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I am submitting herewith a thesis written by Ryan G. Basinger entitled "Initial Effects of Silvicultural Treatments on Food Availability and Vegetation Structure for Wild Turkeys." I have examined the final electronic 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 Wildlife and Fisheries Science.

Craig H. Harper
Major Professor

We have read this thesis
and recommend its acceptance:

David S. Buckley

David A. Buehler

Cathryn H. Greenberg

Accepted for the Council:

Anne Mayhew
Vice Provost and Dean of Graduate Studies

(Original signatures are on file with official student records.)

Initial Effects of Silvicultural Treatments on Food Availability and Vegetation Structure for Wild Turkeys

A Thesis
Presented for the
Master of Science
Degree
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Ryan Glenn Basinger
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DEDICATION

I dedicate this work to the late R.G. Basinger (Pop), who helped instill a love of the outdoors in me.

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ABSTRACT

The eastern wild turkey (*Meleagris gallopavo silvestris*) is an important game species in the mid-South region. Many non-industrial private landowners along with state and federal agencies actively manage property to enhance habitat for wild turkeys. In the past, diameter-limit cutting has been commonly used to harvest hardwood timber on public and private land in this region. Unfortunately, diameter-limit harvests typically "high-grade" stands, leaving low quality stems and altering forest composition in favor of less desirable species, such as red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), winged elm (*Ulmus alata*), and yellow poplar (*Liriodendron tulipifera*). While the most biologically sound method to improve these stands may be clearcutting, it is not an attractive option for many managers who wish to improve forested habitat for wild turkeys and other wildlife species.

Five silvicultural treatments were implemented within the Ridge and Valley physiographic province of east Tennessee in spring 2001 to compare effects of alternative forest management practices on annual food availability and vegetative structure for nesting and brood-rearing wild turkeys. Treatments included shelterwood harvest, wildlife thinning, wildlife thinning with prescribed burn, and prescribed burn only, along with control. Hard and soft mast production was measured and the structure and composition of the responding vegetation was recorded. In addition, macroinvertebrate populations were sampled to estimate food availability for wild turkey poults.

Acorn production across stands at Chuck Swan was variable among treatments and years and showed no distinct pattern. Hard mast collected represents baseline data, as effects of treatments will not be apparent for a few years. Nonetheless, among individual

white oaks, 30 percent of the trees produced 85 percent of the acorns in 2001 and 70 percent of the acorns in 2002. In addition, acorn production varied among individual white oaks as some produced acorns both years, some produced 1 year, and others did not produce acorns either year.

Initial soft mast production was low the first growing season after treatments, but increased sharply the second year. However, variation resulting from the patchy spatial distribution of the responding understory vegetation prevented statistical differences among treatments. Herbaceous coverage remained unchanged within all treatments from 2000 (pre-treatment) to 2002. Although woody understory vegetation predominantly responded within all treatments, suitable nesting and brooding cover was established.

Overall invertebrate density and biomass was similar within all treatments and did not change throughout the brood-rearing period in 2002. Density and biomass of invertebrate classes and orders varied among treatments.

Wildlife thinnings and shelterwood harvests can be used to improve nesting and brood-rearing habitat and increase soft mast production. However, managers should give more consideration to identifying inherently good acorn producers within a stand before thinning or harvesting when increased acorn production is desired. After thinning, prescribed fire should be used to facilitate seed bank germination. Managers should be aware that an increase in soft mast production might not be evident until at least 2 years post treatment.

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CHAPTER I

INTRODUCTION

A silvicultural technique is needed to improve wildlife habitat without harvesting timber in mixed hardwood stands. In Tennessee, 80 percent of the forested land base is privately owned (Schweitzer 2000). However, the quality of many of these forest stands is poor (McGee 1982). Past “management” has left stands of 60 to 80-year-old trees with low-quality stems, closed canopies, and sparse understories, which offer limited food and cover for many wildlife species. Diameter-limit harvests have typically high-graded stands, altering forest composition in favor of less desirable species from both a wildlife and timber standpoint (McGee 1982).

In the mid-South, many non-industrial private landowners actively manage their property for wildlife, especially game species such as the eastern wild turkey (*Meleagris gallopavo silvestris*) and white-tailed deer (*Odocoileus virginianus*). While techniques for improving early successional habitats and pine forests for these species have been developed (Johnson and Landers 1978, Whitehead and McConnell 1979, Campo and Hurst 1980), methods for improving mixed hardwoods common in the mid-South need to be explored, and their effects documented.

Creating forest openings through timber harvest (e.g., shelterwood, clear cut) is commonly used to regenerate stands and improve forested habitat for wildlife (Harlow and Downing 1969, Crawford 1971, Burger 2001). Thinning and timber harvest also have been used to increase acorn production (Healy 1997). However, some landowners wish to improve their forests for wildlife without harvesting timber. Most landholdings are relatively small (<100 acres) and aesthetics is an important consideration. Also, many stands lack enough merchantable timber to warrant harvest.

Prescribed fire is another a tool used to improve wildlife habitat (Whitehead and McConnell 1979, Hurst 1981, Burger 2001) by altering species composition, improving vegetation structure within the forest understory (Cushwa et al. 1966, Lewis and Harshbarger 1976, Langdon 1981, Pack et al. 1988, Barnes and Van Lear 1998), and increasing soft mast production (Johnson and Landers 1978). Many landowners, however, are reluctant to use fire, because of the possibility that it will escape or destroy the stand. While creating forest openings and prescribed burning have been promoted to improve wildlife habitat, these practices have mainly been tested within pine stands and the effect has not been compared to a shelterwood harvest prescribed for regenerating mixed hardwood stands.

Forest management decisions and activities affect wild turkeys through habitat alteration. The wild turkey is highly adaptable and can tolerate a wide range of habitat conditions. However, for wild turkey populations to thrive and expand, certain habitat conditions must be considered. In the southern Appalachians, wild turkeys use a variety of habitat types to satisfy their annual requirements. These requirements differ by sex, age class, and time of year. Wild turkeys need a diverse forest community with a variety of stand age classes to provide food and cover throughout the year. In the mid-South, mature hardwood stands are important for providing food (e.g., hard mast) during fall and winter and roosting cover year around. Early successional habitats (i.e., recently harvested areas, food plots, fallow fields, daylighted roads, powerline rights-of-way) may provide nesting cover, brooding cover, green forage, and/or seeds. By providing the necessary habitat requirements within a smaller area, landowners may be able to support more wild turkeys on their property year around.

Although timber-oriented forest management practices are more common on state, federal, and industrial lands, other options are needed to suit the needs of certain private landowners. This is especially true on poor-quality sites with little merchantable timber or where harvesting timber is not feasible. This study compares the initial effects of wildlife thinnings, prescribed fire, and shelterwood harvests on wildlife habitat, particularly as related to the wild turkey. Results may provide landowners with alternatives to improve their woodlots for wild turkeys, as well as a variety of other wildlife species without harvesting timber. In addition, this study provides baseline data needed to monitor the long-term effects of various silvicultural techniques on food production for wild turkeys and other wildlife in mixed hardwood stands in the mid-South region.

Objectives

The primary objective of this study was to determine the initial effect of various silvicultural practices on habitat suitability for the eastern wild turkey in mixed hardwood forests. Specific objectives were to:

(1) compare the effect of a wildlife thinning and shelterwood harvest on acorn production,

(2) determine the effect of prescribed burning on understory vegetation structure, herbaceous coverage, and understory soft mast production within thinned and unthinned stands,

(3) document macroinvertebrate abundance and biomass within stands receiving a wildlife thinning, wildlife thinning with prescribed fire, prescribed fire alone, or shelterwood harvest.

CHAPTER II

REVIEW OF LITERATURE

Feeding and Food Habits of the Eastern Wild Turkey

Wild turkeys are omnivorous, opportunistic feeders, eating a wide variety of food sources when available. Their diet consists primarily of plant food but macroinvertebrates also are consumed in various quantities, depending on the season (Dickson 2001).

Wild turkeys eat a variety of plant materials throughout the year. During the growing season, forbs, grasses, seeds, and soft mast (e.g., blackberries [*Rubus spp*.] and blueberries [*Vaccinium spp*.]) represent most of the diet. Soft mast is especially important during summer (Korschgen 1967), however, turkeys benefit from fleshy fruits during a large portion of the year. In the South, blackberries, blueberries, and huckleberries (*Gaylussacia spp.*) are available during the summer, where black cherry (*Prunus serotina*), dogwood (*Cornus florida*), blackgum (*Nyssa sylvatica*), and greenbrier (*Smilax spp*.) fruits become available during fall and winter.

Historically, soft mast has been considered a "buffer" food source during years of low hard mast production (Greenberg 2001). Soft mast availability varies from year to year, however. Korschgen (1967) reported fluctuations in fruit production are usually not detrimental to wild turkeys and low production by one species is usually compensated for by high production of another. By compiling data based on wild turkey droppings in Pennsylvania, Missouri, and Michigan, Korschgen (1967) determined soft mast composed 20 percent of the summer diet, half of which was blackberry. Meanley (1956) reported *Rubus* species were the number-one food choice during summer in Arkansas.

Lewis (1962) determined *Rubus* species were the second-most consumed food during summer in Michigan. The most consumed food item in this study was inconclusive.

Within the southern Appalachians, soft mast begins to ripen and become available in June and July, about the time a poult's diet shifts from animal to plant matter. Pack et al. (1980) observed this shift with a change in habitat use by wild turkey broods in West Virginia. Broods started using habitats with high densities of blueberry, huckleberry, and other soft mast during June and July as the fruits began to ripen.

During fall and winter, wild turkeys feed primarily on hard mast (acorns and beechnuts) and dried soft mast (e.g., blackgum, black cherry, wild grape [*Vitis spp*.], dogwood, and greenbrier) as available (Korschgen 1967). Acorns are a principal component in the diet of wild turkeys. Acorns have a relatively high fat and carbohydrate content (6 and 20 percent dry matter for white oaks and black oaks, respectively) and contain protein (6 percent), calcium (< 1 percent), phosphorus (< 1 percent), and vitamins (Goodrum 1959, Goodrum et al. 1971). An abundant acorn crop increases winter survival and prepares birds for reproduction by improving their body condition as they enter the breeding season (Dickson 2001). Good and Webb (1940) reported acorns constituted 63 percent of the winter diet of wild turkeys in Alabama. In Missouri, Wheeler (1948) found wild turkeys consumed acorns during every month, ranging from "trace" in July to 73 percent of their diet in January. Korschgen (1967) combined food habit studies from 6 eastern states and determined acorns composed approximately half of the wild turkey's winter diet.

A third major component in the wild turkey's diet is macroinvertebrates (hereafter invertebrates). Wild turkeys consume many types of invertebrates, including insects, spiders, and snails. Although invertebrates are eaten throughout the year, they are consumed in greatest amounts during summer by young poults (Dalke et al. 1942, Korschgen 1967). Invertebrates are especially important to poults ($<$ 4 weeks). Poults depend on invertebrates to provide high levels of protein (28 percent), calcium (1.2 percent), and phosphorus (0.8 percent) for rapid bone and tissue development. Hurst (1989) reported animal matter composed 90 percent of a poult's diet during its first week. After about a month, the poults' diet shifted to predominantly plant material, similar to that of an adult bird. Hurst and Stringer (1975) showed poults mostly ate insects (79 percent) during their first week after hatching in Mississippi.

Animal-to-plant ratio tends to be greatest during the first week after hatching and gradually decreases as the birds age. This tendency varies because of differences in habitat type, poult age, vegetative conditions, and food abundance and availability (Hurst 1992). For example, Hamrick and Davis (1971) examined the crops of 21 poults and juveniles (21-105 days old) in Alabama and determined the volume of plant and animal matter was 72.3 percent and 26.8 percent, respectively. However, this analysis occurred after the period when poults are most dependent on invertebrates. Barwick et al. (1973) also examined the crop and gizzard contents of 21 poults (1-14 days old) in Florida. They found the contents contained 75 percent plant and 25 percent animal matter by volume. However, analyzing crop and gizzard contents may underestimate animal matter in this study because of differential digestion of hard- and soft-bodied insects (Healy 1985). Conversely, Healy (1985) monitored feeding activity of 2 broods of human-imprinted poults from hatching to 4 weeks of age. It was determined that 65-95 percent of pecks were to consume animal matter, most of which were soft-bodied insects.

A wild turkey's diet is diverse and fluctuates between sex, age, and season. When managing habitat for wild turkeys, it is critical to promote diverse forest communities to satisfy their annual food requirements. Combined habitat types, such as mature hardwoods, fallow fields, supplemental food plots, and other early successional habitats are usually sufficient in providing turkeys with a year-round food supply.

Relationships of Forest Management and Wild Turkey Habitat

Acorn Production and Availability

Acorns are important to numerous wildlife species; therefore, annual hard mast production is of great interest to wildlife managers. Martin et al. (1951) reported approximately 100 species of wildlife in the United States consume acorns. Acorn availability has been shown to influence black bear (*Ursus americanus*) reproduction (Eiler et al. 1989), body weights and antler development in white-tailed deer (Wentworth et al. 1992), reproduction and winter survival of wild turkeys (Dickson 2001), as well as population fluctuations of a variety of other species [e.g., squirrels (*Sciurus carolinensis*), chipmunks (*Tamias striatus*)].

Many factors influence acorn production, such as temperature, rainfall, site conditions, nutrient availability, crowding of roots and crowns, insects and genetics. Many of these factors contribute to high annual variation in acorn production, which results in an unpredictable crop. Two major hypotheses have been proposed to explain variability in acorn yields. The first suggests environmental conditions largely determine acorn production. The second hypothesis suggests acorn production is innate and influenced more by genetic traits of individual trees. Past research has been ineffective at determining which factors have the greatest effect on acorn production among years, species, or locations. Thus, a third hypothesis suggests both genetics and local environmental conditions contribute equally in acorn production. Sharp and Chisman (1961) investigated male flowering and pollen dispersal in white oaks and concurrent environmental conditions. They suggested flowering in white oaks is innate, but acorn set and development is influenced by the environment. Goodrum et al. (1971) reported certain individual oak trees of the same species and diameter class produced variable numbers of acorns. Also, failure of an individual tree to produce any acorns was more prevalent in the relatively poor producers, suggesting a genetic influence.

In the southern Appalachians, acorns are especially important as a food source for many wildlife species because of a lack of diversity in habitat types, where the majority of land cover is mature oak-hickory forest. The ability to predict and increase annual acorn production would be a major advantage for the wildlife manager in this region. Although exhaustive studies have been conducted to understand and predict acorn production, the high variation in annual yields has hindered consistent interpretations (Downs and McQuilkin 1944, Beck 1977, Healy 1997, Healy et al. 1999, Greenberg 2000). Numerous attempts at documenting acorn production and its effect on wildlife populations have been made. Information comparing effects of different forest management techniques (e.g., thinning, burning, timber harvest) on long-term acorn production, however, has not been documented.

Burns et al. (1954) measured various tree characteristics and reported tree crown size as the only variable closely correlated with acorn production. Goodrum et al. (1971) reported acorn yields increased with increasing crown diameter in addition to age and tree diameter (DBH). Greenberg (2000) reported these same findings in oak stands in the southern Appalachians. While studying acorn yield of white oaks, Sharp and Sprague (1967) found open-crowned white oaks produced acorns uniformly within the entire crown, but trees in closed canopies produced acorns only where sunlight reached the crown. Similarly, Reid and Goodrum (1957) reported lower stand density harbored greater average yields per individual tree.

Thinning forest stands has been used to increase seed production in many species, including oaks (Daniel et al. 1979). The effect of thinning is more apparent in shade-intolerant species by increasing available sunlight, thus enhancing seed production potential of crop trees. Managers, however, must maintain balance between enhancing acorn production of an individual tree and maintaining enough seed producers within a stand to compensate for the loss of potential seed producers removed during thinning or logging operations (Healy 1997). Healy (1997) investigated the effect of thinning on acorn production in red oaks and determined the mean number of acorns per tree was greater among those in a thinned stand than an unthinned stand. Thinning in a 40-year-old stand reduced stand density by 85 percent and basal area from 20.0 to 10.2 m^2/ha (90 to 45 ft^2/acre). The number of selected trees bearing fruit was similar within the thinned and unthinned stand. However, during years of poor production, individual trees in the thinned stand had greater yields. Healy also monitored the effect of thinning on total acorn production within the stand. Thinning increased total acorn yields per tree but production was more variable at the stand level. Healy et al. (1999) extended the prior study and determined the effect of thinning was most apparent during the first 5 years post-treatment. Differences in acorn production between the thinned and unthinned stand were reduced thereafter. Acorn production was more consistent, however, from trees in the thinned stand during the eleven-year study.

Soft Mast Production and Availability

Soft mast availability within the forest understory is also important to many wildlife species. Soft mast response to various forest management techniques has been documented in pine forests in the coastal plain (Lay 1966, Johnson and Landers 1978, Stransky and Halls 1979, Campo and Hurst 1980) but little is known from the southern Appalachians.

In the Ouachita Mountains, Perry et al. (1999) measured initial soft mast production and percent cover of shrub-level fruit-producing plants in mixed pine-hardwood stands receiving different silvicultural treatments. In harvested stands (i.e., clearcut, shelterwood, group selection, single-tree selection), coverage of fruit-producing plants was low during the first year following harvest, but increased by year 5. By year 5, overall fruit production was greater in clearcuts and shelterwood cuts than group selection, single-tree selection, and unharvested treatments. The dominant species in clearcuts and shelterwood cuts was pokeberry (*Phytolacca americana*) during the first and third year following harvest and blackberry by year 5. Pokeberry was essentially nonexistent by the fifth year.

Greenberg (2000) also found an increase in pokeberry in recently harvested 2-age upland and cove hardwood stands in the southern Appalachians. Pokeberry increased in both forest types the first year post-harvest and increased more the second year. Greenberg (2000) documented an increase in fruit production from *Rubus* spp. in upland hardwood clearcuts by the second year following harvest, whereas Perry et al. (1999) did not detect increases until 5 years after harvest. Greenberg (2000) found overall fruit production from herbaceous plants increased in upland and cove hardwood clearcuts by year 2. There was little difference among treatments in overall fruit production from trees, shrubs, or vines in either year.

Macroinvertebrate Availability / Brood-Rearing Habitat

Invertebrate availability and concealment cover are the 2 main components of wild turkey brood habitat. The quality of brood-rearing habitat is directly related to vegetation structure, which influences poult survival (Everett et al. 1980, Metzler and Speake 1985).

Invertebrate populations have been studied intensively in many types of openings and wildlife managers have stressed the importance of openings to provide wild turkeys with feeding areas where they can obtain insects and forage. Invertebrate communities are directly related to vegetation composition and structure. This relationship has been explored in forests managed for species such as wild turkeys (Sisson et al. 1991, Harper et el. 2001), ruffed grouse (*Bonasa umbellus*) (Hollifield and Dimmick 1995), and red-cockaded woodpeckers (*Picoides borealis*) (Hanula and Franzreb 1998). However, most studies used a sweep net to sample invertebrates. This method has several limitations and can inaccurately assess invertebrate availability for wild turkey poults (Harper and Guynn 1998). It is difficult to sample habitats with a dense understory, where vegetation can preclude the sampler from making consistent sweeps. Also, it is not possible to obtain accurate density estimates because the area sampled is not known. Lastly, the abundance of invertebrates associated with the leaf litter layer (e.g., spiders, snails, centipedes, millipedes) is underestimated when using a sweep net (Hughes 1955).

It has been documented that insects are more available to wild turkey poults in openings than forested habitats (Hurst and Stringer 1975, Martin and McGinnes 1975, Healy 1985, Harper et al. 2001). All openings, however, do not provide ideal brood habitat, while some forested habitats do (Healy 1985, Williams et al. 1997, Harper et al. 2001). Williams et al. (1974) indicated broods fed in forested areas as long as preferred food was available. Forest stands with 50 percent herbaceous ground cover can supply poults with suitable bugging areas (Healy 1985).

Ideal brood cover in forested habitats is characterized by a relatively open overstory with an herbaceous understory that provides dense overhead cover and allows poults to freely move through the vegetation in search for food (Pack et al. 1980). Herbaceous vegetation is an important feature of brood habitat because it can support adequate invertebrate populations and provide a suitable foraging environment for poults. Sisson et al. (1991) reported insect abundance influenced habitat selection by brood-rearing hens in southern Georgia. They found invertebrate abundance greatest in preferred habitats. Forest openings were preferred over all other habitat types, including annually burned pine stands, which made up the largest percentage of the study area. Annually burned pine stands were avoided, despite the prevalence of herbaceous vegetation; however, invertebrate abundance was lower than in forest openings. Differences may be attributed to high grass and low forb cover within the pine stands, resulting from the century-long burning history of the area (Lewis and Harshbarger

1976). Forest openings were mostly abandoned corn fields (1-3 years), which probably had a mixture forbs and grasses.

Healy (1985) reported poult feeding activity was positively correlated with invertebrate density and biomass, vegetation height, herbaceous cover, vegetation species composition and diversity. Metzler and Speake (1985) found successful hens used areas where herbaceous vegetation was taller and overall cover was more dense between 0.0 and 1.2 m in northern Alabama.

Harper et al. (2001) found a positive correlation between herbaceous ground cover and insect abundance in the southern Appalachians. They also found invertebrate density and biomass greater in forested habitats than managed or unmanaged openings; however, most of the invertebrates collected within the forest were associated with the leaf litter and essentially unavailable to poults. Additionally, when analyzing preferred orders (i.e., Hexapoda) based on their occurrence in the diet of poults (Hurst and Stringer 1975, Healy 1985), they found little difference in density and no difference in biomass among forest types or openings. Invertebrate density in unmanaged openings was greater than managed openings. They reported invertebrate density and biomass was highest on eastern aspects and lowest on western aspects, which was positively correlated with herbaceous cover.

Hollifield and Dimmick (1995) found arthropod abundance and biomass comparable in mature hardwood stands and converted logging roads (orchardgrass and clover) in the southern Appalachians. They attributed this association to a dense layer of herbaceous ground cover in the mature hardwoods stands. They also reported invertebrate abundance increased with forest age when sampling in 3 different-aged clearcuts and 70-

year-old mature stands during the first year of the study. However, a sweep net was used to sample invertebrates. This method is limited in habitats with a dense understory, such as recent clearcuts and possibly underestimated density estimates.

Williams et al. (1997) observed broods using mature hardwoods during early brood-rearing (≤ 2 weeks) in Tennessee. Hens used mature bottomland hardwoods more than other habitat types during early brood-rearing, despite lower invertebrate biomass estimates than openings. Invertebrates were only sampled, however, in bottomland hardwoods and openings. Invertebrates were not sampled in the other 5 habitat types defined in the study even though broods used these habitats. Further, the mean number of locations was quite low during years 1 (22.8) and 2 (42.2), possibly biasing estimated habitat selection.

Vegetation Composition and Structure

Vegetative composition and structure is a key determinant concerning habitat use by wild turkeys. The quality and quantity of food and cover resources is a major factor in overall habitat suitability for wild turkeys. Herbaceous vegetation (especially forbs) is particularly important to wild turkeys because of its food value (foliage and seed) and suitability by hens for brood-rearing cover. Thinning and prescribed burning have been used to improve the condition of the forest understory for turkeys by increasing the structure and coverage of herbaceous vegetation.

Thinning increased forage production (biomass) in cove hardwood stands in the southern Appalachians (Beck 1983). Stand ages ranged from 20-56 years and basal areas from 18-43 m^2/ha (78-188 ft^2/acre). Stands were thinned from below to 12-23 m^2/ha (52-

98 ft^2/acre). Heavier thinnings had the greatest effect on vegetation for the longest duration. Lightly thinned stands, especially in older age classes, had the least effect on the understory. Thinning greatly influenced the woody understory, which increased during the first 3 years after thinning, including substantial increases in blackberry. However, treatments had very little impact on shrubs, vines, and herbaceous plants (e.g., forbs, ferns, grasses). This study included a wide range of age classes thinned at different intensities, and results were pooled for all levels of thinning and assumed to be representative of each stand. Separating stands of different ages and thinning intensities should more accurately describe the effects of thinning on understory vegetation. Beck (1983), however, noted the greatest response was within pole-stage stands (20-30 years), where pre-treatment vegetation coverage was lowest. Another factor that potentially influenced understory response was the midstory left intact after thinning operations. This further obstructed sunlight from reaching the forest floor to achieve desirable understory development. Recommendations called for heavy, repeated thinnings to maximize benefits for wildlife. Thinning used in conjunction with prescribed burning may further improve understory structure for wild turkeys, especially the herbaceous component (Pack et al. 1988, Masters et al. 1993).

Fire can increase the nutritive quality of plants by elevating levels of nitrogen, phosphorus, and calcium (Masters and Engle 1993). An intensive winter burn increased seed production of herbaceous plants in a 1.2-ha (3-acre) clearcut in Georgia (Cushwa et al. 1969), which led to increased herbaceous composition and seed production by 100 and 300 percent, respectively. Increased seed production of many species is important for wildlife food as well as replenishing the seed bank for future regeneration.

Although much attention has been directed toward pine stands in the Coastal Plain, results of studies conducted in mixed hardwood habitats in mountainous regions indicate similar results. Wheeler (1948) suggested fire be excluded in mature hardwood stands because it eliminated the duff layer which contains a variety of turkey foods. However, recent findings do not support this recommendation. In fact, there is evidence that burning mature hardwood stands increases food availability when conducted properly.

Masters et al. (1993) found grasses, legumes, and other forbs increased after one thinning treatment followed by 1 of 4 winter burning regimes (annual, 2-, 3-, 4-year intervals) within mixed pine/hardwood stands the Ouachita Mountains. Stands were thinned to approximately 9 m^2/ha (40 ft^2/acre) using a single stem injection of 2,4-D during summer and burned using strip-head fires during winter. Stands receiving thinning and annual winter burning treatments exhibited the greatest herbaceous coverage, especially grasses and legumes. This treatment also had the most diverse plant composition within the understory. Herbaceous vegetation on sites thinned and not burned showed no difference in the herb layer.

Pack et al. (1988) observed a similar pattern in oak-hickory stands in the southern Appalachian region of West Virginia. Herbaceous coverage increased 2 and 3 years following thinning and burning treatments. Stands burned prior to thinning showed no difference in herbaceous composition. However, fire intensity was lower in these stands, which might have reduced litter layer consumption and inadequately scarified seed (Cushwa et al. 1970). In addition, Pack et al. (1988) noted thinning treatments (i.e., girdling with herbicides) were not effective immediately after burning and the forest canopy remained relatively closed, which prevented sufficient sunlight from reaching the forest floor and stimulating understory development. Finally, mean basal area ranged from 14-23 m^2/ha (60-100 ft^2/acre) on control sites and 16-18 m^2/ha (70-80 ft^2/acre) within treatments. This relatively low level of thinning intensity may be inadequate to stimulate germination of the seed bank (Beck 1983). This is consistent with Murphy and Ehrenreich (1965), who observed timber harvest and stand improvement in the Missouri Ozarks had little effect on forage production. Low forage production was attributed to small decreases in basal area and crown cover.

CHAPTER III

METHODS

Study Area Description

This study was conducted on the Chuck Swan State Forest and Wildlife Management Area (Chuck Swan) in eastern Tennessee, near Sharp's Chapel, Union County. Chuck Swan is a 10,000-ha (24,444-acre) peninsula bordered by Norris Lake to the north, west, and south. It lies in the Ridge and Valley physiographic province approximately 13 km (8 miles) south of the Cumberland Mountain Range. The tract was purchased in 1934 by the Tennessee Valley Authority (TVA) for the purpose of constructing Norris Dam. The Tennessee Department of Conservation initiated wildlife management and recreational activities in 1947 before the property was purchased from TVA in 1952. Currently, the area is managed cooperatively by the Tennessee Wildlife Resources Agency (TWRA) and the Tennessee Division of Forestry (TDF).

Chuck Swan is composed of several forest types including types containing various oaks (white [*Quercus alba*], chestnut [*Quercus prinus*], black [*Quercus velutina*], scarlet [*Quercus coccinea*], and northern red [*Quercus rubra*]), hickories (mockernut [*Carya tomentosa*] and pignut [*Carya glabra*]), red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), and yellow poplar (*Liriodendron tulipifera*). There are also pine stands on the property consisting largely of planted loblolly (*Pinus taeda*) and eastern white pine (*Pinus strobus*). Pine and hardwood stands are managed on 60- and 80-year rotations, respectively. Permanent forest openings include hayfields, wildlife food plots, and seeded logging roads/decks. Hayfields are leased to local farmers and consist primarily of tall fescue (*Festuca arundinacea*). Wildlife food plots are typically planted in a wheat (*Triticum aestivum*)/clover (*Trifolium* spp.) mixture. Logging roads and decks are sowed in orchardgrass (*Dactylis glomerata*)/clover mixtures. In addition, TWRA is in the process of converting some forest openings to native warm-season grasses and associated forbs. Elevations range from 305 to 488 meters (1000 to 1600 feet) above sea level. Annual temperatures in the area range from an average high of 20.4 degrees C (68.7 degrees F) to an average low of 7.9 degrees C (46.2 degrees F). Annual rainfall averages approximately 119.38 cm (47 in) (National Climatic Data Center 2001). Wildlife management is focused on white-tailed deer, wild turkey, and northern bobwhite (*Colinus virginianus*).

Study Area Design

Four stands with similar forest composition, soil type, slope, aspect, and elevation were selected to implement 4 treatments and a control in each. Stands were located at Peavy Hollow, Buck Ridge, Loy Ridge, and Big Loop. Slopes faced northwest and averaged 24 to 30 percent. Each stand was 9.6 ha (24 acres) and divided into 12, 0.8-ha (2-acre) cells that received prescribed fire only, wildlife thinning, wildlife thinning with prescribed fire, and a shelterwood harvest. Treatments and control cells were assigned randomly within each stand. Average pre-treatment basal area ranged from 20-24 m^2/ha (90-105 ft^2/acre).

Treatments

Four shelterwood harvests were implemented within each stand during June/July 2001, providing a total of 16 for the study area. Half of these treatments (two within each stand) will be burned 3-5 years following the initial harvest to test the viability of the shelterwood-burn technique proposed by Brose et al. (1999) in the eastern Tennessee region. A primary objective of this technique is to stimulate regeneration of oak species, while hindering development of shade intolerant, fast growing competitors such as yellow-poplar. The goal was to decrease the stand basal area to 11-13 m^2 per hectare (50-60 ft^2 per acre). The shelterwood cuts were conducted from a forest management perspective only, following the guidelines for a standard shelterwood. Trees removed were those with poor form or quality, but still merchantable. Timber was harvested by B.J. Fortner Hardwoods, Inc.

Four wildlife thinnings were conducted within each stand during February/March 2001, giving a total of 16 for the entire study area. The wildlife thinning was designed to improve wildlife habitat (i.e., mast production, understory structure, snags). The goal was to decrease the stand basal area to approximately 11-13 m^2 per hectare (50-60 ft^2 per acre). Trees selected to be killed were those species that are relatively undesirable for wildlife with respect to mast production, including red maple, sugar maple (*Acer saccharum*), yellow-poplar, and sourwood (*Oxydendrum arboreum*). Individual trees were girdled with a chainsaw or hacked, then treated by spraying a 1:1 Garlon 3A-water solution into the wound. Trees less than 13 cm (5 inches) in diameter were felled and chemical treatment was applied to the stump. Two wildlife thinning treatments within each stand were burned in April 2001. An initial backfire was ignited and stripfires were used to burn the remaining portion of the treatments. On burning days, temperatures ranged from a low of 3.9 degrees C (39 degrees F) to a high of 28.9 degrees C (84 degrees F) with the average low 10.2 degrees C (50 degrees F) and average high 25.22 degrees C (77.4 degrees F). There was no measurable precipitation within at least 3 days of any of the burns. Fire intensity was determined based on flame heights, which averaged 0.9-1.22 m (3-4 ft) in most burned areas.

Two prescribed burn treatments were implemented within each of the 4 stands during April 2001 to evaluate effects of fire alone on food availability and vegetative structure. Burning methods and conditions were conducted as described previously. To evaluate treatments, 2 control cells receiving no treatment were established at each stand.

Deer browsing can affect vegetation composition and alter the structure of an understory (Marquis 1974, DeCalesta 1994). To examine this effect, a 2.44-m (8.0-ft) deer exclusion fence made of plastic mesh was erected around half the treatments in each of the 4 stands (Figure 1). The effect of deer browsing will be monitored at a later date to allow adequate time for plant response to treatments.

Soft Mast Collection

Ripened fleshy fruit was collected from low-growing (< 2m) fruit-producing plants within the forest understory once a month from July through September 2001 and June through September 2002. Soft mast was categorized into 4 species groups: Ericaceous Shrubs (blueberry and huckleberry), Pokeberry, *Rubus*, and Other [solomon's seal (*Polygonatum* spp.), false solomon's seal (*Smilacina racemosa*), Indian cucumber

Deer Exclusion Fence

Uncut Burn	**Shelterwood**	**Wildlife Thinning w/ burn**	**Shelterwood**	**Wildlife Thinning w/ burn**	**Control**
Control	**Wildlife Thinning**	**Shelterwood**	**Wildlife Thinning**	**Shelterwood**	**Uncut Burn**

Figure 1. Example of the randomized split-plot treatment design within a stand at Chuck Swan, Union County, Tennessee, 2001.

(*Medeola virginiana*), ginseng (*Panax quinquefolium*), jack-in-the-pulpit (*Arisaema triphyllum*), and horse nettle (*Solanum carolinense*)]. Groups were selected based on their contribution to total soft mast production at the stand level and their occurrence in the diet of wild turkeys. Three line transects were established systematically within each treatment cell (Figure 2). Each line transect ran parallel to stand contour, generally north-south. Each transect was 50.0 m x 2.0 m and all ripened fruits were collected within this area. Transects were spaced approximately 25.0 m apart and at least 5.0 m from the edge of each cell to prevent sampling plants impacted by an edge effect. Collected fruits were stored in a freezer, then dried at 40 degrees C (104 degrees F) for four days (Campo and Hurst 1980). After drying, fruit was identified, counted, and weighed to quantify soft mast production for each treatment.

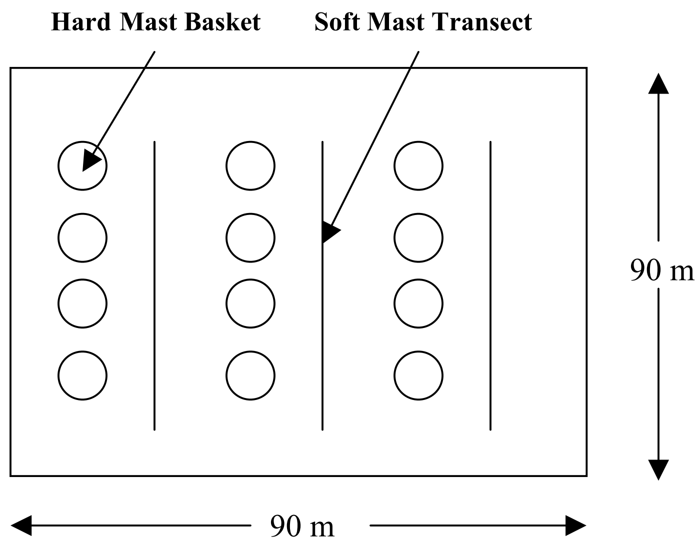

Figure 2. Methods used to collect hard and soft mast in 1, 0.8-ha (2-acre) treatment cell at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Acorn Collection

Hard mast was collected weekly from September through December 2001 and 2002 by systematically placing 12 mast baskets in each unfenced cell (Figure 2). Soft mast transects were used to facilitate placement of mast baskets. In each cell, 4 baskets were placed along each transect and spaced approximately 15.0 m apart. Each row of baskets was located approximately 5.0 m to the side of each soft mast transect. Baskets were constructed with a mesh fabric material attached to a 1.9-cm (0.75-in) pipe 1.13-m in diameter. Baskets were supported approximately 1.0 m above ground by 3 wooden stakes. The opening of each basket represented 1.0 m^2. There were 72 baskets within each of the 4 stands or 288 for the entire study area. A float test was performed on all acorns collected to determine viability. Acorns were identified and counted, but only sound acorns (those that did not float) were weighed and quantified for each treatment.

To determine whether acorn removal by wildlife (e.g., squirrels and chipmunks) was a serious problem, marked acorns were systematically placed in baskets within each treatment. Wildlife use was determined by the proportion of marked acorns that were removed between collection intervals. This was conducted during late October 2001, and mid-October and mid-November 2002.

White Oak Sampling

Because many white oak trees are capable of providing an annual food source for wildlife, individual white oaks were monitored to document their response to treatments. During September 2001, a total of 29 white oak trees were selected and marked within the 4 stands of the study area. Individuals were selected to represent a wide range of size and age classes. Selected trees occupied dominant or co-dominant positions within the canopy. Tree diameter at breast height ranged from 30.0-74.0 cm (12.0-29.0 inches). White oaks were selected within the shelterwood and wildlife thinning treatments and control. None were selected within treatments that were burned. The number of trees selected within the shelterwood harvest, wildlife thinning, and control were 10, 10, and 9, respectively.

Several measurements were taken for each tree during Fall 2001 and 2002 to monitor annual growth. Diameter at breast height was measured on each tree with a diameter tape and a transect tape was used to measure crown diameter perpendicular and parallel to slope.

In addition to measuring tree characteristics, acorn production was monitored by placing 3 mast baskets (as described previously) directly beneath the crown of each tree.

Acorns were collected weekly from September through December 2001 and 2002. A float test was conducted to identify sound acorns. All acorns were counted, but only sound acorns were weighed to quantify annual yields.

Macroinvertebrate Sampling

Peak hatching of wild turkeys in the southern Appalachians occurs during May and June (Pack et al. 1980, Davis 1992, Harper 1998, Norman et al. 2001). Thus, invertebrates were collected during 4 sampling periods (1=mid-May, 2=late May, 3=mid-June, 4=late June) in 2002. Invertebrates were sampled using a portable vacuum sampler and 0.10 m^2 bottomless box with a lid (Harper and Guynn 1998) to collect invertebrates on the vegetation and on top of the leaf litter that were available to wild turkey poults. This also allowed invertebrate density and biomass to be quantified per unit area.

Three sampling locations were established systematically in each unfenced treatment cell within all 4 stands and situated at least 30.5 m apart and from the edge of each cell to prevent sampling edge habitats (Figure 3). Bearings of 0, 120, and 240 degrees were assigned to each sampling location, representing 3 sub-samples. Sub-samples were located by pacing 15 m from plot center in each direction. At each sub-sampling location, the box was placed on the ground to trap all invertebrates within the area. The vacuum sampler then was used to vacuum vegetation and only the top layer of leaf litter into the sample bags. All sample bags were stored in a freezer to prevent decomposition (Murkin et al. 1996). Contents were sorted in white trays where invertebrates were removed and placed in vials. Vials were opened and oven-dried for 48

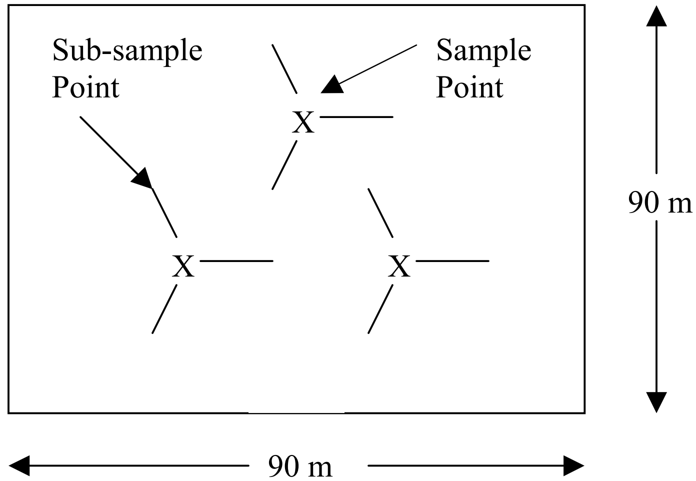

Figure 3. Methods used to collect invertebrates and vegetation data in 1, 0.8-ha (2-acre) treatment cell at Chuck Swan, Union County, Tennessee, 2002.

hours at 60 degrees C (140 degrees F) (Murkin et al. 1996). All invertebrates were counted, weighed, and classified to taxonomic order for each treatment.

Vegetation Sampling

Vertical vegetation density, percent herbaceous cover, and herbaceous vegetation height were measured at each invertebrate sampling location during June 2002 (Figure 3). Percent herbaceous cover was estimated from 180, 11.3-m line transects (36 per treatment). Cover was estimated by the line intercept method (Higgins et al. 1996) in each of the 3 bearings used for invertebrate sub-sampling points. Each transect was 11.3 m in length and percent herbaceous cover was estimated by recording the segment of the transect covered by each herbaceous plant. Herbaceous vegetation height was recorded at 900 locations (180 per treatment). Height was recorded at each 2-m increment along each transect.

Vertical vegetation density was measured at 24 locations within each treatment. A density board was used to estimate vertical vegetative cover (Nudds 1977) at each invertebrate sampling location. The board was divided into 4, 50-cm increments. The estimated percent coverage of each increment was given a value, ranging from 1 to 5, representing 0-20, 21-40, 41-60, 61-80, and 81-100 percent coverage. This measurement was taken at 15 m up and down slope of each sampling location.

Data Analysis

Data were analyzed using Analysis of Variance (General Linear Model procedure, SAS Institute, 2000) with differences declared different at an alpha level of 0.05. Means were separated using the Least Square Means procedure for hard and soft mast production and invertebrate density and biomass. Tukey's mean separation technique was used for white oak production, percent herbaceous cover, herbaceous vegetation height, and vertical vegetation density. Means for white oak crown growth were not tested for statistical differences. Additionally, acorn production by species was not tested statistically. An analysis of covariance was performed on invertebrate density and biomass using herbaceous cover as a covariate.

Normality of the data was tested using the Shapiro-Wilk test, where at a W value of $\geq$ 0.90, data were considered normally distributed. To meet normality and equal variance assumptions for analysis of variance, the natural log plus 0.5 transformation was conducted on hard and soft mast production, white oak acorn production 2001, white oak crown growth, vertical vegetation density, and herbaceous vegetation height. A square root transformation was used for white oak acorn production 2002, invertebrate density and biomass, and percent herbaceous cover.

CHAPTER IV

RESULTS

Acorn Production

Five species of acorns were collected at Chuck Swan during 2001 and 2002, including 2 from the white oak group (white oak and chestnut oak) and 3 from the black oak group (black oak, scarlet oak, and northern red oak).

Acorn production varied considerably among treatments and years (Table 1). Because of this variation, no difference in the number of sound acorns produced was detected among treatments or years (Figure 4). In addition, there was no difference in production by weight among treatments or years. By species, black oak produced the most acorns in 2001, followed by scarlet oak and then white oak (Table 2). During 2002, acorn production followed a different pattern. Scarlet oak produced the most acorns, followed by black oak and then white oak.

Most acorns collected during 2001 and 2002 were unsound, ranging from 53 to 70 percent of all acorns collected within each treatment (Table 1). The proportion of sound to unsound acorns was relatively consistent among all treatments during both years.

Depredation within Mast Baskets

The removal rate of acorns from mast baskets varied, depending on the time it was estimated and the size of the mast crop (Table 3). The overall removal rate for both years averaged just over 11 percent.

Table 1. Mean (± SE) production of unsound and sound acorns and mass (kg/ha) of sound acorns collected within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Year	Treatment	Unsound/ha (SE)[a]	Sound/ha (SE)[b]	kg/ha (SE)[c]
2001	Control	26250.00 (8835.56) A	11458.33 (5614.70) A	34.07 (14.44) A
	Uncut Burn	58125.00 (21608.83) A	33750.00 (22320.53) A	90.76 (56.01) A
	Wildlife Thinning	51458.33 (16868.14) A	40208.33 (23573.60) A	120.32 (62.03) A
	Wildlife Burn	38125.00 (12911.63) A	20000.00 (8186.20) A	101.50 (51.52) A
	Shelterwood	40416.67 (16689.22) A	28958.33 (8252.21) A	112.86 (40.46) A
2002	Control	40000.00 (31358.15) A	35416.67 (29892.75) A	131.35 (99.92) A
	Uncut Burn	37708.33 (17405.08) A	29791.67 (10808.60) A	142.67 (38.39) A
	Wildlife Thinning	44375.00 (8384.39) A	25833.33 (6963.86) A	95.79 (23.14) A
	Wildlife Burn	19583.33 (9703.35) A	14166.67 (4859.13) A	73.91 (32.74) A
	Shelterwood	36875.00 (13929.28) A	20208.33 (8356.74) A	94.82 (34.62) A

Means with the same letter within the same column are not different ($P > 0.05$).
[a]ANOVA statistics: treatment effect ($F=0.59$, $df=24$, $P=0.6719$); year effect ($F=0.51$, $df=3$, $P=0.4063$).
[b]ANOVA statistics: treatment effect ($F=0.40$, $df=24$, $P=0.8051$); year effect ($F=0.08$, $df=3$, $P=0.7944$).
[c]ANOVA statistics: treatment effect ($F=0.21$, $df=24$, $P=0.9322$); year effect ($F=0.32$, $df=3$, $P=0.4802$).

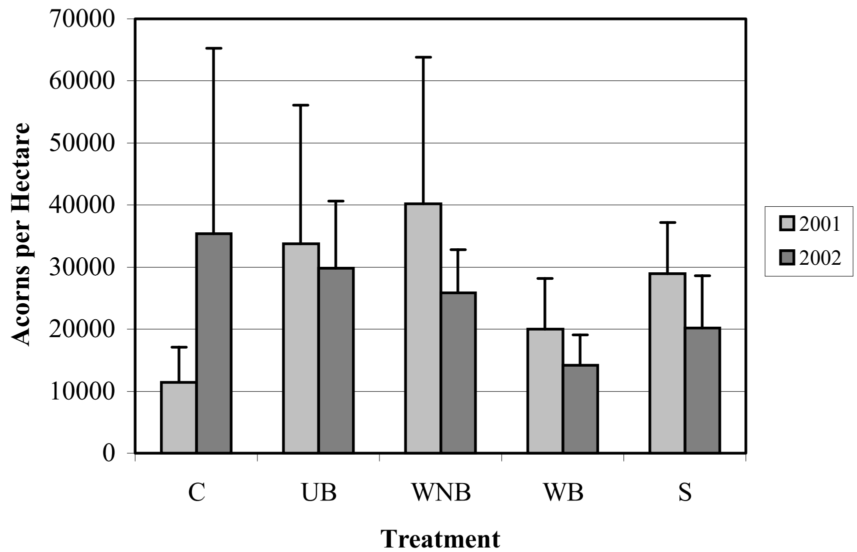

Figure 4. Production of sound acorns at Chuck Swan, Union County, Tennessee, 2001 and 2002. C=control, UB=uncut burn, WNB=wildlife thinning, WB=wildlife burn, and S=shelterwood.

Table 2. Percentage of acorns collected from 5 species of oaks at Chuck Swan, Union County, Tennessee, 2001 and 2002. BO=black oak, WO=white oak, SO=scarlet oak, NRO=northern red oak, CO=chestnut oak.

Year	BO	WO	SO	NRO	CO
2001	69.6	8.3	11.1	7.7	3.3
2002	21.5	17.2	48.5	6.1	6.7

Table 3. Percentage of acorns removed from mast baskets by wildlife at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Year	Collection Interval	Marked Acorns Set Out	Marked Acorns Removed	Percent
2001	25 Oct - 1 Nov	60	3	5.00
2002	10 Oct - 17 Oct	96	16	16.67
2002	7 Nov - 18 Nov	57	5	8.77
	Total	213	24	11.27

Individual White Oak Response and Production

The mean number and mass of acorns collected per meter square of crown area was similar within treatments in 2001 and there was no difference among them (Table 4). Mean crown area was highest in the wildlife thinning and lowest in the shelterwood harvest (Table 4). Just under half (47 percent) the acorns collected were sound for all treatments (Table 5). Half of the total number of acorns collected was produced from 2 trees within the wildlife thinning. Thirty percent of the trees produced nearly 85 percent of the acorns within all treatments. Also, 30 percent of the trees produced no acorns.

In 2002, white oak production was at least 1.5 times greater than 2001 for all treatments. However, there was no difference in the number or mass of acorns produced per meter square of crown area among treatments (Table 4). The mean number of acorns per meter square of crown area and mass (g/m^2) was similar in the wildlife thinning and shelterwood harvest, but lower within the control (Table 4). Mean crown area remained the same for white oaks in the control, increased by 8 percent in the wildlife thinning, and increased by 25 percent within the shelterwood harvest (Table 4). Nearly 65 percent of

Table 4. Mean number of acorns (per m^2 of crown area), mass of acorns (g/m^2 crown area), and crown area of individual white oak trees within 3 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Year	Treatment	Number (m^2)	Mass (g/m^2)	Crown Area (m^2)
2001[a]	Control (n=9)	1.07 (0.52) A	1.29 (0.66) A	122.20 (20.13)
	Wildlife Thinning (n=10)	3.23 (1.78) A	6.98 (4.06) A	132.80 (23.30)
	Shelterwood (n=10)	1.33 (0.36) A	1.40 (0.54) A	91.49 (15.39)
2002[b]	Control (n=9)	2.93 (1.05) A	6.62 (3.26) A	121.98 (11.91)
	Wildlife Thinning (n=10)	5.53 (1.69) A	14.43 (4.84) A	143.13 (16.81)
	Shelterwood (n=10)	6.10 (1.78) A	12.31 (3.68) A	114.74 (15.19)

Means with the same letter within the same year are not different ($P > 0.05$).
[a]ANOVA statistics: number ($F=1.11$, $df=26$, $P=0.3442$); mass ($F=1.74$, $df=26$, $P=0.1946$).
[b]ANOVA statistics: number ($F=1.12$, $df=26$, $P=0.3411$); mass ($F=0.97$, $df=26$, $P=0.3921$).

Table 5. Number of sound and unsound acorns collected from individual white oak trees within 3 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Year	Treatment		Unsound	Sound	Percent Sound
2001	Control (n=9)		18	11	37.9
	Wildlife Thinning (n=10)		42	55	56.7
	Shelterwood (n=10)		28	12	30.0
		total	88	78	47.0
2002	Control (n=9)		34	45	57.0
	Wildlife Thinning (n=10)		58	108	65.1
	Shelterwood (n=10)		64	119	65.0
		total	156	272	63.6

the acorns collected in 2002 were sound (Table 5). Production was uniform and distributed more evenly among individual trees than in 2001 (Table 6). Forty percent of the trees produced nearly 80 percent of the acorns and only 17 percent of the trees did not produce acorns within all treatments.

Soft Mast Production

Eleven species of fleshy fruit were collected during summer 2001 and 2002, including blueberry, huckleberry, pokeberry, raspberry, blackberry, solomon's seal, false solomon's seal, Indian cucumber, ginseng, jack-in-the-pulpit, and horse nettle.

There was no difference in fruit density (P = 0.3849) or dry weight (P = 0.3766) between fenced or unfenced treatments. Therefore, treatments were pooled, creating 5 treatments with 8 replications. Overall soft mast production was highly variable within treatments and years. Because of this variation, no difference in fruit density or biomass was detected among treatments or years (Table 7).

During summer 2001, most fruit was available in July, which was primarily from Ericaceous Shrubs (Figure 5). Little to no fruit was available during August and September with the exception of the wildlife burn treatment, where Pokeberry began to establish.

During summer 2002, most fruit was available during August and September within the uncut burn, wildlife burn, and shelterwood treatments (Figure 6). Production was almost entirely Pokeberry. In the control and wildlife thinning, production was greatest during June and July, which was chiefly Shrubs. Fruit from Shrubs also was most available within the uncut burn, wildlife burn, and shelterwood treatments during this

Table 6. Mean acorn production (per m^2 of crown area) and crown area (m^2) of individual white oak trees within 3 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

		Acorns/m²		**Crown Area (m²)**	
Treatment	**Tree ID**	**2001**	**2002**	**2001**	**2002**
Control	2	0.00	6.00	65.64	97.16
Control	6	0.00	0.33	108.10	108.10
Control	7	1.33	3.33	84.31	113.79
Control	8	0.00	0.00	253.87	204.86
Control	9	0.00	0.00	113.79	110.92
Control	16	4.67	9.00	138.00	128.65
Control	17	0.67	1.33	105.31	108.10
Control	25	2.33	1.33	171.55	144.42
Control	26	0.67	5.00	59.24	81.84
Shelterwood	1	0.00	1.67	49.30	57.18
Shelterwood	18	0.67	14.67	72.36	110.92
Shelterwood	19	2.00	2.33	197.20	220.61
Shelterwood	20	0.33	2.67	70.08	116.69
Shelterwood	21	1.00	5.33	53.17	74.68
Shelterwood	22	0.67	16.00	47.42	89.34
Shelterwood	27	1.67	0.33	81.84	77.03
Shelterwood	28	1.33	4.33	89.34	113.79
Shelterwood	29	4.00	10.67	99.84	122.59
Shelterwood	30	1.67	3.00	154.32	164.55
Wildlife Thinning	4	1.67	3.67	171.55	193.43
Wildlife Thinning	5	0.67	0.00	55.15	63.47
Wildlife Thinning	10	1.00	3.67	308.12	245.33
Wildlife Thinning	11	0.33	0.67	79.42	97.16
Wildlife Thinning	12	1.00	3.00	141.19	150.98
Wildlife Thinning	13	0.00	6.67	77.03	105.31
Wildlife Thinning	14	0.00	0.00	128.65	125.60
Wildlife Thinning	15	0.00	14.33	175.10	175.10
Wildlife Thinning	23	12.67	10.33	99.84	161.10
Wildlife Thinning	24	15.00	13.00	91.91	113.79

Table 7. Mean (± SE) density (per ha) and dry weight (g/ha) of soft mast produced within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

Year	Treatment	Density (SE)[a]	Dry Weight (SE)[b]
2001	Control	243.07 (204.20) A	14.00 (13.05) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	75.01 (54.06) A	0.73 (0.35) A
	Wildlife Burn	197.24 (124.41) A	9.79 (7.53) A
	Shelterwood	158.35 (120.72) A	3.70 (2.76) A
2002	Control	120.84 (57.49) A	5.11 (2.63) A
	Uncut Burn	19583.62 (18927.30) A	1755.10 (1699.47) A
	Wildlife Thinning	213.91 (116.43) A	7.65 (4.27) A
	Wildlife Burn	14404.01 (7305.71) A	1430.59 (790.23) A
	Shelterwood	12508.01 (10850.50) A	1057.50 (897.66) A

Means with the same letter in the same column are not different (P > 0.05).
[a]ANOVA statistics: treatment effect (F=1.15, df=48, P=0.3427); year effect (F=1.60, df=3, P=0.2947).
[b]ANOVA statistics: treatment effect (F=1.24, df=48, P=0.3059); year effect (F=1.58, df=3, P=0.2974).

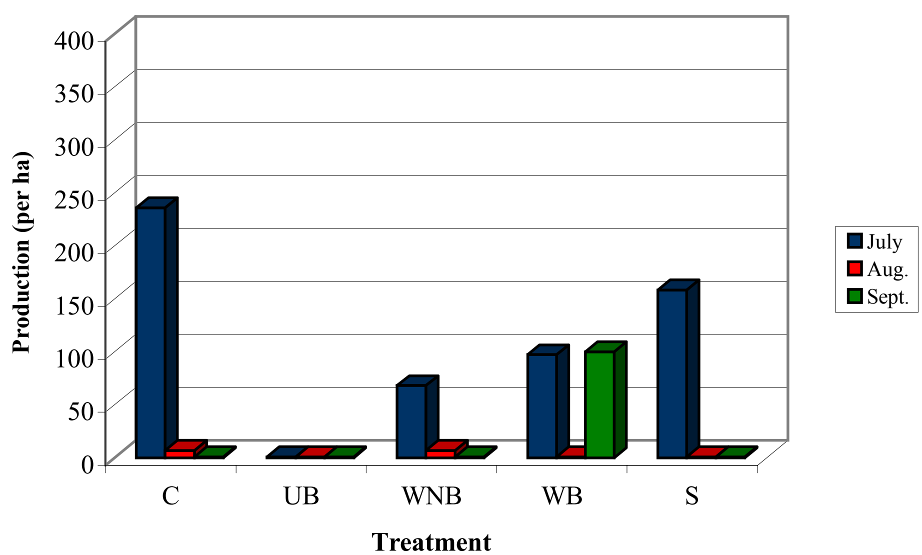

Figure 5. Total fruit production (fruits/ha) during 3 months within 5 treatments during 2001 at Chuck Swan, Union County, Tennessee. C=control, UB=uncut burn, WNB=wildlife thinning, WB=wildlife burn, S=shelterwood.

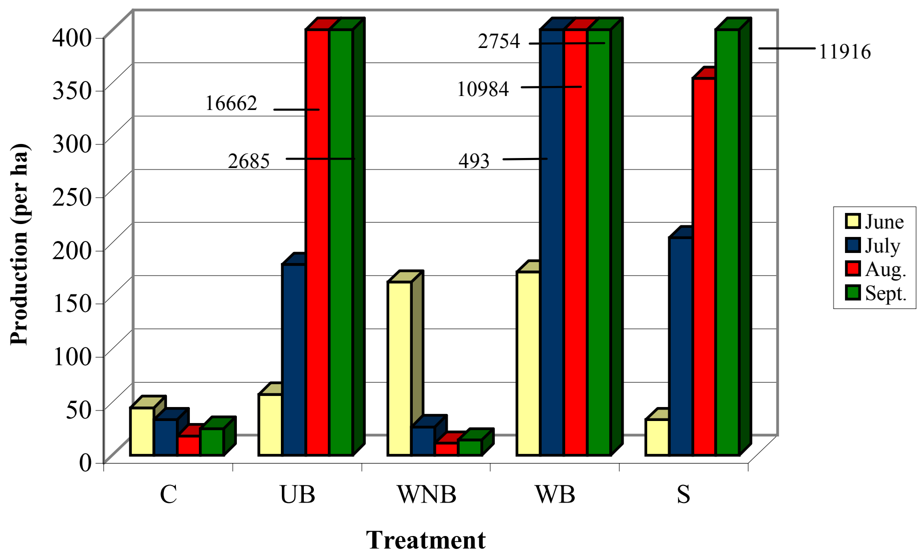

Figure 6. Total fruit production (fruits/ha) during 4 months within 5 treatments during 2002 at Chuck Swan, Union County, Tennessee. C=control, UB=uncut burn, WNB=wildlife thinning, WB=wildlife burn, S=shelterwood.

time. However, production from Shrubs did not compare to Pokeberry in July for these treatments.

Soft Mast Production of Species Groups

Ericaceous Shrubs
(blueberry/huckleberry)

There was no difference in fruit density or dry weight from Shrubs among treatments or years (Table 8). Mean density and dry weight was low and fairly consistent within treatments that were not burned and absent in treatments that were burned.

Fruit production by blueberry and huckleberry increased in 2002, however, there was no difference in fruit density or dry weight among treatments. Mean density and dry

Table 8. Mean (± SE) density (per ha) and dry weight (g/ha) of fruit production from Ericaceous Shrubs (blueberry/huckleberry) within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

		Shrubs	
Year	**Treatment**	**Density (SE)[a]**	**Dry Weight (SE)[b]**
2001	Control	36.11 (36.56) A	0.85 (0.74) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	19.44 (12.03) A	0.55 (0.35) A
	Wildlife Burn	00 (0.00) A	0.00 (0.00) A
	Shelterwood	34.73 (22.75) A	0.89 (0.63) A
2002	Control	88.90 (56.51) A	2.49 (1.51) A
	Uncut Burn	102.78 (77.95) A	2.84 (1.97) A
	Wildlife Thinning	195.85 (119.60) A	6.67 (4.41) A
	Wildlife Burn	269.48 (113.42) A	6.64 (2.96) A
	Shelterwood	440.33 (355.19) A	38.70 (33.18) A

Means with the same letter in the same column are not different ($P > 0.05$).
[a]ANOVA statistics: treatment effect ($F=0.70$, $df=48$, $P=0.5983$); year effect ($F=3.80$, $df=3$, $P=0.1463$).
[b]ANOVA statistics: treatment effect ($F=1.08$, $df=48$, $P=0.3760$); year effect ($F=2.39$, $df=3$, $P=0.2195$).

weight increased by 2.5 times in the control and by at least 10 times within the other treatments.

Pokeberry

There was no difference in Pokeberry density or dry weight among treatments during 2001 or 2002 (Table 9). In fact, Pokeberry was non-existent in all treatments except the wildlife burn, which had very low production.

In 2002, the establishment of Pokeberry within the uncut burn, wildlife burn, and shelterwood treatments caused large increases in fruit production. However, no difference in density or dry weight was detected among treatments. Surprisingly, the wildlife thinning had no effect on Pokeberry production.

Table 9. Mean (± SE) density (per ha) and dry weight (g/ha) of Pokeberry produced within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

		Pokeberry	
Year	**Treatment**	**Density (SE)[a]**	**Dry Weight (SE)[b]**
2001	Control	0.00 (0.00) A	0.00 (0.00) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Burn	100.01 (93.81) A	7.76 (7.56) A
	Shelterwood	0.00 (0.00) A	0.00 (0.00) A
2002	Control	0.00 (0.00) A	0.00 (0.00) A
	Uncut Burn	19479.43 (18940.82) A	1752.22 (1699.85) A
	Wildlife Thinning	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Burn	14134.55 (7308.71) A	1423.93 (790.38) A
	Shelterwood	12026.03 (10917.28) A	1016.50 (903.40) A

Means with the same letter in the same column are not different ($P > 0.05$).
[a]ANOVA statistics: treatment effect ($F=1.17$, $df=48$, $P=0.3378$); year effect ($F=1.51$, $df=3$, $P=0.3066$).
[b]ANOVA statistics: treatment effect ($F=1.25$, $df=48$, $P=0.3028$); year effect ($F=1.53$, $df=3$, $P=0.3044$).

Rubus

(blackberry, dewberry, raspberry)

Fruit production from *Rubus* species was non-existent within all treatments except control during 2001. Production was almost entirely raspberry. No difference in mean density or dry weight existed among treatments or years (Table 10).

In 2002, fruit production from *Rubus* species was not affected by the treatments. Again, fruits of *Rubus* species were absent from all treatments except control, where only "trace" amounts were recorded.

Table 10. Mean (± SE) density (per ha) and dry weight (g/ha) of *Rubus* species produced within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

		Rubus species	
Year	**Treatment**	**Density (SE)[a]**	**Dry Weight (SE)[b]**
2001	Control	206.96 (206.96) A	13.14 (13.14) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Burn	0.00 (0.00) A	0.00 (0.00) A
	Shelterwood	0.00 (0.00) A	0.00 (0.00) A
2002	Control	2.77 (2.77) A	0.15 (0.15) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Burn	0.00 (0.00) A	0.00 (0.00) A
	Shelterwood	0.00 (0.00) A	0.00 (0.00) A

Means with the same letter in the same column are not different (P > 0.05).
[a]ANOVA statistics: treatment effect (F=1.03, df=48, P=0.4031); year effect (F=1.00, df=3, P=0.3910).
[b]ANOVA statistics: treatment effect (F=1.02, df=48, P=0.4060); year effect (F=1.00, df=3, P=0.3910).

Other

(solomon's seal, false solomon's seal, horse nettle, ginseng, Indian cucumber, jack-in-the-pulpit)

In 2001, fruits in the Other category were present in small amounts in the wildlife thinning, wildlife burn, and shelterwood treatments, and non-existent in the uncut burn and control. There was no difference in mean density or dry weight among treatments or years (Table 11).

Similar to 2001, fruits of Other were present in small amounts and contributed very little to overall fruit production during 2002. Again, no difference existed in mean density or dry weight among treatments.

Table 11. Mean (± SE) density (per ha) and dry weight (g/ha) of Other species produced within 5 treatments at Chuck Swan, Union County, Tennessee, 2001 and 2002.

		Other	
Year	Treatment	Density (SE)[a]	Dry Weight (SE)[b]
2001	Control	0.00 (0.00) A	0.00 (0.00) A
	Uncut Burn	0.00 (0.00) A	0.00 (0.00) A
	Wildlife Thinning	55.55 (55.55) A	0.17 (0.17) A
	Wildlife Burn	97.22 (97.22) A	2.03 (2.03) A
	Shelterwood	123.62 (123.62) A	2.82 (2.82) A
2002	Control	29.17 (27.61) A	2.49 (2.40) A
	Uncut Burn	1.38 (1.38) A	0.05 (0.05) A
	Wildlife Thinning	18.06 (13.93) A	0.96 (0.69) A
	Wildlife Burn	0.00 (0.00) A	0.00 (0.00) A
	Shelterwood	41.67 (35.74) A	2.27 (1.70) A

Means with the same letter in the same column are not different ($P > 0.05$).
[a]ANOVA statistics: treatment effect ($F=1.19$, $df=48$, $P=0.3272$); year effect ($F=0.84$, $df=3$, $P=0.4266$).
[b]ANOVA statistics: treatment effect ($F=1.21$, $df=48$, $P=0.3170$); year effect ($F=0.85$, $df=3$, $P=0.4238$).

Macroinvertebrate Availability

Seven hundred and twenty 0.10-m^2 invertebrate samples were collected from 5 treatments during May and June 2002. Six arthropod classes were collected: Arachnida (including orders Acarina, Araneae, Opiliones, and Pseudoscorpiones); Chilopoda, Diplopoda, Gastropoda, Hexapoda (including orders Blattodea, Coleoptera, Collembola, Dermaptera, Diplura, Diptera, Hemiptera, Homoptera, Hymenoptera, Isoptera, Lepidoptera, Mantodea, Mecoptera, Megaloptera, Neuroptera, and Orthoptera); and Malacostraca. Within the class Hexapoda, orders Collembola, Dermaptera, Isoptera, Mantodea, Mecoptera, Megaloptera, and Neuroptera were excluded from the analysis because of the low occurrence in the wild turkey's diet or because insects in these orders were collected infrequently. Order Collembola (springtails) was excluded because springtails are small in size and not considered an important food source for wild turkey poults. By including springtails, density estimates were inflated because of their abundance but biomass estimates were underestimated because of their small size.

During 2002, there was no difference in overall invertebrate density or biomass among treatments (Table 12). An analysis of covariance revealed a weak relationship between invertebrate density and biomass and herbaceous cover (P = 0.0858), indicating herbaceous cover had little influence on invertebrate density or biomass within all treatments.

Invertebrates by Class

Arachnida
(spiders, granddaddy longlegs, mites, pseudoscorpions)

The control contained more Arachnids than the uncut burn and wildlife burn treatments (Table 13). There was no difference in Arachnida density among other treatments. Arachnida biomass was consistent within all treatments and there was no difference among them.

Chilopoda
(centipedes)

Centipede density was greater in the control than wildlife burn (Table 14). There was no difference in centipede density among other treatments. Also, there was no difference in centipede biomass among treatments.

Table 12. Mean (± SE) invertebrate density (per m^2) and biomass (g/m^2) within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	**Density (SE)**[a]	**Biomass (SE)**[b]
Control	132.50 (33.19) A	0.189 (0.029) A
Uncut Burn	75.00 (10.94) A	0.148 (0.028) A
Wildlife Thinning	99.17 (14.31) A	0.182 (0.042) A
Wildlife Burn	83.89 (15.36) A	0.200 (0.068) A
Shelterwood	90.69 (10.47) A	0.150 (0.035) A

Means with the same letter are not different ($P > 0.05$).
[a]ANOVA statistics: ($F=1.86$, $df=48$, $P=0.1327$).
[b]ANOVA statistics: ($F=0.39$, $df=48$, $P=0.8134$).

Table 13. Mean (± SE) density (per m^2) and biomass (g/m^2) of Arachnida within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	**Density (SE)**[a]	**Biomass (SE)**[b]
Control	27.43 (4.41) A	0.0415 (0.0069) A
Uncut Burn	14.38 (1.90) B	0.0364 (0.0072) A
Wildlife Thinning	21.53 (4.52) AB	0.0471 (0.0118) A
Wildlife Burn	16.18 (2.46) B	0.0361 (0.0079) A
Shelterwood	19.72 (2.31) AB	0.0456 (0.0098) A

Means with the same letter are not different ($P > 0.05$).
[a]ANOVA statistics: ($F=3.48$, $df=48$, $P=0.0142$).
[b]ANOVA statistics: ($F=0.36$, $df=48$, $P=0.8325$).

Table 14. Mean (± SE) density (per m^2) and biomass (g/m^2) of Chilopoda within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	Density (SE)[a]	Biomass (SE)[b]
Control	2.22 (0.73) A	0.0094 (0.0054) A
Uncut Burn	1.04 (0.62) AB	0.0028 (0.0016) A
Wildlife Thinning	1.67 (0.90) AB	0.0043 (0.0026) A
Wildlife Burn	0.69 (0.38) B	0.0016 (0.0010) A
Shelterwood	0.97 (0.55) AB	0.0051 (0.0040) A

Means with the same letter are not different ($P > 0.05$).
[a]ANOVA statistics: ($F=3.22$, $df=48$, $P=0.0204$).
[b]ANOVA statistics: ($F=1.29$, $df=48$, $P=0.2882$).

Diplopoda
(millipedes)

Few millipedes were collected within all treatments and density and biomass were relatively homogenous within treatments. There was no difference in millipede density or biomass among treatments (Table 15).

Gastropoda
(snails)

Snails were relatively abundant within treatments. Snail density was greater in the control than uncut burn (Table 16). No difference existed among other treatments. Also, there was no difference in snail biomass among treatments.

Malacostraca
(pill bugs)

Density and biomass pill bugs were relatively low within all treatments (Table 17). In fact, no pill bugs were recorded in the control. There was no difference in pill bug density or biomass among treatments.

Table 15. Mean (± SE) density (per m^2) and biomass (g/m^2) of Diplopoda within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	Density (SE)[a]	Biomass (SE)[b]
Control	1.25 (0.40) A	0.00626 (0.00345) A
Uncut Burn	1.04 (0.83) A	0.00067 (0.00046) A
Wildlife Thinning	1.04 (0.49) A	0.00408 (0.00367) A
Wildlife Burn	1.18 (0.62) A	0.06581 (0.06096) A
Shelterwood	0.83 (0.51) A	0.00133 (0.00119) A

Means with the same letter are not different (P > 0.05).
[a]ANOVA statistics: (F=0.16, df=48, P=0.9591).
[b]ANOVA statistics: (F=1.05, df=48, P=0.3925).

Table 16. Mean (± SE) density (per m^2) and biomass (g/m^2) of Gastropoda within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	Density (SE)[a]	Biomass (SE)[b]
Control	8.82 (3.22) A	0.0155 (0.0079) A
Uncut Burn	2.64 (0.75) B	0.0082 (0.0032) A
Wildlife Thinning	5.14 (1.68) AB	0.0259 (0.0129) A
Wildlife Burn	3.82 (1.17) AB	0.0110 (0.0047) A
Shelterwood	5.07 (1.54) AB	0.0242 (0.0141) A

Means with the same letter are not different (P > 0.05).
[a]ANOVA statistics: (F=2.74, df=48, P=0.0391).
[b]ANOVA statistics: (F=1.03, df=48, P=0.4016).

Table 17. Mean (± SE) density (per m^2) and biomass (g/m^2) of Malacostraca within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	Density (SE)[a]	Biomass (SE)[b]
Control	0.00 (0.00) A	0.00000 (0.00000) A
Uncut Burn	0.14 (0.14) A	0.00008 (0.00008) A
Wildlife Thinning	0.83 (0.37) A	0.00006 (0.00006) A
Wildlife Burn	0.97 (0.42) A	0.00060 (0.00042) A
Shelterwood	0.14 (0.09) A	0.00005 (0.00004) A

Means with the same letter are not different ($P > 0.05$).
[a]ANOVA statistics: ($F=3.18$, $df=48$, $P=0.0213$).
[b]ANOVA statistics: ($F=1.48$, $df=48$, $P=0.2221$).

Hexapoda
(insects)

Insects were relatively abundant within all treatments in 2002 (Table 18). Among treatments, there was no difference in density or biomass of Hexapoda.

Hymenoptera (e.g., ants, bees, wasps) represented the majority of the insects collected. However, there was no difference in Hymenoptera density or biomass among treatments.

Flies (Order Diptera) also were abundant within all treatments. Density of Diptera was greater in the shelterwood than the uncut burn and wildlife burn treatments. No difference existed among other treatments. Biomass of Diptera was not different among treatments.

Biomass of leafhoppers (Order Homoptera) was greater in the shelterwood treatment than control. No difference existed among other treatments. There was no difference in density of leafhoppers among treatments.

Table 18. Mean (± SE) density (per m^2) and biomass (g/m^2) of Hexapoda within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

Treatment	**Density (SE)[a]**	**Biomass (SE)[b]**
Control	87.71 (24.12) A	0.0794 (0.0111) A
Uncut Burn	51.46 (8.00) A	0.0663 (0.0183) A
Wildlife Thinning	65.14 (8.17) A	0.0507 (0.0077) A
Wildlife Burn	56.53 (13.66) A	0.0525 (0.0112) A
Shelterwood	60.69 (7.76) A	0.0537 (0.0118) A

Means with the same letter are not different ($P > 0.05$).
[a]ANOVA statistics: (F=1.15, df=48, P=0.3467).
[b]ANOVA statistics: (F=1.23, df=48, P=0.3124).

Density of beetles (Order Coleoptera) was similar within all treatments. There was no difference in density or biomass of beetles among treatments.

True bugs (Order Hemiptera) were scarce within all treatments in 2002. There was no difference in density or biomass of true bugs among treatments.

Moths and butterflies (Order Lepidoptera) were collected infrequently in all treatments in 2002. There was no difference in density or biomass of Lepidoptera among treatments.

Grasshoppers and crickets (Order Orthoptera) also were seldom collected within all treatments. There was no difference in density or biomass among treatments. Density and biomass of insects within treatments is compared in Table 19.

Invertebrates by Sampling Period

Invertebrate density within the control was greater during Period 1 than Periods 3 and 4 (Table 20). There was no difference in density between sampling periods among

Table 19. Mean (± SE) density (per m^2) and biomass (g/m^2) of selected orders of Hexapoda within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

	Treatment				
Order[a]	**Control (SE)**	**Uncut Burn (SE)**	**Wildlife Thinning (SE)**	**Wildlife Burn (SE)**	**Shelterwood (SE)**
Coleoptera	5.80 (1.24) A	4.87 (0.85) A	6.23 (1.30) A	4.29 (0.60) A	4.77 (1.11) A
	0.02604 (0.00671) A	0.01935 (0.00528) A	0.01495 (0.00366) A	0.01333 (0.00379) A	0.01367 (0.00287) A
Diptera	16.21 (2.84) AB	9.45 (1.34) B	16.61 (2.52) AB	12.18 (1.96) B	20.75 (2.57) A
	0.00283 (0.00087) A	0.00090 (0.00015) A	0.00252 (0.00066) A	0.00263 (0.00119) A	0.00186 (0.00044) A
Hemiptera	0.35 (0.17) A	0.21 (0.11) A	0.83 (0.33) A	1.11 (0.23) A	0.55 (0.27) A
	0.00025 (0.00023) A	0.00003 (0.00002) A	0.00327 (0.00249) A	0.00096 (0.00038) A	0.00253 (0.00227) A
Homoptera	2.98 (0.65) A	6.92 (1.44) A	4.57 (1.36) A	18.76 (12.76) A	6.08 (1.63) A
	0.00180 (0.00057) B	0.00195 (0.00046) AB	0.00239 (0.00093) AB	0.00256 (0.00117) AB	0.00685 (0.00246) A
Hymenoptera	57.92 (23.50) A	25.74 (6.76) AB	30.25 (6.82) AB	16.54 (2.34) B	23.58 (5.64) AB
	0.02111 (0.00840) A	0.01700 (0.01076) A	0.01509 (0.00392) A	0.00541 (0.00093) A	0.01339 (0.00468) A
Lepidoptera	0.69 (0.25) A	0.42 (0.20) A	0.62 (0.25) A	0.42 (0.14) A	0.73 (0.24) A
	0.00257 (0.00109) A	0.00061 (0.00041) A	0.00154 (0.00076) A	0.00276 (0.00160) A	0.00205 (0.00085) A
Orthoptera	0.90 (0.32) A	2.46 (0.59) A	1.32 (0.35) A	1.66 (0.43) A	2.23 (0.71) A
	0.01359 (0.00882) A	0.01797 (0.01228) A	0.00044 (0.00022) A	0.01683 (0.01003) A	0.00377 (0.00207) A

Means with the same letter within each order of Hexapoda are not different ($P > 0.05$).

[a]ANOVA statistics for: Coleoptera density (F=1.41, df=48, P=0.2452), biomass (F=1.62,df =48, P=0.185); Diptera density (F=4.2, df=48, P=0.005), biomass (F=0.98, df=48, P=0.428); Hemiptera density (F=2.19, df=48, P=0.0839), biomass (F=0.9, df=48, P=0.4692); Homoptera density (F=1.15, df=48, P=0.3442), biomass (F=2.71, df=48, P=0.0411); Hymenoptera density (F=2.28, df=48, P=0.0741), biomass (F=0.75, df=48, P=0.5633); Lepidoptera density (F=0.52, df=48, P=0.7209), biomass (F=1.34, df=48, P=0.534); Orthoptera density (F=1.64, df=48, P=0.1803), biomass (F=0.91, df=48, P=0.4634).

Table 20. Mean (± SE) density (per m^2) and biomass (g/m^2) of invertebrates collected within 4 sampling periods in 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

	Period[a]			
Treatment[b]	**1**	**2**	**3**	**4**
Control	271.94 (107.86) A	113.61 (27.82) AB	68.61 (16.11) B	75.83 (18.21) B
	0.330 (0.054) A	0.185 (0.049) A	0.141 (0.023) A	0.101 (0.039) A
Uncut Burn	102.22 (31.35) AB	80.00 (22.50) B	48.33 (9.74) B	69.44 (17.51) B
	0.268 (0.062) A	0.145 (0.063) A	0.077 (0.037) A	0.104 (0.011) A
Wildlife Thinning	159.44 (23.02) AB	84.17 (20.40) B	60.28 (9.13) B	92.78 (35.53) B
	0.430 (0.069) A	0.143 (0.038) A	0.055 (0.013) A	0.100 (0.028) A
Wildlife Burn	75.28 (5.64) B	135.00 (57.19) AB	61.67 (12.18) B	63.61 (8.22) B
	0.287 (0.061) A	0.092 (0.030) A	0.322 (0.269) A	0.098 (0.018) A
Shelterwood	109.72 (19.63) AB	95.56 (30.37) B	73.61 (18.27) B	83.89 (17.65) B
	0.286 (0.104) A	0.151 (0.061) A	0.081 (0.014) A	0.083 (0.010) A

Means with the same letter are not different ($P > 0.05$).
[a]Period: 1=mid-May; 2=late May; 3=mid-June; 4=late June.
[b]ANOVA statistics: density ($F=9.87$, $df=9$, $P=0.0033$); biomass ($F=8.66$, $df=9$, $P=0.0051$).

other treatments. Also, there was no difference in invertebrate biomass between sampling periods among treatments.

During Period 1, more invertebrates were collected within the control than wildlife burn (Table 20). There was no difference in density among other treatments during Period 1. Also, no difference in invertebrate biomass existed among treatments during Period 1.

There was no difference in invertebrate density or biomass among treatments during Periods 2, 3, or 4.

Herbaceous Cover and Height / Vegetation Structure

Herbaceous Vegetation Cover and Height

All treatments contained less than 10 percent herbaceous coverage in 2002. There was no difference in percent cover among treatments as herbaceous cover was virtually absent within all treatments during the second growing season after treatments were implemented (Table 21). The majority (approximately 5 percent) of the herbaceous cover was composed of *Desmodium spp*., panic grasses (*Dicanthelium spp*.), pokeberry, and Christmas fern (*Polystichum acrostichoides*).

Height of the herbaceous vegetation was quite low, with no difference existing among treatments.

Table 21. Percent (± SE) herbaceous cover and height (cm) within 5 treatments at Chuck Swan, Union County, Tennessee, 2000, 2001, and 2002.

Treatment	Percent Cover (SE)[a]	Percent Cover (SE)[a]	Percent Cover (SE)[b]	Height (SE)[c]
Control	12.25 (2.54) A	8.31 (1.82) A	4.67 (1.06) A	7.65 (1.18) A
Uncut Burn	7.77 (1.84) A	4.42 (0.87) A	4.63 (1.09) A	8.53 (1.45) A
Wildlife Thinning	8.85 (1.96) A	6.91 (1.87) A	2.74 (0.55) A	6.56 (0.79) A
Wildlife Burn	5.71 (1.14) A	4.85 (0.96) A	7.92 (1.52) A	6.40 (1.32) A
Shelterwood	9.28 (1.77) A	3.35 (0.55) A	6.43 (1.82) A	12.71 (3.92) A

Means with the same letter in the same column are not different (P > 0.05).
[a]Jackson 2002
[b]ANOVA statistics: (F=0.52, df=12, P=0.7204).
[c]ANOVA statistics: (F=0.35, df=9, P=0.8347).

Vegetation Structure

Vertical vegetation density was relatively homogenous within all treatments. There was no difference between any of the height intervals among treatments (Table 22). There was high visibility (0-20 percent coverage) in the top 3 intervals (57-227 cm) of all treatments except the shelterwood, which averaged just over 20 percent coverage at the 57-113 cm interval. The lowest interval (0-56 cm) was moderately dense (25-55 percent) within all treatments.

Table 22. Mean (± SE) vertical vegetation density measurements[a] within 5 treatments at Chuck Swan, Union County, Tennessee, 2002.

	Density Board Height Interval[b]			
Treatment[c]	**1**	**2**	**3**	**4**
Control	2.5 (0.45) A	1.6 (0.16) A	1.9 (0.21) A	1.3 (0.14) A
Uncut Burn	2.3 (0.39) A	1.4 (0.15) A	1.3 (0.12) A	1.1 (0.06) A
Wildlife Thinning	3.0 (0.25) A	1.5 (0.20) A	1.3 (0.13) A	1.3 (0.19) A
Wildlife Burn	3.4 (0.32) A	1.8 (0.23) A	1.3 (0.17) A	1.2 (0.09) A
Shelterwood	3.4 (0.40) A	2.1 (0.32) A	1.4 (0.17) A	1.5 (0.17) A

Means with the same letter in the same column are not different ($P > 0.05$).
[a] Coverage: 1=0-20%; 2=21-40%; 3=41-60%; 4=61-80%; 5=81-100%.
[b] Height Intervals: 1=0-56 cm; 2=57-113 cm; 3=114-170 cm; 4=171-227 cm.
[c] ANOVA statistics: ($F=2.29$, $df=12$, $P=0.1202$).

CHAPTER V

DISCUSSION

Acorn Production

Making conclusions concerning treatment effects on acorn production is not possible within 2 years after treatment application. In fact, the treatments could not have affected acorn production of the red oak group during 2001 because those acorns require 2 years to develop. Bud primordia for acorn development were set prior to treatment implementation; hence, all acorns of the red oak group collected during 2001 were set in July 2000.

Annual acorn production is erratic at best. As expected, acorn yields at Chuck Swan were highly variable during 2001 and 2002. Numerous researchers have described this variability (Downs and McQuilkin 1944, Goodrum et al. 1971, Beck 1977, Healy et al. 1999, Greenberg 2000). In a 12-year study in the southern Appalachians, Beck (1977) determined acorn production to be above average during 4 years, below average during 5 years, and very low to non-existent the remaining 3 years. He also observed the complementary effect of red and white oaks by greater production of these species groups during different years. It was rare that red oaks and white oaks had equal production within the same year.

In 2002, acorn production at Chuck Swan was lower within all treatments except the control. Surprisingly, production doubled and weight increased by 4 times in the control from 2001. The large increase, however, can be attributed to the stand on Loy

Ridge, where the control cell contained several large scarlet oaks that seemed to be superior acorn producers.

Another possibility for high variation within the data was placement of mast baskets within each treatment cell. Establishing baskets in a systematic fashion caused some baskets to be under trees that were non-oaks; hence, those baskets never collected acorns. In addition, some baskets within the shelterwood treatment were not beneath a tree because of the lower basal area within the treatment.

Thinning is important when managing closed canopy stands for increased mast production. The crown of a tree is released after thinning by reducing competition for moisture, sunlight, and nutrients from adjacent trees. This promotes crown expansion of residuals and consequently, a tree's ability to produce seed increases. At Chuck Swan, mean crown area of selected white oaks slightly increased within the wildlife thinning from 2001 to 2002. However, increases varied depending on the level of release. Some white oaks had larger increases in crown size than others because some of the competitors selected to kill did not die. Jackson (2002) determined basal area within treatments during 2000 (pre-treatment) and 2001 (post-treatment) (Figure 7). Although there was a reduction in basal area within the wildlife thinning and shelterwood treatments, the targeted basal area was not realized. Thus, competition from adjacent trees was not adequately reduced to allow crown growth of residuals within the wildlife thinning. Crown size of white oaks within the shelterwood treatment increased most. In this treatment, competitors were harvested and crowns of residuals were released completely. Although these data describe white oaks only, the effect of treatments on crown growth can be applied to all mast producers.

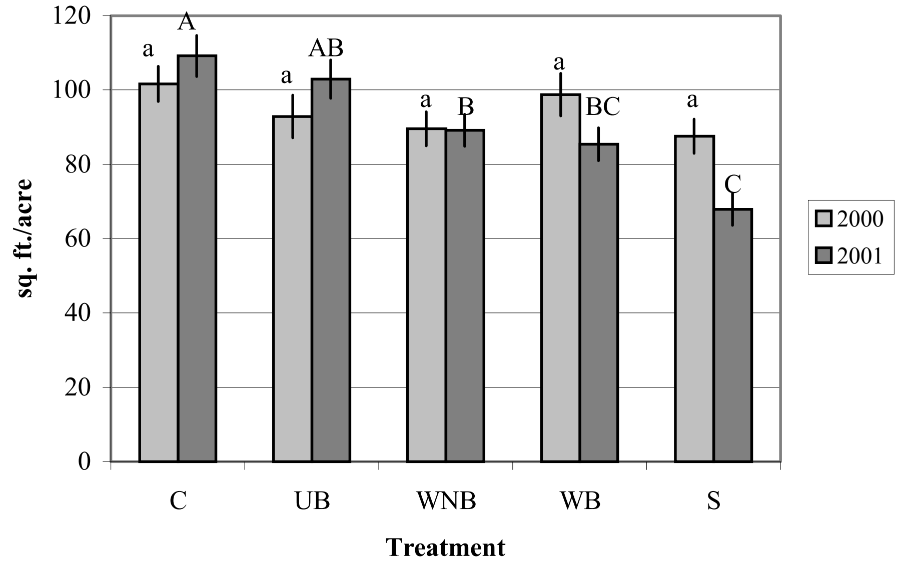

Figure 7. Prism basal area (± SE) within 5 treatments at Chuck Swan, Union County, Tennessee, 2000 and 2001. C=control, UB=uncut burn, WNB=wildlife thinning, WB=wildlife burn, S=shelterwood. Lower case letters compare 2000 data and capital letters compare 2001 data. Means with the same letter within the same year are not different ($P > 0.05$).

A main point of interest for forest and wildlife managers is the amount of time necessary before increased mast production occurs and the amount of time before the forest canopy closes at different levels of thinning. Little information is available describing the initial effects of thinning on acorn production because it takes time (5 - 6 years) for crown development of residual trees. High inter- and intraspecific variation in annual acorn production makes this question difficult to answer.

Healy (1997) examined acorn production in thinned and unthinned mixed-hardwood stands in central Massachusetts. Production was measured 2 years after thinning at the individual tree level and 5 years after thinning at the stand level. Thinning clearly increased production at the individual level within the first 2 years, but effects at the stand level were undetermined within first 5 years. Healy et al. (1999) concluded the effect of thinning on individual tree production was only significant within the first 5 years and was similar to unthinned trees thereafter. The response is a gradual process, depending on factors such as site quality, crown development, and weather.

Thinning mixed hardwood stands that contain oaks and non-oaks may be better suited for increasing acorn production at the stand level because non-oaks can be selected for removal. It may be difficult to increase production in stands with a high stocking of oaks because oaks must be removed during thinning operations to achieve the desired stand density (Healy 1997). This operation may remove the inherently good acorn producers.

Many of the acorns produced each year are not sound. The ratio of sound to unsound acorns produced by an individual tree varies annually, depending on factors such as temperature, rainfall, species, and insect populations. Treatments at Chuck Swan did not appear to affect the ratio of sound to unsound acorns. Unsound acorns composed 50 – 73 percent of all acorns collected during 2001 and 2002. This percentage remained relatively constant for each treatment during the study. Downs and McQuilkin (1944) and Christisen and Korschgen (1955) also found unsound acorns composed 40 – 80 and 59 – 95 percent of acorns, respectively, in upland hardwood stands.

Naturally, production of sound acorns is important for wildlife, especially those species selective in their feeding patterns, consuming preferred acorns first. Most species, such as chipmunks, wood ducks (*Aix sponsa*), white-tailed deer, and wild turkeys, are selective feeders, choosing well-developed or sound acorns of certain species first (Verme and Ullrey 1984, Pyare et al. 1993, Minser et al. 1995, Barras et al. 1996).

Increasing the proportion of sound acorns produced during a given year could benefit selective feeders, including wild turkeys. Healy (1997) determined overall acorn production was greater in thinned than unthinned stands during poor mast years, which is important because it is during these years that reproduction and survival are most likely to suffer the following season (Porter et al. 1983).

Individual White Oak Production

At Chuck Swan, acorn production from white oaks varied among years and individual trees. Beck (1977) determined white oaks produced a sizable crop every other year and a “bumper” crop at 4-year intervals during 12 years in the southern Appalachians.

According to the TWRA annual hard mast survey, acorn production for white oak was considered poor to fair within the Ridge and Valley physiographic province in 2001 and considered production at Chuck Swan to be poor in 2002. White oak production within the treatments was low in 2001 but increased during 2002 within all treatments. It would be difficult, however, to associate treatment effects with increased production this early in the study. Acorn production within the shelterwood treatment in 2002 might have been correlated with increased crown size. Although production was considered poor during 2001 and 2002 by the TWRA survey, mean production increased by 80 percent and average crown size by 25 percent in the shelterwood treatment during 2002. Still, more time is needed to examine the relationships between treatment effects and the natural fluctuations in annual acorn production.

Half the acorns collected in 2001 were sound, but increased to 64 percent in 2002 within all treatments. This does not agree with Goodrum et al. (1971) who determined over 90 percent of white oak acorns were sound. Nonetheless, the percentage of sound acorns varies from year to year. Christisen and Korschgen (1955) determined sound acorns ranged from 14 – 32 percent for white oaks in Missouri and Healy (1997) determined the proportion of sound acorns increased during good seed years for northern red oak. It appears this could be true for white oak as well, as the proportion of sound acorns at Chuck Swan was higher during 2002, which was a better year.

In 2001, 2 individuals produced half the acorns collected. These individuals only accounted for 15 percent of the acorns in 2002, even though production by these trees was similar during both years. In 2001, 30 percent of the trees produced nearly 85 percent of the acorns. Beck (1989) also found 30 percent of the white oaks produce 90 percent of the acorns during any given year. Results in 2002 disagree with this however, when 30 percent of the trees produced 70 percent of the acorns. This is probably because production in 2002 was higher and more evenly distributed among individuals than in 2001.

It appeared there were inherent differences among individual trees. Some individuals produced little in 2001, but many acorns in 2002. Other individuals were constant producers, yielding consistently high or low both years. Some individuals were non-producers, yielding no acorns either year. Greenberg (2000) also observed this pattern in white oaks. A small portion of trees never produced acorns and, conversely, a small portion produced acorns every year. This inherent variation makes it difficult to relate treatment effects to acorn production. However, with long-term monitoring, these disparities can be used to determine treatment effects on annual production.

Soft Mast Production

Although soft mast was not collected in June 2001, overall fruit density and dry weight estimates were not apparently affected. Fruit production from blueberries and huckleberries might have been slightly underestimated because they begin to ripen in June, but most other species did not begin to ripen until July.

In 2001, soft mast production was relatively low within the treatments because of disturbance to the vegetation, which hindered fruit production that year. In addition, it normally requires 2 or more growing seasons for most understory plants to become established following a disturbance and bear fruit.

Fruit production within the shelterwood treatment during year 2 was actually representative of production 1 year following harvest. Shelterwood harvests were implemented in late June and early July 2001, the time when most fruit is produced, therefore, summer 2002 was the first full growing season within the treatment.

With the exception of the control, soft mast production increased tremendously within treatments from 2001 to 2002. Although there appeared to be large differences in fruit production among treatments, they were not statistically significant because of high variation, which resulted from the patchy distribution of fruit-producing vegetation within the forest. Fruit collected along all 3 transects within each treatment was combined in the analysis. Separating the fruit collected along each transect would increase sample size and reduce the amount of variation and, therefore, allow detection of true differences.

Although there was no statistical difference, the uncut burn, wildlife burn, and shelterwood treatments clearly increased overall soft mast production by year 2 of the study. Pokeberry was the primary contributor, but blueberry and huckleberry fruit production increased also. Fruit production within the control and wildlife thinning was relatively unaffected because of the absence of fire or soil disturbance.

Soft Mast Production of Species Groups

Ericaceous Shrubs

Fruit production from Shrubs increased within all treatments by year 2, however, differences were not significant because of high variation. Thinning or burning alone increased production by year 2, but thinning in conjunction with prescribed burning had a greater effect. Production also benefited from the increase in available sunlight within the shelterwood treatment, which had the largest increase by year 2. In the southern Appalachians, Greenberg (2001) also determined fruit production by blueberry was relatively unaffected by clearcutting upland and cove hardwood stands within 3 years post-harvest. However, production of huckleberry increased by 5 times from 2 to 3 years after clearcutting upland hardwood stands.

Pokeberry

Although pokeberries are not known to be significant in the diet of wild turkeys, they are important to other wildlife species (e.g., songbirds, small mammals) (Miller and

Miller 1999). However, many diet studies were conducted from fall and spring harvests when pokeberries are not available. Pokeberry was non-existent prior to treatment implementation (Jackson 2002). In 2001, Pokeberry quickly established within all treatments except the wildlife thinning and control, but produced little fruit. By year 2, fruit production increased sharply. Although differences were not statistically significant because of high variation, the uncut burn, shelterwood, and wildlife burn treatments clearly increased pokeberry density and dry weight. This also has been shown in recently-harvested stands in the Ouachita and southern Appalachian mountains (Perry et al. 1997, Greenberg 2001). Pokeberry requires a high level of site disturbance (i.e., timber harvest, prescribed burning) for germination; therefore, pokeberry establishment and fruit production did not increase in the wildlife thinning or control at Chuck Swan. Thinning alone had no effect on pokeberry establishment or fruit production.

Over time, as understory vegetation develops and crown cover increases in the forest canopy, fruit production from pokeberry will probably decrease. In the Ouachita Mountains, Perry et al. (1997) observed a sharp increase in fruit production from pokeberry within the first 3 years following a clearcut and shelterwood harvest, but decreased thereafter.

Density and dry weight estimates within the uncut burn may be misleading and not necessarily representative of the treatment. The majority of the production occurred within the unfenced treatment at Big Loop. Pokeberries were collected in only 1 other uncut burn treatment at Loy Ridge, which contributed little to overall production. The remaining 6 uncut burn treatments had no production. In these stands, canopy gaps created by fire favored colonization of pokeberry. However, when burning hardwood stands, it is not uncommon for fire-related mortality to occur in a small percentage of the overstory, especially in thin-barked species (e.g., American beech, red maple). In this case, small canopy gaps will be created, promoting establishment of early successional species, such as pokeberry.

Rubus

At Chuck Swan, fruit production from blackberry, dewberry, and raspberry was unaffected by the treatments within 2 years after application. In fact, blackberries and dewberries did not occur in any treatments. There was, however, a dense stand of raspberry that intersected 1 soft mast transect within the control cell at Big Loop. A tree-fall created a canopy gap and promoted establishment of raspberry within the stand. This was not representative of *Rubus* production within the control and inflated density and dry weight estimates. This single transect contained all fruits collected during both years. Density and dry weight within this stand declined in 2002 because the fruit ripened and fell off between collection intervals.

Low initial production from *Rubus* has been documented by others (Perry et al. 1997, Greenberg 2001). Perry et al. 1997, determined production was low or absent within treatments (control, single-tree selection, group selection, shelterwood, clearcut) until 5 years after harvest, when fruit production increased tremendously in clearcut and shelterwood harvests. Greenberg (2001) determined fruit production from *Rubus* species increased slightly in upland hardwood 2-age harvests by year 2 but production increased considerably by year 3. Production in cove hardwood clearcuts was unaffected within 3 years post-harvest.

Although *Rubus* did not produce fruit within treatments at Chuck Swan during the first 2 years after application, more time may be needed for these species to become established and bear fruit. It may require 3 or 4 years following treatment implementation before *Rubus* becomes a significant fruit producer.

Other

As expected, fruit production from Other was relatively low within all treatments at Chuck Swan during 2001 and 2002. There was no distinct pattern in production among treatments or years. In general, production decreased within treatments, excluding the control from 2001 to 2002. There was no evidence that treatments affected production within 2 years post-harvest.

Wild turkeys consume a wide variety of soft mast, depending on availability. Although certain fruit-producing species may not be significant contributors to overall fruit production within an area, they may be important. Similar to acorn production, soft mast production varies annually. Less prevalent species serve as a buffer food source during years when production of more important species is low. Although not considered important, fruits from jack-in-the-pulpit, soloman's seal, and other less common fruit has been reported in the diet of wild turkeys (Healy et al. 1975, Hurst 1992). Therefore, fruit production from Other should be monitored to determine treatment effects over time.

Invertebrate Abundance and Availability

Overall invertebrate density and biomass was similar within all treatments 2 years after implementation. With the exception of Hymenoptera, density and biomass of preferred orders of Hexapoda were relatively similar among all treatments. These invertebrates are more available to poults because they are generally found above the leaf litter and within reach of poults. Harper et al. (2001) found no correlation between hexapod density and biomass with leaf litter depth or weight.

With regard to brood range, invertebrate density can be misleading. More consideration should be given to understory vegetation structure than invertebrate density. Although more invertebrates were collected within the control at Chuck Swan, many are not available to poults. Density of Hexapods (insects) was similar for all treatments. Increasing low-growing vegetation will make these invertebrates more available to poults. Additionally, increased vegetation structure will provide poults with adequate cover to forage while minimizing exposure to potential predators.

There was no relationship between invertebrate density or biomass and herbaceous cover within treatments at Chuck Swan. This was not surprising as herbaceous cover was lacking (< 10 percent) within all treatments.

With the exception of the control, invertebrate density was relatively similar within all treatments during the 4 sampling periods at Chuck Swan. Within Period 1, density was greater within the control than wildlife burn. This is probably a result of more leaf litter present within the control, as fire consumed much of the litter layer within the wildlife burn. Reduction of the litter layer caused a reduction of invertebrates associated with the leaf litter. Fettinger (2002) determined invertebrate density did not change during the early (late May – mid-June) and late (late June – July) brood-rearing periods for ruffed grouse. At Chuck Swan, no difference in invertebrate biomass was found among periods between treatments. This was surprising because Fettinger (2002) found invertebrate biomass to increase from the early to late brood-rearing period.

Invertebrate availability for wild turkey poults is influenced by several factors, such as weather (Murkin et al. 1996) and vegetation composition and structure (Healy 1985, Hollifield and Dimmick 1995, Harper et al. 2001). At Chuck Swan, invertebrate density and biomass seemed adequate during all 4 sampling periods. Management should concentrate on improving vegetation composition and structure within the understory to make invertebrates more available to poults.

Herbaceous Cover and Vegetation Structure

There was little herbaceous vegetation coverage (2–8 percent) within all treatments in 2002. Jackson (2002) also measured herbaceous cover within the same treatments during summer 2001 and found no difference among treatments during the first growing season after implementation. In fact, estimates of percent cover (2-8 percent within treatments) in 2001 were identical to those in 2002. Estimates in 2001, however, included greenbrier, Virginia creeper (*Parthenocissus quinquefolia*), and poison ivy (*Toxicodendron radicans*), which inflated estimates of overall herbaceous cover. Jackson (2002) found the understory was primarily woody vegetation, especially sassafras and yellow poplar in treatments that were burned. The increased response of woody vegetation within the understory hindered development of forbs, grasses, and other herbaceous plants beneficial to wild turkeys. Beck (1983) also observed a sharp increase in woody vegetation within the understory after thinning cove hardwood stands in the southern Appalachians.

One factor that affected understory development within the wildlife thinning and wildlife burn treatments was the timing of the herbicide treatment used to thin the stands. The goal was to reduce the stand basal area to approximately 11-13 m^2/ha (50-60 ft^2/acre), however, only a 50 percent mortality rate during the first year was realized. Low efficacy was caused by application during early spring, when water and carbohydrates are being transported from the roots to the crown (Kochenderfer et al. 2001). In this case, sap from some species (especially red maple) flushed out much of the herbicide, hindering its ability to enter the tree. Although a few additional trees died by year 2, the woody understory had already become established the previous year.

Jackson (2002) determined canopy cover within the wildlife thinning did not differ from the control during the first growing season following treatment implementation (Figure 8). Low herbicide efficacy resulted in less sunlight available to the forest floor to stimulate understory development.

If the herbicide application had been more effective, the woody vegetation within the understory most likely would have increased. However, the effect of a more intensive thinning on woody and herbaceous vegetation varies from site to site. For example, percent herbaceous cover within the shelterwood treatment averaged 20 percent at Big Loop, while herbaceous cover only ranged from < 1 to 4 percent among the other 3 stands. Big Loop was a moister site and oriented slightly northeast while the other stands had a northwestern aspect. Crawford (1976) reported intensive thinnings on xeric sites within the southern Appalachians promoted an increase in woody vegetation.

Vertical vegetation density was surprisingly low within all treatments at Chuck Swan. Treatments were relatively open (0-20 percent coverage) between 57-227 cm

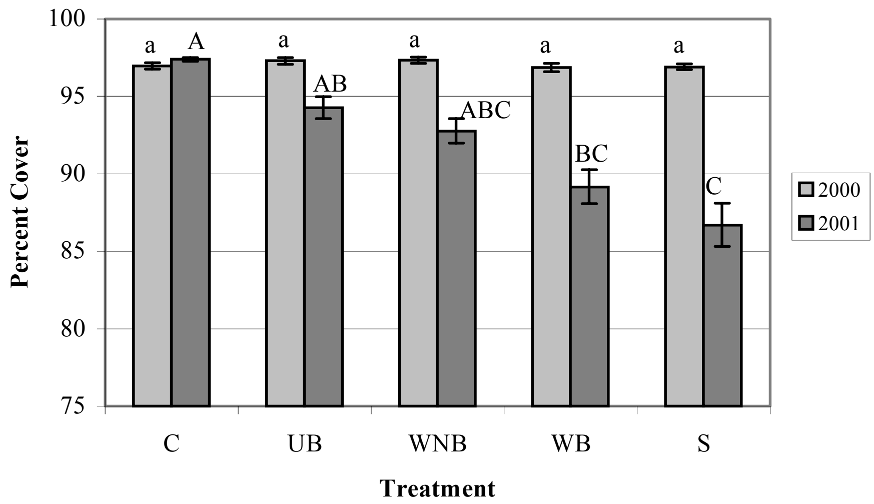

Figure 8. Percent canopy cover (± SE) within 5 treatments at Chuck Swan, Union County, Tennessee, 2000 and 2001. C=control, UB=uncut burn, WNB=wildlife thinning, WB=wildlife burn, S=shelterwood. Lower case letters compare 2000 data and capital letters compare 2001 data. Means with the same letter within the same year are not different ($P > 0.05$).

during 2002. With time, vegetation will reach this level unless additional disturbance is implemented. Understory vegetation within the control is sparse because of a closed forest canopy, permitting little sunlight to reach the forest floor (Jackson 2002).

Although differences were not significant, vertical vegetation density between 0-56 cm within the wildlife burn, wildlife thinning, and shelterwood treatments was 10-15 percent higher than the control and uncut burn. This resulted from stump sprouting within the wildlife thinning and wildlife burn treatments and slash and debris left from the shelterwood harvest. The control contained a high density of red maple stems between 0-56 cm, which made vertical density comparable to other treatments at this level (Jackson 2002). Lower vertical density within the uncut burn was a result of sunlight availability to the forest floor, which was not different from control in 2001 (Jackson 2002).

Overall, the wildlife thinning, wildlife burn, and shelterwood treatments offered suitable nesting cover for wild turkeys with regard to vegetation cover and structure 2 growing seasons after application. Most of the understory was composed of dense woody vegetation (i.e., sassafras, yellow poplar, red maple, blackgum, blueberry). Hens often nest in these areas in the southern Appalachians (Davis 1992, Harper 1998). Forested habitats that provide dense lateral cover 1 meter above forest floor normally meet the requirements for nesting hens (Porter 1992).

The shelterwood treatment provided ideal nesting habitat because of the combination of woody regeneration and the slash left from the harvest. In fact, 2 wild turkey nests were observed in downed tree-tops within this treatment. However, both nests were destroyed and 1 of the hens was preyed upon at the nest site. If applied at a small scale (i.e., < 5 ha), it may be disadvantageous to hens selecting this habitat type for nesting. Predators may develop a search image for slash piles that are attractive to nesting hens (Miller and Leopold).

With respect to brood-rearing habitat, the treatment probably most suitable was the wildlife burn. Although much of the vegetation within the understory was woody, it was relatively dense (50 percent coverage) from 0-56 cm from the ground and open above 56 cm. This would provide concealment cover for poults while affording hens adequate visibility to detect potential predators.

CHAPTER VI

CONCLUSIONS

The first objective of the study was to determine the effect of a wildlife thinning and shelterwood harvest on acorn production. It is much too early to determine any effect because of the high annual variation in acorn production. Further, residual trees were not fully released within the wildlife thinning as they were within the shelterwood harvest. Trees treated that did not die will be treated again during late summer/fall 2003.

Overall soft mast production increased within treatments receiving soil disturbance, however, the patchy distribution of plants caused high variation in the data and prevented statistical differences among treatments. Initial soft mast production was primarily Pokeberry in treatments that were burned or harvested. In time (1-2 years), production of Pokeberry is expected to decrease, while production of Ericaceous Shrubs and *Rubus* species should increase within treatments that were thinned, burned, or harvested.

Herbicide efficacy within the wildlife thinning treatments certainly affected understory development. Since all treated trees did not die, canopy cover was not reduced to the desired level to increase available sunlight to the forest floor and promote understory development. However, in areas where selected trees were killed, the understory did become established and provided suitable nesting and brood-rearing cover for wild turkeys within 2 years post-treatment. This also caused dense patches of vegetation to develop in a mosaic across the treatment.

Understory vegetation within the shelterwood harvest also provided adequate structure for nesting hens by year 2. Two wild turkey hens were observed nesting within this treatment in 2002. The slash and debris remaining after harvest combined with regenerating vegetation provided sufficient nesting cover within the treatment.

Prescribed fire within the wildlife thinning treatment created conditions favorable to nesting and brooding hens. However, the density of understory vegetation within the wildlife burn treatment was not statistically different from stands that received thinning or burning alone.

Invertebrate abundance and biomass was similar within all treatments in 2002. Availability of invertebrates associated the leaf litter layer (i.e., spiders, snails, centipedes) was greater within the control than treatments that were burned. Fire reduced the leaf litter layer and consequently, invertebrates associated with this layer decreased. This, however, is not pertinent for wild turkey poults because they cannot scratch at such a young age. Thus, many invertebrates associated with the litter layer are essentially unavailable. Availability of insects was similar within all treatments, which is important because insects are generally more available to poults. More attention should be given to developing a forest understory to provide suitable brood-rearing cover, thus making invertebrates more accessible.

It is important that managers realize the time necessary to determine habitat changes in response to silvicultural practices. The results of this study are preliminary, making it difficult to quantify changes as related to habitat suitability for wild turkeys. Reduced treatment efficacy and dry weather conditions in 2001 and 2002 further confounded the effort, and certainly affected acorn production, soft mast production, understory vegetation composition and structure, and invertebrate availability.

As data collection continues in the next few years, trends and differences should become apparent. Preliminary data suggest a wildlife thinning may to provide a suitable alternative for landowners wishing to enhance wild turkey habitat in mixed hardwood stands without harvesting timber. Prescribed burning after thinning should further improve the suitability of the treatment for wild turkeys. More time, however, is needed to investigate the long-term effect on food availability and vegetation structure within treatments.

CHAPTER VII

MANAGEMENT RECOMMENDATIONS

Maintaining and encouraging inherent mast producers should be a priority when managing mixed hardwood forests for wild turkeys, white-tailed deer, and many other species. Managers, however, should use caution when thinning stands heavily stocked with mast producers. The stocking level of oaks within a stand should be the primary factor that determines thinning intensity for increased mast production. In stands heavily stocked with oaks, light thinnings are more appropriate. In mixed hardwood stands, heavier thinnings (i.e., 40 - 50 percent reduction in basal area) can be applied to remove non-producers.

Naturally, it is important to retain oaks during thinning operations to prevent potential mast producers from being removed. Additionally, maintaining a variety of oak species, representing both white and red oak groups helps ensure more consistent mast production from year to year. When possible, acorn production should be monitored within a stand for 2 to 3 years prior to thinning to identify inherently good producers.

When thinning with herbicides, it is important to implement the treatment during late summer, fall, or early winter to increase effectiveness and ensure residual trees are released for optimum crown growth. Also, a certain number of species such as flowering dogwood, mulberry, blackgum, and black cherry should be retained if objectives for stand density permit. These species provide important soft mast for turkeys in the fall, which is critical during years of low acorn production.

Thinning with herbicides without felling benefits other wildlife species as well. As treated trees die and decay, snags are created and used by woodpeckers as foraging sites, as well as den sites for cavity nesters such as wrens, flycatchers, squirrels, raccoons, and even wood ducks if located near creeks, streams, or ponds. As snags fall to the forest floor, habitat is created for herpetofauna, such as various species of salamanders, lizards, and snakes.

When a commercial thinning or timber stand improvement is an option, skid trails and/or logging roads can be widened and maintained in linear wildlife food plots. Proper soil amendments (i.e., lime and fertilizer) should be applied according to a soil test. These areas provide quality brood-rearing habitat in close proximity to nesting and escape cover in the adjacent thinned stand. Managers, however, should avoid planting cool-season perennial grasses, such as tall fescue and orchardgrass, because they do not provide adequate structure for brood-rearing habitat and out compete desirable forages planted. Linear openings also can be left fallow and disked during late winter every couple of years. This will promote annual and perennial forbs along with soft mast producers (e.g., brambles and pokeberry) and provide ideal brood cover. On public land, access roads managed in linear food plots should be gated to minimize disturbance.

A shelterwood harvest can be used to enhance wildlife habitat. However, when increased mast production is an objective, shelterwood harvests should be avoided in heavily stocked oak stands because of the reduction in basal area; hence, many oaks would be removed. An exception is when managing large management units (> 200 ha, or 500 acres) that lack early successional habitat. In this case, maintaining portions of the management unit in early succession would be more beneficial to wild turkeys and other species than managing an entire area in fully stocked mature stands.

A shelterwood harvest also permits managers to enlarge log landings and skid trails to be maintained in wildlife food plots. Managers can request logging crews use more log landings scattered across the harvest area. This will reduce the cost of removing timber as well as create a mosaic of small, early successional habitats that benefit wild turkeys across the management unit.

Thinning in conjunction with prescribed burning should increase soft mast production within the understory over time. Burning alone may not be sufficient to dramatically affect production unless fire-related mortality occurs within the overstory. However, a small amount of mortality may not be undesirable. This creates canopy gaps in a mosaic across the management unit and promotes dense patches of vegetation within the understory, which are attractive nesting sites for wild turkey hens.

Although an understory of mixed forbs would be ideal brood habitat, this is not always possible without additional treatment. This is especially true on drier south- and west-facing slopes where woody vegetation commonly predominates in the understory after thinning. When thinning or harvesting stands on xeric sites, especially when the site index is relatively low (i.e., < 70 for oaks), managers should focus on controlling woody vegetation within the understory and promote herbaceous cover. This may be accomplished by using growing season burns. The woody understory also may be controlled using herbicides (e.g., imazapyr and triclopyr) to reduce competition with herbaceous plants; however, more research is needed in this area. Burning should be conducted at 3- to 4-year intervals to maintain understory vegetation at lower levels.

Maintaining the understory in low-growing vegetation will make invertebrates and green forage more accessible to wild turkeys and provide poults with adequate escape cover.

After thinning, burning at 4-year intervals should provide an abundance of soft mast within the understory. Early successional species (e.g., pokeberry) may provide the vast majority of soft mast initially, however, as plants develop, production should shift to blueberries, huckleberries, and brambles. When managing larger units, some areas should be burned on longer rotations (4 to 6-year rotations) to provide adequate time for establishment and production of brambles (e.g., blackberry, dewberry) and shrubs (e.g., blueberry, huckleberry). This also will create a dense understory and provide optimal nesting cover.

Prescribed burning should be conducted in a mosaic pattern across the management unit. Size of the burn depends on the size of the management unit. On large units, entire stands may be burned each year to provide different stages of succession. On small properties (i.e., 40 ha, or 100 acres), 20-30 percent of a stand can be burned each year. For example, small blocks of 4-6 ha (10-15 acres) can be burned at 4-year intervals, burning only 1 block any given year.

In heavily forested areas, another option for managers who do not wish to harvest timber is "daylighting" roads. Clearing a 50-foot swath along each side of a woods road will provide much-needed early successional habitat for nesting and brood-rearing. Eventually, soft mast from pokeberry and brambles will become available. These swaths can be maintained with selective herbicide applications every 2-3 years.

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VITA

Ryan Glenn Basinger was born in Mobile, AL on May 25, 1978. He lived in Fairhope, AL for 13 years before moving to Demopolis, AL. He graduated from Demopolis High School in 1996. In 1998, Ryan received his Associate's degree in Liberal Arts at Alabama Southern Community College in Monroeville, AL. He then transferred to Starkville, MS where he earned his Bachelor of Science degree in Wildlife and Fisheries Science at Mississippi State University in 2001. Ryan attended graduate school at The University of Tennessee in Knoxville, where he obtained his Master of Science degree in Wildlife and Fisheries Science in 2003.

Ryan is currently working as a natural resource manager with the U.S. Army Corps of Engineers in Demopolis, AL, and providing forest and wildlife consulting on private lands.