

**Effects of Clearcutting with Whole Tree Harvesting on Woody and Herbaceous  
Plant Diversity After 17-Years of Regrowth in a Southern Appalachian Forest**

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# Effects of Clearcutting with Whole Tree Harvesting on Woody and Herbaceous Plant Diversity After 17-Years of Regrowth in a Southern Appalachian Forest

David K. Wright

## (ABSTRACT)

This study examines the effects of clearcut regeneration with whole-tree harvesting on plant diversity. Three approaches were used to study changes in species composition and structure: (1) forest level, (2) stand level, and (3) diversity indices. Within each approach the forest was stratified into three horizontal vegetative regions based upon height: herb ( $< 1$  m), shrub (between 1 and 5 m), and tree ( $> 5$  m). Between the pre-harvest and 17-year-old forest, the relative percent cover of 3 out of 45 herbaceous and 2 out of 34 woody species were found to be significantly different ( $df = 3$ ;  $\alpha = 0.10$ ) in the herb stratum; the importance value (average of relative basal area and stem density) of 2 out of 25 woody species in the shrub stratum; and 1 out of 21 woody species in the tree stratum. Within stands, the three lower quality, 17-year-old stands ( $SI_{50} = 12.2, 15.2, \text{ and } 18.3$  m) most resembled their pre-harvest composition; however, increases in ericaceous species were observed in the herb and shrub strata potentially inhibit the future regeneration of tree species. The  $SI_{50} = 21.3$  m stand incurred the greatest changes in composition potentially due to the lack of fire as a disturbance mechanism. The major mechanism that has caused the shifts in species composition and structure is the change in the microenvironment due to the removal of the overstory, which has shifted the competitive advantages from one species to another. In all cases, diversity indices were not found to be significantly different between the 17-year-old and pre-harvest forests. Diversity indices were therefore determined to have limited use if a manager wants to know specific compositions and/or abundance of species.

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## CHAPTER 1

### INTRODUCTION AND JUSTIFICATION

The southern Appalachian Mountains are one of the two most biologically diverse areas of North America (Whittaker 1972). The other area is found in the Klamath Region of the Cascade Mountain range, which was created because of an extreme climatic gradient and mosaic of soil parent material throughout the range (Whittaker 1972). In contrast, the great diversity of the Appalachian Mountain range is due to its unique topographic development and continental climatic conditions (Whittaker 1972). Additionally, natural and human induced disturbances have affected the development of these forest stands.

Since the turn of the century, several major events have shaped the development of the forest stands of the southern Appalachian Mountains. The almost complete harvesting of the forests, introduction of exotic pests, and suppression of wildfires are the most significant. Harvesting of the virgin forests of these mountains created a predominantly even-aged stand structure over most of the Appalachian mountains. The regeneration of these virgin forests occurred in many different ways. Many times after the harvesting the sites were burned, accidentally or intentionally, which often converted the forest land to pasture or completely denuded the site (Clarkson 1964). In the limestone valleys most of the land was converted to agriculture. As these cut-over lands were left to regenerate or when the converted agricultural lands were abandoned due to poor growth, different paths of regeneration were taken. The exact tolls that these anthropocentric actions on the productivity and sustainability of the forest lands will never be fully known.

The forests that now exist in the southern Appalachian Mountains are second or third growth stands. Still little is known about the effects of current harvesting techniques has on the productivity and sustainability of these forests. And with respect to the most predominantly used harvesting technique in the 20<sup>th</sup> century, clearcutting, little information is known about its effect on components of productivity and sustainability of forest stands in the southern Appalachians. This study examines the effects of clearcutting with whole-tree harvesting on the composition and structure of the forests in the Ridge and Valley Physiographic Province.

In the southern Appalachian Mountains, it is not uncommon to have 15 or more commercially important tree species in a single stand (Smith 1994). The Ridge and Valley Physiographic Province contains species and forest stand types common to the southern Appalachian region (Johnson 1992, Thompson 1992). For management purposes, results of research studies done in the Ridge and Valley can be reasonably extrapolated to the southern Appalachians as a whole. The majority of the tree species found in the southern Appalachians are intermediate to intolerant with regard to shade (Burns and Honkala 1990a, 1990b). As a result, clearcutting is a viable and often used regeneration system for this region.

The majority of the southern Appalachian forested area (78 %) is owned by private non-industrial land owners with most land owners' holdings 400 acres or less. The remaining forested land is divided between the USDA Forest Service (11 %), industry (7 %), and other "public lands" (4 %) (Smith 1992). This land distribution makes timber production a predominant management objective since many people own land as an investment. Lands owned by the U. S. Forest Service and industry contain the largest sections of contiguous forest, which is a significant factor when considering biological and habitat diversity (Smith 1992). With the passing of the National Forest Management Act of 1976, maintenance of a sustainable and multiple-use forest has become a major focus (36 CFR 219.27g). Clearcutting has been the predominant method of harvesting on both public and private lands (Cubbage et al. 1993). With the interest of maintaining a sustainable forest ecosystem, investigation of the effects of clearcutting on the sustainability of forests is pertinent.

The majority of stands in the southern Appalachians are 70- to 100-years-old and are of harvestable size for many common forest products. New technologies are making better and more efficient use of raw materials taken from forest stands. Originally, in most stands, the main resource taken from the forest was the bole from sawtimber quality trees. Now forest products can be made from pole-size trees and from trees of lower grade quality. The building of oriented strand board (OSB) plants throughout the southern Appalachian region attests to the increased demand of these expanded wood resources.

This study answers questions about the effects of the clearcutting regeneration method with whole-tree harvesting on the perpetuation of forest stands. The specific objectives are:

- (i) To quantify forest level changes in woody and herbaceous plant species composition and structure;
- (ii) To quantify stand level trends of woody and herbaceous plant species composition and structure, and correlate herbaceous species with stand quality;
- (iii) To compute and evaluate the utility of diversity indices as a forest management tool.

## CHAPTER 2

### LITERATURE REVIEW

#### REGIONAL PHYSIOGRAPHY

The southern Appalachian Mountains extend from Pennsylvania (the northeastern-most point) to Alabama (the southwestern-most point) and cover approximately 74 million acres, of which 48 million acres are forested. Three distinct regions are delineated in the southern Appalachian Mountains: Blue Ridge, Ridge and Valley, and Appalachian Plateaus (Figure 2-1). Each of these physiographic provinces is defined by its unique topographical characteristics, soil type, and climatic conditions (Fenneman 1938). These interacting factors create highly variable habitat types and allow the presence of a mosaic of forest types across the three regions (Braun 1950).

#### FOREST COVER – TYPE GROUPS

Four major forest type groups have been described by Smith (1994) for the Southern Appalachian Hardwood Region: (i) chestnut oak - scarlet oak, (ii) white oak - black oak, (iii) red oak - sugar maple, and (iv) yellow-poplar - mixed-hardwood. These groups were based on a hypothetical available soil-moisture gradient. Each of these forest type groups has developed because of the varying topographic, climatic, and edaphic features found throughout the region. Below is a summarization of each type group taken from Smith (1994).

#### ***Chestnut oak – Scarlet oak Type Group***

The chestnut oak – scarlet oak type group is the least productive from an anthropogenic perspective. This type group is usually found on dry, rocky ridgetops and sideslopes with southern to western aspects and is generally less productive [i.e., site index base age 50 years ( $SI_{50}$ ) for white oak  $\leq 16.8$  m.] due to the shallow soils and adverse exposure. Succession in this type group is often controlled by fire frequency. In the absence of fire, the oaks predominate, while repetitive fires promote the growth of almost pure pine stands. The inaccessibility of these areas and the slow tree growth rates often make these sites non-economical for timber and fiber products. The main tree species found associated with this type group are chestnut oak (*Quercus prinus*) and scarlet oak (*Q. coccinea*), with sassafras (*Sassafras albidum*), bear oak (*Q. ilicifolia*), blackgum (*Nyssa sylvatica*), pitch pine (*Pinus rigida*), Table Mountain pine (*P. pungens*), and Virginia pine (*P. virginiana*). Understory is commonly dominated by ericaceous plants like blueberries (*Vaccinium* spp.), huckleberries (*Gaylussacia* spp.), and mountain laurel (*Kalmia latifolia*).

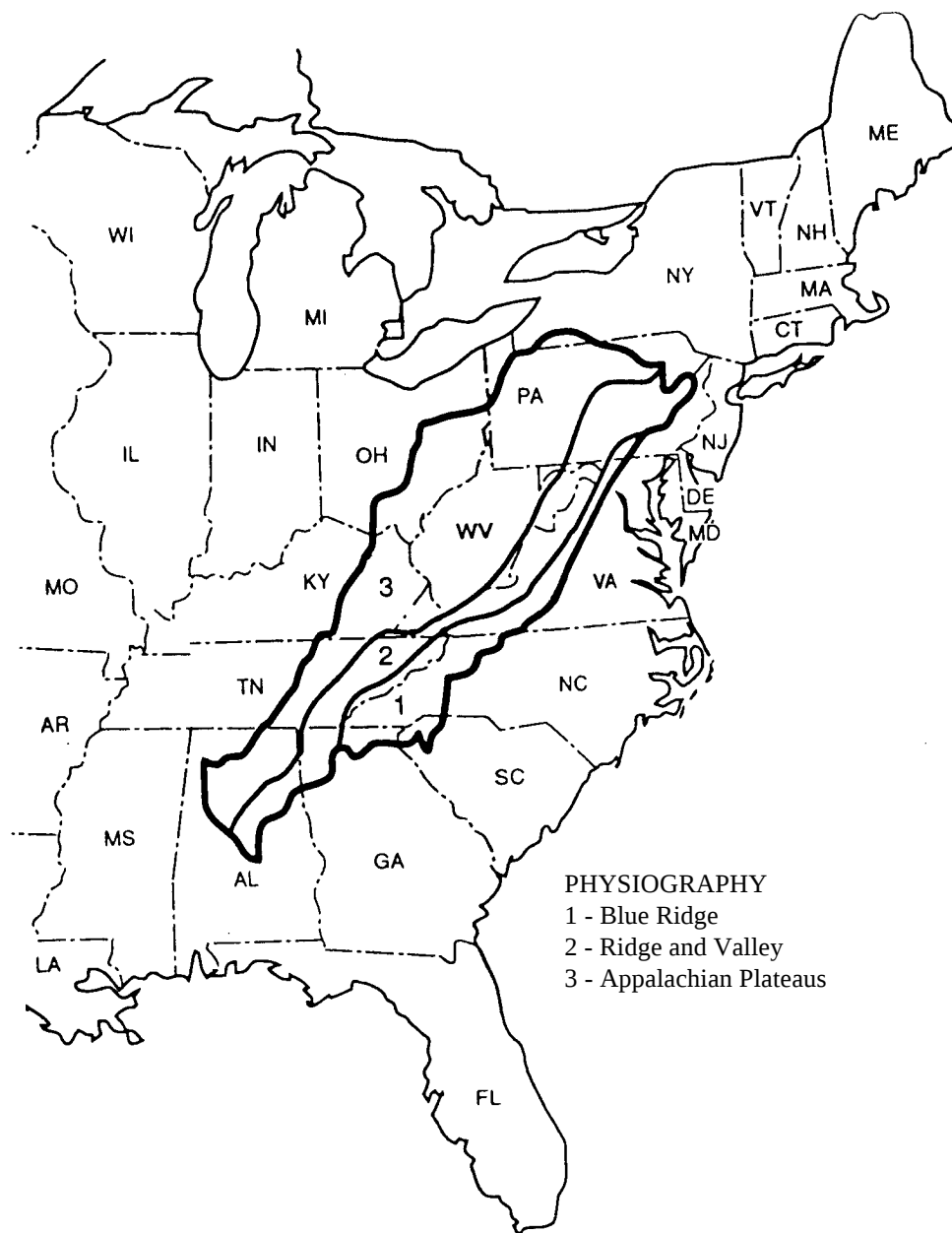


Figure 2-1. Physiographic sub-regions of the Southern Appalachian Hardwood Region. [Adapted from Fenneman (1938)].

### ***White oak – Black oak Type Group***

The most widely distributed type group is the white oak – black oak association. It is found on a wide range of topography that varies from middle and lower slopes with southern and western aspects to upper slopes and ridgetops with northern and eastern aspects. This forest type group is more productive than the chestnut oak – scarlet oak, having  $SI_{50}$  ranging from 16.9 to 21.3 m. If left undisturbed white oak (*Q. alba*) will become the prevalent overstory species due to its longevity and relative growth rate. In mixed stands, white pine (*P. strobus*) can become a large component of the overstory. Depending upon the quality of the stand, it can produce sawtimber, pulpwood, and/or specialty products. Accessibility to some sites and slope steepness, as in the previous type group, can hamper harvesting. Multiple silvicultural techniques can be applied to this association, with clearcutting currently being the most effective to regenerate oak.

The common species associated with this type group are white oak, black oak (*Q. velutina*), scarlet oak, chestnut oak, pignut hickory (*Carya glabra*), shagbark hickory (*C. ovata*), red maple (*Acer rubrum*), and white pine. Understory species include blueberry, huckleberry, azaleas (*Rhododendron* spp.), sourwood (*Oxydendrum arboreum*), blackgum, hollies (*Ilex* spp.), serviceberry (*Amelanchier arborea*), and flowering dogwood (*Cornus florida*).

### ***Red oak – Sugar maple Type Group***

The red oak – sugar maple type group contains the broadest variety of tree species; it includes associations from northern, central, and southern hardwood regions. This type group occurs mainly in the cooler, more mesic environments of the Appalachians. Western and southern aspects of lower slopes or the northern and eastern aspects of the mid- to upper slopes on mountains are indicative of this group type. Mid-successional species (fast growing and shade intolerant/intermediate) are most prevalent in these relatively high productive stands ( $SI_{50}$  between 21.4 and 25.9 m) due to past and current forest management practices. The primary products taken from these stands include sawtimber and veneer, with secondary products being pulpwood and fuelwood. The latter are usually byproducts of intermediate harvest cuts.

Silvicultural alternatives range from single-tree selection to clearcutting, depending upon the desired species composition and management goals. With respect to wood production, clearcutting is the most economically desirable when shade-intermediate and -intolerant species are desired. These higher quality sites tend to have greater diversity and, because they are on more mesic sites, intensive ground disturbance harvesting can potentially alter the stand composition.

Major trees associated with this type group include northern red oak (*Q. rubra*), yellow-poplar, sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*), white ash

(*Fraxinus americana*), basswood (*Tilia americana*), American beech (*Fagus grandifolia*), white oak, and cucumbertree (*Magnolia acuminata*). The understory contains a broad assortment of species including flowering dogwood, spicebush (*Lindera benzoin*), sassafras, hawthorns (*Crataegus* spp.), eastern hophornbeam (*Ostrya virginiana*), American hornbeam (*Carpinus caroliniana*), redbud (*Cercis canadensis*), serviceberry, sumacs (*Rhus* spp.), great rhododendron (*Rhododendron maximum*), and striped maple (*A. pensylvanicum*).

### ***Yellow-poplar – Mixed hardwood Type Group***

The yellow-poplar – mixed-hardwood, the last type group, is found on the most productive sites ( $SI_{50} \geq 26.0$  m). They tend to have eastern to northern aspects with gentle slopes and are often found in major drainages and coves. Deep, moist well-drained soils are always associated with these sites. Yellow-poplar outperforms all other species on these sites because of its pioneer tree attributes, that is it is a consistent, prolific seed-producing tree whose seeds remain viable for many years, and it has a very rapid growth rate. These characteristics allow yellow-poplar to easily establish itself and dominate recently disturbed sites.

As with the red oak-sugar maple type group, high quality sawtimber and veneer are the primary products, with pulpwood a byproduct of intermediate cuts. The same silvicultural techniques can be used for the yellow-poplar – mixed-hardwood group as for the previous group. Clearcutting would be the preferred method to continue the dominance of yellow-poplar on these sites. Associated species are very similar to the red oak – sugar maple type group, except that the yellow-poplar component increases as the site quality increases.

### **RIDGE AND VALLEY FOREST TYPES**

Specifically for the Ridge and Valley region, contiguous forest cover is the main distributional pattern. Valleys are cleared and used for agricultural purposes, while forests have been relegated to the ridgetops and sideslopes (i.e., the unsuitable agricultural sites). The northeast-southwest alignment of the mountains, combined with the discontinuity of the ridges and their spurs, creates many aspect-related microclimates throughout the Ridge and Valley region. Therefore, many different forest types or stands can occur within relatively small areas. These stands can vary from xeric to mesic to hydric soil conditions within a distance of a few hundred meters as a result of variations in aspect, slope position, and slope percent. These stands differ in productivity, which is correlated with topographic characteristics (Meiners et al. 1984).

Of the major forest type groups noted previously by Smith (1994), the white oak black - oak type group predominates within the Ridge and Valley region. The next most prevalent type group is the chestnut oak - scarlet oak, which is usually found along the

ridge tops and on south- to southwest-facing slopes. Small pockets of the red oak - sugar maple and yellow-poplar - mixed-hardwood type groups are found in this area, although they are usually sparse.

In general, the dominant overstory species for the region on xeric sites are chestnut oak, scarlet oak, pitch pine, and Virginia pine. On the mesic sites, species such as yellow-poplar, red maple, sassafras, blackgum, and black birch (*Betula nigra*) prevail. Those sites that lie between these two endpoints of a gradient are covered mainly by white oak, black oak, hickories, and white pine. There is also significant species overlap among these moisture-gradient based site qualities.

#### FORESTRY RELATED PLANT SPECIES DIVERSITY STUDIES

Three time-frame approaches have been used to study the responses of forest systems to disturbance: short-term, long-term, and chronosequence studies. Short-term studies (< 15 years) present immediate results, while long-term (> 15 years/full rotation) and chronosequence studies attempt to explain the longer term implications of a disturbance event. With respect to the latter two study approaches, long-term studies present a higher level of confidence of results through the selection of (a) specific treatment(s), control of systematic errors, and the quantification of uncertainty (Burger and Powers 1991). Chronosequence studies often lack a knowledge of pre-disturbance conditions on all sites and all intermediate disturbances that occurred over the life of the stand. It may also be true that each of the sites used in a chronosequence study do not, in actuality, have similar environments. The main benefit derived from chronosequence studies is the ability to obtain information or ideas about forest processes in a short amount of time expending minimal resources.

Our understanding of changes in diversity in the cycle of forest succession come predominantly from short-term studies, such as those of Swindel et al. (1984) and Halpern (1989), and chronosequence studies, including those of Schoonmaker and McKee (1988), Vankat and Snyder (1991), and Halpern and Spies (1995). General trends reflected in these studies show an initial increase in species richness after disturbance. Diversity tends to increase until a few years before crown closure, at which time diversity will decline because of the decrease in light levels. As the stand ages, some of the short lived or less healthy trees die and create canopy gaps. These openings provide areas for invasion or growth of additional (presumably earlier successional) species. This formation of canopy gaps can create (depending upon species composition) an uneven-aged forest, which allows for the existence of species from many successional stages. This last stage is theorized to lead to the high biodiversity in old-growth forests.

### ***Woody Component***

Studies that investigate the succession of forest systems after disturbances can provide better information for evaluating forest management alternatives. These studies can focus on specific components and/or temporal factors. Muller (1990) found that six years after clearcutting in a central Appalachian hardwood forest the dominant tree species in the understory reflected the pre-harvest overstory stand composition. This return to original stand composition was attributed to the stump sprouting of many of the species on the site.

Studies have shown that considerable change in overstory composition occurs on mesic forest sites. In a report of a ten-year study of a clearcut in a southern Appalachian hardwood stand in northwestern North Carolina, McGee and Hooper (1975) found that on these better sites adequate stocking of desirable hardwood species was achieved, but species dominance shifted. These stands were once dominated by oaks, but now have increased yellow-poplar and red maple components. Beck and Hooper (1986) reported the 20-year results of the same study and found a continuation of the trend; the oaks are a decreasing component, while yellow-poplar, black locust, red maple, and sweet birch now predominate.

Parker and Swank (1982) examined the response of tree species to two successive clearcuts in a southern Appalachian watershed in the Coweeta basin, North Carolina. They found that species dominance was related to slope position and that after each harvest specific species at each of these positions increased in dominance. On the lower slopes and coves yellow-poplar increased in dominance, on the mid- to upper-slope positions red maple increased, and on the ridges and upper slopes chestnut oak increased. Elliott and Swank (1994) evaluated the changes in tree species diversity on the same watershed. Tree species diversity was high after the first cutting, then decreased after the second cutting. Tree diversity was found to be highest in the early stages of stand development, but declined with canopy closure.

### ***Herbaceous Component***

The effect of forest management on herbaceous plants has generally been overlooked in forest studies. Only a few studies have examined the effects of low- (cutting only), moderate- (cutting and burning), and high-intensity stand management (stand conversion or intensive site preparation) on herbaceous diversity. Duffy and Meier (1992) investigated the effects of clearcutting on the herbaceous understory in southern Appalachian upland hardwood forest stands. They used a chronosequence approach to determine the time required for a stand to return to pre-harvest species richness after clearcutting. They concluded that the current rotation lengths (40-150 years) of forest management do not allow sufficient time for the forest to retain all of the forest species.

This paper has been criticized because of observed shortcomings in their methodology and question the validity of the extrapolations made from their results (Elliot and Loftis 1993, Johnson et al. 1993, Steinbeck 1993). The main argument was that the study was based upon a chronosequence; therefore, there is a high probability that the study sites did not have the same disturbance regime over the existence of the stands. They also did not have knowledge of predisturbance species presence/absence. A second criticism of the study was on the methods of the study. They selectively placed their plots to exclude patches of rhododendrons, and only studied spring herbs. Duffy (1993a, 1993b) responded to these criticisms by giving a more detailed history of the sites and by clarifying that, due to lack of resources, sampling was limited to spring ephemeral herbs.

Halpern and Spies (1995) found in moderate-intensity managed pine stands in the Cascade Mountains of Oregon that changes in herbaceous diversity are short-lived ( $< 3$  years) following clearcutting, burning, and artificial regeneration. Most plant species return to pre-disturbance levels prior to canopy closure, except on the microsites where severe burns had occurred. On these microsites, local extinction of plants may occur, or diversity may take 20 years to recover.

The assertion that rotation lengths are too short for retention of residual species (Duffy and Meier 1992) is also expressed in two other studies that evaluate the effects of clearcutting on herbaceous diversity. Swindel et al. (1984) and Halpern and Spies (1995) state that at current rotation lengths, in high-intensity managed pine plantations with artificial regeneration, the long-term trend is a less diverse forest stand. Swindel et al. (1984) note that additional research is necessary to predict the amount of change that will be incurred. Additionally, if the objective is to comply with the National Forest Management Act, assessment of many plantations (that have been artificially regenerated) throughout a region at various temporal stages is necessary for comparison to natural stands. Management on longer rotations may be necessary to maintain the understory species that are less resilient to intensive disturbances caused by short-rotation plantation forestry (Halpern and Spies 1995).

### ***Woody and Herbaceous Components***

Other studies have incorporated more than one vegetative stratum (i.e., overstory, understory, and/or ground vegetation) of the forest and, by comparing the structure of forest stands at different stages of development, an understanding of the interactions between strata can be determined. Gilliam and Turrill (1993) examined the herbaceous layer and overstory of a young 20 year-old clearcut to a 70+ year-old mature selective cut on two watersheds in the Fernow Experimental Forest, West Virginia. They found that herbaceous cover in the young stand correlated positively with soil characteristics, while in the mature stand it was negatively correlated with understory basal area and density. In a related study on the same site, Gilliam et al. (1995) found a correlation between two strata (herbaceous layer and overstory) in the mature forest, but not in the young stand. The

observations from these two studies have led the authors to hypothesize that early forest succession is guided by allogenic factors, but that autogenic factors influence later successional forest development.

In a search through ecological literature on causes of floral diversity reduction, Meier et al. (1995) found and presented five possible ecological mechanisms: (1) reduction of rare herbs due to logging, (2) inability of species to adapt after disturbances, (3) slow growth and reproduction rates, (4) mechanism for seed dispersal is slow (e.g., clonal, ant-dispersed, gravity-dispersed), or (5) logging disturbances create undesirable habitat conditions. These authors still insist, through experiments presented in this paper, that clearcutting directly or indirectly causes loss of species, but they seem to ignore the fact that many natural events can and do cause as much or more disturbance to forest ecosystems as do anthropogenic disturbances (e.g., Duever and McCollom 1993, Sharitz et al. 1993). In many cases, logging disturbances can virtually replicate natural disturbances (e.g., group selections can mimic insect outbreaks) as long as soil disturbance and loss of organic matter are kept at a minimum. If Meier et al. purport that logging disturbances reduce herb diversity then it stands to reason that natural disturbances will have a similar effect. There is inherent in this argument as a prior conclusion that any loss in diversity is bad and that a gain is good. This is certainly open to debate and there is little science to make a strong case above in either direction.

#### BIODIVERSITY

There is a continuing debate over whether plant species diversity helps to maintain the stability (sustainability) of a forest. In early studies testing the diversity-stability theory, most empirical studies came up with inconclusive results (Goodman 1975). Tilman (1996), studying a grassland community, concluded that diversity stabilizes community and ecosystem processes, but does not stabilize population processes. He found that the abundance of a species (number of individuals per species) can greatly fluctuate from one season to the next depending upon the growing conditions. Additionally, high plant richness counterbalances these abundance fluctuations by increasing the number of individuals of species that are not negatively affected by the growing conditions. If this grassland ecosystem relationship also occurs in other ecosystems, such as forests, then it would be in the best interest of humans to maintain the number of species that occur in each of the forest types to best preserve the sustainability and productivity of these forest ecosystems.

The concept of evenness (equal abundance of each species), with respect to diversity, is sometimes construed as a benefit. A community with an even species distribution is perceived to be healthier and more natural. However, having high evenness is not the prevailing distribution in most natural communities (Magurran 1988). Usually, two or three species dominate an area while the other species are relegated to occupy proportions of the remaining area (Pielou 1975). To promote the idea that forest ecosystems (and

other ecosystems as well) should be managed with the goal of producing an even distribution of all species could be construed as a disservice to the propagation of a natural and healthy (sustainable) forest and also to the concept of diversity itself.

Recent literature reveals a shift in thinking on the topic of biological diversity. In response to the dictation that sustainable ecosystems should be a major goal, a change in thought from maintaining biological diversity to biological integrity has been promoted (Karr 1990, Noss 1990, Angermeier and Karr 1994). Biological integrity focuses on maintaining the life functions, processes, and species of an ecosystem so that it will continue to be a productive and viable entity. From this perspective, biological diversity is a component of biological integrity. Many forest processes are performed by multiple species. This redundancy within each of the processes of an ecosystem presumably makes the system more stable (Goodman 1975, Tilman 1996). Disturbances may temporarily decouple the interconnected, natural sub-systems of a habitat. The redundancy of system functions, though, allows a habitat to diffuse the effects of a disturbance and recover without catastrophic consequences (Perry 1995).

There are two relatively recent examples of how forest ecosystems have responded to disturbance events. The introduction of the chestnut blight (*Endothia parasitica*) decimated the American chestnut (*Castanea dentata*), which at one time constituted a large volume (up to ~30%) of the stands in eastern forests (Braun 1950), but now just survives as stump spouts. A more current situation is the spread of the defoliating gypsy moth (*Lymantria dispar*) in the eastern hardwood forest. The moth has caused variable and often extremely high tree mortality, especially of oak species, across a large portion of the eastern forests (Fajvan and Wood 1996). In both cases, the forest has been very resilient (i.e., has continued to be productive) even though it has not returned to its pre-disturbance state in terms of species composition. Although these two events have altered the forest structure, the health (ability to sustain the native organisms) of the land is still great, which attests to the resilience of the system.

Life strategies for plant species also follow a resistance/resilience response approach. Species lie between the two extremes of being organisms that resist competitors or disturbances (Petraitis et al. 1989). It is hypothesized that ecosystems that contain the most species at these extremes will be the most diverse (Petraitis et al. 1989). In most cases, endangered plant species tend to be at extremes of these two strategies (Porter and Wieboldt 1991). This can create a situation where, in order to propagate these limited species, unique areas need to be specially managed and/or disturbances need to be maintained.

If we are truly to understand the health of forests we need to make connections between the biotic and abiotic factors and have knowledge about the historic compositions of these stands. Using a diversity index, a vague descriptor of species evenness and/or richness, does not tell us why certain species are or are not present. In addition, diversity indices

cannot truly tell us about the role each species may play in the maintenance of the forest system. It may be that when data are available over a long period of time or from a series of plots or tracts diversity indices may then be able to reveal trends in forest systems, but that is yet to be seen.

Recently there has been a change in focus on how the maintenance or conservation of diversity should be approached. The current predominant method in maintaining diversity is from a species by species approach. This approach though has draw backs because the rate at which species become threatened by extirpation greatly exceeds the rate at which they are restored to a ecosystem. Therefore, it has been suggested that management of forest systems at a higher level of organization such as forest stand types should be the main focus of diversity maintenance or conservation (Franklin 1993). By obtaining specific information on the multitude of forest types (both compositional and temporal stand types) and their distributions, the ability to manage forest diversity will be easier or more relevant. This present study provides information on the implications of managing upland hardwood stands using a clearcut regeneration method over a complete rotation or successional cycle. The results of this study can then be used in guiding the management objectives of promoting productive and sustainable forests.

It is important to remember that nature abhors a vacuum (i.e., static systems); as a result even naturally regenerated forests change over time. Taken over very lengthy time spans, natural events can and do cause as much or more disturbance to forest ecosystems as do anthropogenic forest management disturbances (e.g., Van Lear and Waldrop 1989, Orwig and Abrams 1993). If anthropogenic disturbances are timed so they occur at the same or similar rate as the historic, natural disturbances then most species, if not all, will persist. It is only when the frequency of disturbance of an area is so short as to preclude regeneration that species can become locally extinct. Additionally, if the type of disturbance causes substantial habitat change it can cause local extinction or reduce the recolonization ability of a species.

Additionally, North American forests have been disturbed by anthropogenic forces for thousands of years (i.e., Native Americans). Their main disturbances included annual burning of the understory and clearing of land for agricultural purposes (Van Lear and Waldrop 1989). These events greatly affected the compositional and structural development of forests prior to European settlement.

#### PLANT SPECIES DIVERSITY

##### ***Assessment of Diversity***

The quantification of diversity has been approached from many perspectives. The prevailing method in the past used diversity indices. More recently, however, ecologists have steered away from the use of indices because of some inherent shortcomings they

contain (Gotelli and Graves 1996). This has resulted because biological interpretations of diversity indices has been virtually impossible. This has lead to the use of more basic diversity measurements of species richness and species/abundance distribution curves. What follows is a short review of the most common diversity indices and distribution curves that have been used in plant ecology studies.

### Diversity indices

Diversity indices were created to simplify/collapse a large amount of information into one number. Most diversity indices are made up of one or two measurements of richness and abundance. Richness pertains to the total number of species, while abundance relates to how the total number of individuals of each species is distributed across space or time. Maximum diversity is typically defined by assuming that the numbers of all the individuals present are evenly distributed among each species (Magurran 1988).

Whittaker (1972) defined three scales of diversity: alpha ( $\alpha$ ), beta ( $\beta$ ) and gamma ( $\gamma$ ). These are based upon the scale, scope, or detail of interest and are defined as, respectively, (i) within habitat, (ii) between habitats, and (iii) ecosystem or landscape habitat. Alpha and gamma diversity deal with, respectively, local and regional diversity in a particular area; they deal with numbers of species and their relative importance values. Beta diversity is based, instead, upon ratios or differences between areas or time. Its evaluation relates to the number of unique habitats that lie across a gradient; or it is a measurement of the similarity between sites (as in an ordination or classification analysis). For this study, only alpha and beta diversity will be investigated because the plots are located within a localized area.

### *Common alpha diversity indices*

As stated above, there are three levels of diversity that provide different types of information. The first, alpha diversity, attempts to describe the local diversity of an area. The most common methods used to describe this diversity are (i) species richness, (ii) Simpson's index, and (iii) the Shannon-Wiener index (Magurran 1988).

Species richness (i) is the easiest and most basic form of measuring diversity. It is a list of the number of species encountered in a given area and is expressed as per unit area. This method is highly dependent upon sampling intensity and area; therefore, it is not very useful when comparing sites that were sampled at different intensities or areas.

Simpson's index (ii) is based upon a measure of concentration of individuals; that is, the probability that two individuals of the same species can be selected, successively, out of the community (Pielou 1975). This index is sensitive to sample size except when the underlying species distribution is in log series form (May 1975). This index is classified as a dominance measure since it is more sensitive to the abundance of the dominant species as opposed to the species richness (Magurran 1988).

The Shannon-Wiener index (iii) is a measure based upon information theory and is probably the most widely used index of this type. This index is based upon a random sampling of an infinite population and therefore has statistical error associated with it (Pielou 1975). This index also assumes that the sample contains all of the species in the community (Magurran 1988). This index is not sensitive to sample sizes and is more affected by species richness than the proportions of the more dominant species (Magurran 1988). This is a dubious index, in that there is not a direct biological interpretation with respect to diversity (Goodman 1975).

#### *Other alpha diversity indices*

There are many other alpha diversity indices that have been developed, but they tend to not be used as often as the above indices. An example is the Brillouin's index, which was also developed from information theory. This index is best used for a census of a population in a known community, and this restriction creates a conservative index estimator with no sampling error (Pielou 1975). Since most studies deal with sampling of populations and not a complete count of individuals, this index is not commonly used. Brillouin's index is sensitive to sample size, unlike the Shannon-Wiener index, in that the value will change if two communities have the same species proportions but different sample sizes (Magurran 1988).

Another diversity index is the log series  $\alpha$ -value. Magurran (1988) points out Taylor's (1978) promotion of the  $\alpha$  index because of its robust ability to discriminate between similar communities, the low sensitivity to sample size, and the virtual insensitivity to underlying species distributions. This richness measurement is also not as affected by the most prevalent species as are the Shannon-Wiener or Simpson indices. One drawback is that it is relatively insensitive to the changes in the evenness component of a community which could be an advantage in certain situations if evenness is not an objective.

#### *Beta diversity indices*

A second level in the measurement of diversity is the measurement of the amount of species change across a defined gradient or in the comparison of sites. The former facet deals with how the habitat is partitioned by each species and whether or not separate habitats can be distinguished along the gradient. This measurement is accomplished with the use of presence and absence beta diversity indices. Wilson and Shmida (1984) evaluated six beta diversity indices based upon four performance criteria: community turnover, additivity, independence from alpha diversity, and independence from over-sampling. They found that Whittaker's index ( $\beta_w$ ) best fulfilled the criteria, followed next by Wilson and Shmida's index ( $\beta_T$ ). The four other beta diversity indices did not perform well with respect to the performance criteria and were, therefore, determined unacceptable.

The second evaluation technique of beta diversity incorporates the comparison of habitat diversity of two or more different areas. Again using presence and absence data, sites are compared by how many similar species they contain between each other. The most commonly used measurements used for this measurement of beta diversity are the Jaccard and Sorenson similarity indices (Magurran 1988). Magurran (1988) noted that Smith (1986) examined these two similarity measurements and several others and concluded that none was fully adequate for examining differences between sites.

One inherent component of these similarity measurements is that they are unaffected by the evenness of the species. Therefore, alternative indices have been created that incorporate quantitative data; they are generally referred to as quantitative similarity indices. An example of this type of index is the Sorenson quantitative coefficient, which measures the likeness between habitats (Magurran 1988). Another is a modified version of the Morista-Horn index, which gained interest in the last decade because it is not greatly affected by species richness and sample size. However, the Morista-Horn index is sensitive to the abundance of the most abundant species (Magurran 1988) and is computationally intensive.

Others have proposed an index-free diversity ordering (Swindel et al. 1987). This measurement is based upon a comparison between cumulative proportional abundance of two areas/times/communities. This information is then interpreted by graphing the two areas/times/communities. By examining the locations and trends of each curve one can tell the diversity rankings of the sites. The biological relevance of this ordering is indeterminable, and it is still necessary to study the original data to determine the effects of the treatments. Two additional approaches to measure beta diversity use cluster analysis and ordination, though, these approaches are not as widely used.

### Species distribution curves

Species abundance models are another approach at describing the diversity of a community. These curves can be used to determine the resource distribution or evenness of a community. These models come from both biological and statistical bases and are presented as species- and/or rank-abundance curves. Biological models are created from two presumed species distributions: (i) geometric and (ii) broken stick. These are established from a niche preemption theory and a resource-apportioning model, respectively. The statistical models are assumed to be artifacts of distributional patterns of organisms; the two main models for these are: (i) log series and (ii) log normal.

### *Biological models*

The geometric model is a model based upon a niche preemption theory, where each species occupies a set proportionate amount of a community. This distribution is

theorized to arise when species enter an unsaturated community at set intervals. Thus, when a species arrives it will occupy the habitat most beneficial for it, while excluding all other species from these areas. Magurran (1988) reports that this type of distribution is also found to occur in systems that are in species-poor (or harsh) environments or in the early stages of succession.

The broken stick model exemplifies a species distribution of a habitat or community that is more evenly distributed. It is based upon the more or less even sharing of an ecological resource among all of the species in the community. This distribution, when used at a larger scale, better predicts the distribution of a combination of many communities (Pielou 1975). The best fits of this distribution arise in communities that have narrowly defined, taxonomically related, organisms (Magurran 1988).

### *Statistical models*

The log-series distribution, created by Fisher et al. (1943), was the first attempt to relate the number of species to the number of individuals in a community (Magurran 1988). It was based upon the observed trend that many communities consist of a few dominant species with many rare species. The communities that exhibit this distribution can be described by the log-series index ( $\alpha$ ) and the total number of individuals in the community. The log-series index tends to be a better general descriptor of the alpha diversity of a community. When the sample sizes are low, or when there are a few dominating ecological factors controlling the community, this type of distribution tends to occur (Magurran 1988). Magurran (1988) notes that this distribution is similar to the geometric with an exception that this distribution will result when species enter an unsaturated environment at random intervals.

The previous three species distribution curves are based upon limiting the number of competitive species in contact with each other. The log normal distribution, in contrast, follows the principle that as the number of species increases the number of factors that determine their relative importance also increases (Whittaker 1972). These importance values, being dependent upon many factors, will tend to be log-normally distributed when plotted on a logarithmic scale. It is important that a large enough sample is taken to satisfy the underlying restrictions of the central limit theorem. This is a continuous distribution; therefore, the data should be indiscrete (Magurran 1988). The communities represented by this distribution tend to be large, mature, and varied natural communities, but this distribution has also been observed in other communities with very large data sets (Magurran 1988).

Of these models, the log normal model tends to closely represent many community distributions studied by ecologists (Sugihara 1980). Chi-square goodness-to-fit ( $\chi^2$ ) parametric or Komogorov-Smirnov (KS) non-parametric statistical tests are used to compare observed distributions to theoretical distributions (Magurran 1988).

### *Other distribution types*

Other types of continuous data distributions that can potentially be applied to many biological arrangements include gamma, beta, chi-squared ( $\chi^2$ ), Poisson, and Weibull (Mendenhall and Scheaffer 1973). The gamma distribution, although not frequently used for species-abundance curves, is a unique function from the previous curves because it contains a family of curves (Pielou 1975). For example, the log-series distribution is a subset of the gamma distribution. This ability to generate a commonly used distribution potentially makes the gamma distribution a very flexible tool to generate an actual distribution.

Although there are many different types of distribution functions, only four have been used on a regular basis in ecology. These include the geometric, broken stick, log-normal, and log-series distributions. Magurran (1988) concludes that even though these curves may not be exact representations of population distributions, these few should be continued to be used for easier comparison to past data sets. Additionally, it may be that exact replication or representation of species distribution is not necessary to explain species arrangements.

### Measurement and sampling considerations

#### *Sample measurements*

When using diversity measurements, attention should be given to the way the data are collected to make sure that valid assessments are made. The most common method is to count the number of individuals of each species (discrete sampling), but sometimes this is impractical. Many times it is not known where one individual ends and the next starts. An alternative solution is to use continuous data variables. The more common measurements of this type include biomass, absolute percent cover, percent cover scales, and frequency. Each of these methods has limitations and benefits (Magurran 1988), so the objectives and resources of a study will determine the most effective sampling approach.

#### *Sample sizes*

Studies are often established with a unique sampling design and sample size. In order to compare two studies with differing sample sizes, one needs to correct for this difference. One approach to correct for different sample size is a method called rarefaction. This is a standardization method that estimates the number of species from a sub-sample (of equal size to the smallest original sample) of a larger sample (Krebs 1989).

There are, however, some restrictions and drawbacks when using this technique. When comparing areas, they should be of similar habitats, taxa, and sampling methods (Krebs

1989). This method tends to overestimate the number of species when individuals have a clumped distribution. The main drawback is the loss of information, where initially the number of individuals for each species was known, now only the number of species is known. In addition, the calculations to obtain the corrected number are tedious (Magurran 1988, Krebs 1989)

### *Distribution-sampling biases*

Most indices that are used to estimate diversity are based upon the assumption that the organisms being measured are randomly distributed. This pattern is not often reflected in nature, as most organisms have clumped or regular distributions. One attempt to correct this bias is to use the method of jackknifing, which was first incorporated using diversity indices by Zahl (1977). With this method, pseudovalues of an index are calculated by successively dropping out one sample. The pseudovalues are then averaged to produce a conservative index value. Further statistical evaluation of the jackknifing of diversity indices was examined by Heltshe and Forrester (1985), with the use of quadrat sampling technique. The results from these studies and others are promising for the improvement of diversity index estimates.

For more specific and concise information on the measurement of biodiversity, two references are Pielou (1975) and Magurran (1988).

### ***Utility of Diversity Indices and Distribution Curves***

#### Diversity indices

The use of diversity indices has been questioned as to whether a 'magic' number is environmentally feasible/applicable (Brown 1994) or of any significant value. Studies show that silvicultural techniques, such as clearcutting, initially increase the alpha diversity of an area (Conde et al. 1983a, 1983b). What they do not discuss is the changes in species compositions and distribution, which are potentially the more important factors. This is also reflected when considering one of the demands of society, to preserve the most number of species. This demand of the public may or may not be realistic and/or scientifically (environmentally) sound. It is important to relate the most effective and accurate information to the public about wise management of forest resources.

Another shortcoming of diversity indices is that they are dependent upon an abundance measurement that is related to a dominance factor in the ecosystem. It may be that the chosen abundance measurement is not reflective of the actual influence that it has on the system. For example, the fungus that caused the American chestnut blight has a relatively low overall productivity (biomass), but it has had a large influence on the present structure of the eastern forests (Hurlbert 1971). Basing an index on biomass in a system such as this can lead to erroneous conclusions. Another example is the gypsy moth, which makes

up a relatively small proportion of the overall forest productivity (i.e., biomass), but has a great influence on the composition of the system (Fajvan and Wood 1996).

Many of the commonly used diversity indices are sample-size dependent (Sugihara 1982). If sample sizes or intensity differences are not corrected (by means of the above mentioned methods) comparison of similar sites to each other may be difficult if not impossible. In some cases, corrections can not be done on data sets, while in other instances, sample size can be ignored if a particular abundance distribution exists for certain indices. For example, Simpson's index is independent of sample size if the underlying abundance distribution is a log-series (May 1975).

The comparison of diversity index values between sites is often misapplied. Many times sites are compared that are obviously regarded as being different even before comparing the index values. Swindel et al. (1984) state that there are sites that are not intrinsically comparable, or where a difference is based on a comparison that has little or no biological significance or apparent meaning.

The main difficulty in interpreting diversity indices relates to the simplistic idea of producing a single number for a particular habitat, community, or ecosystem. Diversity indices often contradict each other, and who is to say one diversity index is better than another? Diversity indices have been clumped into two groups, those that are more sensitive to either (i) richness or (ii) dominance (Magurran 1988). These two sets of indices can and do give opposing results. Even indices within each of these groups can give contrasting results. In one instance, the Simpson's and Shannon-Wiener indices changed in opposite directions when two structurally different communities were compared (Hurlbert 1971). Pielou (1975) further stated that communities can have the same diversity but be arranged in different ways (i.e., a community with few evenly represented species and a community with many, unevenly represented species).

The ability for a diversity index to detect the difference between two similar sites is important. Magurran (1988) notes that Taylor (1978) found that the log series index was the best index for detecting the slightest differences between two sites. But if a diversity index detects a difference between two similar sites, it is still more important to know how they differ. To answer that question, it is necessary to examine the original data to find where the differences occur. This is usually done using statistical methods to compare the data sets, thus making the calculation of an index an unnecessary step.

Studies reporting diversity index values usually conclude, based on these values, that diversity either increases or decreases due to some event. Many times, these studies do not have predisturbance or historic data on their sites. Or they directly correlate the health of the stand to these increases or decreases in diversity indices (Conde et al. 1983a, 1983b). Indices cannot detect the specific changes in species on the sites, such as which ones remained or left the site. For example, an index value may not change from pre- to

post-disturbance, but there may be a large change in the number of similar species (species turnover) that are found during both of those time periods. Alternatively, an index value may change dramatically in response to a change in abundance of only one or two species. If authors then relate either of these occurrences to the health of a stand without more detailed knowledge of species' distributions, then their conclusions would be unsubstantiated.

### Species distribution curves

A benefit that arises from the use of species distribution curves as estimators of species diversity is that there is little loss of information. By reporting the mean, variance, and/or a curve-creating parameter, the original population structure can often be closely reconstructed for some of these distributions. Use of species distribution curves has been promoted (Pielou 1975, Sugihara 1982). By (re-)creating and studying these curves, relationships may be determined between the structure of the community and the underlying processes (Sugihara 1982).

Species distribution curves also can be used to directly compare components of separate communities. Since the curves are created from a ranking of species or abundance, one can be more specific with management objectives. Specific species or types of distributions can be managed far more readily with a quantitative and visual representation of the community. A major drawback for the use of distribution curves is the high information content and associated acquisition or sampling cost that is used to create these curves. This creates a potential data storage problem for studies that have financial constraints.

Based on the review of the recent literature and current approaches used to evaluate diversity, the most appropriate methods for interpreting and expressing diversity are through species richness, abundance, and distribution curves. These methods are most often used in recent studies, because of their direct biological relationships to ecosystem processes.

## CHAPTER 3

### MATERIALS AND METHODS

#### HISTORY OF RESEARCH ON THE STUDY SITE

The Potts Mountain study site was established as a long term research project to evaluate the effects of clearcutting, utilizing whole-tree harvesting, on the structure and productivity of oak forests in the Ridge and Valley region of the southern Appalachian Mountains. Initial studies included the following: (1) soil analysis, (2) biomass and nutrient levels in understory vegetation, (3) browse productivity, and (4) small mammal and avian dynamics. The present study has expanded the original objectives to include also (5) changes in composition and structure of vegetation.

This project began in 1977 with the evaluation of pre-harvest stand structure and composition (McEvoy 1978), and the baseline data were used in many subsequent studies. Ross (1982) studied the effect of clear-cutting on 3-year-old oak regeneration by investigating the regeneration source, either advanced regeneration or stump sprouts. Cook (1988) and Blount (1989) studied the changing composition of these stands through the first eight years after the clearcut, but focused on scarlet and chestnut oak, and sassafras, respectively. Martin (1979) predicted understory biomass from physical vegetative measurements.

Morin (1978) conducted baseline soil relationship studies, investigating the fertility of the soil across varying site and stand compositions. Rauscher (1980) modeled the effect of nitrogen removal from the site as a consequence of whole-tree harvesting. Meiners (1982) correlated the growth potential of the sites with the relationships between topography and moisture availability.

Mammal and avian studies investigated the habitat utilization by white-tail deer (*Odocoileus virginianus*) (Forsythe 1978), white-footed mouse (*Peromyscus leucopus*) and short-tailed shrew (*Blarina brevicauda*) (Bliss 1979), and breeding bird communities (Healy 1979) in these stands.

These past studies focused on determining the patterns or processes that foster change over time in forests. Determining the interactions that occur between and among organisms and their surroundings results in a better understanding of forest management implications (effects). This study expands on previous work by focusing on the temporal changes in the species composition and structure in these typical upland stand types of the southern Appalachians.

## SITE DESCRIPTION

The study site is located in the Jefferson National Forest along Forest Service road 1063 on Potts Mountain in Craig County, Virginia approximately 12 km north of New Castle along state route 311. Sampling plots were established within stands along a 4.5 kilometer transect across the southern-facing mountain-side of Potts Mountain (Figure 3-1). Eight sampling plots (stands A-F, H, and I) were located in three of four non-continuous regeneration clearcuts that were spaced along the road. A ninth sampling plot (stand G), the control stand, was located between two of these regeneration areas in an undisturbed forest.

Slope position and elevation of these stands, with respect to Potts Mountain, are on a sideslope at approximately 730 meters elevation. Slopes range from 8 to 45% and have east to southwest aspects. Soils are classified as mesic, arenic, or typic Hapludults, with a generally coarse texture of mainly siliceous mineralogy derived from residual or colluvial sandstone and/or shale parent material (Morin 1978).

The vegetative composition and structure varies among the stands such that four categories were described based on visual criteria (McEvoy 1978). These vegetation type differences were described by contrasting the overstory and understory characteristics on each of the stands and were classified as one of the following: (i) cove hardwood overstory with an absent ericaceous understory and heavy herbaceous ground cover, (ii) mixed oak with a light ericaceous and moderate herbaceous ground cover, (iii) mixed oak-pine with moderate to heavy ericaceous and moderate herbaceous ground cover, and (iv) mixed pine with heavy ericaceous and sparse herbaceous ground cover.

These stands were evaluated for site quality using three methods (with exception of the control stand, which received two of three): Forest Site Quality Index (FSQI) (Wathen 1977), site index ( $SI_{50}$ ), and basal area increment/tree (Table 3-1). Subsequently, they were ranked by site quality from very poor to moderately good. The control stand was established to detect any significant disturbances that might occur over the life of the study.

Between August 1978 and March 1979, the stands were clearcut with whole-tree harvesting using cable yarding. Cable yarding was used to minimize the impact on the site and soil erosion on the steep slopes. All stands were harvested during the dormant season, except for one of the mixed oak stands (stand I) where harvesting began in August, 1978. Some vegetation in this stand resprouted, but the sprouts were killed by the first fall frost in 1978.

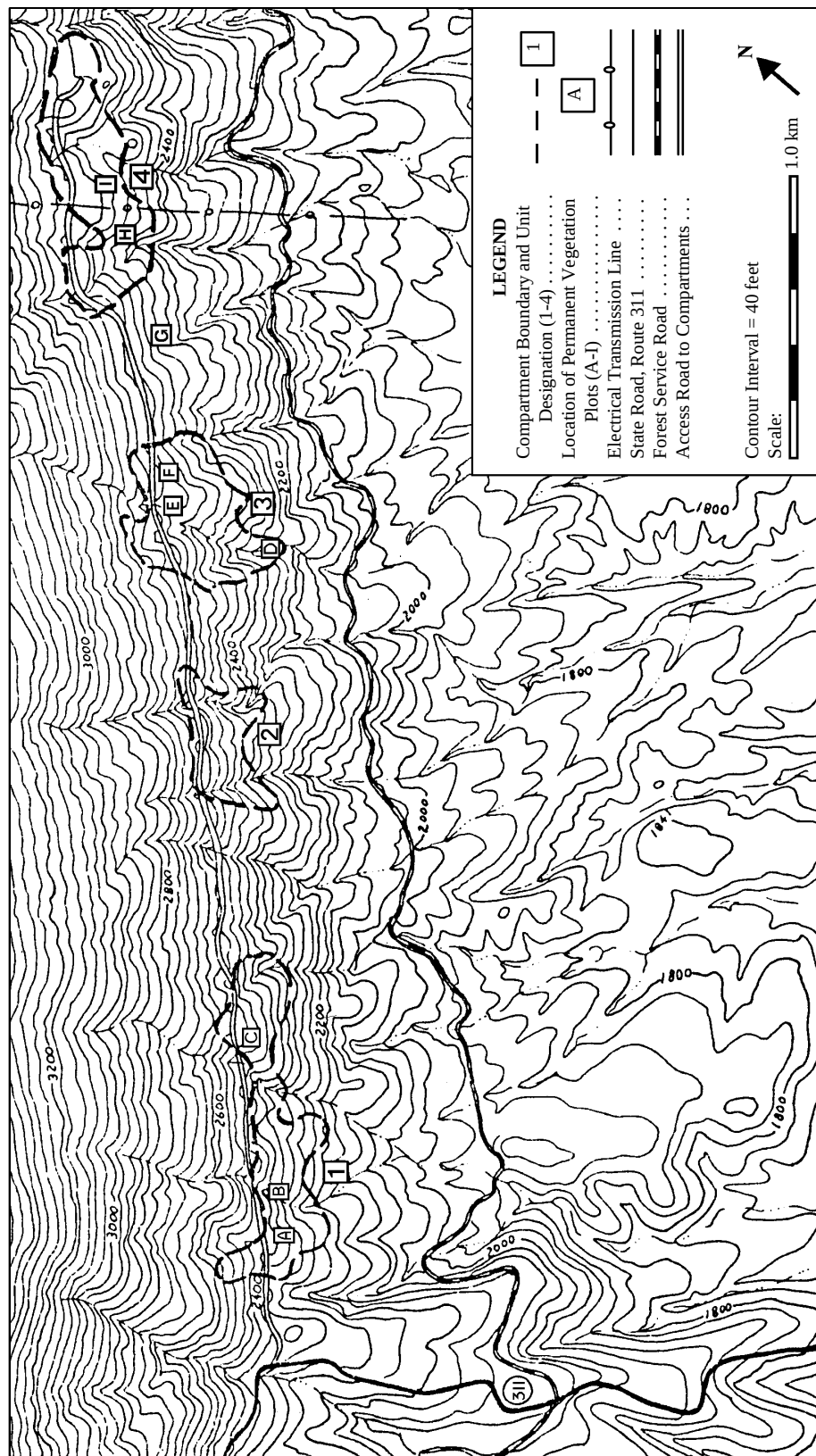


Figure 3-1. Compartments to be regenerated (1-4) and plot locations (A-I) for the Potts Mountain study site, Craig Co., Va. Note: Compartment 2 was never harvested.

Table 3-1. Vegetation types and respective productivity index values for regeneration clearcut stands on the Potts Mountain study site in Craig Co., Va. (From Ross 1982).

| Vegetation Type<br>(Forest Cover Type Group <sup>a</sup> ) | No. of<br>Stands <sup>b</sup> | Forest Site<br>Quality Index <sup>c</sup> | Site<br>Index <sup>d</sup> | Basal Area<br>Increment/Tree <sup>e</sup> |
|------------------------------------------------------------|-------------------------------|-------------------------------------------|----------------------------|-------------------------------------------|
| Mixed pine<br>(chestnut-scarlet oak)                       | 3                             | 5.3                                       | 11.3                       | 46                                        |
| Mixed oak-pine<br>(chestnut-scarlet oak)                   | 1                             | 8.0                                       | 14.9                       | 44                                        |
| Mixed oak<br>(white-black oak)                             | 3                             | 9.3                                       | 18.0                       | 65                                        |
| Mixed hardwood<br>(n. red oak-sugar maple)                 | 1                             | 14.0                                      | 21.6                       | 67                                        |
| Mixed oak-pine (control)<br>(chestnut-scarlet oak)         | 1                             | 8.0                                       | 15.2                       | NA                                        |

a = Forest type group classifications based upon Smith (1994).

b = For vegetation types with more than one stand the averages are given.

c = Based on categorical ranking of aspect, slope percent, and slope position. Values range from 3 to 16, with high values indicating high potential productivity (Wathen, 1977).

d = Based on total height (m) for upland oaks at age 50 (Olson, 1959).

e = Growth increment (cm<sup>2</sup>) during 1968-1978 for stems (of all species) that were alive and taller than 5 m at the time of sampling.

## PLOT ESTABLISHMENT

Nine permanent 1600 m<sup>2</sup> sampling plots were established in 1977 and strategically located to obtain representative samples of the vegetation type of each stand across the study area (Ross 1982). Each sampling plot was oriented so that the upper side of the plot ran parallel to the slope contour. Nested plots were used to sample three strata: (i) tree, (ii) shrub, and (iii) herb (Figure 3-2). Plot sizes for each of the strata are as follows: 10 x 10 m tree subplot, 5 x 5 m shrub subplot, and a 1 x 1 m herb subplot.

## DATA COLLECTION

### ***Sampling Procedure***

Detailed descriptions of sampling procedures for the tree and shrub strata are contained in McEvoy (1978). The original sampling period (pre-harvest) occurred between April 1977 and March 1978. A vertical height restriction was used to delineate the tree, shrub, and herb strata: (i) > 5 meters, (ii) between 1 to 5 meters, and (iii) < 1 meter, respectively. The tree and shrub strata were measured in multiple periods, while the herb stratum was measured only during the pre-harvest and the 1995 sampling periods (Table 3-2). Pre-and post-harvest sampling intensity, method, and type of data collected also varied between strata.

The pre-harvest tree, shrub, and herb strata were sampled at 100, 50, and 5 percent intensity, respectively (Table 3-3). This intensity was reduced for the post-harvest sampling in the shrub and herb strata to 25 and 2.5 percent, respectively. The original sampling scheme was found to be too intensive and time-consuming. The post-harvest sample intensity for the herb stratum was determined by using species area curves (Appendix A).

Pre-harvest sampling methods for each stratum were as follows: (i) a complete sample for the tree stratum, (ii) a rank set for the shrub stratum, and (iii) a stratified-random for the herb stratum (Table 3-3). The post-harvest sampling method was identical except for the herb stratum, which used a completely randomized method.

Measurements recorded for pre-harvest data varied between strata (Table 3-4). Woody species only were recorded for the tree and shrub strata, while woody and herbaceous species were included in the herb stratum. For each individual in the tree stratum, the scientific name, diameter (in centimeters) at 1.37 m above ground level, and total height (in meters) were recorded. Measurements for the shrub stratum for each individual included scientific name, diameter (in centimeters) at 15 cm above ground level, and total height (in meters). In the herb stratum, for each species the scientific name and total vegetative cover (by absolute ocular percentage) were recorded. Also in the herb stratum,

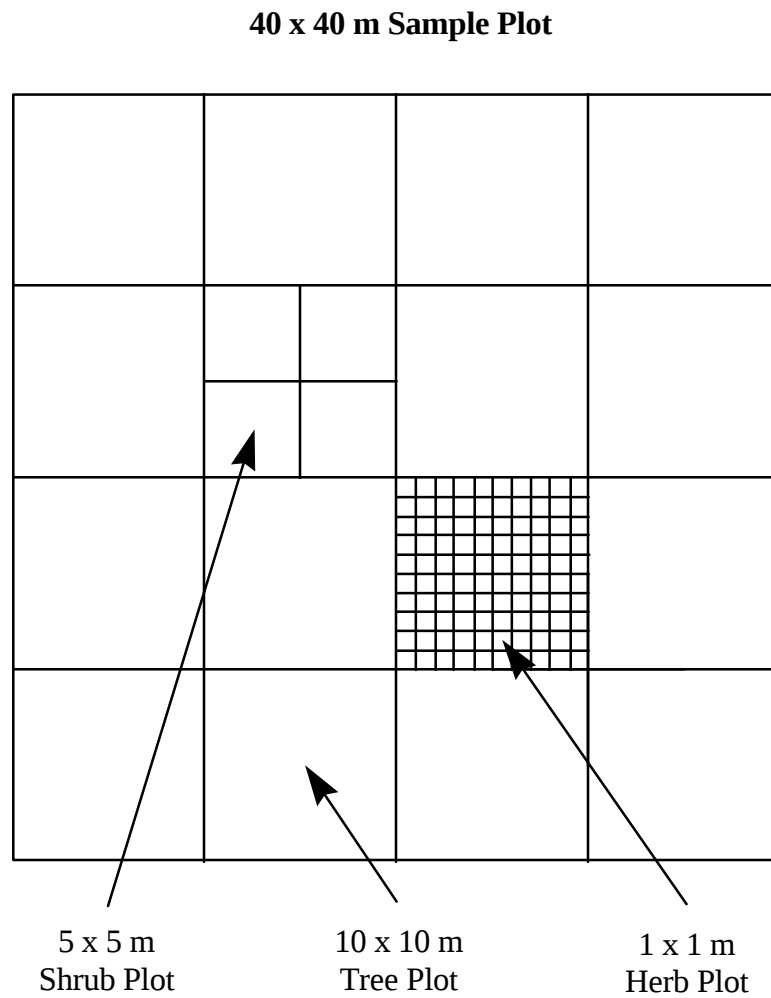


Figure 3-2. Nested plot design for vegetation sampling at the Potts Mountain study site in Craig Co., Va.

Table 3-2. Strata sampled, by year, at the Potts Mountain study site in Craig Co., Va. (t = tree, s = shrub, and h = herb).

| Years<br>post-<br>harvest | Stand <sup>a</sup> |         |         |         |         |         |         |         |         |
|---------------------------|--------------------|---------|---------|---------|---------|---------|---------|---------|---------|
|                           | A                  | B       | C       | D       | E       | F       | G       | H       | I       |
| Pre-<br>harvest           | t, s, h            | t, s, h | t, s, h | t, s, h | t, s, h | t, s, h | t, s, h | t, s, h | t, s, h |
| 1                         | s                  | s       | s       | s       | s       | s       | s       | s       | s       |
| 3                         | s                  | s       | s       | s       | s       | s       | s       | s       | s       |
| 5                         | t                  | t, s    | t, s    | t, s    | t       | t       | t, s    | t       | t, s    |
| 7                         | t                  | t, s    | t, s    | t, s    | t       | t       | s       | t       | t, s    |
| 17                        |                    | t, s    | t, s, h | t, s, h |         |         | t, s, h | t, s, h | t, s, h |

a = Stand vegetation types are: mixed pine (B, E, H), mixed oak-pine (C, G), mixed oak (A, F, I), and mixed hardwood (D).

Table 3-3. Pre- and post-harvest vegetation sampling scheme for measurement of three strata at the Potts Mountain study site in Craig Co., Va. (adapted from McEvoy 1978).

| Height strata               | Subplot size (m) | No. subplots per area |      | Percent of area |      | Sample type       |                   |
|-----------------------------|------------------|-----------------------|------|-----------------|------|-------------------|-------------------|
|                             |                  | Pre                   | Post | Pre             | Post | Pre               | Post              |
| Tree (> 5.0 m)              | 10 x 10          | 16                    | 16   | 100             | 100  | Complete          | Complete          |
| Shrub (1.0 - 5.0 m)         | 5 x 5            | 32                    | 16   | 50              | 25   | Rank set          | Rank set          |
| Herb <sup>a</sup> (< 1.0 m) | 1 x 1            | 80                    | 40   | 5               | 2.5  | Stratified random | Completely random |

a = Post-harvest data for the herbaceous stratum were only collected in 1995.

Table 3-4. Pre- and post-harvest measurements recorded to determine structure and composition of forest stands at the Potts Mountain study site in Craig Co., Va.

| Stratum | Measure (units)                                                                                                                         | Vegetation type      |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| Tree    | Scientific name                                                                                                                         | Woody only           |
|         | Diameter (cm) at 1.37 m                                                                                                                 |                      |
|         | Total height <sup>a</sup> (m)                                                                                                           |                      |
| Shrub   | Scientific name                                                                                                                         | Woody only           |
|         | Diameter (cm) at 15 cm above soil (root collar)                                                                                         |                      |
|         | Total height (m)                                                                                                                        |                      |
| Herb    | Scientific name                                                                                                                         | Woody and herbaceous |
|         | Percent cover by species                                                                                                                |                      |
|         | Percent cover of ground cover features (total vegetation, rock, litter, bare soil, living stems, woody debris, moss, lichen, and water) |                      |
|         |                                                                                                                                         |                      |

a = For the 1995 sampling period the height of approximately every fifth tree of a species was measured

nine ground cover features (total vegetation, rock, litter, bare soil, living stems, woody debris, moss, lichen, and water) were estimated (by percentage) and recorded.

Post-harvest data collection measurements were the same with one exception. In the 1995 measurement period of the tree stratum, the height of approximately every fifth individual of a species was measured instead of every individual because measurement of every individual was too time consuming (Table 3-4).

### ***Sampling for the Post-harvest Measurement Periods***

Over the 17 years of the study, the number of sampling plots sampled at the study site has varied (Table 3-2). For the 1995 measurement period, sampling plots were reestablished in January 1995. Four sampling plots (stands C, D, H, I), one from each of the previously defined vegetation types and the control sampling plot (stand G) (Table 3-1), were randomly selected and measured. After further review of the previous years data sets it was determined that an additional sampling plot (stand B) should be measured in order to maintain the repeated measurement scheme established on this study site. Only tree and shrub data were measured and recorded for this plot.

Herb stratum data were collected during the 1995 growing season in two periods; the first in early June 1995 and then again in late July 1995. Two sampling periods were used to facilitate identification and maximize the potential number of species encountered. Tree and shrub data were collected in March 1996 prior to the initiation of the 1996 growing season. Additional sampling of the shrub strata (i.e., *Rhododendron* spp., *Vaccinium* spp. and *Kalmia* spp.) occurred during March 1997 after an oversight in sampling procedures was found. The one-year of extra growth in these species is not expected to alter the outcome of the study. These sampling periods closely coincided with the pre-harvest sampling times.

### ***Specific Sampling Procedures for 1995 Measurement Period***

For all strata, each species was assigned a six letter species code, which was comprised of the first three letters of each genus and species name.

#### **Tree stratum**

Diameter, measured at 1.37 m above ground (to the nearest tenth of an centimeter) was recorded using a digital caliper. Two measurements were taken perpendicular to each other and then averaged. An exception occurred in sampling plots of stands D and G, where the average diameter exceeded the width of the caliper. Instead, a metric diameter tape was used, and measurements again were taken to the nearest tenth of a centimeter. Total height to the nearest tenth of a meter, using a height pole, was recorded for

approximately every fifth individual per species. Individuals that originated from a common stump were noted.

#### Shrub stratum

Those species that grew with clumped stems were noted in this stratum. A clumped stem was determined by ocular inspection. As long as the stem was separate from all other stems at mineral soil level, it was considered to be an individual.

#### Herb stratum

In contrast to the pre-harvest sampling method of estimating percent cover by an absolute ocular approach, a pre-transformed scale (arc sine) (Little and Hills 1978) of 10 segments was used to ocularly estimate percent cover (Appendix B). Only plants (both herbaceous and woody) whose stems, at mineral soil level, originated within the sampling plot were included in estimates of percent cover. Total percent cover exceeding 100 percent could occur within this data set at each sampling plot because of plant overlap in the horizontal dimension. Additionally, a complete species inventory (sample plot richness list) was collected by completely traversing each 40 x 40 m plot and recording all species (both woody and herbaceous) observed.

The ground cover features of: (1) litter, (2) woody debris, (3) water, (4) bare soil, (5) moss, (6) lichen, (7) living stems, (8) rock, and (9) total vegetation cover (defined in Appendix B) were measured using the pre-transformed, percent cover scale. The ground cover features were measured by visually adding a one meter vertical dimension to the subplot. Anything that intersected this cubic area was counted into one of the above categories, even if it did not originate from within the herbaceous subplot. The total percent cover of this set should be approximately 100 %, excluding total vegetation cover, as long as there were no elevated features within the cubic plot. The percent cover of a ground feature was determined based upon the chance that a fallen seed would land on a specific feature.

#### METHODS OF ANALYSIS

For analysis, data from stands C, D, H, and I were used in all calculations for the herbaceous stratum, while data from stands B, C, D, and I were used in all calculations for the shrub and tree strata. One exception occurred when calculations from the data of stands C, D, H, and I (of all strata) were used for the correlation analysis so that stand structure would be better represented across all strata. In the herbaceous stratum, pre-harvest data conversion was necessary to most effectively compare it to the post-harvest data. The absolute percentages were converted to the transformed scale. Additionally, for both pre- and post-harvest data sets, when plants were only identified to genus, all the same genera were pooled together and the highest transformed scale value was used.

### ***Changes in Forest Composition and Structure***

To investigate the change in forest composition, importance values (IV) by species (calculated from averaging relative basal area and stem density) were examined by averaging four sample plots. The null hypothesis for this evaluation was:

**H<sub>0</sub>:** Forest vegetative composition remains the same after clearcutting with whole-tree harvesting.

The absolute forest values of basal area and stem density were also calculated (in the tree stratum the average heights and diameters were also reported) to compare the development of the new forest with the pre-harvest forest. Complete species lists were provided for future reference. Student's paired t-test was used for statistical analysis to compare the species importance values of the pre-harvest forest to the species importance values of the 17-year old forest. Equal sample sizes, across years, were used to calculate the importance values of each species and the absolute values of basal area and stem density.

Data analysis complications arose when, in some years, individuals were not found in each of the sampling plots. Because the IV values are calculated by averaging the 'averages,' the total IV within these years did not equal 100%. This incidence, though, was not detrimental because it was more important to examine the presence and ranking of each species. This complication occurred in both this forest level analysis and the stand level analysis with respect to IV calculations.

### ***Relationship Between Stand Quality and Vegetative Composition***

The responses of many plant species to clearcutting across stand qualities with whole-tree harvesting has not been thoroughly studied. To address this objective, the changes in importance value (average of relative basal area and relative stem density) by species of the stands were examined and correlated to stand quality. Also, correlations between stand characteristics and stand quality were examined. The null hypothesis for this evaluation was:

**H<sub>0</sub>:** Vegetative composition and structure across a stand quality gradient are unchanged after clearcutting with whole-tree harvesting.

Pearson's product correlation was used to compare the stand characteristics (dependent variable) of herb stratum percent cover, species richness of all stratum, and species composition of each stratum, to stand quality (independent variable) which was based upon SI<sub>50</sub> and FSQI.

The absolute values of stand basal area and stem density were also calculated and plotted (in the tree stratum the average heights and diameters were also reported and plotted) to compare the structural development of the new stands with the pre-harvest stands. Equal sample sizes, across years, were used to calculate the importance values of each species and the absolute values of basal area and stem density.

### ***Plant Species Diversity Assessment***

To investigate alternative measurements that assess the changes in plant species composition over time a variety of alpha and beta diversity indices were calculated. The spatial or temporal scale at which these diversity indices discriminate between stands or detect differences over time within stands are examined. With this knowledge, the potential user can then decide which of these indices to use or not use depending upon their management objective(s). Abundance measurements or species richness were used to calculate the alpha and beta diversity indices. Equal sample sizes, across years, were used to calculate the diversity indices. The alpha diversity index values, species richness, and abundance between the pre-harvest forest and the 17-year old forest were statistically analyzed (using Student's paired t-test) to see if diversity changed over time after a disturbance. The null hypothesis for this evaluation was:

**H<sub>0</sub>:** Alpha and beta diversity remained unchanged after clearcutting with whole-tree harvesting.

The alpha diversity indices that were used include:

|                          |                           |
|--------------------------|---------------------------|
| inverse Simpson's index  | $D' = 1/D = 1/\sum p_i^2$ |
| and Shannon-Wiener index | $H' = \sum p_i \ln p_i$   |

where:

$p_i$  = the proportion of individuals in the  $i^{\text{th}}$  species.

The beta diversity indices (similarity indices) used to test for temporal similarities between these stands were:

|                             |                            |
|-----------------------------|----------------------------|
| Jaccard's                   | $C_J = j / (a + b - j)$    |
| Sorenson's                  | $C_S = 2 * j / (a + b)$    |
| and Sorenson's quantitative | $C_N = 2 * jN / (aN + bN)$ |

where:

$j$  = the number of species found in both sites,  
 $a$  = the number of species in site A,

$b$  = the number of species in site B,  
 $\sum \min(a_i, b_i)$  = the sum of the lower of the two abundances recorded for  
species found in both sites,  
 $a$  = the total number of individuals in site A, and  $b$  = the total  
number of individuals in site B.

These similarity indices equal 1 when the two plots are exactly the same and 0 when they are completely different or have no species in common.

## **CHAPTER 4**

### **INTRODUCTION TO THE RESULTS AND DISCUSSION**

Two approaches were taken to measure the changes in the species composition and structure after a clearcutting disturbance. The first was to use relative dominance measurements of each species and examine their change over time. This approach was performed at two scales: at a forest and stand level. The first section (4.1) of this chapter discusses the forest level changes, while the second section (4.2) discusses the stand level changes. The second approach used to examine change was through the use of diversity indices, which was the topic of the third section (4.3) of this chapter. In the third section, diversity indices were calculated to see if these “compressed data” values could effectively detect biologically significant changes at a spatial and temporal scale.

The following definitions are given to clarify the meanings of the forest and stand level approaches. When the word ‘stand’ is used it refers to one of the forest vegetation types that is also associated with a site quality. When ‘forest’ is mentioned, it is a generalization of the whole forest ecosystem and is thus calculated by averaging the data from the four ‘stands’.

## **CHAPTER 4.1**

### **FOREST LEVEL CHARACTERISTICS**

#### **RESULTS AND DISCUSSION**

To address the first hypothesis, this section discusses the effects that clearcutting with whole-tree harvesting has on forest level vegetative composition and characteristics. Changes in ground cover features, species lists, forest structure characteristics (i.e., basal area, stem density, and tree height and diameter), and species importance values are examined to better understand the changes that occur in forests after a clearcutting disturbance.

#### GROUND COVER FEATURES

Seven of the nine ground cover features (rock, litter, bare soil, living stems, woody debris, moss, and lichens) were found to be statistically significantly different between the pre-harvest and the 17-year old forest (Table 4.1-1). From a biological perspective, though, what do these changes really mean? In most cases, those features that were found statistically different changed marginally. Each of these changes can be accounted for by biological events. In contrast, percent vegetative cover and water were not found to be significantly different, but a large increase was observed in the former. The increase, though, not statistically significant can also be accounted by the biological event of a more open canopy allowing many species to persist and thrive.

Of the seven statistically different features all but litter increased in percent cover. The decrease in litter (from 97.2% to 87.6%) may be attributed to an increase in decomposition rate and decrease of litter input after harvesting. Litter decomposition increases as forest floor temperatures and moistures increase as a result of the complete overstory removal associated with clearcutting (Johnson et al. 1985).

The increase in living stem percent cover (from 0.2% to 0.9%) occurred because the probability of encountering a live stem is greater in a younger forest where the forest floor is responding to the complete loss of the overstory canopy. In contrast, an older forest has few, large stems and a heavily shaded forest floor which suppresses regeneration and understory growth. The increase in rock (from 0.2% to 1.3%) and bare soil (from 0.5% to 1.3%) percent cover may have been caused by the harvesting operation, since some of the forest floor was disturbed by the cable logging system. Alternatively, this increase could have resulted from the reduction in litter, which would expose more rocks and soil that were once covered prior to harvest. The increase in woody debris percent cover (from 0.9% to 4.5%) is also a result of the harvesting operation since the whole tree is generally not taken. When a tree is felled and then dragged to the logging deck, branches are often broken off and left on site. The increase in percent cover of moss (from 0.3% to 1.3%) and lichens (from 0.3% to 1.8%) may also be attributed to a combination of the

Table 4.1-1. Estimated percent cover of ground features at the Potts Mountain study site in Craig Co., Va. (n = 4; Bold type indicates significant difference at  $\alpha = 0.10$ .)

| Year <sup>a</sup>                                                                            |           | Vegetation | Rock        | Litter       | Bare soil   | Living stems | Woody debris | Moss        | Lichens     | Water  |
|----------------------------------------------------------------------------------------------|-----------|------------|-------------|--------------|-------------|--------------|--------------|-------------|-------------|--------|
| Pre-                                                                                         | Average   | 11.7%      | <b>0.2%</b> | <b>97.2%</b> | <b>0.5%</b> | <b>0.2%</b>  | <b>0.9%</b>  | <b>0.3%</b> | <b>0.3%</b> | 0.0%   |
|                                                                                              | Std. dev. | 4.2%       | 0.3%        | 1.8%         | 0.5%        | 0.1%         | 0.5%         | 0.2%        | 0.1%        | 0.0%   |
| 17                                                                                           | Average   | 23.2%      | <b>1.3%</b> | <b>87.6%</b> | <b>1.3%</b> | <b>0.9%</b>  | <b>4.5%</b>  | <b>1.3%</b> | <b>1.8%</b> | 0.1%   |
|                                                                                              | Std. dev. | 18.6%      | 1.2%        | 8.7%         | 0.8%        | 0.6%         | 1.3%         | 0.7%        | 0.5%        | 0.3%   |
| Student's paired t-test of averages between the pre-harvest and 17-year old forests (df = 3) |           |            |             |              |             |              |              |             |             |        |
| t                                                                                            |           | 1.12       | 2.36        | -4.16        | 3.45        | 4.13         | 9.85         | 6.66        | 8.35        | 1.04   |
| P-value                                                                                      |           | > 0.20     | < 0.10      | < 0.05       | < 0.05      | < 0.05       | < 0.01       | < 0.01      | < 0.01      | > 0.20 |

a = Pre-: Pre-harvest forest; 17: 17-year old forest.

decrease in litter and increased woody debris. Moss and lichens are typically found growing on rock, bare soil, and wood. Since these three features increased it would stand to reason that moss and lichens should also increase.

### SPECIES LIST

In the herb stratum a total of 45 herbaceous and 34 woody species were identified within herb stratum sampling units across the four treatment stands over the 17-year study period (Table 4.1-2). A total of 32 and 21 species were identified in the shrub and tree stratum, respectively, across five treatment stands (Table 4.1-3). In the shrub stratum, in order to maintain plot consistency for better statistical analysis, seven species were excluded from the list when the pre-harvest and 17-year old forests were compared because they were found only in the intermediate sampling periods. Six of the excluded species are *B. lenta*, *C. tomentosa*, *Hydrangea arborescens*, *P. serotina*, *Q. rubra*, and *Viburnum acerifolium*. The seventh was either *P. echinata* or *P. pungens* depending upon whether stand H or stand B, respectively, was used for analysis. When the five stands were completely traversed (a “walk-thru” survey) an additional 19 herbaceous and 2 woody species were observed (Table 4.1-4).

A separate species list was created for the control stand (which included all strata) where a total of 20 herbaceous and 24 woody species were observed within the sampling units over the 17-year study period (Table 4.1-5). A complete traversing (“walk-thru”) of the control stand was performed and an additional 6 herbaceous and 1 woody species were identified and included in the species list (Table 4.1-5).

### ***Herb Stratum Herbaceous Plants***

A total of 32 plant species in the four treatment stands were identified within the herb stratum sampling units in the pre-harvest forest (Table 4.1-6). In the 17-year old forest, an additional 13 new species were identified, while 8 pre-harvest species were no longer found within the forest: a net gain of 5 species. A total of 25 species were similar at both times.

### ***Herb Stratum Woody Plants***

Woody plants in the herb stratum of the pre-harvest and 17-year old forest contained 29 species of which 24 were found at both times (Table 4.1-7).

### ***Shrub Stratum Woody Plants***

Within the shrub stratum, species richness ranged from a low of 13 one-year after harvest to a high of 27 five-years after harvest (Table 4.1-8). Twenty-one and 22 woody species

Table 4.1-2. Species lists and codes for herbaceous and woody species found within the herb stratum sample units at the Potts Mountain study site in Craig Co., Va.

| Herbaceous Plants |              |                                   | Woody Plants |              |                                |
|-------------------|--------------|-----------------------------------|--------------|--------------|--------------------------------|
|                   | Species Code | Scientific name                   |              | Species Code | Scientific name                |
| 1                 | ANDSPP       | <i>Andropogon</i> spp.            | 1            | ACEPEN       | <i>Acer pensylvanicum</i>      |
| 2                 | ASCVIR       | <i>Asclepias viridis</i>          | 2            | ACERUB       | <i>Acer rubrum</i>             |
| 3                 | ASTER        | <i>Asteraceae</i> family          | 3            | AMEARB       | <i>Amelanchier arborea</i>     |
| 4                 | ATHFIL       | <i>Athyrium filix-femina</i>      | 4            | CARGLA       | <i>Carya glabra</i>            |
| 5                 | AURLAE       | <i>Aureolaria laevigata</i>       | 5            | CARTOM       | <i>Carya tomentosa</i>         |
| 6                 | BAPTIN       | <i>Baptisia tinctoria</i>         | 6            | CASDEN       | <i>Castanea dentata</i>        |
| 7                 | BARVER       | <i>Barbarea verna</i>             | 7            | CORFLO       | <i>Cornus florida</i>          |
| 8                 | CARSPP       | <i>Carex</i> spp.                 | 8            | GAYBAC       | <i>Gaylussacia baccata</i>     |
| 9                 | CHIMAC       | <i>Chimaphila maculata</i>        | 9            | HAMVIR       | <i>Hamamelis virginiana</i>    |
| 10                | CORMAJ       | <i>Coreopsis major</i>            | 10           | HYDARB       | <i>Hydrangea arborescens</i>   |
| 11                | CYPACA       | <i>Cypripedium acaule</i>         | 11           | ILEVER       | <i>Ilex verticillata</i>       |
| 12                | CYSFRA       | <i>Cystopteris fragilis</i>       | 12           | KALLAT       | <i>Kalmia latifolia</i>        |
| 13                | DANSPP       | <i>Danthonia</i> spp.             | 13           | LIRTUL       | <i>Liriodendron tulipifera</i> |
| 14                | DESSPP       | <i>Desmodium</i> spp.             | 14           | NYSSYL       | <i>Nyssa sylvatica</i>         |
| 15                | DIOVIL       | <i>Dioscorea villosa</i>          | 15           | OXYARB       | <i>Oxydendrum arboreum</i>     |
| 16                | EPIREP       | <i>Epigaea repens</i>             | 16           | PINPUN       | <i>Pinus pungens</i>           |
| 17                | GALAPH       | <i>Galax aphylla</i>              | 17           | PINRIG       | <i>Pinus rigida</i>            |
| 18                | GEUSPP       | <i>Geum</i> spp.                  | 18           | PINVIR       | <i>Pinus virginiana</i>        |
| 19                | GILTRI       | <i>Gillenia trifoliata</i>        | 19           | PRUSER       | <i>Prunus serotina</i>         |
| 20                | HIEVEN       | <i>Hieracium venosum</i>          | 20           | QUEALB       | <i>Quercus alba</i>            |
| 21                | HOUCAE       | <i>Houstonia caerulea</i>         | 21           | QUECOC       | <i>Quercus coccinea</i>        |
| 22                | HYPHIR       | <i>Hypoxis hirsuta</i>            | 22           | QUEILI       | <i>Quercus ilicifolia</i>      |
| 23                | HYPHYP       | <i>Hypericum hypericoides</i>     | 23           | QUEPRI       | <i>Quercus prinus</i>          |
| 24                | IRIVER       | <i>Iris verna</i>                 | 24           | QUEVEL       | <i>Quercus velutina</i>        |
| 25                | ISOVER       | <i>Isotria verticillata</i>       | 25           | RHONUD       | <i>Rhododendron nudiflorum</i> |
| 26                | LESSPP       | <i>Lespedeza</i> spp.             | 26           | RHUCOP       | <i>Rhus copallina</i>          |
| 27                | LOBINF       | <i>Lobelia inflata</i>            | 27           | ROBPSE       | <i>Robinia pseudoacacia</i>    |
| 28                | LUZSPP       | <i>Luzula</i> spp.                | 28           | SASALB       | <i>Sassafras albidum</i>       |
| 29                | LYSQUA       | <i>Lysimachia quadrifolia</i>     | 29           | SMIGLA       | <i>Smilax glauca</i>           |
| 30                | MEDVIR       | <i>Medeola virginiana</i>         | 30           | SMIROT       | <i>Smilax rotundifolia</i>     |
| 31                | MONUNI       | <i>Monotropa uniflora</i>         | 31           | VACPAL       | <i>Vaccinium pallidum</i>      |
| 32                | OSMCIN       | <i>Osmunda cinnamomea</i>         | 32           | VACSTA       | <i>Vaccinium stamineum</i>     |
| 33                | OSMCLA       | <i>Osmunda claytoniana</i>        | 33           | VIBACE       | <i>Viburnum acerifolium</i>    |
| 34                | PANSPP       | <i>Panicum</i> spp.               | 34           | VITSPP       | <i>Vitis</i> spp.              |
| 35                | POA          | <i>Poaceae</i> family             |              |              |                                |
| 36                | POLBIF       | <i>Polygonatum biflorum</i>       |              |              |                                |
| 37                | POTCAN       | <i>Potentilla canadensis</i>      |              |              |                                |
| 38                | PRESPP       | <i>Prenanthes</i> spp.            |              |              |                                |
| 39                | PTEAQU       | <i>Pteridium aquilinum</i>        |              |              |                                |
| 40                | RUBSPP       | <i>Rubus</i> spp.                 |              |              |                                |
| 41                | SMIRAC       | <i>Smilacina racemosa</i>         |              |              |                                |
| 42                | TEPVIR       | <i>Tephrosia virginiana</i>       |              |              |                                |
| 43                | THENOV       | <i>Thelypteris noveboracensis</i> |              |              |                                |
| 44                | UVUPUD       | <i>Uvularia pudica</i>            |              |              |                                |
| 45                | VIOSPP       | <i>Viola</i> spp.                 |              |              |                                |

Table 4.1-3. Species lists and codes for woody species found in the shrub and tree strata, respectively, at the Potts Mountain study site in Craig Co., Va.

| Shrub stratum |              |                                           | Tree stratum |              |                                |
|---------------|--------------|-------------------------------------------|--------------|--------------|--------------------------------|
|               | Species Code | Scientific name                           |              | Species Code | Scientific name                |
| 1             | ACEPEN       | <i>Acer pensylvanicum</i>                 | 1            | ACEPEN       | <i>Acer pensylvanicum</i>      |
| 2             | ACERUB       | <i>Acer rubrum</i>                        | 2            | ACERUB       | <i>Acer rubrum</i>             |
| 3             | ACESAC       | <i>Acer saccharum</i>                     | 3            | BETLEN       | <i>Betula lenta</i>            |
| 4             | AMEARB       | <i>Amelanchier arborea</i>                | 4            | CARGLA       | <i>Carya glabra</i>            |
| 5             | BETLEN       | <i>Betula lenta</i> <sup>a</sup>          | 5            | CAROVA       | <i>Carya ovata</i>             |
| 6             | CARGLA       | <i>Carya glabra</i>                       | 6            | CARTOM       | <i>Carya tomentosa</i>         |
| 7             | CARTOM       | <i>Carya tomentosa</i> <sup>a</sup>       | 7            | CASDEN       | <i>Castanea dentata</i>        |
| 8             | CASDEN       | <i>Castanea dentata</i>                   | 8            | CORFLO       | <i>Cornus florida</i>          |
| 9             | CORFLO       | <i>Cornus florida</i>                     | 9            | HAMVIR       | <i>Hamamelis virginiana</i>    |
| 10            | GAYBAC       | <i>Gaylussacia baccata</i>                | 10           | LIRTUL       | <i>Liriodendron tulipifera</i> |
| 11            | HAMVIR       | <i>Hamamelis virginiana</i>               | 11           | NYSSYL       | <i>Nyssa sylvatica</i>         |
| 12            | HYDARB       | <i>Hydrangea arborescens</i> <sup>a</sup> | 12           | OXYARB       | <i>Oxydendrum arboreum</i>     |
| 13            | ILEVER       | <i>Ilex verticillata</i>                  | 13           | PINPUN       | <i>Pinus pungens</i>           |
| 14            | KALLAT       | <i>Kalmia latifolia</i>                   | 14           | PINRIG       | <i>Pinus rigida</i>            |
| 15            | LIRTUL       | <i>Liriodendron tulipifera</i>            | 15           | PINVIR       | <i>Pinus virginiana</i>        |
| 16            | NYSSYL       | <i>Nyssa sylvatica</i>                    | 16           | QUECOC       | <i>Quercus coccinea</i>        |
| 17            | OXYARB       | <i>Oxydendrum arboreum</i>                | 17           | QUEPRI       | <i>Quercus prinus</i>          |
| 18            | PINECH       | <i>Pinus echinata</i> <sup>b</sup>        | 18           | QUEVEL       | <i>Quercus velutina</i>        |
| 19            | PINPUN       | <i>Pinus pungens</i> <sup>b</sup>         | 19           | ROBPSE       | <i>Robinia pseudoacacia</i>    |
| 20            | PINRIG       | <i>Pinus rigida</i>                       | 20           | SASALB       | <i>Sassafras albidum</i>       |
| 21            | PINVIR       | <i>Pinus virginiana</i>                   | 21           | ULMAME       | <i>Ulmus americana</i>         |
| 22            | PRUSER       | <i>Prunus serotina</i> <sup>a</sup>       |              |              |                                |
| 23            | QUECOC       | <i>Quercus coccinea</i>                   |              |              |                                |
| 24            | QUEILI       | <i>Quercus ilicifolia</i>                 |              |              |                                |
| 25            | QUEPRI       | <i>Quercus prinus</i>                     |              |              |                                |
| 26            | QUERUB       | <i>Quercus rubra</i> <sup>a</sup>         |              |              |                                |
| 27            | QUEVEL       | <i>Quercus velutina</i>                   |              |              |                                |
| 28            | RHONUD       | <i>Rhododendron nudiflorum</i>            |              |              |                                |
| 29            | ROBPSE       | <i>Robinia pseudoacacia</i>               |              |              |                                |
| 30            | SASALB       | <i>Sassafras albidum</i>                  |              |              |                                |
| 31            | VACSTA       | <i>Vaccinium stamineum</i>                |              |              |                                |
| 32            | VIBACE       | <i>Viburnum acerifolium</i> <sup>a</sup>  |              |              |                                |

a = When examining years 1977 and 1995 only, these species are not found on site.

b = When examining 1977 and 1995 only, PINPUN and PINECH are respectively excluded when plot H or plot B is included.

Table 4.1-4. Species list and codes for additional herbaceous and woody species observed while conducting a walk-thru within each stand plot at the Potts Mountain study site in Craig Co., Va.

| Herbaceous Plants |                     |                                   | Woody Plants |                     |                                    |
|-------------------|---------------------|-----------------------------------|--------------|---------------------|------------------------------------|
|                   | Species Code        | Scientific name                   |              | Species Code        | Scientific name                    |
| 1                 | ANTPLA <sup>c</sup> | <i>Antennaria plantaginifolia</i> | 1            | ARASPI <sup>b</sup> | <i>Aralia spinosa</i>              |
| 2                 | ASPPLA <sup>b</sup> | <i>Asplenium platyneuron</i>      | 2            | PARQUI <sup>b</sup> | <i>Parthenocissus quinquefolia</i> |
| 3                 | AURPED <sup>b</sup> | <i>Aureolaria pedicularia</i>     |              |                     |                                    |
| 4                 | CONMAJ <sup>b</sup> | <i>Convallaria majalis</i>        |              |                     |                                    |
| 5                 | CONVOL <sup>b</sup> | <i>Convolvulaceae</i> family      |              |                     |                                    |
| 6                 | CUNORI <sup>a</sup> | <i>Cunila origanoides</i>         |              |                     |                                    |
| 7                 | DENPUN <sup>b</sup> | <i>Dennstaedtia punctilobula</i>  |              |                     |                                    |
| 8                 | EUPSPP <sup>b</sup> | <i>Eupatorium</i> spp.            |              |                     |                                    |
| 9                 | GALLAT <sup>a</sup> | <i>Galium latifolium</i>          |              |                     |                                    |
| 10                | GOOPUB <sup>a</sup> | <i>Goodyera pubescens</i>         |              |                     |                                    |
| 11                | HIEPAN <sup>c</sup> | <i>Hieracium paniculatum</i>      |              |                     |                                    |
| 12                | LECRAC <sup>b</sup> | <i>Lechea racemulosa</i>          |              |                     |                                    |
| 13                | POLACR <sup>a</sup> | <i>Polystichum acrostichoides</i> |              |                     |                                    |
| 14                | POTSIM <sup>b</sup> | <i>Potentilla simplex</i>         |              |                     |                                    |
| 15                | SCROPH <sup>b</sup> | <i>Scrophulariaceae</i> family    |              |                     |                                    |
| 16                | SMIHER <sup>b</sup> | <i>Smilax herbacea</i>            |              |                     |                                    |
| 17                | SPHNIT <sup>a</sup> | <i>Sphenopholis nitida</i>        |              |                     |                                    |
| 18                | UVUPER <sup>b</sup> | <i>Uvularia perfoliata</i>        |              |                     |                                    |
| 19                | ZIZTRI <sup>a</sup> | <i>Zizia trifoliata</i>           |              |                     |                                    |

a = Found within the stands during the pre-harvest sampling.

b = Found within the stands during the 17<sup>th</sup> year sampling.

c = Found within the stands during both the pre-harvest and 17<sup>th</sup> year sampling.

Table 4.1-5. Complete species list and codes for all herbaceous and woody species found within all strata or observed during a walk-thru in the control stand at the Potts Mountain study site in Craig Co., Va.

| Herbaceous Plants |                                          |  | Woody Plants |                                   |  |
|-------------------|------------------------------------------|--|--------------|-----------------------------------|--|
| Species Code      | Scientific name                          |  | Species Code | Scientific name                   |  |
| 1 ANDSPP          | <i>Andropogon</i> spp.                   |  | 1 ACERUB     | <i>Acer rubrum</i>                |  |
| 2 ASTER           | <i>Asteraceae</i> family                 |  | 2 AMEARB     | <i>Amelanchier arborea</i>        |  |
| 3 AURLAE          | <i>Aureolaria laevigata</i>              |  | 3 BETLEN     | <i>Betula lenta</i>               |  |
| 4 CARSPP          | <i>Carex</i> spp.                        |  | 4 CASDEN     | <i>Castanea dentata</i>           |  |
| 5 CHIMAC          | <i>Chimaphila maculata</i>               |  | 5 GAYBAC     | <i>Gaylussacia baccata</i>        |  |
| 6 CONMAJ          | <i>Convallaria majalis</i>               |  | 6 HAMVIR     | <i>Hamamelis virginiana</i>       |  |
| 7 CORMAJ          | <i>Coreopsis major</i>                   |  | 7 KALLAT     | <i>Kalmia latifolia</i>           |  |
| 8 CYPACA          | <i>Cypripedium acaule</i>                |  | 8 NYSSYL     | <i>Nyssa sylvatica</i>            |  |
| 9 DANSPP          | <i>Danthonia</i> spp.                    |  | 9 OXYARB     | <i>Oxydendrum arboreum</i>        |  |
| 10 EPIREP         | <i>Epigaea repens</i>                    |  | 10 PINRIG    | <i>Pinus rigida</i>               |  |
| 11 GALAPH         | <i>Galax aphylla</i>                     |  | 11 PINSTR    | <i>Pinus strobus</i> <sup>a</sup> |  |
| 12 HIEVEN         | <i>Hieracium venosum</i>                 |  | 12 PINVIR    | <i>Pinus virginiana</i>           |  |
| 13 HYPHIR         | <i>Hypoxis hirsuta</i>                   |  | 13 PRUSER    | <i>Prunus serotina</i>            |  |
| 14 IRIVER         | <i>Iris verna</i>                        |  | 14 QUEALB    | <i>Quercus alba</i>               |  |
| 15 LECRAC         | <i>Lechea racemulosa</i> <sup>a</sup>    |  | 15 QUECOC    | <i>Quercus coccinea</i>           |  |
| 16 MONUNI         | <i>Monotropa uniflora</i> <sup>a</sup>   |  | 16 QUEILI    | <i>Quercus ilicifolia</i>         |  |
| 17 PANSPP         | <i>Panicum</i> spp.                      |  | 17 QUEPRI    | <i>Quercus prinus</i>             |  |
| 18 POA            | <i>Poaceae</i> family <sup>a</sup>       |  | 18 QUEVEL    | <i>Quercus velutina</i>           |  |
| 19 POLBIF         | <i>Polygonatum biflorum</i>              |  | 19 RHONUD    | <i>Rhododendron nudiflorum</i>    |  |
| 20 PTEAQU         | <i>Pteridium aquilinum</i>               |  | 20 SASALB    | <i>Sassafras albidum</i>          |  |
| 21 RUBSPP         | <i>Rubus</i> spp. <sup>A</sup>           |  | 21 SMIGLA    | <i>Smilax glauca</i>              |  |
| 22 SORNUT         | <i>Sorghastrum nutans</i> <sup>a</sup>   |  | 22 SMIROT    | <i>Smilax rotundifolia</i>        |  |
| 23 TEPVIR         | <i>Tephrosia virginiana</i> <sup>a</sup> |  | 23 VACPAL    | <i>Vaccinium pallidum</i>         |  |
| 24 UVUPUD         | <i>Uvularia pudica</i>                   |  | 24 VACSTA    | <i>Vaccinium stamineum</i>        |  |
| 25 VIOSPP         | <i>Viola</i> spp.                        |  | 25 VITSPP    | <i>Vitis</i> spp.                 |  |
| 26 ZIZTRI         | <i>Zizia trifoliata</i>                  |  |              |                                   |  |

a = Species found within the stand but not in a herb stratum sampling unit.

Table 4.1-6. Mean relative percent cover and standard error of herbaceous plants for each sampling year for the herb stratum at the Potts Mountain study site in Craig Co., Va. (n = 4; stands CDHI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                           | Pre-harvest |            | 17-year    |            |
|-------------------------------------------|-------------|------------|------------|------------|
|                                           | $\bar{X}$   | SE         | $\bar{X}$  | SE         |
| <i>Chimaphila maculata</i>                | 17.0        | 13.6       | 28.9       | 15.1       |
| <i>Panicum</i> spp.                       | 15.0        | 9.0        | 24.5       | 6.5        |
| <i>Andropogon</i> spp.                    | 12.2        | 8.4        | 9.4        | 6.4        |
| <i>Coreopsis major</i>                    | 10.5        | 6.8        | 3.9        | 2.9        |
| <i>Osmunda claytoniana</i>                | 8.3         | 8.3        | 6.8        | 6.8        |
| <i>Viola</i> spp.                         | <b>7.0</b>  | <b>3.5</b> | <b>5.5</b> | <b>4.2</b> |
| <i>Pteridium aquilinum</i>                | 6.0         | 5.9        | 1.1        | 1.1        |
| <i>Dioscorea villosa</i>                  | 5.6         | 3.9        | 1.3        | 1.1        |
| <i>Galax aphylla</i>                      | 4.0         | 2.9        | 0.2        | 0.2        |
| <i>Athyrium filix-femina</i>              | 3.5         | 3.5        | 1.0        | 1.0        |
| <i>Osmunda cinnamomea</i>                 | 1.8         | 1.8        | 0.4        | 0.4        |
| <i>Desmodium</i> spp.                     | 1.8         | 1.8        | 0.0        | 0.0        |
| <i>Baptisia tinctoria</i>                 | 1.5         | 1.4        | 0.3        | 0.3        |
| <i>Uvularia pudica</i>                    | <b>0.9</b>  | <b>0.4</b> | <b>0.1</b> | <b>0.1</b> |
| <i>Carex</i> spp.                         | <b>0.8</b>  | <b>0.7</b> | <b>6.4</b> | <b>3.0</b> |
| <i>Prenanthes</i> spp.                    | 0.7         | 0.7        | 0.2        | 0.2        |
| <i>Thelypteris noveboracensis</i>         | 0.7         | 0.7        | 0.0        | 0.0        |
| <i>Medeola virginiana</i>                 | 0.5         | 0.5        | < 0.1      | < 0.1      |
| <i>Hieracium venosum</i>                  | 0.5         | 0.3        | 0.2        | 0.1        |
| <i>Aureolaria laevigata</i>               | 0.4         | 0.4        | 0.0        | 0.0        |
| <i>Asteraceae</i> family                  | 0.3         | 0.1        | 0.7        | 0.3        |
| <i>Hypoxis hirsuta</i>                    | 0.2         | 0.1        | 0.1        | 0.1        |
| <i>Iris verna</i>                         | 0.2         | 0.1        | 1.3        | 1.1        |
| <i>Epigaea repens</i>                     | 0.2         | 0.1        | 0.2        | 0.1        |
| <i>Poaceae</i> family                     | 0.1         | 0.1        | 2.2        | 2.2        |
| <i>Polygonatum biflorum</i>               | 0.1         | 0.1        | < 0.1      | < 0.1      |
| <i>Asclepias viridis</i>                  | 0.1         | 0.1        | 0.0        | 0.0        |
| <i>Potentilla canadensis</i>              | 0.1         | 0.1        | 0.0        | 0.0        |
| <i>Tephrosia virginiana</i>               | 0.1         | 0.1        | 0.1        | 0.1        |
| <i>Cystopteris fragilis</i>               | < 0.1       | < 0.1      | 0.0        | 0.0        |
| <i>Isotria verticillata</i>               | < 0.1       | < 0.1      | 0.0        | 0.0        |
| <i>Smilacina racemosa</i>                 | < 0.1       | < 0.1      | 0.0        | 0.0        |
| <i>Barbarea verna</i>                     | 0.0         | 0.0        | 1.7        | 1.7        |
| <i>Lysimachia quadrifolia</i>             | 0.0         | 0.0        | 1.2        | 1.2        |
| <i>Hedyotis (Houstonia) caerulea</i>      | 0.0         | 0.0        | 1.0        | 1.0        |
| <i>Danthonia</i> spp.                     | 0.0         | 0.0        | 0.5        | 0.4        |
| <i>Rubus</i> spp.                         | 0.0         | 0.0        | 0.3        | 0.2        |
| <i>Geum</i> spp.                          | 0.0         | 0.0        | 0.2        | 0.2        |
| <i>Monotropa uniflora</i>                 | 0.0         | 0.0        | 0.2        | 0.2        |
| <i>Lobelia inflata</i>                    | 0.0         | 0.0        | 0.1        | 0.1        |
| <i>Luzula</i> spp.                        | 0.0         | 0.0        | 0.1        | < 0.1      |
| <i>Lespedeza</i> spp.                     | 0.0         | 0.0        | < 0.1      | < 0.1      |
| <i>Hypericum hypericoides</i>             | 0.0         | 0.0        | < 0.1      | < 0.1      |
| <i>Cypripedium acaule</i>                 | 0.0         | 0.0        | < 0.1      | < 0.1      |
| <i>Porteranthus (Gillenia) trifoliata</i> | 0.0         | 0.0        | < 0.1      | < 0.1      |

Table 4.1-7. Mean relative percent cover and standard error of woody plants for each sampling year for the herb stratum at the Potts Mountain study site in Craig Co., Va. (n = 4; stands CDHI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Pre-harvest |            | 17-year     |            |
|--------------------------------|-------------|------------|-------------|------------|
|                                | $\bar{x}$   | SE         | $\bar{x}$   | SE         |
| <i>Vaccinium pallidum</i>      | 25.2        | 8.5        | 25.3        | 9.2        |
| <i>Rhododendron nudiflorum</i> | 13.7        | 6.0        | 7.3         | 3.7        |
| <i>Kalmia latifolia</i>        | 10.2        | 6.9        | 6.3         | 3.2        |
| <i>Sassafras albidum</i>       | <b>8.9</b>  | <b>1.6</b> | <b>20.2</b> | <b>4.3</b> |
| <i>Gaylussacia baccata</i>     | 8.2         | 6.4        | 7.5         | 4.8        |
| <i>Acer rubrum</i>             | 7.4         | 6.9        | 15.3        | 11.6       |
| <i>Quercus prinus</i>          | 6.5         | 5.1        | 3.7         | 3.0        |
| <i>Cornus florida</i>          | 4.6         | 4.4        | < 0.1       | < 0.1      |
| <i>Smilax glauca</i>           | 4.6         | 1.7        | 5.0         | 3.2        |
| <i>Nyssa sylvatica</i>         | 3.6         | 2.2        | 1.9         | 0.6        |
| <i>Smilax rotundifolia</i>     | 2.7         | 2.7        | 2.5         | 2.5        |
| <i>Vaccinium stamineum</i>     | 1.8         | 1.4        | 0.9         | 0.5        |
| <i>Quercus coccinea</i>        | <b>1.4</b>  | <b>0.5</b> | <b>0.5</b>  | <b>0.3</b> |
| <i>Carya glabra</i>            | 0.3         | 0.3        | 0.1         | 0.1        |
| <i>Robinia pseudoacacia</i>    | 0.2         | 0.2        | 0.1         | < 0.1      |
| <i>Castanea dentata</i>        | 0.2         | 0.1        | 0.1         | < 0.1      |
| <i>Oxydendrum arboreum</i>     | 0.1         | 0.1        | 0.0         | 0.0        |
| <i>Hamamelis virginiana</i>    | 0.1         | 0.1        | 0.2         | 0.1        |
| <i>Viburnum acerifolium</i>    | 0.1         | 0.1        | 0.0         | 0.0        |
| <i>Quercus velutina</i>        | 0.1         | < 0.1      | < 0.1       | < 0.1      |
| <i>Vitis spp.</i>              | 0.1         | < 0.1      | 2.8         | 2.4        |
| <i>Pinus rigida</i>            | 0.1         | < 0.1      | < 0.1       | < 0.1      |
| <i>Carya tomentosa</i>         | < 0.1       | < 0.1      | < 0.1       | < 0.1      |
| <i>Amelanchier arborea</i>     | < 0.1       | < 0.1      | < 0.1       | < 0.1      |
| <i>Ilex verticillata</i>       | < 0.1       | < 0.1      | < 0.1       | < 0.1      |
| <i>Hydrangea arborescens</i>   | < 0.1       | < 0.1      | 0.0         | 0.0        |
| <i>Prunus serotina</i>         | < 0.1       | < 0.1      | 0.0         | 0.0        |
| <i>Pinus pungens</i>           | < 0.1       | < 0.1      | 0.0         | 0.0        |
| <i>Quercus ilicifolia</i>      | < 0.1       | < 0.1      | < 0.1       | < 0.1      |
| <i>Acer pensylvanicum</i>      | 0.0         | 0.0        | 0.1         | 0.1        |
| <i>Quercus alba</i>            | 0.0         | 0.0        | < 0.1       | < 0.1      |
| <i>Rhus copallina</i>          | 0.0         | 0.0        | < 0.1       | < 0.1      |
| <i>Liriodendron tulipifera</i> | 0.0         | 0.0        | < 0.1       | < 0.1      |
| <i>Pinus virginiana</i>        | 0.0         | 0.0        | < 0.1       | < 0.1      |

Table 4.1-8. Mean percent importance value and standard error for each sampling year in the shrub stratum at the Potts Mountain study site in Craig Co., Va. (n = 4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |            |           |      |           |      |           |      |           |      |             |            |
|--------------------------------|-------------------|------------|-----------|------|-----------|------|-----------|------|-----------|------|-------------|------------|
|                                | Pre-harvest       |            | 1         |      | 3         |      | 5         |      | 7         |      | 17          |            |
|                                | $\bar{x}$         | SE         | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$   | SE         |
| <i>Kalmia latifolia</i>        | 21.8              | 12.0       | 26.9      | 15.5 | 4.0       | 3.4  | 3.5       | 2.8  | 5.3       | 3.0  | 13.1        | 6.1        |
| <i>Nyssa sylvatica</i>         | 21.6              | 8.0        | 5.2       | 2.3  | 15.3      | 3.3  | 13.9      | 2.5  | 12.9      | 2.1  | 16.5        | 3.4        |
| <i>Sassafras albidum</i>       | 16.0              | 5.5        | 10.5      | 3.5  | 30.9      | 10.2 | 33.0      | 4.9  | 31.1      | 3.5  | 19.2        | 7.8        |
| <i>Rhododendron nudiflorum</i> | 6.6               | 4.2        | 4.2       | 3.3  | 0.4       | 0.4  | 3.0       | 2.2  | 3.7       | 2.9  | 4.6         | 4.5        |
| <i>Quercus prinus</i>          | 4.5               | 1.6        | 8.4       | 3.5  | 14.7      | 5.2  | 14.0      | 4.6  | 14.1      | 5.5  | 9.4         | 7.4        |
| <i>Cornus florida</i>          | 4.3               | 3.1        | 3.3       | 3.3  | 3.1       | 2.6  | 3.8       | 2.7  | 5.3       | 4.1  | 1.4         | 1.4        |
| <i>Acer rubrum</i>             | <b>4.0</b>        | <b>3.1</b> | 9.9       | 8.9  | 8.6       | 4.7  | 7.3       | 4.3  | 6.0       | 3.1  | <b>10.0</b> | <b>6.5</b> |
| <i>Castanea dentata</i>        | <b>3.8</b>        | <b>1.9</b> | 10.9      | 5.8  | 5.1       | 2.0  | 2.1       | 0.7  | 1.2       | 0.4  | <b>0.6</b>  | <b>0.3</b> |
| <i>Quercus coccinea</i>        | 3.7               | 1.4        | 4.7       | 2.7  | 9.9       | 5.4  | 10.3      | 5.2  | 10.5      | 5.0  | 4.0         | 2.0        |
| <i>Gaylussacia baccata</i>     | 2.9               | 1.7        | 0.0       | 0.0  | 0.1       | 0.1  | <0.1      | <0.1 | 0.1       | 0.1  | 0.1         | 0.1        |
| <i>Carya glabra</i>            | 2.7               | 1.7        | 0.0       | 0.0  | 0.1       | 0.1  | 0.4       | 0.2  | 0.4       | 0.3  | 0.8         | 0.6        |
| <i>Quercus velutina</i>        | 2.3               | 1.4        | 2.4       | 2.1  | 1.2       | 0.8  | 1.7       | 0.8  | 1.1       | 0.7  | 1.6         | 0.9        |
| <i>Pinus rigida</i>            | 1.3               | 1.3        | 0.0       | 0.0  | 0.6       | 0.6  | 0.4       | 0.4  | 0.5       | 0.4  | 1.6         | 1.0        |
| <i>Quercus ilicifolia</i>      | 1.1               | 0.7        | 0.0       | 0.0  | 1.2       | 1.0  | 2.0       | 1.7  | 2.2       | 2.0  | 3.0         | 2.1        |
| <i>Vaccinium stamenium</i>     | 0.9               | 0.9        | 0.0       | 0.0  | 0.3       | 0.3  | 0.3       | 0.3  | 0.3       | 0.3  | 0.6         | 0.6        |
| <i>Oxydendrum arboreum</i>     | 0.9               | 0.9        | 1.1       | 1.1  | 1.3       | 1.3  | 1.3       | 1.3  | 1.7       | 1.7  | 3.6         | 3.6        |
| <i>Robinia pseudoacacia</i>    | 0.7               | 0.7        | 11.7      | 9.2  | 2.1       | 1.6  | 1.3       | 1.0  | 0.7       | 0.5  | 0.0         | 0.0        |
| <i>Amelanchier arborea</i>     | 0.4               | 0.4        | 0.0       | 0.0  | 0.1       | 0.1  | 0.1       | 0.1  | 0.2       | 0.1  | 0.0         | 0.0        |
| <i>Acer pensylvanicum</i>      | 0.2               | 0.2        | 0.0       | 0.0  | 0.1       | <0.1 | 0.1       | 0.1  | 0.2       | 0.1  | 0.0         | 0.0        |
| <i>Ilex verticillata</i>       | <0.1              | <0.1       | 0.0       | 0.0  | 0.1       | 0.1  | 0.2       | 0.2  | 0.2       | 0.2  | 0.2         | 0.2        |
| <i>Hamamelis virginiana</i>    | <0.1              | <0.1       | 0.9       | 0.9  | 0.2       | 0.1  | 0.3       | 0.2  | 0.4       | 0.3  | 4.3         | 3.4        |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0        | 0.0       | 0.0  | 0.3       | 0.3  | 0.5       | 0.5  | 1.1       | 1.0  | 3.0         | 2.9        |
| <i>Betula lenta</i>            | 0.0               | 0.0        | 0.0       | 0.0  | 0.1       | 0.1  | 0.4       | 0.4  | 0.6       | 0.6  | 0.0         | 0.0        |
| <i>Pinus pungens</i>           | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.2       | 0.1  | 1.4         | 1.4        |
| <i>Hydrangea arborescens</i>   | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0         | 0.0        |
| <i>Viburnum acerifolium</i>    | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0         | 0.0        |
| <i>Carya tomentosa</i>         | 0.0               | 0.0        | 0.0       | 0.0  | 0.2       | 0.2  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0         | 0.0        |
| <i>Quercus rubra</i>           | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0         | 0.0        |
| <i>Prunus serotina</i>         | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0         | 0.0        |
| <i>Acer saccharum</i>          | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.8         | 0.7        |
| <i>Pinus virginiana</i>        | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.2         | 0.2        |

were found in the pre-harvest and 17-year old forest, respectively, of which 18 species were present at both times: a net gain of 1 species.

### ***Tree Stratum Woody Plants***

Only four sample periods were obtained for the tree stratum because of the longer time necessary for an individual to grow to five meters. A significant number of trees (>10) first entered the tree stratum 5-years (1983) after harvest. Species richness ranged from a low of four species 5-years after harvest to 21 species 17-years after harvest (Table 4.1-9). Thirteen and 21 species were identified in the pre-harvest and 17-year old forest, respectively. All of the 13 species found in the pre-harvest forest were also found in the 17-year old forest.

### **FOREST STRUCTURE CHARACTERISTICS**

Forest level characteristics are those factors that describe the structure of the forest. Within the herb stratum, the characteristics include the abundance of woody and herbaceous plants expressed as percent cover. In the shrub and tree strata, these characteristics include basal area and stem density measurements. Also, within the tree stratum average tree diameter and height were measured.

Pre-harvest tree stratum is characterized by the following measurements of 23.5 m<sup>2</sup>/ha average basal area, 1045 stem/ha average stem density, 14.7 cm average diameter, and 10.6 m average height (Table 4.1-10). The post-harvest tree stratum trends show an increase in all of the forest structure characteristics from the 5<sup>th</sup> year to the 17<sup>th</sup> year after harvest: basal area increases from 0.2 to 10.1 m<sup>2</sup>/ha, stem density increases from 152 to 2858 stems/ha, average diameter increases from 2.2 to 5.8 cm, and average height increases from 2.8 to 7.6 meters (Table 4.1-10). The trees in 17-year old forest are generally smaller and shorter than the pre-harvest forest, which accounts for the higher stem density. In time, it is expected that the forest will return to the pre-harvest levels in all of these characteristics.

Within the shrub stratum, basal area and stem density varied over the study period (Table 4.1-10). Pre-harvest woody stem basal area and stem density were 2.9 m<sup>2</sup>/ha and 5,751 stems/ha. Post-harvest basal area values increased from a low of 0.5 m<sup>2</sup>/ha the 1<sup>st</sup> year after harvest to a high of 9.9 m<sup>2</sup>/ha the 7<sup>th</sup> year after harvest; stem densities increased from 2,232 stems/ha the 1<sup>st</sup> year after harvest to 22,833 stems/ha by the 5<sup>th</sup> year after harvest. By the 17<sup>th</sup> year after harvest, these values had decreased to 4.5 m<sup>2</sup>/ha and 8,080 stems/ha. This pattern of an initially increasing shrub stratum basal area and stem density followed by a decline is expected because as a stand ages individuals grow out of the stratum (i.e., out-growth) and begin to shade the understory. The shading will lead to the loss of individuals from the shrub stratum because light will become a limited resource and prevent survival of shade intermediate and intolerant species.

Table 4.1-9. Mean percent importance value and standard error for each sampling year in the tree stratum at the Potts Mountain study site in Craig Co., Va. (n = 4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |            |           |      |           |       |            |            |
|--------------------------------|-------------------|------------|-----------|------|-----------|-------|------------|------------|
|                                | Pre-harvest       |            | 5         |      | 7         |       | 17         |            |
|                                | $\bar{x}$         | SE         | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$  | SE         |
| <i>Quercus prinus</i>          | 35.0              | 9.5        | 7.5       | 7.1  | 66.1      | 20.0  | 41.5       | 13.3       |
| <i>Quercus coccinea</i>        | 17.1              | 8.3        | 0.0       | 0.0  | 5.8       | 5.2   | 19.0       | 8.6        |
| <i>Pinus rigida</i>            | 16.5              | 13.8       | 0.0       | 0.0  | 0.0       | 0.0   | 0.3        | 0.3        |
| <i>Acer rubrum</i>             | 9.7               | 9.1        | 8.2       | 8.2  | 9.3       | 9.3   | 11.2       | 7.8        |
| <i>Quercus velutina</i>        | <b>4.8</b>        | <b>1.8</b> | 0.0       | 0.0  | 0.0       | 0.0   | <b>0.7</b> | <b>0.5</b> |
| <i>Nyssa sylvatica</i>         | 3.7               | 1.3        | 0.0       | 0.0  | 0.2       | 0.2   | 2.8        | 1.9        |
| <i>Oxydendrum arboreum</i>     | 3.1               | 3.1        | 0.0       | 0.0  | 1.4       | 1.4   | 1.4        | 1.4        |
| <i>Pinus pungens</i>           | 3.1               | 1.9        | 0.0       | 0.0  | 0.0       | 0.0   | 1.4        | 1.0        |
| <i>Carya glabra</i>            | 2.8               | 1.7        | 0.0       | 0.0  | 0.1       | 0.1   | 0.2        | 0.1        |
| <i>Robinia pseudoacacia</i>    | 1.6               | 0.9        | 16.2      | 16.2 | 7.7       | 7.0   | 3.8        | 2.9        |
| <i>Sassafras albidum</i>       | 1.1               | 0.7        | 0.0       | 0.0  | 2.3       | 2.3   | 8.8        | 5.9        |
| <i>Cornus florida</i>          | 0.9               | 0.7        | 0.0       | 0.0  | 0.0       | 0.0   | 1.3        | 0.9        |
| <i>Castanea dentata</i>        | 0.6               | 0.3        | 18.1      | 17.7 | 4.9       | 4.5   | < 0.1      | < 0.1      |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0        | 0.0       | 0.0  | 2.0       | 2.0   | 5.2        | 5.2        |
| <i>Hamamelis virginiana</i>    | 0.0               | 0.0        | 0.0       | 0.0  | 0.1       | 0.1   | 0.6        | 0.6        |
| <i>Betula lenta</i>            | 0.0               | 0.0        | 0.0       | 0.0  | < 0.1     | < 0.1 | 0.9        | 0.9        |
| <i>Pinus virginiana</i>        | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0   | 0.4        | 0.4        |
| <i>Acer pensylvanicum</i>      | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0   | 0.2        | 0.1        |
| <i>Carya tomentosa</i>         | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0   | 0.1        | 0.1        |
| <i>Ulmus americana</i>         | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0   | 0.1        | 0.1        |
| <i>Carya ovata</i>             | 0.0               | 0.0        | 0.0       | 0.0  | 0.0       | 0.0   | < 0.1      | < 0.1      |

Table 4.1-10. Forest level structure characteristics of the herb, shrub, and tree strata at the Potts Mountain study site in Craig Co., Va.

| Stand<br>age<br>(years): | <b>Herb Stratum</b> |                     | <b>Shrub Stratum</b>                               |                           | <b>Tree Stratum</b>                                |                           |                       |                    |
|--------------------------|---------------------|---------------------|----------------------------------------------------|---------------------------|----------------------------------------------------|---------------------------|-----------------------|--------------------|
|                          | Herb.<br>%<br>cover | Woody<br>%<br>cover | Basal<br>area <sup>a</sup><br>(m <sup>2</sup> /ha) | Stem<br>density<br>(#/ha) | Basal<br>area <sup>b</sup><br>(m <sup>2</sup> /ha) | Stem<br>density<br>(#/ha) | Avg.<br>Diam.<br>(cm) | Avg.<br>Ht.<br>(m) |
| Pre-harvest              | 0.3                 | 8.2                 | 2.9                                                | 5751                      | 23.5                                               | 1045                      | 14.7                  | 10.6               |
| 1                        | --                  | --                  | 0.5                                                | 2232                      | --                                                 | --                        | --                    | --                 |
| 3                        | --                  | --                  | 5.0                                                | 17333                     | --                                                 | --                        | --                    | --                 |
| 5                        | --                  | --                  | 8.8                                                | 22833                     | 0.2                                                | 152                       | 2.2                   | 2.8                |
| 7                        | --                  | --                  | 9.9                                                | 21459                     | 1.3                                                | 791                       | 4.5                   | 5.6                |
| 17                       | 2.1                 | 12.3                | 4.5                                                | 8080                      | 10.1                                               | 2858                      | 5.8                   | 7.6                |

a = diameter measured 15 cm above mineral soil (root collar).

b = diameter measured at DBH (1.37 m) above ground.

The abundance of both herbaceous and woody plants increased when the pre-harvest and the 17-year old forest were compared. Herbaceous and woody plants increased from 0.3% to 2.1% and 8.2% to 12.3%, respectively (Table 4.1-10). This increase was expected because the harvesting operation altered the habitat by opening up the stand and provided forest floor conditions that fostered the establishment of new species and enhanced growth of residual species.

#### IMPORTANCE VALUES

The importance values for the shrub and tree strata were calculated by averaging relative basal area and relative stem density. The tables for these latter two values are located in Table 4.1-14 and Appendix C. In order to compute the actual value of a forest level characteristic (i.e., percent cover, basal area, or stem density) for a particular species, multiply the absolute number of the characteristic (Table 4.1-10) by the relative characteristic that was calculated for that species (Tables 4.1-6 through 4.1-9). Relative percent cover was used in the herb stratum.

#### ***Understory Herbaceous Plants***

The predominant plant type found in the pre-harvest forest were grasses (*Panicum* spp., *Andropogon* spp., *Carex* spp. and *Poaceae* family) and ferns (*Osmunda claytoniana*, *Athyrium filix-femina*, *O. cinnamomea*, *Pteridium aquilinum*, *Thelypteris noveboracensis*, and *Cystopteris fragilis*), which comprised of 28.1% and 20.3%, respectively, of the herbaceous ground cover (Table 4.1-6). In the 17-year old forest, the dominance of fern species had declined to 8.2 %, with *T. noveboracensis* and *C. fragilis* no longer being present. In contrast, the grass species increased to 43.1% and had the addition of two other genera *Danthonia* spp. and *Luzula* spp. entering the forest. Within the grass species *Panicum* spp. exhibited the largest increase from 15.0% in the pre-harvest forest to 24.5% in the 17-year old forest. The singular most dominant species in the pre-harvest and 17-year old forest was *Chimaphila maculata* with 17.0% and 28.9% relative percent cover, respectively.

The decrease of the fern component in the younger forest is expected because they tend to grow best beneath full canopies. A full canopy environment typically creates a microhabitat with a high litter layer moisture and a cooler, ground-level air temperature due to increased shading. In contrast, the grass species are more shade intolerant and typical of open grown situations with full sunlight. The increase in these species after the removal of the overstory canopy would be expected. As the forest ages, these grass-like species should decrease in abundance coinciding with increased shading and preceding an increase in the fern species. Another advantage that the grass-like species have is their evergreen characteristic. As soon as the weather becomes warm enough in the spring they can immediately begin photosynthesis and create a food source. Only two other herbaceous species, besides the grass-like species, were evergreen: *Chimaphila maculata*

and *Epigaea repens*. These species tend to respond more like woody species due to their almost woody structure and well developed roots.

All but two of the species identified (*Barbarea verna* and *Lobelia inflata*, which are biennial and annual species) are perennial species (Gleason and Cronquist 1991). Typically, these species have well developed root systems. Three types of rooting systems were classified for the collected plants: rhizomatous, fibrous, and tap root. The majority (25) of the species found in the herb stratum sampling units have rhizomatous root growth followed next by species with fibrous roots (8). The rest of the species have unknown root growth or contained multiple root forms within their genus.

The root form reflects the species' ability to resist disturbance and is therefore important. Species with fibrous or tap roots may be more susceptible to harvesting disturbances because if the plant is separated from the root system there is a high probability that the plant will die. Fibrous rooted species lack a large carbon storage base in contrast to rhizomatous species with tubers. Tap roots are susceptible to damage because if the buds are separated from the top of the root the plant will die. With rhizomatous plants, there is a better chance of survival because if the root is severed and part of it still remains intact in the ground the plant should survive because of the ability to sprout. In this study, little ground disturbance occurred because of the cable yarding system used; therefore, the seasonal growth or root form probably did not play an important role in the survival of herbaceous species in this study.

An alternative approach would be to examine the change in the habitats after a disturbance. Overstory canopy removal causes a large change in the microclimate of the forest floor. Two major events that occur are an increase in solar radiation at the forest floor level and a temporary interruption of the evapotranspiration cycle increasing soil moisture (Adams et al. 1991) and stream flow (Hornbeck et al. 1987). These changes can greatly affect the competitiveness of understory species. The majority of species found in the pre-harvest stand are most often found under intact forest canopies. In contrast, most of the new species (those species listed at the bottom of Table 4.1-6) found in the 17-year old forest are found in more open grown or disturbed areas. A few exceptions included *Cypripedium acaule* and *Monotropa uniflora*. These two species are usually found in later successional forests, but since their relative percent cover in this young forest is very low it is quite probable that they could have been missed during the pre-harvest sampling.

Virtually all of the pre-harvest, non-grass species decreased in relative percent cover from the pre-harvest to 17-year old forest (Table 4.1-6). Some of these species, though, would have been expected to increase but did not. These included *Coreopsis major*, *Baptisia tinctoria*, and *Prenanthes* spp., which are characteristically found in more open growth situations such as those created by harvesting. After 17 years of regrowth, there may be enough stand development to restrict the abundance of these species. They may have already reached their peak abundance and are now in a declining state of abundance.

The relative percent cover of 3 of the 45 total species were found to be significantly different between the pre-harvest and 17-year old stands (Table 4.1-11). These species were *Carex* spp. ( $n = 4$ , Student's paired t-test value = 4.78 ,  $P = 0.02$ ), *Uvularia pudica* ( $n = 4$ ,  $t = -2.51$ ,  $P = 0.09$ ), and *Viola* spp. ( $n = 4$ ,  $t = -2.88$ ,  $P = 0.06$ ). The significant increases in the grass genus of *Carex* spp. can be expected since they thrive better in open growth situations like those that occurred following harvest. *Uvularia pudica* and *Viola* spp. tend to be understory species which prefer more moist, shaded growing conditions; therefore, when the canopy was removed they were unable to survive well in the new habitat

### ***Understory Woody Plants – Herb and Shrub Strata***

In the herb stratum, the five most abundant woody species in the pre-harvest forest, determined from relative percent cover, were *Vaccinium pallidum* (25.2%), *Rhododendron nudiflorum* (13.7%), *Kalmia latifolia* (10.2%), *Sassafras albidum* (8.9%) and *Gaylussacia baccata* (8.2%) (Table 4.1-7). *Quercus* spp. (*Q. prinus*, *Q. coccinea*, *Q. velutina*, and *Q. ilicifolia*) constituted only 8.0% of the pre-harvest percent cover in the herb stratum. *Quercus alba* was only found in the herb stratum of the 17-year old forest. In the shrub stratum, the dominant understory species, determined from importance values (IV), in the pre-harvest forest were *Kalmia latifolia* (21.8%), *Nyssa sylvatica* (21.6%), *S. albidum* (16.0%), *Quercus* spp. (11.6%), and *Rhododendron nudiflorum* (6.6%) (Table 4.1-8).

The understory (woody plants of the herb and shrub stratum) of this forest is dominated by ericaceous species which include *K. latifolia*, *R. nudiflorum*, *V. pallidum*, and *G. baccata*. The growth characteristics of all of these ericaceous species have allowed them to dominate the understory. The former two species are more prominent in the shrub stratum due to the taller growth form they characteristically attain. These species tend to grow in dense clumps which exclude other species from the area by limiting the resources (Harlow et al. 1991, Waterman et al. 1995). *Kalmia latifolia*, in particular, can efficiently accomplished this by preventing the establishment of other species within its sphere of influence. Since it is an evergreen plant with thick, dark leaves, it prevents a high proportion of the available understory light from reaching the forest floor, thereby preventing germination of seeds under its canopy and any subsequent growth of shade intolerant species.

The high relative percent cover and IV of these ericaceous species can be also potentially be explained by their drought tolerance and ability to efficiently use the limited nutrients within the forest. With respect to limited nutrients, the species within the Ericaceae family, tend to be found growing in slightly acidic to acidic soil. Since the soils of this forest are derived from shale and sandstone they tend to be acidic and low in nutrients. Also, due to the shallow, rocky soil, the generally southern-facing aspects, and the steep slopes, moisture is usually the growth limiting factor, which results in a shortened growing

Table 4.1-11. Student's paired t-test results for the herb stratum (herbaceous and woody plants) based upon comparing 1977 and 1995 species relative percent cover values using stands as the sampling unit. Bold type indicates significant difference at the  $\alpha = 0.10$  level. (df = 3; stands CDHI)

| Herbaceous Plants |             |             | Woody Plants  |              |             |
|-------------------|-------------|-------------|---------------|--------------|-------------|
| Species code      | t           | P $\approx$ | Species code  | t            | P $\approx$ |
| ANDSPP            | -0.97       | 0.40        | POASPP        | -1.00        | 0.39        |
| ASCVIR            | -1.00       | 0.39        | POLBIF        | -0.94        | 0.42        |
| ASTER             | 0.62        | 0.58        | POTCAN        | -1.00        | 0.39        |
| ATHFIL            | -1.00       | 0.39        | PRESPP        | -1.00        | 0.39        |
| AURLAE            | -1.00       | 0.39        | PTEAQU        | -1.16        | 0.33        |
| BAPTIN            | -0.71       | 0.53        | RUBSPP        | 1.40         | 0.26        |
| BARVER            | 1.00        | 0.39        | SMIRAC        | -1.00        | 0.39        |
| <b>CARSPP</b>     | <b>4.78</b> | <b>0.02</b> | TEPVIR        | -1.00        | 0.39        |
| CHIMAC            | 0.86        | 0.45        | THENOV        | -1.00        | 0.39        |
| CORMAJ            | -1.08       | 0.36        | <b>UVUPUD</b> | <b>-2.51</b> | <b>0.09</b> |
| CYPACA            | 1.00        | 0.39        | <b>VIOSPP</b> | <b>-2.88</b> | <b>0.06</b> |
| CYSFRA            | -1.00       | 0.39        |               |              |             |
| DANSPP            | 1.36        | 0.27        |               |              |             |
| DESSPP            | -1.00       | 0.39        |               |              |             |
| DIOVIL            | -1.72       | 0.18        |               |              |             |
| EPIREP            | -0.43       | 0.69        |               |              |             |
| GALAPH            | -2.18       | 0.12        |               |              |             |
| GEUSPP            | 1.00        | 0.39        |               |              |             |
| GILTRI            | 1.00        | 0.39        |               |              |             |
| HIEVEN            | -1.52       | 0.23        |               |              |             |
| HOUCAE            | 1.00        | 0.39        |               |              |             |
| HYPHIR            | -1.06       | 0.37        |               |              |             |
| HYPHYP            | 1.00        | 0.39        |               |              |             |
| IRIVER            | -1.71       | 0.19        |               |              |             |
| ISOVER            | -1.00       | 0.39        |               |              |             |
| LESSPP            | 1.00        | 0.39        |               |              |             |
| LOBINF            | 1.00        | 0.39        |               |              |             |
| LUZSPP            | 1.73        | 0.18        |               |              |             |
| LYSQUA            | 1.00        | 0.39        |               |              |             |
| MEDVIR            | -1.00       | 0.39        |               |              |             |
| MONUNI            | 1.00        | 0.39        |               |              |             |
| OSMCIN            | -1.00       | 0.39        |               |              |             |
| OSMCLA            | -1.00       | 0.39        |               |              |             |
| PANSPP            | -1.73       | 0.18        |               |              |             |
|                   |             |             | ACEPEN        | 1.39         | 0.26        |
|                   |             |             | ACERUB        | 2.09         | 0.13        |
|                   |             |             | AMEARB        | -0.98        | 0.40        |
|                   |             |             | CARGLA        | -0.36        | 0.74        |
|                   |             |             | CARTOM        | -0.69        | 0.54        |
|                   |             |             | CASDEN        | -0.89        | 0.44        |
|                   |             |             | CORFLO        | -1.16        | 0.33        |
|                   |             |             | GAYBAC        | -0.07        | 0.95        |
|                   |             |             | HAMVIR        | 1.67         | 0.19        |
|                   |             |             | HYDARB        | -1.00        | 0.39        |
|                   |             |             | ILEVER        | 1.67         | 0.19        |
|                   |             |             | KALLAT        | -0.84        | 0.46        |
|                   |             |             | LIRTUL        | 1.00         | 0.39        |
|                   |             |             | NYSSYL        | -0.43        | 0.70        |
|                   |             |             | OXYARB        | -1.00        | 0.39        |
|                   |             |             | PINPUN        | -1.00        | 0.39        |
|                   |             |             | PINRIG        | -1.42        | 0.25        |
|                   |             |             | PINVIR        | 1.00         | 0.39        |
|                   |             |             | PRUSER        | -1.00        | 0.39        |
|                   |             |             | QUEALB        | 1.00         | 0.39        |
|                   |             |             | <b>QUECOC</b> | <b>-3.22</b> | <b>0.05</b> |
|                   |             |             | QUEILI        | 1.00         | 0.39        |
|                   |             |             | QUEPRI        | -1.41        | 0.25        |
|                   |             |             | QUEVEL        | -0.69        | 0.54        |
|                   |             |             | RHONUD        | -1.28        | 0.29        |
|                   |             |             | RHUCOP        | 1.00         | 0.39        |
|                   |             |             | ROBPSE        | -0.09        | 0.93        |
|                   |             |             | <b>SASALB</b> | <b>3.17</b>  | <b>0.05</b> |
|                   |             |             | SMIGLA        | 0.01         | 0.99        |
|                   |             |             | SMIROT        | -0.64        | 0.57        |
|                   |             |             | VACPAL        | -0.28        | 0.80        |
|                   |             |             | VACSTA        | -0.83        | 0.47        |
|                   |             |             | VIBACE        | -1.00        | 0.39        |
|                   |             |             | VITSPP        | 1.95         | 0.15        |

season (Meiners 1982). All of these factors lead to a reduction in the potential for many other species to become established and survive in the harsh forest floor environment.

One year after harvest, *K. latifolia* remained the most prevalent species in the shrub stratum, with an importance value of 26.9%, while *N. sylvatica* declined to 5.2% (Table 4.1-8). *Quercus* spp. (15.5%) became the second most dominant species, while *Robinia pseudoacacia*, *Castanea dentata*, *S. albidum*, and *A. rubrum* were approximately tied for the third most dominant species at ~10% for each. In the 3<sup>rd</sup>, 5<sup>th</sup>, and 7<sup>th</sup> years after harvest, *K. latifolia* (mean IV across these years;  $\bar{x}$  = 4.3%) dropped in dominance and ranking, while *S. albidum* ( $\bar{x}$  = 31.7%), *Quercus* spp. ( $\bar{x}$  = 27.6%), and *N. sylvatica* ( $\bar{x}$  = 14.0%) became more dominant. By the 17<sup>th</sup> year after harvest, *K. latifolia* (13.1%), *N. sylvatica* (16.5%), and *S. albidum* (19.2%), the three most dominant pre-harvest species, were once again the most abundant though at a reduced level. *Quercus* spp. (18.0%) and *A. rubrum* (10.0%) were the next most prevalent (Table 4.1-8).

In the 17-year old forest, *V. pallidum* (25.3%), *R. nudiflorum* (7.3%), *K. latifolia* (6.3%), *S. albidum* (20.2%), and *Gaylussacia baccata* (7.5%) remained the most abundant in the herb stratum, although changes in their ranking did occur (Table 4.1-7). Additionally, *Acer rubrum* (15.3%) became the third most prevalent species in the herb stratum of the 17-year old forest. The overall influence of these species in the herb stratum from pre-harvest to the 17-year old forest was similar.

The initial decrease then subsequent increase of *Kalmia latifolia* in the understory may be attributed to species stratifying themselves with respect to height within the shrub stratum. After 17 years of regrowth, those species whose growth form relegates them to the shrub stratum have established their niches, while the other species (i.e., mainly tree species) have either died, stagnated in growth, or grown out of the shrub stratum. This has “opened” the understory and redistributed the relative importance of each species. Another reason may be that since they are not commercial species, they are not a focal point of the loggers and are left much intact. The persistence of the ericaceous species following harvest can give them a height advantage over other species attempting to regenerate in the area. Alternatively, if they are knocked over or broken they can readily regenerate through stump or root sprouts.

Ericaceous species were dense prior to harvest and the harvesting operations failed to expose the forest floor across most of the area. The individuals that were left quickly developed a dense understory canopy that prevented the common shade intolerant species one would expect to find when the forest floor is opened. If the ericaceous species continue to increase in importance in the future, they may negatively impact the future regeneration potential of the forest by effectively removing regeneration area at the forest floor.

The most prominent natural control of ericaceous species is fire, but fire suppression has been a major management goal over the past 50 years. Reintroduction of controlled fires is one potential solution to controlling the distribution of ericaceous species. A recent study has shown that fire can reduce the abundance of *Kalmia latifolia* in the understory (McGee et al.1995). Additionally, harvest followed by fire, which was probably prevalent in the past, may have resulted in quite a different understory species composition and distribution after 17-years. Other control measures, including herbicides, may be necessary to reduce the ericaceous component.

*Sassafras albidum* is another dominant understory species and its high abundance after disturbances can be attributed to it being a prolific root sprouter (Blount 1989). The opening of the canopy, the cutting of the few large stems, and/or the breaking of small stems initiated the root sprouting of ability of *S. albidum*. These events have allowed it to reestablish and maintain a presence within the forest understory. Also, *S. albidum* is known to be a pioneer species on dry ridges and upper slopes and is found on a wide range of soil types (Burns and Honkala 1990b). The clearcutting performed in this study provided preferred growing conditions for this species on ridges and upper slopes.

*Quercus* spp. have maintained a strong presence through the development of the forest's understory. *Quercus prinus* and *Q. coccinea* are, respectively, the two most prominent oak species for this forest, while *Q. velutina* has remained a minor component. Since the demise of the American chestnut, the oaks have become a larger component of the Appalachian hardwood forests as they have continued to develop into an oak-hickory forest (McCormick and Platt 1980). The effects of clearcutting as a regeneration method do not seem to have adversely affected the regeneration potential of the oak species in this forest. However, due to the low proportion of *Quercus* spp. seedling cover in the herb stratum, most of the regeneration seems to be coming from stump sprouts (Ross 1982). Regeneration from stump sprouts can leave the future *Quercus* spp. trees more vulnerable to heart and root rot, threatening their long-term survival. But with low stumps and controlled fires, these vulnerabilities can be greatly reduced (Roth and Hepting 1943). Additionally, studies have shown that stump sprouts can produce good quality and hardy stems (Wendel 1975, Lamson 1976).

The majority of the new species found in the forest (such as *Betula lenta*, *Liriodendron tulipifera*, *Pinus pungens*, *Pinus virginiana*, and *Prunus serotina*) tended to have pioneer or early successional characteristics (Burns and Honkala 1990a, 1990b). The open grown forest floor conditions that were created by the clearcut regeneration method greatly benefited these shade intolerant/early successional species. The generally fast growth rates that these species obtain in increased light level situations allow them to readily establish themselves on disturbed sites. Their long-term persistence in the forest will be dependent upon additional disturbances that once again open the forest, increase light levels, and/or reduce light competition.

In the 17-year old forest, the three vine species, *Smilax glauca*, *S. rotundifolia*, and *Vitis* spp. were greater than or equal in dominance than at pre-harvest. In the herb stratum, these species contributed only a total of 4.6%, 2.7% and 0.1% relative percent cover in the pre-harvest forest, respectively, changing to 5.0%, 2.5% and 2.8%, respectively, in the 17-year old forest (Table 4.1-7). The abundance of these vines species is relatively low and is not expected to interfere with the development of the future forest. Their presence is beneficial for providing food and browse for wildlife.

Only two of the 34 woody (herb stratum) species found in the pre-harvest or 17-year old forest were found to be significantly different with respect to relative percent cover (Table 4.1-11). These species were *Sassafras albidum* ( $n = 4$ ,  $t = 3.17$ ,  $P = 0.05$ ) and *Quercus coccinea* ( $n = 4$ ,  $t = -3.22$ ,  $P = 0.05$ ). Out of a total of 25 (shrub stratum) species found in the pre-harvest or 17-year old forest only the importance values of *A. rubrum* ( $n = 4$ ,  $t = 5.16$ ,  $P = 0.01$ ) and *Castanea dentata* ( $n = 4$ ,  $t = -3.36$ ,  $P = 0.04$ ) were found to be significantly different (Table 4.1-12).

In the herb stratum, the increase in *Sassafras albidum* can be attributed to its reproduction strategies. As stated above, it is a prolific root sprouter, and when a main stem is severed several suckers will begin to form from the root stock. Also, the trees on these sites have been found to have very extensive root systems which lead to the wide dispersal of new suckers (Blount 1989). The rational for the significant decrease in *Quercus coccinea* may not be of any great biological importance since it comprised less than 1.5% of the relative percent cover in the herb stratum in both years. Seed crop success or failure can play a large role in the abundance of seedlings within the herb stratum within any one year.

Within the shrub stratum, the likely causes of the increase of *Acer rubrum* and decrease in *Castanea dentata* can be explained by their life history characteristics. *Acer rubrum* is a prolific stump sprouter, is intermediate in shade tolerance, and can quickly respond to increased light conditions when the overstory is reduced or removed (Burns and Honkala 1990b). Therefore, the removal of the overstory and the cutting of *A. rubrum* stems produced may new, small stems which were able to take advantage of the new forest conditions. Additionally, the absence of fire has aided this thin barked species to survive in the understory. The significant decrease of *Castanea dentata*, though not specifically examined within this study, is most likely caused by the American chestnut blight, which has relegated this species to the understory. Its decline in the forest can be expected to continue since its only current means of reproduction in the forest is by stump sprouting. This is the second or third time these trees have been released since first being exposed to the blight and the root carbohydrate reserves are most likely greatly reduced.

Through the examination of the understory, one can generally predict the future overstory composition of the stand since they are highly correlated. Of the dominant species found in the understory, *Quercus* spp., *S. albidum*, *A. rubrum*, and *R. pseudoacacia* had the best potential of reestablishing dominance because of previous occupation of the forest and

Table 4.1-12. Student's paired t-test results for the shrub and tree strata based upon comparing 1977 and 1995 species importance values using stands as the sampling unit. Bold type indicates significant difference at the  $\alpha = 0.10$  level. (df = 3; stands BCDI)

| Shrub         |              |             | Tree          |              |             |
|---------------|--------------|-------------|---------------|--------------|-------------|
| Species code  | t            | P $\approx$ | Species code  | t            | P $\approx$ |
| ACEPEN        | -1.00        | 0.39        | ACEPEN        | 1.62         | 0.20        |
| <b>ACERUB</b> | <b>5.16</b>  | <b>0.01</b> | ACERUB        | 0.61         | 0.58        |
| ACESAC        | 1.34         | 0.27        | BETLEN        | 1.00         | 0.39        |
| AMEARB        | -1.00        | 0.39        | CARGLA        | -2.26        | 0.11        |
| CARGLA        | -1.73        | 0.18        | CAROVA        | 1.00         | 0.39        |
| <b>CASDEN</b> | <b>-3.36</b> | <b>0.04</b> | CARTOM        | 1.70         | 0.19        |
| CORFLO        | -0.88        | 0.45        | CASDEN        | -2.26        | 0.11        |
| GAYBAC        | -2.11        | 0.12        | CORFLO        | 1.38         | 0.26        |
| HAMVIR        | 1.42         | 0.25        | HAMVIR        | 1.00         | 0.39        |
| ILEMON        | 0.44         | 0.69        | LIRTUL        | 1.00         | 0.39        |
| KALLAT        | -1.12        | 0.34        | NYSSYL        | -1.54        | 0.22        |
| LIRTUL        | 1.20         | 0.32        | OXYARB        | -1.00        | 0.39        |
| NYSSYL        | -0.84        | 0.46        | PINPUN        | -1.15        | 0.34        |
| OXYARB        | 1.00         | 0.39        | PINRIG        | -1.28        | 0.29        |
| PINPUN        | 1.00         | 0.39        | PINVIR        | 1.00         | 0.39        |
| PINRIG        | 0.80         | 0.48        | QUECOC        | 0.34         | 0.75        |
| PINVIR        | 1.00         | 0.39        | QUEPRI        | 0.27         | 0.81        |
| QUECOC        | 0.12         | 0.92        | <b>QUEVEL</b> | <b>-2.42</b> | <b>0.09</b> |
| QUEILI        | 1.58         | 0.21        | ROBPSE        | 1.03         | 0.38        |
| QUEPRI        | 0.28         | 0.80        | SASALB        | 1.90         | 0.15        |
| QUEVEL        | -1.73        | 0.18        | ULMAME        | 1.00         | 0.39        |
| RHONUD        | -0.69        | 0.54        |               |              |             |
| ROBPSE        | -1.00        | 0.39        |               |              |             |
| SASALB        | 0.03         | 0.98        |               |              |             |
| VACSTA        | -1.00        | 0.39        |               |              |             |

their growth form. One new species, *L. tulipifera*, established itself in the forest because of its fast growth rate in open growth areas, especially on mesic sites, and the generally abundant seed source adjacent to the harvested sites. The addition of *L. tulipifera* has changed the dynamics of the forest by displacing other species and/or redistributing the resources.

### **Overstory Woody Plants – Tree stratum**

Pre-harvest dominant tree stratum species included *Quercus* spp. (*Q. prinus*, *Q. coccinea*, and *Q. velutina*; 56.9% IV), *Pinus rigida* (16.5%), and *Acer rubrum* (9.7%) (Table 4.1-9). A large number of individuals (>10) first reached in the tree stratum 5 years after harvest on the better sites. At this time, only four species had grown into the tree stratum; *Castanea dentata* (18.1%), *Robinia pseudoacacia* (16.2%), *A. rubrum* (8.2%), and *Q. prinus* (7.5%) (Table 4.1-9). The appearance of *C. dentata* and *R. pseudoacacia* as the initial dominant species after harvest is expected. *Castanea dentata* is a prolific stump sprouter and grows well on the poor to medium quality sites such as those that are found at this study site. *Robinia pseudoacacia* is a early succession, pioneer species that thrives in open conditions where soil disturbance has occurred (Burns and Honkala 1990b). The presence of *Acer rubrum* and *Q. prinus* in the tree stratum occurred because these species also regenerate well from stump sprouts. Studies have shown that individuals from stump sprouts attain significantly higher initial growth rates than those arising from seedlings (e.g., Ross 1982 and Muller 1990). Additionally, *A. rubrum* can respond rapidly to increased light conditions.

By the 7<sup>th</sup> year after harvest, individuals were found in all sample sites and an additional eight species had entered the tree stratum. The same four species of the 5-year old forest continued to be the prevalent species, although their ranking changed. From the 5<sup>th</sup> and 7<sup>th</sup> year after harvesting, *C. dentata* and *R. pseudoacacia* decreased to 4.9% and 7.7%, respectively, while *A. rubrum* and *Q. prinus* increased to 9.3% and 66.1%, respectively (Table 4.1-9). From the 7<sup>th</sup> to 17<sup>th</sup> year, species ranking continued to change. *Quercus* spp. (*Q. prinus*, *Q. coccinea*, and *Q. velutina*; 61.2%) were the most prevalent species (Table 4.1-9). *Acer rubrum* was the second most prominent species in the 17-year old forest, which further increased in dominance to 11.2% IV (Table 4.1-9).

As the forest aged, the importance of *R. pseudoacacia* decreased greatly because it is commonly attacked by the locust borer (*Megcallene robiniae*) and leaf miner (*Odontota dorsalis*) insects (Burns and Honkala 1990b). The locust borer and leaf miner weaken the black locust hardiness and vigor, especially on poor sites, which then makes them more susceptible to ice and snow damage. Another factor contributing to the decline of *R. pseudoacacia* in the forest was due to increasing shade component which inhibits regeneration. In contrast, *Quercus prinus*, being of intermediate shade tolerance, was able to compete better in this developing forest (Burns and Honkala 1990b). *Castanea dentata* continued to decline due to the chestnut blight.

The presence of *Sassafras albidum* and *Liriodendron tulipifera* suggest that these species were effective competitors for resources in the regenerating forest. *Sassafras albidum* and *L. tulipifera* had initial pre-harvest importance values of 1.1% and 0%, respectively, and these values increased to 8.8% and 5.2%, respectively, in the 17-year old forest (Table 4.1-9). These species tend to be site specific with *S. albidum* being found on the poorer quality sites, while *L. tulipifera* is found on the better quality sites. The increase of *S. albidum* can be attributed to its means of reproduction through root sprouting and ability to rapidly colonize open areas, especially on poor quality sites (Blount 1989). *Liriodendron tulipifera* increased because it was able to seed in from a surrounding seed source and take advantage of the open growth conditions, with its pioneer growth characteristics, created by the harvesting operation. *Liriodendron tulipifera*, in particular, has a higher commercial value (Burns and Honkala 1990b), while *S. albidum* has a higher wildlife browse value, especially for deer (Burns and Honkala 1990b).

The establishment of *L. tulipifera* as a main component of the overstory seems to be well set, especially in high site quality portions of the forest. This species should remain a significant portion of the overstory for at least ~100 to 125 years. After that time, if the forest does not receive any drastic disturbances, its continued presence in the overstory will probably decrease since it does not regenerate well beneath a full canopy. Parker and Swank (1982) report that, after successive clearcuts (23 years apart) in a southern Appalachian hardwood forest *L. tulipifera* greatly increased in relative dominance.

*Pinus rigida* has declined significantly having a pre-harvest importance value that has declined from 16.5% to a 17-year old forest importance value of 0.3% (Table 4.1-9). Its virtual absence in the 17-year old forest suggest two events could be occurring. First, pine species tend to be found on the poorer quality sites where they are superior competitors; this results, though, in slow growth due to the limited site resources. Second, the harvesting disturbance did not provide conditions for the adequate regeneration of the species. *Pinus* spp. optimal regeneration medium is scarified soil such as in the case when fire occurs or there is significant soil disturbance associated with the harvesting. The harvesting with the use of cable yarding, which reduces ground disturbance, evidently did not create enough scarified forest floor conditions that promote germination and establishment. Alternatively, regeneration of pine species can often be greatly enhanced with the use of fire. Fire will tend to control competing vegetation and can remove the litter layer (depending upon the fire intensity) from the forest floor. Since there was a low abundance in the shrub stratum of pines over the sampling periods in this study, the latter event is the most likely cause of its absence.

Of the 21 species found in the tree stratum between the pre-harvest and 17-year old forest, only *Q. velutina* ( $n = 4$ ,  $t = -2.42$ ,  $P = 0.09$ ) was found to be significantly different with respect to importance values (Table 4.1-12). The decline of *Q. velutina* in importance value can probably be attributed to its competitive ability. The lower site qualities of this

forest are too poor for it to effectively compete with *Q. prinus* and *Q. coccinea*; while *A. rubrum* and *L. tulipifera*, without some form of disturbance or competition control such as fire, will out compete it on the higher quality sites.

Average height and diameter of each species were two additional growth characteristics that were examined in the tree stratum. In the pre-harvest forest, the average heights of the tallest species were *Q. velutina* (13.4 m), *Q. prinus* (11.7 m), *Q. coccinea* (11.2 m), *A. rubrum* (11.8 m), and *O. arboreum* (11.2 m). The species with the largest average diameters were *Q. velutina* (20.2 cm), *Q. prinus* (16.6 cm), *Q. coccinea* (15.0 cm), *P. pungens* (17.9 cm), and *P. rigida* (17.5 cm) (Table 4.1-13). All of these species, except for *O. arboreum* and *P. pungens*, were dominant species, with respect to stem density, in the pre-harvest forest (Table 4.1-9).

In the 17-year old forest, a different group of species had the largest average height and diameter. *Liriodendron tulipifera* (12.8 m), *B. lenta* (12.0 m), *U. americana* (11.8 m), *C. tomentosa* (9.7 m), and *R. pseudoacacia* (9.5 m) were the tallest species (Table 4.1-13). These species, however, only comprised 7.0% of the relative stem density within the forest (Table 4.1-14). The largest species based on diameter were *L. tulipifera* (12.2 cm), *P. pungens* (11.1 cm), *P. rigida* (10.3 cm), *U. americana* (9.7 cm), and *R. pseudoacacia* (8.2 cm) (Table 4.1-13). Again, these species only represented 6.7% of the relative stem density in the 17-year old forest (Table 4.1-14).

Since the tallest and largest species in the 17-year old forest constitute a small portion of the stand, a better representation of the forest structure can be achieved by examining the average heights and diameters of those species that are the most dominant with respect to relative stem density. The average heights and diameters of these species are: *Q. prinus* (7.2 m and 6.3 cm), *S. albidum* (6.4 m and 4.3 cm), *A. rubrum* (8.8 m and 5.8 cm), and *Q. coccinea* (7.0 m and 5.6 cm) (Table 4.1-13). These species account for 82.7% of the relative stem density in the 17-year old forest (Table 4.1-14).

Many species in the 17-year old forest that have the tallest average height and largest diameter have early successional characteristics. These species primarily are found on higher quality sites and, therefore, are not widely distributed throughout the forest. These species grow faster, which helps them to attain their greater average height and diameter. In contrast, the more abundant species, such as *Quercus* spp. and *Acer rubrum*, have a much wider site quality distribution and incur a wider range of growth conditions which leads to a more conservative estimate of the average height of these individuals.

Table 4.1-13. Mean height (calculated from approximately one-fifth of the total number of individuals) and diameter for each sampling year of all species in the tree stratum at the Potts Mountain study site in Craig Co., Va.

| Mean diameter (cm)             |                    |     |     |      | Mean height (m)                |                    |     |     |      |
|--------------------------------|--------------------|-----|-----|------|--------------------------------|--------------------|-----|-----|------|
| Scientific Name                | Stand age (years): |     |     |      | Scientific Name                | Stand age (years): |     |     |      |
|                                | Pre-               | 5   | 7   | 17   |                                | Pre-               | 5   | 7   | 17   |
| <i>Quercus velutina</i>        | 20.2               | 0.0 | 0.0 | 5.8  | <i>Quercus velutina</i>        | 13.4               | 0.0 | 0.0 | 7.0  |
| <i>Pinus pungens</i>           | 17.9               | 0.0 | 0.0 | 11.1 | <i>Acer rubrum</i>             | 11.8               | 5.5 | 6.1 | 8.8  |
| <i>Pinus rigida</i>            | 17.5               | 0.0 | 0.0 | 10.3 | <i>Quercus prinus</i>          | 11.7               | 5.3 | 5.8 | 7.2  |
| <i>Quercus prinus</i>          | 16.6               | 4.5 | 4.7 | 6.3  | <i>Oxydendrum arboreum</i>     | 11.2               | 0.0 | 5.4 | 9.3  |
| <i>Quercus coccinea</i>        | 15.0               | 0.0 | 5.2 | 5.6  | <i>Quercus coccinea</i>        | 11.2               | 0.0 | 5.3 | 7.0  |
| <i>Robinia pseudoacacia</i>    | 13.4               | 4.6 | 4.9 | 8.2  | <i>Pinus pungens</i>           | 10.8               | 0.0 | 0.0 | 6.4  |
| <i>Oxydendrum arboreum</i>     | 13.1               | 0.0 | 4.5 | 6.9  | <i>Pinus rigida</i>            | 9.3                | 0.0 | 0.0 | 7.0  |
| <i>Acer rubrum</i>             | 11.4               | 3.6 | 4.2 | 5.8  | <i>Robinia pseudoacacia</i>    | 9.1                | 5.6 | 6.5 | 9.5  |
| <i>Carya glabra</i>            | 9.9                | 0.0 | 3.5 | 5.1  | <i>Carya glabra</i>            | 8.9                | 0.0 | 5.0 | 8.8  |
| <i>Sassafras albidum</i>       | 8.9                | 0.0 | 3.6 | 4.3  | <i>Sassafras albidum</i>       | 7.5                | 0.0 | 5.3 | 6.4  |
| <i>Nyssa sylvatica</i>         | 8.4                | 0.0 | 3.2 | 4.5  | <i>Nyssa sylvatica</i>         | 7.2                | 0.0 | 5.3 | 6.5  |
| <i>Cornus florida</i>          | 8.3                | 0.0 | 0.0 | 4.1  | <i>Cornus florida</i>          | 6.4                | 0.0 | 0.0 | 6.0  |
| <i>Castanea dentata</i>        | 6.8                | 4.5 | 4.5 | 3.1  | <i>Castanea dentata</i>        | 6.1                | 5.5 | 5.7 | 5.9  |
| <i>Liriodendron tulipifera</i> | 0.0                | 0.0 | 4.0 | 12.2 | <i>Liriodendron tulipifera</i> | 0.0                | 0.0 | 5.9 | 12.8 |
| <i>Hamamelis virginiana</i>    | 0.0                | 0.0 | 3.3 | 4.1  | <i>Betula lenta</i>            | 0.0                | 0.0 | 5.3 | 12.0 |
| <i>Betula lenta</i>            | 0.0                | 0.0 | 2.6 | 8.0  | <i>Hamamelis virginiana</i>    | 0.0                | 0.0 | 5.0 | 5.6  |
| <i>Ulmus americana</i>         | 0.0                | 0.0 | 0.0 | 9.7  | <i>Ulmus americana</i>         | 0.0                | 0.0 | 0.0 | 11.8 |
| <i>Pinus virginiana</i>        | 0.0                | 0.0 | 0.0 | 7.9  | <i>Carya tomentosa</i>         | 0.0                | 0.0 | 0.0 | 9.7  |
| <i>Carya tomentosa</i>         | 0.0                | 0.0 | 0.0 | 5.5  | <i>Carya ovata</i>             | 0.0                | 0.0 | 0.0 | 8.5  |
| <i>Acer pensylvanicum</i>      | 0.0                | 0.0 | 0.0 | 4.4  | <i>Acer pensylvanicum</i>      | 0.0                | 0.0 | 0.0 | 6.2  |
| <i>Carya ovata</i>             | 0.0                | 0.0 | 0.0 | 3.7  | <i>Pinus virginiana</i>        | 0.0                | 0.0 | 0.0 | 5.6  |

Table 4.1-14. Mean percent relative stem density and standard error for each sampling year in the tree stratum at the Potts Mountain study site in Craig Co., Va. (n = 4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |      |           |      |           |      |           |       |
|--------------------------------|-------------------|------|-----------|------|-----------|------|-----------|-------|
|                                | Pre-harvest       |      | 5         |      | 7         |      | 17        |       |
|                                | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    |
| <i>Quercus prinus</i>          | 31.7              | 8.7  | 6.9       | 6.4  | 66.9      | 20.3 | 37.7      | 13.5  |
| <i>Quercus coccinea</i>        | 17.2              | 8.7  | 0.0       | 0.0  | 4.6       | 4.0  | 19.9      | 9.6   |
| <i>Pinus rigida</i>            | 14.3              | 12.3 | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1   |
| <i>Acer rubrum</i>             | 11.8              | 10.8 | 9.5       | 9.5  | 9.7       | 9.7  | 13.5      | 9.3   |
| <i>Quercus velutina</i>        | 3.4               | 1.1  | 0.0       | 0.0  | 0.0       | 0.0  | 0.7       | 0.5   |
| <i>Nyssa sylvatica</i>         | 5.5               | 1.9  | 0.0       | 0.0  | 0.3       | 0.3  | 3.5       | 2.2   |
| <i>Oxydendrum arboreum</i>     | 3.7               | 3.7  | 0.0       | 0.0  | 1.4       | 1.4  | 1.6       | 1.6   |
| <i>Pinus pungens</i>           | 2.6               | 1.6  | 0.0       | 0.0  | 0.0       | 0.0  | 0.6       | 0.4   |
| <i>Carya glabra</i>            | 3.6               | 2.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.3       | 0.2   |
| <i>Robinia pseudoacacia</i>    | 1.9               | 1.2  | 14.9      | 14.9 | 6.7       | 5.9  | 3.3       | 2.4   |
| <i>Sassafras albidum</i>       | 1.7               | 1.0  | 0.0       | 0.0  | 2.8       | 2.8  | 11.6      | 7.9   |
| <i>Cornus florida</i>          | 1.5               | 1.1  | 0.0       | 0.0  | 0.0       | 0.0  | 1.7       | 1.2   |
| <i>Castanea dentata</i>        | 0.9               | 0.4  | 18.8      | 18.4 | 5.2       | 4.7  | < 0.1     | < 0.1 |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0  | 0.0       | 0.0  | 2.2       | 2.2  | 2.7       | 2.7   |
| <i>Hamamelis virginiana</i>    | 0.0               | 0.0  | 0.0       | 0.0  | 0.2       | 0.2  | 1.0       | 1.0   |
| <i>Betula lenta</i>            | 0.0               | 0.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.9       | 0.9   |
| <i>Pinus virginiana</i>        | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.3       | 0.3   |
| <i>Acer pensylvanicum</i>      | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.2       | 0.2   |
| <i>Carya tomentosa</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1   |
| <i>Ulmus americana</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | < 0.1     | < 0.1 |
| <i>Carya ovata</i>             | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | < 0.1     | < 0.1 |

## CONCLUSIONS

In general, the overall structure of the forest after 17-years of regrowth remained relatively unchanged. The changes in the ground cover features were a result of the alteration of the forest structure and the interruption of forest cycles (e.g., decomposition cycle). Species abundance in all strata has increased. And the regeneration of all three strata is progressing with continued increases in basal area, stem density, average diameter and height in the tree stratum and a leveling of basal area and stem density in the shrub stratum. All of these structural components are expected to eventually resemble the pre-harvest forest conditions as the forest ages.

The majority of herbaceous and woody plant species composition and abundance were not found to be significantly different between the pre-harvest and 17-year old forest. However, changes did occur in the dominance ranking of herbaceous and woody plants. The results of this study suggest that the major cause of change in the composition and abundance of the herbaceous and woody plants was due to an alteration in the microclimate of the forest.

With respect to herbaceous plants, a majority of the pre-harvest forest species had decreased after the disturbance. The clearcutting disturbance changed the forest floor conditions, which shifted the competitive ability of the species. In the pre-harvest forest, grass-like species and ferns were the dominant species each comprising >20% of the relative percent cover, while in the 17-year old forest, the grass-like species were the most prevalent consisting of 43.1% of the relative cover. The increased light conditions at the forest floor benefited the grass-like species but were detrimental to the ferns. The disturbance also allowed the entrance of 13 new herbaceous species while aiding in the reduction or extirpation of 8 pre-harvest species. In many cases, however, the species that were no longer found in the disturbed forests could be located in the surrounding, unharvested forest (personal observation). This leaves the potential for recolonization if enough time passes before the next major disturbance. In the long-term, it is expected that the forest herb composition will return to approximately the same composition and abundance as the pre-harvest forest.

With woody species, the changes in composition and abundance caused by clearcutting were less pronounced. Exceptions occurred when an additional disturbance, fire that helped to form the pre-harvest forest, was prevented from occurring. Eight new species were found in the overstory, while none of the pre-harvest species were lost. *Quercus* spp. were still the most abundant species throughout the forest. Species such as *A. rubrum* and *L. tulipifera* have become more prominent on the better quality sites, while *S. albidum* has increased on the poorer quality sites. The increase in these three has resulted in a decrease in the less dominant species. Fire would have tended to kill the young, thin barked species such as *A. rubrum*, *L. tulipifera*, and *S. albidum*. In the understory, woody species remained relatively unchanged following harvest. Ericaceous species (*Kalmia*

*latifolia*, *Vaccinium* spp., and *Rhododendron* spp.) still dominated and will continue to do so unless an additional disturbance is introduced. These gains and losses of species, and reductions and increases in species abundance appear to be well within the resiliency levels associated with Appalachian hardwood forest ecosystems.

In all strata, both herbaceous and woody species richness remained similar, but the species compositions changed. The number of new species within any one stratum ranged from 3 to 13 while the number of species lost from the pre-harvest stands ranged from 0 to 8. The rare species tended to be the ones that were either lost or gained. The low abundance of the rare species make them more susceptible to disturbances or alterations in microclimates. All the species that were lost from this study are commonly found in forests and their temporary extirpation from the stands can be equivalent to a natural disturbance event. However, if a species that is historically locally, regionally, and/or globally rare then precautions need to be taken to ensure the survival of that species.

The source of the future stand is also important. There is a concern that a forest that regenerates from stump sprouts will produce poor quality stems and be less hardy than that which arises from a seedling source. Stump sprout regenerated forests are typically more susceptible to heart rot, but this can be reduced depending upon stump height, origin height of the sprout on the stump, and fire occurrence (Roth and Hepting 1943). The main regeneration source of the pre-harvest forest came most likely from a seedling source or stump sprouts after a fire occurrence because fires were still a main component of the forest ecosystem in the early 1900s.

Although the majority of the species found were not significantly different between the pre-harvest and 17-year old forest, this does not mean they were unaffected by the harvesting disturbance. The number of stands used in this study (four) is quite low, and they were not replicated within a site quality category, thereby reducing the statistical inference space. This study, however, has added to the extensive knowledge about tree species and to the limited knowledge of herbaceous species distribution and response to disturbance in the Appalachian hardwood region. More studies like this, though expanded, can further add to the knowledge base on the effects that harvesting disturbances have on herbaceous and woody plants.

Most of the eastern U.S. forests have been harvested or severely disturbed and the original composition of these stands is not known. As a result, previous harvesting disturbances may have caused the loss of some species from these forests. These past events have left us with second- and third-growth forests of which we have a better understanding and knowledge of their composition, structure, and function. It is important to remember that these forests are very dynamic and in constant transition so when a forest is disturbed it will never return exactly to what it was prior to the disturbance. These changes allow many species to persist. A major goal of forest ecologists, therefore, would be to learn how certain disturbances affect the compositions of forests. With this knowledge we can

better understand the effects that human disturbances have or might have on forest ecosystems. If these disturbances do not produce the intended forest composition, structure, and/or productivity then more information must be gathered in order to achieve the preferred goals.

## CHAPTER 4.2 STAND LEVEL CHARACTERISTICS

### RESULTS AND DISCUSSION

This section presents a discussion of the effects of clearcutting with whole-tree harvesting on stand level vegetative composition and characteristics. The accumulation of basal area ( $\text{m}^2/\text{ha}$ ), stem density (individuals/ha), ground cover features (percent cover), and species compositions (relative percent cover or importance value) are examined and related to stand quality. Importance values were calculated by averaging relative basal area and relative stem density and the tables for these latter two values are located in Appendix D. General trends are described and reason offered as to why certain stands have particular species associations. An overview of the control stand will be given first to provide a chronology of the general study area. Also, it is important to note that these stands are not replicated.

#### CONTROL STAND

Over the 18 years of this study, the control stand has undergone structural change in the shrub stratum but has remained relatively constant in the tree stratum. The shrub stratum basal area and stem density have decreased from 2.6 to 0.9  $\text{m}^2/\text{ha}$  and 3,325 to 1,325 stems/ha, respectively (Figures 4.2-1 and 4.2-2). The tree stratum increased marginally in basal area from 22.6 to 24.3  $\text{m}^2/\text{ha}$ , while stem density exhibited a slight decrease from 1,181 to 806 stems/ha (Figures 4.2-3 and 4.2-4). Standard errors for all of these values were less than 0.5 units.

One potential reason for the decrease in shrub stem density is that the forest floor in this stand has increased in average vegetation cover from 10.1% in 1977 to 39.1% in 1995, which may impede the development of the shrub layer. The majority of the understory vegetation is comprised of ericaceous plants (*V. pallidum*, *G. baccata*, *K. latifolia*) (Tables 4.2-1 and 4.2-2), which because of the dense foliage and resulting forest floor shading can prevent the regeneration (abundance) of seedlings within their range of influence. This stand is also on the lower end of site quality ( $\text{SI}_{50} = 50$ ) and plants may be stressed from the lack of resources. In an unmanaged ecosystem, an occasional fire would likely reduce the ericaceous understory, expose the forest floor, release some of the stored nutrients, and allow the regeneration of other species. Ross (1982) found that over the 50 years prior to the cutting of these stands, the occurrence of fire has greatly reduced in frequency.

The dominance of ericaceous species in the control stand understory has also affected the composition and abundance of herbaceous plants. Initially, 18 species were identified in the 1977 stand, but in the 1995 stand only 11 species were recorded (Table 4.2-1). The presence of herbaceous plants in each of the sampling subplots ( $n = 40$ ) also reduced from

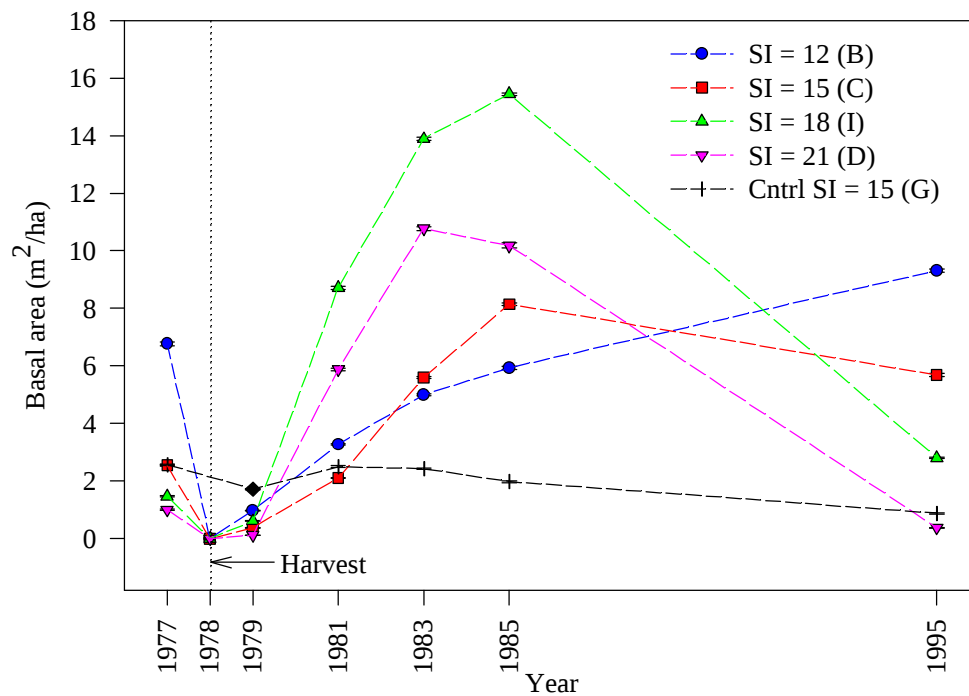


Figure 4.2-1. Shrub stratum mean basal area and standard error (calculated from diameter measured at 15 cm above root collar) of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (For each point  $n=16$ ; standard errors for each point are  $< 0.5$  units; capital letter in parenthesis denotes stand designated in Figure 3-1.)

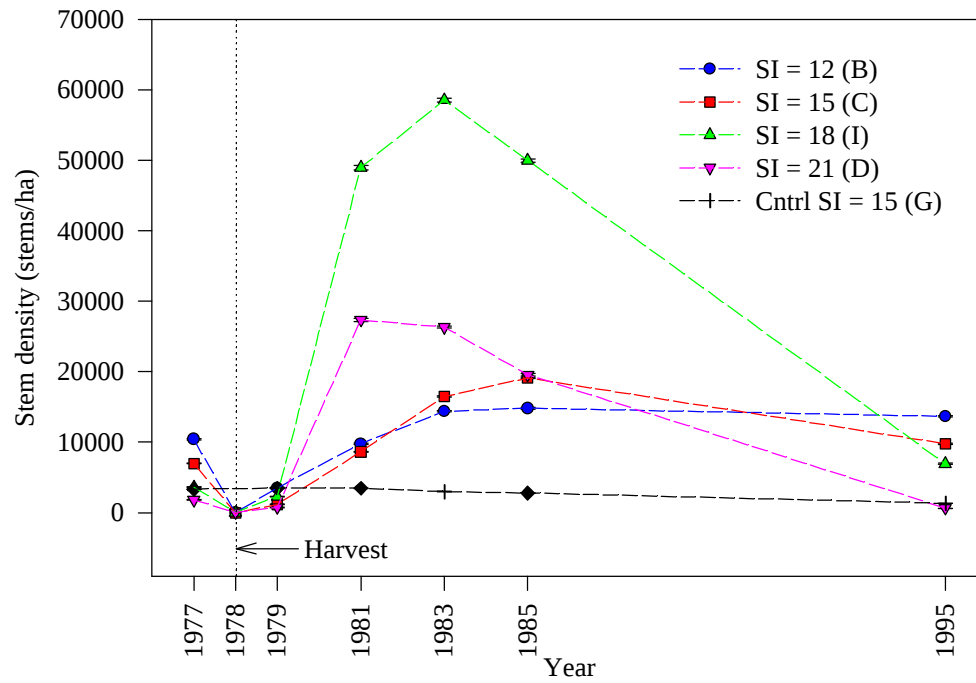


Figure 4.2-2. Shrub stratum mean stem density and standard error of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (for each point  $n=16$ ; standard errors for each point are  $< 0.5$  units; capital letter in parenthesis denotes stand designated in Figure 3-1.)

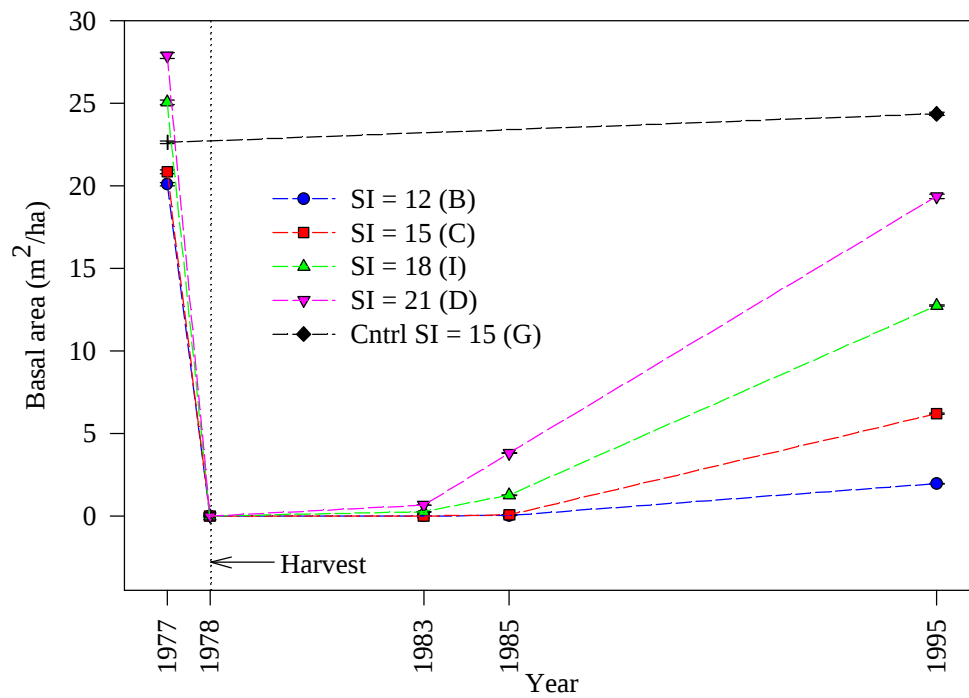


Figure 4.2-3. Tree stratum mean basal area and standard error (calculated from DBH) of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (for each point  $n=16$ ; standard errors for each point are  $< 0.5$  units; capital letter in parenthesis denotes stand designated in Figure 3-1.)

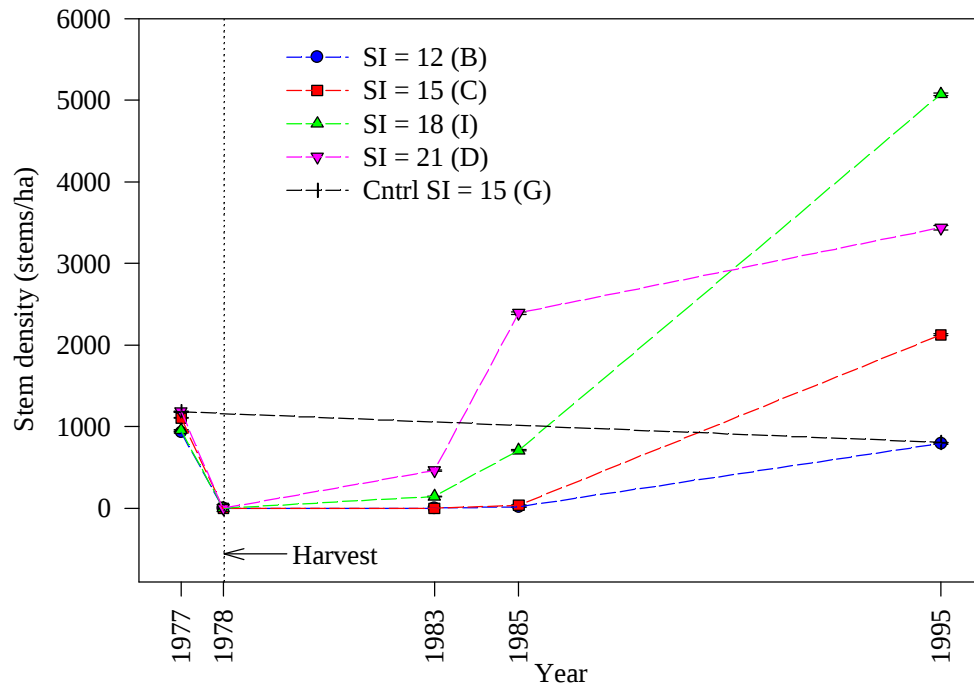


Figure 4.2-4. Tree stratum mean stem density and standard error of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (for each point  $n=16$ ; standard errors for each point are  $< 0.5$  units; capital letter in parenthesis denotes stand designated in Figure 3-1.)

Table 4.2-1. Mean relative percent cover and standard error of herbaceous and woody plants in the herb stratum of the control stand (SI 15 m) at the Potts Mountain study site in Craig, Co. Va. (n = 40)

| Herbaceous Plants |           |      |           |      | Woody Plants |           |      |           |      |
|-------------------|-----------|------|-----------|------|--------------|-----------|------|-----------|------|
| Species Code      | 1977      |      | 1995      |      | Species Code | 1977      |      | 1995      |      |
|                   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |              | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| PANSPP            | 12.0      | 3.98 | 7.1       | 3.26 | VACPAL       | 22.6      | 2.22 | 23.6      | 3.35 |
| GALAPH            | 7.5       | 4.22 | 0.0       | 0.00 | GAYBAC       | 20.1      | 4.03 | 26.5      | 4.49 |
| IRIVER            | 7.4       | 3.07 | 15.0      | 5.72 | SMIGLA       | 10.4      | 1.71 | 5.0       | 0.94 |
| ANDSPP            | 7.0       | 2.34 | 3.8       | 2.77 | SASALB       | 10.3      | 2.15 | 14.6      | 2.46 |
| CYPACA            | 6.7       | 3.62 | 5.0       | 3.49 | QUEPRI       | 7.8       | 2.11 | 2.7       | 0.81 |
| CHIMAC            | 5.2       | 2.90 | 6.3       | 3.66 | ACERUB       | 6.0       | 1.41 | 7.5       | 1.58 |
| CORMAJ            | 5.0       | 3.00 | 2.5       | 2.50 | VACSTA       | 4.6       | 2.03 | 4.7       | 2.06 |
| AURLAE            | 4.8       | 2.11 | 0.0       | 0.00 | KALLAT       | 4.5       | 2.17 | 7.1       | 3.29 |
| CONMAJ            | 4.6       | 2.86 | 0.0       | 0.00 | QUECOC       | 4.1       | 1.18 | 3.8       | 1.79 |
| ASTER             | 2.7       | 1.59 | 0.0       | 0.00 | RHONUD       | 2.4       | 1.09 | 1.1       | 0.53 |
| EPIREP            | 2.3       | 1.30 | 0.0       | 0.00 | AMEARB       | 1.8       | 0.99 | 0.5       | 0.34 |
| PTEAQU            | 1.5       | 1.03 | 0.0       | 0.00 | QUEILI       | 1.6       | 0.85 | 0.0       | 0.00 |
| DANSPP            | 1.3       | 0.96 | 0.8       | 0.83 | NYSSYL       | 1.5       | 0.75 | 1.3       | 1.25 |
| CARSPP            | 1.3       | 1.25 | 0.8       | 0.83 | QUEVEL       | 1.0       | 0.62 | 0.0       | 0.00 |
| HIEVEN            | 1.3       | 1.25 | 0.0       | 0.00 | PINVIR       | 0.8       | 0.58 | 0.3       | 0.19 |
| UVUPUD            | 0.8       | 0.83 | 2.5       | 2.50 | VITSPP       | 0.3       | 0.28 | 0.0       | 0.00 |
| VIOSPP            | 0.8       | 0.83 | 0.0       | 0.00 | PINRIG       | 0.0       | 0.00 | 0.7       | 0.55 |
| POLBIF            | 0.5       | 0.50 | 2.5       | 2.50 | SMIROT       | 0.0       | 0.00 | 0.6       | 0.63 |
| HYPHIR            | 0.0       | 0.00 | 1.3       | 1.25 | PRUSER       | 0.0       | 0.00 | 0.1       | 0.13 |

Table 4.2-2. Mean importance value and standard error of shrub stratum woody plants in the control stand (SI 15 m) at the Potts Mountain study site in Craig Co., Va. (n = 16)

| Species Code | Year      |      |           |      |           |       |           |      |           |      |           |       |
|--------------|-----------|------|-----------|------|-----------|-------|-----------|------|-----------|------|-----------|-------|
|              | 1977      |      | 1979      |      | 1981      |       | 1983      |      | 1985      |      | 1995      |       |
|              | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    |
| QUEPRI       | 22.6      | 8.06 | 16.1      | 8.47 | 16.3      | 7.46  | 17.9      | 7.34 | 15.5      | 7.46 | 3.2       | 3.18  |
| SASALB       | 22.5      | 8.31 | 30.8      | 8.10 | 29.0      | 10.06 | 25.0      | 9.09 | 14.8      | 7.13 | 6.4       | 4.16  |
| KALLAT       | 16.7      | 6.01 | 19.6      | 7.99 | 17.4      | 6.18  | 20.8      | 7.26 | 28.2      | 8.47 | 53.2      | 11.61 |
| NYSSYL       | 9.6       | 5.11 | 6.4       | 3.30 | 9.0       | 4.84  | 9.1       | 5.03 | 7.6       | 4.85 | 2.2       | 2.17  |
| GAYBAC       | 7.7       | 6.23 | 1.0       | 0.98 | 8.8       | 6.29  | 11.6      | 6.22 | 10.1      | 6.59 | 3.1       | 2.94  |
| AMEARB       | 6.3       | 6.25 | 0.0       | 0.00 | 6.3       | 6.25  | 4.0       | 3.97 | 4.5       | 4.13 | 0.0       | 0.00  |
| RHONUD       | 4.1       | 3.14 | 10.4      | 4.49 | 3.9       | 3.03  | 3.5       | 2.72 | 3.0       | 2.48 | 1.2       | 1.17  |
| OXYARB       | 3.8       | 3.81 | 0.0       | 0.00 | 4.0       | 4.03  | 4.5       | 4.52 | 0.0       | 0.00 | 0.0       | 0.00  |
| QUECOC       | 2.0       | 1.20 | 0.0       | 0.00 | 1.8       | 1.54  | 1.1       | 0.85 | 4.0       | 2.80 | 8.0       | 6.27  |
| QUEVEL       | 1.6       | 1.08 | 0.0       | 0.00 | 1.0       | 1.03  | 0.2       | 0.24 | 0.6       | 0.62 | 0.0       | 0.00  |
| CASDEN       | 0.7       | 0.72 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 3.5       | 3.47 | 0.0       | 0.00  |
| VACSTA       | 0.7       | 0.70 | 7.3       | 2.82 | 1.2       | 1.21  | 1.5       | 1.50 | 0.9       | 0.87 | 1.8       | 1.82  |
| QUEALB       | 0.7       | 0.67 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| CARTOM       | 0.5       | 0.49 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| ROBPSE       | 0.4       | 0.40 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| ACERUB       | 0.3       | 0.25 | 1.9       | 1.05 | 0.3       | 0.27  | 0.3       | 0.26 | 0.3       | 0.34 | 1.1       | 1.07  |
| QUEILI       | 0.0       | 0.00 | 0.2       | 0.22 | 0.5       | 0.48  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| CARGLA       | 0.0       | 0.00 | 0.0       | 0.00 | 0.6       | 0.60  | 0.5       | 0.53 | 0.7       | 0.71 | 1.1       | 1.13  |

72.7% in the 1977 stand to 47.6% in 1995 (Table 4.2-1). With respect to herbaceous abundance, there was a much more even distribution of individuals per species in the 1977 stand. In 1977 nine species had > 4.5% relative percent cover with the highest percent being 12.0%; in 1995 only 3 species exceeded 4.5% with a maximum percent cover of 15.0% for any one species (Table 4.2-1). The species that remained in the 1995 stand were predominantly grass-like (i.e., *Panicum* spp.) or had well developed root systems (i.e., *Iris verna* and *Chimaphila maculata*).

The 1977 dominant woody species in the herb stratum were *Vaccinium pallidum* (22.6%), *Gaylussacia baccata* (20.1%), *Smilax glauca* (10.4%), and *Sassafras albidum* (10.3%) (Table 4.2-1). In the 1995 stand, *V. pallidum* (23.6%), *G. baccata* (26.5%), and *S. albidum* (14.6%) had increased in relative dominance. Equal number of species (16) were found in both years with 3 species unique to each year (Table 4.2-1).

In the 1977 shrub stratum, *Quercus* spp., *S. albidum*, and *K. latifolia* were the dominant species. *Kalmia latifolia* has steadily increased in importance value over the 17-year period from 16.7% in 1977 to 53.2% in 1995 (Table 4.2-2). The abundance of the other ericaceous species (*Gaylussacia baccata*, *Rhododendron nudiflorum*, and *Vaccinium stamenium*) when examined individually have fluctuated over the 17 year study. The sum of these three species, though, has composed a large component (> 12% IV) of the shrub stratum in any one year until 1995, in which their summed IV was only 6.1%. *Quercus* spp. (*Q. prinus*, *Q. coccinea*, and *Q. velutina*), in contrast, have decreased from 26.2% to 11.2% over the same time period. The number of species has also decreased from 16 to 10.

In the tree stratum, composition has remained nearly the same over the whole study period. *Quercus prinus*, *Q. coccinea*, and *Pinus rigida* comprise more than 80% of the IV in both 1977 and 1995 (Table 4.2-3). Over this time period, a turnover of one species occurred; *R. pseudoacacia* was no longer found in the tree stratum, while *Q. velutina* entered the tree stratum. The loss and gain of *R. pseudoacacia* and *Q. velutina*, respectively, would be expected because the former is a relatively short lived, early successional species while the latter is a mid- to late-successional species in these stands when disturbances, such as fire, are part of the ecosystem.

#### TREATED STANDS

##### ***Woody Species Basal Area, Stem Density, and Mean Height and Diameter***

Pre-harvest stratification in the shrub stratum, of the treated stands exhibited a trend of decreasing basal area and stem density as the stand site quality increased (ranged from 1.1 to 6.8 m<sup>2</sup>/ha and 1,800 to 10,425 stems/ha, respectively) (Figures 4.2-1 and 4.2-2). The opposite trend was observed within the tree stratum where higher basal area and stem density were observed with increasing stand site quality (ranged from 20.1 to 27.9 m<sup>2</sup>/ha

Table 4.2-3. Mean importance values and standard error of tree stratum woody plants in the control stand (SI 15 m) at the Potts Mountain study site in Craig Co., Va. (n = 16)

| Species Code | Year      |      |           |      |
|--------------|-----------|------|-----------|------|
|              | 1977      |      | 1995      |      |
|              | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| QUEPRI       | 46.4      | 5.96 | 54.3      | 5.35 |
| PINRIG       | 21.0      | 4.91 | 13.2      | 5.20 |
| QUECOC       | 18.6      | 3.17 | 12.5      | 4.22 |
| PINVIR       | 5.6       | 3.19 | 6.0       | 3.50 |
| ACERUB       | 2.9       | 2.24 | 3.6       | 2.43 |
| NYSSYL       | 2.0       | 1.33 | 6.4       | 3.20 |
| AMEARB       | 1.1       | 0.75 | 1.8       | 0.98 |
| ROBPSE       | 0.9       | 0.92 | 0.0       | 0.0  |
| SASALB       | 0.8       | 0.55 | 0.6       | 0.63 |
| OXYARB       | 0.7       | 0.71 | 1.1       | 0.80 |
| QUEVEL       | 0.0       | 0.0  | 0.6       | 0.59 |

and 931 to 1,188 stems/ha, respectively) (Figures 4.2-3 and 4.2-4). Since the better quality stands have more available resources, the individuals on these sites have a higher productivity potential. More individuals are able to grow into the shrub stratum then into the tree stratum at a faster rate.

The inverse relationship of basal area of the tree and shrub strata with respect to stand quality would suggest that there are different limiting factors driving the growth. In the better quality stands, light becomes the controlling growth factor as the larger, faster growing individuals monopolize large proportions of the light resource and shade becomes a controlling factor below the main canopy. This prevents or reduces the potential of understory individuals from acquiring this limited resource. In contrast, in the poorer quality stands, water is the primary limiting factor. Without ample supply of water, individuals can not grow fast, therefore, they will tend to have reduced growth. In the case of this study, Meiners et al. (1984) found that the productivity of these stands was highly correlated to water availability. Since the individuals are slower growing in these poorer stands, canopy closure will take longer to occur (if it ever does), which would then make light a limiting resource.

This switch in limiting factors across stand site qualities follows a similar trend presented in a study by Gilliam and Turrill (1993). Their study on the Fernow Experimental Forest in West Virginia, attempted to discover the ecological factor that determined the development of herb layer in a young and a mature stand. They concluded that in a young stand allogenic factors (i.e., soil fertility) determine herbaceous composition, while autogenic factors (i.e., canopy closure) control the composition in a mature stand. Parallel comparisons can be made with this study because the structures of the poorer and better quality stands resemble young and mature stands, respectively.

The reestablishment of the shrub and tree strata after harvesting followed an expected pattern. The shrub stratum basal area and stem density initially increased on all stands the first few years after harvest (Figures 4.2-1 and 4.2-2). One exception to this trend occurred in the SI 12 stand, which still had an increasing basal area 17 years after harvest. Basal area and stem density reached high values of 15.4 m<sup>2</sup>/ha and 58,525 stems/ha 7 and 5 years after harvest, respectively, in the SI 18 stand. The low-peak value for basal area (8.1 m<sup>2</sup>/ha in the SI 15 stand) and stem density (15,125 stems/ha in the SI 12 stand) occurred at a stand age of 7 years. Seventeen years after harvesting, the stands returned to their initial arrangement of the highest to lowest site quality stands having the least and greatest amount of basal area and stem density in the shrub stratum (ranged from 0.4 to 9.3 m<sup>2</sup>/ha and 625 to 13,650 stems/ha, respectively).

The increase then subsequent decrease in the shrub stratum basal area and stem density occurred because of out-growth and density-induced mortality. As stated before, the higher quality stands have a faster growth rate, which leads to the tree species quickly passing through the shrub stratum. Once individuals have grown tall enough (i.e., into the

tree stratum) their growing canopies shade the entire understory, which causes density-induced mortality, especially since most of the understory species are intermediate or shade intolerant. The decreased light resources end up limiting the understory competition and reducing the survival chances of those intermediate and suppressed individuals that are at the light-compensation point.

Within the tree stratum, the relationship between the basal area/stem density and stand quality had the same arrangement before and after harvest, with the high values occurring in the SI 21 stand 5 and 7 years after harvest. High basal area ( $19.4 \text{ m}^2/\text{ha}$ ) and stem density ( $5075 \text{ stems/ha}$ ) values occurred in the SI 21 and SI 18 stands, respectively, 17 years after harvest (Figures 4.2-3 and 4.2-4). Low-peak values for basal area ( $2.0 \text{ m}^2/\text{ha}$ ) and stem density ( $794 \text{ stems/ha}$ ) occurred in the SI 12 stand at age 17 years.

By leaving a virtually undisturbed forest floor, the majority of roots most woody plants are intact, which provides a resource for a faster regeneration of the forest (Muller 1990). Since this forest was harvested using a cable yarding system, which minimizes ground disturbance, the quick regeneration of these sites should help retain more nutrient on the sites. With respect to nutrient loss due to whole-tree over bole-only harvesting on sites such as these, Rauscher (1980) predicted that the increase in depletion of soil organic matter nitrogen would be relatively little over the first three rotations. Morin (1978) predicted that the poorer quality sites undergo more critical loss of nutrients, especially calcium, due to the increased nutrient removal and extremely low calcium content of the parent material. More time, therefore, is needed to see if the tree stratum basal area will eventually return to or exceed pre-harvest levels in all stands.

Stem density in the tree stratum of each stand should also tend to continue to increase, with the SI 21 expecting to reach its high stem density first, then level off, and eventually drop slightly. The lower site quality stands should take much longer to reach their maximums and these maximums should not exceed those of the higher site quality stands. The stem density restriction is caused by a limitation in moisture availability, which in turn creates a secondary limitation of available nutrients since water aids in the weathering and mineralization processes. Morin (1978) and Meiners et al. (1984) found on these sites that the lower quality stands were typically limited by both factors, but mainly by moisture availability. As the availability of one of these factors improved so did growth. Even when one factor, such as nutrients, was low the water factor could compensate by bringing in nutrients from off site.

Mean heights and diameters were calculated for the tree stratum of each stand over the course of the study. In the pre-harvest stands, the mean tree heights were greater in the better quality stands (mean and standard errors ranged from  $10.1 \pm 0.9 \text{ m}$  to  $12.1 \pm 0.4 \text{ m}$  on SI 12 to SI 21 stands, respectively) (Figure 4.2-5). Five years after harvesting, stems started to enter the tree stratum but only in the higher quality stands. By the 7<sup>th</sup> year, all stands contained tree-sized individuals and the mean height of these trees ranged between

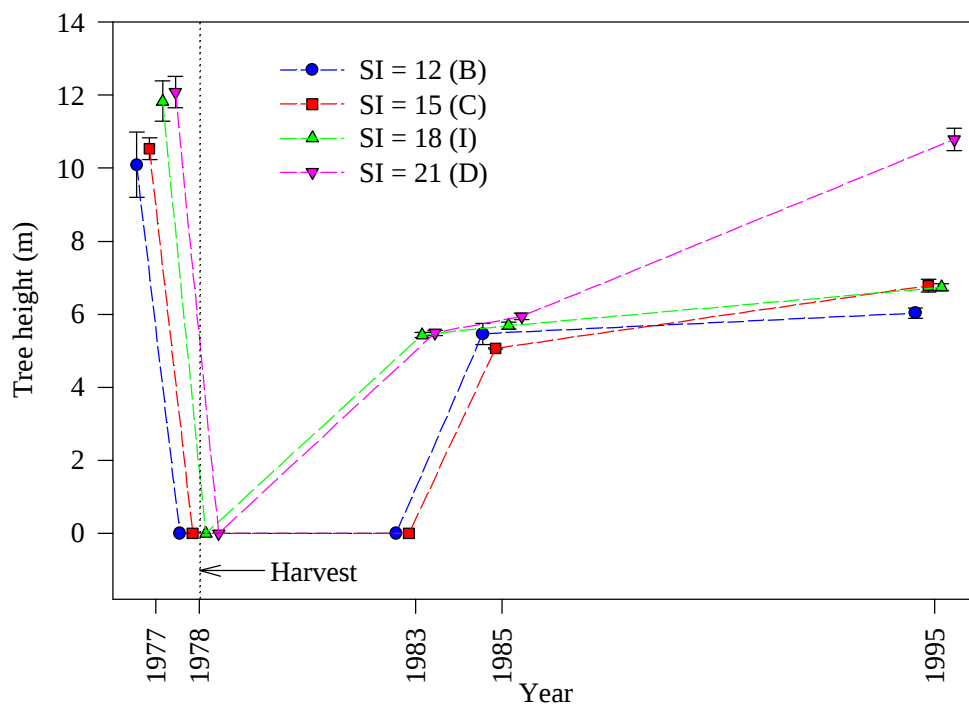


Figure 4.2-5. Tree stratum mean tree height and standard error of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (For each point n=16; capital letter in parenthesis denotes stand designated in Figure 3-1.)

5.1  $\pm$  0.1 m in the SI 15 stand to 5.9  $\pm$  0.1 m in the SI 21 stand. Seventeen years after harvesting, the SI 21 mean height (10.8  $\pm$  0.3 m) was much larger than the other three stands (mean values ranging from 6.0 to 6.8 m with standard errors  $\leq$  0.2 m).

Mean diameters did not differ greatly across the pre-harvest stands with values ranging from 14.1 to 16.3 cm with standard errors  $\leq$  1.0 cm (Figure 4.2-6). The SI 21 and SI 18 stand had the smallest and largest mean diameters. Seven years after harvesting, the mean diameter across all stands was nearly the same (means ranged from 4.3 to 4.8 cm, SE's  $\leq$  0.7 cm). Seventeen years after harvest, the SI 21 stand departed from the other stands with a much larger mean diameter of 7.6  $\pm$  0.3 cm while the other stand values ranged from 5.1 to 5.6 cm with standard errors  $\leq$  0.4 cm).

The greater growth in both height and diameter in the SI 21 stand is a result of site quality and resulting species composition. These stands are typically found adjacent to water sources, such as seeps and streams or on lower slope positions. Also, the soil associated with this stand has the deepest rooting depth of all stands, which leads to greater amounts of nutrients and a higher capacity for moisture storage (Morin 1978). As a result of the disturbance and exclusion of fire, *Liriodendron tulipifera* has established itself in this stand. On the better sites, *L. tulipifera* typically has a fast growth rate, which, in this case, has contributed greatly to the high mean height and large diameter of tree in the 17-year old, SI 21 stand.

### ***Stand Compositions and Correlation***

Stand compositions and species correlations were examined across site quality. Stand characteristics (herb stratum percent cover and species richness of all strata) were also examined across site quality. Site quality was measured two ways: by site index base age 50 for white oak (SI<sub>50</sub>) and with a Forest Site Quality Index (FSQI), which is based on topographic features of the stand (Wathen 1977). Correlations of species composition across stand qualities were performed for all strata but only herbaceous species of the herb stratum will be discussed since a majority of the woody species correlations followed the site quality distributions that have been previously established (see Burns and Honkala 1990a, 1990b). The correlations were only performed for the two measurement periods of the pre-harvest and 17-year-old stands. Many of the species' composition correlation results had r-values greater than 0.8, but most were only found in one stand with no stand replication. Therefore, only correlation r-values  $>$  0.9 will be discussed. All correlation values are presented in Appendix E.

Stand compositions across stand quality varied with grass-like and shade intolerant species predominating in the SI 12 and SI 15 stands, while shade tolerant species and ferns were most prevalent in the SI 18 and SI 21 stands, respectively. Genera and species

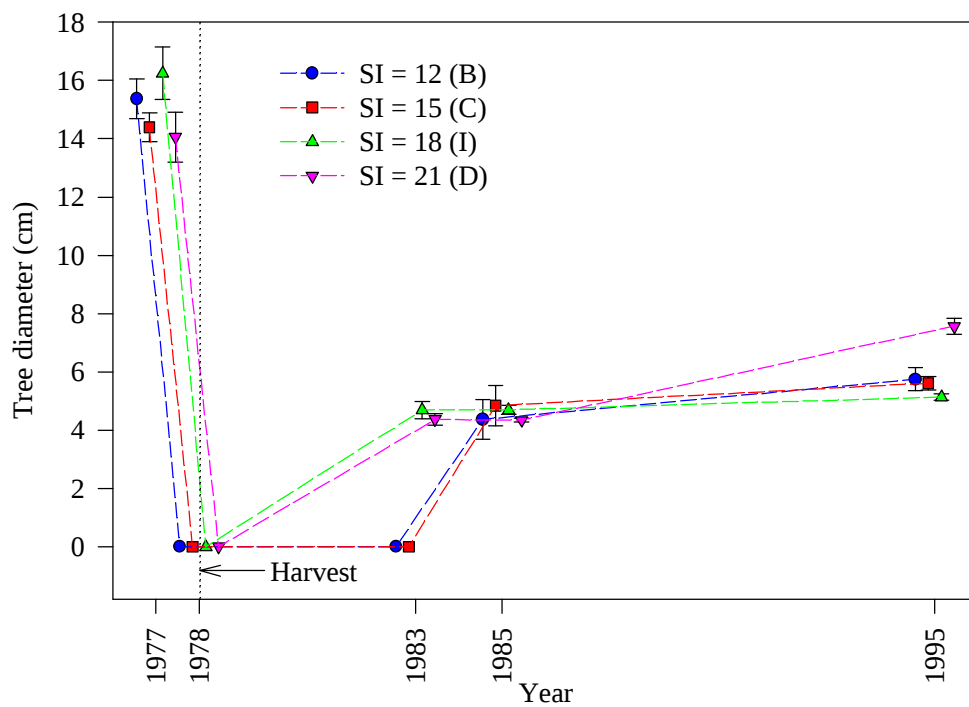


Figure 4.2-6. Tree stratum mean stem diameter and standard error of four different site quality (measured in meters) stands at the Potts Mountain study site in Craig Co., Va. (For each point  $n=16$ ; capital letter in parenthesis denotes stand designated in Figure 3-1.)

typical of the lower quality stands included *Andropogon* spp., *Coreopsis major*, *Panicum* spp., *Baptisia tinctoria*, and *Pteridium aquilinum* (Table 4.2-4). In the SI 18 stand, *Chimaphila maculata*, *Viola* spp., *Dioscorea villosa*, and *Galax aphylla* were dominant. In the SI 21 stand, *Osmunda claytoniana* and *Desmodium* spp. were the two most dominant followed by six other species that had IV values between 4 and 6% (Table 4.2-4).

In the 17-year old stands, shifts in species dominance were greater in the higher quality stands. In the three lower quality stands, at least two of the pre-harvest dominant species were once again one of the top 5 dominant species in the 17-year old stands. The SI 21 stand only retained one species from the pre-harvest dominance ranking. In the two poorer quality stands, dominant herbaceous species were grass-like (*Andropogon* spp., *Panicum* spp. and *Carex* spp.) except for *Chimaphila maculata* in the SI 15 stand (Table 4.2-4). In the two higher quality stands, the dominant species were still understory, shade-tolerant and -philic species (*Chimaphila maculata*, *Dioscorea villosa*, *Osmunda claytoniana*, and *Viola* spp.), but increases also occurred in the Poaceae family (*Panicum* spp. and *Carex* spp.). Canopy removal increased forest floor light which improved the growing conditions for the generally shade intolerant grass-like species. Shade tolerant species showed mixed responses to the changed stand microclimates.

Across all stands, the presence of herbaceous species increased from pre-harvest to the 17-year old stands. In the pre-harvest stands, herbaceous species were found in 50% of the sampling subplots in the SI 12 stand, 62.5% in the SI 15 and SI 18 stands, and 80% of the SI 21 stand. In the 17-year old stands, these value increased to 90% in the SI 12 stand and 85% in the rest of the stands. Evidently, the open canopy created conditions that allowed many different species to take advantage of the new microclimates.

When herbaceous species abundance was correlated with site index and Forest Site Quality Index (FSQI) only five species were found to significantly ( $\alpha = 0.10$ ) correlate with either of these indices (Appendix F). Across the pre-harvest stands, site index correlated negatively with *Andropogon* spp. ( $r$ -value = -0.923,  $P$ -value = 0.08,  $n = 4$ ) and *Coreopsis major* ( $r = -0.940$ ,  $P = 0.06$ ,  $n = 4$ ), and positively with *Viola* spp. ( $r = 0.902$ ,  $P = 0.10$ ,  $n = 4$ ). In the 17-year old stands, site index correlated negatively with *Andropogon* spp. ( $r = -0.922$ ,  $P = 0.08$ ,  $n = 4$ ) and *Panicum* spp. ( $r = -0.949$ ,  $P = 0.05$ ,  $n = 4$ ). Additionally in the 17-year old stands, FSQI correlated negatively with *Panicum* spp. ( $r = -0.983$ ,  $P = 0.02$ ,  $n = 4$ ) and positively with *Rubus* spp. ( $r = 0.917$ ,  $P = 0.08$ ,  $n = 4$ ) and *Viola* spp. ( $r = 0.923$ ,  $P = 0.08$ ,  $n = 4$ ). Since the lower quality stands have a more open canopy, the shade intolerant species (*Andropogon* spp., *Coreopsis major*, and *Panicum* spp.) are more prevalent. *Rubus* spp. are early disturbance species usually found in more mesic stands. *Viola* spp. tend to be found across all sites but are most prominent in mesic stand conditions.

Table 4.2-4. Mean relative percent cover and standard error for herbaceous plants in the herb stratum for each stand quality at the Potts Mountain study site in Craig Co., Va. (n = 40)

| SI 12 m (H) |           |         |           |      | SI 15 m (C) |           |         |           |      | SI 18 m (I) |           |         |           |        | SI 21 m (D) |           |         |           |      |
|-------------|-----------|---------|-----------|------|-------------|-----------|---------|-----------|------|-------------|-----------|---------|-----------|--------|-------------|-----------|---------|-----------|------|
| Pre-harvest |           | 17-year |           |      | Pre-harvest |           | 17-year |           |      | Pre-harvest |           | 17-year |           |        | Pre-harvest |           | 17-year |           |      |
| Spp. Code   | $\bar{X}$ | SE      | $\bar{X}$ | SE   | Spp. Code   | $\bar{X}$ | SE      | $\bar{X}$ | SE   | Spp. Code   | $\bar{X}$ | SE      | $\bar{X}$ | SE     | Spp. Code   | $\bar{X}$ | SE      | $\bar{X}$ | SE   |
| ANDSPP      | 11.5      | 3.62    | 19.3      | 3.49 | PTEAQU      | 13.7      | 4.99    | 9.2       | 3.91 | CHIMAC      | 28.8      | 6.91    | 34.0      | 5.49   | OSMCLA      | 21.0      | 5.52    | 8.6       | 3.84 |
| CORMAJ      | 10.3      | 3.49    | 11.8      | 2.22 | PANSPP      | 11.4      | 3.61    | 15.0      | 4.02 | VIOSPP      | 11.3      | 4.56    | 6.9       | 3.06   | DESSPP      | 14.7      | 5.35    | 0.0       | 0.00 |
| PANSPP      | 9.5       | 3.79    | 23.9      | 2.79 | CHIMAC      | 8.8       | 4.34    | 26.5      | 5.32 | DIOVIL      | 10.0      | 3.67    | 9.3       | 3.87   | ATHFIL      | 5.9       | 2.83    | 4.8       | 2.67 |
| GALAPH      | 5.8       | 3.56    | 0.0       | 0.00 | CORMAJ      | 7.9       | 3.37    | 4.0       | 1.98 | GALAPH      | 8.8       | 3.96    | 3.2       | 2.32   | DIOVIL      | 5.7       | 2.87    | 3.8       | 2.77 |
| BAPTIN      | 4.7       | 2.99    | 0.6       | 0.45 | ANDSPP      | 6.4       | 2.99    | 11.0      | 3.94 | PANSPP      | 1.3       | 1.25    | 17.3      | 4.19   | CHIMAC      | 5.1       | 2.73    | 0.0       | 0.00 |
| VIOSPP      | 1.9       | 1.38    | 1.7       | 0.84 | UVUPUD      | 3.3       | 2.61    | 0.8       | 0.83 | ASTER       | 1.3       | 1.25    | 0.0       | 0.00   | OSMCIN      | 4.9       | 2.62    | 3.0       | 1.77 |
| CARSPP      | 1.3       | 1.25    | 10.7      | 2.22 | POTCAN      | 2.5       | 2.50    | 0.0       | 0.00 | UVUPUD      | 1.3       | 1.25    | 0.0       | 0.00   | CARSPP      | 4.4       | 2.63    | 7.2       | 2.30 |
| CHIMAC      | 0.8       | 0.83    | 9.8       | 2.96 | AURLAE      | 1.5       | 1.03    | 0.0       | 0.00 | LYSQUA      | 0.0       | 0.00    | 4.9       | 1.83   | VIOSPP      | 4.3       | 1.31    | 12.8      | 4.05 |
| IRIVER      | 0.8       | 0.83    | 3.3       | 1.44 | BAPTIN      | 1.3       | 1.25    | 2.9       | 1.68 | CARSPP      | 0.0       | 0.00    | 4.8       | 2.83   | THENOV      | 2.9       | 1.75    | 0.0       | 0.00 |
| ASTER       | 0.8       | 0.83    | 2.5       | 0.99 | EPIREP      | 1.3       | 1.25    | 1.9       | 1.38 | CORMAJ      | 0.0       | 0.00    | 2.3       | 1.43   | ASTER       | 2.5       | 2.50    | 1.7       | 1.28 |
| EPIREP      | 0.8       | 0.83    | 1.7       | 1.16 | ASCVIR      | 1.3       | 1.25    | 0.0       | 0.00 | POLBIF      | 0.0       | 0.00    | 1.3       | 1.25   | PRESPP      | 1.4       | 0.64    | 1.6       | 0.96 |
| TEPVIR      | 0.8       | 0.83    | 1.5       | 1.14 | HIEVEN      | 1.0       | 0.71    | 1.3       | 0.87 | RUBSPP      | 0.0       | 0.00    | 0.6       | 0.63   | GALAPH      | 1.4       | 1.25    | 0.0       | 0.00 |
| HIEVEN      | 0.5       | 0.50    | 0.6       | 0.45 | IRIVER      | 0.8       | 0.83    | 7.9       | 3.32 | CYPACA      | 0.0       | 0.00    | 0.5       | 0.50   | UVUPUD      | 1.2       | 0.59    | 1.7       | 1.31 |
| PTEAQU      | 0.4       | 0.42    | 0.0       | 0.00 | ASTER       | 0.8       | 0.83    | 1.7       | 1.16 |             |           |         |           | MEDVIR | 1.0         | 0.49      | 0.4     | 0.36      |      |
| DANSPP      | 0.0       | 0.00    | 0.9       | 0.61 | HYPHIR      | 0.4       | 0.36    | 0.0       | 0.00 |             |           |         |           | POLBIF | 0.9         | 0.69      | 0.0     | 0.00      |      |
| LESSPP      | 0.0       | 0.00    | 0.8       | 0.57 | VIOSPP      | 0.4       | 0.36    | 0.0       | 0.00 |             |           |         |           | ISOVER | 0.8         | 0.83      | 0.0     | 0.00      |      |
| GILTRI      | 0.0       | 0.00    | 0.6       | 0.63 | CARSPP      | 0.0       | 0.00    | 2.3       | 1.30 |             |           |         |           | POASPP | 0.6         | 0.44      | 7.4     | 3.04      |      |
| UVUPUD      | 0.0       | 0.00    | 0.4       | 0.36 | LUZSPP      | 0.0       | 0.00    | 0.6       | 0.63 |             |           |         |           | HYPHIR | 0.5         | 0.38      | 0.5     | 0.34      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | SMIRAC | 0.4         | 0.36      | 0.0     | 0.00      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | CYSFRA | 0.2         | 0.20      | 0.0     | 0.00      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | PANSPP | 0.1         | 0.14      | 10.9    | 4.36      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | BARVER | 0.0         | 0.00      | 5.7     | 2.81      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | HOUCAE | 0.0         | 0.00      | 5.3     | 2.82      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | MONUNI | 0.0         | 0.00      | 4.6     | 2.86      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | DANSPP | 0.0         | 0.00      | 1.4     | 0.70      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | GEUSPP | 0.0         | 0.00      | 1.1     | 0.62      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | RUBSPP | 0.0         | 0.00      | 0.9     | 0.54      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | ANDSPP | 0.0         | 0.00      | 0.5     | 0.50      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | LUZSPP | 0.0         | 0.00      | 0.5     | 0.50      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | LOBINF | 0.0         | 0.00      | 0.5     | 0.34      |      |
|             |           |         |           |      |             |           |         |           |      |             |           |         |           | HYPHYP | 0.0         | 0.00      | 0.3     | 0.28      |      |

The pre-harvest woody species in the herb stratum were dominated by the ericaceous species *Vaccinium* spp., *Kalmia latifolia*, *Rhododendron nudiflorum*, and *Gaylussacia baccata* in the two lower quality stands. A mixture of these ericaceous species comprised > 68% relative cover in these stands (Table 4.2-5). The SI 18 stand was characterized as a transition stand with a mixture of ericaceous and hardwood species. *Rhododendron nudiflorum*, *Vaccinium* spp., *Quercus prinus*, and *Sassafras albidum* were main component of the SI 18 stand with > 75% relative cover. The composition SI 21 stand shifted more towards the hardwood species and had a more even distribution of dominance. This stand was dominated by *Acer rubrum*, *Cornus florida*, *Smilax rotundifolia*, *Rhododendron nudiflorum*, *Nyssa sylvatica*, and *Sassafras albidum*, which comprised  $\approx$  70% of the relative cover (Table 4.2-5).

The 17-year-old SI 12 and SI 15 stands were also dominated by the ericaceous species but at an equal or lower relative percent cover. In these two lower quality stands, the ericaceous species constituted over 60% of the relative cover (Table 4.2-5). The SI 18 stand was again a transition stand with *Q. prinus* and *S. albidum* being two of the top four dominant species along with the ericaceous species *R. nudiflorum* and *Vaccinium pallidum*. Two other species, *Acer rubrum* and *Vitis* spp., became prevalent components of the SI 18 stand with importance values of  $\approx$  10%. The SI 21 stand, virtually void of ericaceous species, had *A. rubrum*, *S. albidum*, and *S. rotundifolia* as the most prevalent species consisting of > 70% of the relative cover (Table 4.2-5). Additionally, *Cornus florida* was virtually extirpated from herb stratum of the SI 21 site.

For both woody and herbaceous species in the herb stratum, species richness increased in three of the four stands (Tables 4.2-4 and 4.2-5). The exceptions occurred in the SI 15 stand for the herbaceous plants, and the SI 21 stand for the woody plants. The SI 21 stand also had the most number of species when the pre-harvest and 17-year data were combined for both the woody and herbaceous plants. This would suggest that species composition on the highest quality stand is more sensitive to disturbances than the other stand.

In the shrub stratum, similar composition trends to the woody species of the herb stratum were observed. In the pre-harvest stands, the ericaceous species of *K. latifolia* and/or *R. nudiflorum* were most prevalent in the two lower quality sites, followed by *S. albidum* and *N. sylvatica* (Tables 4.2-6 and 4.2-7). The SI 18 stand, a transitional stand between ericaceous and hardwood species, was dominated by *S. albidum*, *N. sylvatica*, and *R. nudiflorum* (Table 4.2-8). The SI 21 stand was dominated by *N. sylvatica*, *A. rubrum*, and *C. florida* (Table 4.2-9). Accumulative importance values of four species in each of the SI 15 and SI 21 stands, and five species in each of the SI 40 and SI 18 stands were needed to generate a sum greater than 80% (Tables 4.2-6 through 4.2-9).

In the shrub stratum of the 17-year old stands, species' dominance ranking shifted moderately in the three lower quality stands, while larger changes occurred in the SI 21

Table 4.2-5. Mean relative percent cover and standard error for woody plants in the herb stratum for each stand quality at the Potts Mountain study site in Craig Co., Va. (n = 40)

| SI 12 m (H) |             |      |           |      | SI 15 m (C) |             |      |           |      | SI 18 m (I) |             |      |           |      | SI 21 m (D) |             |      |           |      |
|-------------|-------------|------|-----------|------|-------------|-------------|------|-----------|------|-------------|-------------|------|-----------|------|-------------|-------------|------|-----------|------|
| Spp. Code   | Pre-harvest |      | 17-year   |      | Spp. Code   | Pre-harvest |      | 17-year   |      | Spp. Code   | Pre-harvest |      | 17-year   |      | Spp. Code   | Pre-harvest |      | 17-year   |      |
|             | $\bar{X}$   | SE   | $\bar{X}$ | SE   |             | $\bar{X}$   | SE   | $\bar{X}$ | SE   |             | $\bar{X}$   | SE   | $\bar{X}$ | SE   |             | $\bar{X}$   | SE   | $\bar{X}$ | SE   |
| KALLAT      | 21.5        | 2.99 | 16.2      | 3.81 | VACPAL      | 28.4        | 3.27 | 20.4      | 2.18 | RHONUD      | 22.6        | 4.12 | 15.8      | 2.44 | ACERUB      | 17.7        | 3.02 | 33.7      | 3.31 |
| VACPAL      | 21.2        | 2.08 | 32.2      | 3.27 | GAYBAC      | 20.8        | 4.10 | 17.9      | 2.37 | VACPAL      | 21.6        | 3.43 | 18.9      | 2.08 | CORFLO      | 13.3        | 3.58 | 0.8       | 0.83 |
| RHONUD      | 15.7        | 3.40 | 10.5      | 2.73 | KALLAT      | 12.5        | 2.91 | 10.8      | 2.25 | QUEPRI      | 18.0        | 2.56 | 10.8      | 1.79 | SMIROT      | 10.4        | 2.49 | 12.0      | 2.49 |
| SASALB      | 10.1        | 1.95 | 14.3      | 2.15 | VACSTA      | 10.9        | 3.39 | 4.8       | 1.93 | SASALB      | 10.7        | 1.22 | 13.6      | 1.71 | RHONUD      | 10.4        | 2.46 | 0.8       | 0.83 |
| GAYBAC      | 8.3         | 2.30 | 9.6       | 2.27 | SMIGLA      | 6.8         | 0.80 | 11.5      | 1.73 | QUECOC      | 4.9         | 2.50 | 3.8       | 1.35 | NYSSYL      | 9.5         | 2.08 | 5.2       | 1.96 |
| NYSSYL      | 6.6         | 1.65 | 4.5       | 1.33 | SASALB      | 5.9         | 0.80 | 11.8      | 2.09 | CASDEN      | 3.4         | 1.86 | 0.0       | 0.00 | SASALB      | 8.5         | 1.96 | 25.0      | 3.77 |
| SMIGLA      | 4.6         | 1.13 | 2.4       | 0.56 | QUECOC      | 5.7         | 2.14 | 1.8       | 0.89 | CORFLO      | 3.1         | 1.50 | 1.0       | 0.74 | SMIGLA      | 7.1         | 1.81 | 6.0       | 1.67 |
| QUECOC      | 2.5         | 1.04 | 1.8       | 1.13 | QUEPRI      | 2.8         | 1.25 | 3.7       | 1.15 | VACSTA      | 3.1         | 1.18 | 4.7       | 1.68 | ROBPSE      | 4.3         | 3.02 | 1.0       | 0.74 |
| ACERUB      | 1.8         | 0.76 | 1.6       | 0.46 | NYSSYL      | 2.3         | 1.30 | 4.6       | 1.18 | NYSSYL      | 2.5         | 1.26 | 2.5       | 1.19 | QUEPRI      | 4.2         | 1.40 | 0.6       | 0.63 |
| CASDEN      | 1.4         | 0.98 | 1.2       | 0.83 | RHONUD      | 2.2         | 0.84 | 6.2       | 1.75 | ACERUB      | 2.3         | 0.88 | 10.3      | 1.45 | CARGLA      | 1.9         | 0.82 | 2.1       | 1.07 |
| QUEPRI      | 1.3         | 0.58 | 1.0       | 0.58 | PINRIG      | 0.9         | 0.55 | 0.0       | 0.00 | KALLAT      | 2.1         | 0.75 | 4.2       | 1.55 | QUECOC      | 1.9         | 0.92 | 0.0       | 0.00 |
| HAMVIR      | 1.3         | 0.66 | 1.9       | 0.64 | PINPUN      | 0.7         | 0.54 | 0.0       | 0.00 | GAYBAC      | 1.8         | 1.65 | 0.0       | 0.00 | OXYARB      | 1.8         | 1.49 | 0.0       | 0.00 |
| QUEVEL      | 1.1         | 0.87 | 0.0       | 0.00 | QUEILI      | 0.1         | 0.06 | 1.6       | 1.08 | VITSPP      | 1.7         | 1.01 | 9.9       | 1.73 | VACPAL      | 1.6         | 1.04 | 0.0       | 0.00 |
| VACSTA      | 1.0         | 0.63 | 0.0       | 0.00 | ACERUB      | 0.0         | 0.00 | 1.9       | 1.05 | CARTOM      | 1.2         | 0.86 | 0.0       | 0.00 | VIBACE      | 1.6         | 1.15 | 0.0       | 0.00 |
| PINRIG      | 0.6         | 0.46 | 0.4       | 0.32 | VITSPP      | 0.0         | 0.00 | 1.7       | 0.65 | SMIGLA      | 0.5         | 0.30 | 1.4       | 0.65 | KALLAT      | 1.4         | 0.83 | 0.0       | 0.00 |
| AMEARB      | 0.5         | 0.50 | 0.0       | 0.00 | QUEVEL      | 0.0         | 0.00 | 0.6       | 0.33 | ROBPSE      | 0.4         | 0.36 | 0.6       | 0.63 | QUEVEL      | 1.1         | 0.87 | 0.0       | 0.00 |
| SMIROT      | 0.3         | 0.32 | 0.0       | 0.00 | RHUCOP      | 0.0         | 0.00 | 0.4       | 0.25 | QUEVEL      | 0.3         | 0.28 | 0.2       | 0.21 | VITSPP      | 0.6         | 0.63 | 1.7       | 0.85 |
| ROBPSE      | 0.0         | 0.00 | 1.0       | 0.61 | ACEPEN      | 0.0         | 0.00 | 0.2       | 0.16 | ACEPEN      | 0.0         | 0.00 | 1.1       | 0.55 | CASDEN      | 0.6         | 0.63 | 0.0       | 0.00 |
| CARGLA      | 0.0         | 0.00 | 0.4       | 0.42 | CASDEN      | 0.0         | 0.00 | 0.2       | 0.14 | CARGLA      | 0.0         | 0.00 | 0.4       | 0.42 | PRUSER      | 0.6         | 0.63 | 0.0       | 0.00 |
| VITSPP      | 0.0         | 0.00 | 0.4       | 0.20 |             |             |      |           |      | ILEVER      | 0.0         | 0.00 | 0.3       | 0.31 | HAMVIR      | 0.6         | 0.40 | 2.5       | 1.50 |
| LIRTUL      | 0.0         | 0.00 | 0.3       | 0.19 |             |             |      |           |      | SMIROT      | 0.0         | 0.00 | 0.3       | 0.28 | ILEVER      | 0.3         | 0.31 | 1.0       | 0.74 |
| CARTOM      | 0.0         | 0.00 | 0.2       | 0.20 |             |             |      |           |      |             |             |      |           |      | AMEARB      | 0.3         | 0.25 | 0.6       | 0.63 |
| PINVIR      | 0.0         | 0.00 | 0.2       | 0.16 |             |             |      |           |      |             |             |      |           |      | HYDARB      | 0.3         | 0.25 | 0.0       | 0.00 |
|             |             |      |           |      |             |             |      |           |      |             |             |      |           |      | QUEALB      | 0.0         | 0.00 | 1.1       | 0.79 |
|             |             |      |           |      |             |             |      |           |      |             |             |      |           |      | GAYBAC      | 0.0         | 0.00 | 0.6       | 0.63 |

Table 4.2-6. Mean importance values and standard errors of shrub stratum woody plants in the SI 12 (H) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |
|--------------|-------------------|------|-----------|------|
|              | Pre-harvest       |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   |
| KALLAT       | 39.3              | 4.90 | 37.4      | 3.93 |
| RHONUD       | 15.0              | 5.63 | 9.7       | 3.79 |
| NYSSYL       | 11.7              | 2.99 | 13.0      | 2.07 |
| SASALB       | 10.9              | 2.11 | 18.7      | 3.67 |
| QUECOC       | 6.5               | 3.57 | 4.0       | 1.96 |
| PINRIG       | 5.3               | 3.15 | 0.0       | 0.00 |
| HAMVIR       | 4.5               | 2.56 | 7.7       | 2.83 |
| QUEVEL       | 2.5               | 2.21 | 2.5       | 1.42 |
| QUEPRI       | 1.8               | 1.26 | 0.4       | 0.44 |
| CASDEN       | 1.2               | 0.61 | 0.7       | 0.42 |
| PINECH       | 0.9               | 0.95 | 0.0       | 0.00 |
| ACERUB       | 0.2               | 0.20 | 2.8       | 1.04 |
| GAYBAC       | 0.1               | 0.12 | 0.0       | 0.00 |
| AMEARB       | 0.0               | 0.00 | 1.8       | 1.65 |
| QUEILI       | 0.0               | 0.00 | 0.4       | 0.44 |
| LIRTUL       | 0.0               | 0.00 | 0.3       | 0.19 |
| ROBPSE       | 0.0               | 0.00 | 0.3       | 0.26 |
| ACEPEN       | 0.0               | 0.00 | 0.1       | 0.10 |

Table 4.2-7. Mean importance value and standard error of shrub stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |       | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| KALLAT       | 36.7              | 5.04 | 50.8      | 11.49 | 1.6       | 0.83 | 1.9       | 0.91 | 6.8       | 1.84 | 22.6      | 3.82 |
| SASALB       | 24.2              | 4.71 | 5.5       | 3.36  | 18.5      | 4.54 | 35.3      | 5.85 | 34.8      | 5.76 | 40.6      | 4.78 |
| NYSSYL       | 8.9               | 3.80 | 0.0       | 0.00  | 17.9      | 5.09 | 14.7      | 4.12 | 11.3      | 3.41 | 10.7      | 4.54 |
| GAYBAC       | 7.6               | 2.20 | 0.0       | 0.00  | 1.5       | 1.38 | 0.1       | 0.13 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 6.4               | 3.09 | 11.2      | 6.88  | 21.4      | 5.64 | 17.4      | 5.39 | 18.0      | 5.04 | 7.6       | 2.15 |
| QUEPRI       | 5.3               | 2.56 | 7.4       | 4.76  | 28.5      | 7.42 | 20.5      | 5.03 | 21.1      | 5.21 | 5.5       | 3.47 |
| VACSTA       | 5.2               | 1.66 | 0.0       | 0.00  | 1.4       | 0.89 | 1.1       | 0.57 | 1.3       | 0.73 | 2.5       | 2.33 |
| QUEVEL       | 3.1               | 2.64 | 0.0       | 0.00  | 3.8       | 1.83 | 3.0       | 1.33 | 1.5       | 1.04 | 1.0       | 1.04 |
| QUEILI       | 1.9               | 1.24 | 0.0       | 0.00  | 0.6       | 0.48 | 2.2       | 1.39 | 1.3       | 0.79 | 4.6       | 2.35 |
| CASDEN       | 0.8               | 0.53 | 0.0       | 0.00  | 2.9       | 1.61 | 1.3       | 0.75 | 0.7       | 0.37 | 0.0       | 0.00 |
| RHONUD       | 0.0               | 0.00 | 6.3       | 6.25  | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.09 | 0.4       | 0.42 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 2.0       | 1.95 | 1.9       | 1.89 | 2.1       | 1.80 | 2.6       | 1.65 |
| PINPUN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.6       | 0.33 | 0.8       | 0.43 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.3       | 0.22 | 1.2       | 0.84 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.6       | 0.50 |

Table 4.2-8. Mean importance value and standard error of shrub stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| SASALB       | 28.1              | 7.55 | 6.0       | 2.52 | 55.9      | 4.78 | 45.7      | 4.65 | 41.4      | 4.04 | 18.3      | 5.33 |
| NYSSYL       | 13.5              | 5.43 | 2.2       | 2.20 | 6.3       | 1.53 | 6.8       | 2.03 | 7.1       | 2.22 | 15.0      | 4.13 |
| RHONUD       | 10.4              | 3.97 | 7.4       | 2.97 | 2.5       | 1.51 | 9.0       | 3.47 | 10.6      | 3.62 | 8.5       | 4.44 |
| ROBPSE       | 9.3               | 6.39 | 3.2       | 1.72 | 1.9       | 0.79 | 0.9       | 0.41 | 0.6       | 0.29 | 0.0       | 0.00 |
| QUEPRI       | 9.2               | 3.93 | 24.0      | 8.99 | 18.5      | 3.22 | 23.6      | 2.52 | 25.2      | 2.25 | 37.9      | 5.40 |
| CASDEN       | 8.9               | 2.42 | 24.5      | 8.63 | 5.5       | 1.90 | 2.7       | 0.92 | 2.1       | 1.12 | 1.0       | 0.60 |
| CARGLA       | 4.6               | 3.94 | 0.0       | 0.00 | 0.8       | 0.68 | 0.7       | 0.40 | 0.9       | 0.48 | 1.2       | 0.65 |
| CORFLO       | 3.9               | 2.29 | 4.5       | 2.91 | 1.6       | 0.58 | 3.9       | 1.67 | 4.6       | 1.75 | 6.1       | 2.96 |
| QUECOC       | 1.5               | 0.89 | 0.2       | 0.23 | 3.9       | 1.30 | 3.8       | 1.23 | 4.1       | 1.38 | 1.9       | 0.89 |
| GAYBAC       | 1.4               | 1.40 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| KALLAT       | 1.3               | 0.98 | 0.3       | 0.28 | 0.2       | 0.15 | 0.2       | 0.16 | 0.7       | 0.50 | 4.2       | 1.98 |
| QUEVEL       | 1.1               | 1.10 | 2.1       | 2.13 | 0.5       | 0.47 | 0.5       | 0.41 | 0.1       | 0.04 | 0.0       | 0.00 |
| ACERUB       | 0.7               | 0.50 | 6.9       | 6.24 | 2.0       | 0.57 | 1.7       | 0.48 | 2.1       | 0.54 | 4.4       | 1.90 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00 | 0.2       | 0.12 | 0.1       | 0.08 | 0.2       | 0.12 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.12 | 0.1       | 0.11 | 0.1       | 0.14 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00 | < 0.1     | 0.02 | 0.1       | 0.07 | 0.1       | 0.07 | 0.3       | 0.33 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.08 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUERUB       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.04 | 0.0       | 0.00 |
| PRUSER       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.03 | 0.0       | 0.00 |
| ILEMON       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.9       | 0.87 |
| ACESAC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.3       | 0.31 |

Table 4.2-9. Mean importance value and standard error of shrub stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| NYSSYL       | 25.2              | 9.17 | 1.7       | 1.71 | 19.5      | 5.07 | 18.0      | 4.32 | 18.3      | 4.63 | 16.5      | 7.30 |
| ACERUB       | 22.9              | 9.79 | 17.5      | 9.48 | 21.5      | 5.67 | 18.8      | 4.62 | 14.7      | 3.27 | 18.8      | 8.71 |
| CORFLO       | 15.0              | 6.81 | 0.0       | 0.00 | 12.5      | 3.45 | 14.2      | 3.33 | 18.8      | 3.95 | 0.0       | 0.00 |
| RHONUD       | 7.5               | 4.29 | 0.0       | 0.00 | 0.0       | 0.00 | 2.0       | 1.22 | 2.4       | 1.34 | 0.0       | 0.00 |
| SASALB       | 5.7               | 4.03 | 0.0       | 0.00 | 23.2      | 5.46 | 27.0      | 5.92 | 28.0      | 5.72 | 0.0       | 0.00 |
| OXYARB       | 5.6               | 3.61 | 6.3       | 6.25 | 7.3       | 4.51 | 4.5       | 2.29 | 3.6       | 1.98 | 8.1       | 5.70 |
| CARGLA       | 5.0               | 3.70 | 0.0       | 0.00 | 0.0       | 0.00 | 0.7       | 0.74 | 0.9       | 0.91 | 1.2       | 1.24 |
| AMEARB       | 2.7               | 2.68 | 0.0       | 0.00 | 0.1       | 0.05 | 0.3       | 0.28 | 0.4       | 0.43 | 0.0       | 0.00 |
| CASDEN       | 1.9               | 1.29 | 6.3       | 6.25 | 1.3       | 0.74 | 0.5       | 0.33 | 0.4       | 0.27 | 0.0       | 0.00 |
| ACEPEN       | 1.7               | 1.69 | 0.0       | 0.00 | 0.2       | 0.18 | 0.3       | 0.26 | 0.8       | 0.81 | 0.0       | 0.00 |
| QUEPRI       | 0.6               | 0.61 | 1.2       | 1.22 | 3.3       | 1.74 | 3.3       | 1.79 | 0.8       | 0.42 | 0.0       | 0.00 |
| ROBPSE       | 0.0               | 0.00 | 10.8      | 7.47 | 8.3       | 2.73 | 4.7       | 1.79 | 1.8       | 0.76 | 0.0       | 0.00 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00 | 0.9       | 0.89 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00 | 0.8       | 0.34 | 1.9       | 0.45 | 3.3       | 0.79 | 10.7      | 7.43 |
| HAMVIR       | 0.0               | 0.00 | 0.0       | 0.00 | 0.6       | 0.31 | 1.1       | 0.55 | 2.1       | 1.03 | 12.1      | 7.10 |
| BETLEN       | 0.0               | 0.00 | 0.0       | 0.00 | 0.5       | 0.50 | 2.3       | 1.01 | 3.6       | 1.40 | 0.0       | 0.00 |
| QUEVEL       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.07 | 0.1       | 0.10 | 0.1       | 0.07 | 0.0       | 0.00 |
| HYDARB       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.13 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.12 | 0.1       | 0.15 | 0.0       | 0.00 |
| VIBACE       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.09 | 0.0       | 0.00 | 0.0       | 0.00 |
| ACESAC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 1.4       | 1.36 |

stand. *Sassafras albidum* virtually doubled in IV in the SI 12 and SI 15 stands, with *K. latifolia*, *R. nudiflorum*, and/or *N. sylvatica* being the other dominant species (Tables 4.2-6 and 4.2-7). Dominance in the SI 18 stand changed to *Q. prinus* (the fifth most dominant species pre-harvest), which became the most prominent followed by *S. albidum*, *N. sylvatica*, and *R. nudiflorum* (Table 4.2-8). The species composition changes in the SI 21 stand were very obvious with *A. rubrum*, *N. sylvatica*, *Hamamelis virginiana*, *O. arboreum*, and *L. tulipifera* becoming the dominant species (Table 4.2-9). As with the pre-harvest stands, accumulative IV of four species in the SI 15 and SI 21 stands, and five species in the SI 40 and SI 18 stands were needed to eclipse an 80% level (Tables 4.2-6 through 4.2-9). Species richness remained the same or increased on all stand qualities except for the highest site quality (Tables 4.2-6 through 4.2-9).

With respect to woody species in the herb and shrub strata, ericaceous species were the most prevalent in the poorer quality stands due to their superior competitive ability on these sites. The SI 18 stand is a transition point in which other species begin to effectively compete with the ericaceous species for the limited resources. In the SI 21 stand, the growing conditions were good enough to allow other species to out compete the ericaceous species. The clearcutting disturbance has increased the proportion of intolerant, pioneer species in the understory, but has not greatly changed the overall composition of the stands.

Two other shifts of woody species in the understory are of importance to note. First, *Sassafras albidum* increased in dominance in all stands in the herb stratum and in the two lower quality sites of the shrub stratum after harvest (Tables 4.2-5 through 4.2-7). The prolific root sprouting ability of this plant, especially after a disturbance, and high competitive ability on poorer quality sites have prompted the increase. Secondly, *Cornus florida* was virtually eliminated from the highest quality site (Tables 4.2-5 and 4.2-9). In the early stages of stand redevelopment, *C. florida* maintained > 10% IV in the shrub stratum, but by the 17<sup>th</sup> year it was no longer found. This decrease was probably caused by the fungus Dogwood anthracnose (*Discula sp.*). In young, open stands the understory receives an abundance of light and the environment is usually drier and hotter when compared to an older stand. As the stand ages and forms a closed canopy, the understory conditions change to a more cool, moist environment where the anthracnose thrives (Mielke and Daugherty 1988).

Stand composition response to the clearcut disturbance in the tree stratum was different for the lower and higher quality stands. Pre-harvest composition in the SI 12 and SI 15 stands found that *Q. prinus*, *Q. coccinea*, and *P. rigida* were the dominant species (Tables 4.2-10 and 4.2-11). In the SI 18 stand, *Q. prinus*, *Q. coccinea*, and *Q. velutina* were the dominant species, while in the SI 21 stand *A. rubrum*, *Q. prinus*, and *O. arboreum* were dominant (Tables 4.2-12 and 4.2-13). To exceed 80% in IV, three species were needed in the SI 12 and SI 18 stands, two species in the SI 15 stand, and 4 species in the SI 21 stand (Tables 4.2-10 and 4.2-13).

Table 4.2-10. Mean importance values and standard errors of tree stratum woody plants in the SI 12 (H) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |
|--------------|-------------------|------|-----------|------|
|              | Pre-harvest       |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   |
| QUECOC       | 31.1              | 5.33 | 39.8      | 8.33 |
| QUEPRI       | 30.4              | 5.44 | 47.9      | 8.38 |
| PINRIG       | 29.8              | 5.01 | 0.0       | 0.00 |
| QUEVEL       | 5.2               | 2.10 | 4.3       | 2.97 |
| NYSSYL       | 2.8               | 1.11 | 1.7       | 1.68 |
| ACERUB       | 0.4               | 0.36 | 2.0       | 1.06 |
| CASDEN       | 0.3               | 0.29 | 0.8       | 0.55 |
| ROBPSE       | 0.0               | 0.00 | 2.2       | 1.71 |
| SASALB       | 0.0               | 0.00 | 0.7       | 0.67 |
| HAMVIR       | 0.0               | 0.00 | 0.6       | 0.65 |

Table 4.2-11. Mean importance value and standard error of tree stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |       |           |      |
|--------------|-------------------|------|-----------|------|-----------|-------|-----------|------|
|              | Pre-harvest       |      | 5         |      | 7         |       | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   |
| QUECOC       | 42.9              | 4.76 | 0.0       | 0.00 | 2.7       | 2.73  | 39.2      | 4.40 |
| QUEPRI       | 41.2              | 4.82 | 0.0       | 0.00 | 22.3      | 10.25 | 52.0      | 6.11 |
| PINRIG       | 8.2               | 2.41 | 0.0       | 0.00 | 0.0       | 0.00  | 0.9       | 0.75 |
| PINPUN       | 3.9               | 1.82 | 0.0       | 0.00 | 0.0       | 0.00  | 3.6       | 1.86 |
| QUEVEL       | 1.2               | 0.66 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| ACERUB       | 0.9               | 0.91 | 0.0       | 0.00 | 0.0       | 0.00  | 2.7       | 2.48 |
| CASDEN       | 0.8               | 0.58 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| NYSSYL       | 0.6               | 0.41 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| CARGLA       | 0.2               | 0.19 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  | 1.5       | 1.14 |

Table 4.2-12. Mean importance value and standard error of tree stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| QUEPRI       | 57.4              | 4.51 | 10.8      | 6.96  | 65.3      | 9.46 | 41.6      | 3.54 |
| QUECOC       | 14.2              | 3.40 | 0.0       | 0.00  | 1.0       | 1.00 | 7.9       | 2.52 |
| QUEVEL       | 8.2               | 2.87 | 0.0       | 0.00  | 0.0       | 0.00 | 0.5       | 0.47 |
| NYSSYL       | 6.4               | 2.37 | 0.0       | 0.00  | 0.0       | 0.00 | 7.8       | 2.42 |
| ROBPSE       | 4.2               | 1.78 | 0.0       | 0.00  | 7.9       | 6.26 | 3.2       | 0.84 |
| CARGLA       | 3.6               | 1.49 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.11 |
| CORFLO       | 2.9               | 1.59 | 0.0       | 0.00  | 0.0       | 0.00 | 4.0       | 1.47 |
| SASALB       | 2.9               | 1.11 | 0.0       | 0.00  | 0.0       | 0.00 | 25.0      | 2.18 |
| CASDEN       | 0.2               | 0.22 | 39.2      | 11.97 | 25.8      | 8.80 | 0.1       | 0.07 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 8.9       | 1.43 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.5       | 0.25 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.3       | 0.21 |

Table 4.2-13. Mean importance value and standard error of tree stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| ACERUB       | 38.8              | 5.91 | 27.0      | 8.57  | 35.6      | 5.69 | 29.7      | 5.01 |
| QUEPRI       | 20.3              | 5.05 | 6.3       | 6.25  | 11.9      | 5.59 | 4.8       | 2.58 |
| OXYARB       | 13.4              | 2.87 | 0.0       | 0.00  | 8.6       | 3.12 | 5.8       | 1.75 |
| CARGLA       | 6.7               | 2.48 | 0.0       | 0.00  | 0.5       | 0.51 | 0.6       | 0.40 |
| QUEVEL       | 6.5               | 3.41 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.14 |
| NYSSYL       | 6.1               | 1.64 | 0.0       | 0.00  | 0.8       | 0.49 | 3.3       | 0.88 |
| ROBPSE       | 4.4               | 1.76 | 48.0      | 10.42 | 24.6      | 6.13 | 13.0      | 3.78 |
| QUECOC       | 1.6               | 1.59 | 0.0       | 0.00  | 0.0       | 0.00 | 2.4       | 1.24 |
| SASALB       | 1.4               | 0.83 | 0.0       | 0.00  | 8.4       | 2.11 | 8.2       | 2.13 |
| CORFLO       | 0.8               | 0.45 | 0.0       | 0.00  | 0.0       | 0.00 | 1.1       | 0.63 |
| CASDEN       | 0.0               | 0.00 | 6.3       | 6.25  | 1.7       | 0.72 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00  | 7.2       | 3.74 | 17.7      | 5.99 |
| HAMVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.6       | 0.63 | 2.7       | 1.80 |
| BETLEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.1       | 0.14 | 3.5       | 1.37 |
| ULMAME       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.21 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.16 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.14 |
| CAROVA       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.12 |

In the 17-year old stands, the two lower quality stands were very similar to the pre-harvest composition, with *Q. prinus* and *Q. coccinea* being the most prevalent in the tree stratum (Tables 4.2-10 and 4.2-11). The exception was with *Pinus rigida*, which was greatly reduced or not present in either of these post-harvest stands. In the SI 18 stand, *Q. prinus* remained the dominant species while *S. albidum* and *A. rubrum* became the next dominant species (Table 4.2-12). In the SI 21 stand, *A. rubrum* remained the dominant species while *L. tulipifera*, *R. pseudoacacia*, and *S. albidum* became the next dominant species (Table 4.2-13). Two species in the SI 12 and SI 15 stands were needed to reach an 80% IV level, while four and five species were needed for the SI 18 and SI 21 stands, respectively (Tables 4.2-10 through 4.2-13).

The relatively constant species ranking and stand composition on the lower quality sites reflects the competitive ability of the species on those sites after a disturbance. *Quercus* spp. prevailed because of their pre-established root systems and the stump sprouting ability. A few new species attempted to establish in these disturbed sites but evidently the poor quality of the sites prevented a wide spread success. The virtual absence of *P. rigida* suggests that the harvesting disturbance did not create exposed mineral soil habitat conditions that promote its regeneration. This lack of a regeneration medium has probably resulted in poor regeneration of *P. rigida*, which is reflected in the low IV in the herb and shrub strata.

The large changes in the higher quality stands resulted from certain species being able to efficiently adapt to the new stand conditions created by the clearcutting. In the SI 18 stand, *Q. prinus* and *S. albidum* dominated the stand because of their sprouting ability and response to the increased light conditions. Even though *A. rubrum* was not found in the pre-harvest tree stratum, it was found in the shrub stratum. *Acer rubrum* responds well when released from shaded conditions and these shrub stratum individuals were able to respond when the canopy was removed. *Acer rubrum* is also a vigorous stump sprouter, which leads to its return of dominance in the SI 21 stand. Also in the SI 21 stand, the establishment of new pioneer species (*L. tulipifera*) and the pre-harvest presence of other pioneer species (*R. pseudoacacia* and *S. albidum*) were able to out compete *Q. prinus* and *O. arboreum* in the early stages of stand development. These changes in species composition, from an oak to a mixed hardwood stand, in high quality sites (generally  $SI_{50} \geq 70$ ) have been observed in other studies (e.g., Parker and Swank 1982 and Elliott et al. 1997).

An additional set of correlations (significance set at  $\alpha = 0.15$ ) compared site quality to the stand characteristics of herb stratum percent cover and stratum species richness (Table 4.2-14). In the pre-harvest stands, a positive correlation of tree stratum species richness to both  $SI_{50}$  and FSQI ( $r$ -values = 0.92,  $P$ -values = 0.08,  $n = 4$ ), and herbaceous percent cover to FSQI ( $r = 0.89$ ,  $P = 0.11$ ,  $n = 4$ ). Higher quality stands have the potential to create a wider range of microclimates, which would allow for the existence of many species.

Table 4.2-14. Pearson's correlation coefficient results for stand characteristics. (Bold type indicates significant difference at the  $\alpha = 0.15$  level; n = 4; stands CDHL.)

| Characteristic <sup>a</sup> | Pre-harvest stands |               |                 |                 | 17-year old stands |               |                 |                 |
|-----------------------------|--------------------|---------------|-----------------|-----------------|--------------------|---------------|-----------------|-----------------|
|                             | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value |
| <b>HHPERCOV</b>             | 0.773              | 0.227         | <b>0.891</b>    | <b>0.109</b>    | -0.715             | 0.285         | -0.674          | 0.326           |
| <b>HWPERCOV</b>             | -0.334             | 0.666         | -0.410          | 0.590           | <b>-0.966</b>      | <b>0.034</b>  | <b>-0.887</b>   | <b>0.113</b>    |
| HHRICH                      | 0.262              | 0.738         | 0.507           | 0.493           | 0.465              | 0.535         | 0.645           | 0.355           |
| <b>HWRICH</b>               | 0.690              | 0.310         | 0.735           | 0.265           | -0.796             | 0.204         | <b>-0.897</b>   | <b>0.103</b>    |
| <b>SRICH</b>                | -0.252             | 0.748         | -0.416          | 0.584           | <b>-0.870</b>      | <b>0.130</b>  | <b>-0.969</b>   | <b>0.032</b>    |
| <b>TRICH</b>                | <b>0.921</b>       | <b>0.079</b>  | <b>0.920</b>    | <b>0.080</b>    | 0.828              | 0.173         | 0.817           | 0.183           |

a: HHPERCOV, HHRICH = herb stratum herbaceous percent cover and species richness; HWPERCOV, HWRICH = herb stratum woody percent cover and species richness; SRICH, TRICH = shrub and tree stratum species richness.

Each of these microclimates can provide specific conditions that favor the presence of a species and allows it to persist in a stand but at a low abundance. With respect to herbaceous percent cover, in the higher quality stands there is virtually no woody understory, so the available light that makes it through the overstory reaches the forest floor promoting greater herbaceous growth.

In the 17-year old stands, herb stratum woody plant percent cover ( $r < -0.89$ ,  $P < 0.11$ ,  $n = 4$ ) and shrub stratum species richness ( $r < -0.87$ ,  $P < 0.13$ ,  $n = 4$ ) correlated negatively with both site quality indices. Woody species richness in the herb stratum was also found to negatively correlate ( $r = -0.90$ ,  $P = 0.10$ ,  $n = 4$ ) with FSQI. As the stands age, the better quality sites allow for fast growth rates, which create closed canopy conditions sooner. These events create a highly shaded understory condition, which limits understory species richness and abundance (percent cover). The lower quality stands have slower growth rates and more opened canopies, which allow the persistence of more species and more abundant growth due to the greater light resources. Woody species, as opposed to herbaceous species, are able to survive better on the poorer quality sites due to their extensive root system, which allows them to obtain resources from a larger area when stressed growing conditions exist.

## CONCLUSIONS

The response of forest structure to clearcutting varied across stand qualities. The lower quality stands were returning to the pre-harvest conditions with the understory containing a high basal area and stem density, while the overstory had low basal area and stem density. The higher quality stands, in contrast, have the opposite development with lower values in the understory and higher values in the overstory. Average heights and diameters of the tree stratum individuals, after harvest, remained virtually the same across the stand qualities until 17-years post-harvest when the SI 21 stand exhibited much greater growth. This increased growth was due to the stand quality and resulting species composition (i.e., establishment of *Liriodendron tulipifera*, a fast growing species on good sites).

Clearcutting has altered the composition and abundance of herbaceous and woody plants by changing the microclimates within each stand. The scale of the compositional changes was not as large in the lower quality stands as in the higher quality stands. The increased forest floor light conditions that the clearcutting harvest provided benefited pioneer, early successional, shade intolerant, and faster growing species, which allowed their establishment. In the herb stratum, all stands exhibited increases in the relative abundance of grass-like genera, such as *Andropogon* spp., *Panicum* spp., and *Carex* spp. Species with well developed root systems (e.g., *Chimaphila maculata*) also increased in relative abundance. Changes in abundance of these species were lower in the poorer quality stands than in the better quality stands due to their more open canopy prior to harvest. Decreases in the relative abundance of shade tolerant species (*Osmunda claytoniana*, *O. cinnamomea*, *Athyrium filix-femina*, *Galax aphylla*, *Viola* spp., and *Dioscorea villosa*) were observed in the higher quality stands as they were not able to compete effectively in the new microclimate conditions.

In the understory, woody species' (herb and shrub strata) response to clearcutting greatly affected the composition of only the highest stand quality. After the harvest, the two lower quality stands continued to be dominated by ericaceous species (*Vaccinium* spp., *Kalmia latifolia*, *Rhododendron nudiflorum*, and/or *Gaylussacia baccata*). The SI 18 stand was a transition stand because the composition of the understory had virtually equal proportions of ericaceous and hardwood species. While the composition in all the stands remained relatively the same, the dominance ranking of the species shifted slightly. The most widespread change in dominance was *Sassafras albidum*, which increased in all three stands, but this increase is not expected to last long. In the highest quality stand, the only pre-harvest species to effectively adapt to the new stand conditions was *Acer rubrum*. Also in the higher quality stand, pioneer species (e.g., *L. tulipifera*) were able to colonize the stand and shade tolerant species (e.g., *Oxydendrum arboreum* and *Hamamelis virginiana*) responded well to release and grew into the shrub stratum from the herb stratum.

In the tree stratum, changes in species composition were more pronounced in the higher quality stands. *Quercus* spp. remained the dominant species in the two lower quality stands. The clearcutting disturbance, however, did not produce favorable forest floor conditions for *Pinus* spp. regeneration in these stands. The SI 18 stand shifted from a *Quercus* spp. dominated stand to an oak-mixed hardwood stand. Again in the SI 21 stand, *A. rubrum* was the only pre-harvest species to respond to the new habitat conditions and compete with the colonization of pioneer species (*L. tulipifera*, *Robinia pseudoacacia*, and *S. albidum*).

The potential for these stands, with the exception of the highest quality stand, to return to a similar pre-harvest composition and structure is high. The exclusion of additional disturbances, such as fire, will likely reduce the *Pinus* spp. component in the lower quality stands and the *Quercus* spp. component in the higher quality stands. The altered microclimate was the main factor in creating the changes in the composition and dominance of species within these stands.

## CHAPTER 4.3 MEASURING DIVERSITY

### RESULTS AND DISCUSSION

This section presents a discussion of the effects that clearcutting with whole-tree harvesting has on diversity index values and their potential use as management tools. Inverse Simpson's ( $D'$ ) and Shannon-Wiener ( $H'$ ) indices were calculated for the shrub and tree stratum for pre-harvest, and for all post-harvest measurement samplings. Since herb stratum data were collected for only pre-harvest and 17 years after harvest, index values were only calculated for these years in the herb stratum. There were no individuals in the tree stratum 1- and 3-years after harvest, therefore, no diversity values were calculated. Diversity index values were calculated separately for each stand and then averaged to provide a forest level index for each measurement year. In the tree stratum of the unharvested control stand, no measurements were taken in 1983 and 1985 (5 and 7 years post-harvest), therefore, index values for these years were not calculated. Within each stratum, the pre-harvest forest average values of each alpha diversity index were statistically tested to each post-harvest value using Student's t-test. The all of the t-test values are presented in Appendix F.

Three beta diversity indices [Jaccard ( $C_J$ ), Sorenson ( $C_S$ ), and Sorenson quantitative similarity index ( $C_N$ )] were used to detect temporal changes that occurred within a stand and across the forest. The  $C_J$  and  $C_S$  similarity indices are calculated from the number of similar species between two measurement periods, while the  $C_N$  similarity index is calculated from the species abundance data of the similar species. Values for these indices range from 0 to 1 where a value of 1 indicates that the sites are identical. Indices were calculated for each of the three strata with the herb stratum being further divided into two sub-sections of herbaceous and woody plants. An overview of the control stand will be given first to provide a chronology of the general study area.

#### CONTROL STAND

Herbaceous plant diversity values in 1977 and 1995 were 5.95 and 3.46 for  $D'$  and 2.15 and 1.57 for  $H'$ , respectively (Table 4.3-1). Eighteen herbaceous species were found in 1977, while 11 were found in 1995 (Table 4.3-2). Actual herbaceous percent cover was 0.5% in 1977 and 0.1% in 1995 (Table 4.3-2). Beta diversity indices indicated that species turnover and changes in abundance of similar species occurred between 1977 and 1995 ( $C_J = 0.53$ ,  $C_S = 0.69$ , and  $C_N = 0.40$ ) (Table 4.3-3). The similarity values suggest that the herbaceous plants can be very transitional even in the absence of harvesting disturbance.

The diversity indices of woody plants in the herb stratum in 1977 and 1995 were 4.27 and 3.54 for  $D'$  and 1.77 and 1.52 for  $H'$ , respectively (Table 4.3-1). Control stand

Table 4.3-1. Stand and forest alpha diversity values for herbaceous and woody plants of the herb stratum from data collected at the Potts Mountain study site in Craig Co., Va. No significant differences were found ( $\alpha = 0.10$ ) between the pre-harvest and post-harvest forest average values.

| Plant form:  | Inverse Simpson's index ( $D'$ ) |         |             |         | Shannon-Wiener index ( $H'$ ) |         |             |         |
|--------------|----------------------------------|---------|-------------|---------|-------------------------------|---------|-------------|---------|
|              | Herbaceous                       |         | Woody       |         | Herbaceous                    |         | Woody       |         |
|              | Pre-harvest                      | 17-year | Pre-harvest | 17-year | Pre-harvest                   | 17-year | Pre-harvest | 17-year |
| Site quality |                                  |         |             |         |                               |         |             |         |
| 12.2         | 3.78                             | 3.75    | 4.48        | 3.82    | 1.56                          | 1.58    | 1.77        | 1.65    |
| 15.2         | 4.35                             | 3.06    | 4.00        | 5.46    | 1.76                          | 1.48    | 1.67        | 1.93    |
| 18.3         | 2.56                             | 2.40    | 4.15        | 6.02    | 1.19                          | 1.22    | 1.61        | 1.96    |
| 21.3         | 5.99                             | 6.84    | 6.36        | 2.75    | 2.18                          | 2.26    | 2.10        | 1.26    |
| Forest avg.  | 4.17                             | 4.01    | 4.75        | 4.51    | 1.67                          | 1.64    | 1.79        | 1.70    |
| Std. error   | 0.71                             | 0.98    | 0.55        | 0.75    | 0.21                          | 0.22    | 0.11        | 0.16    |
| Year:        | 1977                             | 1995    | 1977        | 1995    | 1977                          | 1995    | 1977        | 1995    |
| Cntrl (15.2) | 5.95                             | 3.46    | 4.27        | 3.54    | 2.15                          | 1.57    | 1.77        | 1.52    |

Table 4.3-2. Stand and forest species richness and total abundance for herbaceous and woody plants in the herb stratum from data collected at the Potts Mountain study site in Craig Co., Va. No significant differences were found ( $\alpha = 0.10$ ) between the pre-harvest and post-harvest forest average values. (Total number of herbaceous and woody species over the whole time period was 45 and 32, respectively.)

| Plant form:  | Species richness |         |             |         | Percent cover (%) |         |             |         |
|--------------|------------------|---------|-------------|---------|-------------------|---------|-------------|---------|
|              | Herbaceous       |         | Woody       |         | Herbaceous        |         | Woody       |         |
|              | Pre-harvest      | 17-year | Pre-harvest | 17-year | Pre-harvest       | 17-year | Pre-harvest | 17-year |
| Site quality |                  |         |             |         |                   |         |             |         |
| 12.2         | 14               | 16      | 17          | 19      | 0.4               | 4.4     | 8.2         | 27.2    |
| 15.2         | 16               | 13      | 13          | 17      | 0.4               | 1.2     | 18.8        | 24.5    |
| 18.3         | 7                | 11      | 17          | 18      | 0.4               | 1.6     | 13.6        | 9.5     |
| 21.3         | 21               | 23      | 23          | 16      | 1.3               | 1.5     | 4.6         | 4.5     |
| Forest avg.  | 14.5             | 15.8    | 17.5        | 17.5    | 0.7               | 2.2     | 11.3        | 16.4    |
| Std. error   | 2.9              | 2.6     | 2.1         | 0.7     | 0.2               | 0.8     | 3.1         | 5.6     |
| Year:        | 1977             | 1995    | 1977        | 1995    | 1977              | 1995    | 1977        | 1995    |
| Cntrl (15.2) | 18               | 11      | 16          | 16      | 0.5               | 0.1     | 8.7         | 24.5    |

Table 4.3-3. Stand and forest beta diversity values for herbaceous and woody plants in the herb stratum from data collected at the Potts Mountain study site in Craig Co., Va. Values range between 0 and 1; a value of 1 means the stands/forests are exactly the same. (Control plot was not harvested.)

|              | <b>Jaccard similarity index (<math>C_J</math>)</b>     |       | <b>Sorenson similarity index (<math>C_S</math>)</b> |       | <b>Sorenson quantitative similarity index (<math>C_N</math>)</b> |       |
|--------------|--------------------------------------------------------|-------|-----------------------------------------------------|-------|------------------------------------------------------------------|-------|
|              | Herbaceous                                             | Woody | Herbaceous                                          | Woody | Herbaceous                                                       | Woody |
| Site quality | Comparison between a pre-harvest and 17-year old stand |       |                                                     |       |                                                                  |       |
| 12.2         | 0.67                                                   | 0.57  | 0.80                                                | 0.72  | 0.17                                                             | 0.46  |
| 15.2         | 0.61                                                   | 0.58  | 0.76                                                | 0.73  | 0.40                                                             | 0.81  |
| 18.3         | 0.38                                                   | 0.67  | 0.56                                                | 0.80  | 0.39                                                             | 0.64  |
| 21.3         | 0.42                                                   | 0.56  | 0.59                                                | 0.72  | 0.53                                                             | 0.55  |
| Forest avg.  | 0.52                                                   | 0.59  | 0.68                                                | 0.74  | 0.37                                                             | 0.62  |
| Std. error   | 0.07                                                   | 0.02  | 0.06                                                | 0.02  | 0.08                                                             | 0.07  |
| Year:        | 1977                                                   | 1995  | 1977                                                | 1995  | 1977                                                             | 1995  |
| Cntrl (15.2) | 0.53                                                   | 0.68  | 0.69                                                | 0.81  | 0.40                                                             | 0.50  |

species richness was 16 in both 1977 and 1995 (Table 4.3-2). Actual woody species percent cover was 8.7% in 1977 and 24.5% in 1995 (Table 4.3-2). Beta diversity indices values ( $C_J = 0.68$ ,  $C_S = 0.81$ , and  $C_N = 0.50$ ) suggest that a moderate turnover in species richness and a large difference in abundance of similar species occurred between 1977 and 1997 measurement periods (Table 4.3-3).

The control stand alpha diversity index values in the shrub stratum ranged over the 17 year study period from 2.85 to 6.57 for  $D'$  and 1.54 to 2.09 for  $H'$  (Table 4.3-4). Low values of  $D'$  and  $H'$  occurred in 1995, while high values occurred in 1983. Species richness ranged from a high of 16 in 1977 to 9 species in 1979 (Table 4.3-5). In 1995, a total of 10 species were found in the shrub stratum of the control plot. Abundance (number of stems) ranged from 53 stems in 1995 to 138 stems in 1979 and 1981 (Table 4.3-5). The 1977 abundance was 133 stems. Beta diversity values ranged from 0.47 to 0.71 for  $C_J$ , 0.64 to 0.83 for  $C_S$ , and 0.52 to 0.86 for  $C_N$  (Table 4.3-6). These similarity values, that compared the 1977 and 1995 measurement periods, suggest that discernible changes in composition have occurred and support the fact that forest ecosystems are in a constant state of transition, even without a harvesting disturbance.

In the tree stratum, control stand alpha diversity values in 1977 and 1995 were 3.90 and 3.56 for  $D'$  and 1.64 and 1.69 for  $H'$ , respectively (Table 4.3-7). Species richness was 10 in both the 1977 and 1995 measurement periods (Table 4.3-8). Stem abundance was 189 stems in 1977 and 129 stems in 1995 (Table 4.3-8). Tree stratum beta diversity values remained high when the 1977 and 1995 measurements were compared ( $C_J = 0.82$ ,  $C_S = 0.90$ , and  $C_N = 0.75$ ) (Table 4.3-9). The tree stratum has remained relatively constant.

#### TREATED STANDS

##### ***Alpha Diversity***

Herb stratum data were separated into woody and herbaceous plants and index values were calculated separately for each. For herbaceous plants, pre-harvest stand alpha diversity values ranged from 2.56 to 5.99 for  $D'$  and 1.19 to 2.18 for  $H'$ . Seventeen years after harvest, stand values ranged from 2.40 to 6.84 for  $D'$  and 1.22 to 2.26 for  $H'$  (Table 4.3-1). Both indices responded similarly across the stand site qualities. Variation of index values within a sampling year were smaller in the pre-harvest than the 17-year old forest. No significant difference ( $\alpha = 0.10$ ) was found between the  $D'$  and  $H'$  pre-harvest forest (forest mean and standard error of  $4.17 \pm 0.71$  and  $1.67 \pm 0.21$ , respectively) and the 17-year old forest index values ( $\bar{x} = 4.01 \pm 0.98$  and  $\bar{x} = 1.64 \pm 0.22$ , respectively) (Table 4.3-1).

For woody plants in the herb stratum, pre-harvest stand alpha diversity values ( $D'$  and  $H'$ ) ranged from 4.00 to 6.36 and 1.61 to 2.10, respectively. Seventeen years after harvest,

Table 4.3-4. Stand and forest alpha diversity values for the shrub stratum from data collected at the Potts Mountain study site in Craig Co., Va. No significant differences were found ( $\alpha = 0.10$ ) between the pre-harvest and post-harvest forest average values.

| Site quality | Inverse Simpson's index ( $D'$ ) |                   |      |      |      |      | Shannon-Wiener index ( $H'$ ) |                   |      |      |      |      |
|--------------|----------------------------------|-------------------|------|------|------|------|-------------------------------|-------------------|------|------|------|------|
|              | Pre-harvest                      | Stand age (years) |      |      |      |      | Pre-harvest                   | Stand age (years) |      |      |      |      |
|              |                                  | 1                 | 3    | 5    | 7    | 17   |                               | 1                 | 3    | 5    | 7    | 17   |
| 12.2         | 2.63                             | 4.45              | 7.01 | 5.69 | 5.88 | 5.12 | 1.51                          | 1.80              | 2.10 | 1.98 | 2.00 | 1.91 |
| 15.2         | 4.15                             | 2.65              | 4.90 | 4.54 | 4.81 | 4.11 | 1.75                          | 1.22              | 1.79 | 1.76 | 1.81 | 1.73 |
| 18.3         | 5.03                             | 5.99              | 2.30 | 3.38 | 4.06 | 4.79 | 1.96                          | 1.98              | 1.31 | 1.58 | 1.69 | 1.87 |
| 21.3         | 4.94                             | 3.25              | 5.13 | 5.88 | 6.17 | 5.25 | 1.93                          | 1.38              | 1.88 | 2.08 | 2.09 | 1.77 |
| Forest avg.  | 4.19                             | 4.08              | 4.83 | 4.87 | 5.23 | 4.82 | 1.79                          | 1.59              | 1.77 | 1.85 | 1.90 | 1.82 |
| Std. error   | 1.11                             | 1.47              | 1.94 | 1.16 | 0.98 | 0.51 | 0.21                          | 0.35              | 0.33 | 0.22 | 0.18 | 0.09 |
| Year:        | 1977                             | 1979              | 1981 | 1983 | 1986 | 1995 | 1977                          | 1979              | 1981 | 1983 | 1986 | 1995 |
| Cntrl (15.2) | 6.44                             | 4.96              | 6.37 | 6.57 | 5.86 | 2.85 | 2.13                          | 1.80              | 2.09 | 2.07 | 2.08 | 1.54 |

Table 4.3-5. Stand and forest species richness and total abundance in the shrub stratum from data collected at the Potts Mountain study site in Craig Co., Va. Bold type represent a significant difference ( $\alpha = 0.10$ ) between the pre-harvest average and post-harvest forest average value. (Total number of species over the whole time period was 31.)

| Site quality | Species richness |                   |             |      |             |      | Abundance   |                   |       |        |        |       |
|--------------|------------------|-------------------|-------------|------|-------------|------|-------------|-------------------|-------|--------|--------|-------|
|              | Pre-harvest      | Stand age (years) |             |      |             |      | Pre-harvest | Stand age (years) |       |        |        |       |
|              |                  | 1                 | 3           | 5    | 7           | 17   |             | 1                 | 3     | 5      | 7      | 17    |
| 12.2         | 13               | 10                | 14          | 13   | 15          | 13   | 417         | 140               | 391   | 575    | 592    | 546   |
| 15.2         | 10               | 5                 | 11          | 12   | 13          | 12   | 279         | 46                | 345   | 658    | 764    | 390   |
| 18.3         | 13               | 11                | 15          | 16   | 17          | 13   | 145         | 92                | 1958  | 2341   | 1998   | 277   |
| 21.3         | 11               | 6                 | 15          | 19   | 17          | 7    | 72          | 29                | 1093  | 1052   | 782    | 25    |
| Forest avg.  | 11.8             | <b>8.0</b>        | <b>13.8</b> | 15.0 | <b>15.5</b> | 11.3 | 228.3       | <b>76.8</b>       | 946.8 | 1156.5 | 1034.0 | 309.5 |
| Std. error   | 0.8              | 1.5               | 1.0         | 1.6  | 1.0         | 1.4  | 76.1        | 24.9              | 378.0 | 408.3  | 324.2  | 109.7 |
| Year:        | 1977             | 1979              | 1981        | 1983 | 1985        | 1995 | 1977        | 1979              | 1981  | 1983   | 1985   | 1995  |
| Cntrl (15.2) | 16               | 9                 | 14          | 13   | 13          | 10   | 133         | 138               | 138   | 119    | 111    | 53    |

Table 4.3-6. Stand and forest beta diversity values for the shrub stratum from data collected at the Potts Mountain study site in Craig Co., Va. Values range between 0 and 1; a value of 1 means the stands/forests are exactly the same. (Control plot was not harvested.)

|              | Jaccard similarity index (C <sub>J</sub> )                            |      |      |      |      | Sorenson similarity index (C <sub>S</sub> ) |      |      |      |      | Sorenson quantitative similarity index (C <sub>N</sub> ) |      |      |      |      |
|--------------|-----------------------------------------------------------------------|------|------|------|------|---------------------------------------------|------|------|------|------|----------------------------------------------------------|------|------|------|------|
|              | Comparison between the pre-harvest stand and the stand at age (year): |      |      |      |      |                                             |      |      |      |      |                                                          |      |      |      |      |
| Site quality | 1                                                                     | 3    | 5    | 7    | 17   | 1                                           | 3    | 5    | 7    | 17   | 1                                                        | 3    | 5    | 7    | 17   |
| 12.2         | 0.64                                                                  | 0.93 | 1.00 | 0.87 | 0.86 | 0.78                                        | 0.96 | 1.00 | 0.93 | 0.92 | 0.43                                                     | 0.47 | 0.42 | 0.46 | 0.64 |
| 15.2         | 0.36                                                                  | 0.91 | 0.83 | 0.64 | 0.57 | 0.53                                        | 0.95 | 0.91 | 0.78 | 0.73 | 0.26                                                     | 0.37 | 0.29 | 0.41 | 0.70 |
| 18.3         | 0.85                                                                  | 0.65 | 0.71 | 0.67 | 0.63 | 0.92                                        | 0.79 | 0.83 | 0.80 | 0.77 | 0.53                                                     | 0.13 | 0.11 | 0.13 | 0.52 |
| 21.3         | 0.42                                                                  | 0.53 | 0.50 | 0.56 | 0.29 | 0.59                                        | 0.69 | 0.67 | 0.71 | 0.44 | 0.36                                                     | 0.10 | 0.13 | 0.17 | 0.33 |
| Forest avg.  | 0.57                                                                  | 0.76 | 0.76 | 0.69 | 0.59 | 0.71                                        | 0.85 | 0.85 | 0.81 | 0.72 | 0.40                                                     | 0.27 | 0.24 | 0.29 | 0.55 |
| Std. error   | 0.11                                                                  | 0.10 | 0.11 | 0.07 | 0.12 | 0.09                                        | 0.07 | 0.07 | 0.05 | 0.10 | 0.06                                                     | 0.09 | 0.07 | 0.08 | 0.08 |
| Year:        | 1979                                                                  | 1981 | 1983 | 1985 | 1995 | 1979                                        | 1981 | 1983 | 1985 | 1995 | 1979                                                     | 1981 | 1983 | 1985 | 1995 |
| Cntrl (15.2) | 0.47                                                                  | 0.50 | 0.71 | 0.71 | 0.53 | 0.64                                        | 0.67 | 0.83 | 0.83 | 0.69 | 0.72                                                     | 0.86 | 0.87 | 0.76 | 0.52 |

Table 4.3-7. Stand and forest alpha diversity values for the tree stratum from data collected at the Potts Mountain study site in Craig Co., Va. Bold type represent a significant difference ( $\alpha = 0.10$ ) between the pre-harvest and post-harvest forest average value.

| Site quality | Inverse Simpson's index (D') |                   |             |      | Shannon-Wiener index (H') |                   |             |      |
|--------------|------------------------------|-------------------|-------------|------|---------------------------|-------------------|-------------|------|
|              | Pre-harvest                  | Stand age (years) |             |      | Pre-harvest               | Stand age (years) |             |      |
|              |                              | 5                 | 7           | 17   |                           | 5                 | 7           | 17   |
| 12.2         | 3.09                         | 0.00              | 1.00        | 1.93 | 1.49                      | 0.00              | 0.00        | 0.83 |
| 15.2         | 2.81                         | 0.00              | 1.38        | 2.25 | 1.29                      | 0.00              | 0.45        | 0.96 |
| 18.3         | 3.34                         | 1.63              | 1.61        | 4.26 | 1.63                      | 0.57              | 0.69        | 1.71 |
| 21.3         | 3.91                         | 2.14              | 4.20        | 4.79 | 1.70                      | 0.88              | 1.71        | 2.02 |
| Forest avg.  | 3.29                         | <b>0.94</b>       | <b>2.05</b> | 3.31 | 1.53                      | <b>0.36</b>       | <b>0.71</b> | 1.38 |
| Std. error   | 0.47                         | 1.11              | 1.46        | 1.43 | 0.18                      | 0.44              | 0.72        | 0.57 |
| Year:        | 1977                         | 1983              | 1985        | 1995 | 1977                      | 1983              | 1985        | 1995 |
| Cntrl (15.2) | 3.90                         | --                | --          | 3.56 | 1.64                      | --                | --          | 1.69 |

Table 4.3-8. Stand and forest stratum species richness and total abundance in the tree stratum from data collected at the Potts Mountain study site in Craig Co., Va. Bold type represent a significant difference ( $\alpha = 0.10$ ) between the pre-harvest and post-harvest forest average value. (Total number of species over the whole time period was 21.)

| Site quality | Species richness |                   |            |      | Abundance |                   |       |       |
|--------------|------------------|-------------------|------------|------|-----------|-------------------|-------|-------|
|              | Pre-             | Stand age (years) |            |      | Pre-      | Stand age (years) |       |       |
|              | harvest          | 5                 | 7          | 17   | harvest   | 5                 | 7     | 17    |
| 12.2         | 9                | 0                 | 1          | 5    | 148       | 0                 | 3     | 127   |
| 15.2         | 9                | 0                 | 2          | 6    | 177       | 0                 | 6     | 340   |
| 18.3         | 9                | 2                 | 4          | 12   | 153       | 23                | 114   | 812   |
| 21.3         | 10               | 4                 | 11         | 17   | 190       | 74                | 383   | 550   |
| Forest avg.  | 9.3              | <b>1.5</b>        | <b>4.5</b> | 10.0 | 167.0     | <b>24.3</b>       | 126.5 | 457.3 |
| Std. error   | 0.3              | 1.0               | 2.3        | 2.8  | 9.9       | 17.4              | 89.3  | 146.4 |
| Year:        | 1977             | 1983              | 1985       | 1995 | 1977      | 1983              | 1985  | 1995  |
| Cntrl (15.2) | 10               | --                | --         | 10   | 189       | --                | --    | 129   |

Table 4.3-9. Stand and forest beta diversity values for the tree stratum from data collected at the Potts Mountain study site in Craig Co., Va. Values range between 0 and 1; a value of 1 means the stands/forests are exactly the same. (Control plot was not harvested.)

|              | Jaccard similarity index<br>(C <sub>J</sub> )                         |      |      | Sorenson similarity<br>index (C <sub>S</sub> ) |      |      | Sorenson quantitative<br>similarity index (C <sub>N</sub> ) |      |      |
|--------------|-----------------------------------------------------------------------|------|------|------------------------------------------------|------|------|-------------------------------------------------------------|------|------|
|              | Comparison between the pre-harvest stand and the stand at age (year): |      |      |                                                |      |      |                                                             |      |      |
| Site quality | 5                                                                     | 7    | 17   | 5                                              | 7    | 17   | 5                                                           | 7    | 17   |
| 12.2         | 0.00                                                                  | 0.11 | 0.56 | 0.00                                           | 0.20 | 0.71 | 0.00                                                        | 0.04 | 0.39 |
| 15.2         | 0.00                                                                  | 0.22 | 0.50 | 0.00                                           | 0.36 | 0.67 | 0.00                                                        | 0.07 | 0.61 |
| 18.3         | 0.22                                                                  | 0.44 | 0.75 | 0.36                                           | 0.62 | 0.86 | 0.08                                                        | 0.63 | 0.28 |
| 21.3         | 0.17                                                                  | 0.50 | 0.50 | 0.29                                           | 0.67 | 0.67 | 0.07                                                        | 0.52 | 0.44 |
| Forest avg.  | 0.10                                                                  | 0.32 | 0.58 | 0.16                                           | 0.46 | 0.73 | 0.04                                                        | 0.32 | 0.43 |
| Std. error   | 0.06                                                                  | 0.09 | 0.06 | 0.09                                           | 0.11 | 0.05 | 0.02                                                        | 0.15 | 0.07 |
| Year:        | 1983                                                                  | 1985 | 1995 | 1983                                           | 1985 | 1995 | 1983                                                        | 1985 | 1995 |
| Cntrl (15.2) | --                                                                    | --   | 0.82 | --                                             | --   | 0.90 | --                                                          | --   | 0.75 |

stand values ranged from 2.75 to 6.02 for  $D'$  and 1.26 to 1.96 for  $H'$  (Table 4.3-1). Alpha diversity index values  $D'$  and  $H'$  responded similarly across stand qualities. There was less variation within the pre-harvest forest than in the 17-year old forest. No significant difference ( $\alpha = 0.10$ ) was found between the  $D'$  and  $H'$  pre-harvest forest ( $\bar{x} = 4.75 \pm 0.55$  and  $\bar{x} = 1.79 \pm 0.11$ , respectively) and the 17-year old forest index values ( $\bar{x} = 4.51 \pm 0.75$  and  $\bar{x} = 1.70 \pm 0.11$ , respectively) (Table 4.3-1).

The stand values of  $D'$  and  $H'$  for the shrub stratum varied widely across stand qualities and year (ranged from 2.30 to 6.17, and 1.22 to 2.10, respectively) (Table 4.3-4). Forest values, in contrast, were less variable with ranges of 4.08 to 5.23 for  $D'$  and 1.59 to 1.90 for  $H'$ . Forest alpha index values were higher in the 17-year old forests than in the pre-harvest forests ( $\bar{x} = 4.82 \pm 0.51$  and  $\bar{x} = 4.19 \pm 1.11$  for  $D'$ , respectively, and  $\bar{x} = 1.82 \pm 0.09$  and  $\bar{x} = 1.79 \pm 0.21$  for  $H'$ , respectively) (Table 4.3-4). In all but one post-harvest forest, alpha index values were higher than the pre-harvest stand value. Variation of index values within a sampling year were greater in the pre-harvest than the 17-year old forest. No significant differences ( $\alpha = 0.10$ ), however, were found when post-harvest forest values were compared to the pre-harvest forest values.

In the tree stratum, after an initial decrease in all stands after harvesting, diversity index values increased at varying rates. Stand values of  $D'$  and  $H'$  ranged from 0 to 4.79 and 0 to 2.02, respectively. Forest values for  $D'$  and  $H'$  ranged from  $\bar{x} = 0.94 \pm 1.11$  to  $\bar{x} = 3.31 \pm 1.43$  and  $\bar{x} = 0.36 \pm 0.44$  to  $\bar{x} = 1.53 \pm 0.18$ , respectively (Table 4.3-7). Forest level diversity values were lowest right after harvest, but 17-years after harvest ( $D' = 3.31 \pm 1.43$ ;  $H' = 1.38 \pm 0.57$ ) they had returned to pre-harvest levels ( $D' = 3.29 \pm 0.47$ ;  $H' = 1.53 \pm 0.18$ ) (Table 4.3-7). The  $D'$  and  $H'$  forest values 5- and 7-years after harvest were found to be significantly different ( $\alpha = 0.10$ ) when compared to the pre-harvest values. Variation of index values within a sampling year were smaller in the pre-harvest than the 17-year old forest.

The alpha diversity indices in all three strata exhibited changes both over the sampling years across stands and the forest but only in the tree stratum were significant differences found between pre- and post-harvest values. The longer development time of this stratum was most likely accountable for the difference. The two diversity indices responded similarly to changes in species richness and total abundance in the stands and forest, however, no major trends were observed within any stratum or stand. No stand quality or forest age had consistently higher values within any one year. Less variation occurred in the herb and tree strata of the pre-harvest forest than in the 17-year old forest suggesting a more stable (less transitional) state. The shrub stratum, in contrast, had a greater forest level variation in index values, which only suggests that the sample plots at 17-years have more similar index values than the sample plots at pre-harvest.

When the statistical comparisons of the pre-harvest and 17-year old forest values were examined no differences were detected between these two forests, but an ecologist with limited knowledge of forest succession would know that these forests are quite different, especially with respect to structure. These alpha diversity indices, however, are calculated from the relative abundance of each species. It is, therefore, difficult to tell exactly how these stands changed; was it due to changes in the number of species or the relative abundance of species or both? By examining the actual values of species richness and abundance more specific information relating to biological events may be understood.

### ***Species Richness and Abundance***

Species richness (S) for the herbaceous plants was greatest in the SI 21 stand for the pre-harvest and 17-year old forest ( $S = 21$  and  $23$ , respectively) while the lowest richness occurred on the SI 18 stand for both forests ( $S = 7$  and  $11$ , respectively) (Table 4.3-2). On average, more species were found in the 17-year old forest ( $\bar{x} = 15.8 \pm 2.6$  species) than in the pre-harvest forest ( $\bar{x} = 14.5 \pm 2.9$  species). Total number of herbaceous species in the herb stratum between the two measurement periods was 45. Stand percent cover for the herbaceous plants was lower in the pre-harvest stands (ranged from 0.4 to 1.3%) than in the 17-year old stands (ranged from 1.2 to 4.4%). Mean herbaceous percent cover was also lower in the pre-harvest forest than in the 17-year old forest ( $\bar{x} = 0.7 \pm 0.2$  vs.  $\bar{x} = 2.2 \pm 0.8\%$ ) (Table 4.3-2). No significant differences ( $\alpha = 0.10$ ) were found when post-harvest forest values were compared to the pre-harvest forest values.

Pre-harvest species richness for woody plants in the herb stratum was equal to or higher in all stands, except SI 21 stand, when compared 17-year old stands. The highest species richness for the pre-harvest and 17-year old stands occurred in the SI 21 (23 species) and SI 18 (18 species) stands, respectively; while the low species richness values were recorded in the SI 15 (13 species) and SI 21 (15 species) stands (Table 4.3-2). The average number of species in the pre-harvest and 17-year old forest were the same ( $\bar{x} = 17.5 \pm 2.1$  vs.  $\bar{x} = 17.5 \pm 0.7$  species). Total number of woody species in the herb stratum over the two measurement periods was 32. Woody plant percent cover was generally higher in the 17-year old stands (ranged from 4.5 to 27.2%) than the pre-harvest stands (4.6 to 18.8%). Woody percent cover was also higher in the 17-year old forest than in the pre-harvest forest ( $\bar{x} = 16.4 \pm 5.6\%$  vs.  $\bar{x} = 11.3 \pm 3.1\%$ , respectively) (Table 4.3-2). No significant differences ( $\alpha = 0.10$ ) were found when post-harvest forest values were compared to the pre-harvest forest values.

Shrub stratum species richness for woody plants ranged from a low stand value of 5 to a high of 19 species (Table 4.3-5). Three years after harvest, stand species richness was greater than pre-harvest levels and all stands have remained above pre-harvest level through the 17<sup>th</sup> year of regrowth with the exception of the SI 21 stand. The highest number of species within any stand occurred in the SI 21 stand (19 species). Average

number of species in a forest ranged from  $8.0 \pm 1.5$  species (1-year after harvest ) to  $15.5 \pm 1.0$  species (5-years after harvest) (Table 4.3-5). The pre-harvest and 17-year old forest contained an average of  $11.8 \pm 0.8$  and  $11.3 \pm 1.4$  species, respectively. When the species richness of the pre-harvest forest was compared to the species richness of each successive forest measurement period, the 1-, 3-, and 7-year old stands were found to be significantly different.

Shrub stratum total abundance (number of stems) varied greatly across stands with values ranging from 25 to 2,341 stems (Table 4.3-5). In general, the SI 18 and SI 21 stands attained a higher number of stems than the SI 12 and SI 15 stands. The highest stem numbers occurred in the SI 18 stand 5 years after harvest. The lowest stem numbers were found in the SI 21 stand 17-years after harvest. Forest level average abundance values ranged from  $76.8 \pm 24.9$  stems to  $1156.8 \pm 408.3$  stems (Table 4.3-5). The pre-harvest and 17-year old forest contained an average of  $228.3 \pm 76.1$  stems and  $309.5 \pm 109.7$  stems, respectively. The pre-harvest forest abundance was only significantly different to the abundance of the 1-year old forest.

Tree stratum species richness patterns showed that the better stands contained a higher number of species across all years. Within each year, the most number of species were found in the SI 21 stand (Table 4.3-8). In the 17-year old stands, tree species richness was highest in the SI 21 stand (17 species), and lowest in the SI 12 stand (5 species). Forest species richness was highest in the 17-year old forest with an average of  $10.0 \pm 2.8$  species, while the pre-harvest forest contained an average of  $9.3 \pm 0.3$  species (Table 4.3-8). The species richness in the 5- and 7-year old forest was found to be significantly different from the pre-harvest forest.

Within the tree stratum, the pre-harvest abundance across all stands was relatively similar with values ranging from 148 to 190 stems (Table 4.3-8). In the post-harvest years, stem abundance was found to be greatest in the SI 18 and SI 21 stands, and least in the SI 12 and SI 15 stands. In the 17-year old forest, the SI 12 and SI 18 stands had the least (127) and greatest (810) amount of stems, respectively. When forest values were calculated, a low value of  $24.3 \pm 17.4$  stems occurred in the 5-year old forest, while the high value of  $457.3 \pm 146.4$  stems was observed in the 17-year old forest (Table 4.3-8). The pre-harvest forest contained  $167.0 \pm 9.9$  stems. Only the stem abundance in the 5-year old forest was found to be significantly different from the pre-harvest forest stem abundance.

Species richness and abundance changed as the harvested stands/forest began to regrow. Typically, species richness and abundance were highest in the early developmental years (years 5 through 7) of the stands and forest for the shrub stratum. The tree stratum high values occurred later as the development of this stratum takes longer due to the higher biological maximums that can be attained. High values in species richness and abundance occur in the better quality sites (SI 18 and SI 21). Their high availability of resources and

wider range of microclimates promote greater growth and diversity. As these stands and forest develop, the reductions in species richness and abundance are caused due to canopy closure which greatly reduces light in the understory and at the forest floor. The reduced light conditions prevent the survival and/or recruitment of shade intolerant species. Since the poorer quality stands have slower growth rates, reductions in species richness and abundance are predicted to take longer to occur.

In the herb stratum, due to the time between measurements the forest was evidently able to recover, therefore, species richness or abundance (percent cover) did not differ. Intermediate measurements, though, would have been expected to detect changes, but this would take further study. In most post-harvest years, species richness in the shrub and tree strata was shown to be statistically different from the pre-harvest levels. This measurement, therefore can aid in the detection of changing forest composition and structure. With respect to abundance in the shrub and tree strata, due to the site quality gradient, variation across these sites were too great to detect changes. If the sites had been selected randomly then an abundance trend may have been detected. All of these measurements, however, do not report changes in specific species or abundance of specific species. The number of similar species is not known nor is the number of new or lost species. One approach to measure this is with the use of beta diversity indices, which measure relative changes between similar species and similar species abundance.

### ***Beta Diversity***

In the herb stratum, for both herbaceous and woody plants, the  $C_J$  (Jaccard),  $C_S$  (Sorenson), and  $C_N$  (Sorenson quantitative) similarity index values suggest that changes occurred in species composition and species abundance between the pre-harvest and 17-year old stands (Table 4.3-3).  $C_J$  and  $C_S$  stand values for herbaceous plants ranged from 0.38 to 0.67 and 0.56 to 0.80, respectively; for woody plants values ranged from 0.56 to 0.67 and 0.72 to 0.80, respectively. The  $C_N$  stand values of herbaceous and woody plant values ranged from 0.17 to 0.53, and 0.46 to 0.81, respectively (Table 4.3-3). When forest average values for  $C_J$ ,  $C_S$ , and  $C_N$  were calculated, herbaceous plant values were  $0.52 \pm 0.07$ ,  $0.68 \pm 0.06$ , and  $0.37 \pm 0.08$ , respectively; while woody plant values were  $0.59 \pm 0.02$ ,  $0.74 \pm 0.02$ , and  $0.62 \pm 0.07$ , respectively.

The similarity index values for the shrub and tree strata were calculated multiple times by comparing the pre-harvest stand to each post-harvest stand. Shrub stratum stand values for  $C_J$  and  $C_S$  ranged from 0.29 to 1.00 and 0.44 to 1.00, respectively (Table 4.3-6). Stand values for  $C_N$  (based upon abundance) ranged from 0.10 to 0.70. When forest average values were calculated,  $C_J$  ranged from  $0.57 \pm 0.11$  to  $0.76 \pm 0.11$ ,  $C_S$  ranged from  $0.71 \pm 0.09$  to  $0.85 \pm 0.07$ , and  $C_N$  ranged from  $0.24 \pm 0.07$  to  $0.55 \pm 0.08$  (Table 4.3-6). Forest average beta diversity values for the pre-harvest and 17-year forest comparison were  $C_J = 0.59 \pm 0.12$ ,  $C_S = 0.72 \pm 0.10$ , and  $C_N = 0.55 \pm 0.08$ .

Tree stratum stand level index values ranged from 0.00 to 0.75 for  $C_J$ , 0.00 to 0.86 for  $C_S$ , and 0.00 to 0.61 for  $C_N$  (Table 4.3-9). Forest average values ranged from  $0.10 \pm 0.06$  to  $0.58 \pm 0.06$  for  $C_J$ ,  $0.16 \pm 0.09$  to  $0.73 \pm 0.05$  for  $C_S$ , and  $0.04 \pm 0.02$  to  $0.43 \pm 0.07$  for  $C_N$  (Table 4.3-9). Forest average beta diversity values for the pre-harvest and 17-year forest comparison were  $C_J = 0.58 \pm 0.06$ ,  $C_S = 0.73 \pm 0.05$ , and  $C_N = 0.43 \pm 0.07$ . The beta diversity values from the shrub and tree strata suggest that changes occurred in both species composition and species abundance.

Beta diversity indices are relative representations of how similar two sites are with respect to the species and the abundance of the similar species. In general, no post-harvest stand quality or forest was consistently more similar to its pre-harvest stand or forest. The values of  $C_N$  tend to be much lower than  $C_J$  or  $C_S$  because they are a measurement of the abundance of the similar species, meaning that changes occur in both the abundance of each species and the number of similar species between two sites.

As might be expected, herbaceous species composition tended to differ more than woody species when the pre-harvest and 17-year old stands or forest were compared. The more stout growth form of woody species tends to make them more resistant to disturbance. In the tree stratum, the beta diversity values are steadily increasing, but there are no great differences across stand quality after 17 years of regrowth. In the tree stratum, because the stands are placed across a site quality gradient (which affects the relative growth rate of individuals) beta diversity values were lower in the poorer stands at 5- and 7-years post-harvest. This gradient created a temporal development difference in each of the stands; the lower quality stands took longer to have individual trees grow into the tree stratum.

When the pre-harvest and 17-year old forest control stand beta diversity values were compared the equivalent forest averages, the control stand had a mixed result. Within the herb stratum, all of the control beta values with respect to the herbaceous species can be considered similar to the forest averages (Table 4.3-3). With respect to woody species in the herb stratum, the control stand beta values exceed the forest averages. In the shrub stratum, the control values are similar to the forest averages except for the  $C_N$  index which is lower (Table 4.3-6). Finally, in the tree stratum, the control stand is consistently greater than the forest average.

From this information, no general trend can be discerned to the ability of beta diversity indices ability to detect difference in species composition or abundance of a treated and untreated stand. Also, if knowledge of specific species is desired, these indices are insufficient. Beta diversity indices reflect only the relative change of a group of species, but do not reflect what species or by how many individuals, the group has changed.

## CONCLUSIONS

Diversity indices were a unique development in the ecological literature that attempted to condense a large amount of information into a smaller, more manageable, supposedly more meaningful number. The goal was that changes that occur in values of the indices will represent biologically important changes in the ecosystems. In this study, large variations in the values of the alpha diversity indices were exhibited across site quality and stand age. When the forest averages were examined the variation was greatly reduced and after 17-years of regrowth the forest values were not significantly different from the pre-harvest levels. This result suggests that the forest diversity has not changed, but the forest has changed especially with respect to structure (e.g. stem abundance and species composition).

If a forest manager is only interested, which would be rarely the case, in maintaining a certain level of diversity, and is not interested in the number of species and/or abundance, or in the presence of any particular species, then alpha diversity indices are a useful tool. Very limited biological knowledge can be attained from these indices in terms of any difference that might occur. More detailed knowledge can be gleaned from species richness and abundance numbers if the number of species and their abundance are desired knowledge. However, if knowledge of changes in species composition and/or abundance over time or between two sites is desired then the use of beta diversity indices can be applied. Beta diversity indices also yield limited information because they only return relative changes in the species composition and/or abundance; the specific species and their relative abundance are still unknown. Therefore, for further knowledge of the changes of specific species and their relative abundance, approaches like those in the first two sections of this chapter must be taken. Studying the individual species and learning how they respond to disturbance can yield the most detailed information and provide the best knowledge for creating the desired future forest conditions.

## CHAPTER 5

### OVERALL CONCLUSIONS

Compositional and structural changes that occurred in this forest ecosystem were examined from two perspectives: by biological measurements and by diversity indices. The latter method was produced by condensing the information of the former method to potentially create an efficient management tool. Diversity indices were found to provide limited management information with respect to changes in species composition or structure. In some cases, forest composition and/or structure were very different but the diversity indices exhibited little differences. These changes were only detected by examining the biological data. From this biological information, the changes in species composition and structure were observed from which biological interpretations could be made as to why these shifts occurred in this forest ecosystem and an assessment made as to the importance of the changes in terms of various forest values and uses.

This study has shown that clearcut regeneration method with whole-tree harvesting has shifted the plant composition of the forest ecosystem both at the forest and stand level. This shift in species composition was primarily caused by the changed microenvironment of the forest due to the removal of the overstory. As these stands (or forest) continue to develop the species compositions will continue to change as observed in the undisturbed control stand. If the current disturbance regime (fire suppression, ice storm damage) is left in place, the three lower quality sites are expected to eventually return to a similar composition present prior to the harvest. On the higher quality sites, the composition of the newly developing forest is predicted to differ from the pre-harvest forest primarily due to the lack of a disturbance mechanism (fire) that helped create the pre-harvest forest. For example, yellow-poplar, a new and abundant species on these sites, has thin bark up through the sapling stage and tends to be easily killed or damaged during fire events.

The suppression of natural fires, a human practice invoked over the past 60 years, has been a perceived event that has aided in the changing structure of the forest and stands. This effect seems to be most obvious in the understory of the forest. Where once an occasional fire may have reduced the abundance of the dense growing ericaceous species, these species now thrive even after harvesting and preclude other (tree) species from regenerating. Additionally, occasional fires would also promote the development of better, healthier stump sprouts from cut trees. Fire has benefits for biological, social and economical components. Biologically, the regenerating forest will most likely retain the majority of the species and species associations, both plant and animal, that were present before the disturbance; socially, the forest aesthetics will more readily recover (faster reformation of a closed canopy) from a harvesting disturbance; and economically, the future forest will provide better quality (form) trees.

The effect of the clearcutting disturbance was not greatly different from what would be expected from a natural disturbance such as a catastrophic fire or hurricane. In fact, catastrophic fires can potentially alter the productivity of the forest or stand by instantaneously volatilizing limited nutrients, such as nitrogen and phosphorous. Another point, whereas humans heavily rely upon the goods and services provided by forest ecosystems, a catastrophic fire provides no goods from the land while harvesting provides at the minimum wood fiber.

If society continues to perceive that clearcut harvesting is detrimental to the diversity of forests then it is necessary to reintroduce other natural disturbances or create other human induced disturbance into the forest ecosystem to perpetuate the existence of certain species that are dependent upon intensive disturbances. Clearcutting is not detrimental to forest diversity, it is simply mimicking natural disturbances that used to occur more frequently across the landscape. These natural disturbances also reset or set back the natural evolution or succession of these forest systems. Within the natural succession of forest ecosystems, there are natural assemblages of species that excel in certain conditions over other species. As the forest or stand level conditions change over time, so does the assemblage of species. The species that are best adapted to the conditions or microenvironments of the forest at a particular time, age, and/or structure will be the species that predominate within these forests. In most cases, when one or more species are extirpated from a site due to a disturbance, they can be located in the adjacent, undisturbed stands or forests leaving the potential for recolonization at a later time.

By acknowledging that forests change over time with or without disturbances is to recognize that these ecosystems are always in a dynamic state. Through manipulations, humans have been able to control or halt the progression of natural succession in forest ecosystems to obtain the natural resources that are desired by society and can be provided by these systems. In doing so, some of these forests are managed more intensely and disturbed differently than what historically occurred in the past. If humans want to maintain similar species compositions and structures, disturbance frequency needs to mimic natural disturbance frequency and intensity. If these natural disturbances and frequencies are not maintained, humans need to understand that the historic composition and structure may not occur. Therefore, depending upon the objectives that humans establish for the use of forested land (or all lands), we need to understand and accept the outcome of our actions. This may mean that humans need to set aside land specifically for the use of producing specific forest products such as timber, wildlife, recreation and/or aesthetics. Each of these areas can then be managed to the best of human knowledge to produce the most desirable goods.

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## **APPENDICES**

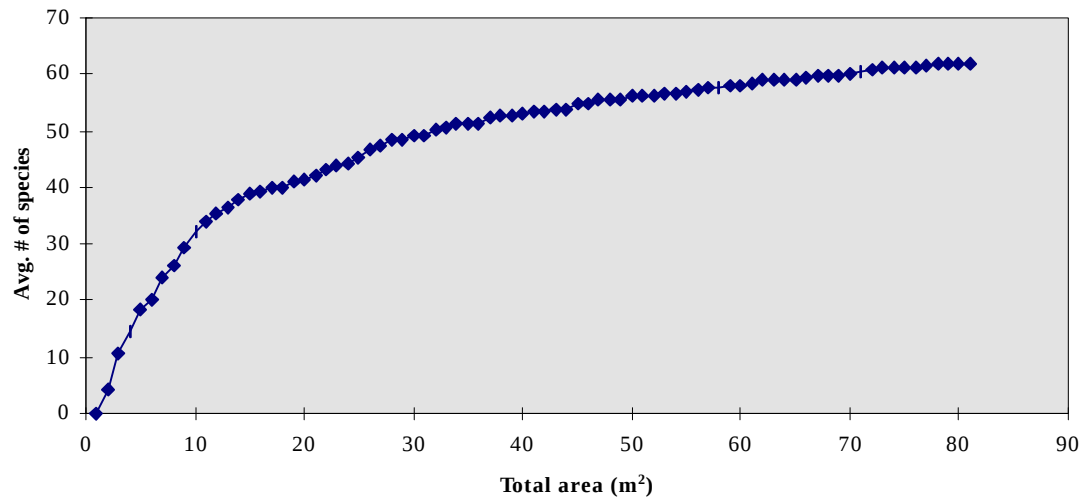
### **A through F**

## APPENDIX A

Herbaceous species area curves developed to attain the most efficient sampling of four representative stands (one of each vegetation type) on the Potts mountain study site.

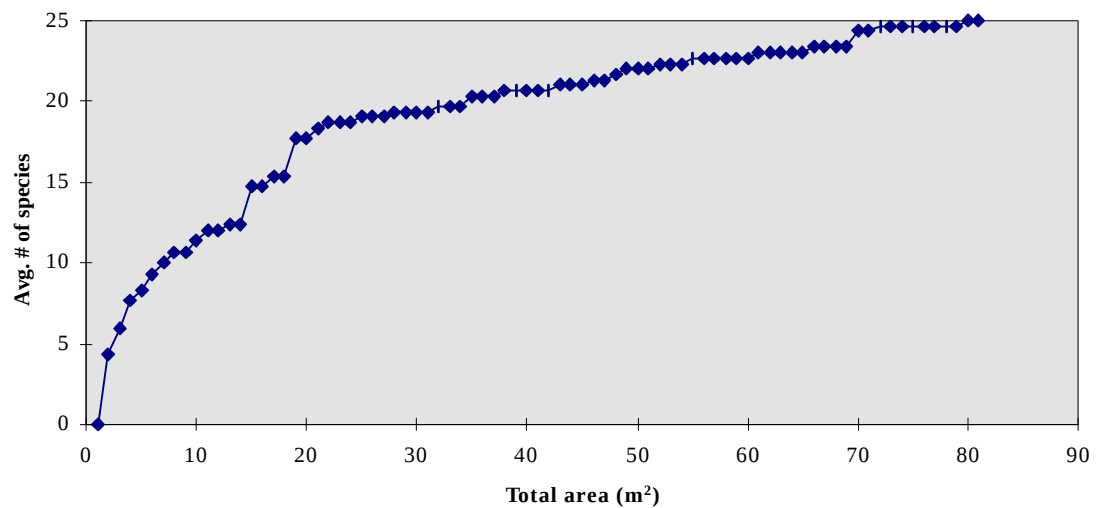
Stand A – mixed oak

**Plot A -- Species area curves**



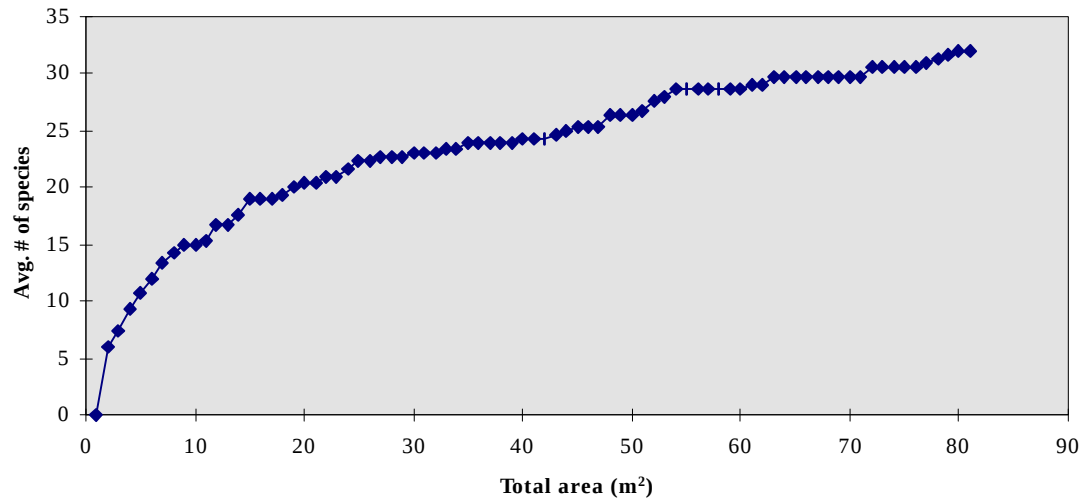
Stand B – mixed pine

**Plot B -- Species area curves**



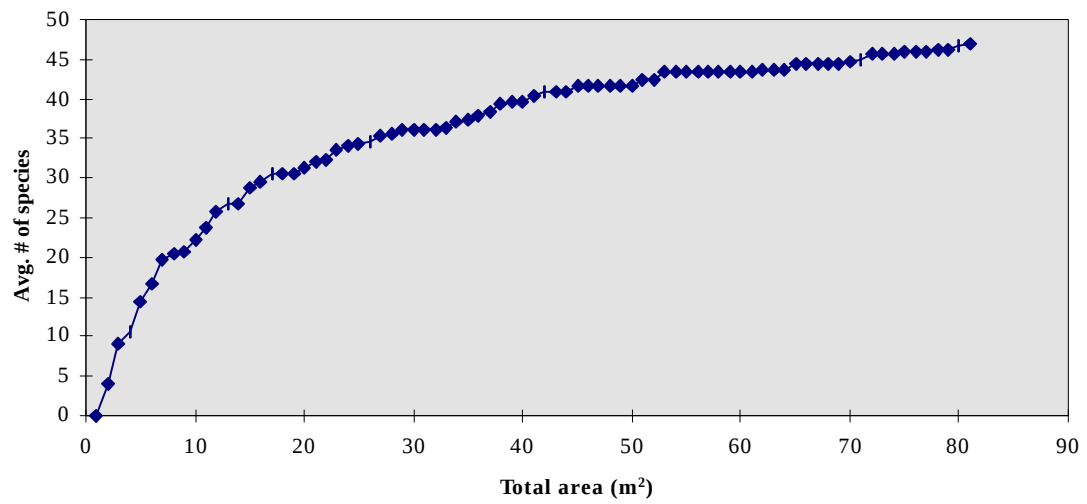
Stand C – mixed pine-oak

Plot C -- Species area curves



Stand D – mixed hardwood

Plot D -- Species area curves



## APPENDIX B

Table B-1. Cover classes established for estimates of percent cover of plant cover and ground cover features in herb stratum.

| Cover class | Percent cover |
|-------------|---------------|
| 0           | 0             |
| 1           | 2.5           |
| 2           | 10            |
| 3           | 21            |
| 4           | 35            |
| 5           | 50            |
| 6           | 65            |
| 7           | 79            |
| 8           | 90            |
| 9           | 97.5          |
| 10          | 100           |

To convert back to percent value multiply the average cover class of the species by 9. This is the transformed angle. Take the sine (in radians) of the transformed angle, which will give you the radian equivalent. Lastly, square the radian equivalent to determine the average percent cover.

Table B-2. Definitions of ground cover features; measurements taken from the herb stratum.

- (1) woody debris - any plant debris that is not a leaf or petiole
- (2) litter - leaves and their petioles; non-determinable organic matter (i.e., bark, twigs, or wood that has decayed beyond identification.)
- (3) bare soil - ground substance that contains semblance of mineral soil
- (4) living stem [of tree or shrub] - self explanatory
- (5) water, rock, moss, and lichens are self explanatory

# APPENDIX C

Table C-1. Mean percent relative basal area and standard error for each sampling year in the shrub stratum at the Potts Mountain study site in Craig Co., Va. (n=4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------------------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|                                | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|                                | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| <i>Kalmia latifolia</i>        | 17.9              | 9.7  | 29.3      | 16.8 | 4.5       | 3.8  | 3.4       | 2.8  | 3.8       | 2.5  | 8.1       | 3.8  |
| <i>Nyssa sylvatica</i>         | 28.0              | 8.5  | 4.0       | 1.8  | 12.6      | 2.7  | 11.6      | 1.9  | 11.6      | 1.4  | 17.9      | 4.3  |
| <i>Sassafras albidum</i>       | 15.9              | 5.6  | 13.1      | 4.4  | 29.2      | 9.7  | 30.4      | 6.0  | 30.6      | 5.8  | 22.9      | 8.7  |
| <i>Rhododendron nudiflorum</i> | 3.3               | 2.0  | 3.0       | 2.3  | 0.3       | 0.3  | 1.3       | 1.0  | 1.3       | 1.0  | 2.0       | 2.0  |
| <i>Quercus prinus</i>          | 6.4               | 2.4  | 7.0       | 2.6  | 15.0      | 5.5  | 16.4      | 5.1  | 16.2      | 6.3  | 9.2       | 7.3  |
| <i>Cornus florida</i>          | 3.9               | 2.8  | 4.1       | 4.1  | 2.6       | 2.1  | 3.5       | 2.4  | 5.2       | 3.7  | 2.3       | 2.3  |
| <i>Acer rubrum</i>             | 3.6               | 2.6  | 8.7       | 7.6  | 9.1       | 5.4  | 7.9       | 4.8  | 5.2       | 2.4  | 11.0      | 6.6  |
| <i>Castanea dentata</i>        | 4.1               | 2.2  | 11.0      | 6.0  | 6.6       | 2.3  | 2.3       | 0.9  | 1.3       | 0.5  | 0.5       | 0.3  |
| <i>Quercus coccinea</i>        | 4.5               | 1.8  | 3.6       | 2.0  | 11.3      | 6.1  | 13.4      | 6.6  | 14.5      | 6.8  | 5.3       | 2.8  |
| <i>Gaylussacia baccata</i>     | 0.6               | 0.4  | 0.0       | 0.0  | <0.1      | <0.1 | <0.1      | <0.1 | <0.1      | <0.1 | <0.1      | <0.1 |
| <i>Carya glabra</i>            | 3.5               | 2.1  | 0.0       | 0.0  | 0.1       | 0.1  | 0.5       | 0.3  | 0.5       | 0.3  | 0.4       | 0.2  |
| <i>Quercus velutina</i>        | 3.5               | 2.4  | 1.6       | 1.4  | 1.4       | 1.0  | 2.2       | 1.0  | 1.6       | 1.0  | 2.6       | 1.5  |
| <i>Pinus rigida</i>            | 2.3               | 2.3  | 0.0       | 0.0  | 1.2       | 1.2  | 0.8       | 0.8  | 0.9       | 0.7  | 2.7       | 1.7  |
| <i>Quercus ilicifolia</i>      | 0.7               | 0.5  | 0.0       | 0.0  | 0.8       | 0.7  | 1.5       | 1.3  | 1.5       | 1.4  | 2.1       | 1.4  |
| <i>Vaccinium stamenium</i>     | 0.4               | 0.4  | 0.0       | 0.0  | 0.2       | 0.2  | 0.1       | 0.1  | 0.1       | 0.1  | 0.2       | 0.2  |
| <i>Oxydendrum arboreum</i>     | 0.4               | 0.4  | 1.3       | 1.3  | 1.3       | 1.3  | 1.7       | 1.7  | 2.4       | 2.4  | 4.2       | 4.2  |
| <i>Robinia pseudoacacia</i>    | 0.9               | 0.9  | 12.7      | 10.3 | 2.9       | 2.3  | 1.8       | 1.4  | 0.8       | 0.6  | 0.0       | 0.0  |
| <i>Amelanchier arborea</i>     | <0.1              | <0.1 | 0.0       | 0.0  | 0.1       | 0.1  | <0.1      | <0.1 | 0.1       | 0.1  | 0.0       | 0.0  |
| <i>Acer pensylvanicum</i>      | 0.1               | 0.1  | 0.0       | 0.0  | 0.1       | <0.1 | 0.1       | 0.1  | 0.2       | 0.1  | 0.0       | 0.0  |
| <i>Ilex verticillata</i>       | <0.1              | <0.1 | 0.0       | 0.0  | 0.1       | 0.1  | 0.1       | 0.1  | 0.1       | 0.1  | 0.2       | 0.2  |
| <i>Hamamelis virginiana</i>    | <0.1              | <0.1 | 0.8       | 0.8  | 0.1       | 0.1  | 0.1       | 0.1  | 0.3       | 0.2  | 2.4       | 2.2  |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0  | 0.0       | 0.0  | 0.2       | 0.2  | 0.4       | 0.4  | 0.8       | 0.8  | 2.8       | 2.8  |
| <i>Betula lenta</i>            | 0.0               | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.2       | 0.2  | 0.6       | 0.6  | 0.0       | 0.0  |
| <i>Pinus pungens</i>           | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.2       | 0.2  | 2.4       | 2.4  |
| <i>Hydrangea arborescens</i>   | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0  |
| <i>Viburnum acerifolium</i>    | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0  |
| <i>Carya tomentosa</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.3       | 0.3  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0  |
| <i>Quercus rubra</i>           | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  |
| <i>Prunus serotina</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  |
| <i>Acer saccharum</i>          | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.5       | 0.5  |
| <i>Pinus virginiana</i>        | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.3       | 0.3  |

Table C-2. Mean percent stem density and standard error for each sampling year in the shrub stratum at the Potts Mountain study site in Craig Co., Va. (n=4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |      |           |      |           |      |           |      |           |      |           |     |
|--------------------------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|-----|
|                                | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |     |
|                                | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE  |
| <i>Kalmia latifolia</i>        | 25.8              | 14.8 | 24.6      | 14.2 | 3.5       | 3.0  | 3.5       | 2.7  | 6.7       | 3.7  | 18.1      | 8.4 |
| <i>Nyssa sylvatica</i>         | 15.3              | 7.4  | 6.4       | 2.9  | 18.1      | 4.0  | 16.3      | 3.2  | 14.2      | 2.9  | 15.0      | 2.7 |
| <i>Sassafras albidum</i>       | 16.2              | 5.4  | 7.9       | 2.7  | 32.6      | 10.8 | 35.5      | 4.2  | 31.7      | 2.7  | 15.6      | 7.3 |
| <i>Rhododendron nudiflorum</i> | 9.8               | 7.0  | 5.3       | 4.4  | 0.6       | 0.6  | 4.7       | 3.4  | 6.2       | 4.8  | 7.2       | 7.0 |
| <i>Quercus prinus</i>          | 2.6               | 1.0  | 9.9       | 4.4  | 14.4      | 4.9  | 11.6      | 4.3  | 12.1      | 5.1  | 9.6       | 7.5 |
| <i>Cornus florida</i>          | 4.7               | 3.3  | 2.4       | 2.4  | 3.6       | 3.1  | 4.0       | 3.1  | 5.5       | 4.5  | 0.5       | 0.5 |
| <i>Acer rubrum</i>             | 4.4               | 3.6  | 11.1      | 10.1 | 8.2       | 3.9  | 6.6       | 3.8  | 6.7       | 3.8  | 9.1       | 6.3 |
| <i>Castanea dentata</i>        | 3.6               | 1.6  | 10.7      | 5.5  | 3.5       | 1.8  | 1.8       | 0.5  | 1.1       | 0.2  | 0.7       | 0.4 |
| <i>Quercus coccinea</i>        | 3.0               | 1.1  | 5.7       | 3.5  | 8.5       | 4.7  | 7.3       | 3.8  | 6.4       | 3.2  | 2.7       | 1.2 |
| <i>Gaylussacia baccata</i>     | 5.3               | 3.0  | 0.0       | 0.0  | 0.2       | 0.1  | 0.1       | <0.1 | 0.1       | 0.1  | 0.2       | 0.2 |
| <i>Carya glabra</i>            | 1.9               | 1.3  | 0.0       | 0.0  | 0.1       | 0.1  | 0.3       | 0.2  | 0.3       | 0.2  | 1.3       | 0.9 |
| <i>Quercus velutina</i>        | 1.0               | 0.4  | 3.1       | 2.8  | 1.0       | 0.6  | 1.2       | 0.5  | 0.7       | 0.4  | 0.5       | 0.3 |
| <i>Pinus rigida</i>            | 0.3               | 0.3  | 0.0       | 0.0  | 0.1       | 0.1  | 0.1       | <0.1 | 0.2       | 0.1  | 0.5       | 0.3 |
| <i>Quercus ilicifolia</i>      | 1.5               | 1.0  | 0.0       | 0.0  | 1.6       | 1.4  | 2.6       | 2.1  | 2.9       | 2.6  | 3.9       | 2.7 |
| <i>Vaccinium stamenium</i>     | 1.4               | 1.4  | 0.0       | 0.0  | 0.4       | 0.4  | 0.4       | 0.4  | 0.5       | 0.5  | 1.0       | 1.0 |
| <i>Oxydendrum arboreum</i>     | 1.4               | 1.4  | 0.9       | 0.9  | 1.2       | 1.2  | 1.0       | 1.0  | 0.9       | 0.9  | 3.0       | 3.0 |
| <i>Robinia pseudoacacia</i>    | 0.5               | 0.5  | 10.8      | 8.2  | 1.2       | 0.9  | 0.8       | 0.6  | 0.6       | 0.5  | 0.0       | 0.0 |
| <i>Amelanchier arborea</i>     | 0.7               | 0.7  | 0.0       | 0.0  | 0.1       | 0.1  | 0.2       | 0.2  | 0.3       | 0.2  | 0.0       | 0.0 |
| <i>Acer pensylvanicum</i>      | 0.3               | 0.3  | 0.0       | 0.0  | 0.1       | 0.1  | 0.1       | 0.1  | 0.1       | 0.1  | 0.0       | 0.0 |
| <i>Ilex verticillata</i>       | 0.1               | 0.1  | 0.0       | 0.0  | 0.2       | 0.2  | 0.2       | 0.2  | 0.3       | 0.3  | 0.2       | 0.2 |
| <i>Hamamelis virginiana</i>    | 0.1               | 0.1  | 1.1       | 1.1  | 0.3       | 0.2  | 0.4       | 0.3  | 0.5       | 0.4  | 6.2       | 4.7 |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0  | 0.0       | 0.0  | 0.4       | 0.4  | 0.7       | 0.6  | 1.4       | 1.3  | 3.1       | 3.0 |
| <i>Betula lenta</i>            | 0.0               | 0.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.5       | 0.5  | 0.7       | 0.7  | 0.0       | 0.0 |
| <i>Pinus pungens</i>           | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1  | 0.1       | 0.1  | 0.5       | 0.5 |
| <i>Hydrangea arborescens</i>   | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0 |
| <i>Viburnum acerifolium</i>    | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0 |
| <i>Carya tomentosa</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.2       | 0.2  | <0.1      | <0.1 | 0.0       | 0.0  | 0.0       | 0.0 |
| <i>Quercus rubra</i>           | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0 |
| <i>Prunus serotina</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | <0.1      | <0.1 | 0.0       | 0.0 |
| <i>Acer saccharum</i>          | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 1.1       | 1.0 |
| <i>Pinus virginiana</i>        | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.0       | 0.0  | 0.1       | 0.1 |

Table C-3. Mean percent relative basal area and standard error for each sampling year in the tree stratum at the Potts Mountain study site in Craig Co., Va. (n=4; stands BCDI). Bold type represents significant difference ( $\alpha = 0.10$ ) within a species between the two years.

| Scientific name                | Stand age (years) |      |           |      |           |       |           |       |
|--------------------------------|-------------------|------|-----------|------|-----------|-------|-----------|-------|
|                                | Pre-harvest       |      | 5         |      | 7         |       | 17        |       |
|                                | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE    |
| <i>Quercus prinus</i>          | 38.3              | 10.8 | 8.1       | 7.8  | 65.4      | 19.8  | 45.3      | 13.6  |
| <i>Quercus coccinea</i>        | 17.0              | 8.1  | 0.0       | 0.0  | 6.9       | 6.4   | 18.2      | 7.7   |
| <i>Pinus rigida</i>            | 18.7              | 15.4 | 0.0       | 0.0  | 0.0       | 0.0   | 0.4       | 0.4   |
| <i>Acer rubrum</i>             | 7.5               | 7.4  | 7.0       | 7.0  | 8.9       | 8.9   | 8.9       | 6.3   |
| <i>Quercus velutina</i>        | 6.2               | 3.0  | 0.0       | 0.0  | 0.0       | 0.0   | 0.7       | 0.5   |
| <i>Nyssa sylvatica</i>         | 1.8               | 0.8  | 0.0       | 0.0  | 0.2       | 0.2   | 2.1       | 1.6   |
| <i>Oxydendrum arboreum</i>     | 2.6               | 2.6  | 0.0       | 0.0  | 1.4       | 1.4   | 1.2       | 1.2   |
| <i>Pinus pungens</i>           | 3.5               | 2.2  | 0.0       | 0.0  | 0.0       | 0.0   | 2.1       | 1.5   |
| <i>Carya glabra</i>            | 2.0               | 1.6  | 0.0       | 0.0  | < 0.1     | < 0.1 | 0.1       | 0.1   |
| <i>Robinia pseudoacacia</i>    | 1.3               | 0.9  | 17.5      | 17.5 | 8.7       | 8.0   | 4.3       | 3.4   |
| <i>Sassafras albidum</i>       | 0.5               | 0.3  | 0.0       | 0.0  | 1.9       | 1.9   | 6.1       | 3.9   |
| <i>Cornus florida</i>          | 0.4               | 0.3  | 0.0       | 0.0  | 0.0       | 0.0   | 0.8       | 0.7   |
| <i>Castanea dentata</i>        | 0.2               | 0.1  | 17.5      | 17.0 | 4.7       | 4.3   | < 0.1     | < 0.1 |
| <i>Liriodendron tulipifera</i> | 0.0               | 0.0  | 0.0       | 0.0  | 1.8       | 1.8   | 7.6       | 7.6   |
| <i>Hamamelis virginiana</i>    | 0.0               | 0.0  | 0.0       | 0.0  | 0.1       | 0.1   | 0.3       | 0.3   |
| <i>Betula lenta</i>            | 0.0               | 0.0  | 0.0       | 0.0  | < 0.1     | < 0.1 | 1.0       | 1.0   |
| <i>Pinus virginiana</i>        | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0   | 0.5       | 0.5   |
| <i>Acer pensylvanicum</i>      | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0   | 0.1       | 0.1   |
| <i>Carya tomentosa</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0   | 0.1       | 0.1   |
| <i>Ulmus americana</i>         | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0   | 0.1       | 0.1   |
| <i>Carya ovata</i>             | 0.0               | 0.0  | 0.0       | 0.0  | 0.0       | 0.0   | < 0.1     | < 0.1 |

# APPENDIX D

Table D-1. Mean relative basal area and standard error of shrub stratum woody plants in the control stand (SI 15 m) at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |       |           |       |           |      |           |       |
|--------------|-------------------|------|-----------|------|-----------|-------|-----------|-------|-----------|------|-----------|-------|
|              | Pre-harvest       |      | 1         |      | 3         |       | 5         |       | 7         |      | 17        |       |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE    |
| QUEPRI       | 25.2              | 9.38 | 14.9      | 8.40 | 17.7      | 8.02  | 16.4      | 7.86  | 18.7      | 8.58 | 3.2       | 3.23  |
| SASALB       | 23.2              | 9.60 | 35.9      | 9.34 | 30.6      | 10.81 | 26.7      | 10.62 | 16.0      | 8.18 | 7.7       | 5.12  |
| KALLAT       | 15.8              | 7.31 | 22.5      | 9.27 | 17.2      | 7.24  | 22.5      | 8.91  | 26.5      | 9.44 | 53.1      | 11.74 |
| NYSSYL       | 12.9              | 7.14 | 8.9       | 4.46 | 11.2      | 6.13  | 12.4      | 7.01  | 9.7       | 6.40 | 3.1       | 3.10  |
| GAYBAC       | 6.5               | 6.24 | 0.6       | 0.57 | 6.7       | 6.23  | 7.1       | 6.20  | 7.1       | 6.23 | 2.8       | 2.76  |
| AMEARB       | 6.3               | 6.25 | 0.0       | 0.00 | 6.3       | 6.25  | 5.9       | 5.86  | 5.9       | 5.77 | 0.0       | 0.00  |
| RHONUD       | 2.0               | 1.65 | 7.0       | 3.38 | 2.3       | 1.96  | 1.8       | 1.53  | 1.3       | 1.16 | 0.8       | 0.78  |
| OXYARB       | 4.5               | 4.50 | 0.0       | 0.00 | 4.9       | 4.94  | 4.9       | 4.87  | 0.0       | 0.00 | 0.0       | 0.00  |
| QUECOC       | 0.9               | 0.61 | 0.0       | 0.00 | 0.8       | 0.73  | 0.5       | 0.42  | 3.3       | 2.24 | 7.3       | 6.24  |
| QUEVEL       | 1.0               | 0.85 | 0.0       | 0.00 | 0.9       | 0.89  | 0.1       | 0.11  | 0.3       | 0.27 | 0.0       | 0.00  |
| CASDEN       | 0.7               | 0.66 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00  | 3.8       | 3.81 | 0.0       | 0.00  |
| VACSTA       | 0.4               | 0.40 | 2.6       | 1.23 | 0.6       | 0.55  | 1.1       | 1.05  | 0.5       | 0.55 | 1.4       | 1.43  |
| QUEALB       | 0.1               | 0.10 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00  |
| CARTOM       | 0.4               | 0.35 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00  |
| ROBPSE       | 0.2               | 0.17 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00  |
| ACERUB       | 0.1               | 0.05 | 1.4       | 0.74 | 0.1       | 0.15  | 0.2       | 0.16  | 0.2       | 0.20 | 0.6       | 0.58  |
| QUEILI       | 0.0               | 0.00 | 0.1       | 0.07 | 0.2       | 0.17  | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00  |
| CARGLA       | 0.0               | 0.00 | 0.0       | 0.00 | 0.5       | 0.51  | 0.5       | 0.50  | 0.5       | 0.53 | 1.2       | 1.22  |

Table D-2. Mean relative stem density and standard error of shrub stratum woody plants in the control stand (SI 15 m) at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |       |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|-------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |       |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    |
| QUEPRI       | 20.1              | 7.68 | 17.4      | 8.68 | 14.9      | 7.28 | 19.3      | 7.92 | 12.3      | 6.56 | 3.1       | 3.13  |
| SASALB       | 21.7              | 7.59 | 25.8      | 7.62 | 27.3      | 9.73 | 23.4      | 8.32 | 13.5      | 6.67 | 5.1       | 3.39  |
| KALLAT       | 17.6              | 5.14 | 16.7      | 6.94 | 17.6      | 5.56 | 19.0      | 6.03 | 30.0      | 8.17 | 53.2      | 11.60 |
| NYSSYL       | 6.2               | 3.34 | 4.0       | 2.27 | 6.8       | 3.96 | 5.9       | 3.27 | 5.6       | 3.33 | 1.3       | 1.25  |
| GAYBAC       | 8.8               | 6.32 | 1.4       | 1.39 | 10.9      | 6.65 | 16.1      | 6.69 | 13.1      | 7.55 | 3.5       | 3.12  |
| AMEARB       | 6.3               | 6.25 | 0.0       | 0.00 | 6.3       | 6.25 | 2.1       | 2.08 | 9.4       | 6.55 | 0.0       | 0.00  |
| RHONUD       | 6.3               | 4.64 | 13.7      | 5.67 | 5.5       | 4.11 | 5.2       | 3.94 | 4.7       | 3.81 | 1.6       | 1.56  |
| OXYARB       | 3.1               | 3.13 | 0.0       | 0.00 | 3.1       | 3.13 | 4.2       | 4.17 | 0.0       | 0.00 | 0.0       | 0.00  |
| QUECOC       | 3.1               | 1.82 | 0.0       | 0.00 | 2.7       | 2.35 | 1.6       | 1.28 | 4.7       | 3.40 | 8.7       | 6.33  |
| QUEVEL       | 2.1               | 1.49 | 0.0       | 0.00 | 1.2       | 1.17 | 0.4       | 0.37 | 1.0       | 0.96 | 0.0       | 0.00  |
| CASDEN       | 0.8               | 0.78 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 3.1       | 3.13 | 0.0       | 0.00  |
| VACSTA       | 1.0               | 0.99 | 11.9      | 4.55 | 1.9       | 1.88 | 2.0       | 1.95 | 1.2       | 1.19 | 2.2       | 2.21  |
| QUEALB       | 1.3               | 1.25 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| CARTOM       | 0.6               | 0.63 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| ROBPSE       | 0.6               | 0.63 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| ACERUB       | 0.4               | 0.45 | 2.5       | 1.36 | 0.4       | 0.39 | 0.4       | 0.37 | 0.5       | 0.48 | 1.6       | 1.56  |
| QUEILI       | 0.0               | 0.00 | 0.4       | 0.37 | 0.8       | 0.78 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  |
| CARGLA       | 0.0               | 0.00 | 0.0       | 0.00 | 0.7       | 0.69 | 0.6       | 0.57 | 0.9       | 0.89 | 1.0       | 1.04  |

Table D-3. Mean relative basal areas and relative stem densities and their standard errors of tree stratum woody plants in the control stand (SI 15 m) at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Relative Basal Area |      |           |      | Relative Stem Density |      |           |      |
|--------------|---------------------|------|-----------|------|-----------------------|------|-----------|------|
|              | Pre-harvest         |      | 17-year   |      | Pre-harvest           |      | 17-year   |      |
|              | $\bar{x}$           | SE   | $\bar{x}$ | SE   | $\bar{x}$             | SE   | $\bar{x}$ | SE   |
| QUEPRI       | 51.7                | 7.19 | 57.8      | 6.58 | 41.1                  | 5.72 | 50.8      | 5.46 |
| PINRIG       | 24.3                | 6.47 | 16.3      | 6.92 | 17.8                  | 4.07 | 10.1      | 3.66 |
| QUECOC       | 13.9                | 2.85 | 13.6      | 5.14 | 23.3                  | 4.06 | 11.4      | 3.56 |
| PINVIR       | 5.2                 | 2.92 | 5.7       | 3.23 | 6.0                   | 3.46 | 6.3       | 3.78 |
| ACERUB       | 1.6                 | 1.09 | 1.9       | 1.33 | 4.2                   | 3.46 | 5.2       | 3.54 |
| NYSSYL       | 1.3                 | 0.87 | 3.2       | 1.96 | 2.7                   | 1.80 | 9.5       | 4.49 |
| AMEARB       | 0.4                 | 0.28 | 0.7       | 0.42 | 1.7                   | 1.24 | 2.8       | 1.56 |
| ROBPSE       | 0.8                 | 0.80 | 0.0       | 0.0  | 1.0                   | 1.04 | 0.0       | 0.0  |
| SASALB       | 0.4                 | 0.31 | 0.1       | 0.12 | 1.2                   | 0.84 | 1.1       | 1.14 |
| OXYARB       | 0.5                 | 0.46 | 0.4       | 0.29 | 1.0                   | 0.96 | 1.8       | 1.34 |
| QUEVEL       | 0.0                 | 0.0  | 0.1       | 0.13 | 0.0                   | 0.0  | 1.0       | 1.04 |

Table D-4. Mean relative basal areas and relative stem densities and their standard errors of shrub stratum woody plants in the SI 12 (H) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Relative Basal Area |       |           |       | Relative Stem Density |      |           |      |
|--------------|---------------------|-------|-----------|-------|-----------------------|------|-----------|------|
|              | Pre-harvest         |       | 17-year   |       | Pre-harvest           |      | 17-year   |      |
|              | $\bar{x}$           | SE    | $\bar{x}$ | SE    | $\bar{x}$             | SE   | $\bar{x}$ | SE   |
| KALLAT       | 32.6                | 5.72  | 28.0      | 3.70  | 46.0                  | 5.01 | 46.9      | 4.63 |
| RHONUD       | 10.0                | 4.81  | 5.9       | 2.67  | 19.9                  | 6.63 | 13.5      | 4.98 |
| NYSSYL       | 15.5                | 4.56  | 17.7      | 3.50  | 7.9                   | 1.87 | 8.4       | 1.16 |
| SASALB       | 9.5                 | 2.71  | 24.6      | 4.59  | 12.3                  | 2.15 | 12.8      | 2.91 |
| QUECOC       | 10.1                | 5.77  | 6.0       | 3.24  | 2.9                   | 1.53 | 2.0       | 0.92 |
| PINRIG       | 9.3                 | 5.39  | 0.0       | 0.00  | 1.4                   | 0.96 | 0.0       | 0.00 |
| HAMVIR       | 3.7                 | 2.23  | 5.4       | 2.12  | 5.4                   | 2.91 | 10.1      | 3.76 |
| QUEVEL       | 4.1                 | 3.72  | 4.1       | 2.36  | 1.0                   | 0.74 | 0.9       | 0.53 |
| QUEPRI       | 3.2                 | 2.25  | 0.7       | 0.66  | 0.4                   | 0.27 | 0.2       | 0.21 |
| CASDEN       | 0.7                 | 0.41  | 0.6       | 0.37  | 1.7                   | 0.92 | 0.9       | 0.52 |
| PINECH       | 1.2                 | 1.20  | 0.0       | 0.00  | 0.7                   | 0.69 | 0.0       | 0.00 |
| ACERUB       | < 0.1               | 0.05  | 3.7       | 1.50  | 0.3                   | 0.35 | 1.9       | 0.67 |
| GAYBAC       | < 0.1               | <0.03 | 0.0       | 0.00  | 0.2                   | 0.21 | 0.0       | 0.00 |
| AMEARB       | 0.0                 | 0.00  | 2.3       | 2.16  | 0.0                   | 0.00 | 1.4       | 1.14 |
| QUEILI       | 0.0                 | 0.00  | 0.4       | 0.44  | 0.0                   | 0.00 | 0.4       | 0.45 |
| LIRTUL       | 0.0                 | 0.00  | 0.2       | 0.17  | 0.0                   | 0.00 | 0.3       | 0.24 |
| ROBPSE       | 0.0                 | 0.00  | 0.4       | 0.40  | 0.0                   | 0.00 | 0.1       | 0.12 |
| ACEPEN       | 0.0                 | 0.00  | < 0.1     | <0.01 | 0.0                   | 0.00 | 0.2       | 0.19 |

Table D-5. Mean relative basal area and standard error of shrub stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |       | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| KALLAT       | 35.0              | 5.38 | 51.2      | 11.54 | 1.7       | 0.90 | 1.5       | 0.67 | 3.5       | 0.96 | 13.7      | 2.86 |
| SASALB       | 26.6              | 6.12 | 6.7       | 4.25  | 18.5      | 5.00 | 30.1      | 6.18 | 28.8      | 6.42 | 47.3      | 6.31 |
| NYSSYL       | 10.6              | 5.05 | 0.0       | 0.00  | 14.9      | 4.53 | 12.7      | 3.69 | 9.6       | 2.97 | 11.8      | 5.45 |
| GAYBAC       | 2.7               | 0.84 | 0.0       | 0.00  | 0.7       | 0.67 | < 0.1     | 0.03 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 7.2               | 3.85 | 10.5      | 6.79  | 23.3      | 6.24 | 20.7      | 6.38 | 23.0      | 6.63 | 10.2      | 3.30 |
| QUEPRI       | 8.3               | 4.44 | 6.6       | 4.30  | 29.2      | 7.55 | 24.4      | 5.90 | 26.8      | 6.64 | 4.9       | 3.06 |
| VACSTA       | 3.4               | 1.09 | 0.0       | 0.00  | 0.9       | 0.60 | 0.7       | 0.43 | 0.7       | 0.44 | 1.4       | 1.31 |
| QUEVEL       | 3.9               | 3.58 | 0.0       | 0.00  | 4.6       | 2.25 | 4.0       | 1.82 | 2.2       | 1.51 | 1.7       | 1.68 |
| QUEILI       | 1.8               | 1.22 | 0.0       | 0.00  | 0.4       | 0.32 | 2.0       | 1.28 | 1.1       | 0.70 | 3.5       | 1.72 |
| CASDEN       | 0.5               | 0.42 | 0.0       | 0.00  | 3.8       | 2.03 | 0.9       | 0.51 | 0.7       | 0.45 | 0.0       | 0.00 |
| RHONUD       | 0.0               | 0.00 | 6.3       | 6.25  | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.02 | 0.1       | 0.14 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 2.0       | 1.96 | 2.4       | 2.44 | 2.3       | 2.19 | 2.5       | 1.55 |
| PINPUN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.6       | 0.33 | 1.0       | 0.55 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.4       | 0.28 | 2.0       | 1.40 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.8       | 0.75 |

Table D-6. Mean relative stem density and standard error of shrub stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |       | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| KALLAT       | 38.4              | 5.41 | 50.4      | 11.51 | 1.4       | 0.76 | 2.3       | 1.16 | 10.0      | 2.73 | 31.5      | 4.93 |
| SASALB       | 21.9              | 4.33 | 4.3       | 2.55  | 18.5      | 4.30 | 40.5      | 5.69 | 40.8      | 5.45 | 33.8      | 3.56 |
| NYSSYL       | 7.3               | 2.73 | 0.0       | 0.00  | 20.9      | 5.72 | 16.6      | 4.64 | 12.9      | 3.89 | 9.7       | 3.94 |
| GAYBAC       | 12.5              | 3.62 | 0.0       | 0.00  | 2.2       | 2.08 | 0.2       | 0.22 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 5.5               | 2.37 | 12.0      | 7.05  | 19.5      | 5.13 | 14.0      | 4.45 | 13.0      | 3.59 | 5.0       | 1.19 |
| QUEPRI       | 2.2               | 0.86 | 8.3       | 5.25  | 27.7      | 7.41 | 16.6      | 4.28 | 15.4      | 3.95 | 6.0       | 3.89 |
| VACSTA       | 7.0               | 2.36 | 0.0       | 0.00  | 1.8       | 1.17 | 1.5       | 0.71 | 2.0       | 1.03 | 3.6       | 3.36 |
| QUEVEL       | 2.2               | 1.71 | 0.0       | 0.00  | 3.1       | 1.55 | 2.0       | 0.91 | 0.8       | 0.65 | 0.4       | 0.40 |
| QUEILI       | 2.1               | 1.27 | 0.0       | 0.00  | 0.9       | 0.65 | 2.5       | 1.51 | 1.6       | 0.89 | 5.8       | 3.08 |
| CASDEN       | 1.0               | 0.70 | 0.0       | 0.00  | 2.1       | 1.24 | 1.8       | 1.08 | 0.7       | 0.38 | 0.0       | 0.00 |
| RHONUD       | 0.0               | 0.00 | 6.3       | 6.25  | 0.0       | 0.00 | 0.0       | 0.00 | 0.2       | 0.15 | 0.7       | 0.69 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 1.9       | 1.94 | 1.3       | 1.34 | 1.8       | 1.42 | 2.7       | 1.77 |
| PINPUN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.6       | 0.34 | 0.6       | 0.33 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.2       | 0.17 | 0.4       | 0.29 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.5       | 0.34 |

Table D-7. Mean relative basal area and standard error of shrub stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| SASALB       | 24.6              | 8.52 | 6.8       | 2.84 | 53.8      | 4.51 | 45.4      | 4.60 | 43.6      | 3.80 | 24.5      | 6.85 |
| NYSSYL       | 18.6              | 7.74 | 1.7       | 1.72 | 5.7       | 1.45 | 6.6       | 2.24 | 8.0       | 2.85 | 15.6      | 4.98 |
| RHONUD       | 4.6               | 2.03 | 5.7       | 2.42 | 1.6       | 0.97 | 4.3       | 1.90 | 4.2       | 1.65 | 5.6       | 3.20 |
| ROBPSE       | 10.9              | 6.72 | 3.0       | 1.76 | 2.5       | 1.00 | 1.4       | 0.66 | 0.9       | 0.41 | 0.0       | 0.00 |
| QUEPRI       | 11.6              | 5.87 | 23.2      | 9.03 | 18.9      | 3.34 | 25.3      | 3.35 | 25.1      | 2.61 | 33.5      | 5.56 |
| CASDEN       | 9.1               | 3.00 | 25.9      | 9.08 | 8.0       | 2.77 | 3.6       | 1.28 | 2.3       | 1.46 | 0.6       | 0.42 |
| CARGLA       | 6.3               | 5.37 | 0.0       | 0.00 | 0.7       | 0.59 | 0.8       | 0.51 | 1.0       | 0.55 | 0.6       | 0.34 |
| CORFLO       | 4.2               | 2.99 | 5.2       | 3.41 | 1.5       | 0.56 | 4.2       | 1.98 | 5.3       | 2.20 | 8.2       | 4.05 |
| QUECOC       | 1.7               | 1.15 | 0.2       | 0.17 | 4.6       | 1.49 | 5.3       | 1.83 | 6.4       | 2.33 | 1.5       | 0.65 |
| GAYBAC       | 0.1               | 0.13 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| KALLAT       | 1.4               | 1.00 | 0.3       | 0.27 | 0.3       | 0.18 | 0.2       | 0.15 | 0.6       | 0.46 | 3.2       | 1.74 |
| QUEVEL       | 0.1               | 0.12 | 2.2       | 2.17 | 0.5       | 0.49 | 0.7       | 0.65 | < 0.1     | 0.02 | 0.0       | 0.00 |
| ACERUB       | 0.5               | 0.36 | 7.0       | 6.25 | 1.8       | 0.51 | 1.6       | 0.50 | 2.1       | 0.60 | 5.5       | 2.42 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.08 | 0.1       | 0.08 | 0.2       | 0.14 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.12 | 0.2       | 0.17 | 0.2       | 0.22 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00 | < 0.1     | 0.01 | 0.1       | 0.04 | 0.1       | 0.05 | 0.1       | 0.13 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.11 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUERUB       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.02 | 0.0       | 0.00 |
| PRUSER       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.01 | 0.0       | 0.00 |
| ILEMON       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 1.1       | 1.09 |
| ACESAC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.06 |

Table D-8. Mean relative stem density and standard error of shrub stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| SASALB       | 31.5              | 8.17 | 5.1       | 2.37 | 58.1      | 5.17 | 46.1      | 5.00 | 39.3      | 4.59 | 12.0      | 3.99 |
| NYSSYL       | 8.3               | 3.34 | 2.7       | 2.68 | 6.9       | 1.66 | 6.9       | 1.88 | 6.3       | 1.69 | 14.4      | 3.76 |
| RHONUD       | 16.2              | 6.31 | 9.2       | 3.59 | 3.5       | 2.09 | 13.6      | 5.09 | 17.0      | 5.66 | 11.4      | 5.70 |
| ROBPSE       | 7.7               | 6.24 | 3.4       | 1.87 | 1.4       | 0.62 | 0.5       | 0.17 | 0.3       | 0.16 | 0.0       | 0.00 |
| QUEPRI       | 6.8               | 2.93 | 24.8      | 9.03 | 18.2      | 3.20 | 21.8      | 2.26 | 25.3      | 2.72 | 42.3      | 5.61 |
| CASDEN       | 8.6               | 2.66 | 23.0      | 8.22 | 3.0       | 1.07 | 1.8       | 0.73 | 1.8       | 0.80 | 1.4       | 0.93 |
| CARGLA       | 2.9               | 2.50 | 0.0       | 0.00 | 0.9       | 0.78 | 0.6       | 0.36 | 0.8       | 0.47 | 1.8       | 0.97 |
| CORFLO       | 3.6               | 1.77 | 3.8       | 2.46 | 1.7       | 0.63 | 3.6       | 1.44 | 3.8       | 1.40 | 4.1       | 2.30 |
| QUECOC       | 1.4               | 0.74 | 0.3       | 0.30 | 3.2       | 1.13 | 2.3       | 0.66 | 1.8       | 0.47 | 2.4       | 1.15 |
| GAYBAC       | 2.7               | 2.68 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| KALLAT       | 1.2               | 0.97 | 0.3       | 0.30 | 0.2       | 0.12 | 0.2       | 0.18 | 0.8       | 0.53 | 5.2       | 2.27 |
| QUEVEL       | 2.1               | 2.08 | 2.1       | 2.08 | 0.5       | 0.45 | 0.3       | 0.18 | 0.1       | 0.07 | 0.0       | 0.00 |
| ACERUB       | 1.0               | 0.68 | 6.7       | 6.24 | 2.2       | 0.64 | 1.9       | 0.50 | 2.1       | 0.53 | 3.4       | 1.60 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00 | 0.2       | 0.16 | 0.1       | 0.09 | 0.2       | 0.11 | 0.0       | 0.00 |
| PINRIG       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.11 | 0.1       | 0.06 | 0.1       | 0.06 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00 | < 0.1     | 0.04 | 0.2       | 0.10 | 0.2       | 0.10 | 0.5       | 0.52 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.06 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUERUB       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.07 | 0.0       | 0.00 |
| PRUSER       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.06 | 0.0       | 0.00 |
| ILEMON       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.7       | 0.66 |
| ACESAC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.6       | 0.57 |

Table D-9. Mean relative basal area and standard error of shrub stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |       |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|-------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |       | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| NYSSYL       | 28.7              | 10.40 | 1.3       | 1.35 | 16.2      | 4.42 | 15.7      | 4.13 | 18.5      | 5.23 | 17.9      | 7.91 |
| ACERUB       | 21.6              | 9.84  | 17.4      | 9.40 | 23.9      | 6.75 | 20.9      | 5.68 | 12.9      | 3.09 | 18.3      | 8.73 |
| CORFLO       | 13.5              | 7.11  | 0.0       | 0.00 | 10.6      | 2.89 | 13.9      | 3.75 | 18.4      | 4.70 | 0.0       | 0.00 |
| RHONUD       | 7.3               | 4.51  | 0.0       | 0.00 | 0.0       | 0.00 | 0.9       | 0.64 | 1.2       | 0.79 | 0.0       | 0.00 |
| SASALB       | 6.5               | 4.85  | 0.0       | 0.00 | 21.7      | 5.22 | 26.0      | 6.08 | 30.7      | 6.04 | 0.0       | 0.00 |
| OXYARB       | 6.4               | 5.03  | 6.3       | 6.25 | 8.1       | 4.85 | 5.9       | 3.20 | 5.2       | 2.99 | 8.9       | 6.40 |
| CARGLA       | 6.1               | 4.52  | 0.0       | 0.00 | 0.0       | 0.00 | 1.0       | 0.96 | 1.3       | 1.30 | 0.4       | 0.39 |
| AMEARB       | 1.2               | 1.20  | 0.0       | 0.0  | < 0.1     | 0.02 | 0.1       | 0.08 | 0.2       | 0.15 | 0.0       | 0.00 |
| CASDEN       | 1.8               | 1.26  | 6.3       | 6.25 | 1.9       | 1.10 | 0.6       | 0.45 | 0.2       | 0.11 | 0.0       | 0.00 |
| ACEPEN       | 0.3               | 0.25  | 0.0       | 0.0  | 0.1       | 0.10 | 0.3       | 0.28 | 1.1       | 1.10 | 0.0       | 0.00 |
| QUEPRI       | 0.3               | 0.32  | 1.4       | 1.40 | 3.4       | 1.91 | 4.4       | 2.60 | 0.7       | 0.39 | 0.0       | 0.00 |
| ROBPSE       | 0.0               | 0.00  | 11.2      | 7.68 | 11.7      | 4.13 | 6.5       | 2.90 | 1.9       | 0.81 | 0.0       | 0.00 |
| CARTOM       | 0.0               | 0.00  | 0.0       | 0.00 | 1.0       | 1.04 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00  | 0.0       | 0.00 | 0.7       | 0.32 | 1.5       | 0.44 | 2.5       | 0.84 | 11.0      | 7.60 |
| HAMVIR       | 0.0               | 0.00  | 0.0       | 0.00 | 0.3       | 0.18 | 0.7       | 0.38 | 1.7       | 1.01 | 11.6      | 7.05 |
| BETLEN       | 0.0               | 0.00  | 0.0       | 0.00 | 0.3       | 0.26 | 1.3       | 0.66 | 3.4       | 1.56 | 0.0       | 0.00 |
| QUEVEL       | 0.0               | 0.00  | 0.0       | 0.00 | < 0.1     | 0.04 | 0.1       | 0.10 | 0.1       | 0.05 | 0.0       | 0.00 |
| HYDARB       | 0.0               | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.04 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 0.0               | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.12 | 0.1       | 0.12 | 0.0       | 0.00 |
| VIBACE       | 0.0               | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | < 0.1     | 0.01 | 0.0       | 0.00 | 0.0       | 0.00 |
| ACESAC       | 0.0               | 0.00  | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.6       | 0.64 |

Table D-10. Mean relative stem density and standard error of shrub stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |      |           |      |           |      |           |      |
|--------------|-------------------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 1         |      | 3         |      | 5         |      | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| NYSSYL       | 21.7              | 8.27 | 2.1       | 2.08 | 22.8      | 5.79 | 20.3      | 4.67 | 18.1      | 4.24 | 15.1      | 6.98 |
| ACERUB       | 24.1              | 9.78 | 17.7      | 9.56 | 19.2      | 4.83 | 16.7      | 3.92 | 16.5      | 3.69 | 19.3      | 8.73 |
| CORFLO       | 16.5              | 6.98 | 0.0       | 0.00 | 14.4      | 4.13 | 14.5      | 3.38 | 19.2      | 3.54 | 0.0       | 0.00 |
| RHONUD       | 7.7               | 4.21 | 0.0       | 0.00 | 0.0       | 0.00 | 3.1       | 1.81 | 3.5       | 1.91 | 0.0       | 0.00 |
| SASALB       | 4.9               | 3.24 | 0.0       | 0.00 | 24.7      | 5.74 | 27.9      | 5.96 | 25.2      | 5.58 | 0.0       | 0.00 |
| OXYARB       | 4.8               | 2.40 | 6.3       | 6.25 | 6.4       | 4.22 | 3.0       | 1.46 | 2.0       | 1.11 | 7.3       | 5.04 |
| CARGLA       | 3.9               | 2.88 | 0.0       | 0.00 | 0.0       | 0.00 | 0.5       | 0.52 | 0.5       | 0.51 | 2.1       | 2.08 |
| AMEARB       | 4.2               | 4.17 | 0.0       | 0.00 | 0.1       | 0.08 | 0.5       | 0.47 | 0.7       | 0.70 | 0.0       | 0.00 |
| CASDEN       | 1.9               | 1.33 | 6.3       | 6.25 | 0.7       | 0.38 | 0.4       | 0.24 | 0.6       | 0.43 | 0.0       | 0.00 |
| ACEPEN       | 3.1               | 3.13 | 0.0       | 0.00 | 0.3       | 0.27 | 0.3       | 0.25 | 0.5       | 0.52 | 0.0       | 0.00 |
| QUEPRI       | 0.9               | 0.89 | 1.0       | 1.04 | 3.2       | 1.66 | 2.3       | 1.04 | 0.9       | 0.49 | 0.0       | 0.00 |
| ROBPSE       | 0.0               | 0.00 | 10.4      | 7.28 | 5.0       | 1.46 | 2.9       | 0.82 | 1.7       | 0.73 | 0.0       | 0.00 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00 | 0.7       | 0.74 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00 | 0.9       | 0.38 | 2.3       | 0.54 | 4.0       | 0.92 | 10.4      | 7.28 |
| HAMVIR       | 0.0               | 0.00 | 0.0       | 0.00 | 0.9       | 0.44 | 1.5       | 0.74 | 2.5       | 1.11 | 12.5      | 7.22 |
| BETLEN       | 0.0               | 0.00 | 0.0       | 0.00 | 0.7       | 0.74 | 3.2       | 1.40 | 3.7       | 1.32 | 0.0       | 0.00 |
| QUEVEL       | 0.0               | 0.00 | 0.0       | 0.00 | 0.1       | 0.09 | 0.2       | 0.11 | 0.1       | 0.09 | 0.0       | 0.00 |
| HYDARB       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.2       | 0.21 | 0.0       | 0.00 | 0.0       | 0.00 |
| QUECOC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.1       | 0.12 | 0.2       | 0.17 | 0.0       | 0.00 |
| VIBACE       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.2       | 0.17 | 0.0       | 0.00 | 0.0       | 0.00 |
| ACESAC       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 0.0       | 0.00 | 2.1       | 2.08 |

Table D-11. Mean relative basal areas and relative stem densities and their standard errors of tree stratum woody plants in the SI 12 (H) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Relative Basal Area |      |           |      | Relative Stem Density |      |           |      |
|--------------|---------------------|------|-----------|------|-----------------------|------|-----------|------|
|              | Pre-harvest         |      | 17-year   |      | Pre-harvest           |      | 17-year   |      |
|              | $\bar{x}$           | SE   | $\bar{x}$ | SE   | $\bar{x}$             | SE   | $\bar{x}$ | SE   |
| QUECOC       | 30.3                | 5.59 | 40.8      | 8.87 | 32.0                  | 5.39 | 38.8      | 7.91 |
| QUEPRI       | 32.4                | 6.02 | 50.2      | 8.79 | 28.4                  | 5.32 | 45.6      | 8.04 |
| PINRIG       | 31.4                | 5.26 | 0.0       | 0.00 | 28.2                  | 5.28 | 0.0       | 0.00 |
| QUEVEL       | 4.5                 | 1.93 | 4.3       | 3.00 | 5.9                   | 2.33 | 4.3       | 2.95 |
| NYSSYL       | 1.2                 | 0.51 | 1.2       | 1.19 | 4.4                   | 1.73 | 2.2       | 2.17 |
| ACERUB       | 0.1                 | 0.09 | 0.8       | 0.41 | 0.6                   | 0.63 | 3.1       | 1.75 |
| CASDEN       | 0.1                 | 0.11 | 0.3       | 0.24 | 0.5                   | 0.48 | 1.2       | 0.86 |
| ROBPSE       | 0.0                 | 0.00 | 1.7       | 1.28 | 0.0                   | 0.00 | 2.8       | 2.15 |
| SASALB       | 0.0                 | 0.00 | 0.4       | 0.44 | 0.0                   | 0.00 | 0.9       | 0.89 |
| HAMVIR       | 0.0                 | 0.00 | 0.2       | 0.17 | 0.0                   | 0.00 | 1.1       | 1.12 |

Table D-12. Mean relative basal area and standard error of tree stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |       |           |      |
|--------------|-------------------|------|-----------|------|-----------|-------|-----------|------|
|              | Pre-harvest       |      | 5         |      | 7         |       | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   |
| QUECOC       | 42.4              | 4.99 | 0.0       | 0.00 | 3.4       | 3.37  | 37.9      | 4.21 |
| QUEPRI       | 41.0              | 5.09 | 0.0       | 0.00 | 21.6      | 10.13 | 52.0      | 5.93 |
| PINRIG       | 10.5              | 3.36 | 0.0       | 0.00 | 0.0       | 0.00  | 1.4       | 1.19 |
| PINPUN       | 4.0               | 2.03 | 0.0       | 0.00 | 0.0       | 0.00  | 5.3       | 2.66 |
| QUEVEL       | 0.9               | 0.51 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| ACERUB       | 0.3               | 0.27 | 0.0       | 0.00 | 0.0       | 0.00  | 1.6       | 1.45 |
| CASDEN       | 0.5               | 0.46 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| NYSSYL       | 0.3               | 0.22 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| CARGLA       | < 0.1             | 0.03 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  | 1.8       | 1.33 |

Table D-13. Mean relative stem density and standard error of tree stratum woody plants in the SI 15 (C) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |      |           |       |           |      |
|--------------|-------------------|------|-----------|------|-----------|-------|-----------|------|
|              | Pre-harvest       |      | 5         |      | 7         |       | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   |
| QUECOC       | 43.3              | 5.07 | 0.0       | 0.00 | 2.1       | 2.08  | 40.5      | 5.11 |
| QUEPRI       | 41.5              | 5.21 | 0.0       | 0.00 | 22.9      | 10.42 | 52.1      | 6.36 |
| PINRIG       | 5.9               | 1.70 | 0.0       | 0.00 | 0.0       | 0.00  | 0.4       | 0.31 |
| PINPUN       | 3.9               | 1.65 | 0.0       | 0.00 | 0.0       | 0.00  | 1.8       | 1.13 |
| QUEVEL       | 1.5               | 0.83 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| ACERUB       | 1.6               | 1.56 | 0.0       | 0.00 | 0.0       | 0.00  | 3.8       | 3.51 |
| CASDEN       | 1.1               | 0.74 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| NYSSYL       | 0.9               | 0.61 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| CARGLA       | 0.3               | 0.35 | 0.0       | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 |
| PINVIR       | 0.0               | 0.00 | 0.0       | 0.00 | 0.0       | 0.00  | 1.3       | 0.96 |

Table D-14. Mean relative basal area and standard error of tree stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| QUEPRI       | 64.9              | 5.15 | 10.9      | 7.15  | 65.7      | 9.49 | 52.3      | 4.38 |
| QUECOC       | 15.6              | 4.12 | 0.0       | 0.00  | 1.0       | 1.05 | 8.9       | 2.91 |
| QUEVEL       | 10.3              | 3.86 | 0.0       | 0.00  | 0.0       | 0.00 | 0.6       | 0.61 |
| NYSSYL       | 2.3               | 1.01 | 0.0       | 0.00  | 0.0       | 0.00 | 7.1       | 2.47 |
| ROBPSE       | 2.4               | 1.08 | 0.0       | 0.00  | 7.7       | 6.26 | 3.0       | 0.76 |
| CARGLA       | 1.5               | 0.75 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.10 |
| CORFLO       | 1.6               | 0.98 | 0.0       | 0.00  | 0.0       | 0.00 | 2.9       | 1.04 |
| SASALB       | 1.3               | 0.54 | 0.0       | 0.00  | 0.0       | 0.00 | 17.1      | 1.85 |
| CASDEN       | < 0.1             | 0.03 | 39.1      | 12.03 | 25.5      | 8.78 | < 0.1     | 0.04 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 7.5       | 1.43 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.3       | 0.14 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.17 |

Table D-15. Mean relative stem density and standard error of tree stratum woody plants in the SI 18 (I) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| QUEPRI       | 49.8              | 5.02 | 10.6      | 6.80  | 64.9      | 9.45 | 31.0      | 2.94 |
| QUECOC       | 12.9              | 3.05 | 0.0       | 0.00  | 1.0       | 0.96 | 7.0       | 2.27 |
| QUEVEL       | 6.1               | 1.96 | 0.0       | 0.00  | 0.0       | 0.00 | 0.3       | 0.34 |
| NYSSYL       | 10.6              | 3.77 | 0.0       | 0.00  | 0.0       | 0.00 | 8.4       | 2.56 |
| ROBPSE       | 6.0               | 2.51 | 0.0       | 0.00  | 8.0       | 6.27 | 3.5       | 0.98 |
| CARGLA       | 5.6               | 2.28 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.12 |
| CORFLO       | 4.2               | 2.27 | 0.0       | 0.00  | 0.0       | 0.00 | 5.1       | 1.90 |
| SASALB       | 4.4               | 1.70 | 0.0       | 0.00  | 0.0       | 0.00 | 32.9      | 2.62 |
| CASDEN       | 0.4               | 0.42 | 39.4      | 11.92 | 26.1      | 8.84 | 0.1       | 0.10 |
| ACERUB       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 10.3      | 1.53 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.8       | 0.37 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.4       | 0.27 |

Table D-16. Mean relative basal area and standard error of tree stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| ACERUB       | 32.7              | 7.16 | 23.7      | 8.06  | 33.7      | 5.84 | 24.6      | 5.11 |
| QUEPRI       | 26.6              | 7.55 | 6.3       | 6.25  | 12.4      | 5.80 | 6.8       | 3.83 |
| OXYARB       | 12.2              | 3.36 | 0.0       | 0.00  | 9.0       | 3.36 | 5.0       | 1.47 |
| CARGLA       | 6.0               | 3.33 | 0.0       | 0.00  | 0.4       | 0.39 | 0.4       | 0.27 |
| QUEVEL       | 10.4              | 5.86 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.11 |
| NYSSYL       | 3.5               | 1.54 | 0.0       | 0.00  | 0.6       | 0.36 | 1.6       | 0.45 |
| ROBPSE       | 4.7               | 2.29 | 51.3      | 10.53 | 27.9      | 6.50 | 15.2      | 4.66 |
| QUECOC       | 2.7               | 2.65 | 0.0       | 0.00  | 0.0       | 0.00 | 2.9       | 1.55 |
| SASALB       | 1.0               | 0.72 | 0.0       | 0.00  | 6.9       | 1.72 | 7.0       | 2.04 |
| CORFLO       | 0.2               | 0.12 | 0.0       | 0.00  | 0.0       | 0.00 | 0.4       | 0.24 |
| CASDEN       | 0.0               | 0.00 | 6.3       | 6.25  | 1.7       | 0.73 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00  | 6.9       | 3.48 | 24.1      | 7.46 |
| HAMVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.5       | 0.47 | 1.1       | 0.78 |
| BETLEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.1       | 0.07 | 3.9       | 1.71 |
| ULMAME       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.21 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.19 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.12 |
| CAROVA       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | < 0.1     | 0.03 |

Table D-17. Mean relative stem density and standard error of tree stratum woody plants in the SI 21 (D) stand at the Potts Mountain study site in Craig Co., Va. (n=16)

| Species Code | Stand age (years) |      |           |       |           |      |           |      |
|--------------|-------------------|------|-----------|-------|-----------|------|-----------|------|
|              | Pre-harvest       |      | 5         |       | 7         |      | 17        |      |
|              | $\bar{x}$         | SE   | $\bar{x}$ | SE    | $\bar{x}$ | SE   | $\bar{x}$ | SE   |
| ACERUB       | 45.0              | 5.45 | 30.2      | 9.21  | 37.6      | 5.63 | 34.8      | 5.24 |
| QUEPRI       | 14.0              | 3.19 | 6.3       | 6.25  | 11.4      | 5.39 | 2.9       | 1.39 |
| OXYARB       | 14.5              | 2.97 | 0.0       | 0.00  | 8.2       | 2.91 | 6.6       | 2.13 |
| CARGLA       | 7.5               | 2.21 | 0.0       | 0.00  | 0.6       | 0.63 | 0.9       | 0.54 |
| QUEVEL       | 2.5               | 1.17 | 0.0       | 0.00  | 0.0       | 0.00 | 0.3       | 0.19 |
| NYSSYL       | 8.7               | 2.34 | 0.0       | 0.00  | 1.1       | 0.63 | 5.0       | 1.34 |
| ROBPSE       | 4.0               | 1.52 | 44.8      | 10.44 | 21.3      | 5.90 | 10.8      | 3.01 |
| QUECOC       | 0.5               | 0.52 | 0.0       | 0.00  | 0.0       | 0.00 | 1.9       | 0.94 |
| SASALB       | 1.8               | 0.99 | 0.0       | 0.00  | 9.8       | 2.54 | 9.5       | 2.31 |
| CORFLO       | 1.5               | 0.79 | 0.0       | 0.00  | 0.0       | 0.00 | 1.7       | 1.02 |
| CASDEN       | 0.0               | 0.00 | 6.3       | 6.25  | 1.6       | 0.72 | 0.0       | 0.00 |
| LIRTUL       | 0.0               | 0.00 | 0.0       | 0.00  | 7.4       | 4.05 | 11.3      | 5.15 |
| HAMVIR       | 0.0               | 0.00 | 0.0       | 0.00  | 0.8       | 0.78 | 4.3       | 2.82 |
| BETLEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.2       | 0.20 | 3.1       | 1.18 |
| ULMAME       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.21 |
| CARTOM       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.1       | 0.13 |
| ACEPEN       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.15 |
| CAROVA       | 0.0               | 0.00 | 0.0       | 0.00  | 0.0       | 0.00 | 0.2       | 0.21 |

# APPENDIX E

Table E-1. Pearson's correlation coefficient results for herbaceous plants in the herb stratum. (Bold type indicates significant difference at the  $\alpha = 0.10$  level.) n=4; stands CDHI. (np = not present)

| Species code  | Pre-harvest stands |               |                 |                 | 17-year old stands |               |                 |                 |
|---------------|--------------------|---------------|-----------------|-----------------|--------------------|---------------|-----------------|-----------------|
|               | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value |
| <b>ANDSPP</b> | <b>-0.923</b>      | <b>0.077</b>  | -0.826          | 0.174           | <b>-0.922</b>      | <b>0.079</b>  | -0.824          | 0.176           |
| ASCVIR        | -0.263             | 0.737         | -0.178          | 0.822           | np                 | np            | np              | np              |
| ASTER         | -0.799             | 0.201         | -0.897          | 0.103           | -0.333             | 0.667         | -0.123          | 0.877           |
| ATHFIL        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| AURLAE        | -0.263             | 0.737         | -0.178          | 0.822           | np                 | np            | np              | np              |
| BAPTIN        | -0.806             | 0.194         | -0.739          | 0.261           | -0.372             | 0.628         | -0.276          | 0.724           |
| BARVER        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| CARSPP        | 0.701              | 0.299         | 0.831           | 0.169           | 0.187              | 0.813         | 0.339           | 0.661           |
| CHIMAC        | 0.304              | 0.696         | 0.044           | 0.956           | -0.036             | 0.965         | -0.217          | 0.783           |
| <b>CORMAJ</b> | <b>-0.940</b>      | <b>0.060</b>  | -0.835          | 0.165           | -0.854             | 0.146         | -0.794          | 0.206           |
| CYPACA        | np                 | np            | np              | np              | 0.263              | 0.737         | 0.000           | 1.000           |
| CYSFRA        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| DANSPP        | np                 | np            | np              | np              | 0.727              | 0.273         | 0.853           | 0.147           |
| DESSPP        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| DIOVIL        | 0.555              | 0.445         | 0.318           | 0.682           | 0.343              | 0.657         | 0.083           | 0.917           |
| EPIREP        | -0.889             | 0.111         | -0.763          | 0.237           | -0.507             | 0.493         | -0.399          | 0.601           |
| GALAPH        | 0.098              | 0.902         | -0.163          | 0.837           | 0.263              | 0.737         | 0.000           | 1.000           |
| GEUSPP        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| GILTRI        | np                 | np            | np              | np              | -0.773             | 0.227         | -0.713          | 0.287           |
| HIEVEN        | -0.475             | 0.525         | -0.370          | 0.630           | -0.507             | 0.493         | -0.399          | 0.601           |
| HOUCAE        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| HYPHIR        | 0.534              | 0.466         | 0.711           | 0.289           | 0.773              | 0.227         | 0.891           | 0.109           |
| HYPHYP        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| IRIVER        | -0.889             | 0.111         | -0.763          | 0.237           | -0.433             | 0.567         | -0.332          | 0.668           |
| ISOVER        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| LESSPP        | np                 | np            | np              | np              | -0.773             | 0.227         | -0.713          | 0.287           |
| LOBINF        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| LUZSPP        | np                 | np            | np              | np              | 0.364              | 0.636         | 0.537           | 0.463           |
| LYSQUA        | np                 | np            | np              | np              | 0.263              | 0.737         | 0.000           | 1.000           |
| MEDVIR        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| MONUNI        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| OSMCIN        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| OSMCLA        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| <b>PANSPP</b> | <b>-0.752</b>      | <b>0.248</b>  | <b>-0.629</b>   | <b>0.371</b>    | <b>-0.949</b>      | <b>0.051</b>  | <b>-0.983</b>   | <b>0.017</b>    |
| POASPP        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| POLBIF        | 0.773              | 0.227         | 0.891           | 0.109           | 0.263              | 0.737         | 0.000           | 1.000           |
| POTCAN        | -0.263             | 0.737         | -0.178          | 0.822           | np                 | np            | np              | np              |
| PRESPP        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| PTEAQU        | -0.276             | 0.724         | -0.190          | 0.810           | -0.263             | 0.737         | -0.178          | 0.822           |
| <b>RUBSPP</b> | <b>np</b>          | <b>np</b>     | <b>np</b>       | <b>np</b>       | <b>0.823</b>       | <b>0.177</b>  | <b>0.917</b>    | <b>0.083</b>    |
| SMIRAC        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| TEPVIR        | -0.773             | 0.227         | -0.713          | 0.287           | -0.773             | 0.227         | -0.713          | 0.287           |
| THENOV        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| UVUPUD        | 0.637              | 0.363         | 0.780           | 0.220           | 0.695              | 0.305         | 0.858           | 0.142           |
| <b>VIOSPP</b> | <b>0.902</b>       | <b>0.098</b>  | 0.797           | 0.203           | 0.849              | 0.151         | <b>0.923</b>    | <b>0.077</b>    |

Table E-2. Pearson's correlation coefficient results for woody plants in the herb stratum. (Bold type indicates significant difference at the  $\alpha = 0.10$  level.) n=4; stands CDHI. (np = not present)

| Species code  | Pre-harvest stands |               |                 |                 | 17-year old stands |               |                 |                 |
|---------------|--------------------|---------------|-----------------|-----------------|--------------------|---------------|-----------------|-----------------|
|               | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value |
| ACEPEN        | np                 | np            | np              | np              | 0.245              | 0.756         | -0.018          | 0.982           |
| <b>ACERUB</b> | 0.774              | 0.226         | 0.888           | 0.112           | 0.870              | 0.130         | <b>0.935</b>    | <b>0.065</b>    |
| AMEARB        | 0.354              | 0.647         | 0.510           | 0.490           | 0.773              | 0.227         | 0.891           | 0.109           |
| CARGLA        | 0.773              | 0.227         | 0.891           | 0.109           | 0.783              | 0.217         | 0.895           | 0.105           |
| CARTOM        | 0.263              | 0.737         | 0.000           | 1.000           | -0.773             | 0.227         | -0.713          | 0.287           |
| CASDEN        | 0.008              | 0.992         | -0.244          | 0.756           | -0.834             | 0.166         | -0.761          | 0.239           |
| <b>CORFLO</b> | 0.789              | 0.211         | <b>0.900</b>    | <b>0.100</b>    | 0.700              | 0.300         | 0.492           | 0.508           |
| GAYBAC        | -0.439             | 0.561         | -0.337          | 0.663           | -0.673             | 0.328         | -0.552          | 0.448           |
| HAMVIR        | -0.448             | 0.552         | -0.329          | 0.671           | -0.250             | 0.750         | -0.111          | 0.889           |
| HYDARB        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| <b>ILEVER</b> | 0.773              | 0.227         | 0.891           | 0.109           | 0.831              | 0.169         | <b>0.921</b>    | <b>0.079</b>    |
| <b>KALLAT</b> | <b>-0.913</b>      | <b>0.087</b>  | -0.821          | 0.179           | <b>-0.976</b>      | <b>0.024</b>  | -0.886          | 0.114           |
| LIRTUL        | np                 | np            | np              | np              | -0.773             | 0.227         | -0.713          | 0.287           |
| NYSSYL        | 0.541              | 0.459         | 0.683           | 0.317           | -0.499             | 0.501         | -0.289          | 0.711           |
| OXYARB        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| PINPUN        | -0.263             | 0.737         | -0.178          | 0.822           | np                 | np            | np              | np              |
| PINRIG        | -0.726             | 0.274         | -0.603          | 0.397           | -0.773             | 0.227         | -0.713          | 0.287           |
| PINVIR        | np                 | np            | np              | np              | -0.773             | 0.227         | -0.713          | 0.287           |
| PRUSER        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| QUEALB        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| QUECOC        | -0.303             | 0.697         | -0.349          | 0.651           | -0.003             | 0.997         | -0.256          | 0.744           |
| QUEILI        | -0.263             | 0.737         | -0.178          | 0.822           | -0.263             | 0.737         | -0.178          | 0.822           |
| QUEPRI        | 0.353              | 0.647         | 0.094           | 0.906           | 0.221              | 0.779         | -0.040          | 0.960           |
| QUEVEL        | 0.394              | 0.607         | 0.533           | 0.467           | -0.199             | 0.801         | -0.189          | 0.811           |
| RHONUD        | 0.122              | 0.878         | -0.108          | 0.892           | -0.256             | 0.744         | -0.496          | 0.504           |
| RHUCOP        | np                 | np            | np              | np              | -0.263             | 0.737         | -0.178          | 0.822           |
| ROBPSE        | 0.780              | 0.220         | 0.895           | 0.105           | -0.240             | 0.760         | -0.116          | 0.884           |
| SASALB        | 0.575              | 0.425         | 0.364           | 0.636           | 0.731              | 0.269         | 0.833           | 0.167           |
| SMIGLA        | 0.033              | 0.967         | 0.271           | 0.729           | -0.112             | 0.888         | 0.019           | 0.981           |
| SMIROT        | 0.772              | 0.228         | 0.890           | 0.110           | 0.774              | 0.226         | 0.891           | 0.109           |
| <b>VACPAL</b> | -0.769             | 0.231         | -0.849          | 0.152           | <b>-0.947</b>      | <b>0.054</b>  | <b>-0.998</b>   | <b>0.002</b>    |
| VACSTA        | -0.258             | 0.742         | -0.209          | 0.791           | 0.044              | 0.956         | -0.138          | 0.862           |
| VIBACE        | 0.773              | 0.227         | 0.891           | 0.109           | np                 | np            | np              | np              |
| VITSPP        | 0.426              | 0.574         | 0.174           | 0.827           | 0.294              | 0.706         | 0.032           | 0.968           |

Table E-3. Pearson's correlation coefficient results for woody plants in the shrub stratum. (Bold type indicates significant difference at the  $\alpha = 0.10$  level.) n=4; stands CDHI. (np = not present)

| Species code  | Pre-harvest stands |               |                 |                 | 17-year old stands |               |                 |                 |
|---------------|--------------------|---------------|-----------------|-----------------|--------------------|---------------|-----------------|-----------------|
|               | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value |
| ACEPEN        | 0.773              | 0.227         | 0.891           | 0.109           | -0.773             | 0.227         | -0.713          | 0.287           |
| <b>ACERUB</b> | 0.800              | 0.200         | <b>0.904</b>    | <b>0.096</b>    | 0.804              | 0.196         | <b>0.901</b>    | <b>0.099</b>    |
| <b>ACESAC</b> | np                 | np            | np              | np              | 0.808              | 0.192         | <b>0.910</b>    | <b>0.090</b>    |
| AMEARB        | 0.773              | 0.227         | 0.891           | 0.109           | -0.773             | 0.227         | -0.713          | 0.287           |
| <b>CARGLA</b> | <b>0.950</b>       | <b>0.051</b>  | <b>0.916</b>    | <b>0.084</b>    | <b>0.920</b>       | <b>0.080</b>  | <b>0.945</b>    | <b>0.055</b>    |
| CASDEN        | 0.471              | 0.529         | 0.224           | 0.777           | -0.146             | 0.854         | -0.387          | 0.613           |
| <b>CORFLO</b> | <b>0.910</b>       | <b>0.090</b>  | <b>0.945</b>    | <b>0.055</b>    | 0.263              | 0.737         | 0.000           | 1.000           |
| GAYBAC        | -0.250             | 0.750         | -0.200          | 0.800           | np                 | np            | np              | np              |
| HAMVIR        | -0.773             | 0.227         | -0.713          | 0.287           | 0.313              | 0.687         | 0.470           | 0.530           |
| ILEVER        | np                 | np            | np              | np              | 0.263              | 0.737         | 0.000           | 1.000           |
| <b>KALLAT</b> | -0.862             | 0.138         | -0.746          | 0.254           | <b>-0.981</b>      | <b>0.019</b>  | -0.897          | 0.103           |
| LIRTUL        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.888           | 0.112           |
| <b>NYSSYL</b> | 0.856              | 0.144         | <b>0.941</b>    | <b>0.059</b>    | 0.777              | 0.223         | 0.876           | 0.124           |
| OXYARB        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| PINECH        | -0.773             | 0.227         | -0.713          | 0.287           | np                 | np            | np              | np              |
| PINRIG        | -0.773             | 0.227         | -0.713          | 0.287           | -0.263             | 0.737         | -0.178          | 0.822           |
| PINVIR        | np                 | np            | np              | np              | -0.263             | 0.737         | -0.178          | 0.822           |
| <b>QUECOC</b> | <b>-0.979</b>      | <b>0.021</b>  | <b>-0.961</b>   | <b>0.039</b>    | -0.664             | 0.336         | -0.619          | 0.381           |
| QUEILI        | -0.263             | 0.737         | -0.178          | 0.822           | -0.311             | 0.689         | -0.221          | 0.779           |
| QUEPRI        | 0.033              | 0.967         | -0.206          | 0.794           | 0.217              | 0.783         | -0.042          | 0.958           |
| <b>QUEVEL</b> | -0.855             | 0.145         | -0.759          | 0.241           | <b>-0.923</b>      | <b>0.077</b>  | -0.799          | 0.201           |
| RHONUD        | -0.084             | 0.917         | -0.241          | 0.759           | -0.311             | 0.689         | -0.525          | 0.475           |
| ROBPSE        | 0.263              | 0.737         | 0.000           | 1.000           | -0.773             | 0.227         | -0.713          | 0.287           |
| SASALB        | -0.102             | 0.898         | -0.320          | 0.680           | -0.618             | 0.382         | -0.626          | 0.374           |
| VACSTA        | -0.263             | 0.737         | -0.178          | 0.822           | -0.263             | 0.737         | -0.178          | 0.822           |

Table E-4. Pearson's correlation coefficient results for woody plants in the tree stratum. (Bold type indicates significant difference at the  $\alpha = 0.10$  level.) n=4; stands CDHI. (np = not present)

| Species code  | Pre-harvest stands |               |                 |                 | 17-year old stands |               |                 |                 |
|---------------|--------------------|---------------|-----------------|-----------------|--------------------|---------------|-----------------|-----------------|
|               | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value | SI<br>r-value      | SI<br>p-value | FSQI<br>r-value | FSQI<br>p-value |
| ACEPEN        | np                 | np            | np              | np              | 0.542              | 0.458         | 0.303           | 0.697           |
| <b>ACERUB</b> | 0.768              | 0.232         | 0.889           | 0.111           | 0.868              | 0.132         | <b>0.932</b>    | <b>0.068</b>    |
| BETLEN        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| <b>CARGLA</b> | <b>0.954</b>       | <b>0.046</b>  | <b>0.943</b>    | <b>0.057</b>    | 0.864              | 0.136         | <b>0.935</b>    | <b>0.065</b>    |
| CAROVA        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| CARTOM        | np                 | np            | np              | np              | 0.707              | 0.293         | 0.501           | 0.499           |
| CASDEN        | -0.550             | 0.451         | -0.543          | 0.457           | -0.766             | 0.234         | -0.739          | 0.261           |
| CORFLO        | 0.545              | 0.455         | 0.306           | 0.694           | 0.505              | 0.495         | 0.261           | 0.739           |
| HAMVIR        | np                 | np            | np              | np              | 0.412              | 0.588         | 0.567           | 0.433           |
| LIRTUL        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |
| NYSSYL        | 0.773              | 0.227         | 0.689           | 0.311           | 0.393              | 0.607         | 0.158           | 0.842           |
| OXYARB        | 0.773              | 0.227         | 0.891           | 0.109           | 0.773              | 0.227         | 0.891           | 0.109           |
| PINPUN        | -0.263             | 0.737         | -0.178          | 0.822           | -0.263             | 0.737         | -0.178          | 0.822           |
| PINRIG        | -0.899             | 0.101         | -0.810          | 0.190           | -0.263             | 0.737         | -0.178          | 0.822           |
| PINVIR        | np                 | np            | np              | np              | -0.263             | 0.737         | -0.178          | 0.822           |
| QUECOC        | -0.871             | 0.129         | -0.826          | 0.174           | -0.893             | 0.107         | -0.791          | 0.209           |
| <b>QUEPRI</b> | -0.051             | 0.949         | -0.284          | 0.716           | -0.889             | 0.111         | <b>-0.949</b>   | <b>0.051</b>    |
| QUEVEL        | 0.616              | 0.384         | 0.472           | 0.528           | -0.726             | 0.274         | -0.685          | 0.315           |
| <b>ROBPSE</b> | <b>0.931</b>       | <b>0.069</b>  | 0.838           | 0.162           | 0.852              | 0.148         | <b>0.913</b>    | <b>0.087</b>    |
| SASALB        | 0.560              | 0.440         | 0.323           | 0.677           | 0.543              | 0.457         | 0.305           | 0.695           |
| ULMAME        | np                 | np            | np              | np              | 0.773              | 0.227         | 0.891           | 0.109           |

# APPENDIX F

Table F-1. Student's paired t-test t-values for comparing the pre-harvest forest diversity values to each post-harvest forest diversity values. ( $\alpha = 0.10$  and  $n = 4$ ) Numbers in bold represent significant difference between the pre-harvest forest average and the post-harvest forest average.

| Stratum    | Inverse Simpson's index ( $D'$ ) |       |             |             |       | Shannon-Wiener index ( $H'$ ) |      |             |             |       |
|------------|----------------------------------|-------|-------------|-------------|-------|-------------------------------|------|-------------|-------------|-------|
|            | Stand age (years)                |       |             |             |       | Stand age (years)             |      |             |             |       |
|            | 1                                | 3     | 5           | 7           | 17    | 1                             | 3    | 5           | 7           | 17    |
| Herb       |                                  |       |             |             |       |                               |      |             |             |       |
| herbaceous | --                               | --    | --          | --          | 0.36  | --                            | --   | --          | --          | 0.46  |
| woody      | --                               | --    | --          | --          | 0.19  | --                            | --   | --          | --          | 0.32  |
| Shrub      | 0.12                             | -0.44 | -0.71       | -1.20       | -1.00 | 0.93                          | 0.07 | -0.35       | -0.70       | -0.26 |
| Tree       | --                               | --    | <b>6.62</b> | <b>2.35</b> | -0.04 | --                            | --   | <b>8.05</b> | <b>2.63</b> | 0.68  |

Table F-2. Student's paired t-test t-values for comparing the pre-harvest forest diversity values to each post-harvest forest diversity values. ( $\alpha = 0.10$  and  $n = 4$ ) Numbers in bold represent significant difference between the pre-harvest forest average and the post-harvest forest average.

| Stratum    | Species richness  |              |              |              |       | Percent cover/Abundance |       |              |       |       |
|------------|-------------------|--------------|--------------|--------------|-------|-------------------------|-------|--------------|-------|-------|
|            | Stand age (years) |              |              |              |       | Stand age (years)       |       |              |       |       |
|            | 1                 | 3            | 5            | 7            | 17    | 1                       | 3     | 5            | 7     | 17    |
| Herb       |                   |              |              |              |       |                         |       |              |       |       |
| herbaceous | --                | --           | --           | --           | -0.84 | --                      | --    | --           | --    | -1.84 |
| woody      | --                | --           | --           | --           | 0.00  | --                      | --    | --           | --    | -1.02 |
| Shrub      | <b>5.00</b>       | <b>-2.83</b> | -1.91        | <b>-4.39</b> | 0.40  | <b>2.51</b>             | -1.65 | -2.03        | -2.20 | -1.89 |
| Tree       | --                | --           | <b>10.33</b> | <b>2.36</b>  | -0.29 | --                      | --    | <b>10.85</b> | 0.49  | -2.00 |

## VITA

David Kenyon Wright was born on October 15, 1970 in Monterey, California. He grew up in central California and attended East Union High School in Manteca, California. For one year during high school he participated in an international exchange and spent a year in New Zealand where he had a thoroughly good time. He then decided to continue his education at Purdue University in West Lafayette, Indiana where he earned his B. S. degree in Wildlife Science in 1994. Feeling that he had not spent enough time in school he decided to continue his education and expand his range of knowledge by earning his M. S. at Virginia Tech in Forestry, of which is presented before you. His current goal is to now utilize the knowledge and information he has acquired over these past years and apply it in a productive and beneficial manner while having lots of fun.