To the Graduate Council:

I am submitting herewith a thesis written by Virgil Lee Andrews, Jr. entitled "Effects of Four Pine-Hardwood Regeneration Techniques on First Year Regeneration and Wildlife Habitat". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Dr. Edward R. Buckner, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

EFFECTS OF FOUR PINE-HARDWOOD REGENERATION TECHNIQUES ON FIRST YEAR REGENERATION AND WILDLIFE HABITAT

A Thesis

Presented for the

Master of Science

Degree

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Virgil Lee Andrews, Jr.

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DEDICATION

I would like to dedicate this thesis to my mother,

Vickie Andrews

and thank her for her love and support all of these years,

and for making it possible for me to achieve.

I Love You.

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ABSTRACT

Pine-hardwood mixtures are declining in the southern states due to a variety of factors. Interest has increased in obtaining information on the pine-hardwood forest cover type, its silviculture, and its significance to wildlife and wildlife habitat. The purpose of this study was to compare the effectiveness of the fell-and-burn treatment for regenerating a mixed pine-hardwood stand with other widely-used silvicultural treatments, and to evaluate the wildlife habitat resulting from those treatments.

Four site preparation techniques currently employed as regeneration techniques in the southern United States were tested as methods to successfully regenerate mixed pine-hardwood stands. Treatments included no site preparation following harvest (commercial clearcut), felling of residual stems following harvest (silvicultural clearcut), felling of residual stems following harvest with summer burning (fell-and-burn), and herbicidal treatment with summer burning (brown-and-burn).

Overall pine seedling survival varied significantly by treatment. Pine seedling survival was best in the fell-and-burn and brown-and-burn treatments after one growing season. White pine survival in burned treatments was significantly higher than in unburned treatments. Loblolly pine survival did not differ among treatments. Survival differences were likely due to reduced levels of competition from sprouting hardwoods provided by burning.

Total height growth of planted pines did not differ among treatments. Height increased significantly for loblolly pine in the burned treatments. Pine seedling height

growth in unburned treatments was lower than in burned treatments, apparently due to hardwood competition.

Twenty-nine hardwood species representing 18 families were identified in the regeneration. Sassafras, red maple, sourwood, and blackgum made up 56.6 percent of all stems. These species were most frequent in the unburned treatments. Hardwood stems were tallest in the unburned treatments but had nearly two seasons of growth compared to only one in the burned treatments. Unburned and fell-and-burn plots had the largest number of stems per hectare.

Thirty-four species of herbaceous plants representing 17 families were identified after application of treatments. Fireweed occurred in 84 percent of the sample plots; it dominated herbaceous biomass weights. The fell-and-burn treatment produced the highest average biomass per sample (124.5 g/m^2). The commercial clearcut yielded the least herbaceous biomass (32.1 g/m^2). Biomass weights for fireweed and horseweed varied significantly among treatments and were highest in the burned treatments.

Results indicated that the fell-and-burn and brown-and-burn treatments are likely to produce pine-hardwood stands. The fell-and-burn treatment produced the best mixture, since it had a better hardwood component (more oaks/hectare) than the brown-and-burn treatment. The commercial clearcut and silvicultural clearcut treatments are not likely to produce mixed pine-hardwood stands due to extremely vigorous competition from hardwoods, but this is difficult to predict accurately after only one growing season.

Wildlife habitat needs were met to varying degrees dependent upon treatment. Burned treatments contained more herbaceous forage than unburned treatments, due

primarily to the presence of fireweed and horseweed. However, the unburned treatments contained more preferred forages such as smilax, muscadine, and pokeweed.

The unburned treatments and fell-and-burn treatment contained high numbers of stems per hectare of woody browse species including flowering dogwood, red maple, sassafras, and oak. In contrast, the brown-and-burn treatment had a low hardwood stem-count per hectare. Oaks and hickories were also less abundant in the brown-and-burn treatment. Long-term estimates of hard mast for all treatments showed that the commercial clearcut, silvicultural clearcut, and fell-and-burn treatments will likely contain a sufficient stocking of oaks to meet wildlife needs. The brown-and-burn will not achieve these stocking goals.

Overhead and horizontal cover was greatest in the unburned treatments due to high hardwood stem densities. However, the fell-and-burn treatment contained a high hardwood stem-count and a large amount of herbaceous matter. This characteristic of the fell-and-burn treatment adds a structural diversity component that none of the other treatments showed. This diversity is important to breeding songbirds, since grassland and shrubland guilds will be represented on the same area. This effect will disappear as the stand matures.

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CHAPTER 1

INTRODUCTION

Mixed pine-hardwood is a subclimax forest type maintained by disturbance (Martin 1989). The likelihood that pine-hardwood forest types will continue to be represented in the forests of the southeastern United States under present forest management strategies has recently come into question. In recent decades, foresters have observed a marked decrease in mixed pine-hardwood forest cover types over much of the southeastern United States (USDA 1988). This gradual, long-term trend periodically becomes rapid due to such variables as location within the region, insect/disease epidemic (especially the southern pine beetle), changes in land use, extent of forest protection, and alteration of disturbance patterns (Sheffield et al. 1989).

These trends emphasize the need to develop silvicultural treatments for regenerating mixed pine-hardwood stands on suitable sites. This need was brought to the attention of the mainstream of southern foresters at the Southern Forest Productivity Program Development Workshop in 1987, although many forestry professionals recognized the decline in mixed pine-hardwood stands prior to this date. Among the ideas introduced at this meeting pertaining to pine-hardwood stands and their management were the needs to:

1) develop low-cost regeneration techniques for mixed pine-hardwood stands,

2) recognize the role of small landowners in maintaining pine-hardwood types for timber production, and

3) better understand the basic principles of pine-hardwood management and how they relate to wildlife management considerations.

This workshop resulted in an increased awareness of the need to study all facets of pine-hardwood management and silviculture. Two years later, the United States Forest Service (USFS), Southeastern Forest Experiment Station hosted a symposium on the ecology and management of pine-hardwood mixtures to provide a summary of recent research dealing with the subject. The proceedings of this symposium (Waldrop 1989) clearly reflected the need for more research on methods for maintaining pine-hardwood mixtures in eastern forest ecosystems.

Two important management objectives for southern foresters and game managers were emphasized. One objective was to introduce pine-hardwood silviculture to non-industrial private forest (NIPF) landowners as an alternative to pine monocultures. To accomplish this objective, low-cost silvicultural practices were emphasized. The rationale for this objective was that low-cost silvicultural practices for pine-hardwood management would compensate for potential monetary losses resulting from a change to pine-hardwood management from intensive pine management, which generally has a higher income potential. The second objective was to utilize silvicultural practices in pine-hardwood management that enhance food and cover for wildlife.

These objectives have provided the basic guidance for USFS research programs designed to improve pine-hardwood management on NIPF holdings. Since the majority (90 percent) of all timberland in the southern United States is privately owned (USDA 1988), and 68.7 percent of all pine-hardwood forest acreage is privately owned (Waddell

et al. 1989), improving timber production on these lands would add significantly to the available timber supply. The southeastern United States is a leading timber and wood-products-producing region in the United States (Alig et al. 1986), so cost-effectiveness would always be an important consideration. Also, simultaneous improvement in wildlife habitat would enhance the multiple benefits of forest management on NIPF holdings.

Advantages to wildlife would largely result from increases in stand type diversity on a local and regional basis. These advantages are likely assuming increased pine-hardwood management on NIPF lands. This would presumably lead to increased diversity of wildlife populations. Wigley et al. (1989) stated that pine-hardwood stands offer increased diversity of food and cover choices to wildlife species compared to pine monocultures, due to the presence of a hardwood component, but not necessarily more food. These stands would also provide the habitat requirements necessary to support species which require or prefer pines as part of their habitat (Kerpez and Stauffer 1989, Loeb and Lennartz 1989, Still and Bauman 1989).

NIPF landowners rank wildlife values high among the multiple uses for which their stands are managed (Nabi et al. 1983, Owen et al. 1985). For many landowners, providing a balance between timber and wildlife values is important. Pine-hardwood management may be the best way to achieve this balance (Wigley et al. 1989).

Improving or preserving wildlife habitat may be the major factor that motivates some NIPF landowners to implement pine-hardwood management. Many landowners object to pine monocultures because they perceive aesthetic qualities as low in these stands. Another important consideration is the possibility for additional revenue to

landowners through hunting leases when wildlife habitat improvements associated with pine-hardwood management have been implemented.

Influenced by the many perceived advantages of pine-hardwood management, the USFS has made a commitment in the southeastern United States to study the ecology of pine-hardwood mixtures and to evaluate how pine-hardwood can contribute to forest productivity both for both timber and wildlife. This study was one among several supported by the USFS that focused on the management of pine-hardwood mixtures in the southern Appalachian Mountains and Piedmont regions of the southeastern United States. It was the only study, however, that was located within the Ridge and Valley Physiographic Province and the only one that compared two pine species, white and loblolly (Scientific names for all plant species mentioned in the text or tables of this thesis were taken from Little (1988) or Wofford (1989) and are located in Appendix A.).

The objectives of this study were to:

1) compare the effectiveness of the fell-and-burn site preparation technique with three other techniques that are widely used:

   A) a commercial clearcut,

   B) a silvicultural clearcut, and

   C) a technique closely approximating the current industry standard (brown-and-burn) for establishing pine-hardwood stands, and

2) evaluate the resulting site conditions in terms of habitat quality for certain wildlife species native to the region.

This study evaluated wildlife habitat conditions following four site preparation treatments and evaluated their suitability for selected wildlife species native to the study

area. Two wildlife groups were chosen for primary analysis in this study, but information on other selected species was also provided for additional relevance with respect to pine-hardwood stands or stand manipulation. The two main groups were songbirds and eastern wild turkeys. Songbirds were chosen due to the research prominence they have attained in recent years and due to the vast amount of information available on their habitat preferences. Eastern wild turkeys were chosen due to the relationships they tend to show to stand age. (Scientific names for all animal species mentioned in the text or tables of this thesis were taken from Conant (1975), Burt and Grossenheider (1976), or Ehrlich et al. (1988) and are located in Appendix B.) Of particular interest were the effects of the fell-and-burn site preparation technique on these species.

CHAPTER 2

LITERATURE REVIEW

Pine-Hardwood Cover Types

Cover Type Description

Pine-hardwood cover types have often been described as "oak-pine" types due to the perceived importance of the oak component of these stands. USFS forest inventories in many southeastern states have combined all mixed stands under this designation although stand composition likely differed among states. The Society of American Foresters (SAF) (Eyre 1980) recognized five oak-pine and pine-hardwood cover types. This study considered pine-hardwood as a variation of the loblolly pine-hardwood cover type designated by the SAF but recognized the importance of an oak component in mixed stands for timber and wildlife considerations. The loblolly pine-hardwood type was described as a mixed stand where loblolly pine is not dominant but comprises at least 20 percent of the stand and, on upland sites, can be found in association with various oaks, hickories, and yellow-poplar (Switzer 1980). Loblolly pine is not native to the southern Appalachian region, but it is widely planted and is currently regenerating naturally.

In the Blue Ridge Mountains, pine-hardwood communities occupy mesic to xeric sites on south-facing slopes and are characterized by a relatively high proportion of oak, a diminishing pine component, and an increase in hickories compared to other pine types of the area (Racine 1966). Racine (1966) reported several important associate species for pine-hardwood stands in the Blue Ridge Mountains including chestnut oak, red maple,

blackgum, sourwood, black oak, and various hickories. Forest surveys have shown that this type occupies nearly 1.3 million hectares, or 12 percent of the southeastern United States' timberland (Knight and Phillips 1986).

Successional Stage

Martin (1989) considers pine-hardwood types to be sub-climax, existing only due to disturbance. Evans (1978) stated that a pine-hardwood forest regenerating from a clearcut will show the entire range of pine-hardwood forest components during stand development. Pine-hardwood succession from a clearcut differs from the more typical "old-field" type of pine-hardwood succession where pine dominates initially, often in pure stands, and the hardwood component does not establish itself until a number of years later. Pine-hardwood types eventually become hardwood types unless mechanisms to re-establish pine trees are present.

The Fell-and-Burn Treatment

Description

This study focused on the fell-and-burn technique for converting low-quality hardwood stands into pine-hardwood mixtures. This site preparation technique, described by Abercrombie and Sims (1986), Phillips and Abercrombie (1987), and Van Lear and Waldrop (1988), is an inexpensive way to improve the value of low-quality hardwood stands by introducing a pine component (Phillips and Abercrombie 1987). The fell-and-

burn treatment is generally applied in the following manner. In the spring following a commercial clearcut, residual stems greater than 1.83 meters (6 feet) tall are felled following complete leaf-out. The clearcut and felled areas are then burned during mid- to late summer or fall following the spring felling. Burning is conducted 1 to 3 days following a soaking rain when 10-hour time-lag fuel moisture content is 10 percent (Waldrop 1989).

Effects on Wildlife

The fell-and-burn site preparation technique has not been studied extensively with respect to its effects on wildlife populations and wildlife habitat. Evans (1990) and Evans et al. (1991a,b) documented the fell-and-burn technique's effects on populations of small mammals and insects. These studies determined that the fell-and-burn treatment increased forage production and richness of vegetation, particularly on winter-felled study plots. They also reported more small mammals following burning but fewer insects. They hypothesized that small mammal increases were the result of increased forage production. Van Lear and Kapeluck (1989) reported that shrub and herbaceous biomass on burned plots was almost twice that of unburned plots after one growing season. This suggested a positive influence on wildlife populations due to increased food availability. Other impacts of this site preparation technique on wildlife populations and habitat have not been defined sufficiently (Evans et al. 1991b).

Relationships of Wildlife to Pine-Hardwood Stands

Songbirds

Pine-hardwood stands are important breeding habitats for many bird species. Meyers and Johnson (1978) determined that bird density and richness in mixed stands was similar (high) to that of mature hardwood forests. They also reported that the average density of breeding pairs in mixed stands was 550 per km^2 and that at least 20 species are normally found in pine-hardwood stands on mesic sites.

Noble and Hamilton (1975) found that breeding bird diversity in mature pine-hardwoods was less than that of a 46-year-old even-aged pine stand. However, bird densities were from 2.4 to 4.9 times higher in pine-hardwood stands than in younger pine stands. Johnston and Odum (1956) also noted low densities of breeding birds as a characteristic of young pine forests in the southeastern United States. Noble and Hamilton (1975) reported that winter bird species diversity was greatest in an uneven-aged pine-hardwood stand when compared to pine monocultures of various, younger ages in Louisiana.

The practice of converting low-quality hardwoods to pines or pine-hardwoods may affect stand composition and cause changes in neotropical migratory bird community composition and diversity (Thompson et al. 1993). Thompson et al. (1993) showed that bird populations in pine plantations were dependent on the presence of a hardwood understory. Control of hardwoods in these situations would be detrimental to birds.

Certain birds are dependent on pine-hardwood stands or the pine component of those stands. These bird species can experience population declines, become isolated,

or become extirpated from all or part of their existing ranges as pine-hardwood stands diminish. Kerpez and Stauffer (1989) claimed that as many as 9 bird species would be extirpated from pine-hardwood forests in the southern United States if these forests were converted to oak-hickory or loblolly-shortleaf pine stands. These species included three (long-eared owl, black-throated green warbler, and Bachman's sparrow) for which pine-hardwoods provide optimal or suitable breeding habitat and six (turkey vulture, black vulture, ruffed grouse, chuck-will's-widow, black-and-white warbler, and ovenbird) for which pine-hardwoods provide optimal or suitable wintering habitat.

Some species, like the pine warbler, forage primarily on insects living on pine trees (Ehrlich et al. 1988). Others rely on a pine component for breeding, nesting, or resting purposes. Johnston and Odum (1956) noted that the brown-headed nuthatch, red-cockaded woodpecker, and pine warbler are the only breeding species restricted to southern pines. They further noted that all other birds in pine forests are either associated with the hardwood understory or a portion of the pine tree's life history.

An example of this relationship was documented by Hardy (1991) near the study area for this thesis. She reported that white pine- and loblolly pine-dominated stands with well-developed hardwood understories provided breeding and wintering habitat for diverse bird communities. Further evidence of the importance of mixed stands to bird communities was reported in a simulation study by Kerpez and Stauffer (1989) who found that pine-hardwood forests provided either optimal habitat or more suitable wintering habitat for more bird species than either pure pine or pure hardwood forests. They also reported more bird species breeding in mixed stands than in pure pine forests.

Strelke and Dickson (1980) found that pine-hardwood forest edges supported more breeding birds, had higher species diversity, and greater abundance of birds than did interior forests or clearcuts. Evans (1978) stated that oak-pine forests are of greater value to wintering birds than are oak-hickory forests. Ryder and Ryder (1976) compared populations of wintering birds in pine-hardwood forests and oak-hickory forests. They determined that the pine-hardwood stand they studied supported more than twice the number of commonly-occurring bird species (n=23) than the two oak-hickory stands studied (n=8,11).

Perkins and Hurst (1989) noted 23 bird species breeding in pine-hardwood forests in Mississippi. Fowler et al. (1985) found that mixed stands provided suitable habitat for common ravens in Kentucky. Fifteen bird species were listed by Shugart et al. (1978) as preferring pine-hardwood for breeding habitat. Several researchers have documented that at least 15 breeding bird species utilize pine-hardwood forests (Meyers and Johnson 1978, Dickson and Segelquist 1979, Dickson et al. 1980, Noble et al. 1980, Childers et al. 1986). Presumably, pine-hardwood stands provide enough vegetative and faunal (insect) forage to support such diverse populations of breeding and wintering birds.

Dickson and Segelquist (1978) studied the effects of stand structure on winter bird populations in pine and pine-hardwood stands in east Texas. They found that young stands of both types generally had more birds than mature stands of the same type. Mid-aged pine sapling stands generally contained the fewest birds. Pine-hardwood stands and pine stands showed similar numbers of species in their study, but pine-hardwood stands

were lower in bird density than pine stands of comparable height. Meyers and Johnson (1978) and Briggs et al. (1982) asserted that southern pines are most valuable for birds when mixed with hardwoods.

Eastern Wild Turkey

Speake et al. (1975) suggested that where stands were dominated by pines (pine >90%), wild turkey density decreased. Still and Bauman (1989) observed that wild turkey hens utilized pine-hardwood stands preferentially for nesting . Other authors have documented wild turkey preference of pine-hardwood stands in Texas (Hopkins 1981) and in Georgia for wintering turkeys (Sisson et al. 1990). Smith and Teitelbaum (1986) reported similar results, showing that pine-hardwood stands were used frequently for roosting by wild turkeys. Similar findings were reported by Fleming and Webb (1974) for South Carolina gobblers. Their study showed that 54 percent of gobbler roost locations were in pine-hardwood stands, and that gobblers favored loblolly pine as roost trees within mixed stand types.

Pine-hardwood stands provide a variety of foods for wild turkeys. Wild turkeys feed on pine seeds, particularly in the absence of other food sources (Korschgen 1967, Kennamer et al. 1980a, Exum et al. 1987). Turkeys also prefer pine-hardwood stands as fall-winter habitats (Sisson et al. 1990), especially when acorns are in short supply. This relationship was demonstrated in at least one study in east Tennessee in the vicinity of this study (Minser et al., unpublished data).

Other Wildlife Species

The importance of maintaining the pine-hardwood cover type for wildlife should not be minimized. It has been estimated that by the year 2030, white-tailed deer population densities in the USFS's Southeast Region will have dropped from an average of 6.8 animals per square kilometer (17.7 animals per square mile) to 5.6 animals per square kilometer (14.5 animals per square mile), partly due to conversion of oak-pine to pine monocultures (USDA 1988). A similar drop is projected in the south-central United States. Eastern wild turkey populations are also expected to decline (USDA 1988). The populations of other species could also decrease as the area in pine-hardwood stands declines.

Small mammals such as squirrels utilize pine seeds. In particular, the decline of the fox squirrel has been attributed to the decline of pine-hardwood stands in the southeastern United States (Loeb and Lennartz 1989). Fox squirrels utilize pine seeds, buds, and staminate cones when available. As pine-hardwood stands decline, so may populations of the fox squirrel, unless alternative food sources, such as tree buds, fungi, and insects, can be utilized.

Pine-hardwood stands do not provide important habitat for some species. Boyd (1990) found that ruffed grouse utilized mature pine and pine-hardwood stands in the southern Appalachian Mountains less than the availability of those stands. Similar relationships would likely be evident for other species which require hardwood stands.

Effects of Stand Manipulation on Wildlife Species

The wildlife species occupying forest stands subjected to stand manipulation are altered depending on the magnitude of the manipulation. The literature reviewed here was limited to the effects of the four primary treatments applied in this study on stand development and wildlife populations. The primary silvicultural practice utilized in this study was clearcutting. Of the four modifications of clearcutting that comprised the treatments, one (commercial clearcutting) is not considered a silvicultural practice. For songbirds in particular, this discussion differentiates the subtle differences between natural and silvicultural changes in vegetation.

Songbirds

Clearcutting

Clearcutting favors the development of shade-intolerant species, including yellow-poplar and some oaks, as well as the regeneration of sprouting species, such as red maple, flowering dogwood, and sourwood. In particular, this silvicultural technique provides optimum light conditions for rapid growth of intolerant species from both seedling and coppice origins.

Spurr and Barnes (1980) described competition and secondary succession in even-aged stands as follows:

> "In even-aged stands, competition for light, moisture, and nutrients depends largely on the number of stems per unit area. In time, crowns of trees come together and crown class differentiation becomes pronounced. Due to a combination of environmental and genetic factors, some trees develop rapidly and exhibit large, well-formed crowns. Other

> trees grow more slowly and their crowns become more or less restricted; in time some trees are gradually overtopped and suppressed. Root competition is often severe in the even-aged stand, although it is much less observable than crown competition. . . . Except at very low densities, mortality is caused by competition among trees and between trees and associated vegetation for light, water, nutrients, and other site resources. Mortality is greatest in the seedling stage when the number of seedlings per hectare is highest."

The impacts of clearcutting on bird populations vary and are dependent primarily on habitat requirements. However, intensive forest management, including clearcutting, generally results in an apparent loss of spatial, temporal, and vertical ecosystem diversity which is considered essential for a variety of wildlife species and aesthetic amenities (White 1975). Thomas et al. (1975) described the influences of various silvicultural techniques utilized in timber stands of differing ages on different bird guilds. They found that the effects of clearcutting on birds varied depending on the age of the stand that was cut and on the nesting and feeding characteristics of the bird species. This led the authors to identify three primary concerns regarding forest management's effect on birds which were:

1) truncated succession (Simpler vegetation structure leads to less diverse faunal populations.),

2) loss of old-growth habitats (Mature forests support more diverse bird populations.), and

3) removal of snags or standing dead trees (These support numerous species which are unlikely to adapt to other conditions.).

Zeedyk and Evans (1975) noted that six distinct habitat layers - bare ground, forest floor duff, herbaceous ground cover, low understory shrubs, midstory, and overstory trees - can exist in varying arrangements and quantities. These layers are

influenced by the configuration of the overstory, silvicultural practices, or other environmental perturbations. When silvicultural manipulations are involved, they are usually the primary instigators of succession and resulting stand development.

Stand development following clearcutting in upland hardwoods is a dynamic process. After a clearcut, the "brushy stage" is characterized by a high number of hardwood stems, typically greater than 20,000 per hectare (Evans 1978). By age 20, most non-timber tree species have died or become suppressed and the stem density has dropped to a few thousand stems per hectare. Even without thinning, Gingrich (1971) and Zeedyk and Evans (1975) estimated that 90 percent of these trees will die prior to stand maturation.

Positive and negative impacts to bird populations and communities have been documented following clearcutting, giving rise to two clear lines of argument. Most of the literature detailing negative effects on birds has dealt with stenoecious species, particularly forest-interior or area-sensitive species which cannot exist in small stands or in young or middle-aged seral stages (Robbins et al. 1989, Freemark and Collins 1992). Species such as the ovenbird, hooded warbler, and eastern wood-pewee may be replaced in clearcuts by indigo buntings, rufous-sided towhees, and field sparrows (Bent 1953).

Certain bird species (i.e., forest-interior species) may experience population declines resulting from clearcutting within larger stands. The resulting increase in edge can also increase predation and brood parasitism for some species. Clearcutting (McComb et al. 1991) and fragmentation (Webb et al. 1977, Robbins 1984) cause decreases in abundance of ovenbirds and several other warblers. Regeneration cuts result

in the replacement of bird communities typical of mature forests with bird communities typical of young forests (Thompson et al. 1993).

Recent observations suggest that brood parasitism by brown-headed cowbirds (Brittingham and Temple 1983) and nest predation by edge-dwelling predators (Wilcove 1985, Yahner and Scott 1988), such as common crows, striped skunks, opossums, black racers, and rat snakes, may be responsible for population declines. Other declines may be the result of edge-induced reduction of avian reproductive rates. While edge effects such as these may exist around harvest cuts, the impact of such effects on a population in a forested landscape may be minimal when compared to the impact of converting mature forest to young forest (Thompson et al. 1993).

Most of the positive effects of clearcutting on bird populations reported in the literature deal with increased species diversity resulting from the shift of forest bird communities to communities of birds preferring young stands. Thompson et al. (1992) found no loss of forest-interior species within a large study area managed by clearcutting when compared to an area without clearcutting. However, densities of these species declined in those portions of the study area which were clearcut and in adjacent mature stands. McComb and Noble (1980) documented increases in seasonal bird species (and small mammal) diversity following cutting in pine-hardwood stands in Mississippi. Hooper (1967) and Ambrose (1975) noted higher bird diversity in clearcuts than in uncut forest areas in southwestern Virginia and Tennessee, respectively.

A mixture of successional stages and forest age classes in different size stands is preferable for non-game bird management (Zeedyk and Evans 1975). Certain bird

species show an affinity to the type of diverse landscape juxtaposition provided by even-aged management. For example, mockingbirds and loggerhead shrikes require, as part of their breeding territories, two or more communities of widely different ecological stages (Johnston and Odum 1956). Bird diversity can be increased by accepting a stand basal area that is somewhat less than the optimum for growing timber (Hamilton and Noble 1975).

Conner and Adkisson (1975) studied the effects of clearcutting on bird communities in southwestern Virginia. They found that clearcutting initially reduced the diversity of breeding songbirds and the number of birds seen. However, older clearcuts (e.g., 7 years) showed an increase of bird species and numbers of birds seen, with clearcuts providing habitat for many species of birds not found in mature forests.

Conner and Adkisson (1975) further noted that older clearcuts exhibited characteristics preferred by some birds. Older clearcuts provided access to the ground for ground-foraging birds, dense clumps of vegetation and slash suitable for nesting and foraging of insectivorous birds, and more diversity in vegetation heights and foliage levels. They suggested that disking and burning be eliminated as site preparation methods if bird populations are to increase following clearcutting and that dead snags and some live trees be left in clearcuts.

Clearcutting usually leaves residual vegetation structure that is important to some birds. Many species of songbirds are likely to nest and forage for seeds and invertebrates in regenerating areas (Gates 1991). Downy and hairy woodpeckers were shown by Conner and Crawford (1974) to utilize logging slash extensively for foraging

in a mixed-oak study area in southwestern Virginia. However, use of these clearcuts by downy and hairy woodpeckers declined substantially as the regenerating stand grew older. Use of clearcuts by common flickers was greatest when flowering dogwood fruits were plentiful, which was approximately 5 years following clearcutting. Pileated woodpeckers did not generally utilize clearcuts unless standing snags were present. Residual standing trees or dead snags also enhanced the use of clearcuts by downy and hairy woodpeckers.

McPeek (1985) documented the utilization of mixed mesophytic forests by bark-foraging birds in southeastern Kentucky. This study found that bark-foraging birds used large-diameter snags more than small-diameter snags for foraging, and pine snags more than other (hardwood) species. No nesting or roosting cavities were evident after two years in created snags.

Noble and Hamilton (1975) highlighted the importance of leaving snags following clearcutting. Some bird species were largely associated with, and concentrated around, dead trees and snags. This was true for woodpeckers (except the red-cockaded woodpecker), eastern bluebird, brown-headed nuthatch, tufted titmouse, barred owl, great-crested flycatcher, and prothonotary warbler, and, to a lesser extent, for the eastern wood-pewee, Carolina chickadee, and American kestrel. Balda (1975) also noted the importance of snags for bird guilds which are secondary cavity-nesters (those birds which nest in old woodpecker holes and natural cavities). He pointed out that these species can often contribute significantly to the diversity of birds and to the overall number of breeding pairs that may occupy an area.

Clearcutting provides suitable nesting habitat and cover for a number of species which nest less than six feet from the ground (Yahner 1986). Clearcuts were the only sites utilized for nesting by common flickers in one Virginia study that compared woodpecker nesting preferences in cut and uncut areas (Conner et al. 1975). Downy, hairy, and pileated woodpeckers also nested in clearcuts if suitable sites were available. However, nest utilization by common flickers was much higher than that shown by downy, hairy, or pileated woodpeckers.

Felling

Felling following clearcutting is a widely accepted and successful method of regenerating southern Appalachian hardwoods (Beck and Hooper 1986). Felling converts a commercial clearcut to a silvicultural clearcut when applied properly and can also have implications on the bird communities existing there. The removal of dead or topped trees by felling following commercial clearcutting destroys habitat features that favor many species of breeding insectivorous birds such as the hairy woodpecker, red-bellied woodpecker, Carolina chickadee, tufted titmouse, brown-headed nuthatch, and eastern bluebird (Hamilton and Noble 1975). Pinkowski (1976) observed that even-aged timber management and extensive removal of dead trees was detrimental to bluebirds.

Burning

Marshall (1963) examined the relationship of birds to burned and unburned pine-hardwood stands. His study revealed that bird species adjusted to the open understory

created by burning. The scattered trees that were abundant in the burned pine-hardwood stand also improved habitat for birds. Conversely, the bird species that inhabited the unburned pine-hardwood stand were those that preferred a heavy shrub layer. Komarek (1969) listed 77 bird species for which habitat was improved by burning.

Bendell (1974) summarized a number of studies of the effect of fire on birds and small mammals. He showed that most birds and small mammals (over 80 percent) stayed on the burned area following a fire. He attributed this, at least partially, to the interspersion of unburned habitats that typically remains following a fire. Certain species disappeared from the area shortly after the burn, but these were replaced by other species, particularly ground-foraging birds. Buckner and Landers (1979) found that burning stimulated the germination of fire-adapted plants, such as legumes, which yielded more total plants and seeds for use by birds. Similar results were documented in other studies (Devet and Hopkins 1967, Buckner et al. 1983).

Herbicides

Herbicides generally alter the structure and composition of the plant communities to which they are applied. Morrison and Meslow (1984) noted that the primary effect of herbicide application was a reduction in the complexity of vegetation resulting from the removal of deciduous trees. These types of vegetation alterations often result in avian community changes or, as Morrison and Meslow (1984) reported in Oregon, (foraging) behavior alterations. Similar behavior modifications were noted by Sullivan (1985).

An increase in herbaceous biomass will likely result from herbicide applications in clearcut areas. Hurst and Palmer (1988) showed that site preparation consisting of burning and a herbicide application in 1- to 2-year-old loblolly pine plantations resulted in a plant community initially dominated by forbs. This effect of herbicides was also noted by Gibbens et al. (1986) and was shown to have a positive effect on the amount of seeds available to avian communities in Georgia (Stone 1986).

Herbicide treatments resulted in higher avian diversity and numbers compared to mechanically-prepared areas in 17 loblolly and shortleaf pine areas in east-central Mississippi (Darden 1980). However, the same study detected negligible differences in avian diversity due to site preparation by the time the stand was 7 years old. This suggests that the advantages of high herbaceous biomass gained early in the life of a stand through herbicide applications have little long-term effect on avian diversity. Herbicide use slows the development of a clearcut into a forest and consequently causes the bird community to remain longer as an early successional bird community (McArthur 1980).

Relationships of Songbirds to Habitat Characteristics

Important factors identified as important in habitat selection by birds include landscape features, vegetation structure, and spatial arrangement of the vegetation (Wiens 1969). Vegetation structure is the most important of these factors. Karr and Roth (1971) found that bird diversity generally changes in relation to stand development.

MacArthur and MacArthur (1961) reported that bird diversity was strongly correlated with foliage height diversity, which is a measure of the amount of leaf surface area present in horizontal layers above the ground. They further noted that plant species diversity may be an important influence on avian diversity, but that it was not as important as foliage height diversity. Hooper et al. (1973) also found that bird density increased with the addition of vegetative layers. This increase was attributed to the increased development and density of understory canopy layers.

Balda (1975) suggested that if bird diversity is positively related to foliage height diversity, then bird numbers will increase with stand development. This would mean that the number of bird species occupying an area will increase with time (Beecher 1942, Kendeigh 1946, Johnston and Odum 1956). Evidence in support of this relationship was offered by Shugart and James (1973) who found that bird density and diversity increased with the relative age of the stand to the point that maximum species diversity was usually achieved in mature stands.

Bird diversity can be characterized as lowest in young stands, higher in mid-aged stands, and highest in mature stands (Hamilton and Noble 1975). The youngest stands are structurally the simplest and the most unstable, while mature stands the most stable and complex (Odum 1969). Bird diversity in the early, changing stages of stand development is also the most variable (Kricher 1973). Bird diversities in mature stands fluctuate but not as dramatically as in young stands.

The relationship of steadily increasing numbers of bird species as succession progresses is based on theoretical principles. In reality, bird communities and

populations often change dramatically over time. Exceptions to the idea of increasing numbers of bird species during stand development were noted by Conner and Adkisson (1975). They documented situations where breeding bird densities in regenerating forests were similar to or greater than those in mature stands, with densities lowest in the mid-successional pole-sized stands.

Shugart et al. (1975) noted that through succession, bird populations typically increase in density and diversity. They noted that habitat selection is an important determining factor for bird distributions and that various habitat factors are more important than specific food-availability factors. In addition to the increase in species diversity with succession, there is a gradual change in species composition between seral stages. Shugart and James (1973) identified upland successional stages in northwestern Arkansas as: 1) fields dominated by grasses and forbs, 2) fields dominated by shrubs and shade-intolerant trees, and 3) forests dominated by trees (the authors' terms). Each of these contained distinctive breeding bird species.

The differences in bird communities, as evidenced by differences in species composition, are the result of structural changes in the constituent vegetation (Hamilton and Noble 1975). In general, young stands support foliage-gleaning neotropical migratory birds, some aerial foragers, and ground-foraging migrants because of the fruits, insects, and suitable nest sites they provide. Foliage-gleaning birds are most abundant in stands regenerating from hardwood coppice due to rapid canopy closure; ground-foragers prefer "old field" situations until canopy closure and again at stand maturity (Thompson et al. 1993).

Habitat selection by birds may be influenced by factors other than the number of canopy layers present. MacArthur et al. (1962) concluded that patchiness (the horizontal variability in habitat structure) was the principal factor affecting bird species diversity and that its effect was much more important than that of additional vegetation layers (vertical variability) in supporting both ground and canopy species. Balda (1969) and Pearson (1971) determined that foliage volume influenced bird density. They showed that a greater foliage volume contained more birds.

Utilizing data collected on an area less than 15 kilometers from this study site, Anderson and Shugart (1974) found that some bird species were distributed according to specific habitat characteristics. For example, the abundance of downy woodpeckers was highly correlated with the number of saplings present. They also found that cardinals preferred areas characterized by dense shrubs and vines, a relationship also noted by Dow (1968) at another Tennessee location.

Zeedyk and Evans (1975) showed that the population density and diversity of bird species was influenced strongly by forest management practices. Euryoecious birds initially occupied regenerating stands. As the stand matured, however, more stenoecious species inhabited the area. Stenoecious species are those species which exhibit specific habitat requirements for at least one phase of their life cycle; euryoecious species are adaptable to habitat variability.

Eastern Wild Turkey

Clearcutting

Clearcutting provides suitable nesting habitat for many avian species that nest less than 3 meters from the ground including the wild turkey, American woodcock, gray catbird, common yellowthroat, rufous-sided towhee, and field sparrow (Yahner 1986). Wild turkey hens prefer regenerating forest stands (Hillestad 1973, Speake et al. 1975, Still and Baumann 1989), scattered brush, or logging slash for nesting (Speake et al. 1973). Other authors have noted that wild turkeys will also nest in young pine plantations (Exum et al. 1987, Sisson et al. 1990, Smith et al. 1990). Everett et al. (1985) reported that wild turkey hens with broods preferred pastures, clearcut hardwoods, and other openings as brood habitat.

A number of authors have shown that wild turkey use of open areas decreases in favor of use of forested areas as winter habitat (Barwick and Speake 1973, Speake et al. 1975, Kennamer et al. 1980b). However, wild turkeys will use open areas as winter habitat in Tennessee if sufficient food items are present (Lewis 1964), particularly if acorn crops are light or fail (Dickson 1990). Hens and gobblers will seek openings as spring habitats, often moving large distances (Barwick and Speake 1973, Speake et al. 1975).

Felling

No applicable literature detailing the effects of felling on wild turkeys was found.

Burning

Wild turkey and white-tailed deer habitats are favored by burning (Spurr and Barnes 1980). Burning benefits wild turkeys and bobwhite quail through increases in legumes, reduction in external parasites, maintenance of brood habitat, and increases in arthropod food supply (Speake 1966, Lewis and Harshburger 1976). Hurst (1978) reported increases in total animal food availability for wild turkeys during the first 3 years following burning. Wild turkey poults prefer a diet high in arthropods due to their high protein requirements (Barwick et al. 1973, Hurst and Stringer 1975, Exum et al. 1987), but Hamrick and Davis (1971) documented high vegetable utilization of older juvenile turkeys. Juvenile and adult turkeys choose a higher percentage of vegetable foods (Barwick et al. 1973, Hurst 1992).

Herbicides

Bramble (1962) noted considerable alteration of plant cover, both in amount and kind, following broadcast and basal herbicide applications. Fireweed became prominent for several years after which the composition of the plant community shifted toward its original components, except that blueberry, which was practically eliminated by broadcast sprays, remained sparse. The development of edges and cover type interspersion through cutting plus the elimination of woody brush through the use of herbicides has favored such species as turkey and rabbits. Miller et al. (1989b) found that heavy grass cover on chemically-prepared sites favored rodents and provided summer foraging sites for wild turkey.

In summarizing available literature on the subject, the Herbicide Sub-Committee, Southeastern Section of The Wildlife Society concluded that widespread application of herbicides on upland, pine-hardwood sites benefits deer and rabbits, temporarily benefits ruffed grouse, and harms squirrels, turkeys, and raccoons (Chamberlain and Goodrich 1962). They also found that as the age of the pine stand increases, conditions for deer and rabbit become worse.

Other Wildlife Species

The overall effects of site preparation on wildlife habitat were described by Hunter (1990). He lists the following effects:

1. Accelerated succession,
2. Increased forage production with light site preparation,
3. Reduced forage production and understory plants with intensive site preparation,
4. Reduced biological diversity where logs and snags are removed,
5. Increased plant species diversity on burned sites, and
6. Increased plant species richness on mechanically prepared sites compared to chemically prepared sites.

Clearcutting

In addition to songbirds, game birds are likely to use the dense cover resulting from clearcutting. Ruffed grouse (Boyd 1990) and their broods (Epperson 1988) use regenerating hardwoods preferentially in the southern Appalachians. Increases in ruffed

grouse numbers have been observed where increases in the area of regenerating hardwoods occur in east Tennessee (Pelren 1991). Burt (1976) found that increasing populations of bobwhite quail, songbirds, and mourning doves were associated with the successional stage that followed clearcutting of hardwoods and conversion to pine in east Tennessee.

Not all wildlife species are attracted to the heavy cover that develops following clearcutting. Gates (1991) found that raccoons and gray squirrels avoided these areas while use by predators such as gray foxes and several species of snakes increased. The increase in predatory species may result from increased prey abundance. He also found that snakes preferred the edges of the regenerating areas, which is similar to the findings of other authors (Weatherhead and Charland 1985, Gibbons and Semlitsch 1987). Other predators are likely to invade the interior areas of the unburned treatments. This increase in predators is the most obvious reason for the avoidance behavior that many prey species exhibit with respect to older, thicker regenerating areas.

Clearcutting provides increased food availability for many wildlife species. One-year-old pine plantations subject to intensive site preparation in Georgia supported increased populations of seed-eating small mammals due to the prevalence of annual plants (Atkeson and Johnson 1979). The same study also demonstrated a shift in small mammal composition in the stand after three years, where herbivorous animals were the predominant species, since the stand was dominated by perennial grasses. However, all small mammals declined as the stand matured to age 15.

Total forage yield on clearcut plots in east Texas averaged 1,713 kilograms per hectare compared to only 345 kilograms per hectare for control (uncut) plots (Stransky 1980). The same study showed clearcut and burned plots averaged 3,416 kilograms per hectare after one growing season, but the amount of forage on those plots decreased significantly after five years. Similarly, Della-Bianca and Johnson (1965) showed that deer browse increased in the southern Appalachian Mountains following clearcutting, particularly on lower slope positions where the increase was 10 fold.

Felling

Some small mammals, such as deer mice, were more numerous and preferred fell-and-burn treatment plots over other site preparation techniques and unharvested areas (Evans et al. 1991a). This closely parallels the findings of Cushwa and Redd (1966) who found that there was 7 times more game on a cut-burned area than on a cut-unburned area.

Burning

Game birds, such as bobwhite quail (Stoddard 1931) and ruffed grouse (Vogl 1967), are more frequently studied with respect to their responses to burning than are non-game birds. Fire's role in the creation, destruction, or alteration of wildlife habitat has been detailed in Komarek (1966) and Neel (1967). The negative effects of fire on most wildlife species deal with habitat destruction (e.g., breeding cover) (Ream 1981), but these are usually short-term effects (Taylor 1981).

The positive effects of burning generally involve alteration of habitats to produce preferred habitats and increase food availability. Habitats created by fire include an abundance of vegetative growth on or near the ground, the growth of shrubs and trees in open stands with thick branches, and twigs, large fruits and seeds which may remain on the plant, tending to favor animals that browse or graze and are of relatively large size (Spurr and Barnes 1980). Evans et al. (1991b) found that burned plots supported richer, more productive plant communities and higher numbers of small mammals than did unburned plots. Teuke and Van Lear (1982) reported that prescribed burning increased the percentage of oak in one Appalachian Mountains study. Stransky and Halls (1976) determined that burning increased the quality of browse following site preparation. These authors later showed that burning increased fruit yield on burned plots (Stransky and Halls 1980).

Herbicides

Miller et al. (1989a) developed an annotated bibliography of the effects of herbicides on wildlife habitat. Four of the reported studies dealt with the effects of Imazapyr (Arsenal) on forage availability. These studies are particularly relevant, since Arsenal was the herbicide used in this study. Hurst (1988b) found less deer forage on Arsenal treated plots than on control plots. He also found decreases in total plant biomass, amount of deer forage, and number of plant species during the first growing season in a loblolly pine plantation treated with Arsenal (Hurst 1988a). However, no significant differences were evident following two growing seasons. Hardwood control

resulted in an increase in selected deer forage, mainly forbs, while blackberry and many legumes were resistant to Arsenal. Hurst (1987) reported fewer grasses and woody plants and a greater number of forbs and vines after Arsenal treatment. Legumes increased, and deer forage shifted from woody browse to forbs (legumes) and vines. Similar results were reported by Watkins et al. (1989). They showed that the species transition following Arsenal application benefitted wildlife by having greater and more preferred wildlife foods. This study found fewer grasses and woody plants and more forbs, including legumes, and vines in the herbicide-treated plots.

Numerous other studies have investigated the relationship between herbicide use and vegetation (forage) amounts (McKee 1972, Easley 1977, DeFazio 1986, Hurst and Warren 1986, Blake et al. 1987, Hurst and Blake 1987, Hurst 1988b, Hurst and Palmer 1988, Miller et al. 1989b). Each of these studies dealt primarily with white-tailed deer forage. There are direct relationships between herbicide applications for hardwood control and the production of deer forage (Chamberlain 1969). These relationships are generally dependent on the type and application rate of the herbicide used.

Herbicide application alters both habitat composition and structure resulting in differential response to herbicide-treated stands by terrestrial vertebrates (McComb and Hurst 1987). Frequently, the abundance of the vegetation on chemically prepared sites is greater than that which occurred prior to timber harvest or results from mechanical site preparation. Many of the woody mast producers escape injury or recover to sprout following application. If regeneration areas are well interspersed with mature stands, and

if stand rotation length is sufficient to allow sprouts to reach mast-bearing age, the long-term effects of chemical site preparation should not be detrimental (Carter et al. 1975).

Several studies have documented more wildlife forage availability following herbicide treatments. Hurst and Warren (1986) determined that forage amounts increased following herbicide application relative to site preparation techniques which had no herbicide treatment. McKee (1972) measured more white-tailed deer foods on clearcut and site prepared (herbicide) areas than in uncut forests. Hurst and Palmer (1988) found more forbs on chemically-treated plots than on untreated plots and more legumes after two years on the same plots. Hurst and Blake (1987) documented similar results within a loblolly pine plantation, finding more grasses, legumes, vines, woody browse, and sedges on herbicide treated plots than on untreated plots.

DeFazio (1986) determined that forage amounts for herbicide treated and control plots did not differ, but forage availability in the treated plots increased. Hurst (1988b) found less forage on plots treated with Arsenal than on untreated control plots. Miller et al. (1989b) reported less forb and woody vegetation on chemically-treated areas clearcuts, but several forb species, including grasses and legumes, were more abundant in chemically-treated areas.

Blake et al. (1987) found less forage on clearcut and herbicide plots after one year but no difference after two growing seasons when compared to plots without herbicide applications. Hurst (1988a) documented similar results. Easley (1977) obtained mixed results in loblolly pine plantations sprayed with herbicide. He found decreases in vine

and forb availability, no decrease in woody browse availability, and an increase in grasses.

Fewer small mammals were captured on herbicide-treated clearcuts than on untreated clearcuts for 3 years following treatment (Santillo 1987). This reduction was attributed to a reduction of invertebrates and fewer plants on herbicide plots, plus the herbicide-induced reduction in cover. A similar reduction in small mammal abundance was observed in one pine-hardwood study due to herbicide-induced differences in seed and insect availability (DeFazio et al. 1988). This indicates a negative effect on important foods of deer mice. In contrast, Sullivan (1985) found that herbicide treatment (Glyphosate) did not have a negative effect on the distribution and abundance of small mammal populations during the first year after treatment.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA

Location

The study area was on the University of Tennessee Forest Experiment Station and Arboretum (UTFESA). The UTFESA lies within the city limits of Oak Ridge, Tennessee (Figure 1), which is situated in the southwestern portion of Anderson County, Tennessee. This area is part of the Great Valley of east Tennessee, a part of the Valley and Ridge Physiographic Province (Moneymaker 1981).

This area of Tennessee is characterized by parallel ridges separated by narrow valleys. This topographic pattern was shaped by stream erosion and differential weathering of the folded and faulted alternating beds of sandstone, shale, and limestone that make up this region (Luther 1977). The area is drained by tributaries of the Clinch River, which is a tributary of the Tennessee River, the primary drainage system for the region.

Two study sites along the south slope of Chestnut Ridge (an east-west oriented ridge) were clearcut in preparation for this study. The west site was the larger of the two sites and was near the end of Chestnut Ridge Road in the UTFESA. The east site was at the end of Chestnut Ridge Road near the boundary of the UTFESA and the adjoining United States Department of Energy (DOE) property.

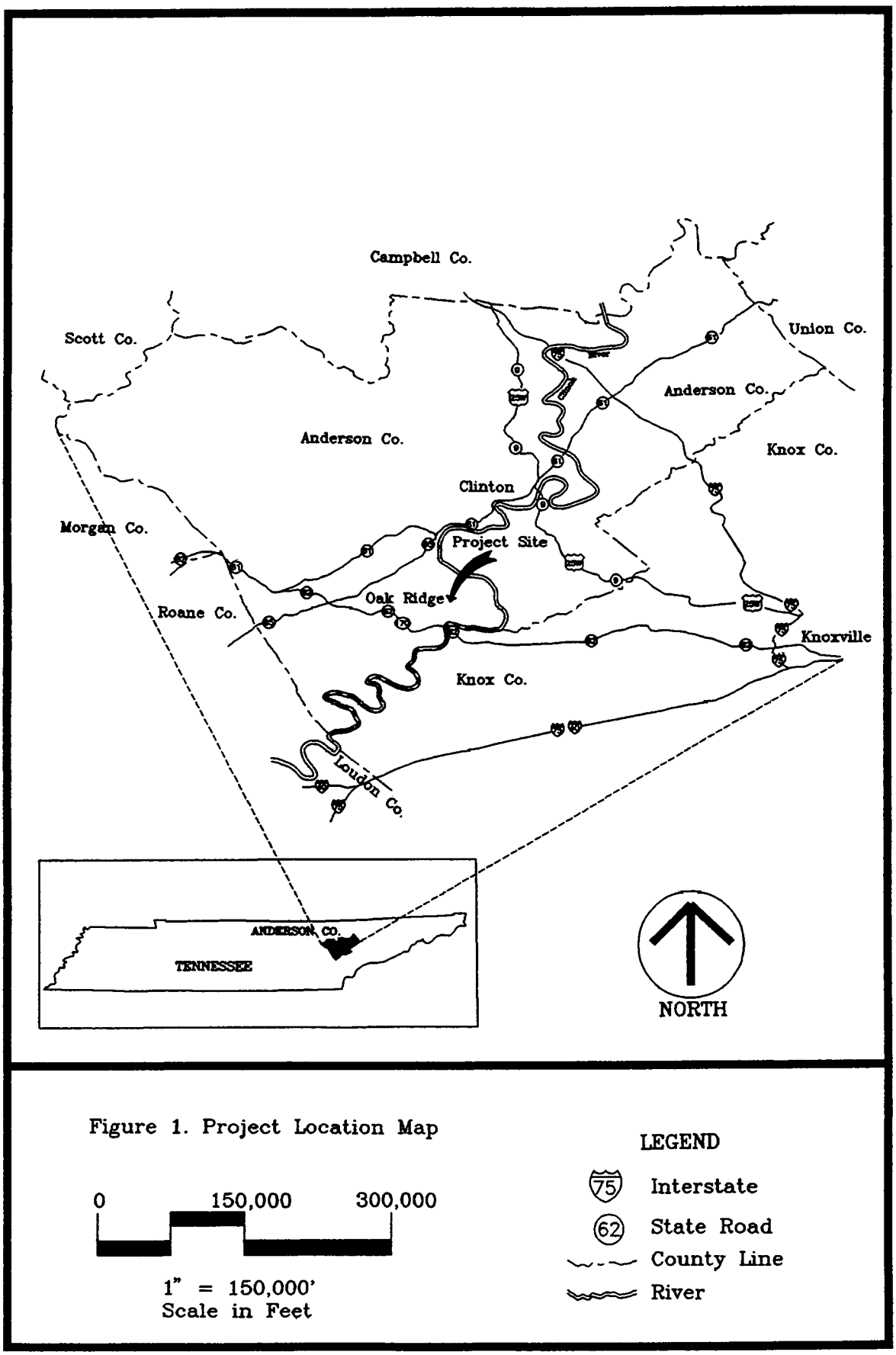


Figure 1. Project Location Map

0 150,000 300,000

1" = 150,000'
Scale in Feet

LEGEND

75 Interstate

62 State Road

County Line

River

Regional Forest Cover Types

The study area was situated within a section of the Valley and Ridge Physiographic Province that lies on the border of the oak-chestnut and oak-pine forest regions described by Braun (1950). Uplands of this area contain oak-dominated communities of the white oak-black oak-northern red oak forest cover type described by the SAF (Eyre 1980) or mixtures of oaks with Virginia and shortleaf pines (Martin 1971). Yellow-poplar is often a dominant canopy species on fertile, well-drained sites of this area (Buckner and McCracken 1978).

Both study sites supported mature stands of upland hardwoods similar to those described by the previously mentioned authors. The pre-harvest stands included white oak, chestnut oak, black oak, yellow-poplar, red maple, and other associated species prior to timber harvest. The west site contained the same species but also contained a number of mature shortleaf pines. Both sites were located on upper slope positions.

Soils

The soils of the study area were Fullerton cherty silt loams. These soils developed from highly-weathered dolomite of Cambrian-to-Mississippian age that have undergone severe folding and faulting (Moneymaker 1981). The soils are low in fertility and are rated medium in available water capacity, permeability, and runoff capability. The soils are also acidic and thinner on upper slope positions than on lower slope positions.

Climate

The climate of the study area is characterized by relatively mild, wet winters and warm, humid summers. Average temperature and precipitation measurements for the study area were obtained from the National Oceanic and Atmospheric Administration weather station in Oak Ridge, Tennessee (NOAA 1991). This weather station was within 8 kilometers of the study area. December and January are the coldest months averaging temperatures of 2.2 degrees C to 3.9 degrees C. The summer months (June, July, and August) had average temperatures of 22.8 degrees C to 25 degrees C.

Annual precipitation typically averages 134.04 cm, of which 40 percent occurs from December through March. Precipitation levels were above average for 1990 and 1991 (Table 1). Over 55 centimeters of rain were measured during the growing seasons (April through September) in both 1990 and 1991.

Table 1. Precipitation by Month for 1990 and 1991 at the National Oceanic and Atmospheric Administration Weather Station, Oak Ridge, Tennessee.

Month	1990 (cm)	1991 (cm)
January	13.4	7.5
February	20.3	20.2
March	12.9	18.9
April	6.5	9.8
May	16.7	6.5
June	3.9	17.9
July	12.9	10.3
August	12.9	11.7
September	3.7	7.3
October	10.3	4.5
November	6.1	10.5
December	32.1	27.7
Yearly Totals	151.8	152.8

CHAPTER 4

METHODS

Treatment Plot Establishment

The area selected for study supported a mature, upland hardwood forest dominated by various species of oaks. Twenty 0.4 hectare (1 acre) treatment plots were established, and plot centers and corners were staked with metal posts prior to administering a commercial sawtimber and pulpwood sale. Topographic variation and differences in stand conditions dictated the use of 2 study sites, a "west site" of approximately 10 hectares (24.7 acres) and an "east site" of approximately 4 hectares (9.9 acres) (Figure 2). The west site contained 12 of the 20 treatment plots; the remaining plots were located in the east site. Treatment plots were separated by 6.1-meter (20-foot) borders which, following timber harvest, were seeded with grasses to prevent erosion.

Following establishment of treatment plot corners and centers, a pre-harvest inventory was conducted. A point sample was made at each treatment plot center using a 10-factor prism. Dbh of all trees lying within the point sample was measured to the nearest tenth of an inch, and the species of each tree was noted. The distance to trees lying near the limit of the point sample was measured to assure that only trees within the point sample were tallied. Plots measured in the pre-harvest inventory were not the same plots used to collect post-treatment data.

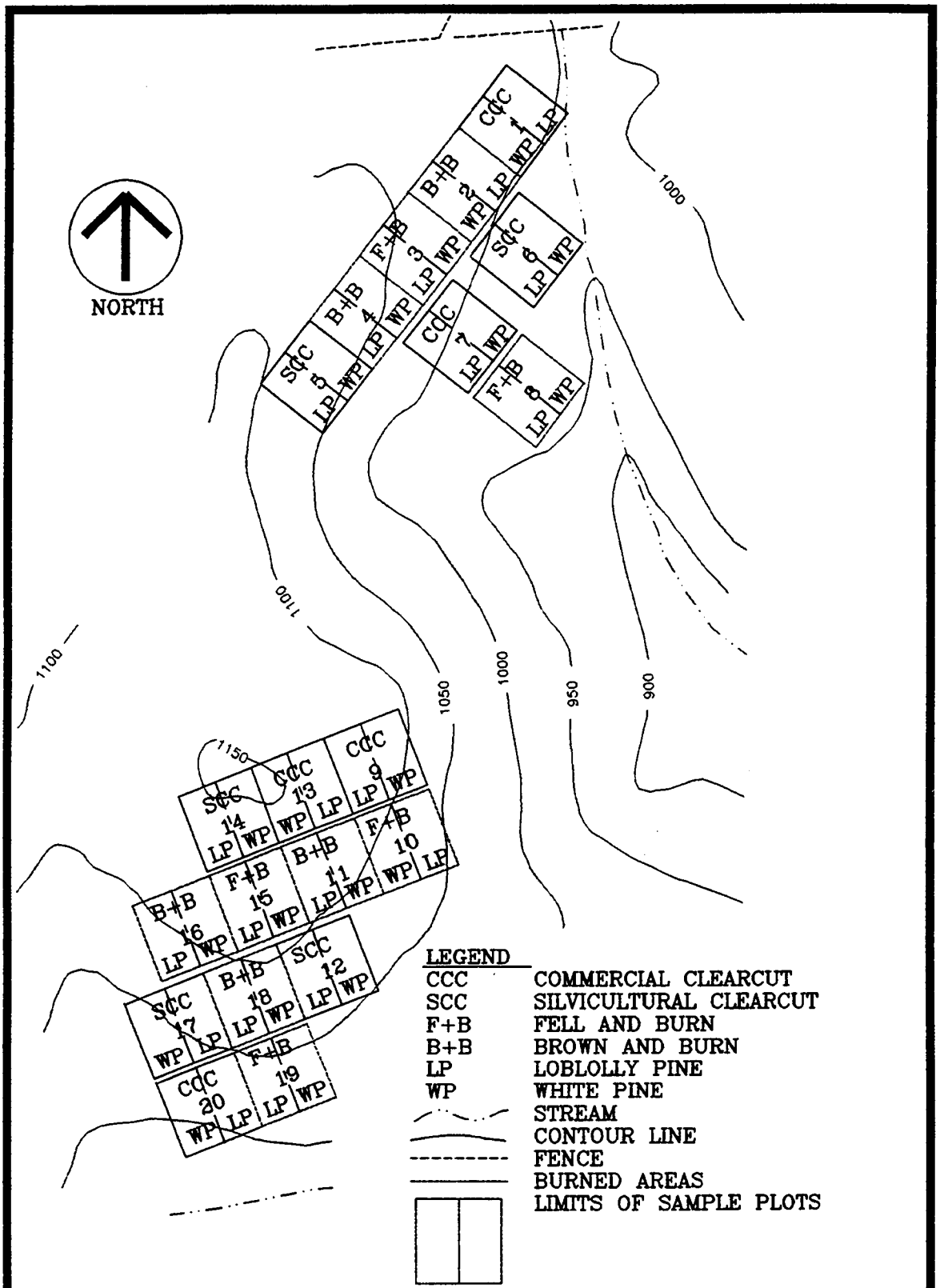


Figure 2. Sample Plot Arrangement of the Pine–Hardwood Silviculture Study Area on the University of Tennessee Forestry Station and Arboretum. Oak Ridge, Tennessee.

Treatment plots were divided into quadrants based on cardinal directions. Four 0.02 hectare (1/20th-acre) circular plots were then established, one in each quadrant of the treatment plot. Plot centers were 15.24 meters (50 feet) from each treatment center at 90 degree intervals beginning at a randomly assigned compass heading between north (0 degrees) and east (90 degrees). All trees taller than 1.83 meters (6 feet) were tallied by species into 2.54 centimeter (1 inch) dbh classes within each 0.02 hectare sample plot. All trees less than 1.83 meters (6 feet) were tallied by species within 1.83 meter (6 foot) circular subplots that shared a common center with the 0.02 hectare circular plots. Trees within the 1.83 meter circular subplots less than 0.3 meter (1 foot) tall were tallied as seedlings. Trees that were taller than 0.3 meter (1 foot) but less than 1.83 meters (6 feet) tall were tallied as advanced regeneration.

An inventory of all trees above 15.24 centimeters (6 inches) dbh was then conducted within the timber sale area. The timber sale area, which included the treatment plots (study area) and surrounding forest, was tallied utilizing a 100 percent cruise. Timber volume was estimated using the Doyle log rule and the International 1/4 inch log rule. Trees larger than 30.48 centimeters (12 inches) dbh were evaluated for tree grade and tallied by species, dbh, grade, and number of logs. Firewood trees above 15.24 centimeters (6 inches) dbh were tallied and converted to volume estimates (cords). Trees unsuitable for either sawtimber or firewood were culled.

The pre-harvest inventory was completed in November 1988 and served as the basis for the timber sale. The timber sale included the removal of sawtimber, pulpwood,

and firewood. The timber harvest was completed prior to the application of study treatments during the summer of 1989.

Treatment Application

The arrangement of treatment plots provided five replications of the four treatments tested. A split-plot randomized complete block design was used (Ott 1988). Whole plot effects included four combinations of harvesting and site preparation treatments (described below). Within each whole plot, loblolly pines were planted on one-half of the area and white pines were planted in the other half (subplot effects). Treatment plots were assigned to blocks (replications) following timber harvest. Site similarities and pre- and post-harvest conditions were evaluated in assigning treatment plots to blocks to assure that within-block site conditions were as uniform as possible. Treatment plots 1,2,6, and 8 were assigned to block 1; plots 3, 4, 5, and 7 to block 2; plots 9, 10, 11, and 12 to block 3; plots 13, 14, 15, and 16 to block 4; and plots 17, 18, 19, and 20 to block 5. Treatments were randomly assigned to plots within blocks. Treatments evaluated were:

1) commercial clearcut,
2) silvicultural clearcut,
3) brown-and-burn, and
4) fell-and-burn.

All treatments, except fell-and-burn, were representative of current forest practices that are widely used in southeastern forests. The fell-and-burn, while relatively new in the region, was being studied as a low-cost alternative for establishing pine-hardwood stands on NIPF lands.

The control treatment (commercial clearcutting) approximated the prevailing timber harvest method used on most private lands in the southeastern United States. Commercial clearcutting was not considered a forest management practice, because the logger simply harvested the timber that he wanted and left the remainder. In the commercial clearcut plots, all stems remaining after logging were allowed to stand with no other disturbance to the residual vegetation.

The silvicultural clearcut treatment is widely used for regenerating hardwoods and softwoods in many areas of the southeastern United States. In this treatment, all residual, living stems taller than 1.83 meters (6 feet) were hand-felled once the timber harvest was completed and complete leaf-out occurred. Felling occurred prior to June 5, 1989.

The brown-and-burn treatment closely approximated the intensive site preparation techniques used on many industrial forest lands in the southern United States. Plots were sprayed with a herbicide mixture of 0.84 kilogram (3/4 pound) of Arsenal, 4.68 liters (2 quarts) of glyphosate, and 2.34 liters (1 quart) of ionic surfactant in 93.54 liters (10 gallons) of water per 0.4 hectare (1 acre) in early summer of 1989. Spraying was accomplished by walking five strips (12.19 meters wide) in each treatment plot twice to yield an application rate of approximately 93.54 liters (10 gallons) per 0.4 hectare (1

acre). Plots 1-8 were sprayed on August 3, 1989; plots 9-20 were sprayed on July 27, 1989. All spraying in brown-and-burn plots was completed by UTFESA personnel using an elevated spraying apparatus to simulate aerial application.

After the deadened stems and leaves had dried in the fall, the brown-and-burn treatment plots were burned. Brown-and-burn plots 11, 18, and the eastern portion of plot 16 were burned on September 8, 1989; plots 2, 4, and the western portion of plot 16 were burned the next day. Plot 16 was burned on two days due to deteriorating burning conditions experienced on the evening of September 8, 1989.

The fell-and-burn treatment represented a modification of the silvicultural clearcut treatment. It differed from a silvicultural clearcut primarily in the degree of site preparation. It was investigated as a regeneration method for the non-industrial private forest landowner because of its relatively low cost and low environmental impact. In the spring following the timber harvest, the treatment was applied by felling all residual stems taller than 1.83 meters (6 feet) following complete leaf-out. Felling occurred prior to June 5, 1989. Fell-and-burn plots 10, 15, and 19 were burned on September 8, 1989; plots 3 and 8 were burned the next day.

The timing of the felling was very important for two reasons. First, complete leaf-out followed by felling resulted in additional leaf biomass which helped carry the prescribed fire. Second, hardwood sprout vigor was reduced by cutting when root carbohydrate reserves were depleted (Hodgkins 1958, Geisinger et al. 1989). The success of the treatment was also influenced by the completeness of the fire. To reduce

hardwood sprouting, the fire was planned to occur prior to the time carbohydrates were returned to the roots.

Prescribed Fire Application

The September 8 prescribed fire was initiated at approximately 1:00 PM EDT when the relative humidity was 61 percent and fuel moisture was 11 percent. The fire was started in the northeast corner of plot 19, but it quickly jumped the control line. A back-fire and flank-fire were started in plots 15, 16, 18, and 19 to protect adjoining no-burn plots, but approximately 30 feet of the southwest corner of plot 12 was accidently burned. In addition, two small break-over fires started within plots 13 and 14. These fires were contained with water or a bulldozed fire break. Neither fire encroached on plot center.

Plots 10 and 11 were burned starting at approximately 3:00 PM EDT. Relative humidity at that time was 54 percent and fuel moisture was 9 percent. A flank fire was started along the western side of plot 16, but only one-half of the plot was burned on September 8. Burning of the "west site" plots was completed by 5:30 PM EDT.

Wind direction for the September 8 burn was generally from the west and west-northwest during the burning period. Wind velocities ranged from 0.5 to 3.3 m/s during the same period; air temperatures ranged from 30 to 34 degrees C. The Oak Ridge NOAA station recorded the last measurable rainfall on September 1, 1989, when 1.5 centimeters of rain fell. However, a light rain shower of less than 0.1 centimeter occurred in the evening of September 5, 1989 and was recorded at the UTFESA.

Plots 2, 3, 4, and 8 and the remaining portion of 16 were burned on Saturday, September 9, 1989. Control burning began with the remaining portion of plot 16 at 10:30 AM EDT. Relative humidity was 68 percent and fuel moisture was 11.5 percent. Plots 2 and 4 were burned from 11:15 AM EDT to 1:00 PM EDT. Plots 3 and 8 were burned between 1:00 and 3:15 PM EDT. No humidity or fuel moisture measurements were taken after the initial reading.

Wind direction for the September 9 burn was generally from the west during the burning period. Wind velocities ranged from 0.5 to 4.2 m/s during the same period; air temperatures ranged from 29 to 34 degrees C.

Pine Seedling Establishment

Following application of treatments, the treatment plots were divided into two equal rectangular subplots. The division of treatment plots was approximately perpendicular to the contour of the slope within each treatment plot. This division was intended to minimize within subplot variation and was responsible for the split-plot design.

Loblolly and eastern white pines were tested as potential components of the pine-hardwood stand. Loblolly pine was chosen because it is a vigorous competitor and had been used in all other tests of the fell-and-burn technique; white pine was used because it is native to the southern Appalachian Mountains and is more tolerant of competition than loblolly pine. Seedlings were obtained from the Tennessee Division of Forestry

(TDF) nursery and were planted in early 1990 by UTFESA personnel. Loblolly pine seedlings were 1-0 and white pine seedlings were 2-0. All planted seedlings were marked by placing blue wire-pin flags adjacent to each seedling for easy identification during field sampling.

The pine seedlings were planted in rows roughly perpendicular to the slope. The upslope-and-downslope row arrangement prevented one species from being planted in the potentially more favorable downslope portion of the treatment plot. Seedlings were planted on a wide 6.1 meter by 6.1 meter (20 feet by 20 feet) spacing that yielded a stand density of 247 seedlings per hectare (100 seedlings per acre). This was done to allow the development of a sufficient complement of naturally regenerated hardwoods, thus potentially facilitating the establishment of the desired pine-hardwood stand. Closer spacing generally would have yielded pine-dominated stands that look more like pine plantations than pine-hardwood stands due to higher pine densities and their effects on stand dynamics (Daniel et al. 1979). The 10 rows in each treatment plot were split into two, 5-row subplots to which the two pine species were randomly assigned.

This arrangement provided a total of 100 seedlings per treatment plot, with 50 seedlings of each species represented in each treatment subplot. The seedlings planted closest to the treatment plot edges were more than 3 meters from the plot's edge in order to provide a buffer between the seedlings and the disturbed edge of each treatment plot. Numbered wooden stakes marked the beginning of all seedling rows.

Pine Seedling Data Collection

The following information was obtained for all planted pine seedlings:

1) survival,

2) height at planting,

3) height at end of first growing season,

4) vigor, and

5) competition class relative to competing vegetation immediately surrounding each planted pine.

Seedling mortality was tallied at the end of the first growing season. Each surviving seedling was also assigned to one of the following vigor classes: dead (0), vigorous (1), intermediate vigor (2), and poor vigor (3). These classes were based on the relative health of each seedling as indicated by needle color and length, height, and first season's growth. The size of a plant is positively related to its survivorship (Werner 1975, Regehr and Bazzaz 1979, Grace and Wetzel 1981).

The heights of planted pine seedlings (n=2000) were measured to the nearest 3.05 centimeter group (0.1 foot) soon after planting and again after one growing season. This yielded two measurements: height at planting and total height at the end of the growing season. Growth during the first season was the difference between the height at planting and the total height measurements.

Each seedling was evaluated relative to the likelihood that it would outgrow competing vegetation. The relative canopy position of each planted seedling was evaluated using the following subjective competition classes:

1) suppressed - likely to die or be strongly suppressed by competition due to excessive overhead cover from hardwood saplings, residual trees left after logging operations, or slash piles which would impede the seedling's ability to receive sunlight.

2) likely suppressed - may be eliminated, but the extent of competition is not as severe as the above class.

3) competitive - some competition but likely to survive as long as adjacent vegetation does not invade the overhead space of the seedling.

4) free to grow - little or no overhead competition and none threatening the seedling's growth.

Post-Treatment Site Condition Evaluation

Post-treatment site conditions were evaluated after planting and prior to the first growing season to ensure that sampling was done where the treatment applied was successful. The criteria that were used to determine whether or not the intended treatment effect was obtained included the following:

1) The commercial clearcut did not show any significant disturbance beyond those incurred in timber harvesting.

2) The silvicultural clearcut treatment had all woody stems taller than 1.83 meters (6 feet) felled.

3) The brown-and-burn treatment showed complete leaf death in residual (post-harvest) flora and was burned.

4) The fell-and-burn treatment had all woody stems taller than 1.83 meters (6 feet) felled and the area was burned.

5) Burn intensity was generally variable. Therefore, any level of burning from spotty to severely burned was considered representative of actual post-burning conditions and was subject to sampling.

6) Any area 37.16 m^2 (400 ft^2) or greater (the area within 4 pine seedlings on a 6.1 meter by 6.1 meter spacing) within a burned treatment plot that was entirely unburned was not considered an area of successful treatment effect.

7) Any burned area in a control or silvicultural clearcut treatment plot was not sampled.

8) Any area significantly altered by logging activities such as major skid roads, bulldozer trails, or major erosion of these was not sampled.

Soil exposure within treatment plots was determined by estimating the amount of the residual organic layer remaining within a 0.91-meter (3-foot) radius of each pine seedling. Estimates were based on whether or not fire burned off the overlying leaf layer and whether or not any organic root layer remained following fire. Severe burning during site preparation could result in excessive losses of soil organic matter and could subsequently decrease long-term productivity (Boring et al. 1990). Although Van Lear and Danielovich (1988) noted that erosion was the same on burned and unburned areas in one study, severe burning resulted in heavy erosion in one study (Van Lear and Kapeluck 1989). Van Lear and Kapeluck (1989) found minimal erosion when root mats remained following site preparation.

Three soil/litter layer conditions were used to characterize the ground surface around each seedling, as follows:

1) Class 1 showed no residual organic layer and reflected a major disturbance, including trails resulting from logging activities or complete consumption of the litter layer by fire.

2) Class 2 included a thin organic layer and usually included a burned area where the mineral soil was not exposed or an unburned area with minor logging disturbances.

3) Class 3 had a thick organic mat that remained intact after the treatment was applied. Class 3 typically included those areas untouched by fire or other logging effects that retained their original leaf litter.

Woody Regeneration Sampling

Plots for sampling woody regeneration were randomly located and were permanently established in all treatment plots where intended treatment application was successful. Twelve woody regeneration plots were randomly assigned in each treatment plot (n=240) using a random number table (Ott 1988) within a grid that divided the treatments into equal areas. Hardwood regeneration was measured within a 1.13 meter (3.7-foot) radius (millacre) of the plot center. Where the sampling scheme located a plot in an area where treatment effects were unsuccessful, it was moved to the nearest area showing intended treatment effects. A record was made of plot locations adjusted in this manner.

Guidelines for establishing woody regeneration plots were as follows:

1) Woody regeneration plots were not located closer than 9.14 meters (30 feet) to the edge of the treatment plots (to avoid any edge effects).

2) No woody regeneration plots were located between planted seedling rows 5 and 6 to avoid edge effects between seedling subplots.

3) Plots were located between the rows of pine seedlings to avoid disturbances due to seedling planting or seedling data collection.

Measurements taken in each plot included the height of all woody stems by species. The heights of all woody stems were categorized as follows:

1) Class 1 contained stems less than 0.3 meter (1 foot) tall.

2) Class 2 contained stems that were 0.3 meter (1 foot) to 0.91 meter (3 feet) tall.

3) Class 3 contained stems that were 0.91 meter (3 feet) to 1.83 meters (6 feet) tall.

4) Class 4 contained stems that were taller than 1.83 meters (6 feet).

All stems were individually counted except for stump sprouts. Stump sprouts were counted and measured as follows (Muncy 1980):

1) Where 10 or fewer sprouts occurred on any single stump, they were individually counted, and the height of each sprout was measured.

2) Where stumps contained 11 to 30 sprouts, the number of sprouts was estimated and placed into categories of ten (i.e., 11-20, 21-30), and the height of the tallest sprout of the entire clump was measured.

3) Where stumps contained 31 or more sprouts, the number of sprouts was grouped in a category of 31 or greater sprouts, and the height of the tallest sprout was measured.

All stems were also characterized as to whether they were seedlings, root sprouts, or stump sprouts.

Herbaceous Biomass Sampling

Herbaceous biomass was sampled in a manner similar to that used for woody regeneration. Eight 1-m^2 (10.76 ft^2) sample plots per treatment plot (n=160) were randomly located from a grid system using a random number table (Ott 1988). Plots were placed at chosen sites as long as they fell within an area of acceptable treatment

effects. Plots that did not fall within an acceptable area were assigned to the closest grid containing successful treatment effects. Four sample plots per species subplot were sampled.

Herbaceous biomass was measured by clipping all plants at the ground level and sorting by species. Oven-dry weights by species were obtained using a forced draft oven and a scale accurate to 0.01 gram. Samples were dried at 75 degrees C until a constant weight was maintained.

Wildlife Habitat Evaluation

The effects of treatments on wildlife habitat during the first growing season were identified and compared to the habitat requirements generally preferred by neotropical migratory songbirds, eastern wild turkeys, and other species likely to occur on the study area. The effects of treatments on wildlife species, in general, were determined where applicable. For instance, the effects of treatments on habitat for white-tailed deer, certain game birds, and small mammals were evaluated. All comparisons were based on those site conditions present following one growing season. They were evaluated according to the known effects of the applied treatments on wildlife habitat, and the wildlife species likely to inhabit the area.

Predictions of future stand conditions and the quality of wildlife habitat they would provide were also made. Predictions were also based on stand conditions at the

end of the first growing season, the available literature, and a knowledge of stand dynamics as it pertains to this study area.

Statistical Analysis

Data analysis was accomplished using the SAS system for statistical analysis (SAS Institute 1988). Analyses included means and frequencies of important variables, testing for normality of observations around means, and testing for significant differences among variables. The SAS General Linear Models (GLM) procedure, instead of the Analysis of Variance (ANOVA) procedure, was used for testing significance due to the presence of missing data for each variable type.

Duncan's New Multiple Range (Duncan's) test was used to graphically show ranks while the Least Significant (LS) Means procedure was the mean separation test used. The LS Means procedure was used instead of Duncan's test as a mean separation test due to the presence of missing data. This allowed for the computation of adjusted means of many variables. All means reported were LS Means except where noted.

Whole-plot (treatment) effects were differentiated from subplot (species) effects where necessary to describe differences observed between the two species of pine seedlings planted in the study area. Whole-plot effects were tested in the SAS GLM procedure F-test by specifying the error term REP*TREAT (replication*treatment). Sub-plot effects were tested in the SAS GLM procedure F-test by specifying the error term REP*TREAT*SPEC (replication*treatment*species).

Table 2 is an example of the GLM ANOVA table produced by SAS when testing for differences using a model that includes both whole-plot (treatment) and sub-plot (species) effects. For F-tests, significance was assumed at the 0.05 level. P-values less than 0.01 were considered highly significant. In the example shown in Table 2, the test to detect the effect of treatments (TREAT) would not be significant since the Pr > F (p-value) equals 0.4478; the effect of species (SPEC) would be significant (Pr > F equals 0.0001.).

Table 2. **Sample Analysis of Variance Table From the SAS General Linear Models Procedure With F-Tests Using Separate Error Terms for Whole-Plot and Sub-Plot Effects.**

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	4	0.30003138	0.07500785	8.58	0.0001
TREAT	3	0.05772010	0.01924003	2.20	0.0862
REP*TREAT	12	0.24328637	0.02027386	2.32	0.0062
SPEC	1	2.14542329	2.14542329	245.48	0.0001
TREAT*SPEC	3	0.17804522	0.05934841	6.79	0.0002
REP*TREAT*SPEC	16	0.74159685	0.04634980	5.30	0.0001

Tests of Hypotheses using the Type III MS for REP*TREAT as an error term

Source	DF	Type III SS	Mean Square	F value	Pr > F
TREAT	3	0.05772010	0.01924003	0.95	0.4478

Tests of Hypotheses using the Type III MS for REP*TREAT*SPEC as an error term

Source	DF	Type III SS	Mean Square	F value	Pr > F
SPEC	1	2.14542329	2.14542329	46.29	0.0001

Tests of Hypotheses using the Type III MS for REP*TREAT*SPEC as an error term

Source	DF	Type III SS	Mean Square	F value	Pr > F
TREAT*SPEC	3	0.17804522	0.05934841	1.28	0.3149

CHAPTER 5

RESULTS

Data collection was concluded at the end of the 1990 growing season. The timing of data collection was such that hardwood regeneration in the commercial clearcut and silvicultural clearcut treatments had completed approximately two seasons of growth. The regeneration in the two burned treatments had completed only one full growing season after burns.

The Pine Component

Seedling Survival

Overall survival for both pine species was 67.9 percent. Survival was 68.6 percent for loblolly pine and 67.2 percent for white pine. However, combined seedling survival of both species did not differ among treatments except in the commercial clearcut treatment ($p \geq 0.0148$) where survival was poor for both pine species (Table 3).

Average survival rates for the two species did not differ significantly ($p \geq 0.7579$) as determined by the SAS General Linear Models (GLM) Procedure (SAS Institute 1988). Loblolly pine survival did not differ among treatments ($p \geq 0.1377$) (Table 3). However, there were highly significant treatment differences in survival of white pine ($p \geq 0.0001$). Survival of white pine in the fell-and-burn and brown-and-burn

Table 3. Survival[1] by Treatment of White Pine and Loblolly Pine Following the 1990 Growing Season.

Species	Commercial Clearcut (%)	Silvicultural Clearcut (%)	Brown-and-Burn (%)	Fell-and-burn (%)	P-value
White Pine	50.8 a1	55.2 a1	81.2 b1	81.6 b1	0.0001
Loblolly Pine	56.4 a1	70.0 a1	72.4 a1	75.6 a1	0.1377
Treatment Average	53.6 a	62.6 ab	76.8 b	78.6 b	0.0148
P-value	0.3655	0.0740	0.7360	0.9615	

[1] Survival rates within a row that are followed by the same letter indicate no significance at the 0.05 level. Survival rates within a column followed by the same number indicate no significance at the 0.05 level.

treatments was significantly better than that in the commercial clearcut or silvicultural clearcut treatments.

Between the two species, loblolly pine seedlings tended to have higher survival rates than white pine seedlings. However, there were no significant differences between the two species for any treatment. In commercial clearcut plots, 56.4 percent of the loblolly pine seedlings survived their first growing season compared to 50.8 percent for white pine ($p \geq 0.3655$). In the silvicultural clearcut plots loblolly pine survival was 70.0 percent compared to only 55.2 percent for white pines, a difference approaching significance at the $p \geq 0.05$ level ($p \geq 0.0740$).

In both the brown-and-burn and fell-and-burn treatments white pine had higher survival than loblolly pine (Table 3). Survival in the brown-and-burn treatment was 81.2 percent for white pine and 72.4 percent for loblolly pine ($p \geq 0.7360$). White pine

survival in the fell-and-burn treatment was 81.6 percent; for loblolly pine it was 75.6 percent. This difference was not significant ($p \geq 0.9615$). White pine survival (81.6 percent) in the brown-and-burn treatment was the highest recorded in this study for either species but was essentially the same as in the fell-and-burn treatment.

Seedling Height Growth

The average height growth of all planted seedlings during the first growing season was 0.18 meters. Although much more variable, loblolly pine grew faster than white pine. Loblolly pine total height growth was 0.22 meters compared to 0.13 meters for white pine. Seedling height differences were significant at planting ($p \geq 0.0001$).

Treatments did not appear to have an effect on total height growth of both species combined ($p \geq 0.4478$) (Table 4). However, there was a significant difference between species within treatments ($p \geq 0.0001$). The height growth advantage of loblolly pine over white pine was 0.05 meter in the commercial clearcut, 0.08 meter in the silvicultural clearcut treatment, 0.11 meter in the fell-and-burn treatment, and 0.12 meter in the brown-and-burn treatment. These differences were highly significant in both burned treatments and the silvicultural clearcut treatment (Table 4). White pine grew significantly taller in the commercial clearcut ($p \geq 0.0222$).

Competition appeared to have an effect on height growth of pine seedlings (Table 5). Seedlings subjected to high competition from surrounding vegetation (class 1) grew significantly less ($p \geq 0.0001$) than those subjected to reduced competition levels (classes 3 and 4) regardless of species. Species differences were not significant, but loblolly pine

Table 4. Total Seedling Growth[1] and Range (in parentheses) by Treatment of White Pine and Loblolly Pine Following the 1990 Growing Season.

Species	Commercial Clearcut (m)	Silvicultural Clearcut (m)	Brown-and-Burn (m)	Fell-and-burn (m)	P-value
White Pine	0.15 a1 (0-0.37)	0.12 b1 (0-0.30)	0.12 b1 (0-0.30)	0.12 b1 (0-0.27)	0.0222
Loblolly Pine	0.20 a1 (0-0.52)	0.20 a2 (0-0.67)	0.24 a2 (0-0.61)	0.23 a2 (0-0.60)	0.2582
Treatment Average	0.18 a	0.16 a	0.18 a	0.18 a	0.4478
P-value	0.1551	0.0073	0.0001	0.0001	

[1] Growths within a row that are followed by the same letter indicate no significance at the 0.05 level. Growths within a column followed by the same number indicate no significance at the 0.05 level.

Table 5. Height Growth[1] and Numbers of Pine Seedlings (in parentheses) by Competition Class[2] of White Pine and Loblolly Pine Following the 1990 Growing Season.

Species	Class 1 (m)	Class 2 (m)	Class 3 (m)	Class 4 (m)
White Pine	0.06 a1 (n=266)	0.08 b1 (n=90)	0.09 b1 (n=68)	0.10 b1 (n=576)
Loblolly Pine	0.09 a1 (n=240)	0.15 b1 (n=80)	0.18 b1 (n=76)	0.18 b1 (n=604)

[1] Growths within a row that are followed by the same letter indicate no significance at the 0.05 level. Growths within a column followed by the same number indicate no significance at the 0.05 level.

[2] Competition class 1 shows the most overhead competition from hardwoods; class 2 includes seedlings which are likely to be suppressed; class 3 contains seedlings which are likely to survive due to reduced levels of competition from hardwoods; class 4 seedlings are considered "free-to-grow".

seedlings grew in areas of competition classes 3 and 4 at twice the rate shown in competition class 1. White pine seedlings in competition class 4 grew at nearly twice the rate of seedlings growing in competition class 1.

The Hardwood Component

Pre-harvest Stand

The pre-harvest stand was a mature, two-aged stand of mixed hardwoods. Average dbh of oaks (n=803 trees) was 45.7 centimeters (18 inches) and ranged from 47.5 centimeters (18.7 inches) for red oaks to 44.5 centimeters (17.5 inches) for white and chestnut oak (Table 6). Average dbh for other stand constituents was 43.4 centimeters (17.1 inches) dbh for hickories, 40.6 centimeters (16.0 inches) dbh for yellow-poplar, 39.6 centimeters (15.6 inches) dbh for miscellaneous hardwoods, and 33.0 centimeters (13.0 inches) dbh for pines.

The pre-harvest inventory of the study area estimated 15,587 board feet per hectare (all sawtimber volumes were estimated by the Doyle rule) (6,309 board feet per acre) (Table 6). Eighty-two percent of this volume was oak (39 percent red oaks, 11 percent white oaks, and 32 percent chestnut oak); nine percent was yellow-poplar. The pre-harvest inventory also estimated 64.75 cords of firewood from miscellaneous hardwoods within the study area.

Actual total timber removal from the study area was 96,017 board feet which averaged 9,828 board feet per hectare (3,977 board feet per acre). Red and white oaks

Table 6. Average dbh by Species Group, Volume Estimates of Sawtimber From the Pre-harvest Inventory, and Removal Volumes From the Mill Tally.

Species/Group	Average dbh (cm)	Pre-harvest Inventory (board feet/ha)	Mill Tally (board feet/ha)
Red Oaks[1]	47.5	6267	4547
White Oaks[2]	44.5	1640	1303
Chestnut Oak	44.5	5081	2076
Yellow-Poplar	40.6	1297	1195
Other species[3]	varied	1302	707
Total	NA	15587	9828

1 This group includes black oak, northern red oak, scarlet oak, and southern red oak.
2 This group includes white oak and post oak.
3 This group includes black cherry, black gum, hickories, shortleaf pine, red maple, and Virginia pine.

comprised 60 percent of the actual volume removed from the stand and tallied at the sawmill (Table 6). Chestnut oak comprised 21 percent of volume removals; yellow-poplar accounted for 12 percent. Total removals for the entire timber sale, which included areas outside of the study area, totaled 220,593 board feet.

Nearly 50 percent of all red and white oaks were graded as log grade 2 or higher. Fifty percent of yellow-poplar was also log grade 2 or higher. However, only 35 percent of chestnut oak trees were log grade 2 or higher. Other species generally had less than 20 percent of trees graded log grade 2 or higher, and pine trees were not graded. Thirteen oak trees were graded as premium veneer quality.

The canopy of the pre-harvest stand was dominated by oaks. Chestnut oak and black oak had the highest basal areas of the species found in the pre-harvest inventory

(Table 7). Northern and southern red oak, post oak, scarlet oak, and white oak were also present. Other important components of the pre-harvest stand were red maple, sourwood, blackgum, sassafras, yellow-poplar, and hickories (Table 7). Pine and several other species were only minor components of the pre-harvest stand.

Regeneration present in the understory of the pre-harvest stand was dominated by seedlings, particularly seedlings of chestnut oak, red maple, and sassafras (Table 8). Seedlings of hickories, dogwood, blackgum, and black oak were also prevalent. Red maple, hickory, blackgum, sassafras, and black oak stems dominated the advanced regeneration in the pre-harvest stand (Table 9). Sourwood, black cherry, scarlet oak, and dogwood were present but in fewer numbers as advanced regeneration.

Post-treatment Stand

Species Composition

After one growing season (1990), 29 species of naturally-regenerating hardwoods representing 18 families were sampled in the post-treatment regeneration (Appendix C). Sassafras, red maple, sourwood, and blackgum were the most abundant species within treatments comprising 56.6 percent of all stems (Table 10). Species composition was not influenced by treatments when compared to the species found in the pre-harvest inventory. Species composition of the pre-harvest stand did not differ among treatments for the understory ($p \geq 0.7312$), midstory ($p \geq 0.6522$), or canopy ($p \geq 0.3485$).

Table 7. Basal Area by Species on the Treatment Plots in the Pre-harvest Stand.

Species	Commercial Clearcut (m^2/ha)	Silvicultural Clearcut (m^2/ha)	Brown-and-Burn (m^2/ha)	Fell-and-Burn (m^2/ha)
Blackgum	0.92	0.92	1.38	0.46
Black oak	7.35[1]	6.89[1]	4.59[1]	7.81[1]
Chestnut oak	6.89	5.51	13.78	5.97
Hickories	1.84[1]	0.46	0.46	0.46
Northern red oak	0	0.92	0	0
Post oak	0.92[1]	0	0.46[1]	0.46
Red maple	2.30	2.76	3.22	2.30
Sassafras	0.92	0.92	0	1.38
Scarlet oak	2.30	0.46[1]	0.92	2.30
Shortleaf pine	0	0	0.46	0
Sourwood	3.22	2.76	4.59	5.51
Southern red oak	0.92	0.92	0	0.46
White oak	1.38	2.30	0	0.92
Yellow-poplar	1.84	0	0.92	1.84
Other species	0.46	0	0	0
Totals	31.26	24.82	30.78	29.87

[1] These values include some dead, standing timber which was harvested.

Table 8. Stems Per Hectare of Seedlings Present in the Pre-harvest Stand.

Species	Commercial Clearcut (stems/ha)	Silvicultural Clearcut (stems/ha)	Brown-and-Burn (stems/ha)	Fell-and-Burn (stems/ha)
Black cherry	476	714	428	952
Blackgum	762	1523	1476	1190
Black oak	1190	1809	1999	1285
Chestnut oak	23466	21801	16517	17517
Dogwood	1142	1142	1000	857
Hickories	1904	1666	1476	1904
Northern red oak	95	238	48	0
Pawpaw	190	0	0	0
Post oak	48	48	0	0
Red maple	16755	21087	19802	21468
Sassafras	14994	12519	7664	8949
Scarlet oak	381	762	428	1000
Sourwood	48	333	381	333
Southern red oak	333	48	0	0
White oak	238	428	190	238
Yellow-poplar	143	48	619	95
Other species	1714	952	1047	476

Table 9. Stems Per Hectare of Advanced Regeneration Present in the Pre-harvest Stand.

Species	Commercial Clearcut (stems/ha)	Silvicultural Clearcut (stems/ha)	Brown-and-Burn (stems/ha)	Fell-and-Burn (stems/ha)
Black cherry	428	48	190	381
Blackgum	619	1190	619	1285
Black oak	333	286	1333	190
Chestnut oak	714	95	33	524
Dogwood	381	95	95	952
Hickories	1238	762	762	952
Northern red oak	48	95	0	0
Pawpaw	428	0	0	0
Post oak	48	0	0	0
Red maple	3046	2951	3903	2047
Sassafras	190	619	571	286
Scarlet oak	143	95	143	238
Sourwood	143	95	381	48
Southern red oak	48	0	0	0
White oak	95	0	48	95
Yellow-poplar	95	190	48	48
Other species	524	286	333	524

Table 10. Frequency of Hardwoods by Treatment Following the 1990 Growing Season.

Species	Commercial Clearcut (stems/ha)	Silvicultural Clearcut (stems/ha)	Brown-and-Burn (stems/ha)	Fell-and-Burn (stems/ha)	Percent of Total
Sassafras	3487	2813	1302	1322	24.70
Red maple	2907	2752	162	472	17.42
Sourwood/Blackgum[1]	722	2017	533	1963	14.49
Chestnut oak	1386	1740	79[2]	315[2]	9.75
Smooth sumac	371	94	897	1996	9.30
Yellow-poplar	870	816	863	594	8.70
Flowering dogwood	844	823	68[2]	34[2]	4.90
Carolina buckthorn	461	115	0	692	3.51
Hickories	202	270	40	310	2.28
Black oak	205	169	124	80	1.60
Northern red oak	127	120	19	161	1.18
Black cherry	128	229	0	21	1.05
White oak	54	88	0	0	0.39
All other species	115	110	24	15	0.73
Total	11879	12156	4111	7975	100.00

[1] Sourwood and blackgum are grouped due to a data transcription error.
[2] Unadjusted mean

Species present in the regeneration were largely the same as those found in the pre-harvest stand. These included sassafras, red maple, sourwood, blackgum, yellow-poplar, chestnut oak, flowering dogwood, black cherry, black oak, and hickories. The predominant hardwood species present in regenerating commercial clearcut plots were sassafras, red maple, and chestnut oak which comprised 65.5 percent of the regenerating stems in that treatment; the predominant species in the silvicultural clearcut plots were sassafras, red maple, and sourwood/blackgum (Sourwood and blackgum were grouped in the statistical analysis due to a data transcription error.) which comprised 62.4 percent of the regenerating stems in that treatment; the predominant species in the brown-and-burn plots were sassafras, smooth sumac, and yellow-poplar which comprised 74.5 percent of the regenerating stems in that treatment; and the predominant species in the fell-and-burn plots were smooth sumac, sourwood/blackgum, and sassafras which comprised 66.2 percent of the regenerating stems in that treatment (Table 10). Red maple was significantly less frequent in the burned treatments than in the unburned treatments. The burned treatments controlled red maple, a prolific sprouter.

Hardwood Stem Heights

Stem heights were tallest in the commercial clearcut and silvicultural clearcut treatments, averaging 0.96 meter and 0.94 meter, respectively (Table 11). Stem heights in the fell-and-burn treatment averaged 0.85 meter, and stems in the brown-and-burn treatment averaged 0.66 meter. Hardwood stem heights in the brown-and-burn treatment

Table 11. Height[1] by Treatment of Regenerating Hardwoods Following the 1990 Growing Season.

Treatment	N	Height (m)	Range of Classes
Commercial Clearcut	1929	0.96 a	1 - 4
Silvicultural Clearcut	1924	0.94 a	1 - 4
Brown-and-Burn	736[2]	0.66 b	1 - 3
Fell-and-Burn	1526	0.85 a	1 - 4

[1] Heights within a column that are followed by the same letter indicate no significance at the 0.05 level.

[2] Three brown-and-burn sample plots had no regenerating woody species.

were significantly less than in the other treatments ($p \geq 0.0001$) (Table 11). No stems taller than six feet were found in the brown-and-burn treatment.

Shorter hardwood stem heights in the two burned treatments were expected as all stems in these treatments were killed back to the ground through the use of fire in late summer. Unburned plots had the advantage of an extra partial growing season. On a species basis, black cherry ($p \geq 0.0188$), the hickories ($p \geq 0.0033$), northern red oak ($p \geq 0.0413$), sassafras ($p \geq 0.0005$), sourwood/blackgum ($p \geq 0.0286$), smooth sumac ($p \geq 0.0192$), and yellow-poplar ($p \geq 0.0220$) showed significant stem height differences among treatments (Table 12). Table 12 shows average height by species and treatment using measurement classifications. These measurements are also given as the approximate meter equivalents. These species were generally tallest in the unburned treatments, but it appeared that felling in the fell-and-burn treatment increased heights for northern red oak, blackgum, and sourwood.

Table 12. Mean Height Category by Species and Treatment of Regenerating Hardwoods Showing Significance Following the 1990 Growing Season.

Species	Commercial Clearcut class (m)	Silvicultural Clearcut class (m)	Brown-and-Burn class (m)	Fell-and-burn class (m)
Black cherry	3.3[1] (2.1)[2] a[3]	2.9 (1.7) a	-	1.1 (0.4) b
Hickories	1.4 (0.5) a	1.3 (0.4) a	1.0 (0.3) b	1.0 (0.3) b
Northern red oak	1.6 (0.7) ab	1.4 (0.5) b	0.4 (0.1) c	1.9 (0.9) a
Sassafras	2.1 (1.0) a	2.0 (0.9) a	1.2 (0.4) b	1.3 (0.4) b
Smooth sumac	2.2 (1.1) a	1.8 (0.8) ab	1.0 (0.3) b	1.2 (0.4) b
Sourwood/Blackgum	2.2 (1.1) a	2.3 (1.2) a	1.4 (0.5) b	1.7 (0.8) ab
Yellow-poplar	2.0 (0.9) a	1.7 (0.8) ab	1.0 (0.3) b	1.1 (0.4) b

1 Stem height categories included: Class 1 - stems less than 0.3 meter (1 foot), Class 2 - stems 0.3 meter (1 foot) to 0.91 meter (3 feet), Class 3 - stems 0.91 meter (3 feet) to 1.83 meters (6 feet), and Class 4 - stems taller than 1.83 meters (6 feet).

2 Values in parentheses are estimated heights in meters interpolated from stem height classification values.

3 Heights within a row that are followed by the same letter indicate no significance at the 0.05 level.

Stem Density

The commercial clearcut and silvicultural clearcut treatments had the highest (and essentially the same) number of stems per hectare (Table 13). The fell-and-burn treatment contained nearly twice as many stems per hectare as did the brown-and-burn treatment, but both treatments generally had fewer stems per hectare than the unburned treatments (Table 13). The fell-and-burn treatment was not different from the brown-and-burn or silvicultural clearcut treatments. Significant treatment differences ($p \geq 0.0050$) were due to the low number of hardwood stems in the brown-and-burn treatment.

Highly significant treatment differences were evident for red maple ($p \geq 0.0075$), smooth sumac ($p \geq 0.0107$), and sourwood/blackgum ($p \geq 0.0005$) (Table 10). Sassafras

Table 13. Stem Count[1] by Treatment of Regenerating Hardwoods Following the 1990 Growing Season.

Treatment	Stem Count (stems/ha)	Range (stems/ha)
Commercial Clearcut	11879 ab	8012 - 13964
Silvicultural Clearcut	12156 a	9332 - 15107
Brown-and-Burn	4111 c	2817 - 7886
Fell-and-Burn	7975 bc	6011 - 10244

1 Stem counts within a column that are followed by the same letter indicate no significance at the 0.05 level.

approached significance among treatments ($p \geq 0.0805$) due to a difference in the number of stems per hectare in the brown-and-burn treatment. All other species did not differ among treatments.

Species and Family Trends

Stem heights were tested for treatment effects by species (Table 12). Several species could not be tested for significance since they were found in only one treatment or were sampled in numbers too small for meaningful analysis. Some species occurred only in certain treatments while other species were found in all treatments. Shortleaf pine and Virginia pine showed no treatment preference but occurred in those areas where mature pines were harvested prior to application of treatments. Mockernut hickory, black cherry, and Carolina buckthorn occurred in every treatment except the brown-and-burn treatment, which suggests that they were sensitive to the herbicide treatment. Most of the remaining species were found in all treatments.

Families having special significance for wildlife were grouped together for analysis in order to determine if these groups showed significant height differences by treatment. The members of the genus *Quercus* were treated as a group because oaks are very important to long-term habitat quality for many of the wildlife species that occur in this region. Members of the Juglandaceae, which includes the hickories and black walnut, were grouped for the same reason. A third significant group contained those species that produce fruit at an early age. This group included black cherry, eastern red bud, flowering dogwood, green ash, pawpaw, red mulberry, and smooth sumac.

All of these groups showed highly significant height differences among treatments ($p \geq 0.0001$). In general, the commercial clearcut and silvicultural clearcut treatments contained taller individuals of each of these three important groups than did the fell-and-burn and brown-and-burn treatments, meaning that these species will likely out-compete the pine component to become dominant (except for the early-fruiting species). This was likely due primarily to the additional growing season these treatments had compared to the burned treatments and vigorous root and stump sprouting. The majority of stems preferred by wildlife (such as oaks) originated from sprouts.

The Herbaceous Component

Species Composition

Thirty-four species of herbaceous plants representing 17 families were identified (Appendix D). Fireweed was found in 134 of the 160 (84 percent) sample stations

(Table 14). When present, it tended to dominate herbaceous biomass weights. This relationship was especially true of the fell-and-burn and brown-and-burn plots. Horseweed was also a large component in many of the same treatment plots. Muscadine or smilax were observed most frequently in some plots, especially within the commercial clearcut and silvicultural clearcut treatments.

Herbaceous Biomass

The fell-and-burn treatment contained the most herbaceous biomass (124.5 g/m^2) and the commercial clearcut plots the least (32.1 g/m^2) (Table 15). The brown-and-burn treatment and the silvicultural clearcut treatment ranked in the middle averaging 107.9 g/m^2 and 56.0 g/m^2, respectively (Table 15). These wide differences were indicative of highly significant treatment effects among treatments ($p \geq 0.0006$).

The amount of herbaceous biomass per individual sample plot varied significantly by treatment ($p \geq 0.0005$) and replication ($p \geq 0.0212$). A significant interaction was also evident ($p \geq 0.0042$) between treatments and replications. The brown-and-burn and fell-and-burn treatment averaged 323.7 g/m^2 and 373.4 g/m^2, respectively, per sample plot. The commercial clearcut averaged 98.7 g/m^2 while the silvicultural clearcut averaged 160.5 g/m^2. Burned treatments contained significantly more herbaceous biomass per sample plot than did unburned treatments.

Table 14. Frequency by Treatment of Herbaceous Species Following the 1990 Growing Season.

Species	Commercial Clearcut (# plots)	Silvicultural Clearcut (# plots)	Brown-and-Burn[1] (# plots)	Fell-and-Burn (# plots)	Percent of Total
Fireweed	25	34	37	38	21.68
Smilax	23	25	7	24	12.78
Horseweed	4	6	23	19	8.41
Grasses	5	2	11	23	6.63
Blueberry	11	11	1	14	5.99
Muscadine	17	8	6	5	5.83
Pokeweed	11	11	8	6	5.83
Panicum	4	3	8	15	4.85
Blackberry	7	8	7	6	4.53
Virginia creeper	14	10	0	3	4.37
Lespedeza	0	1	9	15	4.05
Sedges	1	4	6	7	2.91
Desmodium	3	5	3	6	2.75
Rabbit tobacco	0	2	5	6	2.10
Poison ivy	5	4	0	0	1.46
Euonymus	6	1	0	0	1.13
Raspberry	2	1	2	2	1.13
Mountain laurel	2	2	0	0	0.65
16 other species	6	4	2	6	2.92
Totals	146	142	135	195	100.00

[1] Two brown-and-burn sample plots contained no herbaceous plants.

Table 15. Weights[1] Per Sample by Treatment of Herbaceous Biomass Following the 1990 Growing Season.

Plot Type	Weight (g/m^2)	Range (g/m^2)
Commercial Clearcut	32.1 b	0.07 - 374.7
Silvicultural Clearcut	56.0 b	0.05 - 798.2
Brown-and-Burn	107.9 a	0.03 - 602.1
Fell-and-Burn	124.5 a	0.02 - 762.1

1 Weights within a column followed by the same letter indicate no significance at the 0.05 level.

Species and Family Trends

The biomass of herbaceous species and important family groupings were evaluated to detect probable treatment effects on wildlife habitat quality. The biomass of fireweed ($p \geq 0.0007$) and horseweed ($p \geq 0.0389$) varied significantly among all treatments (Table 16). Fireweed biomass was greatest in the fell-and-burn and brown-and-burn treatments and least in the commercial clearcut treatment suggesting a fire effect. Average weights of horseweed were similar in the two burned treatments and several times greater than in the two unburned plots. No other species varied significantly among treatments.

Weights of blueberry did not differ significantly among all treatments ($p \geq 0.0835$), but a difference was evident between the unburned treatments and the brown-and-burn treatment (Table 16). Its weights were higher in the commercial clearcut and silvicultural clearcut treatments. The average weights of blueberry in the unburned treatments were generally four times greater than its average weights in the unburned treatments.

Table 16. Biomass[1] by Species and Treatment of Selected Herbaceous Species Following the 1990 Growing Season.

Species	Commercial Clearcut (kg/ha)	Silvicultural Clearcut (kg/ha)	Brown-and-Burn (kg/ha)	Fell-and-Burn (kg/ha)	P-value
Blackberry	4	216	0	46	0.1285
Blueberry	88	66	0	14	0.0835
Desmodium	11	0.1	4	7	0.3587
Fireweed	396 b	984 b	2019 a	2589 a	0.0007
Grasses	2	4	6	10	0.3603
Horseweed	52 c	59 bc	1107 a	947 ab	0.0389
Lespedeza	-	0	0	0	0.3589
Muscadine	80	59	0	10	0.2957
Poison ivy	27	18	-	-	0.6305
Pokeweed	206	157	116	120	0.7575
Smilax	49	161	0	36	0.3504
Virginia creeper	39	18	-	1	0.2446

[1] Biomasses within a row that are followed by the same letter indicate no significance at the 0.05 level.

Muscadine biomass was greatest in the commercial clearcut treatment, followed by the silvicultural clearcut treatment, and was nearly absent in the brown-and-burn treatment. Its weights were generally five times higher in the burned treatments. Other species either did not vary significantly among treatments or were not sampled in quantities large enough to allow a meaningful analysis. The results for fireweed, horseweed, blueberry and muscadine indicated that fire favored the growth of herbaceous plants.

Families of herbaceous plants that are important for wildlife were also analyzed for biomass differences among treatments. Nine family groupings were analyzed -- Anacardiaceae, Asteraceae, Ericaceae, Fabaceae, Phytolaccaceae, Poaceae, Rosaceae, Smilaceae, and Vitaceae (Table 17). These families provide browse and other types of wildlife forage. Among treatments, the Asteraceae showed the only significant difference ($p \geq 0.0001$). This difference was likely due to the extremes in biomass shown by horseweed and fireweed.

The biomasses of Ericaceae and Rosaceae were generally higher in the unburned plots and the fell-and-burn treatment than in the brown-and-burn treatment. For these families, the burned treatments were not different. For Vitaceae, the commercial clearcut treatment contained significantly more biomass than the fell-and-burn treatment. The burned treatments and the brown-and-burn treatment were not different.

Within families, herbaceous biomass weights differed significantly according to treatments ($p \geq 0.0134$). Biomass weights in the burned treatments were significantly higher than those in unburned treatments. The fell-and-burn treatment contained 479

Table 17. Biomass[1] by Treatment of Important Herbaceous Families to Wildlife Following the 1990 Growing Season.

Family	Commercial Clearcut (kg/ha)	Silvicultural Clearcut (kg/ha)	Brown-and-Burn (kg/ha)	Fell-and-Burn (kg/ha)	P-Value
Anacardiaceae	27	18	0	-	0.2714
Asteraceae	448 b	1025 b	3159 a	3557 a	0.0001
Ericaceae	111	76	0	10	0.0959
Fabaceae	11	1	7	11	0.3042
Phytolaccaceae	206	157	116	120	0.7575
Poaceae	8	46	14	36	0.3865
Rosaceae	19	213	10	46	0.1469
Smilaceae	49	161	0	36	0.3504
Vitaceae	123	59	0	14	0.1219

[1] Biomasses within a row that are followed by the same letter indicate no significance at the 0.05 level.

kg/ha; the brown-and-burn contained 463 kg/ha; the silvicultural clearcut contained 178 kg/ha; and the commercial clearcut contained 109 kg/ha.

Browse species were also analyzed according to their suitability as wildlife food. Soft browse species included desmodium, euonymus, grasses, lespedeza, and pokeweed; hard browse species included mountain laurel, smilax, Virginia creeper, passion flower, poison ivy, muscadine, raspberry, blueberry, deerberry, and blackberry. All other species were grouped into a "not browse" category. Biomass for these categories were determined by treatment (Table 18). The "not browse" category showed significant differences in biomass among treatments ($p \geq 0.0001$) (Table 18). These differences were

Table 18. Biomass[1] by Treatment of Browse Categories Following the 1990 Growing Season.

Browse Category	Commercial Clearcut (kg/ha)	Silvicultural Clearcut (kg/ha)	Brown-and-Burn (kg/ha)	Fell-and-Burn (kg/ha)	P-Value
Soft browse	215.6	158.6	50.4	29.0	0.2714
Hard browse	290.0	453.0	14.7	90.7	0.0959
Not browse	456.2 b	1068.8 b	3172.2 a	3614.4 a	0.0001

[1] Biomasses within a row that are followed by the same letter indicate no significance at the 0.05 level.

probably due to the preponderance of fireweed and horseweed in burn plots. Biomasses of soft browse and hard browse did not differ among treatments, although hard browse approached significance due to high quantities of browse (high stem count) in the unburned treatments.

CHAPTER 6

DISCUSSION

Planted Pines

Seedling Survival

Survival of all planted pines was 67.9 percent after one growing season. Survival of both species of planted pines was higher in the fell-and-burn (78.6 percent) and brown-and-burn (76.8 percent) treatments than in the commercial clearcut (53.6 percent) or silvicultural clearcut (62.6 percent) treatments (Table 3). These survival rates in burned treatments were somewhat lower than the 83 percent survival rate reported by Waldrop et al. (1989) for shortleaf and loblolly pine seedlings planted in burned plots in the mountains of South Carolina following six growing seasons. However, results similar to those found in this study were reported by Phillips and Abercrombie (1987) where survival of shortleaf pine seedlings planted following fell-and-burn site preparation was 75 percent after four growing seasons.

These results suggested a positive linear relationship between pine survival and increasing intensity of site preparation. Other authors (Geisinger et al. 1989, McMinn 1989, Zedaker et al. 1989, Sims and McMinn 1990) observed pine survival rates similar to those reported in this study following intensive site preparation. McMinn (1989) observed increased pine survival and height in naturally-regenerating mixed stands that were subjected to intensive harvesting of hardwood stems during the growing season

compared to stands that were subjected to a lesser degree of felling during the dormant season. Similar results were obtained by Sims and McMinn (1990).

Basal area of planted pine also increased significantly in 5-year-old regenerating stands in Virginia with increasing herbicidal control of hardwoods (Zedaker et al. 1989). Geisinger et al. (1989) reported shorter hardwood sprouts following spring felling and a summer burn in mixed stands containing planted pine seedlings, likely leading to the establishment of a pine-hardwood stand. Based on the similarities that these reported studies share with this study, it was expected that the pine seedlings in the fell-and-burn and brown-and-burn treatments would continue to show high survival rates.

Survival of loblolly pine and white pine over all treatments was 68.6 percent and 67.2 percent, respectively. Although total survival did not differ between species, certain relationships between species were evident (Table 3). For example, loblolly pine showed relatively uniform survival rates of 56.4 percent, 70 percent, 75.6 percent, and 72.4 percent in the commercial clearcut, silvicultural clearcut, fell-and-burn, and brown-and-burn treatments, respectively (Table 3). One would have expected that survival of loblolly pine, an intolerant species, would be poor in both unburned treatments, given the amount of hardwood competition present in these plots. This did not occur. Instead, loblolly pine survival in the silvicultural clearcut was nearly that in both burned treatments. The reason(s) for this survival pattern could not be determined.

Survival rates for white pine exhibited a different relationship among treatments than those shown by loblolly pine. Survival of white pine in the fell-and-burn (81.6 percent) and the brown-and-burn (81.2 percent) treatments was significantly higher than

survival in either the commercial clearcut treatment (50.8 percent) or the silvicultural clearcut treatment (55.2 percent) (Table 3). This relationship was more representative of the reported effects of these treatments on intolerant pines.

The relative survival of white and loblolly pines was difficult to explain. White pine seedling survival in the burned treatments was the highest reported for any treatment in this study. It survived better than loblolly pine in these treatments (Table 3). This relationship was contrary to most of the reported literature. The intensive site preparation that characterized these treatments suppressed the growth of competing woody vegetation, allowing most of the pine seedlings to survive through their first growing season. It was expected that loblolly pine, due to its intolerance and rapid early growth, would achieve a competitive advantage, due to the relative lack of competition in these treatments, leading to high survival rates for the species. However, higher survival rates (than white pine) did not occur for loblolly pine, a much more intolerant species than white pine. The reasons for this seemingly inconsistent performance were not clear.

Survival differences among treatments during the first growing season suggested that treatments would influence the composition of developing stands, but 1-year results are too early for a clear determination of eventual pine-hardwood status (Waldrop 1995). Even with the wide spacing at which the pine seedlings were planted, the fell-and-burn and brown-and-burn treatments should show a high pine component as these stands develop. The majority of surviving seedlings in these treatments should ultimately maintain a height advantage over competing hardwoods.

Differential survival rates between the burned treatments (77.7 percent) and the unburned treatments (58.1 percent) was anticipated due to high competition levels in the unburned treatments. Fewer surviving seedlings and, for loblolly pine, greater susceptibility to competition made the pine component of the unburned treatments marginal for designation as pine-hardwood stands. Some loblolly pines which exhibited fast early height growth coupled with little direct hardwood competition became established in these stands. White pine should survive better than loblolly pine in unburned treatments due to its higher degree of shade tolerance even though it showed slow early growth.

Seedling Growth

Within species, average total growth rates of white pine and loblolly pine did not differ significantly among treatments (Table 4). However, growth of all seedlings was less as competition increased (Table 5). Loblolly pine grew significantly better than white pine in all treatments except the commercial clearcut treatment (Table 4).

For loblolly pine there was an essentially linear increase in growth rate associated with increases in the intensity of site preparation (Table 5). White pine growth rates did not vary as much as growth rates for loblolly pine and showed a slightly negative relationship between average height growth and intensity of site preparation (Table 5). Rapid growth of loblolly pine seedlings in the fell-and-burn and brown-and-burn treatments was expected due to the reduced levels of competition from sprouting hardwoods within these treatments. The relationship shown between white pine and

competition suggested that white pine preferred the relatively sheltered microclimate conditions provided by less intense site preparation techniques.

The use of fire in the fell-and-burn treatment and the use of fire and a herbicide in the brown-and-burn treatment significantly reduced the number of potentially competing hardwood stems in those treatments (Table 13). The reduction of hardwood stems by fire accomplished several things in this study. First, it reduced competition allowing higher pine seedling survival (Table 3). Second, it reduced white pine growth (Table 4). Third, the removal of logging slash and understory hardwood stems facilitated pine seedling planting. Fourth, these actions resulted in increased pine seedling growth for loblolly pine (Table 4).

Loblolly pine seedlings should acquire a dominant crown position over competing hardwoods in both burn treatments, due to suppression of competing hardwoods, thus assuring their survival and the potential development of a mixed pine-hardwood stand. Conversely, rapid height growth and the high density of the competing hardwoods in the commercial clearcut and silvicultural clearcut treatments should result in additional loblolly pine mortality and/or reduced vigor and growth of pines in future years. It was more difficult to predict the success of the white pine seedlings based on their slower growth rates. They showed excellent survival in the burn treatments which, combined with their tolerance of moderate shading, may assure their continued presence in the developing stand.

Table 5 showed the positive linear relationships between height growth of white pine and loblolly pine and the amount of overhead competition surrounding each

seedling. Seedlings with the most overhead competition grew the least in all treatments. Seedlings with little or no overhead competition from surrounding hardwoods grew best regardless of treatment.

Hardwood Regeneration

Species Composition

Treatments had little effect on species composition of regenerating hardwoods, with the possible exception of the brown-and-burn treatment where only 14 of the 29 species found in study plots were present. Species which were relatively common in other treatments, such as black cherry, were completely absent in the samples taken from the brown-and-burn treatment (Table 10). Other common species, such as red maple and chestnut oak, had their lowest frequencies in the brown-and-burn plots. However, these effects may be due to sampling limitations (Pre-harvest and post-treatment sample plots were not the same.) and not necessarily the result of treatments.

Loftis (1988) stated that stand development in the Appalachians is largely the result of the pre-existing stand and its initial floristic composition. However, the resultant stand could be quite different where competition from fast-growing sprouters, which are generally less desirable species, is severe. This shift generally occurs on better (mesic) sites than studied here due to competition from shade-tolerant species (Beck and Hooper 1986, Lorimer 1992).

In this study, the composition of the regenerating hardwood component of stands following fell-and-burn, silvicultural clearcut, and commercial clearcut treatments was very similar to the composition of the pre-harvest stand. Lorimer (1992) noted that this relationship is common on poor sites. Vigorous sprouters that were present, but not dominant (Table 7), in the pre-harvest stand, such as sassafras, red maple, and sourwood, were the most abundant species in the regenerating stand (Table 10). Similar pre- and post-harvest composition was documented by two other studies dealing with the fell-and-burn treatment (Geisinger et al. 1989, Waldrop 1995).

It is likely that many vigorous sprouters will be overtopped by other species, including the oaks which dominated the pre-harvest stand with yellow-poplar. The oaks present on the study area are moderately tolerant (Smith 1992) and should increase in dominance as the stands mature. As reflected in the pre-harvest (Tables 8 and 9) and post-treatment (Table 10) inventory data, chestnut oak and black oak were the major oak components present both before and after harvest. The pre-harvest data show that these two species were major components of the overstory and regeneration in the understory. The post-treatment data show high numbers of these species relative to other oaks (Table 10). They are likely to continue as components of the developing stand based on study findings where pre-harvest and post-harvest stands contained the same species. The hickories showed a similar relationship. However, white oak was not a common component of the developing stands in the burned treatments.

Yellow-poplar appeared more common in the post-treatment regeneration than in the pre-harvest stand. Yellow-poplar was an occasional canopy tree in the pre-harvest

stand and was rarely present in the regeneration of that stand. However, in the post-treatment stand, it is expected to be co-dominant with chestnut oak or loblolly pine (depending on the treatment) due to uniformly high numbers of stems present.

Several other species were common in both the pre-harvest and post-treatment stands. These included red maple, sassafras, sourwood, blackgum, and black cherry. These species are noted sprouters. Based on this common trait, these species were expected to be common components of the post-treatment regeneration since they were present in the pre-harvest stand (Tables 8 and 9). While this was the case for all five species, it was noteworthy for sassafras and sourwood since they were less prevalent than blackgum and red maple in the pre-harvest stand.

Post-treatment regeneration in the brown-and-burn plots showed a slightly different relationship with pre-harvest conditions than that shown by the other three treatments. Each of the other treatments had over two times as many hardwood stems as did the brown-and-burn treatment (Table 13). Sassafras, red maple, sourwood, and yellow-poplar were the predominant hardwood species in the post-treatment regeneration of the brown-and-burn sample plots. They are likely to remain longer in the developing stand due to reduced numbers of oaks (Table 10). Smooth sumac, although frequent in all treatments, will not be a component of the mature stand. Although dominant in the pre-harvest stand, oaks and hickories were not well represented in the post-treatment regeneration of the brown-and-burn sample plots. The absence of these species could have serious implications on the wildlife habitat in the developing stands. These early

measurements suggested that yellow-poplar will be the predominant hardwood timber species in stands developing following the brown-and-burn treatment.

The fell-and-burn treatment contained 18 of the 29 woody species identified in this study. The predominant species were sourwood, smooth sumac, red maple, sassafras, and yellow-poplar. Of these, smooth sumac is unlikely to be a component of the mature stand. Due to their high numbers, yellow-poplar and chestnut oak are likely to increase in stature within the developing stand to become the dominant hardwood species once they suppressed sassafras and sourwood. McQuilkin (1990) noted that chestnut oak is a good competitor on dry sites. In the fell-and-burn plots, black walnut, pignut hickory, Virginia pine, and witch-hazel were so infrequent that they will not be significant components of the developing stand.

The fell-and-burn treatment contained greater numbers of the oaks (except white oak) and hickories compared to the brown-and-burn. White oak was not present in either burned treatment but was present in moderate numbers in both of the unburned treatments. This suggested that white oak does not regenerate well following the burn treatment, since it was present in all treatments in the pre-harvest stand (Tables 8 and 9).

The lack of white oak following burning was contrary to the findings of other authors (Augspurger et al. 1987, Van Lear 1991). They reported that broadcast burning would increase the number of high quality oak sprouts in the southern Appalachians. However, Lorimer (1992) stated that the evidence suggesting positive effects on oak regeneration were "rather inconclusive", noting that other studies had shown little or no increase in oaks following burns.

While not abundant, pignut hickory was present in the commercial clearcut and silvicultural clearcut treatments. It appeared that the burn treatment had a negative effect on the already limited occurrence of pignut hickory.

The silvicultural clearcut and commercial clearcut treatments contained 21 and 24, respectively, of the 29 sampled species. Sassafras, red maple, sourwood, yellow-poplar, and chestnut oak were the predominant hardwood species regenerating in these treatments (Table 10). All of these species were present in the understory of the pre-harvest stand (Tables 8 and 9). Flowering dogwood was also present in large numbers in the post-treatment regeneration of the silvicultural clearcut treatment. Its frequency, and that of sourwood and chestnut oak, appeared to increase with the increased cutting of residual stems in the silvicultural clearcut treatment.

Several species that were not present in the burned treatment regeneration but were present in the silvicultural clearcut and commercial clearcut treatments included: American elm, cucumber magnolia, eastern redbud, green ash, pawpaw, post oak, red mulberry, southern red oak, sugar maple, and white oak. The fact that these species were limited to the unburned treatments was likely an indication of: 1) the sensitivity of some of these species to fire and/or herbicides, 2) a lack of sampling sensitivity due to small hardwood-sampling plots, or 3) the absence of these species in the pre-harvest stand within individual treatment plots. It may also suggest that the fire consumed all available seeds or that these species were present but were not sampled.

Height and Density

The height of regenerating hardwoods in burned treatments was less (Table 11) and there were fewer hardwood stems per hectare (Table 13) in burned treatments compared to unburned treatments. The brown-and-burn treatment showed significantly shorter regenerating hardwoods (Table 11) and significantly fewer hardwood stems per hectare (Table 13) than did any of the other treatments. The brown-and-burn treatment was so effective at controlling hardwoods that no stems in sample plots were taller than 1.83 meters (six feet) (height class 3) (Table 11), and the number of stems per hectare was generally less than half of the number in other treatment plots (Table 13).

According to Geisinger et al. (1989), differential height growth between burned and unburned treatments occurs due to differing site preparation intensities. This occurred in the case of the brown-and-burn treatment. However, there was no significant difference in hardwood height growth between the fell-and-burn treatment and the two unburned treatments even though hardwoods in the fell-and-burn had almost a year less to grow due to treatment. This indicated that stems in the fell-and-burn treatment had faster growth rates than stems in the unburned treatment plots, although this effect was not measured.

Both burned treatments are likely to continue to be mixed pine-hardwood stands. They both contained hardwood species which are likely to remain in the stand, and both showed good survival of pine seedlings. However, two potential problems existed that influenced the success or failure of regenerating a mixed pine-hardwood stand. First, the use of Arsenal appeared to inhibit the regeneration of desirable hardwoods to the extent

that those species were not prevalent in the developing stand. The essential absence of oak and hickory regeneration was particularly noteworthy when future wildlife needs were considered. Hardwood densities in the brown-and-burn were generally low, but were ample given good survival of yellow-poplar. Van Lear and Watt (1992) stated that vigorous and abundant sprouting of oaks usually occurs following burning of clearcut areas, but this did not occur in the brown-and-burn treatment. A pine-dominated stand, instead of a mixed pine-hardwood stand, would develop if too few desirable hardwoods remained following the brown-and-burn treatment.

Based on the lack of height class 4 (greater than 1.83 meters tall) hardwood stems (Table 11) and a significant reduction in woody stems per hectare (Table 13), it appeared that the use of Arsenal in the brown-and-burn treatment contributed more to a reduction in hardwood height growth and stem density than did prescribed fire with felling. The implications of this relationship were unclear, because the exact degree to which the fell-and-burn and brown-and-burn treatments retarded hardwood development and could still yield a mixed pine-hardwood stand was unknown. This was particularly true with respect to the brown-and-burn treatment. This treatment was designed to eliminate hardwoods in association with intensive pine management in the southeastern United States. It would not normally favor the development of mixed stands, but pines planted on a wide spacing, as was the case in this study, could allow the development of a mixed stand. The low number of regenerating hardwoods combined with the absence of many preferred wildlife and timber species could limit the suitability of this treatment for pine-hardwood regeneration.

Second, the degree to which hardwood regeneration was affected by the fell-and-burn treatment was somewhat questionable. While differences in height growth and stem density in this treatment were not statistically different from the unburned treatments, they were generally lower than those of the unburned treatments. When comparisons of stem height were made by species, the fell-and-burn generally did not differ from the unburned treatments (Table 12). Whether or not these differences would favor pine development sufficient for the establishment of a mixed pine-hardwood stand remained to be seen. Future measurements will be necessary to evaluate the degree to which this treatment reduced hardwood competition sufficient to establish a desirable pine-hardwood mixture.

Herbaceous Composition and Biomass

The composition of herbaceous samples did not vary significantly among treatments. However, the unburned treatments contained several herbaceous species that were not present in the burned treatments (Table 14).

Species dominance appeared to be strongly influenced by treatments. The burn treatments were generally dominated by asters, particularly fireweed and/or horseweed, and other forbs. Several authors have stated that site preparation involving burning and/or herbicides generally results in a plant community initially dominated by forbs (Gibbens et al. 1986, Hurst and Palmer 1988). Smilax formed a major component in a

number of fell-and-burn sample plots (Table 14). Although other species were present in these treatments, they were of secondary importance.

The opposite was true of the two unburned treatments. In these treatments, neither fireweed nor horseweed were generally dominant. Numerous species, including fireweed and horseweed, would dominate at any given sample location. However, the dominant species was often dictated by the particular condition of the sample location. For instance, fireweed or horseweed often dominated disturbed areas within the unburned treatment; other species, such as smilax, blueberry, muscadine, and Virginia creeper, would dominate relatively undisturbed portions of these treatments, such as areas covered by logging slash.

Euonymus and poison ivy appeared to be strongly suppressed by the burn treatments as neither of these species was found in any burn treatments (Table 14). Lespedeza was not present in the commercial clearcut treatment and only appeared in one sample in the silvicultural clearcut treatment, but it was relatively abundant in the burned treatments (Table 14). Lespedeza frequency increased with treatment intensity or burning, a relationship also noted by Lewis and Harshburger (1976) and Buckner and Landers (1979). Virginia creeper was not found in the brown-and-burn treatment but was found in all other treatments. This possibly reflected a high susceptibility of this species to the herbicide used.

There were significant differences in herbaceous biomass among treatments (Table 15). Burned treatments contained significantly more herbaceous biomass than did the unburned treatments. This was due primarily to the proliferation of fireweed and

horseweed. Other authors have noted the same, positive response of herbaceous plants to fire (Buckner and Landers 1979, Evans et al. 1990).

The three-fold increase in herbaceous biomass that the burned plots showed compared to the commercial clearcut treatment and the two-fold increased they showed compared to the silvicultural clearcut were likely the result of fire. However, differences in fire intensity within treatments could have also contributed to the observed variation in average sample plot weights of herbaceous biomass as evidenced by significant differences for replication ($p \geq 0.0212$) and the treatment/replication interaction ($p \geq 0.0042$). Burn intensities within treatments were variable yielding heterogeneous biomass distributions within treatments. However, herbaceous biomass generally increased with the intensity of the site preparation.

Herbaceous biomass per sample was uniformly high in burned treatments (Table 15). Fell-and-burn treatments averaged 124.5 g/m^2 and brown-and-burn treatments averaged 107.9 g/m^2. The commercial clearcut treatment averaged 32.1 g/m^2, and the silvicultural clearcut averaged 56.0 g/m^2. Only rarely did the weights of samples from unburned plots approach the weights of samples from burned treatments.

Fireweed and horseweed were the only species that showed significant biomass differences among treatments (Table 16). Fireweed and horseweed showed significantly higher biomasses in the burned treatments. Blueberry and muscadine were common in the unburned treatments, sparse in the fell-and-burn treatment, and seldom observed in the brown-and-burn treatment. Smilax was most abundant in the silvicultural clearcut

treatment; grasses were most abundant in the burned treatments; and pokeweed was abundant in all treatments (Table 16).

Neither the composition nor the biomass of the herbaceous vegetation developing within the study area could have much effect on the development of the stands resulting from the various treatments. The burned plots contained herbaceous species that are poor competitors. They will not seriously impact the regeneration of hardwoods or the growth of planted pine seedlings. The unburned plots contained certain species, such as blackberry, muscadine, and smilax, that could potentially impact hardwood regeneration or pine seedling survival by overtopping regenerating hardwoods or planted pine seedlings. Areas where these species predominate were limited and will not seriously influence hardwood regeneration or seedling survival in the long-term. Most were early successional species that will not be present in older stands.

Treatment Effects on Wildlife Habitat and Populations

Songbirds

The study area contained shrubland in the unburned treatments and a mixture of shrubland and grassland in the burned treatments. As such, its bird community would initially be typical of shrubland and/or grassland communities. The structure of these areas determined the songbird species that were present.

Songbirds commonly found in regenerating stands include ground and shrub foragers, foliage gleaning neotropical migratory birds, and ground-foraging short distance

migrants; aerial foragers and a few pursuers, such as flycatchers are also present in young stands (Thompson et. al. 1993). Buehler (unpublished data) censused breeding birds 12 times on the study area in July 1993 and identified 20 bird species. Yellow-breasted chat, indigo bunting, and rufous-sided towhee were the most abundant breeding songbirds present. White-eyed vireo, northern cardinal, and Carolina chickadee were also common. These results supported the findings of Meyers and Johnson (1978), Conner and Adkisson (1975), and Thompson et al. (1993) who identified many of the same species in regenerating areas. Meyers and Johnson (1978) noted that prairie warblers, yellow-breasted chats, indigo buntings, white-eyed vireo, common yellowthroat, and field sparrow were common breeding species found in shrubland.

Many of the 30 bird species identified by Buehler on the study area and their relationships to regenerating stands of different ages are shown in Table 19. Table 19 was adapted from Conner and Adkisson's (1975) work in mixed oak clearcuts in Virginia. Avian communities on the study area should vary with stand age in a manner similar to that developed by Conner and Adkisson (1975) since many of the species were the same in both studies.

Buehler (unpublished data) also found 19 bird species in a census of a mature hardwood forest surrounding the study area. The predominant species found in the mature forest were red-eyed vireo, ovenbird, blue-gray gnatcatcher, Carolina chickadee, and scarlet tanager. The forest was censused 30 times (more than twice the amount of the clearcut area), but species diversity in the clearcut study area was greater than that in the mature forest. Relationships evident from Buehler's data included:

Table 19. Potential Abundance[1] of Bird Species Found in Various Age Stands After Clearcutting Mixed Oak Stands[2].

Species	Clearcut Age					
	1 year	3 years	7 years	12 years	Pole Stand	Mature Stand
Indigo bunting	A	B	B	C		
Carolina wren	B	C	C		C	
Carolina chickadee	C		C			
Downy woodpecker	C					C
American goldfinch	C	C	C	C		
Brown-headed cowbird	B	C	C	C	B	C
Prairie warbler		B	B	A		
Field sparrow		B	B	C		
Rufous-sided towhee		B	B	B	C	
Yellow-breasted chat		C	C	B		
Northern cardinal		C	C	C		
Ruby-throated hummingbird		C	C	C		
Hairy woodpecker		C				C
White-eyed vireo			C			
Red-eyed vireo				C		B
Scarlet tanager				C	C	C
Ovenbird					A	B
Blue-gray gnatcatcher					B	C
Wood thrush					B	B
Acadian flycatcher					C	C
Tufted titmouse					B	C
White-breasted nuthatch						C

1 A = most abundant
B = abundant
C = common

2 Table 19 is a modification of a table adapted from Conner and Adkisson (1975) as cited in Evans (1978) using field data obtained from Buehler (unpublished).

1) Woodpeckers were not observed within the clearcut area although snags remained in the commercial clearcut treatment and, to a limited extent, in the brown-and-burn treatment. Three woodpecker species (red-bellied woodpecker, hairy woodpecker, and downy woodpecker) were observed in the mature forest. No mention was made as to whether or not woodpeckers were observed in treated areas.

2) Brown-headed cowbirds were observed twice as often in the clearcut area, suggesting the possibility of increased nest parasitism in these areas.

3) Some bird species showed expected preferences for habitat. For example, yellow-breasted chats, prairie warblers, field sparrows, and rufous-sided towhees were not observed in the mature stand. Similarly, ovenbirds, yellow-billed cuckoos, and Acadian flycatchers were not observed in clearcuts.

4) Other species were present in both habitats, including summer tanagers and Carolina chickadees.

Heavy use of study area by those bird species found in clearcuts was partially attributable to the safety and woody plant diversity provided by these young stands. Avian use of these areas may also be related to presence of many trees of sprout origin. These trees typically produce seed (mast) at an early age and provide the necessary habitat needs for a wide range of bird species at an early age. These factors made the study area attractive to many songbird species.

Table 20 demonstrates the relationship between stand age and habitat value for breeding and wintering birds. Only the more important hardwood species sampled on the study area that produce food (mast) for birds were shown. These relationships were based on bird and hardwood species life history characteristics relative to food production for birds. For instance, mast food values for breeding birds were likely low in the study area. This was because birds breed at a time when plants generally do not provide mast

Table 20. Food and Cover Values[1,2] by Stand Age[3] of Mast-Producing Hardwood Species Occurring on the Study Area for Songbirds.

Species	Breeding Songbirds						Wintering Songbirds					
	Seedling Stand		Pole-Size Stand		Mature Stand		Seedling Stand		Pole-Size Stand		Mature Stand	
	Food	Cover	Food	Cover	Food	Cover	Food	Cover	Food	Cover	Food	Cover
Oaks	1	3	2	2	2	3	1	3	2	2	3	3
Hickories	1	3	2	2	2	3	1	3	2	2	2	3
Red maple	1	3	1	2	1	3	2	3	3	2	3	3
Yellow-poplar	1	3	1	2	1	3	1	3	2	2	3	3
Smooth sumac	2	2	2	3	1	1	3	2	3	3	1	1
Flowering dogwood	1	3	1	2	1	3	3	3	3	2	2	3
Carolina buckthorn	2	3	2	2	2	3	3	3	3	2	2	3
Black cherry	1	3	1	2	1	3	2	3	3	2	2	3

[1] 1 = low value
2 = moderate value
3 = high value

[2] Food values account only for the mast produced by each species and not for other possible food values.

[3] Stand ages are: seedling stand = 1-10 years old
pole-size stand = 11-30 years old
mature stand = >30 years old.

due to fall or winter seed maturation dates and because destruction of seeds by insects, rodents, and other consumers often reaches 90 percent (Marquis et al. 1976, Galford et al. 1991). Smith (1992) stated that destruction of acorns was also caused by disease and adverse weather conditions. Dey (1992) stated that viable acorns generally remain on the forest floor for six months or less. In addition, oaks and hickories (even those of sprout origin) take many years to bear seeds making mast production from these species unlikely in the young regenerating stand.

Wintering songbirds were likely to find adequate mast at all stand ages. Smooth sumac, flowering dogwood, Carolina buckthorn, red maple, and black cherry provide soft mast in the early stages of stand development. The results of this study showed that these early-fruiting species were taller and more numerous in the unburned treatments than in the burned treatments. This relationship will be a positive influence for birds on unburned plots, but the amount of mast from these species will decline as canopy closure occurs. Mast from canopy species, including oaks, hickories, and yellow-poplar, increases after that point. These species were also taller and more abundant in the unburned plots, leading to the assumption that these species will dominate the maturing stands in these plots. The progression from early-fruiting species to oaks and hickories will mean that wintering avian communities will change as stand structure and mast production change during stand development.

Cover values of both young and mature stands for breeding and wintering songbirds will be high, particularly in the burned plots. This prediction was based on the reported increases in avian communities where structural diversity is highest (e.g.,

burned short-term stands were a mixture of shrub and grassland/forb communities compared to shrub communities of unburned plots) (Dickson and Segelquist 1978) and where pine-hardwood is likely to dominate (mature stands of burned plots) (Evans 1978, Shugart et al. 1978, Kerpez and Stauffer 1989). Mid-aged stand cover values will be lower as documented by Conner and Adkisson (1975).

This did not mean that the unburned treatments were without birds or suitable bird habitat. They contain both as Buehler's (unpublished) data support. However, they likely contained simple bird communities due to the uniform habitat structure in young stands (shrubland only) and due to the lack of a significant pine component in the mature stand.

Seed producing plants were also present in all treatments and were likely an important food source to birds. Fireweed and horseweed were prolific seed producers in every sample plot in which they were found. Their biomass and that of other members of the Asteraceae was significantly higher in burned plots (Table 17). Members of the Ericaceae were more common in unburned plots, producing foods like blueberries which are important for birds. Representatives of the Fabaceae (*Desmodium* spp. and *Lespedeza* spp.) were present in all treatments, although lespedeza was more prevalent in burned plots. This was similar to the results of Cushwa et al. (1970) who found that the numbers of legumes did not differ significantly between burned and unburned areas. Seeds of these species were likely utilized by birds and small mammals.

The best seed producers were fireweed and horseweed. However, the utilization of these two species as food sources might have been limited. The wind-dispersed seeds of these two plants have coarse hairs which birds may have difficulty swallowing.

Berry producers such as blackberry, raspberry, and blueberry were more abundant in unburned plots than in burned plots (Table 17). Blackberry was shown to increase initially as young clearcuts develop and to provide the majority of soft mast prior to stand closure (Campo and Hurst 1980). As canopy closure occurs, blackberry will decrease. These species are important foods for birds and small mammals until canopy closure. Flowering dogwood was also more abundant in the unburned treatments (Table 10), particularly the silvicultural clearcut, and will provide food for birds at all stand ages.

Based on the high survival of pine seedlings in the fell-and-burn and brown-and-burn plots, it appeared that these treatments will satisfy many of the habitat needs of songbirds that required a pine component. These effects will become more pronounced as the stand matures. It was unlikely that the commercial clearcut or silvicultural clearcut treatments contained a sufficient number of pine trees at maturity to attract those birds requiring pines for life history requirements.

Stand age will be a major determinant of bird composition on the study area (Table 19). Golden-crowned kinglets and ruby-crowned kinglets are common to abundant winter residents in pine and mixed pine-hardwoods and are found in association with year-round residents such as Carolina chickadees, tufted titmice, and downy woodpeckers; pine warblers will be common where there is a high pine component; and yellow-rumped warblers will be common in younger and older stands with resident bird

species (Meyers and Johnson 1978). These species and species assemblages will probably be wintering and breeding residents of the study area at maturity, although no wintering songbird data has been collected on the study area.

Woodpeckers and other cavity nesters, such as the Carolina chickadee, tufted titmouse, great-crested flycatcher, and white-breasted nuthatch, should become more common (Meyers and Johnson 1978) as all stands mature. These species will typically be joined by birds that prefer hardwood forests, such as the broad-winged hawk, Acadian flycatcher, wood thrush, red-eyed vireo, black-and-white warbler, ovenbird, and scarlet tanager (Meyers and Johnson 1978).

The unburned treatments and fell-and-burn treatment contained a high oak and hickory component that, at maturity, will provide good habitat for many bird species (Table 10). Martin et al. (1951) listed 37 species of birds that eat acorns and 6 that eat hickory nuts, noting that competition for mast is high among some game birds, non-game birds, and mammals. Blue jays, red-bellied and red-headed woodpeckers, and common grackles are among the songbirds known to consume hard mast. While mast production is likely to be extremely variable, management to favor mast-bearing species is essential if favorable wildlife habitat is to develop. This is particularly true in the mountains where management of mast producing stands should recognize the influence of elevation and aspect on stand development.

Eastern Wild Turkey

Wild turkeys will utilize the regenerating stands in a variety of ways. Turkey hens will utilize young stands for nesting cover for a number of years and for brood rearing habitat for 2 to 4 years. Adult turkeys utilize regenerating stands until the cover becomes too dense to enter safely. The study area will not provide good roosting habitat or wintering habitat until sawtimber-sized trees are present and producing hard mast, but it could provide occasional habitat at other times of the year.

Wild turkeys are omnivorous birds that eat a wide variety of animal and vegetable foods. Prominent turkey foods in the southeastern United States include hard mast (acorns, hickory nuts, and pine seed), soft mast (flowering dogwood, poison ivy, muscadine, red mulberry, blackberry, and blueberry), arthropods and other invertebrates, green forage, and grass seeds (Hurst 1992). Table 21 contains wild turkey seasonal foods that were sampled on the study area.

Wild turkeys utilize foods subject to their availability (Korschgen 1967), but acorns and the fruits of flowering dogwood are considered the most important (Korschgen 1967, Dickson 1990). Dickson (1990) showed acorn and dogwood fruit production to be highest in hardwood and shortleaf pine-hardwood stands in an Arkansas study.

In a study of wild turkey habitat near this study site, Minser et al. (unpublished data) observed more green herbaceous growth in pine and mixed pine-hardwood stands than in hardwood stands. Such observations suggest that the mature stands that will

Table 21. Principal Wild Turkey Foods Present on the Study Area Following the 1990 Growing Season[1].

Winter	Spring	Summer	Fall
acorns	acorns	green leaves	animal foods
green leaves	green leaves	blackberries	acorns
grapes	sedges	animal foods	green leaves
dogwood	animal foods	acorns	tick trefoils
sumac fruits		panic grasses	grapes
animal foods		blueberries	panic grasses
sedges			grasses

[1] Table was adapted from Korschgen (1967, 1973).

occupy the study site's burned plots will contain a valuable herbaceous component for wild turkey.

Flowering dogwood was abundant in the unburned treatments (Table 10). It is an important fall-winter food for wild turkeys (Kennamer et al. 1980a, Exum et al. 1987) and for squirrels, small mammals, and numerous songbirds. Exum et al. (1987) reported that flowering dogwood was most abundant in pine and mixed pine-hardwood stands in Alabama, and Sisson et al. (1990) suggested that dogwood fruits, which are common in pine-hardwood stands, are important foods in winter during years of poor acorn production. Flowering dogwood and other foods (e.g., insects and muscadine) were present in the burned treatments due to their shrubland and grassland structure at this development stage. However, vegetation density probably determined whether or not these foods were utilized by wild turkeys. Wild turkeys tend to avoid areas of tall, dense vegetation.

Chestnut oak, black oak, and northern red oak were the major mast-producing species present in the hardwood regeneration of burned plots that will provide wild turkey food in the long term (Table 10). However, the presence of oak as a major component of the canopy can only be reasonably determined once the stand is pole-sized (Lorimer 1992). It is at this stage that the stand has developed a closed canopy and has begun to stratify into crown classes.

There were 315 chestnut oak, 80 black oak, and 161 northern red oak stems per hectare in the fell-and-burn (Table 10). The brown-and-burn contained 79 chestnut oak, 124 black oak, and 19 northern red oak stems per hectare. Lower numbers of oaks and hickories compared to the other species present in these treatments, meant that flowering dogwood, red maple, and yellow-poplar were the only mast producers remaining that were likely to produce mast initially in sufficient quantities for wildlife use. The lack of black cherry in the brown-and-burn treatment and the absence of white oak from both burned treatments also limited food choices for turkeys. Smooth sumac produced mast suitable for turkeys in the short term.

The extent to which wild turkeys will utilize soft mast in young clearcuts is not known. The cover of these areas is too dense for turkeys to feel safe foraging. Wild turkey use of sapling or pole-size stands will also be limited until canopy closure reduces the density of the understory and midstory.

Table 22 contains the value of the predominant regenerating hardwoods as wild turkey food and cover. These relationships were based on knowledge of wild turkey habitat requirements and characteristics of the regenerating stand. These characteristics

Table 22. Food and Cover Values[1,2] by Stand Age[3] of Mast-Producing Hardwood Species Occurring on the Study Area for Wild Turkeys.

Species	Seedling Stand		Pole-size Stand		Mature Stand	
	Food	Cover	Food	Cover	Food	Cover
Oaks	1	3	2	2	3	3
Hickories	1	3	1	2	2	3
Red maple	2	3	2	2	3	3
Yellow-poplar	2	2	2	2	2	3
Smooth sumac	2	2	3	2	1	1
Flowering dogwood	2	3	3	2	3	2
Carolina buckthorn	2	2	2	2	2	2
Black cherry	2	3	3	2	3	3

[1] 1 = low value
2 = moderate value
3 = high value

[2] Short-term stand cover values for wild turkeys are based primarily on the potential for nesting wild turkey hens.

[3] Stand ages are: seedling stand = 1-10 years old
pole-size stand = 11-30 years old
mature stand = >30 years old.

were predicted in a manner similar to that described previously for songbird usage of regenerating woody stems. For example, the high cover value of young stands was primarily due to turkey hen use of these areas for nesting. Similarly, hard mast-producing species that mature late were unlikely to provide high food values in sapling or pole-size stands. Food values of the predominant cover species are also presented in Table 22. These values do not account for other possible foods (e.g., insects) that were present.

Other Wildlife Species

Wildlife food availability in the stands developing after all treatments was ample. Woody browse was abundant in the unburned plots. The burned plots contained more herbaceous food (by weight) than unburned plots. These results were similar to those of Bidwell et al. (1989) who found that pine plantations in Oklahoma had more green herbaceous cover during winter than naturally regenerated stands but less hard mast. Young stands did not produce hard mast, but it is reasonable to assume that they will in the future with adequate stocking of appropriate species.

The height, density, and composition of the regenerating hardwoods influenced the quality of the wildlife habitat provided. The satisfactory survival and growth of the pine seedlings in the commercial clearcut and silvicultural clearcut treatments was in jeopardy due to vigorous competition from hardwood species. However, this was not necessarily detrimental to the wildlife habitat that is provided in the short-term. The creation of young stands and edge habitats certainly benefited some wildlife species (Yahner and Howell 1975, McComb 1985, McComb et al. 1991).

Ground-level forage production will change as the stand matures. Understory forage production is typically inversely related to stand basal area and to the number of canopy layers (Halls and Schuster 1965, Blair and Enghardt 1976, Wiggers et al. 1978). Relative diversity and richness of understory species declined as pine-hardwood stands aged in one Mississippi study (Leopold et al. 1989). Wigley et al. (1989) found that forage production in stands containing 50 percent pine versus 90 percent pine did not differ. A high percentage of pine reduced acorn production, but also increased foliage

height diversity, which has been shown to enhance songbird habitat (MacArthur and MacArthur 1961). Overall forage production decreased due to increasing canopy coverage. The food and cover availability for species dependent on ground-level vegetation will likely decline as the overstory closes.

Greater herbaceous biomass in the burn plots was largely due to the presence of fireweed and horseweed. This was consistent with the findings of Danielovich et al. (1987) and Evans et al. (1991a), who reported twice the herbaceous biomass on burned plots compared with unburned plots in the southern Appalachians. Van Lear and Kapeluck (1989) found shrub and herbaceous biomass in burned plots to be nearly double that of unburned plots. Cushwa et al. (1969) noted that burning a clearcut area in the Georgia Piedmont increased seed production 300 percent and plant abundance increased 100 percent in a pine-dominated stand.

Fireweed and horseweed densely colonized the burned plots following prescribed fire. Many early successional species, annual plants in particular, use persistent seed banks in the soil from which to germinate. Germination of these species is stimulated by increases in light and temperature (Luken 1990), which, in the case of this study, occurred due to cutting.

Fireweed and horseweed were likely only marginally important as forage for browsers due to their fibrous nature, but they could be palatable as young plants. Small mammals likely utilized their seeds since they can chew off the coarse hairs on the seeds. These early successional species tend to allocate more resources toward reproductive structures (flowers, fruits, and seeds) (Newell and Tramer 1978) than do late successional

species. Desirable forage biomass was locally abundant in the unburned plots in the form of smilax, blackberry, muscadine, poison ivy, and pokeweed -- five important browse species for white-tailed deer.

Late successional species allocate more energy and resources for vegetative reproduction (including sprouting) and underground energy storage making their root/total biomass ratios higher (Newell and Tramer 1978). When these stands are cut, sprouting strongly influences composition. Growth rates of sprouts exceed those of trees established from seed, particularly in the early stages of development. If prolific sprouting occurs, the resultant community will be dominated by sprouting species (Luken 1990), which was the case in this study. These regenerating species are often important browse species for white-tailed deer.

The dense ground-level woody vegetation provided by the commercial clearcut and silvicultural clearcut treatments was likely beneficial to white-tailed deer. In particular, blueberry, muscadine, and several species of woody browse were found more often in unburned plots. McComb et al. (1991) found that white-tailed deer were locally abundant in young clearcuts, which they use as sanctuaries and for foraging. The abundant woody browse in the unburned treatments will likely be utilized extensively as forage but only for several years. Woody browse in these treatments was already significantly taller than woody browse in the burned treatments and will likely be unusable as stem heights increase and canopies begin to form. The shorter stem heights of woody browse in the burned treatments may prolong forage availability in those treatments and allow the planted pines to become established.

Many of the regenerating species found in sample plots were likely browse foods for white-tailed deer (Halls and Ripley 1961). These included red maple, flowering dogwood, euonymus, yellow-poplar, sourwood, oaks, blackberry, sassafras, smilax, blueberry, and muscadine. Sassafras, muscadine, and blackberry were rated as preferred browse foods by Wolters et al. (1977), while red maple, flowering dogwood, white oak, poison ivy, muscadine, and Virginia creeper were rated medium.

Palatability of browse species varies, but most sprouts and young leaves are eaten. Black cherry is not considered good deer browse. Therefore, the apparent loss of it in the brown-and-burn treatment was of little consequence without accounting for the needs of other species.

Deer require leafy forage from woody and herbaceous plants in forest understory or openings (Harlow and Hooper 1971). Lay (1969) estimated that white-tailed deer consumed an average of 1.1 kilograms of forage (dry weight) per 45 kilograms of body weight per day. All treatments contained a high stem count of woody browse species and numerous mast producing stems (Table 23). Although specific amounts of available deer forage were not measured, the study area appeared to have sufficient forage available based on the amounts of herbaceous forage present and the stem counts of browse species.

Harlow and Hooper (1971) analyzed 956 rumen samples of white-tailed deer from all regions of the southeastern United States and determined the dominant food items of deer for each season. They found yellow-poplar fruit and green leaves, acorns, the fruit of apple, and the green leaves of sourwood, honeysuckle, blueberry, blackberry, and

Table 23. Important Wildlife Foods by Treatment Following the 1990 Growing Season.

Species	Commercial Clearcut (stems/ha)	Silvicultural Clearcut (stems/ha)	Brown-and-Burn (stems/ha)	Fell-and-Burn (stems/ha)
Sassafras	3487	2813	1302	1322
Red maple	2907	2752	162	472
Sourwood/Blackgum	722	2017	533	1963
Yellow-poplar	870	816	863	594
Oaks	1772	2117	222[1]	556[1]
Smooth sumac	371	94	897	1996
Carolina buckthorn	461	115	0	692
Hickories	202	270	40	310
Black cherry	128	229	0	21
Totals	10920	11223	4019	7926

[1] No white oak (*Quercus alba*) regeneration was present in sample plots.

legumes were the dominant spring foods of deer in the southern Appalachian Mountains. Summer foods in the Appalachian Mountains were predominately the green leaves of red maple, oak, sourwood, flowering dogwood and honeysuckle, the leaves and stems of legumes, and the fruits of chinaberry. Oak mast was most commonly eaten in fall followed by the fruits of apple, persimmon, and grape, the green leaves of rhododendron and honeysuckle, grasses, sedges, and fungi. Winter foods of deer in the Appalachian Mountains included acorns, dry leaves of deciduous plants, green herbaceous stems and leaves, hardened stems of woody plants, and mushrooms. Similar results were obtained

by Harlow et al. (1974). Many of these important white-tailed deer foods occurred on the study area.

Evidence that smilax, pokeweed, and muscadine were browsed by deer in the commercial clearcut and silvicultural clearcut treatments was extensive although quantitative measurements of utilization were not made. Pokeweed, in particular, appeared to be preferred by deer. Nearly every pokeweed plant observed showed some sign of being browsed, with the majority of the plants having all leaves eaten. White-tailed deer will use these areas for foraging until the woody species are too high for them to reach the buds and leaves or until herbaceous browse species are eliminated by overhead competition. However, deer will continue to use these areas for cover and travel long after they have lost their usefulness as foraging areas.

The fell-and-burn and brown-and-burn treatments provided for the habitat needs of many wildlife species. However, these plots differed from the commercial clearcut and silvicultural clearcut treatments in how and when suitable habitat for wildlife species was be provided. First, the structure of these plots was such that initially they would not be able to provide the dense, woody cover required by many species. Second, the effects of fire and herbicides on hardwood regeneration would delay the fruiting of species and thus delay food availability (Ahlgren and Ahlgren 1960, Wright and Bailey 1982). For oaks in particular, Wendell and Smith (1986) and Merritt and Pope (1991) showed little or no increase in oak establishment and an increase of other species following prescribed fire. This indicates a potential reduction in oak mast or at least a delay in oak maturation.

As these stands mature, the amount of browse will decrease. Shading from the developing canopy will eliminate intolerant understory species. Halls (1973) showed reduced amounts of browse with increasing pine canopy cover and Halls and Schuster (1965) documented that browse is reduced in pine-hardwood forests as canopy cover increases.

Habitat requirements that were sacrificed early in the life of the stand to favor the establishment of the pine component could be compensated for through the development of a good pine-hardwood mixture. Wigley et al. (1989) found that pine-hardwood mixtures have stable amounts of herbaceous forage in stands in which the ratio of pines to hardwoods in the overstory varied widely. Conversely, a number of authors have noted that understory biomass production for white-tailed deer is inhibited by dense midstory hardwoods (Schuster and Halls 1963, Halls and Schuster 1965, Blair 1967, Blair 1969, Blair and Feduccia 1977, Hurst et al. 1979). A pine component would create a measure of diversity in the stand by producing different types of food and cover than would be expected from either a pure hardwood or pure pine stand without sacrificing the positive food and cover values of hardwoods.

Several physical characteristics of developing pine-hardwood stands will influence wildlife habitat (Meyers and Johnson 1978). First, mixed stands tend to develop three vertical strata of vegetation - groundstory (0-3 m), understory (3-10 m), and overstory (over 10 m). Second, horizontal clumping (patchiness) is more prevalent in mixed stands. Third, lightning, red heart disease (*Fomes pini*), and southern pine beetle

(*Dendroctonus frontalis*) often cause small openings in which regeneration creates uneven age stands. Fourth, snags become more abundant as the pine component begins to die.

Murphy and Crawford (1970) found that 85 percent of oak-pine plots in a Missouri had canopy closure greater than 70 percent. Sixty percent of these stands were sawtimber; 33 percent were pole stands; and 7 percent were seedling stands. Total understory biomass on these plots was low and generally less than 224 kilograms of oven dry material per hectare (200 pounds per acre) per year. The most frequent understory plants in oak-pine forests were blueberry, lespedeza, tick trefoil, and panic grass. Large amounts of hickory, white oak, sassafras, black oak, post oak, muscadine, and flowering dogwood browse were present and comprised most of the available understory biomass. The high percentage canopy closure appeared to contribute to the low amount of forage present in these stands. These same species were present in this study's regenerating stand demonstrating a wide variety of potential food sources in the developing stands. In particular, the fell-and-burn contained each of these (except white oak), and pine seedling survival was good.

The unburned study plots contained more regenerating oak stems per hectare than the burned study plots (Table 23). Therefore, the unburned plots should produce more oak mast at maturity. Of the burned plots, the fell-and-burn treatment was more likely to regenerate a mixed stand containing a sizable oak component than the brown-and-burn treatment. The brown-and-burn treatment will likely develop into a predominately pine stand or into a pine/yellow-poplar stand based on the results of this study.

Oaks do not consistently produce mast for wildlife. Annual oak mast yields have been shown to fluctuate from less than 3.36 to more than 501.01 kilograms per hectare (3 to 447 pounds per acre). Other hardwood species, such as flowering dogwood, grape, and blackgum, typically produce some mast each year (Dickson and Rogers 1980). Deer will select mast over woody browse when it is available, especially in the fall and winter when the percentage of woody browse in deer diets declines (Rayburn et al. 1986).

Goodrum et al. (1971) demonstrated negligible acorn yield for oak trees 10-19 years old, increased yield of oak trees 20-29 years old, and the largest yields in oak trees over 40 years old. Their study found that the white oak group produced good mast every two years. Members of the red oak group showed good production less often (e.g., southern red oak once every four years). They found that acorns were consumed quickly by a wide variety of wildlife including white-tailed deer, gray and fox squirrels, common crows, blue jays, woodpeckers, raccoons, rabbits, and gray foxes.

Wildlife species (including deer, wild turkeys, gray squirrels, and bobwhite quail) utilize acorns most of the year, not just during the time that acorns are actively falling. Using the acorn requirement data from Goodrum et al. (1971), a total of 41.92 kilograms per hectare (37.4 pounds per acre) of acorns would be required for a 180-day food supply or 69.94 kilograms per hectare (62.3 pounds per acre) for 300 days to support 5 deer, 50 squirrels, and 2 turkeys on 40.47 hectares (100 acres). Applied to this study, this meant that the 180-day food requirement for these species would be met by:

1) thirty-two 25.4-centimeter (10-inch) diameter breast height (dbh) white oaks or thirty 25.4-centimeter dbh red oaks per hectare,

2) twenty 30.48-centimeter (12-inch) dbh white oaks or red oaks per hectare,

3) ten 40.64-centimeter (16-inch) dbh white oaks or twelve 40.64-centimeter dbh red oaks per hectare, or

4) seven 50.8 centimeter (20-inch) dbh white oaks or red oaks per hectare.

A range of 7 to 32 white oaks per hectare or 7 to 30 red oaks per hectare would be necessary to achieve the 300 day food requirement.

Marquis et al. (1992), using data developed in northeastern United States hardwood stands considered an area stocked with oak when 23,164 oak stems less than 1.37 meters (4.5 feet) tall were present per hectare or when 951 oak stems greater than 1.37 meters were present per hectare. The objectives of pine-hardwood management are much different from those in the northeastern United States, but, even so, meeting the regeneration goal of 951 oaks stems taller than 1.37 meters was realistic in the commercial clearcut, silvicultural clearcut, and, possibly, fell-and-burn treatments given the numbers of oak stems present (Table 23). Meeting the goal of having 23,164 oak stems per hectare goal did not appear reasonable in any treatment. The brown-and-burn treatment will not achieve either oak stocking goal due to a lack of tall stems and the overall lack of oak regeneration.

Small mammals such as rabbits and eastern chipmunks utilized the commercial clearcut and silvicultural clearcut areas. These areas provided cover from predators such as hawks and foxes, and the areas could increase foraging success of these predators (Gates 1991). Rabbits also utilized the burned plots due to larger amounts of forage present, but they likely returned to the cover of the unburned treatments for resting and

protection from predators. Eastern chipmunks were not observed in the burned treatments.

The study area will provide suitable habitat for bobwhite quail for several years. Bobwhites were observed on several occasions in both burned and unburned plots. Bobwhites are known to utilize young clearcuts and pine plantations (Brunswig and Johnson 1973). Several preferred bobwhite foods were present in the study area including *Lespedeza* spp., *Desmodium* spp., *Panicum* spp., and sumac (Brunswig and Johnson 1973). Other less utilized foods, such as pokeweed, acorns, dogwood, Virginia creeper, and green leaves (Brunswig and Johnson 1973) also occurred on the study area.

The treatments tested had varying effects on wildlife habitat. Several evaluations were made to identify the treatment that best provided for both the development of a mixed pine-hardwood stand and for the broadest range of wildlife habitat requirements. The commercial clearcut and silvicultural clearcut treatments would probably develop into pure hardwood or hardwood-dominated stands. High pine seedling mortality and vigorous hardwood regeneration were the primary reasons that these stands would lose their pine component. However, they would potentially provide very good wildlife habitat in the short- and long-term, especially with respect to hard mast production.

The brown-and-burn and fell-and-burn treatments were similar with respect to their effects on the developing stands and on wildlife habitat with one important exception. The brown-and-burn treatment lacked a suitable hardwood component, particularly oaks and hickories, that would provide food and cover in the short-term stand and eventually produce hard mast in the mature stand. Instead of an oak and hickory

component, the brown-and-burn contained more yellow-poplar. Therefore, it appeared that the fell-and-burn would produce the best pine-hardwood mixture while providing for the habitat needs of a wide variety of wildlife species. A summary of potential effects on wildlife habitat by treatment is contained in Table 24.

Table 24. Summary of Treatment Effects on Stand Development and Wildlife Habitat Following the 1990 Growing Season.

Treatment	Potential Pine-Hardwood Stand?	Site-Preparation Costs?	Songbird Habitat?	Wild Turkey Habitat?	Habitat For Other Species?
Commercial Clearcut	Unlikely	NA	Yes, shrub species	Potential nesting habitat	High forage and cover values
Silvicultural Clearcut	Unlikely	Low	Yes, shrub species	Potential nesting habitat	High forage and cover values
Brown-and-Burn	Probable	High	Yes, mostly grass species	Potential nesting and foraging habitat	Moderate forage and cover values
Fell-and-Burn	Yes	Moderate	Yes, shrub and grass species	Potential nesting and foraging habitat	High forage and cover values

CHAPTER 7

SUMMARY AND CONCLUSIONS

The objectives of this study were:

1) To compare the fell-and-burn site preparation technique for establishing pine-hardwood mixtures with three widely used regeneration techniques, and

2) To evaluate the site conditions created by those techniques for wildlife habitat.

For NIPF landowners, establishment of pine-hardwood mixtures through the utilization of this technique may provide multiple benefits including improved forest productivity, minimized investment, and improved wildlife habitat (Phillips and Abercrombie 1987).

The lack of easily installed, economical forest management practices to promote mixed pine-hardwood stands has been cited as a primary reason that many NIPF landowners do not maintain their mixed stands (Waldrop et al. 1989). Many landowners will maintain the type only if it is economical. In other cases, landowners value aesthetics and wildlife, along with economic gains, when measuring returns on their forests. In general, landowner objectives ultimately determine how a forest stand is managed. This study indicated that the fell-and-burn technique is an efficient and cost-effective method for regenerating pine-hardwood stands in the southeastern United States. It also provided empirical data that the fell-and-burn technique provides for the needs of certain wildlife species, particularly many of those species native to the Valley and Ridge Physiographic Province.

Table 24 provided a summary of important stand development and wildlife habitat potentials relative to the treatments applied in this study. Two of the treatments tested in this study will likely provide the conditions necessary for the development of a mixed pine-hardwood stand. The fell-and-burn and brown-and-burn treatments showed good survival of pine seedlings combined with effective control of competing hardwoods. This situation will likely lead to the development of pine-hardwood stands of various stockings based on the treatment applied. It is expected that the fell-and-burn plots will, at maturity, become an oak-pine stand. The brown-and-burn plots will likely become a yellow-poplar-pine-oak or yellow-poplar-pine stand. These stands will provide for the needs of wildlife species to varying degrees as noted in Table 24.

The fell-and-burn technique offered several advantages over the brown-and-burn treatment:

1) The fell-and-burn technique promises to be successful in regenerating mixed pine-hardwood stands in the southern Appalachians.

2) The structure of the competing hardwood regeneration in fell-and-burn plots increased the probability that pine seedlings will survive to become co-dominant with the hardwoods.

3) This study demonstrated that the hardwood component of the future stands will contain a favorable diversity of preferred species including more oak and hickory stems than were present in the brown-and-burn treatment.

4) At the present stage of stand development, it is not clear if the brown-and-burn treatment will encourage stocking with "pioneer" species.

The diversity of hardwood species present in the fell-and-burn plots will likely provide the habitat requirements of many wildlife species native to the study area. The resulting stands are capable of providing the structure and food diversities necessary for

attracting native wildlife species. There is great potential for maintaining a diverse base of native wildlife species in the maturing stands as the pine component adds its food and cover values. The extent to which this will occur in the fell-and-burn and brown-and-burn plots cannot, however, be predicted accurately at this time.

However, a number of habitat relationships can be accurately characterized or predicted at this time. First, the study area, as a whole, contained more breeding bird species than the surrounding mature forest and contained those avian species expected for young, regenerating stands in the Appalachian Mountains. Buehler's data (unpublished) collected on the study area tended to support this. Second, each treatment, except for possibly the brown-and-burn treatment, contained enough oak stems per hectare to support native wildlife species once the stands mature. However, only the burned treatments were likely to provide the habitat values the pine component adds. Third, food and cover amounts were ample to support species native to the study area.

The amount of food and cover differed among treatments. Burned treatments contained more herbaceous biomass than unburned treatments but less woody browse. Cover values were higher in the commercial clearcut and silvicultural clearcut treatments than in the burned plots, particularly the brown-and-burn treatment.

It is unlikely that the commercial clearcut or silvicultural clearcut treatments will produce a satisfactory pine-hardwood mixture. Mortality of pine seedlings reduced the initial stocking of pines in these treatments, and still fewer trees are likely to survive in subsequent years due to the heavy competition from hardwoods. Some individual pine trees are likely to survive due to their position relative to competing hardwoods. Pine

seedlings along skid-trails or other disturbed areas may survive due to reduced levels of competition immediately surrounding them. However, survival of these trees was not representative of treatment effects.

Healthy populations of songbirds, wild turkeys, and several other native species are expected in the unburned plots until stands mature to the point that the wildlife habitat value these areas initially provided are diminished. It is questionable whether the habitat provided by these treatments will be as good, in the long term, as that provided by the burn plots due to the high density of species not preferred by wildlife. While burning does create a condition of generally poor wildlife habitat for a short time (weeks to a few months), there are many more stems regenerating in unburned treatments that are marginal as wildlife food producers, and these plots did not produce as much herbaceous biomass.

In addition, the fell-and-burn treatments will likely contain a high percentage of hard mast-producing trees even though their numbers are not currently high relative to the total number of stems. Mast-production in the brown-and-burn may be reduced due to lower numbers of oaks. The combination of hard mast-producing trees and a sizable pine component at maturation in the fell-and-burn will provide a wider range of habitat requirements than would normally be found in either pure pine or pure hardwood stands in the southern Appalachian Mountains.

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APPENDICES

APPENDIX A

LIST OF PLANTS MENTIONED IN THESIS TEXT AND TABLES

APPENDIX A

List of Plants Mentioned in Thesis Text and Tables

Woody plants	Scientific Name[1]
American elm	*Ulmus americana* L.
Apple	*Malus* spp.
Black cherry	*Prunus serotina* Ehrh.
Blackgum	*Nyssa sylvatica* Marsh.
Black oak	*Quercus velutina* Lam.
Black walnut	*Juglans nigra* L.
Carolina buckthorn	*Rhamnus caroliniana* Walt.
Chestnut oak	*Quercus prinus* L.
Chinaberry	*Melia azedarach* L.
Cucumber magnolia	*Magnolia acuminata* L.
Eastern redbud	*Cercis canadensis* L.
Flowering dogwood	*Cornus florida* L.
Green ash	*Fraxinus pennsylvanica* Marsh.
Loblolly pine	*Pinus taeda* L.
Mockernut hickory	*Carya tomentosa* (Poir.) Nutt.
Northern red oak	*Quercus rubra* L.
Pawpaw	*Asimina triloba* (L.) Dunal
Persimmon	*Diospyros virginiana* L.
Pignut hickory	*Carya glabra* (Mill.) Sweet
Post oak	*Quercus falcata* Wangenh.
Red maple	*Acer rubrum* L.
Red mulberry	*Morus rubra* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Shagbark hickory	*Carya ovata* (Mill.) K. Koch
Shortleaf pine	*Pinus echinata* Mill.
Smooth sumac	*Rhus glabra* L.
Sourwood	*Oxydendrum arboreum* (L.) DC.
Southern red oak	*Quercus falcata* Michx.
Sugar maple	*Acer saccharum* Marsh.
Virginia pine	*Pinus virginiana* Mill.
White oak	*Quercus alba* L.
White pine	*Pinus strobus* L.
Witch-hazel	*Hamamelis virginiana* L.
Yellow-poplar	*Liriodendron tulipifera* L.

[1] Taxonomy follows Little (1988).

APPENDIX A (Continued)

List of Plants Mentioned in Thesis Text and Tables

Herbaceous plants	Scientific Name[2]
Aristolochia	*Aristolochia serpentaria* L.
Aster	*Aster pilosus* Wild.
Blackberry	*Rubus* spp.
Blueberry	*Vaccinium* spp.
Deerberry	*Vaccinium stamineum* L.
Desmodium	*Desmodium* spp.
Euonymus	*Euonymus americanus* L.
Eupatorium	*Eupatorium* spp.
Fireweed	*Erechtites hieracifolia* (L.) Raf.
Golden aster	*Chrysopsis camporum* Greene
Goldenrod	*Solidago* spp.
Grasses	various
Horse nettle	*Solanum carolinense* L.
Horseweed	*Conyza canadensis* (L.) Cronq.
Lespedeza	*Lespedeza* spp.
Little brown jug	*Hexastylis arifolia* Michx.
Mountain laurel	*Kalmia latifolia* L.
Muscadine	*Vitis rotundifolia* Michx.
Panicum (panic grass)	*Panicum* spp.
Passion flower	*Passiflora incarnata* L.
Physalis	*Physalis* spp.
Pipsissewa	*Chimaphila maculata* (L.) Pursh
Poison ivy	*Toxicodendron radicans* (L.) Kuntze
Pokeweed	*Phytolacca americana* L.
Rabbit tobacco	*Gnaphalium obtusifolium* L.
Raspberry	*Rubus* spp.
Rushes	*Juncus* spp.
Sanicula	*Sanicula canadensis* L.
Sedges	*Carex* spp.
Smilax	*Smilax* spp.
Smooth sumac	*Rhus glabra* L.
Violet	*Viola* spp.
Virginia creeper	*Parthenocissus quinquefolia* (L.) Planch
Wild lettuce	*Lactuca canadensis* L.

[2] Taxonomy follows Wofford (1989).

APPENDIX B

LIST OF ANIMALS MENTIONED IN THESIS TEXT AND TABLES

APPENDIX B

List of Animals Mentioned in Thesis Text and Tables

Birds	Scientific Name[1]
Acadian flycatcher	*Empidonax virescens* Vieillot
American goldfinch	*Carduelis tristis* L.
American kestrel	*Falco sparverius* L.
American woodcock	*Scolopax minor* Gmelin
Bachman's sparrow	*Aimophila aestivalis* Lichtenstein
Barred owl	*Strix varia* Barton
Black-and-white warbler	*Mniotilta varia* L.
Black-throated green warbler	*Dendroica virens* Gmelin
Black vulture	*Coragyps atratus* Bechstein
Blue jay	*Cyanocitta cristata* L.
Blue-gray gnatcatcher	*Polioptila caerulea* L.
Blue-winged warbler	*Vermivora pinus* L.
Bobwhite quail	*Colinus virginianus* L.
Broad-winged hawk	*Buteo platypterus* Vieillot
Brown-headed cowbird	*Molothrus ater* Boddaert
Brown-headed nuthatch	*Sitta pusilla* Latham
Brown thrasher	*Toxostoma rufum* L.
Carolina chickadee	*Parus carolinensis* Audubon
Carolina wren	*Thryothorus ludovicianus* Latham
Chestnut-sided warbler	*Dendroica pensylvanica* L.
Chuck-will's-widow	*Caprimulgus carolinensis* Gmelin
Common crow	*Corvus brachyrhynchos* Brehm
Common flicker	*Colaptes auratus* L.
Common grackle	*Quiscalus quiscula* L.
Common raven	*Corvus corax* L.
Common yellowthroat	*Geothlypis trichas* L.
Downy woodpecker	*Picoides pubescens* L.
Eastern bluebird	*Sialia sialis* L.
Eastern wood pewee	*Contopus virens* L.
Field sparrow	*Spizella pusilla* Wilson
Golden-winged warbler	*Vermivora chrysoptera* L.
Gray catbird	*Dumetella carolinensis* L.
Great-crested flycatcher	*Myiarchus crinitus* L.
Hairy woodpecker	*Picoides villosus* L.
Hooded warbler	*Wilsonia citrina* Boddaert
Indigo bunting	*Passerina cyanea* L.
Kentucky warbler	*Oporornis formosus* Wilson

APPENDIX B (continued)

List of Animals Mentioned in Thesis Text and Tables

Birds (continued)	Scientific Name[1]
Loggerhead shrike	*Lanius ludovicianus* L.
Long-eared owl	*Asio otus* L.
Mourning dove	*Zenaida macroura* L.
Northern cardinal	*Cardinalis cardinalis* L.
Northern mockingbird	*Mimus polyglottos* L.
Ovenbird	*Seiurus aurocapillus* L.
Pileated woodpecker	*Dryocopus pileatus* L.
Pine warbler	*Dendroica pinus* Wilson
Prairie warbler	*Dendroica discolor* Vieillot
Prothonotary warbler	*Protonotaria citrea* Boddaert
Red-bellied woodpecker	*Melanerpes carolinus* L.
Red-cockaded woodpecker	*Picoides borealis* Vieillot
Red-eyed vireo	*Vireo olivaceus* L.
Red-headed woodpecker	*Melanerpes erythrocephalus* L.
Ruby-throated hummingbird	*Archilochus colubris* L.
Ruffed grouse	*Bonasa umbellus* L.
Rufous-sided towhee	*Pipilo erythrophthalmus* L.
Scarlet tanager	*Piranga olivacea* Gmelin
Summer tanager	*Piranga rubra* L.
Tufted titmouse	*Parus bicolor* L.
Turkey vulture	*Cathartes aura* L.
White-breasted nuthatch	*Sitta carolinensis* Latham
White-eyed vireo	*Vireo griseus* Boddaert
Whip-poor-will	*Caprimulgus vociferus* Wilson
Wild turkey	*Meleagris gallopavo* L.
Wood thrush	*Hylocichla mustelina* Gmelin
Worm-eating warbler	*Helmitheros vermivorus* Gmelin
Yellow-billed cuckoo	*Coccyzus americanus* L.
Yellow-breasted chat	*Icteria virens* L.
Yellow-rumped warbler	*Dendroica coronata* L.

[1] Taxonomy follows Ehrlich et al. (1988).

APPENDIX B (continued)

List of Animals Mentioned in Thesis Text and Tables

Mammals	Scientific Name[2]
Deer	*Odocoileus* spp.
Deer mouse	*Peromyscus* spp.
Eastern chipmunk	*Tamias striatus*
Fox squirrel	*Sciurus niger*
Gray fox	*Urocyon cinereoargenteus*
Gray squirrel	*Sciurus carolinensis*
Oppossum	*Didelphis virginianus*
Rabbit	*Sylvilagus* spp.
Raccoon	*Procyon lotor*
Squirrel	*Sciurus* spp.
Striped skunk	*Mephitis mephitis*
White-tailed deer	*Odocoileus virginianus*

[2] Taxonomy follows Burt and Grossenheider (1976).

Reptiles	Scientific Name[3]
Black racer	*Coluber constrictor*
Rat snake	*Elaphe obsoleta*

[3] Taxonomy follows Conant (1975).

APPENDIX C

TAXA OF HARDWOOD SPECIES FOUND IN SAMPLE PLOTS

APPENDIX C

Taxa of Hardwood Species Found in Sample Plots

Common Name	Scientific Name[1]	Family
American elm	*Ulmus americana* L.	Ulmaceae
Blackgum	*Nyssa sylvatica* Marsh.	Nyssaceae
Black cherry	*Prunus serotina* Ehrh.	Rosaceae
Black oak	*Quercus velutina* Lam.	Fagaceae
Black walnut	*Juglans nigra* L.	Juglandaceae
Carolina buckthorn	*Rhamnus caroliniana* Walt.	Rhamnaceae
Chestnut oak	*Quercus prinus* L.	Fagaceae
Cucumber magnolia	*Magnolia acuminata* L.	Magnoliaceae
Eastern redbud	*Cercis canadensis* L.	Fabaceae
Flowering dogwood	*Cornus florida* L.	Cornaceae
Green ash	*Fraxinus pennsylvanica* Marsh.	Oleaceae
Mockernut hickory	*Carya tomentosa* (Poir.) Nutt.	Juglandaceae
Northern red oak	*Quercus rubra* L.	Fagaceae
Pawpaw	*Asimina triloba* (L.) Dunal	Annonaceae
Pignut hickory	*Carya glabra* (Mill.) Sweet	Juglandaceae
Post oak	*Quercus stellata* Wangenh.	Fagaceae
Red maple	*Acer rubrum* L.	Aceraceae
Red mulberry	*Morus rubra* L.	Moraceae
Sassafras	*Sassafras albidum* (Nutt.) Nees	Lauraceae
Shagbark hickory	*Carya ovata* (Mill.) K. Koch	Juglandaceae
Shortleaf pine	*Pinus echinata* Mill.	Pinaceae
Smooth sumac	*Rhus glabra* L.	Anacardiaceae
Sourwood	*Oxydendron arboreum* (L.) DC.	Ericaeae
Southern red oak	*Quercus falcata* Michx.	Fagaceae
Sugar maple	*Acer saccharum* Marsh.	Aceraceae
Virginia pine	*Pinus virginiana* Mill.	Pinaceae
White oak	*Quercus alba* L.	Fagaceae
Witch-hazel	*Hamamelis virginiana* L.	Hamamelidaceae
Yellow-poplar	*Liriodendron tulipifera* L.	Magnoliaceae

[1] Taxonomy follows Little (1988).

APPENDIX D

TAXA OF HERBACEOUS PLANTS FOUND IN SAMPLE PLOTS

APPENDIX D

Taxa of Herbaceous Plants Found in Sample Plots

Common Name	Scientific Name[1]	Family
Aristolochia	*Aristolochia serpentaria* L.	Aristolochiaceae
Aster	*Aster pilosus* Wild.	Asteraceae
Blackberry	*Rubus* sp.	Rosaceae
Blueberry	*Vaccinium* sp.	Ericaceae
Deerberry	*Vaccinium stamineum* L.	Ericaceae
Desmodium	*Desmodium* sp.	Fabaceae
Euonymus	*Euonymus americanus* L.	Celastraceae
Eupatorium	*Eupatorium* sp.	Asteraceae
Fireweed	*Erechtites hieracifolia* (L.) Raf.	Asteraceae
Golden aster	*Chrysopsis camporum* Greene	Asteraceae
Goldenrod	*Solidago* sp.	Asteraceae
Grasses	various	Poaceae
Horse nettle	*Solanum carolinense* L.	Solanaceae
Horseweed	*Conyza canadensis* (L.) Cronq.	Asteraceae
Lespedeza	*Lespedeza* sp.	Fabaceae
Little brown jug	*Hexastylis arifolia* Michx.	Aristolochiaceae
Mountain laurel	*Kalmia latifolia* L.	Ericaceae
Muscadine	*Vitis rotundifolia* Michx.	Vitaceae
Panicum	*Panicum* sp.	Poaceae
Passion flower	*Passiflora incarnata* L.	Passifloraceae
Physalis	*Physalis* sp.	Solanaceae
Pipsissewa	*Chimaphila maculata* (L.) Pursh	Ericaceae
Poison ivy	*Toxicodendron radicans* (L.) Kuntze	Anacardiaceae
Pokeweed	*Phytolacca americana* L.	Phytolaccaceae
Rabbit tobacco	*Gnaphalium obtusifolium* L.	Asteraceae
Raspberry	*Rubus* sp.	Rosaceae
Rushes	*Juncus* sp.	Juncaceae
Sanicula	*Sanicula canadensis* L.	Apiaceae
Sedges	*Carex* sp.	Cyperaceae
Smilax	*Smilax* sp.	Smilacaceae
Smooth sumac	*Rhus glabra* L.	Anacardiaceae
Violet	*Viola* sp.	Violaceae
Virginia creeper	*Parthenocissus quinquefolia* (L.) Planch	Vitaceae
Wild lettuce	*Lactuca canadensis* L.	Asteraceae

[1] Taxonomy follows Wofford (1989).

VITA

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Virgil Lee Andrews, Jr. was born in Hammond, Indiana on May 23, 1967. He attended public elementary schools operated by the City of Clinton, Tennessee and secondary schools operated by the Anderson County, Tennessee Board of Education. He graduated from Clinton Senior High School in June 1985. He entered the University of Tennessee, Knoxville during September 1985 and began work on a Bachelor of Science degree in Wildlife and Fisheries Science. He graduated with a degree in Wildlife and Fisheries Science in August 1989 and immediately began a Master's program in Forestry at the University of Tennessee, Knoxville under the direction of Dr. Edward R. Buckner. In September 1991, he accepted a position with Breedlove, Dennis, and Associates, an environmental consulting firm in Orlando, Florida, where he initiated a career of work with endangered species. One year later, he accepted a similar position with Ebasco Environmental in Atlanta, Georgia. In January 1994, he accepted a Senior Environmental Scientist position with Maguire Associates, Inc., another Atlanta environmental firm. He received the Master of Science degree in Forestry in December 1995.

He is presently a Supervisory Fish and Wildlife Biologist with the United States Fish and Wildlife Service at Fort Benning, Georgia. In this position, he directs a comprehensive inventory of endangered and threatened wildlife and plant species of Fort Benning.