	15	0.38 *	0.02	0.45 *	0.13 *	0.03
Clearcut	15	0.35 *	0.02	0.48 *	0.10 *	0.05 *

¹ Treatment effects were significant within columns for all dependent variables except CH.

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

PH = Phanerophytes

CH = Chamaephytes

HE = Hemicryptophytes

CR = Cryptophytes

TH = Therophytes

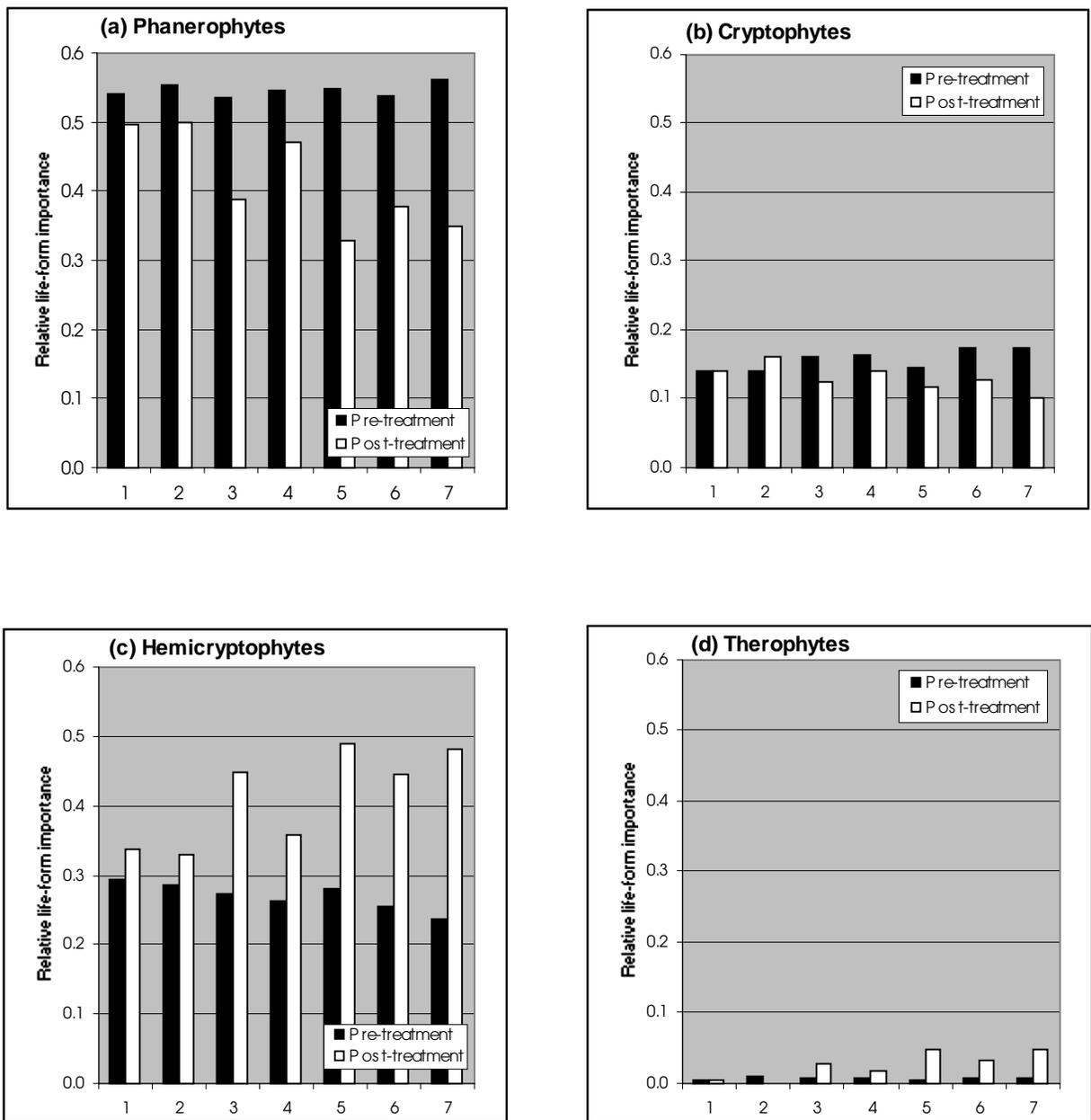


Figure 4.2 a-d. Pre- to post-treatment change in relative life-form importance for seven silvicultural alternatives on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia: (a) Phanerophytes, (b) Cryptophytes, (c) Hemicryptophytes, (d) Therophytes. Treatment effects were insignificant for Chamaephytes. Treatments are (1) control, (2) understory herbicide, (3) group selection, (4) high-leave shelterwood, (5) low-leave shelterwood, (6) leave tree, and (7) clearcut.

TABLE 4.18. Pre and post-treatment life-form spectra for the Diversity Study, compared with Raunkiaer's normal spectrum and other regional spectra.

Treatment	No. species	PH	CH	HE	CR	TH
Raunkiaer's normal	1000	0.46	0.09	0.26	0.06	0.13
Indiana (MacDonald 1937)	2109	0.14	0.02	0.49	0.18	0.17
Kentucky (Gibson 1961)	1846	0.16	0.01	0.51	0.15	0.16
Bull Run Mt., VA (Allard 1944)	980	0.18	0.01	0.52	0.11	0.17
Diversity Study:						
Pre-treatment	286	0.27	0.02	0.55	0.14	0.02
Post-treatment	491	0.16	0.02	0.63	0.12	0.07
Post-treatment (weighted):						
Group		0.39	0.01	0.45	0.12	0.03
SW 11-14		0.47	0.01	0.36	0.14	0.02
SW 4-7		0.33	0.02	0.49	0.12	0.05
Leave tree		0.38	0.02	0.45	0.13	0.03
Clearcut		0.35	0.02	0.48	0.10	0.05

PH = Phanerophytes
 CH = Chamaephytes
 HE = Hemicryptophytes
 CR = Cryptophytes
 TH = Therophytes

pre- and post-treatment communities. The resulting post-treatment spectrum closely resembled other comprehensive spectra from Virginia (Allard 1944), Kentucky (Gibson 1961), and Indiana (McDonald 1937).

Growth-forms

Weighted, pre-treatment growth-form spectra were constant across all prescriptions (*table 4.19*). Trees were the most important growth-form, representing 39% of all species. Perennial forbs were nearly as important (37%). Woody shrubs comprised 13%, while woody vines and ferns each accounted for four percent of all species. Neither graminoids nor annual/biennial forbs accounted for greater than one percent of species. Significant treatment effects were observed in post-treatment communities for trees, annual forbs, and graminoids (*table 4.20*). The Wilk's Lambda statistic indicated no overall significant treatment differences among growth-form spectra. Compared to the control, the post-treatment relative importance of trees decreased with increasing disturbance intensity (*figure 4.3a*). Graminoids (*figure 4.3b*) and annual/biennial forbs (*figure 4.3c*) increased with increasing disturbance intensity. Multivariate analysis indicates a positive correlation between graminoids and annual/biennial forbs ($r = 0.73$). Perennial forbs replaced trees as the most important growth-form in the post-harvest community.

TABLE 4.19. Pre-treatment growth-form spectra¹ for seven silvicultural alternatives implemented on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	n	A/BF	PF	GR	TR	WS	PT	WV
Control	15	0.01	0.37	0.01	0.41	0.13	0.04	0.03
Understory herbicide	12	0.01	0.37	0.01	0.39	0.15	0.03	0.03
Group selection	15	0.01	0.38	0.02	0.39	0.12	0.04	0.04
Shelterwood (11-14 m ² /ha)	15	0.01	0.36	0.01	0.40	0.12	0.06	0.04
Shelterwood (4-7 m ² /ha)	12	0.01	0.38	0.01	0.37	0.15	0.03	0.05
Leave tree	15	0.01	0.36	0.03	0.39	0.13	0.06	0.03
Clearcut	15	0.01	0.36	0.01	0.41	0.12	0.05	0.04
<i>MEAN SPECTRUM</i>		0.01	0.37	0.02	0.39	0.13	0.04	0.04

¹ No significant treatment effect within columns for any dependent variable ($p < 0.10$).

A/BF = Annual and biennial forbs

PF = Perennial forbs

GR = graminoids

TR = trees

WS = woody shrubs

PT = pteridophytes

WV = woody vines

TABLE 4.20. Post-treatment growth-form spectra¹ for seven silvicultural alternatives implemented on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Treatment	N	A/BF	PF	GR	TR	WS	PT	WV
Control	15	0.01	0.38	0.05 *	0.34	0.12	0.05	0.05
Understory herbicide	12	0.00	0.39	0.05 *	0.34	0.13	0.04	0.06
Group selection	15	0.03	0.40	0.11 *	0.29 *	0.09	0.03	0.04
Shelterwood (11-14 m ² /ha)	15	0.01	0.35	0.08 *	0.34 *	0.11	0.05	0.05
Shelterwood (4-7 m ² /ha)	12	0.07 *	0.38	0.16 *	0.22 *	0.09	0.03	0.05
Leave tree	15	0.04	0.38	0.12 *	0.27 *	0.11	0.04	0.04
Clearcut	15	0.05	0.40	0.13 *	0.25 *	0.10	0.03	0.04

¹ Treatment effects within columns were significant only for A/BF, GR, TR ($p < 0.10$).

* Post-treatment value is significantly different from pre-treatment value ($p < 0.10$).

A/BF = Annual and biennial forbs

PF = Perennial forbs

GR = graminoids

TR = trees

WS = woody shrubs

PT = pteridophytes

WV = woody vines

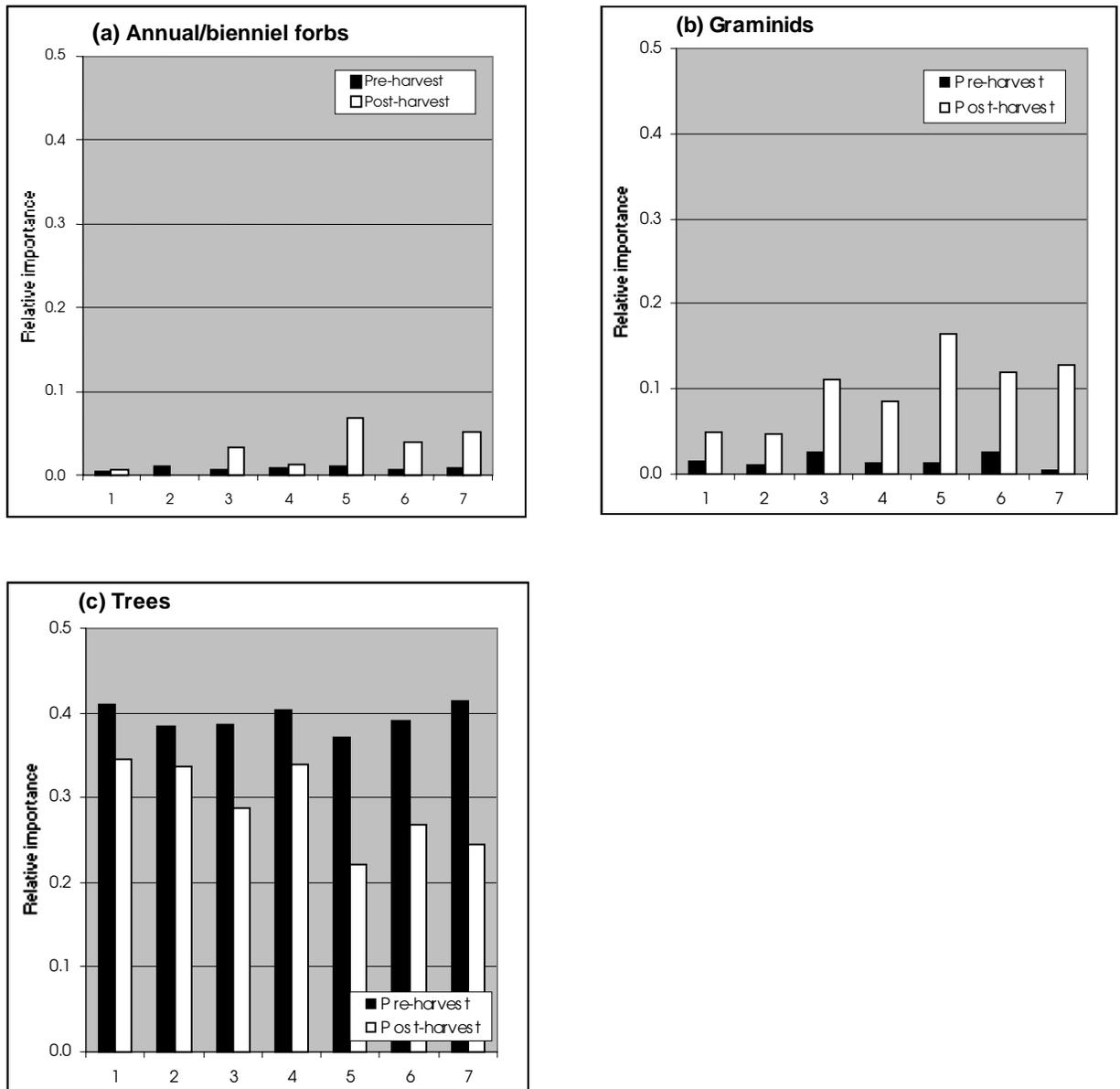


Figure 4.3 a-c. Pre- to post-treatment change in relative growth-form importance for seven silvicultural prescriptions on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia: (a) Annual and biennial forbs, (b) Graminoids, (c) Trees. Treatment effects were insignificant for other growth-forms. Treatments are (1) control, (2) understory herbicide, (3) group selection, (4) high-leave shelterwood, (5) low-leave shelterwood, (6) leave tree, and (7) clearcut.

V. DISCUSSION

Prescription comparison

Low-disturbance prescriptions

Control

The control was intended to be an undisturbed reference stand. Even stands free of silvicultural manipulation, however, are subject to natural disturbance. Natural stands, therefore, are dynamic and exhibit structural and compositional changes (Davison and Forman 1982, Clebsch and Busing 1989), as evidenced by a pre- to post-treatment decline in shrub cover for the control prescription. A plausible explanation for reduced shrub cover in the control stands is the closure of canopy gaps produced by ice damage in 1994 (David Smith, Virginia Tech, pers. comm.). Enhanced light resources and reduced overstory competition in such gaps may have promoted woody stems from the shrub layer to the tree layer, thereby reducing shrub cover prior to post-treatment sampling. The possibility of human error, either by inconsistent measurement or calculation, must also be considered to explain the disparity between pre- and post-treatment shrub cover.

Although overstory canopy structure in post-treatment control plots remained largely undisturbed on all sites, none of the control plots should be considered free of silvicultural impacts. On two sites (BB1 and CL2) control plots were impacted by primary skid trails. Because the Diversity Study is concerned with operational silviculture, skid trail design and placement was left to the discretion of the logger. Neither the skid trail at BB1 nor CL2 was far enough interior to the treatment plot to impact tree plots; therefore, post-treatment basal area and d.b.h. estimates did not reflect canopy disturbance resulting from skid trails.

Likewise, all measured attributes that relied on subplot data (e.g., quantitative community similarity, heterogeneity indices) were not likely affected by the skid trails. The presence of skid trails, however, was reflected in the species presence data collected at the 2-ha, treatment-plot level. Non-woody species richness increased substantially in control plots, particularly at BB1 and CL2. Increased forest-floor radiation from logging has been proposed as a mechanism that encourages weedy and exotic herbaceous species (Meier et al. 1995). Also, reclamation of primary skid trails involved replanting with commercial seed mixes; graminoids were, consequently, a major component of the new species in impacted control plots. Treatment-plot, non-woody species richness also increased to a lesser degree on control plots not directly impacted by skid trails. Because buffers were not established between treatment plots, canopy manipulation of adjacent treatment plots exposed one or more sides of all control plots. The resulting edge effect provided an avenue for species colonization some distance toward the interior of control plots. Hemicryptophytes and therophytes accounted for many of the colonizing species.

Understory herbicide

Shrub-stratum cover was visibly reduced by streamline, basal herbicide applications. The success of the prescription in increasing the solar radiation available at the forest floor, however, is dubious, given the lack of overstory canopy manipulation (Jenkins and Chambers 1989). Also, a substantial level of shrub cover was retained in preferred species that were not treated with herbicides. As a result, the vascular plant community in understory herbicide plots exhibited little observable change from pre- to post-treatment. Understory herbicide plots mirrored the response of control plots in terms of community similarity, species diversity, and functional plant spectra. In fact, because none of the five

understory herbicide treatment plots were impacted by skid trails, those plots may have been less affected by the overall silvicultural operation than were the control plots. Although herbicide plots were equally as impacted by edge effect, a greater number of exotic species were observed in control plots, possibly because of skid trails.

Intermediate-disturbance prescriptions

Group selection

In terms of residual basal area, the group selection represents the lowest intensity of the five prescriptions that involve overstory harvesting. In its overall effect on the plant community, the anticipated group selection response was intermediate between the extremes of the control and clearcut. Community similarity coefficients indicate a greater pre- to post-treatment change in species composition than occurred for control and understory herbicide prescriptions, but less change than observed in high-disturbance prescriptions. Graminoids and annual/biennial forbs increased in importance, but were less important than in the clearcut, leave tree, or low-leave shelterwood. Tree-stratum richness for the group selection was lower only than control and understory herbicide richness. In other aspects, however, the group selection plant community responded similarly to that in high-disturbance prescriptions. Post-treatment species richness at the treatment-plot level, for example, was not significantly different among the group selection, clearcut, leave tree, or low-leave shelterwood for woody, non-woody exotic, or total non-woody species.

The similarity of the group selection to both unharvested and high-disturbance treatments is not surprising, because both conditions are represented in a group selection harvest. In effect the group selection contains three levels of disturbance intensity: (1) high disturbance within group openings, (2) intermediate disturbance from the timber stand

improvement between groups, and (3) low disturbance in the untreated perimeter canopy matrix. Unlike other prescriptions, canopy manipulation was not uniform across the entire treatment plot for the group selection. For this study, group openings were randomly positioned in the treatment plot, without regard for the location of tree plots. Tree and subplot measurements, therefore, represent both canopy-gap and intact-canopy conditions. Numerous studies have examined the vegetation response of variously sized canopy gaps (e.g., Ehrenfeld 1980, Clinton et al. 1994), but in this study, the effect of interest is that of the entire canopy matrix, including areas within and between group openings. The intact post-treatment matrix is expected to retain most of its original species assemblage, although some forest-interior species may be affected by an increase in forest edge. In Oregon, for example, Jules (1998) observed reduced recruitment of an interior herb, *Trillium ovatum*, along forest edges compared to forest interiors. Forest-interior herbaceous species richness has been demonstrated to decline in large canopy openings (Elliot et al. 1997). Large openings, however, exhibit a net gain in herbaceous species, as disturbance-tolerant or weedy pioneer species take advantage of newly available niche space. This pattern has been observed in the Pacific Northwest, where a minor loss of interior species in canopy gaps is greatly offset by species invasions (Halpern 1989). The vegetation response of the thinned, between-group matrix—where canopy gaps are small—should be intermediate compared to the response of the intact matrix and group openings. Of all prescriptions, the group selection may be the most structurally diverse and presumably could accommodate a species assemblage with a broad range of resource requirements.

High-leave shelterwood

Although the high-leave shelterwood retained less basal area than the group selection, the plant community exhibited a less observable response in the shelterwood. The two prescriptions were not significantly different from each other with respect to community similarity or woody species richness. However, at the tree and treatment-plot level, non-woody species richness for the shelterwood was most similar to the unharvested prescriptions, while the group selection more closely resembled the high-disturbance prescriptions. Post-treatment life-form spectra for the shelterwood also more closely followed unharvested prescriptions. Unlike the group selection and other harvested prescriptions, hemicryptophytes did not replace phanerophytes as the most important life-form in the shelterwood. Likewise, graminoids and annual/biennial forbs were less important in the shelterwood than in the group selection.

The differing degree of plant community response to the high-leave shelterwood and group-selection was likely a function of residual canopy arrangement. Despite similarities in residual basal area, the two prescriptions were markedly different in their structural arrangement. Residual stems were more evenly distributed in the shelterwood, and canopy gaps did not approach the size of group selection openings. Unlike larger canopy openings, small gaps primarily promote only herbaceous cover, but not species richness (Moore and Vankat 1985). The shelterwood may favor neither interior-forest species nor shade-intolerant pioneers, while the group selection favors both.

High-disturbance prescriptions

Leave-tree

Foresters have described the leave-tree harvest as the aesthetically pleasing alternative to a clearcut, and from a regeneration standpoint, few ostensible differences exist between the prescriptions. Similarities in the observed plant community response between the two prescriptions further suggest that the leave-tree is functionally equivalent to the clearcut. Few significant differences in community similarity, species diversity, or functional plant spectra were observed between the leave-tree and clearcut.

Low-leave shelterwood

Similar to the trend observed in the leave-tree, few statistical differences were observed between the low-leave shelterwood and the clearcut. Of all prescriptions, only the clearcut retained less basal area than the low-leave shelterwood. At the herb-plot, tree-plot, and treatment-plot level, non-woody richness was statistically equivalent in the shelterwood and the clearcut, post-treatment. Similarly, the shelterwood and clearcut favored the same groups of species. In particular, the initial response of graminoids and annual/biennial forbs in the shelterwood paralleled their response in the clearcut. Greater dissimilarities between these prescriptions may emerge as the stands approach canopy closure.

Clearcut

Presumably, clearcuts provide the least amount of refugia for forest-interior species but provide the greatest amount of niche space for invasive, shade-intolerant species (Meier et al. 1995). Consequently, following a clearcut, net species richness increases and species composition shifts away from the pre-treatment assemblage. Herbaceous growth-forms

temporarily replace trees and woody shrubs as dominants. Following clearcutting and burning in Oregon, Halpern (1989) observed peaks in herbaceous cover within a couple growing seasons, while shrub and tree cover gradually became more important over time. The community response to the clearcut in the Diversity study supports a similar trend in terms of species richness, rather than cover. Exotic and total non-woody species richness increased significantly. Community similarity coefficients indicated a high degree of dissimilarity between pre- and post-treatment communities. Hemicryptophytes increased while phanerophytes decreased in importance. Graminoids and annual/biennial forbs also established greater importance. This is consistent with Halpern (1989), who noted the most rapid peak in abundance among exotic annual species.

Species diversity

Species richness

Observable post-treatment differences in woody species richness among prescriptions were detected in both the tree and herbaceous stratum. Canopy manipulation is obviously responsible for loss of species in the tree stratum; however, that loss does not preclude a species' existence in the shrub or herb stratum. All-strata surveys at the treatment-plot level indicated no overall loss of woody species from any prescription. No observable change in shrub-stratum richness occurred in response to prescriptions. Because the shrub stratum was directly treated only in the understory herbicide, there is no reason to suspect that richness would be affected by harvesting. Woody, herb-stratum richness increased for harvested prescriptions. Canopy disturbance increases forest-floor radiation, encouraging germination of dormant seed. Light-seeded, pioneer species also contribute to increased woody herb-stratum richness.

Non-woody species richness increased at the treatment-plot level for harvested prescriptions. Treatment differences were less observable at the tree-plot level, and were undetected at the herb-plot level. Although 1-m² plots are commonly used to sample forest understories, these results suggest small-area plots may be inappropriate for detecting changes in the understory community. Pre-treatment, each herb plot captured, on average, over 7% of the non-woody species in treatment plots. A typical tree plot captured over 45% of non-woody species. For post-treatment clearcuts, the average herb plot represented less than 5% of non-woody treatment-plot richness, while tree plots captured less than 40% of non-woody species. Even when pooled to the tree plot level, herb plots are unlikely to represent even a quarter of non-woody species in a treatment plot.

Heterogeneity indices

Neither Shannon's nor Simpson's indices were able to detect differences in herb-stratum species diversity among prescriptions. Again, 1-m² plots may be too small to detect changes in species richness and/or abundance. Species diversity estimates derived from 1-m² plots in this study, or others, should be interpreted with caution. When not prohibitively labor or time-intensive, larger sampling areas may provide a worthwhile and more accurate description of species composition. Additional shortcomings of heterogeneity indices, or other single-number indices, have been abundantly described in the literature. In short, diversity indices reduce otherwise descriptive data into meaningless, single numbers that ignore species names, life-history attributes, and a species' respective role in the community.

Comparative diversity profiles

Although comparative diversity profiles also ignore species names, the curves are more descriptive than diversity indices. Because they are effectively plots of raw abundance data, graphical profiles provide information about a community's abundance structure. The contribution of rare or common species may be of particular interest. The profiles are also useful for assessing trends in diversity or abundance over time (Swindel et al. 1987). The construction of graphical profiles is only slightly more involved than Shannon's or Simpson's index calculations.

Exotic species

The mechanisms that govern exotic species diversity are no better understood than mechanisms of native species diversity (Stohlgren et al. 1999). The results of this study demonstrate a positive correlation between disturbance intensity and exotic non-woody species richness. At the treatment-plot level, exotic species were most prevalent in the low-leave shelterwood, leave tree, and clearcut. The long-term effects of disturbance on exotic-native species interactions are unknown. As disturbed stands approach canopy closure and resources become limiting, the possibility exists for aggressive, exotic species to displace native species. However, because many exotic species are early successional species, another plausible scenario predicts that stand closure will eliminate exotics and native species will reclaim dominance.

Exotic species complicate land management and species conservation issues. The assumption that native but not exotic species are best adapted to persist under the natural disturbance regime is untested. Furthermore, disturbance regimes that favor high species

diversity may also encourage exotic species invasion (Stohlgren et al. 1999), further complicating the role of forest management in maintaining diversity.

Plant functional groups

According to current models of secondary succession, timber harvesting—particularly when it involves soil disturbance—favors species with efficient dispersal mechanisms and aggressive growth strategies. Timber harvesting ostensibly selects against slow-growing species with low rates of reproduction or dispersal (Meier et al. 1995). Applying these generalizations to Raunkiaer’s life-forms, harvested sites should exhibit a decline in forest-interior cryptophytes, which are often associated with slow growth rates and high sensitivity to desiccation. Therophytes and light-seeded hemicryptophytes should increase in importance. Because therophytes are annuals, their reproductive success is predicated on an aggressive strategy of resource exploitation. As the forest canopy is harvested, phanerophytes should decline in importance. Results of this study confirm the above trends with the exception of cryptophytes, which did not decline in importance. Even in clearcuts, enough refugia apparently were available to allow forest-interior species to persist. Shade tolerance in a species is indicative of its ability to compete in a light-limited environment, but does imply that the species requires shade for survival. The observed trend in growth-forms also follows the above general pattern of succession. Tree and shrub species exhibited reduced post-treatment dominance, while graminoids and annual/biennial forbs were more important in high-disturbance prescriptions. Neither graminoids nor annuals are typically adapted to forest-interior conditions. As forest-floor radiation and exposed soil became more available following harvesting, those growth-forms were better adapted to compete.

VI. MANAGEMENT IMPLICATIONS

The seven silvicultural alternatives examined by the Diversity Study represent various levels and spatial patterns of forest canopy removal to which measurable differences in plant-community response could presumably be observed. The results of the study, to date, encompass only the initial response of the vascular plant community to disturbance. The relationship of these initial community-disturbance dynamics to long-term trends is unclear, and should be the subject of future research. In the second growing-season, post-treatment, the clearcut, leave tree, and low-leave shelterwood prescriptions were not appreciably different in terms of disturbance effect. The group selection and high-leave shelterwood retained more characteristics of the unharvested prescriptions, but changes in their respective plant communities were considerable, nonetheless. The untreated control was also measurably affected by adjacent canopy disturbance.

Management decisions based only on initial or short-term data are inappropriate. Similarity in the initial plant community response among prescriptions is not a predictor of similarity in the response over time. Intermediate and long-term effects may, therefore, be observed even when initial differences in community response are absent. The intermediate and long-term responses to each silvicultural prescription will be influenced by their regeneration methods, spatial arrangements of residual stems, and requirements for intermediate harvests.

Stand development and the subsequent recovery of the plant community are dependent on the regeneration method. Of the seven prescriptions, only the five that required removal of the overstory canopy were methods of regeneration, meaning they will promote the initiation of new trees (Smith et al. 1997). Clearcut and leave-tree harvests are

predominately dependent on coppice growth and secondarily on advanced regeneration and seeds. The resulting stands are even-aged and uniform in structure (Smith et al. 1997). Shelterwoods are designed to promote advanced regeneration, and will ultimately create an even-aged stand, but not until removal of the residual shelter. In the case of the low-leave shelterwood, the residual shelter will not necessarily be removed, creating a two-cohort stand. Openings within the group selection are superficially similar to a clearcut; however, regeneration is more influenced by the size of the opening. The ultimate stand created by a group selection is uneven-aged. The impacts of greater disturbance frequency are a concern for the group selection or shelterwood practices that require additional or repeated stand entries. Repeated stand entry for group selections, for example, may perpetuate the invasion of exotic species that would otherwise be outcompeted following stand closure.

Teasing apart the mechanisms that govern a plant community's response to disturbance is dependent on understanding species' life-history attributes (Halpern and Spies 1995, Goldstein 1999). Although functional plant classifications (e.g., life-forms, growth-forms) may be useful in characterizing community response to disturbance, Goldstein (1999) also argues for the evaluation of individual species and populations, rather than perceived groups of species. Future work in the Diversity Study will seek to relate more species-specific attributes (e.g., dispersal mechanisms, growth requirements) to disturbance-mediated, biotic, and abiotic factors.

Lastly, the results presented, to date, represent only two post-treatment growing seasons of what is intended to be a long-term study. Long-term data of this nature are lacking, and the Diversity Study will contribute significantly to our understanding of long-term trends in plant community development following silvicultural disturbance. Periodic

monitoring throughout a rotation length typical of the southern Appalachians will clarify the long-term effects of silviculture on the vascular plant community. The evaluation of community attributes throughout successional development will contribute to the development of mechanistic models of species diversity and succession in southern Appalachian forested systems.

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APPENDIX A: Preferred species list

List of 14 preferred species that were selected for in understory herbicide treatments. Preferred species were selected according to merchantability, wildlife value, longevity, and resistance to gypsy moth. Species are listed in declining order of preference.

Species	Common name
<i>Prunus serotina</i>	black cherry
<i>Quercus rubra</i>	northern red oak
<i>Carya glabra</i>	pignut hickory
<i>Carya tomentosa</i>	mockernut hickory
<i>Quercus alba</i>	white oak
<i>Acer saccharum</i>	sugar maple
<i>Quercus velutina</i>	black oak
<i>Fraxinus americana</i>	white ash
<i>Fraxinus pennsylvanica</i>	green ash
<i>Quercus prinus</i>	chestnut oak
<i>Quercus coccinea</i>	scarlet oak
<i>Fagus grandifolia</i>	American beech
<i>Pinus strobus</i>	eastern white pine
<i>Liriodendron tulipifera</i>	yellow-poplar

APPENDIX B: Five-site, unique species list

Pre- and post-treatment species list compiled from five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia. Exotic species indicated by **bold** font.

Species	Family	Woody/herb	Raunkiaer	Growth-form	Pre	Post
<i>Acalypha rhomboidea</i>	Euphorbiaceae	h	TH	AF		*
<i>Acer pensylvanicum</i>	Aceraceae	w	PH	TR	*	*
<i>Acer rubrum</i>	Aceraceae	w	PH	TR	*	*
<i>Acer saccharum</i>	Aceraceae	w	PH	TR	*	*
<i>Achillea millefolium</i>	Asteraceae	h	HE	PF		*
<i>Adiantum pedatum</i>	Polypodiaceae	h	HE	PT		*
<i>Agalinis tenuifolia</i>	Scrophulariaceae	h	TH	AF		*
<i>Agrimonia gryposepala</i>	Rosaceae	h	HE	PF		*
<i>Agrimonia parviflora</i>	Rosaceae	h	HE	PF		*
<i>Agrimonia pubescens</i>	Rosaceae	h	HE	PF		*
<i>Agrimonia rostellata</i>	Rosaceae	h	HE	PF		*
<i>Agrimonia sp</i>	Rosaceae	h			*	
<i>Agrostis alba</i>	Poaceae	h	HE	GR	*	*
<i>Agrostis gigantea</i>	Poaceae	h	HE	GR		*
<i>Agrostis perennans</i>	Poaceae	h	HE	GR	*	*
<i>Agrostis tenuis</i>	Poaceae	h	HE	GR		*
<i>Ailanthus altissima</i>	Simaroubaceae	w	PH	TR		*
<i>Allium sp</i>	Liliaceae	h			*	
<i>Allium vineale</i>	Liliaceae	h	CR	PF		*
<i>Ambrosia artemisiifolia</i>	Asteraceae	h	TH	AF		*
<i>Amelanchier arborea</i>	Rosaceae	w	PH	TR	*	*
<i>Amphicarpa bracteata</i>	Fabaceae	h	TH	AF		*
<i>Andropogon virginicus</i>	Poaceae	h	HE	GR	*	*
<i>Anemone quinquefolia</i>	Ranunculaceae	h	HE	PF	*	*
<i>Anemone virginiana</i>	Ranunculaceae	h	HE	PF		*
<i>Angelica venenosa</i>	Apiaceae	h	HE	PF	*	*
<i>Antennaria parlinii</i>	Asteraceae	h	CH	PF		*
<i>Antennaria plantaginifolia</i>	Asteraceae	h	CH	PF	*	*
<i>Anthoxanthum odoratum</i>	Poaceae	h	HE	GR		*
<i>Aplectrum hyemale</i>	Orchidaceae	h	CR	PF	*	
<i>Apocynum androsaemifolium</i>	Apocynaceae	h	HE	PF	*	*
<i>Apocynum cannabinum</i>	Apocynaceae	h	HE	PF		*
<i>Arabidopsis thaliana</i>	Brassicaceae	h	TH	AF		*
<i>Arabis canadensis</i>	Brassicaceae	h	HE	BF	*	*
<i>Arabis laevigata</i>	Brassicaceae	h	HE	BF		*
<i>Aralia nudicaulis</i>	Araliaceae	h	HE	PF	*	*
<i>Aralia spinosa</i>	Araliaceae	w	PH	TR	*	*
<i>Arctium minus</i>	Asteraceae	h	HE	PF		*
<i>Arenaria serpyllifolia</i>	Caryophyllaceae	h	TH	AF		*
<i>Arisaema triphyllum</i>	Araceae	h	CR	PF	*	*
<i>Aristolochia macrophylla</i>	Aristolochiaceae	w	PH	WV	*	*
<i>Aristolochia serpentaria</i>	Aristolochiaceae	h	CR	PF		*
<i>Arrhenatherum elatius</i>	Poaceae	h	HE	GR		*
<i>Asclepias amplexicaulis</i>	Asclepiadaceae	h	HE	PF	*	
<i>Asclepias exaltata</i>	Asclepiadaceae	h	HE	PF		*
<i>Asclepias incarnata</i>	Asclepiadaceae	h	HE	PF		*

<i>Asclepias quadrifolia</i>	Asclepiadaceae	h	HE	PF	*	*
<i>Asclepias syriaca</i>	Asclepiadaceae	h	CR	PF		*
<i>Asclepias tuberosa</i>	Asclepiadaceae	h	HE	PF	*	
<i>Asclepias variegata</i>	Asclepiadaceae	h	HE	PF	*	*
<i>Asplenium montanum</i>	Aspleniaceae	h	HE	PT	*	
<i>Asplenium platyneuron</i>	Aspleniaceae	h	HE	PT	*	*
<i>Aster acuminatus</i>	Asteraceae	h	HE	PF	*	*
<i>Aster argutus</i>	Asteraceae	h	HE	PF		*
<i>Aster cordifolius</i>	Asteraceae	h	HE	PF		*
<i>Aster divaricatus</i>	Asteraceae	h	HE	PF	*	*
<i>Aster dumosus</i>	Asteraceae	h	HE	PF		*
<i>Aster infirmus</i>	Asteraceae	h	HE	PF	*	*
<i>Aster lateriflorus</i>	Asteraceae	h	HE	PF	*	*
<i>Aster linariifolius</i>	Asteraceae	h	HE	PF		*
<i>Aster lineara</i>	Asteraceae	h	HE	PF		*
<i>Aster macrophyllus</i>	Asteraceae	h	HE	PF	*	*
<i>Aster paternus</i>	Asteraceae	h	HE	PF		*
<i>Aster pilosus</i>	Asteraceae	h	HE	PF		*
<i>Aster prenanthoides</i>	Asteraceae	h	HE	PF	*	
<i>Aster simplex</i>	Asteraceae	h	HE	PF		*
<i>Aster umbellatus</i>	Asteraceae	h	HE	PF		*
<i>Aster undulatus</i>	Asteraceae	h	HE	PF	*	*
<i>Athyrium filix-femina</i>	Aspleniaceae	h	HE	PT	*	*
<i>Athyrium thelypteroides</i>	Aspleniaceae	h	HE	PT		*
<i>Aureolaria flava</i>	Scrophulariaceae	h	HE	PF	*	
<i>Aureolaria laevigata</i>	Scrophulariaceae	h	HE	PF	*	*
<i>Aureolaria pectinata</i>	Scrophulariaceae	h	HE	PF		*
<i>Aureolaria pedicularia</i>	Scrophulariaceae	h	HE	PF		*
<i>Aureolaria virginica</i>	Scrophulariaceae	h	HE	PF		*
<i>Baptisia tinctoria</i>	Fabaceae	h	HE	PF	*	*
Barbarea verna	Brassicaceae	h	HE	PF		*
Barbarea vulgaris	Brassicaceae	h	HE	PF		*
Berberis thunbergii	Berberidaceae	w	PH	WS		*
<i>Betula lenta</i>	Betulaceae	w	PH	TR	*	*
<i>Bidens frondosa</i>	Asteraceae	h	TH	AF		*
<i>Botrychium dissectum</i>	Ophioglossaceae	h	HE	PT		*
<i>Botrychium virginianum</i>	Ophioglossaceae	h	HE	PT	*	*
<i>Boykinia aconitifolia</i>	Saxifragaceae	h	HE	PF	*	*
<i>Brachyelytrum erectum</i>	Poaceae	h	HE	GR	*	*
<i>Bromus pubescens</i>	Poaceae	h	HE	GR		*
<i>Cacalia atriplicifolia</i>	Asteraceae	h	HE	PF		*
<i>Calamagrostis porteri</i>	Poaceae	h	HE	GR	*	
<i>Caltha palustris</i>	Ranunculaceae	h	HE	PF	*	
<i>Campanula americana</i>	Campanulaceae	h	HE	BF		*
<i>Campanula divaricata</i>	Campanulaceae	h	HE	PF	*	*
<i>Cardamine hirsuta</i>	Brassicaceae	h	TH	AF		*
<i>Cardamine parviflora</i>	Brassicaceae	h	TH	AF		*
<i>Cardamine sp</i>	Brassicaceae	h				*
Carduus acanthoides	Asteraceae	h	HE	BF		*
Carduus nutans	Asteraceae	h	HE	BF		*
<i>Carex aestivalis</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex atlantica</i>	Cyperaceae	h	HE	GR		*

<i>Carex baileyi</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex blanda</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex brevior</i>	Cyperaceae	h	HE	GR		*
<i>Carex brunnescens</i>	Cyperaceae	h	HE	GR		*
<i>Carex cephalophora</i>	Cyperaceae	h	HE	GR		*
<i>Carex communis</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex crinita</i>	Cyperaceae	h	HE	GR		*
<i>Carex debilis</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex digitalis</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex flaccosperma</i>	Cyperaceae	h	HE	GR		*
<i>Carex gracillima</i>	Cyperaceae	h	HE	GR	*	
<i>Carex hirsutella</i>	Cyperaceae	h	CR	GR		*
<i>Carex intumescens</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex laxiflora</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex leptoneura</i>	Cyperaceae	h	HE	GR	*	
<i>Carex lurida</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex muhlenbergii</i>	Cyperaceae	h	CR	GR		*
<i>Carex nigromarginata</i>	Cyperaceae	h	HE	GR		*
<i>Carex normalis</i>	Cyperaceae	h	HE	GR		*
<i>Carex pennsylvanica</i>	Cyperaceae	h	CR	GR	*	*
<i>Carex prasina</i>	Cyperaceae	h	HE	GR		*
<i>Carex radiata</i>	Cyperaceae	h	HE	GR		*
<i>Carex roanensis</i>	Cyperaceae	h	HE	GR		*
<i>Carex rosea</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex scabrata</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex scoparia</i>	Cyperaceae	h	HE	GR		*
<i>Carex stipata</i>	Cyperaceae	h	HE	GR		*
<i>Carex styloflexa</i>	Cyperaceae	h	CR	GR		*
<i>Carex swanii</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex umbellata</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex virescens</i>	Cyperaceae	h	HE	GR	*	*
<i>Carex vulpinoidea</i>	Cyperaceae	h	CR	GR	*	*
<i>Carex willdenowii</i>	Cyperaceae	h	HE	GR		*
<i>Carpinus caroliniana</i>	Betulaceae	w	PH	TR	*	
<i>Carya glabra</i>	Juglandaceae	w	PH	TR	*	*
<i>Carya ovata</i>	Juglandaceae	w	PH	GR	*	
<i>Carya tomentosa</i>	Juglandaceae	w	PH	TR	*	*
<i>Cassia marilandica</i>	Fabaceae	h	HE	PF	*	
<i>Castanea dentata</i>	Fagaceae	w	PH	TR	*	*
<i>Castanea pumila</i>	Fagaceae	w	PH	TR	*	*
<i>Ceanothus americanus</i>	Rhamnaceae	w	PH	WS		*
Cerastium glomeratum	Caryophyllaceae	h	TH	AF		*
Cerastium vulgatum	Caryophyllaceae	h	CH	AF		*
<i>Cercis canadensis</i>	Fabaceae	w	PH	TR	*	*
<i>Chamaelirium luteum</i>	Liliaceae	h	CR	PF	*	*
<i>Chelone glabra</i>	Scrophulariaceae	h	HE	PF	*	*
<i>Chimaphila maculata</i>	Pyrolaceae	h	HE	PF	*	*
<i>Chimaphila umbellata</i>	Pyrolaceae	h	HE	PF		*
Chrysanthemum leucanthemum	Asteraceae	h	HE	PF		*
<i>Chrysopsis mariana</i>	Asteraceae	h	HE	PF		*
<i>Cimicifuga racemosa</i>	Ranunculaceae	h	CR	PF	*	*
<i>Circaea lutetiana</i>	Onagraceae	h	CR	PF		*

Cirsium arvense	Asteraceae	h	HE	PF		*
<i>Cirsium discolor</i>	Asteraceae	h	HE	BF		*
<i>Cirsium sp</i>	Asteraceae	h			*	
Cirsium vulgare	Asteraceae	h	HE	BF		*
<i>Clematis virginiana</i>	Ranunculaceae	h	PH	PF		*
<i>Clintonia umbellulata</i>	Liliaceae	h	CR	PF	*	*
<i>Collinsonia canadensis</i>	Lamiaceae	h	CR	PF		*
<i>Conopholis americana</i>	Orobanchaceae	h	CR	PF	*	*
<i>Convallaria montana</i>	Liliaceae	h	CR	PF	*	*
Convolvulus arvensis	Convolvulaceae	h	HE	PF		*
<i>Corallorhiza maculata</i>	Orchidaceae	h	CR	PF	*	*
<i>Coreopsis major</i>	Asteraceae	h	HE	PF	*	*
<i>Cornus florida</i>	Cornaceae	w	PH	TR	*	*
Coronilla varia	Fabaceae	h	CR	PF		*
<i>Corydalis sempervirens</i>	Fumariaceae	h	HE	BF		*
<i>Corylus americana</i>	Betulaceae	w	PH	WS		*
<i>Corylus cornuta</i>	Betulaceae	w	PH	WS	*	*
<i>Crataegus sp</i>	Rosaceae	w	PH	WS	*	*
Crepis capillaris	Asteraceae	h	TH	AF		*
<i>Cynoglossum virginianum</i>	Boraginaceae	h	HE	PF		*
<i>Cyperus filiculmis</i>	Cyperaceae	h	CR	GR		*
<i>Cyperus lancastriensis</i>	Cyperaceae	h	CR	GR		*
<i>Cyperus strigosus</i>	Cyperaceae	h	CR	GR		*
<i>Cypripedium acaule</i>	Orchidaceae	h	CR	PF	*	*
Dactylis glomerata	Poaceae	h	HE	GR	*	*
<i>Danthonia compressa</i>	Poaceae	h	HE	GR	*	*
<i>Danthonia spicata</i>	Poaceae	h	HE	GR	*	*
Daucus carota	Apiaceae	h	HE	BF		*
<i>Dennstaedtia punctilobula</i>	Pteridiaceae	h	HE	PT	*	*
<i>Dentaria multifida</i>	Brassicaceae	h	HE	PF	*	
<i>Desmodium canescens</i>	Fabaceae	h	HE	PF		*
<i>Desmodium glabellum</i>	Fabaceae	h	HE	PF		*
<i>Desmodium laevigatum</i>	Fabaceae	h	HE	PF		*
<i>Desmodium nudiflorum</i>	Fabaceae	h	HE	PF	*	*
<i>Desmodium paniculatum</i>	Fabaceae	h	HE	PF	*	*
<i>Desmodium rotundifolium</i>	Fabaceae	h	HE	PF		*
Digitaria ischaemum	Poaceae	h	TH	GR		*
<i>Digitaria sanguinalis</i>	Poaceae	h	TH	GR		*
<i>Dioscorea villosa</i>	Dioscoreaceae	h	CR	PF	*	*
<i>Disporum lanuginosum</i>	Liliaceae	h	CR	PF	*	*
<i>Dryopteris intermedia</i>	Aspleniaceae	h	HE	PT	*	*
<i>Dryopteris marginalis</i>	Aspleniaceae	h	HE	PT		*
Elaeagnus umbellata	Elaeagnaceae	w	PH	WS	*	*
<i>Eleocharis obtusa</i>	Cyperaceae	h	TH	GR		*
<i>Eleocharis tenuis</i>	Cyperaceae	h	CR	GR	*	*
<i>Epifagus virginiana</i>	Orobanchaceae	h	CR	PF	*	*
<i>Epigaea repens</i>	Ericaceae	h	CH	PF	*	*
<i>Epilobium coloratum</i>	Onagraceae	h	HE	PF		*
<i>Epilobium leptophyllum</i>	Onagraceae	h	HE	PF	*	
<i>Equisetum arvense</i>	Equisetaceae	h	TH	AF	*	*
<i>Erechtites hieracifolia</i>	Asteraceae	h	TH	AF	*	*
<i>Erigeron annuus</i>	Asteraceae	h	TH	AF		*

<i>Erigeron canadensis</i>	Asteraceae	h	TH	AF	*
<i>Erigeron philadelphicus</i>	Asteraceae	h	HE	PF	*
<i>Erigeron strigosus</i>	Asteraceae	h	TH	AF	*
<i>Eupatorium fistulosum</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium maculatum</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium perfoliatum</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium purpureum</i>	Asteraceae	h	HE	PF	* *
<i>Eupatorium rotundifolium, var. ovatum</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium rugosum</i>	Asteraceae	h	HE	PF	* *
<i>Eupatorium serotinum</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium sessilifolium</i>	Asteraceae	h	HE	PF	*
<i>Eupatorium steelii</i>	Asteraceae	h	HE	PF	* *
<i>Euphorbia corollata</i>	Euphorbiaceae	h	CR	PF	* *
<i>Fagus grandifolia</i>	Fagaceae	w	PH	TR	* *
<i>Festuca elatior</i>	Poaceae	h	HE	GR	* *
<i>Festuca obtusa</i>	Poaceae	h	HE	GR	*
<i>Fragaria virginiana</i>	Rosaceae	h	HE	PF	*
<i>Fraxinus americana</i>	Oleaceae	w	PH	TR	* *
<i>Fraxinus pennsylvanica</i>	Oleaceae	w	PH	TR	* *
<i>Galax aphylla</i>	Diapensiaceae	h	CR	PF	* *
<i>Galium aparine</i>	Rubiaceae	h	TH	AF	* *
<i>Galium circaeazans</i>	Rubiaceae	h	HE	PF	* *
<i>Galium lanceolatum</i>	Rubiaceae	h	HE	PF	*
<i>Galium latifolium</i>	Rubiaceae	h	HE	PF	* *
<i>Galium pilosum</i>	Rubiaceae	h	HE	PF	*
<i>Galium tinctorium</i>	Rubiaceae	h	HE	PF	*
<i>Galium triflorum</i>	Rubiaceae	h	HE	PF	* *
<i>Gaultheria procumbens</i>	Ericaceae	w	HE	WS	* *
<i>Gaylussacia baccata</i>	Ericaceae	w	PH	WS	* *
<i>Gentiana decora</i>	Gentianaceae	h	HE	PF	* *
<i>Geranium carolinianum</i>	Geraniaceae	h	TH	AF	*
<i>Geranium maculatum</i>	Geraniaceae	h	HE	PF	* *
<i>Geum hirsutum</i>	Rosaceae	h	HE	PF	*
<i>Geum laciniatum</i>	Rosaceae	h	HE	PF	*
<i>Geum virginianum</i>	Rosaceae	h	HE	PF	*
<i>Gillenia trifoliata</i>	Rosaceae	h	HE	PF	* *
<i>Glechoma hederacea</i>	Lamiaceae	h	HE	PF	* *
<i>Glyceria striata</i>	Poaceae	h	HE	GR	* *
<i>Gnaphalium obtusifolium</i>	Asteraceae	h	TH	AF	* *
<i>Gnaphalium purpureum</i>	Asteraceae	h	HE	PF	*
<i>Goodyera pubescens</i>	Orchidaceae	h	HE	PF	* *
<i>Goodyera repens</i>	Orchidaceae	h	HE	PF	* *
<i>Gratiola neglecta</i>	Scrophulariaceae	h	TH	AF	*
<i>Habenaria clavellata</i>	Orchidaceae	h	CR	PF	* *
<i>Habenaria orbiculata</i>	Orchidaceae	h	CR	PF	* *
<i>Hamamelis virginiana</i>	Hamamelidaceae	w	PH	TR	* *
<i>Hedeoma pulegioides</i>	Lamiaceae	h	TH	AF	*
<i>Helianthus divaricatus</i>	Asteraceae	h	CR	PF	*
<i>Helianthus microcephalus</i>	Asteraceae	h	HE	PF	*
<i>Heuchera alba</i>	Saxifragaceae	h	HE	PF	*
<i>Heuchera americana</i>	Saxifragaceae	h	HE	PF	* *
<i>Hieracium paniculatum</i>	Asteraceae	h	HE	PF	* *

Hieracium pilosella	Asteraceae	h	HE	PF	*	*
Hieracium pratense	Asteraceae	h	HE	PF	*	*
<i>Hieracium venosum</i>	Asteraceae	h	HE	PF	*	*
Holcus lanatus	Poaceae	h	HE	GR	*	*
<i>Houstonia longifolia</i>	Rubiaceae	h	HE	PF	*	*
<i>Houstonia purpurea</i>	Rubiaceae	h	HE	PF	*	*
<i>Humulus lupulus</i>	Cannabinaceae	h	CR	PF		*
<i>Hydrangea arborescens</i>	Hydrangeaceae	w	PH	WS	*	*
<i>Hypericum canadense</i>	Clusiaceae	h	HE	PF	*	*
<i>Hypericum gentianoides</i>	Clusiaceae	h	HE	AF		*
<i>Hypericum hypericoides</i>	Clusiaceae	h	CH	PF	*	*
<i>Hypericum mutilum</i>	Clusiaceae	h	HE	PF		*
<i>Hypericum prolificum</i>	Clusiaceae	h	PH	PF		*
<i>Hypericum punctatum</i>	Clusiaceae	h	CR	PF	*	*
Hypochaeris radicata	Asteraceae	h	HE	PF		*
<i>Hypoxis hirsuta</i>	Amaryllidaceae	h	CR	PF	*	*
<i>Ilex montana</i>	Aquifoliaceae	w	PH	TR	*	*
<i>Ilex verticillata</i>	Aquifoliaceae	w	PH	TR	*	
<i>Impatiens sp</i>	Balsaminaceae	h	TH	AF	*	*
<i>Ipomoea pandurata</i>	Convolvulaceae	h	CR	PF	*	*
Ipomoea purpurea	Convolvulaceae	h	TH	AF	*	
<i>Iris verna</i>	Iridaceae	h	CR	PF	*	*
<i>Isotria verticillata</i>	Orchidaceae	h	CR	PF	*	*
<i>Itea virginica</i>	Saxifragaceae	w	PH	WS	*	
<i>Juncus canadensis</i>	Juncaceae	h	CR	GR		*
<i>Juncus effusus</i>	Juncaceae	h	HE	GR	*	*
<i>Juncus marginatus</i>	Juncaceae	h	HE	GR		*
<i>Juncus subcaudatus</i>	Juncaceae	h	CR	GR	*	*
<i>Juncus tenuis</i>	Juncaceae	h	HE	GR	*	*
<i>Juniperus virginiana</i>	Cupressaceae	w	PH	TR	*	*
<i>Kalmia latifolia</i>	Ericaceae	w	PH	WS	*	*
<i>Lactuca canadensis</i>	Asteraceae	h	HE	BF		*
Lactuca scariola	Asteraceae	h	HE	AF		*
<i>Lechea racemulosa</i>	Cistaceae	h	HE	PF		*
<i>Leersia virginica</i>	Poaceae	h	HE	GR		*
Lespedeza bicolor	Fabaceae	h	HE	PF		*
Lespedeza cuneata	Fabaceae	h	HE	PF		*
<i>Lespedeza hirta</i>	Fabaceae	h	HE	PF	*	*
<i>Lespedeza intermedia</i>	Fabaceae	h	HE	PF		*
<i>Lespedeza nuttallii</i>	Fabaceae	h	HE	PF		*
<i>Lespedeza procumbens</i>	Fabaceae	h	HE	PF		*
<i>Lespedeza repens</i>	Fabaceae	h	HE	PF		*
<i>Lespedeza virginica</i>	Fabaceae	h	HE	PF		*
<i>Ligusticum canadense</i>	Apiaceae	h	HE	PF		*
<i>Lilium michauxii</i>	Liliaceae	h	CR	PF	*	*
<i>Lilium philadelphicum</i>	Liliaceae	h	CR	PF	*	
<i>Lindera benzoin</i>	Lauraceae	w	PH	WS	*	*
<i>Linum striatum</i>	Linaceae	h	HE	PF		*
<i>Linum virginianum</i>	Linaceae	h	HE	PF		*
<i>Liriodendron tulipifera</i>	Magnoliaceae	w	PH	TR	*	*
<i>Lobelia cardinalis</i>	Campanulaceae	h	HE	PF		*
<i>Lobelia inflata</i>	Campanulaceae	h	HE	PF	*	*

<i>Lobelia spicata</i>	Campanulaceae	h	HE	PF	*
<i>Lolium perenne</i>	Poaceae	h	HE	GR	*
<i>Lotus corniculatus</i>	Fabaceae	h	HE	PF	*
<i>Ludwigia alternifolia</i>	Onagraceae	h	HE	PF	*
<i>Luzula echinata</i>	Juncaceae	h	HE	GR	*
<i>Luzula multiflora</i>	Juncaceae	h	HE	GR	*
<i>Lycopodium obscurum</i>	Lycopodiaceae	h	CR	PF	*
<i>Lycopus americanus</i>	Lamiaceae	h	HE	PF	*
<i>Lycopus uniflorus</i>	Lamiaceae	h	HE	PF	*
<i>Lycopus virginicus</i>	Lamiaceae	h	HE	PF	*
<i>Lysimachia quadrifolia</i>	Primulaceae	h	HE	PF	*
<i>Magnolia acuminata</i>	Magnoliaceae	w	PH	TR	*
<i>Magnolia fraseri</i>	Magnoliaceae	w	PH	TR	*
<i>Maianthemum canadense</i>	Liliaceae	h	HE	PF	*
<i>Malaxis unifolia</i>	Orchidaceae	h	CR	PF	*
<i>Medeola virginiana</i>	Liliaceae	h	CR	PF	*
<i>Melanthium hybridum</i>	Liliaceae	h	CR	PF	*
<i>Melilotus officinalis</i>	Fabaceae	h	HE	BF	*
<i>Mentha sp</i>	Lamiaceae	h			*
<i>Menziesia pilosa</i>	Ericaceae	w	PH	WS	*
<i>Mimulus ringens</i>	Scrophulariaceae	h	HE	PF	*
<i>Mitchella repens</i>	Rubiaceae	h	CH	PF	*
<i>Monarda sp</i>	Lamiaceae	h			*
<i>Monotropa hypopithys</i>	Monotropaceae	h	CR	PF	*
<i>Monotropa uniflora</i>	Monotropaceae	h	CR	PF	*
<i>Muhlenbergia frondosa</i>	Poaceae	h	HE	GR	*
<i>Muhlenbergia schreberi</i>	Poaceae	h	HE	GR	*
<i>Muhlenbergia tenuiflora</i>	Poaceae	h	HE	GR	*
<i>Nyssa sylvatica</i>	Nyssaceae	w	PH	TR	*
<i>Oenothera biennis</i>	Onagraceae	h	HE	PT	*
<i>Onoclea sensibilis</i>	Onocleaceae	h	HE	PT	*
<i>Orchis spectabilis</i>	Orchidaceae	h	CR	PF	*
<i>Osmunda cinnamomea</i>	Osmundaceae	h	HE	PT	*
<i>Osmunda claytoniana</i>	Osmundaceae	h	HE	PT	*
<i>Osmunda regalis</i>	Osmundaceae	h	HE	PT	*
<i>Ostrya virginiana</i>	Betulaceae	w	PH	TR	*
<i>Oxalis dillenii</i>	Oxalidaceae	h	HE	PF	*
<i>Oxalis stricta</i>	Oxalidaceae	h	HE	PF	*
<i>Oxalis violacea</i>	Oxalidaceae	h	CR	PF	*
<i>Oxydendrum arboreum</i>	Ericaceae	w	PH	TR	*
<i>Oxypolis rigidior</i>	Apiaceae	h	HE	PF	*
<i>Panicum acuminatum</i>	Poaceae	h	HE	GR	*
<i>Panicum boscii</i>	Poaceae	h	HE	GR	*
<i>Panicum capillare</i>	Poaceae	h	HE	GR	*
<i>Panicum clandestinum</i>	Poaceae	h	HE	GR	*
<i>Panicum commutatum</i>	Poaceae	h	HE	GR	*
<i>Panicum depauperatum</i>	Poaceae	h	HE	GR	*
<i>Panicum dichotomum</i>	Poaceae	h	HE	GR	*
<i>Panicum latifolium</i>	Poaceae	h	HE	GR	*
<i>Panicum linearifolium</i>	Poaceae	h	HE	GR	*
<i>Panicum longifolium</i>	Poaceae	h	HE	GR	*
<i>Panicum sphaerocarpon</i>	Poaceae	h	HE	GR	*

<i>Parnassia asarifolia</i>	Saxifragaceae	h	HE	PF		*
<i>Parnassia glauca</i>	Saxifragaceae	h	HE	PF	*	
<i>Paronychia canadensis</i>	Caryophyllaceae	h	TH	AF		*
<i>Parthenocissus quinquefolia</i>	Vitaceae	w	PH	WV	*	*
<i>Paspalum setaceum</i>	Poaceae	h	HE	GR		*
<i>Passiflora lutea</i>	Passifloraceae	h	HE	PF		*
<i>Paulownia tomentosa</i>	Scrophulariaceae	w	PH	TR		*
<i>Phalaris arundinacea</i>	Poaceae	h	HE	GR		*
<i>Phleum pratense</i>	Poaceae	h	HE	GR		*
<i>Phytolacca americana</i>	Phytolaccaceae	h	CR	PF		*
<i>Pinus echinata</i>	Pinaceae	w	PH	TR	*	*
<i>Pinus pungens</i>	Pinaceae	w	PH	TR	*	*
<i>Pinus rigida</i>	Pinaceae	w	PH	TR	*	*
<i>Pinus strobus</i>	Pinaceae	w	PH	TR	*	*
<i>Pinus virginiana</i>	Pinaceae	w	PH	TR	*	*
<i>Plantago lanceolata</i>	Plantaginaceae	h	HE	PF		*
<i>Plantago major</i>	Plantaginaceae	h	HE	PF		*
<i>Plantago rugelii</i>	Plantaginaceae	h	HE	PF		*
<i>Plantago virginica</i>	Plantaginaceae	h	HE	PF		*
<i>Platanus occidentalis</i>	Platanaceae	w	PH	TR	*	*
<i>Poa compressa</i>	Poaceae	h	HE	GR		*
<i>Poa cuspidata</i>	Poaceae	h	HE	GR	*	*
<i>Poa pratensis</i>	Poaceae	h	CR	GR		*
<i>Podophyllum peltatum</i>	Berberidaceae	h	CR	PF	*	*
<i>Polygala polygama</i>	Polygalaceae	h	HE	BF		*
<i>Polygala senega</i>	Polygalaceae	h	HE	PF	*	
<i>Polygonatum biflorum</i>	Liliaceae	h	CR	PF	*	*
<i>Polygonum acre</i>	Polygonaceae	h	HE	PF		*
<i>Polygonum persicaria</i>	Polygonaceae	h	TH	AF		*
<i>Polygonum scandens</i>	Polygonaceae	h	HE	PF		*
<i>Polypodium appalachianum</i>	Polypodiaceae	h	HE	PT	*	*
<i>Polypodium virginianum</i>	Polypodiaceae	h	HE	PT	*	*
<i>Polystichum acrostichoides</i>	Aspleniaceae	h	HE	PT	*	*
<i>Populus grandidentata</i>	Salicaceae	w	PH	TR	*	*
<i>Potentilla canadensis</i>	Rosaceae	h	HE	PF	*	*
<i>Potentilla norvegica</i>	Rosaceae	h	HE	BF		*
<i>Potentilla simplex</i>	Rosaceae	h	HE	PF	*	*
<i>Prenanthes sp</i>	Asteraceae	h			*	*
<i>Prunella vulgaris</i>	Lamiaceae	h	HE	PF		*
<i>Prunus avium</i>	Rosaceae	w	PH	TR	*	
<i>Prunus pensylvanica</i>	Rosaceae	w	PH	TR	*	
<i>Prunus serotina</i>	Rosaceae	w	PH	TR	*	*
<i>Pteridium aquilinum</i>	Pteridiaceae	h	HE	PT	*	*
<i>Pycnanthemum incanum</i>	Lamiaceae	h	HE	PF		*
<i>Pyrola americana</i>	Ericaceae	h	HE	PF	*	
<i>Pyrola rotundifolia</i>	Ericaceae	h	HE	PF	*	*
<i>Quercus alba</i>	Fagaceae	w	PH	TR	*	*
<i>Quercus coccinea</i>	Fagaceae	w	PH	TR	*	*
<i>Quercus ilicifolia</i>	Fagaceae	w	PH	TR	*	
<i>Quercus prinus</i>	Fagaceae	w	PH	TR	*	*
<i>Quercus rubra</i>	Fagaceae	w	PH	TR	*	*
<i>Quercus velutina</i>	Fagaceae	w	PH	TR	*	*

<i>Ranunculus abortivus</i>	Ranunculaceae	h	HE	BF		*
<i>Ranunculus allegheniensis</i>	Ranunculaceae	h	TH	AF		*
<i>Ranunculus hispidus</i>	Ranunculaceae	h	HE	PF		*
<i>Ranunculus recurvatus</i>	Ranunculaceae	h	HE	PF	*	*
<i>Ranunculus septentrionalis</i>	Ranunculaceae	h	HE	PF		*
<i>Rhododendron calendulaceum</i>	Ericaceae	w	PH	WS	*	*
<i>Rhododendron maximum</i>	Ericaceae	w	PH	WS	*	*
<i>Rhododendron periclymenoides</i>	Ericaceae	w	PH	WS		*
<i>Rhus copallina</i>	Anacardiaceae	w	PH	WS		*
<i>Rhus glabra</i>	Anacardiaceae	w	PH	WS		*
<i>Rhus typhina</i>	Anacardiaceae	w	PH	WS		*
<i>Rhynchospora capitellata</i>	Cyperaceae	h	HE	GR	*	*
<i>Robinia pseudoacacia</i>	Fabaceae	w	PH	TR	*	*
<i>Rosa carolina</i>	Rosaceae	w	PH	WS		*
<i>Rosa multiflora</i>	Rosaceae	w	PH	WS	*	*
<i>Rubus allegheniensis</i>	Rosaceae	w	HE	WS	*	*
<i>Rubus argutus</i>	Rosaceae	w	HE	WS		*
<i>Rubus canadensis</i>	Rosaceae	w	HE	WS	*	*
<i>Rubus flagellaris</i>	Rosaceae	w	HE	WS	*	*
<i>Rubus occidentalis</i>	Rosaceae	w	HE	WS		*
<i>Rubus phoenicolasius</i>	Rosaceae	w	HE	WS		*
<i>Rudbeckia laciniata</i>	Asteraceae	h	HE	PF		*
<i>Rumex acetosella</i>	Polygonaceae	h	HE	PF		*
<i>Rumex obtusifolius</i>	Polygonaceae	h	HE	PF		*
<i>Sambucus canadensis</i>	Caprifoliaceae	w	PH	WS	*	*
<i>Sambucus pubens</i>	Caprifoliaceae	w	PH	WS	*	*
<i>Sanicula canadensis</i>	Apiaceae	h	HE	PF		*
<i>Sassafras albidum</i>	Lauraceae	w	PH	TR	*	*
<i>Satureja vulgaris</i>	Lamiaceae	h	HE	PF		*
<i>Saxifraga michauxii</i>	Saxifragaceae	h	HE	PF	*	
<i>Schizachyrium scoparium</i>	Poaceae	h	HE	GR		*
<i>Scirpus atrovirens</i>	Cyperaceae	h	HE	GR	*	*
<i>Scirpus cyperinus</i>	Cyperaceae	h	HE	GR	*	*
<i>Scirpus polyphyllus</i>	Cyperaceae	h	HE	GR		*
<i>Scutellaria elliptica</i>	Lamiaceae	h	HE	PF		*
<i>Scutellaria sp</i>	Lamiaceae	h			*	
<i>Senecio anonymus</i>	Asteraceae	h	HE	PF		*
<i>Senecio aureus</i>	Asteraceae	h	HE	PF	*	*
<i>Senecio obovatus</i>	Asteraceae	h	HE	PF		*
<i>Setaria faberi</i>	Poaceae	h	TH	GR		*
<i>Setaria viridis</i>	Poaceae	h	TH	GR		*
<i>Silene stellata</i>	Caryophyllaceae	h	HE	PF	*	*
<i>Silene virginica</i>	Caryophyllaceae	h	HE	PF	*	*
<i>Sisyrinchium angustifolium</i>	Iridaceae	h	HE	PF		*
<i>Smilacina racemosa</i>	Liliaceae	h	CR	PF	*	*
<i>Smilax glauca</i>	Liliaceae	w	PH	WV	*	*
<i>Smilax herbacea</i>	Liliaceae	h	HE	PF	*	*
<i>Smilax rotundifolia</i>	Liliaceae	w	PH	WV	*	*
<i>Solanum carolinense</i>	Solanaceae	h	CR	PF		*
<i>Solanum ptycanthum</i>	Solanaceae	h	TH	AF		*
<i>Solidago altissima</i>	Asteraceae	h	HE	PF		*
<i>Solidago arguta</i>	Asteraceae	h	HE	PF		*

<i>Solidago bicolor</i>	Asteraceae	h	HE	PF		*
<i>Solidago caesia</i>	Asteraceae	h	HE	PF	*	*
<i>Solidago canadensis</i>	Asteraceae	h	HE	PF		*
<i>Solidago curtisii</i>	Asteraceae	h	HE	PF	*	*
<i>Solidago erecta</i>	Asteraceae	h	HE	PF		*
<i>Solidago flexicaulis</i>	Asteraceae	h	HE	PF	*	
<i>Solidago gigantea</i>	Asteraceae	h	HE	PF		*
<i>Solidago graminifolia</i>	Asteraceae	h	HE	PF	*	*
<i>Solidago nemoralis</i>	Asteraceae	h	HE	PF		*
<i>Solidago puberula</i>	Asteraceae	h	HE	PF	*	*
<i>Solidago roanensis</i>	Asteraceae	h	HE	PF		*
<i>Solidago rugosa</i>	Asteraceae	h	HE	PF	*	*
<i>Solidago ulmifolia</i>	Asteraceae	h	HE	PF		*
Sonchus asper	Asteraceae	h	TH	AF		*
Sonchus oleraceus	Asteraceae	h	TH	AF		*
<i>Specularia perfoliata</i>	Campanulaceae	h	TH	AF		*
<i>Sphenopholis nitida</i>	Poaceae	h	HE	GR		*
<i>Sphenopholis obtusata</i>	Poaceae	h	HE	GR		*
Spiraea japonica	Rosaceae	w	PH	WS	*	*
<i>Spiranthes sp</i>	Orchidaceae	h			*	
<i>Stellaria pubera</i>	Caryophyllaceae	h	CH	PF	*	*
<i>Taenidia integerrima</i>	Apiaceae	h	HE	PF		*
Taraxacum officinale	Asteraceae	h	HE	PF	*	*
<i>Tephrosia virginiana</i>	Fabaceae	h	HE	PF		*
<i>Thalictrum dioicum</i>	Ranunculaceae	h	HE	PF		*
<i>Thalictrum revolutum</i>	Ranunculaceae	h	HE	PF		*
<i>Thalictrum sp</i>	Ranunculaceae	h			*	
<i>Thaspium trifoliatum</i>	Apiaceae	h	HE	PF		*
<i>Thelypteris noveboracensis</i>	Aspleniaceae	h	HE	PT	*	*
<i>Tilia americana</i>	Tiliaceae	w	PH	TR	*	*
<i>Tipularia discolor</i>	Orchidaceae	h	CR	PF		*
<i>Toxicodendron radicans</i>	Anacardiaceae	w	PH	WV	*	*
Trifolium campestre	Fabaceae	h	TH	AF		*
Trifolium hybridum	Fabaceae	h	HE	PF		*
Trifolium pratense	Fabaceae	h	HE	PF	*	*
<i>Trifolium repens</i>	Fabaceae	h	HE	PF		*
<i>Trillium undulatum</i>	Liliaceae	h	CR	PF	*	*
<i>Tsuga canadensis</i>	Pinaceae	w	PH	TR	*	*
Tussilago farfara	Asteraceae	h	CR	PF		*
<i>Ulmus americana</i>	Ulmaceae	w	PH	TR		*
<i>Ulmus rubra</i>	Ulmaceae	w	PH	TR	*	
<i>Uvularia perfoliata</i>	Liliaceae	h	CR	PF	*	*
<i>Uvularia pudica</i>	Liliaceae	h	CR	PF	*	*
<i>Uvularia sessilifolia</i>	Liliaceae	h	CR	PF	*	
<i>Vaccinium corymbosum</i>	Ericaceae	w	PH	WS	*	
<i>Vaccinium pallidum</i>	Ericaceae	w	PH	WS	*	*
<i>Vaccinium simulatum</i>	Ericaceae	w	PH	WS		*
<i>Vaccinium stamineum</i>	Ericaceae	w	PH	WS	*	*
Verbascum blattaria	Scrophulariaceae	h	HE	BF		*
Verbascum thapsus	Scrophulariaceae	h	HE	BF		*
<i>Verbena urticifolia</i>	Verbenaceae	h	HE	PF		*
<i>Verbesina occidentalis</i>	Asteraceae	h	HE	PF		*

<i>Vernonia novaborascensis</i>	Asteraceae	h	HE	PF		*
<i>Veronica arvensis</i>	Scrophulariaceae	h	TH	AF		*
<i>Veronica officinalis</i>	Scrophulariaceae	h	CH	PF		*
<i>Viburnum acerifolium</i>	Caprifoliaceae	w	PH	WS	*	*
<i>Viburnum alnifolium</i>	Caprifoliaceae	w	PH	WS	*	*
<i>Viburnum cassinoides</i>	Caprifoliaceae	w	PH	WS		*
<i>Viburnum prunifolium</i>	Caprifoliaceae	w	PH	WS	*	*
<i>Vicia caroliniana</i>	Fabaceae	h	HE	PF		*
<i>Vicia sp</i>	Fabaceae	h			*	
<i>Viola blanda</i>	Violaceae	h	HE	PF	*	*
<i>Viola cucullata</i>	Violaceae	h	HE	PF	*	*
<i>Viola eriocarpa</i>	Violaceae	h	HE	PF		*
<i>Viola fimbriatula</i>	Violaceae	h	HE	PF		*
<i>Viola hastata</i>	Violaceae	h	HE	PF	*	*
<i>Viola hirsutula</i>	Violaceae	h	HE	PF	*	*
<i>Viola palmata</i>	Violaceae	h	HE	PF	*	*
<i>Viola pedata</i>	Violaceae	h	HE	PF	*	*
<i>Viola rotundifolia</i>	Violaceae	h	HE	PF	*	*
<i>Viola sororia</i>	Violaceae	h	HE	PF	*	*
<i>Vitis aestivalis</i>	Vitaceae	w	PH	WV	*	*
<i>Vulpia myuros</i>	Poaceae	h	HE	GR		*
<i>Zizia aptera</i>	Apiaceae	h	HE	PF	*	
<i>Zizia aurea</i>	Apiaceae	h	HE	PF		*
<i>Zizia trifoliata</i>	Apiaceae	h	HE	PF	*	*

Growth-forms: AF = annual forb, BF = biennial forb, PF = perennial forb, GR = graminoid, PT = pteridophyte,
 WS = woody shrub, WV = woody vine, TR = tree

Raunkiaer's life-forms: PH = phanerophytes, CH = chamaephytes, HE = hemicryptophytes, CR = cryptophytes,
 TH = therophytes

APPENDIX C-1: Ranked herb-stratum abundance—Control

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in control treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
Anemone quinquefolia	812	0.1862	0.1862	Anemone quinquefolia	625	0.2122	0.2122
Thelypteris noveboracensis	701	0.1608	0.3470	Rhododendron sp	296	0.1005	0.3127
Rhododendron sp	319	0.0732	0.4202	Vaccinium pallidum	192	0.0652	0.3779
Viola sp	310	0.0711	0.4913	Acer rubrum	191	0.0649	0.4428
Vaccinium pallidum	258	0.0592	0.5505	Thelypteris noveboracensis	183	0.0621	0.5049
Acer rubrum	236	0.0541	0.6046	Viola sp	177	0.0601	0.5650
Medeola virginiana	183	0.0420	0.6466	Gaultheria procumbens	99	0.0336	0.5986
Gaultheria procumbens	127	0.0291	0.6757	Medeola virginiana	97	0.0329	0.6316
Galax aphylla	112	0.0257	0.7014	Galax aphylla	89	0.0302	0.6618
Sassafras albidum	104	0.0239	0.7252	Sassafras albidum	82	0.0278	0.6896
Gaylussacia baccata	86	0.0197	0.7450	Smilax rotundifolia	76	0.0258	0.7154
Smilax glauca	86	0.0197	0.7647	Smilax glauca	75	0.0255	0.7409
Smilax rotundifolia	80	0.0183	0.7830	Gaylussacia baccata	72	0.0244	0.7654
Conopholis americana	65	0.0149	0.7979	Vaccinium stamineum	67	0.0228	0.7881
Quercus prinus	62	0.0142	0.8122	Quercus rubra	49	0.0166	0.8048
Dioscorea villosa	60	0.0138	0.8259	Dioscorea villosa	45	0.0153	0.8200
Vaccinium stamineum	59	0.0135	0.8394	Quercus alba	41	0.0139	0.8340
Quercus rubra	58	0.0133	0.8528	Quercus coccinea	34	0.0115	0.8455
Quercus alba	54	0.0124	0.8651	Quercus prinus	33	0.0112	0.8567
Desmodium nudiflorum	47	0.0108	0.8759	Desmodium nudiflorum	31	0.0105	0.8672
Chimaphila maculata	36	0.0083	0.8842	Amelanchier arborea	25	0.0085	0.8757
Amelanchier arborea	35	0.0080	0.8922	Chimaphila maculata	25	0.0085	0.8842
Quercus coccinea	35	0.0080	0.9002	Uvularia pudica	23	0.0078	0.8920
Polystichum acrostichoides	28	0.0064	0.9067	Potentilla sp	22	0.0075	0.8995
Nyssa sylvatica	23	0.0053	0.9119	Rubus sp	22	0.0075	0.9070
Vaccinium corymbosum	22	0.0050	0.9170	Danthonia spicata	17	0.0058	0.9127
Uvularia pudica	20	0.0046	0.9216	Quercus velutina	17	0.0058	0.9185
Potentilla sp	19	0.0044	0.9259	Vaccinium simulatum	17	0.0058	0.9243
Rubus sp	19	0.0044	0.9303	Carex sp	15	0.0051	0.9294
Dennstaedtia punctilobula	17	0.0039	0.9342	Desmodium paniculatum	11	0.0037	0.9331
Carex sp	15	0.0034	0.9376	Nyssa sylvatica	10	0.0034	0.9365
Trillium undulatum	15	0.0034	0.9411	Smilacina racemosa	10	0.0034	0.9399
Lysimachia quadrifolia	14	0.0032	0.9443	Prunus serotina	9	0.0031	0.9430
Prunus serotina	13	0.0030	0.9472	Polygonum arifolium	8	0.0027	0.9457
Aster sp	11	0.0025	0.9498	Rosa sp	8	0.0027	0.9484
Parthenocissus quinquefolia	11	0.0025	0.9523	Uvularia perfoliata	8	0.0027	0.9511
Acer pensylvanicum	10	0.0023	0.9546	Dennstaedtia punctilobula	7	0.0024	0.9535
Hamamelis virginiana	10	0.0023	0.9569	Hamamelis virginiana	7	0.0024	0.9559
Quercus velutina	9	0.0021	0.9589	Magnolia fraseri	7	0.0024	0.9582
Smilacina racemosa	9	0.0021	0.9610	Vitis aestivalis	7	0.0024	0.9606
Athyrium filix-femina	8	0.0018	0.9628	Aster sp	6	0.0020	0.9626
Castanea dentata	8	0.0018	0.9647	Castanea dentata	6	0.0020	0.9647
Desmodium sp	8	0.0018	0.9665	Conopholis americana	5	0.0017	0.9664
Mitchella repens	8	0.0018	0.9683	Magnolia acuminata	5	0.0017	0.9681

Polygonatum biflorum	8	0.0018	0.9702	Solidago sp	5	0.0017	0.9698
Rosa sp	8	0.0018	0.9720	Trillium undulatum	5	0.0017	0.9715
Vitis aestivalis	8	0.0018	0.9739	Juncus sp	4	0.0014	0.9728
Kalmia latifolia	7	0.0016	0.9755	Osmunda cinnamomea	4	0.0014	0.9742
Magnolia fraseri	7	0.0016	0.9771	Parthenocissus quinquefolia	4	0.0014	0.9756
Panicum sp	6	0.0014	0.9784	Stellaria pubera	4	0.0014	0.9769
Smilax herbacea	6	0.0014	0.9798	Viburnum acerifolium	4	0.0014	0.9783
Uvularia perfoliata	6	0.0014	0.9812	Betula lenta	3	0.0010	0.9793
Gentiana sp	5	0.0011	0.9823	Fraxinus sp	3	0.0010	0.9803
Magnolia acuminata	5	0.0011	0.9835	Gentiana decora	3	0.0010	0.9813
Solidago sp	5	0.0011	0.9846	Goodyera pubescens	3	0.0010	0.9823
Viburnum acerifolium	5	0.0011	0.9858	Liriodendron tulipifera	3	0.0010	0.9834
Asclepias quadrifolia	4	0.0009	0.9867	Lysimachia quadrifolia	3	0.0010	0.9844
Carya tomentosa	4	0.0009	0.9876	Mitchella repens	3	0.0010	0.9854
Eupatorium sp	4	0.0009	0.9885	Oxydendrum arboreum	3	0.0010	0.9864
Goodyera pubescens	4	0.0009	0.9894	Polygonatum biflorum	3	0.0010	0.9874
Liriodendron tulipifera	4	0.0009	0.9904	Prenanthes sp	3	0.0010	0.9885
Stellaria pubera	4	0.0009	0.9913	Smilax herbacea	3	0.0010	0.9895
Carya glabra	3	0.0007	0.9920	Carya tomentosa	2	0.0007	0.9902
Galium sp	3	0.0007	0.9927	Coreopsis major	2	0.0007	0.9908
Isotria verticillata	3	0.0007	0.9933	Eupatorium sp	2	0.0007	0.9915
Osmunda cinnamomea	3	0.0007	0.9940	Galium sp	2	0.0007	0.9922
Prenanthes sp	3	0.0007	0.9947	Heuchera americana	2	0.0007	0.9929
Aureolaria flava	2	0.0005	0.9952	Hieracium paniculatum	2	0.0007	0.9935
Betula lenta	2	0.0005	0.9956	Lindera benzoin	2	0.0007	0.9942
Cornus florida	2	0.0005	0.9961	Osmunda claytoniana	2	0.0007	0.9949
Fraxinus sp	2	0.0005	0.9966	Panicum sp	2	0.0007	0.9956
Geranium maculata	2	0.0005	0.9970	Acer pensylvanicum	1	0.0003	0.9959
Heuchera sp	2	0.0005	0.9975	Acer saccharum	1	0.0003	0.9963
Osmunda claytoniana	2	0.0005	0.9979	Botrychium virginianum	1	0.0003	0.9966
Acer saccharum	1	0.0002	0.9982	Carya glabra	1	0.0003	0.9969
Cassia marilandica	1	0.0002	0.9984	Castanea pumila	1	0.0003	0.9973
Coreopsis major	1	0.0002	0.9986	Ceanothus americanus	1	0.0003	0.9976
Crataegus sp	1	0.0002	0.9989	Epigaea repens	1	0.0003	0.9980
Ilex montana	1	0.0002	0.9991	Geranium maculata	1	0.0003	0.9983
Ipomoea sp	1	0.0002	0.9993	Gillenia trifoliata	1	0.0003	0.9986
Oxydendrum arboreum	1	0.0002	0.9995	Ipomoea sp	1	0.0003	0.9990
Pteridium aquilinum	1	0.0002	0.9998	Kalmia latifolia	1	0.0003	0.9993
Uvularia sessilifolia	1	0.0002	1.0000	Muhlenbergia tenuiflora	1	0.0003	0.9997
				Pteridium aquilinum	1	0.0003	1.0000

APPENDIX C-2: Ranked herb-stratum abundance—Understory herbicide

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in understory herbicide treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
<i>Thelypteris noveboracensis</i>	1092	0.3069	0.3069	<i>Thelypteris noveboracensis</i>	483	0.2157	0.2157
<i>Anemone quinquefolia</i>	614	0.1726	0.4795	<i>Anemone quinquefolia</i>	364	0.1626	0.3783
<i>Vaccinium pallidum</i>	288	0.0809	0.5604	<i>Vaccinium pallidum</i>	184	0.0822	0.4605
<i>Rhododendron</i> sp	156	0.0438	0.6043	<i>Rhododendron</i> sp	112	0.0500	0.5105
<i>Viola</i> sp	139	0.0391	0.6433	<i>Vaccinium stamineum</i>	99	0.0442	0.5547
<i>Sassafras albidum</i>	100	0.0281	0.6714	<i>Acer rubrum</i>	93	0.0415	0.5962
<i>Dennstaedtia punctilobula</i>	89	0.0250	0.6965	<i>Sassafras albidum</i>	82	0.0366	0.6329
<i>Acer rubrum</i>	79	0.0222	0.7187	<i>Viola</i> sp	70	0.0313	0.6641
<i>Desmodium nudiflorum</i>	78	0.0219	0.7406	<i>Dennstaedtia punctilobula</i>	49	0.0219	0.6860
<i>Dioscorea villosa</i>	74	0.0208	0.7614	<i>Gaultheria procumbens</i>	45	0.0201	0.7061
<i>Quercus prinus</i>	72	0.0202	0.7816	<i>Quercus coccinea</i>	45	0.0201	0.7262
<i>Vaccinium stamineum</i>	58	0.0163	0.7979	<i>Galax aphylla</i>	42	0.0188	0.7450
<i>Gaultheria procumbens</i>	56	0.0157	0.8137	<i>Medeola virginiana</i>	42	0.0188	0.7637
<i>Medeola virginiana</i>	48	0.0135	0.8272	<i>Desmodium nudiflorum</i>	39	0.0174	0.7812
<i>Quercus coccinea</i>	47	0.0132	0.8404	<i>Amelanchier arborea</i>	37	0.0165	0.7977
<i>Amelanchier arborea</i>	40	0.0112	0.8516	<i>Quercus alba</i>	33	0.0147	0.8124
<i>Smilax rotundifolia</i>	38	0.0107	0.8623	<i>Quercus prinus</i>	32	0.0143	0.8267
<i>Potentilla</i> sp	34	0.0096	0.8718	<i>Smilax rotundifolia</i>	30	0.0134	0.8401
<i>Galax aphylla</i>	32	0.0090	0.8808	<i>Chimaphila maculata</i>	29	0.0130	0.8531
<i>Uvularia pudica</i>	30	0.0084	0.8893	<i>Dioscorea villosa</i>	24	0.0107	0.8638
<i>Rubus</i> sp	27	0.0076	0.8969	<i>Potentilla</i> sp	23	0.0103	0.8741
<i>Quercus alba</i>	25	0.0070	0.9039	<i>Quercus velutina</i>	23	0.0103	0.8843
<i>Poa</i> sp	23	0.0065	0.9103	<i>Smilax glauca</i>	23	0.0103	0.8946
<i>Rosa</i> sp	21	0.0059	0.9162	<i>Rosa</i> sp	19	0.0085	0.9031
<i>Conopholis americana</i>	20	0.0056	0.9219	<i>Uvularia pudica</i>	19	0.0085	0.9116
<i>Smilax glauca</i>	20	0.0056	0.9275	<i>Quercus rubra</i>	18	0.0080	0.9196
<i>Chimaphila maculata</i>	19	0.0053	0.9328	<i>Danthonia compressa</i>	15	0.0067	0.9263
<i>Quercus rubra</i>	18	0.0051	0.9379	<i>Rubus</i> sp	12	0.0054	0.9317
<i>Carex</i> sp	16	0.0045	0.9424	<i>Polygonatum biflorum</i>	11	0.0049	0.9366
<i>Quercus velutina</i>	16	0.0045	0.9469	<i>Viburnum acerifolium</i>	10	0.0045	0.9410
<i>Smilacina racemosa</i>	14	0.0039	0.9508	<i>Hieracium venosum</i>	9	0.0040	0.9451
<i>Nyssa sylvatica</i>	12	0.0034	0.9542	<i>Smilacina racemosa</i>	9	0.0040	0.9491
<i>Viburnum acerifolium</i>	12	0.0034	0.9576	<i>Panicum</i> sp	8	0.0036	0.9527
<i>Panicum</i> sp	11	0.0031	0.9607	<i>Carya glabra</i>	7	0.0031	0.9558
<i>Polygonatum biflorum</i>	11	0.0031	0.9637	<i>Aster</i> sp	6	0.0027	0.9585
<i>Aster</i> sp	9	0.0025	0.9663	<i>Liriodendron tulipifera</i>	5	0.0022	0.9607
<i>Cornus florida</i>	8	0.0022	0.9685	<i>Lysimachia quadrifolia</i>	5	0.0022	0.9629
<i>Liriodendron tulipifera</i>	8	0.0022	0.9708	<i>Vaccinium simulatum</i>	5	0.0022	0.9652
<i>Hieracium venosum</i>	7	0.0020	0.9727	<i>Aureolaria laevigata</i>	4	0.0018	0.9669
<i>Lysimachia quadrifolia</i>	7	0.0020	0.9747	<i>Coreopsis major</i>	4	0.0018	0.9687
<i>Epigaea repens</i>	6	0.0017	0.9764	<i>Nyssa sylvatica</i>	4	0.0018	0.9705
<i>Stellaria pubera</i>	6	0.0017	0.9781	<i>Prunus serotina</i>	4	0.0018	0.9723
<i>Vitis aestivalis</i>	6	0.0017	0.9798	<i>Pteridium aquilinum</i>	4	0.0018	0.9741
<i>Carya glabra</i>	5	0.0014	0.9812	<i>Robinia pseudoacacia</i>	4	0.0018	0.9759

Coreopsis major	5	0.0014	0.9826	Vitis aestivalis	4	0.0018	0.9777
Ipomoea sp	5	0.0014	0.9840	Zizia trifoliata	4	0.0018	0.9795
Prunus serotina	5	0.0014	0.9854	Carya tomentosa	3	0.0013	0.9808
Zizia trifoliata	5	0.0014	0.9868	Ipomoea sp	3	0.0013	0.9821
Carya tomentosa	4	0.0011	0.9879	Lespedeza hirta	3	0.0013	0.9835
Gentiana sp	4	0.0011	0.9890	Conopholis americana	2	0.0009	0.9844
Hieracium paniculatum	4	0.0011	0.9902	Cornus florida	2	0.0009	0.9853
Prenanthes sp	4	0.0011	0.9913	Epigaea repens	2	0.0009	0.9862
Robinia pseudoacacia	4	0.0011	0.9924	Eupatorium sp	2	0.0009	0.9870
Galium sp	3	0.0008	0.9933	Fraxinus sp	2	0.0009	0.9879
Pteridium aquilinum	3	0.0008	0.9941	Galium sp	2	0.0009	0.9888
Solidago sp	3	0.0008	0.9949	Gaylussacia baccata	2	0.0009	0.9897
Angelica venenosa	2	0.0006	0.9955	Gentiana decora	2	0.0009	0.9906
Aureolaria flava	2	0.0006	0.9961	Goodyera pubescens	2	0.0009	0.9915
Desmodium sp	2	0.0006	0.9966	Hieracium paniculatum	2	0.0009	0.9924
Eupatorium sp	2	0.0006	0.9972	Lactuca canadensis	2	0.0009	0.9933
Magnolia fraseri	2	0.0006	0.9978	Magnolia fraseri	2	0.0009	0.9942
Oxydendrum arboreum	2	0.0006	0.9983	Smilax herbacea	2	0.0009	0.9951
Castanea dentata	1	0.0003	0.9986	Solidago sp	2	0.0009	0.9960
Fraxinus sp	1	0.0003	0.9989	Trillium undulatum	2	0.0009	0.9969
Gaylussacia baccata	1	0.0003	0.9992	Carex sp	1	0.0004	0.9973
Goodyera repens	1	0.0003	0.9994	Castanea dentata	1	0.0004	0.9978
Pinus strobus	1	0.0003	0.9997	Gillenia trifoliata	1	0.0004	0.9982
Trillium undulatum	1	0.0003	1.0000	Magnolia acuminata	1	0.0004	0.9987
				Prenanthes sp	1	0.0004	0.9991
				Viburnum prunifolium	1	0.0004	0.9996
				Viburnum sp	1	0.0004	1.0000

APPENDIX C-3: Ranked herb-stratum abundance—Group selection

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in group selection treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
<i>Thelypteris noveboracensis</i>	966	0.2214	0.2214	<i>Erechtites hieracifolia</i>	832	0.1912	0.1912
<i>Anemone quinquefolia</i>	932	0.2136	0.4349	<i>Anemone quinquefolia</i>	542	0.1246	0.3158
<i>Viola</i> sp	497	0.1139	0.5488	<i>Viola</i> sp	361	0.0830	0.3988
<i>Vaccinium pallidum</i>	247	0.0566	0.6054	<i>Thelypteris noveboracensis</i>	342	0.0786	0.4774
<i>Acer rubrum</i>	166	0.0380	0.6434	<i>Acer rubrum</i>	196	0.0450	0.5224
<i>Sassafras albidum</i>	129	0.0296	0.6730	<i>Potentilla</i> sp	170	0.0391	0.5615
<i>Desmodium nudiflorum</i>	127	0.0291	0.7021	<i>Vaccinium pallidum</i>	157	0.0361	0.5976
<i>Smilax rotundifolia</i>	121	0.0277	0.7298	<i>Rubus</i> sp	139	0.0319	0.6295
<i>Rhododendron</i> sp	94	0.0215	0.7514	<i>Panicum</i> sp	134	0.0308	0.6603
<i>Prenanthes</i> sp	84	0.0192	0.7706	<i>Sassafras albidum</i>	126	0.0290	0.6893
<i>Carex</i> sp	73	0.0167	0.7874	<i>Smilax rotundifolia</i>	126	0.0290	0.7182
<i>Quercus coccinea</i>	60	0.0137	0.8011	<i>Dennstaedtia punctilobula</i>	90	0.0207	0.7389
<i>Quercus prinus</i>	55	0.0126	0.8137	<i>Desmodium nudiflorum</i>	76	0.0175	0.7564
<i>Quercus alba</i>	47	0.0108	0.8245	<i>Carex</i> sp	67	0.0154	0.7718
<i>Dennstaedtia punctilobula</i>	42	0.0096	0.8341	<i>Rhododendron</i> sp	63	0.0145	0.7863
<i>Smilax glauca</i>	42	0.0096	0.8437	<i>Smilax glauca</i>	57	0.0131	0.7994
<i>Amelanchier arborea</i>	41	0.0094	0.8531	<i>Vitis aestivalis</i>	47	0.0108	0.8102
<i>Mitchella repens</i>	37	0.0085	0.8616	<i>Liriodendron tulipifera</i>	44	0.0101	0.8203
<i>Potentilla</i> sp	36	0.0082	0.8698	<i>Amelanchier arborea</i>	43	0.0099	0.8302
<i>Dioscorea villosa</i>	30	0.0069	0.8767	<i>Nyssa sylvatica</i>	43	0.0099	0.8400
<i>Acer pensylvanicum</i>	27	0.0062	0.8829	<i>Quercus coccinea</i>	40	0.0092	0.8492
<i>Fraxinus</i> sp	27	0.0062	0.8891	<i>Danthonia spicata</i>	39	0.0090	0.8582
<i>Quercus rubra</i>	25	0.0057	0.8948	<i>Quercus rubra</i>	33	0.0076	0.8658
<i>Nyssa sylvatica</i>	23	0.0053	0.9001	<i>Prenanthes</i> sp	32	0.0074	0.8731
<i>Gaultheria procumbens</i>	22	0.0050	0.9051	<i>Quercus prinus</i>	32	0.0074	0.8805
<i>Uvularia pudica</i>	22	0.0050	0.9102	<i>Quercus alba</i>	31	0.0071	0.8876
<i>Vaccinium stamineum</i>	22	0.0050	0.9152	<i>Dioscorea villosa</i>	28	0.0064	0.8940
<i>Smilacina racemosa</i>	21	0.0048	0.9200	<i>Prunus serotina</i>	28	0.0064	0.9005
<i>Desmodium</i> sp	17	0.0039	0.9239	<i>Vaccinium stamineum</i>	24	0.0055	0.9060
<i>Uvularia perfoliata</i>	17	0.0039	0.9278	<i>Galium</i> sp	20	0.0046	0.9106
<i>Medeola virginiana</i>	15	0.0034	0.9313	<i>Uvularia pudica</i>	20	0.0046	0.9152
<i>Cornus florida</i>	14	0.0032	0.9345	<i>Athyrium filix-femina</i>	14	0.0032	0.9184
<i>Galium</i> sp	14	0.0032	0.9377	<i>Medeola virginiana</i>	14	0.0032	0.9216
<i>Rubus</i> sp	14	0.0032	0.9409	<i>Quercus velutina</i>	14	0.0032	0.9248
<i>Carya tomentosa</i>	12	0.0027	0.9436	<i>Solidago</i> sp	14	0.0032	0.9281
<i>Prunus serotina</i>	12	0.0027	0.9464	<i>Fagus grandifolia</i>	13	0.0030	0.9311
<i>Solidago</i> sp	12	0.0027	0.9491	<i>Smilacina racemosa</i>	13	0.0030	0.9340
<i>Chimaphila maculata</i>	11	0.0025	0.9516	<i>Danthonia compressa</i>	12	0.0028	0.9368
<i>Quercus velutina</i>	11	0.0025	0.9542	<i>Magnolia acuminata</i>	12	0.0028	0.9396
<i>Impatiens capensis</i>	10	0.0023	0.9565	<i>Lobelia inflata</i>	11	0.0025	0.9421
<i>Lindera benzoin</i>	9	0.0021	0.9585	<i>Phytolacca americana</i>	11	0.0025	0.9446
<i>Magnolia acuminata</i>	9	0.0021	0.9606	<i>Lysimachia quadrifolia</i>	10	0.0023	0.9469
<i>Rosa</i> sp	9	0.0021	0.9626	<i>Mitchella repens</i>	10	0.0023	0.9492
<i>Vitis aestivalis</i>	9	0.0021	0.9647	<i>Poa</i> sp	10	0.0023	0.9515

Viburnum acerifolium	8	0.0018	0.9665	Scutellaria elliptica	10	0.0023	0.9538
Aster sp	7	0.0016	0.9681	Carya tomentosa	9	0.0021	0.9559
Campanula divaricata	7	0.0016	0.9698	Parthenocissus quinquefolia	9	0.0021	0.9579
Castanea dentata	7	0.0016	0.9714	Polygonatum biflorum	9	0.0021	0.9600
Oxydendrum arboreum	7	0.0016	0.9730	Betula lenta	8	0.0018	0.9618
Parthenocissus quinquefolia	7	0.0016	0.9746	Carya glabra	8	0.0018	0.9637
Carya glabra	6	0.0014	0.9759	Cornus florida	8	0.0018	0.9655
Zizia trifoliata	6	0.0014	0.9773	Fraxinus sp	7	0.0016	0.9671
Geranium maculata	5	0.0011	0.9785	Gaultheria procumbens	7	0.0016	0.9687
Hieracium venosum	5	0.0011	0.9796	Oxydendrum arboreum	7	0.0016	0.9704
Liriodendron tulipifera	5	0.0011	0.9808	Gaylussacia baccata	6	0.0014	0.9717
Lysimachia quadrifolia	5	0.0011	0.9819	Robinia pseudoacacia	6	0.0014	0.9731
Magnolia fraseri	5	0.0011	0.9830	Rosa sp	6	0.0014	0.9745
Panicum sp	5	0.0011	0.9842	Acer pensylvanicum	5	0.0011	0.9756
Polygonatum biflorum	5	0.0011	0.9853	Eupatorium sp	5	0.0011	0.9768
Trillium undulatum	5	0.0011	0.9865	Houstonia purpurea	5	0.0011	0.9779
Antennaria plantaginifolia	4	0.0009	0.9874	Magnolia fraseri	5	0.0011	0.9791
Eupatorium sp	4	0.0009	0.9883	Uvularia perfoliata	5	0.0011	0.9802
Fagus grandifolia	4	0.0009	0.9892	Aster sp	4	0.0009	0.9812
Gaylussacia baccata	3	0.0007	0.9899	Campanula divaricata	4	0.0009	0.9821
Gentiana sp	3	0.0007	0.9906	Luzula echinata	4	0.0009	0.9830
Hamamelis virginiana	3	0.0007	0.9913	Zizia trifoliata	4	0.0009	0.9839
Ipomoea sp	3	0.0007	0.9920	Agrostis perennans	3	0.0007	0.9846
Smilax herbacea	3	0.0007	0.9927	Ailanthus altissima	3	0.0007	0.9853
Betula lenta	2	0.0005	0.9931	Botrychium virginianum	3	0.0007	0.9860
Botrychium virginianum	2	0.0005	0.9936	Hieracium paniculatum	3	0.0007	0.9867
Cimicifuga racemosa	2	0.0005	0.9940	Hieracium venosum	3	0.0007	0.9874
Collinsonia canadensis	2	0.0005	0.9945	Houstonia longifolia	3	0.0007	0.9880
Conopholis americana	2	0.0005	0.9950	Lindera benzoin	3	0.0007	0.9887
Coreopsis major	2	0.0005	0.9954	Thaspium sp	3	0.0007	0.9894
Poa sp	2	0.0005	0.9959	Trillium undulatum	3	0.0007	0.9901
Pteridium aquilinum	2	0.0005	0.9963	Vaccinium simulatum	3	0.0007	0.9908
Robinia pseudoacacia	2	0.0005	0.9968	Viburnum acerifolium	3	0.0007	0.9915
Stellaria pubera	2	0.0005	0.9973	Castanea dentata	2	0.0005	0.9920
Uvularia sessilifolia	2	0.0005	0.9977	Chimaphila maculata	2	0.0005	0.9924
Vaccinium corymbosum	2	0.0005	0.9982	Collinsonia canadensis	2	0.0005	0.9929
Acer saccharum	1	0.0002	0.9984	Gentiana decora	2	0.0005	0.9933
Botrychium sp	1	0.0002	0.9986	Hamamelis virginiana	2	0.0005	0.9938
Clintonia sp	1	0.0002	0.9989	Lobelia spicata	2	0.0005	0.9943
Goodyera pubescens	1	0.0002	0.9991	Pteridium aquilinum	2	0.0005	0.9947
Goodyera repens	1	0.0002	0.9993	Senecio obovatus	2	0.0005	0.9952
Hieracium sp	1	0.0002	0.9995	Veronica officinalis	2	0.0005	0.9956
Osmunda claytoniana	1	0.0002	0.9998	Amphicarpa bracteata	1	0.0002	0.9959
Pinus sp	1	0.0002	1.0000	Andropogon virginicus	1	0.0002	0.9961
				Angelica venenosa	1	0.0002	0.9963
				Antennaria plantaginifolia	1	0.0002	0.9966
				Ceanothus americanus	1	0.0002	0.9968
				Cimicifuga racemosa	1	0.0002	0.9970
				Clintonia umbellulata	1	0.0002	0.9972
				Coreopsis major	1	0.0002	0.9975
				Crataegus sp	1	0.0002	0.9977
				Erigeron canadensis	1	0.0002	0.9979

<i>Isotria verticillata</i>	1	0.0002	0.9982
<i>Juniperus virginiana</i>	1	0.0002	0.9984
<i>Lespedeza cuneata</i>	1	0.0002	0.9986
<i>Lespedeza intermedia</i>	1	0.0002	0.9989
<i>Lespedeza repens</i>	1	0.0002	0.9991
<i>Lespedeza sp</i>	1	0.0002	0.9993
<i>Lilium michauxii</i>	1	0.0002	0.9995
<i>Osmunda claytoniana</i>	1	0.0002	0.9998
<i>Taraxicum officinale</i>	1	0.0002	1.0000

APPENDIX C-4: Ranked herb-stratum abundance—High-leave shelterwood

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in high-leave shelterwood treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
Anemone quinquefolia	389	0.1329	0.1329	Anemone quinquefolia	267	0.0841	0.0841
Vaccinium pallidum	303	0.1035	0.2363	Vaccinium pallidum	241	0.0759	0.1600
Viola sp	240	0.0820	0.3183	Erechtites hieracifolia	181	0.0570	0.2170
Gaylussacia baccata	184	0.0628	0.3811	Smilax rotundifolia	181	0.0570	0.2740
Acer rubrum	180	0.0615	0.4426	Acer rubrum	175	0.0551	0.3291
Rhododendron sp	173	0.0591	0.5017	Viola sp	174	0.0548	0.3839
Smilax rotundifolia	156	0.0533	0.5550	Rubus sp	150	0.0472	0.4312
Thelypteris noveboracensis	124	0.0423	0.5973	Gaylussacia baccata	144	0.0454	0.4765
Smilax glauca	84	0.0287	0.6260	Liriodendron tulipifera	138	0.0435	0.5200
Medeola virginiana	83	0.0283	0.6544	Rhododendron sp	138	0.0435	0.5635
Quercus prinus	78	0.0266	0.6810	Sassafras albidum	113	0.0356	0.5991
Galax aphylla	74	0.0253	0.7063	Smilax glauca	110	0.0346	0.6337
Sassafras albidum	69	0.0236	0.7298	Thelypteris noveboracensis	100	0.0315	0.6652
Epigaea repens	67	0.0229	0.7527	Vaccinium stamineum	70	0.0220	0.6872
Dennstaedtia punctilobula	56	0.0191	0.7719	Dennstaedtia punctilobula	65	0.0205	0.7077
Vaccinium stamineum	56	0.0191	0.7910	Panicum sp	62	0.0195	0.7272
Mitchella repens	47	0.0161	0.8070	Medeola virginiana	59	0.0186	0.7458
Quercus coccinea	46	0.0157	0.8227	Galax aphylla	58	0.0183	0.7641
Desmodium nudiflorum	34	0.0116	0.8344	Vitis aestivalis	57	0.0180	0.7820
Uvularia pudica	28	0.0096	0.8439	Desmodium nudiflorum	50	0.0157	0.7978
Amelanchier arborea	27	0.0092	0.8531	Quercus prinus	46	0.0145	0.8123
Vaccinium corymbosum	27	0.0092	0.8624	Aster sp	44	0.0139	0.8261
Aster sp	24	0.0082	0.8706	Nyssa sylvatica	43	0.0135	0.8397
Quercus rubra	24	0.0082	0.8788	Uvularia pudica	40	0.0126	0.8523
Chimaphila maculata	23	0.0079	0.8866	Amelanchier arborea	35	0.0110	0.8633
Prenanthes sp	22	0.0075	0.8941	Quercus coccinea	34	0.0107	0.8740
Nyssa sylvatica	21	0.0072	0.9013	Epigaea repens	32	0.0101	0.8841
Quercus alba	21	0.0072	0.9085	Mitchella repens	29	0.0091	0.8932
Gaultheria procumbens	17	0.0058	0.9143	Carex sp	28	0.0088	0.9020
Kalmia latifolia	16	0.0055	0.9197	Quercus rubra	25	0.0079	0.9099
Carex sp	15	0.0051	0.9249	Dioscorea villosa	18	0.0057	0.9156
Isotria verticillata	15	0.0051	0.9300	Magnolia acuminata	18	0.0057	0.9213
Monotropa uniflora	15	0.0051	0.9351	Betula lenta	16	0.0050	0.9263
Quercus velutina	15	0.0051	0.9402	Magnolia fraseri	15	0.0047	0.9310
Dioscorea villosa	14	0.0048	0.9450	Festuca elatior	12	0.0038	0.9348
Trillium undulatum	12	0.0041	0.9491	Prunus serotina	11	0.0035	0.9383
Rubus sp	11	0.0038	0.9529	Prenanthes sp	10	0.0031	0.9414
Castanea dentata	10	0.0034	0.9563	Quercus velutina	10	0.0031	0.9446
Oxypolis rigidior	10	0.0034	0.9597	Fagus grandifolia	9	0.0028	0.9474
Acer pensylvanicum	9	0.0031	0.9628	Polygonatum biflorum	9	0.0028	0.9502
Polygonatum biflorum	8	0.0027	0.9655	Smilacina racemosa	9	0.0028	0.9531
Prunus serotina	8	0.0027	0.9682	Vaccinium simulatum	9	0.0028	0.9559
Betula lenta	7	0.0024	0.9706	Hamamelis virginiana	8	0.0025	0.9584
Panicum sp	7	0.0024	0.9730	Lobelia inflata	8	0.0025	0.9609

<i>Oxydendrum arboreum</i>	6	0.0020	0.9751	<i>Oxydendrum arboreum</i>	8	0.0025	0.9635
<i>Magnolia acuminata</i>	5	0.0017	0.9768	<i>Chimaphila maculata</i>	7	0.0022	0.9657
<i>Pteridium aquilinum</i>	5	0.0017	0.9785	<i>Robinia pseudoacacia</i>	7	0.0022	0.9679
<i>Smilacina racemosa</i>	5	0.0017	0.9802	<i>Carya glabra</i>	6	0.0019	0.9698
<i>Vitis aestivalis</i>	5	0.0017	0.9819	<i>Gaultheria procumbens</i>	6	0.0019	0.9717
<i>Carya glabra</i>	4	0.0014	0.9833	<i>Lysimachia quadrifolia</i>	6	0.0019	0.9735
<i>Pinus strobus</i>	4	0.0014	0.9846	<i>Rhus sp</i>	6	0.0019	0.9754
<i>Aristolochia macrophylla</i>	3	0.0010	0.9857	<i>Cornus florida</i>	5	0.0016	0.9770
<i>Carya tomentosa</i>	3	0.0010	0.9867	<i>Isotria verticillata</i>	5	0.0016	0.9786
<i>Hamamelis virginiana</i>	3	0.0010	0.9877	<i>Pteridium aquilinum</i>	5	0.0016	0.9802
<i>Iris verna</i>	3	0.0010	0.9887	<i>Quercus alba</i>	5	0.0016	0.9817
<i>Osmunda cinnamomea</i>	3	0.0010	0.9898	<i>Ailanthus altissima</i>	4	0.0013	0.9830
<i>Osmunda claytoniana</i>	3	0.0010	0.9908	<i>Galium sp</i>	4	0.0013	0.9843
<i>Cornus florida</i>	2	0.0007	0.9915	<i>Osmunda cinnamomea</i>	4	0.0013	0.9855
<i>Desmodium sp</i>	2	0.0007	0.9921	<i>Acer pensylvanicum</i>	3	0.0009	0.9865
<i>Dryopteris intermedia</i>	2	0.0007	0.9928	<i>Castanea pumila</i>	3	0.0009	0.9874
<i>Eupatorium sp</i>	2	0.0007	0.9935	<i>Phytolacca americana</i>	3	0.0009	0.9883
<i>Fraxinus sp</i>	2	0.0007	0.9942	<i>Pinus strobus</i>	3	0.0009	0.9893
<i>Liriodendron tulipifera</i>	2	0.0007	0.9949	<i>Castanea dentata</i>	2	0.0006	0.9899
<i>Magnolia fraseri</i>	2	0.0007	0.9956	<i>Ceanothus americanus</i>	2	0.0006	0.9906
<i>Solidago sp</i>	2	0.0007	0.9962	<i>Danthonia compressa</i>	2	0.0006	0.9912
<i>Stellaria pubera</i>	2	0.0007	0.9969	<i>Lespedeza sp</i>	2	0.0006	0.9918
<i>Agrimonia sp</i>	1	0.0003	0.9973	<i>Oxypolis rigidior</i>	2	0.0006	0.9924
<i>Carya sp</i>	1	0.0003	0.9976	<i>Potentilla sp</i>	2	0.0006	0.9931
<i>Coreopsis major</i>	1	0.0003	0.9980	<i>Trillium undulatum</i>	2	0.0006	0.9937
<i>Hieracium sp</i>	1	0.0003	0.9983	<i>Andropogon virginicus</i>	1	0.0003	0.9940
<i>Pinus rigida</i>	1	0.0003	0.9986	<i>Carya tomentosa</i>	1	0.0003	0.9943
<i>Rosa sp</i>	1	0.0003	0.9990	<i>Coreopsis major</i>	1	0.0003	0.9946
<i>Smilax herbacea</i>	1	0.0003	0.9993	<i>Dactylis glomerata</i>	1	0.0003	0.9950
<i>Vaccinium sp</i>	1	0.0003	0.9997	<i>Desmodium paniculatum</i>	1	0.0003	0.9953
<i>Viburnum acerifolium</i>	1	0.0003	1.0000	<i>Erigeron canadensis</i>	1	0.0003	0.9956
				<i>Eupatorium sp</i>	1	0.0003	0.9959
				<i>Heuchera americana</i>	1	0.0003	0.9962
				<i>Ilex montana</i>	1	0.0003	0.9965
				<i>Ipomoea sp</i>	1	0.0003	0.9969
				<i>Kalmia latifolia</i>	1	0.0003	0.9972
				<i>Lespedeza cuneata</i>	1	0.0003	0.9975
				<i>Muhlenbergia tenuiflora</i>	1	0.0003	0.9978
				<i>Parthenocissus quinquefolia</i>	1	0.0003	0.9981
				<i>Pinus sp</i>	1	0.0003	0.9984
				<i>Populus grandidentata</i>	1	0.0003	0.9987
				<i>Rosa sp</i>	1	0.0003	0.9991
				<i>Smilax herbacea</i>	1	0.0003	0.9994
				<i>Solidago sp</i>	1	0.0003	0.9997
				<i>Viburnum acerifolium</i>	1	0.0003	1.0000

APPENDIX C-5: Ranked herb-stratum abundance—Low-leave shelterwood

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in low-leave shelterwood treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
Anemone quinquefolia	781	0.2658	0.2658	Anemone quinquefolia	776	0.1660	0.1660
Viola sp	259	0.0882	0.3540	Erechtites hieracifolia	730	0.1561	0.3221
Vaccinium pallidum	188	0.0640	0.4180	Viola sp	342	0.0731	0.3952
Desmodium nudiflorum	134	0.0456	0.4636	Liriodendron tulipifera	191	0.0408	0.4361
Acer rubrum	111	0.0378	0.5014	Vitis aestivalis	153	0.0327	0.4688
Gaylussacia baccata	84	0.0286	0.5300	Potentilla sp	150	0.0321	0.5009
Sassafras albidum	83	0.0283	0.5582	Vaccinium pallidum	147	0.0314	0.5323
Medeola virginiana	71	0.0242	0.5824	Panicum sp	146	0.0312	0.5635
Prunus serotina	69	0.0235	0.6059	Glechoma hederacea	140	0.0299	0.5935
Parthenocissus quinquefolia	55	0.0187	0.6246	Lobelia inflata	140	0.0299	0.6234
Rhododendron sp	55	0.0187	0.6433	Rubus sp	119	0.0254	0.6488
Thelypteris noveboracensis	55	0.0187	0.6620	Sassafras albidum	107	0.0229	0.6717
Conopholis americana	53	0.0180	0.6801	Smilax rotundifolia	106	0.0227	0.6944
Dioscorea villosa	50	0.0170	0.6971	Carex sp	98	0.0210	0.7154
Smilax glauca	48	0.0163	0.7134	Acer rubrum	82	0.0175	0.7329
Smilax rotundifolia	48	0.0163	0.7297	Phytolacca americana	74	0.0158	0.7487
Amelanchier arborea	47	0.0160	0.7457	Thelypteris noveboracensis	72	0.0154	0.7641
Chimaphila maculata	47	0.0160	0.7617	Smilax glauca	68	0.0145	0.7787
Viburnum acerifolium	44	0.0150	0.7767	Parthenocissus quinquefolia	66	0.0141	0.7928
Galium sp	39	0.0133	0.7900	Galium sp	61	0.0130	0.8058
Quercus coccinea	35	0.0119	0.8019	Desmodium nudiflorum	57	0.0122	0.8180
Prenanthes sp	33	0.0112	0.8131	Gaylussacia baccata	46	0.0098	0.8278
Rubus sp	31	0.0106	0.8237	Nyssa sylvatica	44	0.0094	0.8373
Polygonatum biflorum	30	0.0102	0.8339	Dennstaedtia punctilobula	41	0.0088	0.8460
Dennstaedtia punctilobula	28	0.0095	0.8434	Prunus serotina	41	0.0088	0.8548
Epigaea repens	28	0.0095	0.8530	Viburnum acerifolium	35	0.0075	0.8623
Glechoma hederacea	28	0.0095	0.8625	Dioscorea villosa	33	0.0071	0.8693
Carex sp	27	0.0092	0.8717	Stellaria sp	32	0.0068	0.8762
Uvularia perfoliata	27	0.0092	0.8809	Rhododendron sp	30	0.0064	0.8826
Quercus prinus	26	0.0088	0.8897	Quercus coccinea	25	0.0053	0.8879
Uvularia pudica	25	0.0085	0.8982	Uvularia perfoliata	24	0.0051	0.8931
Panicum sp	24	0.0082	0.9064	Medeola virginiana	23	0.0049	0.8980
Quercus alba	24	0.0082	0.9146	Epigaea repens	20	0.0043	0.9023
Vaccinium stamineum	19	0.0065	0.9210	Bidens frondosa	19	0.0041	0.9063
Quercus rubra	18	0.0061	0.9272	Quercus rubra	18	0.0038	0.9102
Vaccinium corymbosum	17	0.0058	0.9329	Robinia pseudoacacia	18	0.0038	0.9140
Vitis aestivalis	15	0.0051	0.9381	Lysimachia quadrifolia	16	0.0034	0.9175
Geranium maculata	13	0.0044	0.9425	Vaccinium simulatum	15	0.0032	0.9207
Nyssa sylvatica	13	0.0044	0.9469	Eupatorium sp	14	0.0030	0.9237
Quercus velutina	13	0.0044	0.9513	Uvularia pudica	13	0.0028	0.9264
Fraxinus sp	11	0.0037	0.9551	Prenanthes sp	12	0.0026	0.9290
Potentilla sp	10	0.0034	0.9585	Quercus prinus	12	0.0026	0.9316
Lindera benzoin	9	0.0031	0.9615	Amelanchier arborea	11	0.0024	0.9339
Eupatorium sp	7	0.0024	0.9639	Stellaria pubera	11	0.0024	0.9363

Hamamelis virginiana	7	0.0024	0.9663	Amphicarpa bracteata	10	0.0021	0.9384
Liriodendron tulipifera	7	0.0024	0.9687	Fraxinus sp	10	0.0021	0.9405
Oxalis stricta	7	0.0024	0.9711	Festuca elatior	9	0.0019	0.9425
Rosa sp	6	0.0020	0.9731	Juncus tenuis	9	0.0019	0.9444
Magnolia acuminata	5	0.0017	0.9748	Polygonatum biflorum	9	0.0019	0.9463
Ostrya virginiana	5	0.0017	0.9765	Solidago sp	9	0.0019	0.9482
Carya glabra	4	0.0014	0.9779	Vaccinium stamineum	9	0.0019	0.9502
Castanea dentata	4	0.0014	0.9792	Sisyrinchium angustifolium	8	0.0017	0.9519
Galax aphylla	4	0.0014	0.9806	Smilacina racemosa	8	0.0017	0.9536
Smilax herbacea	4	0.0014	0.9820	Carya tomentosa	7	0.0015	0.9551
Stellaria pubera	4	0.0014	0.9833	Danthonia spicata	7	0.0015	0.9566
Aster sp	3	0.0010	0.9843	Ilex montana	7	0.0015	0.9581
Carya tomentosa	3	0.0010	0.9854	Magnolia fraseri	7	0.0015	0.9596
Desmodium sp	3	0.0010	0.9864	Smilax herbacea	7	0.0015	0.9611
Geranium sp	3	0.0010	0.9874	Antennaria plantaginifolia	6	0.0013	0.9624
Magnolia fraseri	3	0.0010	0.9884	Danthonia compressa	6	0.0013	0.9636
Oxydendrum arboreum	3	0.0010	0.9894	Kalmia latifolia	6	0.0013	0.9649
Thalictrum sp	3	0.0010	0.9905	Oxalis dellinii	6	0.0013	0.9662
Cimicifuga racemosa	2	0.0007	0.9912	Oxalis sp	6	0.0013	0.9675
Hieracium venosum	2	0.0007	0.9918	Quercus alba	6	0.0013	0.9688
Hydrangea arborescens	2	0.0007	0.9925	Rosa sp	6	0.0013	0.9701
Ilex montana	2	0.0007	0.9932	Anthoxanthum odoratum	5	0.0011	0.9711
Lysimachia quadrifolia	2	0.0007	0.9939	Galax aphylla	5	0.0011	0.9722
Robinia pseudoacacia	2	0.0007	0.9946	Hamamelis virginiana	5	0.0011	0.9733
Scutellaria sp	2	0.0007	0.9952	Lindera benzoin	5	0.0011	0.9743
Uvularia sessilifolia	2	0.0007	0.9959	Muhlenbergia schreberi	5	0.0011	0.9754
Botrychium virginianum	1	0.0003	0.9963	Oxalis corniculata	5	0.0011	0.9765
Coreopsis major	1	0.0003	0.9966	Oxydendrum arboreum	5	0.0011	0.9775
Cornus florida	1	0.0003	0.9969	Carya glabra	4	0.0009	0.9784
Disporum lanuginosum	1	0.0003	0.9973	Caulophyllum thalictroides	4	0.0009	0.9793
Euphorbia corollata	1	0.0003	0.9976	Coreopsis major	4	0.0009	0.9801
Gentiana sp	1	0.0003	0.9980	Geranium maculata	4	0.0009	0.9810
Impatiens sp	1	0.0003	0.9983	Gnaphalium obtusifolium	4	0.0009	0.9818
Ipomoea sp	1	0.0003	0.9986	Lespedeza hirta	4	0.0009	0.9827
Poa sp	1	0.0003	0.9990	Magnolia acuminata	4	0.0009	0.9835
Smilacina racemosa	1	0.0003	0.9993	Quercus velutina	4	0.0009	0.9844
Solidago sp	1	0.0003	0.9997	Castanea dentata	3	0.0006	0.9850
Zizia trifoliata	1	0.0003	1.0000	Cimicifuga racemosa	3	0.0006	0.9857
				Cirsium sp	3	0.0006	0.9863
				Houstonia purpurea	3	0.0006	0.9870
				Pycnanthemum incanum	3	0.0006	0.9876
				Rhus typhina	3	0.0006	0.9882
				Taraxicum officinale	3	0.0006	0.9889
				Thaspium sp	3	0.0006	0.9895
				Zizia trifoliata	3	0.0006	0.9902
				Ailanthus altissima	2	0.0004	0.9906
				Campanula divaricata	2	0.0004	0.9910
				Ceanothus americanus	2	0.0004	0.9914
				Collinsonia canadensis	2	0.0004	0.9919
				Coronilla varia	2	0.0004	0.9923
				Dactylis glomerata	2	0.0004	0.9927
				Dryopteris intermedia	2	0.0004	0.9932

<i>Erigeron canadensis</i>	2	0.0004	0.9936
<i>Hypericum punctatum</i>	2	0.0004	0.9940
<i>Juncus</i> sp	2	0.0004	0.9944
<i>Lespedeza</i> sp	2	0.0004	0.9949
<i>Poa</i> sp	2	0.0004	0.9953
<i>Sambucus canadensis</i>	2	0.0004	0.9957
<i>Agrimonia</i> sp	1	0.0002	0.9959
<i>Agrostis perennans</i>	1	0.0002	0.9962
<i>Betula lenta</i>	1	0.0002	0.9964
<i>Chimaphila maculata</i>	1	0.0002	0.9966
<i>Erigeron philadelphicus</i>	1	0.0002	0.9968
<i>Gnaphalium purpureum</i>	1	0.0002	0.9970
<i>Heuchera americana</i>	1	0.0002	0.9972
<i>Hieracium</i> sp	1	0.0002	0.9974
<i>Holcus lanatus</i>	1	0.0002	0.9976
<i>Hydrangea arborescens</i>	1	0.0002	0.9979
<i>Ipomoea</i> sp	1	0.0002	0.9981
<i>Lactuca canadensis</i>	1	0.0002	0.9983
<i>Lespedeza procumbens</i>	1	0.0002	0.9985
<i>Ostrya virginiana</i>	1	0.0002	0.9987
<i>Oxypolis rigidior</i>	1	0.0002	0.9989
<i>Paulownia tomentosa</i>	1	0.0002	0.9991
<i>Satureja vulgaris</i>	1	0.0002	0.9994
<i>Scutellaria</i> sp	1	0.0002	0.9996
<i>Senecio obovatus</i>	1	0.0002	0.9998
<i>Vicia caroliniana</i>	1	0.0002	1.0000

APPENDIX C-6: Ranked herb-stratum abundance—Leave tree

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in leave tree treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
<i>Thelypteris noveboracensis</i>	891	0.2551	0.2551	<i>Erechtites hieracifolia</i>	1061	0.2027	0.2027
<i>Viola</i> sp	330	0.0945	0.3496	<i>Thelypteris noveboracensis</i>	466	0.0890	0.2917
<i>Anemone quinquefolia</i>	265	0.0759	0.4254	<i>Anemone quinquefolia</i>	432	0.0825	0.3742
<i>Vaccinium pallidum</i>	214	0.0613	0.4867	<i>Viola</i> sp	310	0.0592	0.4334
<i>Dennstaedtia punctilobula</i>	192	0.0550	0.5417	<i>Liriodendron tulipifera</i>	295	0.0564	0.4898
<i>Galax aphylla</i>	136	0.0389	0.5806	<i>Lobelia inflata</i>	292	0.0558	0.5456
<i>Rhododendron</i> sp	132	0.0378	0.6184	<i>Rubus</i> sp	211	0.0403	0.5859
<i>Acer rubrum</i>	103	0.0295	0.6479	<i>Vaccinium pallidum</i>	199	0.0380	0.6239
<i>Medeola virginiana</i>	97	0.0278	0.6756	<i>Dennstaedtia punctilobula</i>	145	0.0277	0.6516
<i>Smilax rotundifolia</i>	79	0.0226	0.6983	<i>Panicum</i> sp	131	0.0250	0.6766
<i>Dioscorea villosa</i>	74	0.0212	0.7194	<i>Sassafras albidum</i>	124	0.0237	0.7003
<i>Quercus prinus</i>	59	0.0169	0.7363	<i>Vitis aestivalis</i>	116	0.0222	0.7224
<i>Sassafras albidum</i>	58	0.0166	0.7529	<i>Carex</i> sp	105	0.0201	0.7425
<i>Smilacina racemosa</i>	51	0.0146	0.7675	<i>Galax aphylla</i>	103	0.0197	0.7622
<i>Chimaphila maculata</i>	47	0.0135	0.7810	<i>Acer rubrum</i>	91	0.0174	0.7796
<i>Smilax glauca</i>	43	0.0123	0.7933	<i>Smilax rotundifolia</i>	82	0.0157	0.7952
<i>Rubus</i> sp	37	0.0106	0.8039	<i>Dioscorea villosa</i>	78	0.0149	0.8101
<i>Acer pensylvanicum</i>	36	0.0103	0.8142	<i>Smilax glauca</i>	77	0.0147	0.8248
<i>Uvularia perfoliata</i>	36	0.0103	0.8245	<i>Rhododendron</i> sp	66	0.0126	0.8374
<i>Parthenocissus quinquefolia</i>	33	0.0094	0.8340	<i>Medeola virginiana</i>	60	0.0115	0.8489
<i>Prenanthes</i> sp	31	0.0089	0.8428	<i>Quercus prinus</i>	50	0.0096	0.8585
<i>Liriodendron tulipifera</i>	29	0.0083	0.8511	<i>Desmodium nudiflorum</i>	40	0.0076	0.8661
<i>Polygonatum biflorum</i>	29	0.0083	0.8594	<i>Smilacina racemosa</i>	36	0.0069	0.8730
<i>Quercus coccinea</i>	29	0.0083	0.8677	<i>Prunus serotina</i>	32	0.0061	0.8791
<i>Quercus velutina</i>	27	0.0077	0.8755	<i>Uvularia perfoliata</i>	32	0.0061	0.8852
<i>Quercus alba</i>	25	0.0072	0.8826	<i>Lysimachia quadrifolia</i>	29	0.0055	0.8907
<i>Vaccinium stamineum</i>	24	0.0069	0.8895	<i>Parthenocissus quinquefolia</i>	27	0.0052	0.8959
<i>Desmodium</i> sp	21	0.0060	0.8955	<i>Prenanthes</i> sp	25	0.0048	0.9007
<i>Conopholis americana</i>	20	0.0057	0.9012	<i>Vaccinium stamineum</i>	23	0.0044	0.9051
<i>Monotropa uniflora</i>	20	0.0057	0.9070	<i>Quercus alba</i>	22	0.0042	0.9093
<i>Cornus florida</i>	16	0.0046	0.9115	<i>Quercus coccinea</i>	22	0.0042	0.9135
<i>Vaccinium corymbosum</i>	16	0.0046	0.9161	<i>Magnolia fraseri</i>	19	0.0036	0.9171
<i>Athyrium filix-femina</i>	15	0.0043	0.9204	<i>Festuca elatior</i>	17	0.0032	0.9203
<i>Carex</i> sp	15	0.0043	0.9247	<i>Pteridium aquilinum</i>	16	0.0031	0.9234
<i>Desmodium nudiflorum</i>	15	0.0043	0.9290	<i>Potentilla</i> sp	15	0.0029	0.9263
<i>Geranium maculata</i>	14	0.0040	0.9330	<i>Uvularia pudica</i>	15	0.0029	0.9291
<i>Uvularia pudica</i>	14	0.0040	0.9370	<i>Nyssa sylvatica</i>	14	0.0027	0.9318
<i>Quercus rubra</i>	13	0.0037	0.9407	<i>Amelanchier arborea</i>	13	0.0025	0.9343
<i>Vitis aestivalis</i>	12	0.0034	0.9442	<i>Betula lenta</i>	13	0.0025	0.9368
<i>Prunus serotina</i>	11	0.0031	0.9473	<i>Polygonatum biflorum</i>	13	0.0025	0.9393
<i>Epigaea repens</i>	9	0.0026	0.9499	<i>Rosa</i> sp	13	0.0025	0.9417
<i>Magnolia fraseri</i>	9	0.0026	0.9525	<i>Quercus rubra</i>	12	0.0023	0.9440
<i>Viburnum acerifolium</i>	9	0.0026	0.9551	<i>Quercus velutina</i>	12	0.0023	0.9463
<i>Amelanchier arborea</i>	8	0.0023	0.9573	<i>Acer pensylvanicum</i>	11	0.0021	0.9484

Isotria verticillata	8	0.0023	0.9596	Athyrium filix-femina	11	0.0021	0.9505
Osmunda claytoniana	7	0.0020	0.9616	Cornus florida	10	0.0019	0.9524
Potentilla sp	7	0.0020	0.9636	Galium sp	10	0.0019	0.9543
Fagus grandifolia	6	0.0017	0.9654	Oxydendrum arboreum	10	0.0019	0.9563
Fraxinus sp	6	0.0017	0.9671	Viburnum acerifolium	9	0.0017	0.9580
Galium sp	6	0.0017	0.9688	Geranium maculata	8	0.0015	0.9595
Mitchella repens	6	0.0017	0.9705	Juncus tenuis	8	0.0015	0.9610
Panicum sp	6	0.0017	0.9722	Phytolacca americana	8	0.0015	0.9626
Stellaria pubera	6	0.0017	0.9739	Robinia pseudoacacia	8	0.0015	0.9641
Aristolochia macrophylla	5	0.0014	0.9754	Scutellaria elliptica	8	0.0015	0.9656
Carya glabra	5	0.0014	0.9768	Stellaria pubera	8	0.0015	0.9671
Castanea dentata	5	0.0014	0.9782	Gaylussacia baccata	7	0.0013	0.9685
Kalmia latifolia	5	0.0014	0.9797	Hamamelis virginiana	7	0.0013	0.9698
Lysimachia quadrifolia	5	0.0014	0.9811	Osmunda cinnamomea	6	0.0011	0.9710
Nyssa sylvatica	5	0.0014	0.9825	Vaccinium simulatum	6	0.0011	0.9721
Rosa sp	5	0.0014	0.9840	Ailanthus altissima	5	0.0010	0.9731
Carya tomentosa	4	0.0011	0.9851	Coreopsis major	5	0.0010	0.9740
Gaylussacia baccata	4	0.0011	0.9863	Desmodium paniculatum	5	0.0010	0.9750
Eupatorium sp	3	0.0009	0.9871	Fagus grandifolia	5	0.0010	0.9759
Solidago sp	3	0.0009	0.9880	Lespedeza bicolor	5	0.0010	0.9769
Uvularia sessilifolia	3	0.0009	0.9888	Carya glabra	4	0.0008	0.9777
Aureolaria laevigata	2	0.0006	0.9894	Lespedeza intermedia	4	0.0008	0.9784
Clintonia sp	2	0.0006	0.9900	Magnolia acuminata	4	0.0008	0.9792
Convallaria montana	2	0.0006	0.9906	Smilax herbacea	4	0.0008	0.9799
Coreopsis major	2	0.0006	0.9911	Thalictrum sp	4	0.0008	0.9807
Dryopteris intermedia	2	0.0006	0.9917	Agrostis gigantea	3	0.0006	0.9813
Gentiana sp	2	0.0006	0.9923	Brassica sp	3	0.0006	0.9819
Goodyera pubescens	2	0.0006	0.9928	Chamaelirium luteum	3	0.0006	0.9824
Hamamelis virginiana	2	0.0006	0.9934	Chimaphila maculata	3	0.0006	0.9830
Magnolia acuminata	2	0.0006	0.9940	Cimicifuga racemosa	3	0.0006	0.9836
Oxydendrum arboreum	2	0.0006	0.9946	Convallaria montana	3	0.0006	0.9841
Pteridium aquilinum	2	0.0006	0.9951	Hypericum hypericoides	3	0.0006	0.9847
Thalictrum sp	2	0.0006	0.9957	Ipomoea sp	3	0.0006	0.9853
Acer saccharum	1	0.0003	0.9960	Kalmia latifolia	3	0.0006	0.9859
Aralia nudicaulis	1	0.0003	0.9963	Lespedeza repens	3	0.0006	0.9864
Arisaema triphyllum	1	0.0003	0.9966	Ludwigia alternifolia	3	0.0006	0.9870
Aster sp	1	0.0003	0.9969	Trifolium pratense	3	0.0006	0.9876
Betula lenta	1	0.0003	0.9971	Trifolium repens	3	0.0006	0.9882
Cimicifuga racemosa	1	0.0003	0.9974	Zizia trifoliata	3	0.0006	0.9887
Goodyera repens	1	0.0003	0.9977	Agrimonia sp	2	0.0004	0.9891
Heuchera sp	1	0.0003	0.9980	Agrostis perennans	2	0.0004	0.9895
Ipomoea sp	1	0.0003	0.9983	Carya tomentosa	2	0.0004	0.9899
Pinus strobus	1	0.0003	0.9986	Castanea dentata	2	0.0004	0.9903
Robinia pseudoacacia	1	0.0003	0.9989	Clintonia umbellulata	2	0.0004	0.9906
Scutellaria sp	1	0.0003	0.9991	Conopholis americana	2	0.0004	0.9910
Smilax herbacea	1	0.0003	0.9994	Fraxinus sp	2	0.0004	0.9914
Toxicodendron radicans	1	0.0003	0.9997	Gillenia trifoliata	2	0.0004	0.9918
Zizia trifoliata	1	0.0003	1.0000	Hieracium paniculatum	2	0.0004	0.9922
				Hypericum punctatum	2	0.0004	0.9926
				Ilex montana	2	0.0004	0.9929
				Lechea racemulosa	2	0.0004	0.9933
				Lolium perenne	2	0.0004	0.9937

Mitchella repens	2	0.0004	0.9941
Monotropa uniflora	2	0.0004	0.9945
Muhlenbergia schreberi	2	0.0004	0.9948
Oxalis dellinii	2	0.0004	0.9952
Pycnanthemum incanum	2	0.0004	0.9956
Acer saccharum	1	0.0002	0.9958
Ambrosia artemisiifolia	1	0.0002	0.9960
Aralia spinosa	1	0.0002	0.9962
Aster sp	1	0.0002	0.9964
Baptisia tinctoria	1	0.0002	0.9966
Collinsonia canadensis	1	0.0002	0.9968
Dactylis glomerata	1	0.0002	0.9969
Danthonia compressa	1	0.0002	0.9971
Eupatorium sp	1	0.0002	0.9973
Geum virginianum	1	0.0002	0.9975
Goodyera pubescens	1	0.0002	0.9977
Heuchera americana	1	0.0002	0.9979
Isotria verticillata	1	0.0002	0.9981
Juncus marginatus	1	0.0002	0.9983
Lespedeza hirta	1	0.0002	0.9985
Lespedeza nuttallii	1	0.0002	0.9987
Lespedeza sp	1	0.0002	0.9989
Lilium michauxii	1	0.0002	0.9990
Lindera benzoin	1	0.0002	0.9992
Lobelia spicata	1	0.0002	0.9994
Lotus corniculatus	1	0.0002	0.9996
Spirea japonica	1	0.0002	0.9998
Toxicodendron radicans	1	0.0002	1.0000

APPENDIX C-7: Ranked herb-stratum abundance—Clearcut

Ranked abundance of herb stratum species compiled from pooled, 1-m² herb plots in clearcut treatments on five sites in the Ridge and Valley, Cumberland Plateau, and Allegheny Plateau of Virginia and West Virginia.

Species	Individuals	Rel %	Cum %	Species	Individuals	Rel %	Cum %
-----Pre-treatment-----				-----Post-treatment-----			
<i>Thelypteris noveboracensis</i>	932	0.2477	0.2477	<i>Erechtites hieracifolia</i>	843	0.1318	0.1318
<i>Viola</i> sp	460	0.1223	0.3700	<i>Thelypteris noveboracensis</i>	720	0.1126	0.2443
<i>Vaccinium pallidum</i>	319	0.0848	0.4548	<i>Viola</i> sp	570	0.0891	0.3334
<i>Anemone quinquefolia</i>	222	0.0590	0.5138	<i>Vaccinium pallidum</i>	390	0.0610	0.3944
<i>Rhododendron</i> sp	172	0.0457	0.5595	<i>Dennstaedtia punctilobula</i>	344	0.0538	0.4482
<i>Acer rubrum</i>	170	0.0452	0.6047	<i>Potentilla</i> sp	304	0.0475	0.4957
<i>Dennstaedtia punctilobula</i>	148	0.0393	0.6441	<i>Panicum</i> sp	294	0.0460	0.5417
<i>Smilax rotundifolia</i>	135	0.0359	0.6800	<i>Rubus</i> sp	229	0.0358	0.5775
<i>Sassafras albidum</i>	77	0.0205	0.7004	<i>Anemone quinquefolia</i>	223	0.0349	0.6123
<i>Gaylussacia baccata</i>	70	0.0186	0.7190	<i>Carex</i> sp	185	0.0289	0.6412
<i>Gaultheria procumbens</i>	67	0.0178	0.7368	<i>Smilax rotundifolia</i>	160	0.0250	0.6662
<i>Galax aphylla</i>	66	0.0175	0.7544	<i>Liriodendron tulipifera</i>	132	0.0206	0.6869
<i>Vaccinium stamineum</i>	56	0.0149	0.7693	<i>Sassafras albidum</i>	122	0.0191	0.7060
<i>Smilax glauca</i>	55	0.0146	0.7839	<i>Rhododendron</i> sp	118	0.0184	0.7244
<i>Quercus prinus</i>	53	0.0141	0.7980	<i>Acer rubrum</i>	103	0.0161	0.7405
<i>Geranium maculata</i>	48	0.0128	0.8107	<i>Danthonia spicata</i>	93	0.0145	0.7550
<i>Quercus alba</i>	47	0.0125	0.8232	<i>Vitis aestivalis</i>	91	0.0142	0.7693
<i>Quercus coccinea</i>	37	0.0098	0.8331	<i>Vaccinium stamineum</i>	85	0.0133	0.7826
<i>Quercus rubra</i>	36	0.0096	0.8426	<i>Gaultheria procumbens</i>	76	0.0119	0.7944
<i>Potentilla</i> sp	33	0.0088	0.8514	<i>Galax aphylla</i>	69	0.0108	0.8052
<i>Chimaphila maculata</i>	30	0.0080	0.8594	<i>Gaylussacia baccata</i>	68	0.0106	0.8159
<i>Mitchella repens</i>	30	0.0080	0.8674	<i>Poa</i> sp	65	0.0102	0.8260
<i>Amelanchier arborea</i>	28	0.0074	0.8748	<i>Smilax glauca</i>	63	0.0098	0.8359
<i>Aster</i> sp	28	0.0074	0.8822	<i>Veronica officinalis</i>	63	0.0098	0.8457
<i>Nyssa sylvatica</i>	27	0.0072	0.8894	<i>Festuca elatior</i>	53	0.0083	0.8540
<i>Rubus</i> sp	26	0.0069	0.8963	<i>Quercus coccinea</i>	52	0.0081	0.8621
<i>Epigaea repens</i>	24	0.0064	0.9027	<i>Nyssa sylvatica</i>	48	0.0075	0.8696
<i>Carex</i> sp	21	0.0056	0.9083	<i>Oxalis dellinii</i>	42	0.0066	0.8762
<i>Quercus velutina</i>	18	0.0048	0.9131	<i>Lobelia inflata</i>	35	0.0055	0.8817
<i>Smilacina racemosa</i>	16	0.0043	0.9173	<i>Aster</i> sp	33	0.0052	0.8868
<i>Uvularia pudica</i>	16	0.0043	0.9216	<i>Quercus alba</i>	32	0.0050	0.8918
<i>Viburnum acerifolium</i>	16	0.0043	0.9258	<i>Amelanchier arborea</i>	31	0.0048	0.8967
<i>Fraxinus</i> sp	15	0.0040	0.9298	<i>Quercus prinus</i>	31	0.0048	0.9015
<i>Magnolia acuminata</i>	14	0.0037	0.9335	<i>Epigaea repens</i>	29	0.0045	0.9060
<i>Panicum</i> sp	14	0.0037	0.9373	<i>Galium</i> sp	29	0.0045	0.9106
<i>Cornus florida</i>	13	0.0035	0.9407	<i>Quercus rubra</i>	26	0.0041	0.9146
<i>Polygonatum biflorum</i>	13	0.0035	0.9442	<i>Andropogon virginicus</i>	25	0.0039	0.9186
<i>Acer pensylvanicum</i>	12	0.0032	0.9474	<i>Quercus velutina</i>	21	0.0033	0.9218
<i>Dioscorea villosa</i>	12	0.0032	0.9506	<i>Smilacina racemosa</i>	21	0.0033	0.9251
<i>Medeola virginiana</i>	12	0.0032	0.9537	<i>Agrostis gigantea</i>	19	0.0030	0.9281
<i>Prenanthes</i> sp	12	0.0032	0.9569	<i>Erigeron canadensis</i>	19	0.0030	0.9311
<i>Vaccinium corymbosum</i>	12	0.0032	0.9601	<i>Lespedeza</i> sp	16	0.0025	0.9336
<i>Betula lenta</i>	11	0.0029	0.9631	<i>Desmodium nudiflorum</i>	15	0.0023	0.9359
<i>Desmodium nudiflorum</i>	9	0.0024	0.9654	<i>Solidago</i> sp	15	0.0023	0.9383

Liriodendron tulipifera	9	0.0024	0.9678	Leersia virginica	14	0.0022	0.9404
Lysimachia quadrifolia	8	0.0021	0.9700	Geranium maculata	13	0.0020	0.9425
Solidago sp	8	0.0021	0.9721	Prunus serotina	13	0.0020	0.9445
Magnolia fraseri	7	0.0019	0.9740	Ribes sp	13	0.0020	0.9465
Carya tomentosa	6	0.0016	0.9755	Uvularia pudica	13	0.0020	0.9486
Galium sp	6	0.0016	0.9771	Dioscorea villosa	12	0.0019	0.9504
Prunus serotina	6	0.0016	0.9787	Houstonia longifolia	12	0.0019	0.9523
Rosa sp	6	0.0016	0.9803	Mitchella repens	12	0.0019	0.9542
Eupatorium sp	5	0.0013	0.9817	Robinia pseudoacacia	12	0.0019	0.9561
Agrostis alba	4	0.0011	0.9827	Fraxinus sp	11	0.0017	0.9578
Calamagrostis porteri	4	0.0011	0.9838	Agrostis perennans	10	0.0016	0.9594
Carya glabra	4	0.0011	0.9848	Fagus grandifolia	10	0.0016	0.9609
Desmodium sp	4	0.0011	0.9859	Juncus subcaudatus	10	0.0016	0.9625
Fagus grandifolia	4	0.0011	0.9870	Magnolia fraseri	10	0.0016	0.9640
Parthenocissus quinquefolia	4	0.0011	0.9880	Polygonatum biflorum	10	0.0016	0.9656
Smilax herbacea	4	0.0011	0.9891	Taraxicum officinale	10	0.0016	0.9672
Stellaria pubera	4	0.0011	0.9902	Lysimachia quadrifolia	9	0.0014	0.9686
Vitis aestivalis	4	0.0011	0.9912	Magnolia acuminata	9	0.0014	0.9700
Castanea dentata	3	0.0008	0.9920	Scutellaria elliptica	9	0.0014	0.9714
Hamamelis virginiana	3	0.0008	0.9928	Betula lenta	8	0.0013	0.9726
Hypericum sp	3	0.0008	0.9936	Oxydendrum arboreum	8	0.0013	0.9739
Trillium undulatum	3	0.0008	0.9944	Trifolium repens	8	0.0013	0.9751
Viburnum prunifolium	3	0.0008	0.9952	Acer pensylvanicum	7	0.0011	0.9762
Dryopteris intermedia	2	0.0005	0.9957	Carya glabra	7	0.0011	0.9773
Ilex montana	2	0.0005	0.9963	Hamamelis virginiana	7	0.0011	0.9784
Isotria verticillata	2	0.0005	0.9968	Juncus effusus	7	0.0011	0.9795
Kalmia latifolia	2	0.0005	0.9973	Medeola virginiana	7	0.0011	0.9806
Cimicifuga racemosa	1	0.0003	0.9976	Viburnum acerifolium	7	0.0011	0.9817
Collinsonia canadensis	1	0.0003	0.9979	Viburnum prunifolium	7	0.0011	0.9828
Coreopsis major	1	0.0003	0.9981	Juncus marginatus	6	0.0009	0.9837
Cypripedium acaule	1	0.0003	0.9984	Juncus tenuis	6	0.0009	0.9847
Eleagnus umbellata	1	0.0003	0.9987	Cornus florida	5	0.0008	0.9855
Gentiana sp	1	0.0003	0.9989	Iris verna	5	0.0008	0.9862
Houstonia longifolia	1	0.0003	0.9992	Lespedeza hirta	5	0.0008	0.9870
Oxydendrum arboreum	1	0.0003	0.9995	Castanea dentata	4	0.0006	0.9877
Scutellaria sp	1	0.0003	0.9997	Hypericum hypericoides	4	0.0006	0.9883
Uvularia perfoliata	1	0.0003	1.0000	Hypericum mutilum	4	0.0006	0.9889
				Lechea racemulosa	4	0.0006	0.9895
				Oxalis stricta	4	0.0006	0.9902
				Rosa sp	4	0.0006	0.9908
				Smilax herbacea	4	0.0006	0.9914
				Vaccinium simulatum	4	0.0006	0.9920
				Helianthus hirsutus	3	0.0005	0.9925
				Phytolacca americana	3	0.0005	0.9930
				Stellaria pubera	3	0.0005	0.9934
				Ailanthus altissima	2	0.0003	0.9937
				Chimaphila maculata	2	0.0003	0.9941
				Kalmia latifolia	2	0.0003	0.9944
				Melampyrum lineare	2	0.0003	0.9947
				Prenanthes sp	2	0.0003	0.9950
				Angelica venenosa	1	0.0002	0.9952
				Asclepias quadrifolia	1	0.0002	0.9953

<i>Aureolaria laevigata</i>	1	0.0002	0.9955
<i>Baptisia tinctoria</i>	1	0.0002	0.9956
<i>Campanula divaricata</i>	1	0.0002	0.9958
<i>Carya tomentosa</i>	1	0.0002	0.9959
<i>Convallaria montana</i>	1	0.0002	0.9961
<i>Corylus americana</i>	1	0.0002	0.9962
<i>Dactylis glomerata</i>	1	0.0002	0.9964
<i>Danthonia compressa</i>	1	0.0002	0.9966
<i>Desmodium rotundifolium</i>	1	0.0002	0.9967
<i>Eupatorium</i> sp	1	0.0002	0.9969
<i>Gnaphalium obtusifolium</i>	1	0.0002	0.9970
<i>Hieracium</i> sp	1	0.0002	0.9972
<i>Lactuca</i> sp	1	0.0002	0.9973
<i>Lespedeza procumbens</i>	1	0.0002	0.9975
<i>Lilium michauxii</i>	1	0.0002	0.9977
<i>Lobelia spicata</i>	1	0.0002	0.9978
<i>Ludwigia alternifolia</i>	1	0.0002	0.9980
<i>Luzula echinata</i>	1	0.0002	0.9981
<i>Parthenocissus quinquefolia</i>	1	0.0002	0.9983
<i>Phalaris arundinacea</i>	1	0.0002	0.9984
<i>Pinus virginiana</i>	1	0.0002	0.9986
<i>Plantago rugelii</i>	1	0.0002	0.9987
<i>Pteridium aquilinum</i>	1	0.0002	0.9989
<i>Ranunculus recurvatus</i>	1	0.0002	0.9991
<i>Taenidia integerrima</i>	1	0.0002	0.9992
<i>Trifolium campestre</i>	1	0.0002	0.9994
<i>Trifolium pratense</i>	1	0.0002	0.9995
<i>Verbascum thapsus</i>	1	0.0002	0.9997
<i>Veronica arvensis</i>	1	0.0002	0.9998
<i>Vicia caroliniana</i>	1	0.0002	1.0000

VITA

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The author was born June 3, 1973 in Woodstock, Virginia, a rural town in the northern Shenandoah Valley. His interests in ecology and conservation emerged from a childhood spent with his two brothers on the Shenandoah River and in the surrounding George Washington National Forest. He received a B.S. in Forestry from the University of Kentucky in 1997 before pursuing a M.S. in Forestry from Virginia Polytechnic Institute and State University.