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Third Year Effects of Shelterwood Cutting, Wildlife Thinning, and Prescribed Burning on Oak Regeneration, Understory Vegetation Development, and Acorn Production in Tennessee

Daniel Stuart Gordon
University of Tennessee - Knoxville

To the Graduate Council:

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David S. Buckley, Major Professor

We have read this thesis and recommend its acceptance:

Craig A. Harper, Jack W. Ranney

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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A Thesis Presented
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Degree
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Daniel Stuart Gordon

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ABSTRACT

In 2000, a study was implemented at Chuck Swan State Forest and Wildlife Management Area to compare the effectiveness of prescribed burning, shelterwood cutting, wildlife thinning, and wildlife thinning with prescribed fire for improving wildlife habitat and enhancing oak regeneration. Treatments were implemented in four similar mixed hardwood stands with a northwest aspect.

In 2003, a follow-up study was conducted to:

1) document third-year effects of prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting on the density and size of oak regeneration and woody competitors,

2) quantify effects of prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting on understory composition and the development of understory structure,

3) investigate effects of deer browsing on plant response from prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting, and

4) document white oak acorn production within the control and shelterwood cutting and wildlife thinning treatments.

In 2003, the response of yellow poplar, sassafras, black cherry, blackgum, and sumac to the treatments was stronger than the response of oak, as evidenced by significant increases in the abundance of these competitors over oak, and no significant differences between treatments in the abundance of red and white oaks. Treatments did not significantly affect composition of herbaceous species, and this was likely due to the low overall abundance of herbaceous cover and high variability in the composition of herbaceous species within and between the replicate stands. Understory structure up to 101 cm (39.8 in) was significantly increased by the shelterwood, wildlife thinning, and wildlife thinning with prescribed fire treatments. However, this structure was mainly comprised of woody species. Effects of deer browsing on understory vegetation were not detected. Species richness and percent herbaceous cover did not differ between fenced and unfenced treatments. Mean values for white oak acorn production and crown size were highest in the wildlife thinning treatments. Differences in the means were not significant in 2003, but it appears that a trend is emerging. Future monitoring of deer browsing effects and white oak acorn production is warranted, and future work involving additional applications of prescribed fire and mechanical and chemical treatment of undesirable components of the woody understory would be useful with respect to oak regeneration and development of herbaceous species.

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CHAPTER I

INTRODUCTION

Problem

Non-industrial private landowners and managers in the mid-South have a keen interest in improving mature mixed hardwood stands for wildlife, especially wild turkeys and white-tailed deer. Current successional trends in oak-hickory forests toward increased dominance of species with greater shade tolerance and lesser wildlife value will have an important ecological impact on wildlife, and clear economic consequences. It is thought that the exclusion of fire from oak-hickory forests over much of the 20th Century has allowed hardwood species that are less tolerant of fire than oak such as yellow poplar, red maple, sugar maple, and American beech to increase in dominance (Crow 1988, Lorimer 1989, Van Lear and Watt 1993). Of these species, shade-intolerant yellow poplar often dominates after major canopy disturbances when light is abundant, whereas the remaining tolerant species tend to dominate in the absence of canopy disturbance when light is limited. Intermediate light levels resulting from moderate amounts of canopy disturbance favor the moderately shade-tolerant oaks (Kramer 1944, Beck 1970, Johnson 1976, McGee 1981, Loftis 1990). It can be argued that relatively low levels of disturbance such as fire and cutting over the past 70-90 years have resulted in changes in forest structure and composition in the Southern Appalachians (Brose et al. 2001), to the detriment of certain wildlife species and tree species such as oak with high economic and wildlife value. Although oaks and hickories remain the dominant species in the canopy of these forests, shade-tolerant tree species dominate the middlestory strata, and limit development of herbs, shrubs, soft mast producers, and overall structure in the understory. This problem can be exacerbated by high deer populations. Although populations in the Southern Appalachians are quite variable, white-tailed deer can negatively impact understory structure, certain herb and shrub species, and oak regeneration (Marquis et al. 1976, Alverson et al. 1988, Buckley et al. 1998).

Potential solutions

Options available to non-industrial private landowners and managers for solving this problem include silvicultural practices such as cutting, girdling, herbicide application, and prescribed burning. These practices can be used to restore appropriate types and levels of disturbance, and favor desirable herb, shrub, and tree species and understory structure over undesirable tree species and a lack of understory structure. The shelterwood method is a partial, multiple-step cutting method that is well-suited for regenerating moderately shade-tolerant species such as oak, while limiting shade-intolerant species such as yellow poplar (Johnson et al. 1986, Loftis 1990). This technique also increases the availability of resources for development of understory herbs, shrubs, and soft mast producers. Girdling combined with herbicide treatment of cut surfaces can also be used to kill and remove selected overstory trees (Heiligmann 1997, Kochenderfer et al. 2001). Similar to shelterwoods, these techniques result in partial removal of the canopy, thereby increasing the availability of resources for understory development and creating intermediate understory light levels favorable for regeneration of oak. In contrast to cutting and girdling methods, prescribed surface fire mainly impacts the understory and middlestory, though it can affect future composition of the overstory. Prescribed fire selects against understory red maple, sugar maple, American beech and yellow poplar, and favors regeneration of oak (Brose et al. 1999). Fire produces other favorable changes in the understory by promoting development of herbaceous vegetation and soft mast producers (Thor and Nichols 1973, Hamilton 1981). A combination of prescribed fire and shelterwood cutting for favoring oak regeneration has also been tested (Brose et al. 1999).

Although cutting, girdling, and prescribed fire can all be used to increase the development of understory structure, soft mast producers, and oak regeneration, these practices differ in several respects. Shelterwood cutting generates revenue as stems removed can be sold as pulp and sawlogs, whereas girdling and girdling combined with herbicide treatment require an investment on the part of landowners and managers. Prescribed fire also represents an investment, but is generally less labor-intensive than cutting or girdling independent stems. Prescribed fire is also more suited to managers with the appropriate training in firing techniques and fire control than non-industrial private landowners. Girdling techniques represent an attractive alternative for those non-industrial private landowners with a primary interest in wildlife who do not wish to have commercial logging take place on their land. Girdling may also be more feasible for those landowners who may be interested in carrying out the treatments themselves on a part-time basis. Logging damage to residual trees (Miller 1996) and substantial soil disturbance can accompany shelterwood cutting, whereas these do not occur in girdling.

Although the viability of shelterwood cutting, girdling, and prescribed fire for guiding plant species composition and stimulating the development of herbs, shrubs, and tree regeneration have been investigated in previous studies, testing of these treatments in different regions is incomplete. Differences in factors such as species composition, site characteristics, and even deer density are likely to influence the effectiveness of these practices at regional and local levels. Thus, additional tests of these practices are needed in order to adapt and refine them for a given region.

Previous work

In East Tennessee in 2000, a replicated test was initiated involving shelterwood cutting, wildlife thinning, wildlife thinning with prescribed fire, and prescribed fire alone for increasing the availability of light and other resources needed to stimulate understory development, oak regeneration, and mast production for wildlife. Within each replicate stand, full sets of treatments and controls were implemented within and outside a 2.4 m (8 ft) fence to investigate the effects of deer browsing on understory vegetation responding to treatments. Jackson (2002) documented understory vegetation and tree regeneration before and after the implementation of treatments in 2000 and 2001, and Basinger (2003) continued to follow the development of understory vegetation structure, as well as quantifying mast production and invertebrate availability.

Present study

In 2003, a follow-up study was conducted to investigate third-year effects of the treatments implemented on understory species composition, percent cover of herbs and soft mast producers, tree seedling and sapling density, vertical structure, and oak regeneration. Mast production, crown size of canopy white oaks, rodent depredation rates in mast collection baskets, and snags were also quantified.

Objectives

Specific objectives of this study were to document:

1. Third-year effects of prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting on the density and size of oak regeneration and woody competitors.
2. Third-year effects of prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting on understory composition and the development of understory structure.
3. Effects of deer browsing on plant response from prescribed fire alone, wildlife thinning, wildlife thinning with prescribed fire, and shelterwood cutting.
4. White oak acorn production within the control and shelterwood cutting and wildlife thinning treatments.

CHAPTER II

METHODS

Study area

Chuck Swan State Forest and Wildlife Management Area is located within the Southern Appalachian Ridge and Valley province in Union and Campbell counties on Highway 33, approximately 1.5 hours driving time north of Knoxville (Figure 1). In 1934, the Tennessee Valley Authority acquired the area as part of the land acquisition prior to the construction of Norris Dam. The land area is approximately 9,825 ha (24,279 ac) with half the area historically small family farms. Experimental forestry work and timber inventories began as early as 1934. Forest stand structure consists of 35% pine and about 65% hardwoods with 20% of the stands ranging from 90-200 years in age. Wildlife management and recreational development started in 1947. Around 607 ha (1500 ac) have been set aside and managed as wildlife food plots (TDADF 2005). Recreational activities include hunting, fishing, hiking, camping, and site seeing. A forest ranger was assigned to the area in 1973 to supervise the management of the area. The Tennessee Division of Forestry and the Tennessee Wildlife Resources Agency both manage the area for the improvement of wildlife habitat and forest stand conditions.

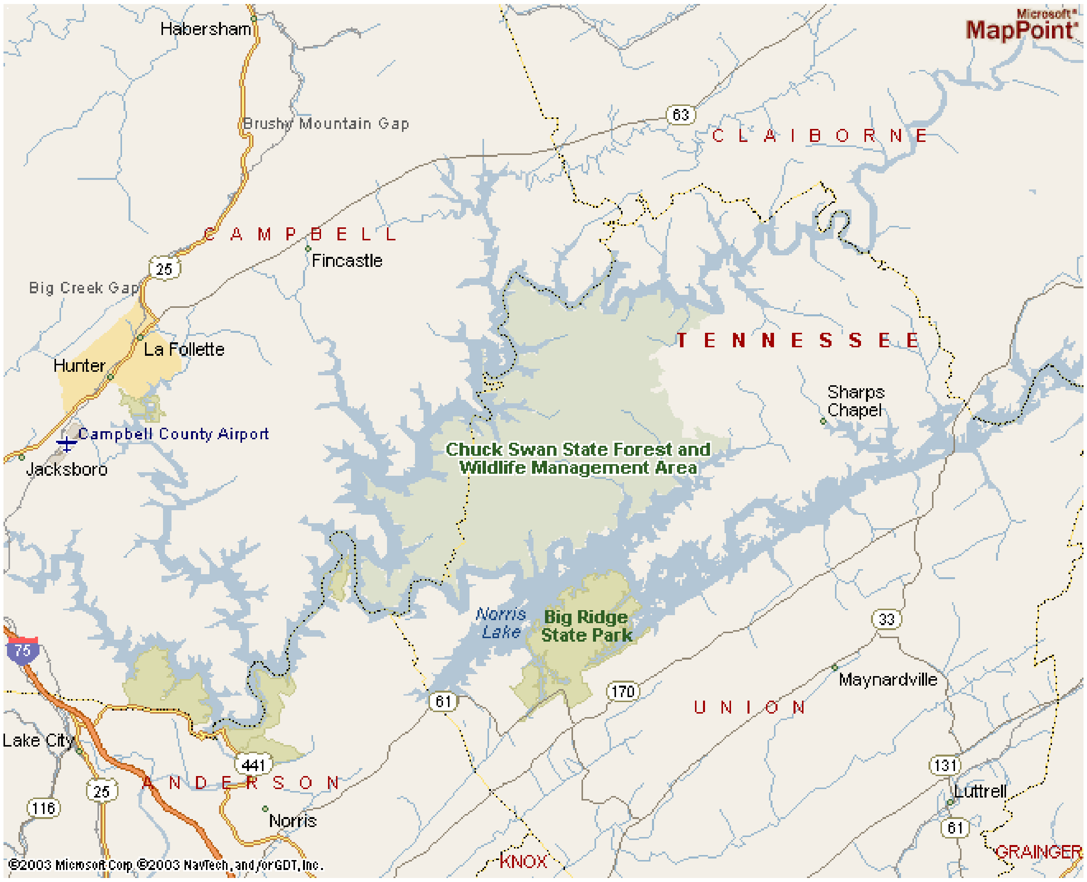

Figure 1. Location of Chuck Swan State Forest and Wildlife Management Area.

Experimental design and plot layout

In 2000, four similar 9.7 ha (24 ac) stands were delineated for study. Each stand was divided into twelve .81 ha (2 ac) cells (Figure 2). Each of four treatments and a control were assigned at random to 2 cells within each stand. A fifth treatment was assigned to 2 cells within each stand for future research purposes, and was not included in the 2003 study described here. This layout resulted in a randomized complete block design. Half of each stand was also fenced with a 2.4 m (8 ft) fence to preclude deer, and each half included a full complement of treatments and a control

Fenced

Wildlife Thinning With Prescribed Fire	Shelterwood Cuttting	Prescribed Fire Alone
Control	Wildlife Thinning	

Unfenced

Wildlife Thinning With Prescribed Fire	Shelterwood Cutting	Prescribed Fire Alone
Control	Wildlife Thinning	

Figure 2. Illustration of experimental design and silvicultural treatments implemented at Chuck Swan State Forest in 2001.

(Figure 2). Each stand had an average slope of 24-30 percent, elevation ranging from 305 m-488 m (1000 ft-1600 ft) above sea level with a northwest aspect. Stands were comprised of mixed hardwoods 60-80 years of age with a basal area ranging from 20 m^2 -24 m^2 per ha (90 ft^2 -105 ft^2) basal area per ac. Most numerous species were maple, oak, hickory with very little pine.

Three permanent sampling plots were established within each cell (Figure 3). Thus, a total of 144 plots were sampled in the study. The plots were at least 30.5 m (100 ft) from the treatment edge and 30.5 m (100 ft) from adjacent cells to minimize light edge effects (Figure 3). Both shelterwood and wildlife thinning were reduced to a target residual basal area of 11 m^2-13 m^2 / ha (50 ft^2-60 ft^2/ ac).

Treatments

The shelterwood treatment were carried out by a logging contractor from June 19 to July 20, 2001 using one sawyer in the woods for felling, one bulldozer operator for skidding, and one person at landing for log trimming and loading. Stands were marked based on timber and regeneration goals, and the target basal area was 11.5 m^2/ha (50 ft^2/ac). Oak species were favored during marking, while red maple, yellow poplar, and American beech were selected against.

Girdling combined with herbicide treatment of cut surfaces was implemented with the goal of enhancing habitat and food production for wildlife. Hereafter, this treatment will be referred to as wildlife thinning. The wildlife thinning treatment was

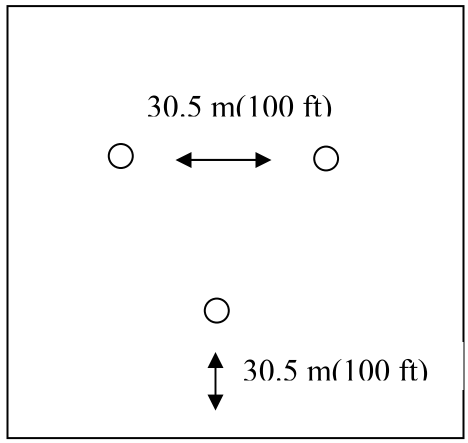

Figure 3. Layout of sampling plots within silvicultural treatments and control cells in each replicate stand treated at Chuck Swan State Forest.

completed in late February through March of 2001, and was accomplished by using a chainsaw or hatchet to girdle trees selected for killing, followed by spraying cut surfaces with Garlon 3A in a 50:50 mixture with water. This mixture was recommended by a representative of the manufacturer, DuPont Chemicals. Smaller stems were felled with a chainsaw, and the cut surfaces of stumps were similarly treated with Garlon 3A to prevent sprouting. As was the case for the shelterwood treatment, the target basal area for the wildlife thinning treatment was 11.5 m^2/ha (50 ft^2/ac). In contrast to the shelterwood treatment, stems were selected for either retention or killing based on their value for wildlife. Examples of species selected for treatment include red maple, yellow poplar, sourwood and Virginia pine. Oak species, persimmon and select stems of blackgum, American beech, and hickory species were favored.

The prescribed fire alone and prescribed fire combined with wildlife thinning treatments were accomplished by prescribed burning in April, 2001. Stands were burned on April 9, 10, 20, 23, and 27, 2001. Details on fire weather conditions for these dates are described by Jackson (2002), and flame heights averaged 0.9-1.2 m (3-4 ft) above ground.

Measurement of treatment effects on overstory

Circular plots with a radius of 11.3 m (37 ft) and .04 ha (0.1 ac) area were established at each of the 3 sampling locations per cell (Figures 3, 4). All trees >11.4 cm (4.6 in) dbh within this plot were recorded by species and measured for dbh. A cloth dbh tape

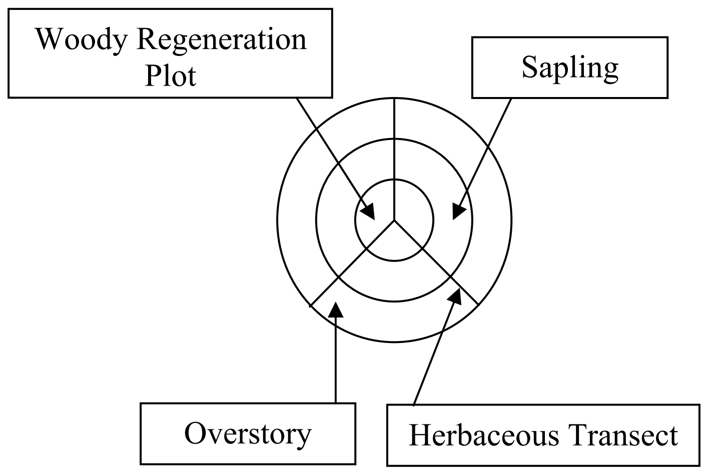

Figure 4. One of three sets of plots and transects used per silvicultural treatment and control cell within each replicate stand treated at Chuck Swan State Forest in 2001.

was used to measure dbh, and these measurements were used in subsequent calculations of basal area. Basal area per ha and ac also was estimated using a 10-factor prism. The number of snags (dead standing timber) >15.24 cm (6 in) in dbh was recorded in each 11.3 m (37 ft) circular plot. A hand-held densiometer was used to measure canopy coverage 5.6 m (18.37 ft) from plot center in each of the four cardinal directions. At each location, a reading was taken in each of the four cardinal directions, and an average was calculated for each location.

Measurements of regeneration of oak and woody competitors

A circular plot with a radius of 3.6 m (11.81 ft) and an area of .004 ha (.01 ac) was established around plot center and nested within each of the larger .04 ha (0.1 ac) overstory plots (Figure 4). Within plots of this size, all woody vegetation less than or equal to 1.4 m (4.5 ft) tall was identified and tallied in one of two height classes: <10 cm (4 in) tall and 10 cm – 1.4 m (4 in-4.5 ft) tall. These height classes were determined based on vegetation height required to provide cover for young wild turkey broods (Harper 1998).

A plot of intermediate size with a radius of 5.7 m (18.70 ft) and area of .01 ha (.025 ac) was established around the same center point used for each of the .004 ha (.01 ac) and .04 ha (0.1 ac) plots in order to tally woody plants <11.4 cm (4.6 in) dbh and >1.4 m (4.5 ft) tall by species (Figure 4). All stems within the size classes were recorded into one of four diameter sub-classes: < 2.54 cm (1 in), 2.54 cm – 5.8 cm (1-2 in), 5.9 cm – 7.62 cm (2.04-3 in), and > 7.62 cm (>3 in).

Measurements of understory vegetation composition and structure

Percent cover of herbaceous plants, recumbent woody vines and *Rubus spp.* was measured along three 11.3 m (37.07 ft) transects radiating out from plot center at 0, 120, and 240 degrees within each of the three sampling plots within each treatment cell (Figures 3, 4). Plants intersecting each transect were identified to species, and the length of transect covered in each instance was recorded to calculate percent cover along the transect. The height of the herbaceous and recumbent woody vines and *Rubus spp.* canopy was measured at 2 m (6.56 ft.) intervals along each transect to help quantify vertical structure.

Vegetation structure was further quantified with a density board divided into four 1500 cm^2 (232.5 in^2) sections. The height interval for section 1 was 0-50 cm (0-19.68 in), section 2 was 51-101 cm (20.07–39.76 in), section 3 was 102-151 cm (40.15-59.44 in), and section 4 was 152-202 cm (59.84-79.52 in). Measurements of foliage density were taken 15 m (49.21 ft) directly upslope and downslope from each plot center. Upslope and downslope measurements were later averaged for each plot. During measurements, percent vegetation coverage was estimated separately for each section of the board. A 1 was recorded if there was only 0–20 percent coverage, a 2 was recorded for 21–40 percent coverage, a 3 was recorded for 41-60 percent coverage, a 4 was recorded for 61-80 percent coverage, and a 5 was recorded for 81-100 percent coverage.

Finally, the percent of the forest floor covered by the crowns of woody species less than or equal to 5 m (16.40 ft) tall was visually estimated in the .01 ha (.025 ac) plot. The percent of the shrub crown cover comprised of soft-mast producers was visually estimated.

Measurement of effects of deer browsing

Effects of deer browsing on the response of oak regeneration and understory vegetation to treatments were not quantified using direct measurements or tallies such as the number of seedling stems browsed. Instead, potential effects of deer browsing were investigated by conducting statistical comparisons of the variables measured between fenced and unfenced sets of plots.

Measurement of white oak acorn production

Crown dimensions of 30 previously selected and identified white oaks were determined using a transect tape to measure crown width along four azimuths spaced 45 degrees apart. Two additional azimuths were added for the 2003 measurements at the suggestion of Basinger (2003), who measured the same trees in 2001 and 2002. Dbh was also re-measured and recorded for each tree. Acorn production from these trees was determined using three 1 m^2 (10.76 ft^2) baskets placed under the canopy of each tree. The baskets were constructed from a plastic tube formed into a circle with a mesh fabric bag hanging below to collect the acorns as they dropped. Three wooden stakes supported the baskets 1 m (3 ft) above the ground. Acorn collection was completed weekly from September through December, 2003. Rodent depredation rates in the mast collection baskets were quantified by marking and placing 50% of the sound acorns collected that week back into the baskets. Acorn predation was determined by the proportion of marked acorns removed between collection intervals. The percentage of sound acorns was determined by floatation in water (Schopmeyer 1974, Basinger 2003).

Data analysis

The balanced randomized complete block design allowed the use of Analysis of Variance (General Linear Model (GLM) procedure, SAS Institute, 2000) to test specific hypotheses about the effects of treatments on vegetation response. Due to relatively few cases of browsing observed in the field, statistical tests of differences between fenced and unfenced sets of treatments in understory vegetation variables were run at the outset of the analysis. No significant differences were found between fenced and unfenced sets of treatments for any understory variable. As a result, fenced and unfenced treatment plots were considered equivalent, and it was possible to increase the number of replicates from 4 to 8 in order to increase statistical power.

CHAPTER III

RESULTS

Treatment effects on overstory

As expected, canopy cover was significantly greater in the controls than all treatments except for prescribed fire alone (Table 1). The shelterwood, wildlife thinning, and wildlife thinning with prescribed fire treatments contained less canopy cover than prescribed fire alone (Table 1). The control and shelterwood treatments contained fewer snags per ac than the prescribed fire alone and wildlife thinning with prescribed fire treatments. Both basal area of trees >11.4 cm (4.6 in) dbh calculated from diameter measurements and basal area estimated with the 10 factor prism differed among treatments (Table 2). Analysis of both measures of basal area indicated the control had more basal area than the wildlife thinning, wildlife thinning with prescribed fire, and shelterwoood treatments.

Table 1. Overstory measurement means (± SE) within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Treatment	**Percent canopy cover**[b]	**Number of snags per ac**[a]
Control	88 (1)A	24 (5)B
Prescribed Fire Alone	85 (1)A	53 (11)A
Wildlife Thinning	73 (2)B	41 (20)AB
Wildlife Thinning With Prescribed Fire	63 (3)B	52 (11)A
Shelterwood	77 (2)B	24 (10)B

Means with the same letter in the same column are not different (P>0.05).

[a]ANOVA statistics: (P=.0003)

[b]ANOVA statistics: (P=.0001)

Table 2. Basal area per ac measurements mean (± SE) within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Treatment	Basal area using 10 factor Prism[a]	Basal Area using DBH[b]
Control	101 (5)A	120 (9)A
Prescribed Fire Alone	87 (6)A	111 (8)A
Wildlife Thinning	68 (6)B	80 (8)B
Wildlife With Prescribed Fire	64 (4)B	87 (7)B
Shelterwood	63 (4)B	85 (8)B

Means with the same letter in the same column are not different ($P>0.05$).

[a]ANOVA statistics: ($P=.0004$)

[b]ANOVA statistics: ($P=.0440$)

Basal area calculated from diameter measurements was consistently greater than that estimated with the 10 factor prism across all treatments and the control.

Regeneration of oak and woody competitors

The number of saplings <10 cm (3.9 in) in height of various species was quite variable (Table 3). There were no differences among treatments and controls for oak or any other species in this size class except black cherry, which was significantly more abundant in the control than in the treatments. There were significant differences in the abundance of sumac, and yellow poplar in the >10 cm-1.4 m (4 in-4.59 ft) tall size class, but no differences for oak species in this class (Table 4). Sumac was more abundant in the wildlife thinning with prescribed fire treatment than in the control and the wildlife thinning treatment. Yellow poplar was more abundant

Table 3. Mean (± SE) stems per ac <10 cm (4 in.) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Species	Treatment					P Value
	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife Thinning With Prescribed Fire	Shelterwood	
American Beech	4 (4)A	13 (9)A	0 (0)A	4 (4)A	0 (0)A	0.2452
Black Cherry	114 (42)A	25 (25)B	13 (9)B	13 (13)B	25 (19)B	0.0353
Blackgum	401 (128)A	316 (103)A	299 (102)A	304 (91)A	274 (68)A	0.2791
Flowering Dogwood	8 (8)A	21 (15)A	0 (0)A	8 (8)A	38 (22)A	0.4178
Grapevine	30 (19)A	139 (486)A	51 (23)A	236 (123)A	63 (26)A	0.1219
Hickory spp.	13 (9)A	51 (19)A	97 (76)A	21 (11)A	34 (20)A	0.5295
Red Maple	3530 (639)A	3753 (451)A	3821 (635)A	2151 (353)A	4027 (639)A	0.4605
Red Oak spp.	89 (27)A	181 (69)A	207 (58)A	93 (24)A	25 (14)A	0.1285
Sassafras	156 (78)A	746 (154)A	412 (149)A	1046 (355)A	468 (112)A	0.1859
Sourwood	0 (0)A	0 (0)A	4 (4)A	0 (0)A	0 (0)A	0.4509
Sugar Maple	101 (46)A	0 (0)A	0 (0)A	0 (0)A	21 (12)A	0.0854
Sumac spp.	0 (0)A	80 (48)A	25 (13)A	55 (35)A	8 (8)A	0.1951
White Oak spp.	557 (212)A	401 (154)A	228 (92)A	295 (139)A	350 (164)A	0.3111
Yellow Poplar	202 (65)A	1438 (554)A	510 (122)A	1387 (504)A	848 (182)A	0.2478

Means with the same letter in the same row are not different (P>0.05).

Table 4. Mean (± SE) stems per ac 10 cm-1.4 m (4 in-4.59 ft) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Species	Treatment					**P Value**
	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife Thinning With Prescribed Fire	Shelterwood	
American Beech	321 (126)A	447 (246)A	283 (92)A	53 (22)A	114 (42)A	0.3750
Black Cherry	274 (73)A	93 (24)A	169 (45)A	42 (20)A	224 (65)A	0.1531
Blackgum	877 (236)A	1050 (222)A	1299 (213)A	1700 (381)A	1333 (309)A	0.7637
Flowering Dogwood	186 (106)A	67 (39)A	0 (0)A	76 (42)A	599 (339)A	0.0634
Grapevine	240 (61)A	557 (110)A	270 (95)A	1071 (487)A	789 (215)A	0.2132
Hickory spp.	363 (103)A	270 (71)A	257 (66)A	198 (69)A	283 (57)A	0.1049
Red Maple	8279 (1959)A	6625 (1943)A	8907 (1503)A	4297 (1136)A	8072 (1450)A	0.4619
Red Oak spp.	536 (130)A	1160 (243)A	1771 (869)A	654 (124)A	671 (192)A	0.2912
Sassafras	751 (230)A	5331 (1048)A	1780 (368)A	7760 (2486)A	2885 (616)A	0.1179
Sourwood	97 (37)A	194 (76)A	266 (82)A	240 (81)A	202 (101)A	0.8077
Sugar Maple	342 (142)A	25 (19)A	72 (41)A	0 (0)A	245 (68)A	0.1766
Sumac spp.	0 (0)B	261 (97)AB	21 (15)B	536 (129)A	160 (56)AB	0.0052
White Oak spp.	3374 (3194)A	1763 (657)A	1969 (953)A	1932 (1070)A	1864 (857)A	0.3149
Yellow Poplar	101 (61)A	3758 (1002)B	738 (186)A	3458 (703)B	1936 (449)A	0.0407

Means with the same letter in the same row are not different (P>0.05).

in the treatments with prescribed fire than in the shelterwood, wildlife thinning, and control.

Differences were not detected within oak or any other species in the <11.4 cm (4.6in) dbh and >1.4 m (4.59ft) tall size classes, except for blackgum and sassafras in the <2.54 cm (1 in) dbh and > 1.4 (4.59 ft) tall size class (Tables 5, 6, 7, 8). Blackgum in the < 2.54 cm (1 in) dbh and > 1.4 (4.59 ft) tall size class was more abundant in the wildlife thinning with prescribed fire and shelterwood treatments than in the remaining treatments and controls (Table 5). Sassafras in the < 2.54 cm (1 in) dbh and > 1.4 (4.59 ft) tall size class was more abundant in the wildlife thinning with prescribed fire than in any other treatment and the control.

Understory vegetation composition and structure

There were no differences in percent cover of herbaceous vegetation either by species or for all species combined among the treatments and control (Table 9). Likewise, there were no significant differences among treatments and the control in mean herbaceous canopy height (Table 9). The percentage of Japanese grass was highest in the shelterwood treatment (65%) and least in the prescribed fire alone treatment (0%).

No difference in percent cover of recumbent woody vines and *Rubus spp.* occurred among treatments and the controls (Table 10).

Table 5. Mean (± SE) stems per ac <2.54 cm (1 in.) dbh and > 1.4 m (4.59 ft) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Species	Treatment					P Value
	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife Thinning With Prescribed Fire	Shelterwood	
American Beech	143 (65)A	2 (2)A	47 (21)A	0 (0)A	12 (5)A	0.4219
Black Cherry	0 (0)A	2 (2)A	7 (5)A	3 (3)A	8 (7)A	0.7317
Blackgum	12 (9)B	18 (11)B	46 (14)B	172 (43)A	78 (36)A	0.0273
Chestnut Oak	0 (0)A	0 (0)A	0 (0)A	2 (2)A	8 (8)A	0.5071
Flowering Dogwood	35 (15)A	23 (14)A	0 (0)A	0 (0)A	23 (9)A	0.2498
Hickory spp.	0 (0)A	14 (9)A	0 (0)A	0 (0)A	8 (5)A	0.4992
Red Maple	164 (59)A	188 (74)A	374 (104)A	234 (61)A	331 (87)A	0.3359
Red Oak spp.	0 (0)A	9 (6)A	29 (24)A	0 (0)A	2 (2)A	0.6265
Sassafras	0 (0)B	97 (29)B	241 (55)A	169 (40)A	51 (19)B	0.0017
Sourwood	34 (12)A	44 (16)A	111 (29)A	115 (31)A	54 (19)A	0.4392
Sugar Maple	0 (0)A	0 (0)A	0 (0)A	0 (0)A	8 (5)A	0.1856
Sumac spp.	0 (0)A	0 (0)A	0 (0)A	44 (34)A	0 (0)A	0.4257
White Oak spp.	2 (2)A	2 (2)A	5 (5)A	2 (2)A	5 (4)A	0.7388
Yellow Poplar	7 (7)A	100 (51)A	66 (21)A	201 (86)A	106 (39)A	0.3501

Means with the same letter in the same row are not different (P>0.05).

Table 6. Mean (± SE) stems per ac 2.54 cm-5.8 cm (1-2 in) dbh and > 1.4 m (4.59 ft) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

	Treatment					
Species	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife With Prescribed Fire	Shelterwood	**P Value**
American Beech	2 (2)A	0 (0)A	0 (0)A	0 (0)A	2 (2)A	0.6223
Black Cherry	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Blackgum	5 (4)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.1468
Chestnut Oak	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Flowering Dogwood	16 (6)A	20 (13)A	0 (0)A	0 (0)A	8 (5)A	0.4947
Hickory spp.	2 (2)A	8 (6)A	0 (0)A	0 (0)A	0 (0)A	0.5705
Red Maple	22 (10)A	12 (8)A	2 (2)A	3 (3)A	10 (5)A	0.3050
Red Oak spp.	0 (0)A	2 (2)A	0 (0)A	0 (0)A	0 (0)A	0.4209
Sassafras	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000.
Sourwood	2 (2)A	5 (4)A	2 (2)A	7 (5)A	2 (2)A	0.8526
Sugar Maple	0 (0)A	0 (0)A	0 (0)A	0 (0)A	2 (2)A	0.4509
Sumac spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
White Oak spp.	0 (0)A	5 (4)A	0 (0)A	0 (0)A	0 (0)A	0.4509
Yellow Poplar	0 (0)A	7 (3)A	0 (0)A	0 (0)A	0 (0)A	0.3058

Means with the same letter in the same row are not different (P>0.05).

Table 7. Mean (± SE) stems per ac 5.9 cm-7.62 cm (2-3 in) dbh and > 1.4 m (4.59 ft) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

	Treatment					
Species	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife With Prescribed Fire	Shelterwood	**P Value**
American Beech	0 (0)A	0 (0)A	5 (4)A	2 (2)A	3 (2)A	0.3258
Black Cherry	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Blackgum	5 (3)A	8 (4)A	5 (4)A	8 (5)A	2 (2)A	0.2849
Chestnut Oak	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Flowering Dogwood	25 (8)A	22 (10)A	22 (8)A	12 (5)A	39 (11)A	0.3180
Hickory spp.	3 (3)A	5 (5)A	2 (2)A	0 (0)A	2 (2)A	0.5684
Red Maple	19 (7)A	22 (8)A	15 (5)A	13 (6)A	25 (7)A	0.4760
Red Oak spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sassafras	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sourwood	2 (2)A	5 (4)A	5 (4)A	5 (4)A	3 (2)A	0.3225
Sugar Maple	0 (0)A	0 (0)A	3 (3)A	2 (2)A	0 (0)A	0.4785
Sumac spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
White Oak spp.	0 (0)A	2 (2)A	0 (0)A	0 (0)A	0 (0)A	0.4199
Yellow Poplar	2 (2)A	8 (5)A	5 (3)A	0 (0)A	3 (2)A	0.4509

Means with the same letter in the same row are not different (P>0.05).

Table 8. Mean (± SE) stems per ac > 7.62 cm (>3 in) dbh and > 1.4 m (4.59 ft) in height within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Species	Treatment					P Value
	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife With Prescribed Fire	Shelterwood	
American Beech	2 (2)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.3587
Black Cherry	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Blackgum	2 (2)A	2 (2)A	0 (0)A	0 (0)A	0 (0)A	0.1578
Chestnut Oak	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Flowering Dogwood	3 (3)A	3 (3)A	0 (0)A	0 (0)A	0 (0)A	0.7508
Hickory spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Red Maple	5 (4)A	2 (2)A	0 (0)A	0 (0)A	3 (3)A	0.6979
Red Oak spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sassafras	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sourwood	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sugar Maple	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Sumac spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
White Oak spp.	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0 (0)A	0.0000
Yellow Poplar	2 (2)A	3 (3)A	0 (0)A	0 (0)A	0 (0)A	0.4509

Means with the same letter in the same row are not different (P>0.05).

Table 9. Mean (± SE) percent cover of prevalent herbaceous species and average height (cm) within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

Species	**Treatment**					**P Value**
	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife Thinning With Prescribed Fire	Shelterwood	
Beggarslice	2.25 (0.41)A	2.57 (0.44)A	2.39 (0.60)A	1.34 (0.21)A	.28 (0.06)A	0.1087
Grass spp.	.01 (0.04)A	.90 (0.28)A	1.00 (0.29)A	.35 (0.07)A	1.24 (0.29)A	0.3140
Hogpeanut	.00 (0.00)A	.12 (0.06)A	.75 (0.25)A	.01 (0.01)A	.23 (0.07)A	0.0515
Japanesegrass	.68 (0.39)A	.01 (0.00)A	.19 (0.09)A	.19 (0.10)A	1.91 (0.86)A	0.4645
Wild Yam	.16 (0.04)A	.10 (0.05)A	.27 (0.08)A	.38 (0.11)A	.15 (0.06)A	0.2929
Total herb coverage	7.61 (1.64)A	6.45 (1.22)A	10.49 (2.56)A	5.57 (1.01)A	9.24 (2.95)A	0.6333
Average Height	11.27 (1.29)A	8.14 (0.92)A	17.64 (2.08)A	11.67 (1.30)A	16.27 (1.73)A	0.0770

Means with the same letter in the same row are not different (P>0.05).

Table 10. Mean (± SE) percent cover of recumbent woody vines and *Rubus spp.* within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

	Treatment					
Species	Control	Prescribed Fire Alone	Wildlife Thinning	Wildlife Thinning With Prescribed Fire	Shelterwood	**P Value**
Greenbrier	.72 (.10)A	.69 (.10)A	.78 (.11)A	1.13 (.23)A	.57 (.10)A	0.7192
Poison Ivy	.12 (.04)A	.08 (.03)A	.41 (.12)A	.14 (.06)A	.14 (.04)A	0.6541
Honeysuckle	.00 (.00)A	.01 (.01)A	.06 (.02)A	.03 (.02)A	.01 (.00)A	0.6676
Virginia Creeper	1.17 (.44)A	.18 (.10)A	.42 (.15)A	.04 (.02)A	.08 (.03)A	0.4293
Rubus spp.	0.00 (.00)A	.15 (.06)A	.01 (.01)A	1.10 (.31)A	1.51 (.60)A	0.2261

Means with the same letter in the same row are not different (P>0.05).

Differences were detected in sections of the density board (Table 11). The control and prescribed fire alone treatments had less vertical vegetation density in sections one and two than the wildlife thinning, wildlife thinning with prescribed fire, and the shelterwood treatments.

Percent cover of soft mast species did not differ among treatments and controls (Table 12). Percent of the forest floor covered by the crowns of all woody plant species combined less than or equal to 5 m (16.40 ft) tall differed between treatments. The wildlife thinning with prescribed fire had a greater percentage of woody plant crown cover than control. Percent crown cover of all woody plant species combined less than or equal to 5 m (16.40 ft) tall varied between the other treatments (Table 12).

Effects of deer browsing

No significant differences were found between fenced and unfenced treatments and controls for any understory vegetation variable. For comparison, means for selected variables are summarized in Table 13.

White oak acorn production

Although there was no statistically significant difference, there was a pattern in which mean acorn production and crown area were greater in the wildlife thinning treatment

Table 11. Mean (± SE) vertical vegetation density measurements[a] within 4 silvicultural treatments and a control at Chuck Swan State Forest in 2003.

	Density Board Height Interval[b]			
Treatment[c]	**1**	**2**	**3**	**4**
Control	2.27 (.27)A	1.60 (.20)A	1.35 (.12)A	1.17 (.09A
Prescribed Fire Alone	2.19 (.29)A	1.63 (.25)A	1.27 (.14)A	1.13 (.09)A
Wildlife Thinning	3.44 (.32)B	2.48 (.30)B	1.75 (.22)A	1.29 (.17)A
Wildlife Thinning With Prescribed Fire	4.13 (.24)B	3.35 (.27)B	2.10 (.20)A	1.40 (.14)A
Shelterwood	4.06 (.23)B	3.46 (.29)B	2.79 (.30)A	2.25 (.26)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=0-50 cm (0-19.68 in); 2=51-101 cm (20.07-39.76 in); 3=102-151cm (40.15-59.44 in);4=152=202cm (59.84-79.52 in)
[c]ANOVA statistics: (P=.0137)

Table 12. Mean (± SE) visual estimates of percent crown cover of soft mast species and all woody plant species combined less than or equal to 5 m (16.40 ft) tall within each .01 ha (.025 ac) plot at Chuck Swan State Forest in 2003.

Treatment	**Percent cover of soft mast species[a]**	**Percent cover of woody species less than or equal to 5 m (16.40 ft) tall[b]**
Control	3.14 (1.29)A	24.04 (2.18)B
Control Burn	2.12 (0.46)A	38.58 (1.82)AB
Wildlife Thinning	1.79 (0.40)A	40.83 (1.77)AB
Wildlife Burn	2.65 (0.80)A	49.16 (1.63)A
Shelterwood	1.79 (0.29)A	41.04 (1.63)AB

Means with the same letter in the same column are not different (P>0.05).

[a]ANOVA statistics: (P=.6950)
[b]ANOVA statistics: (P=.005)

Table 13. Mean (± SE) for selected vegetation variables in fenced and unfenced plots at Chuck Swan State Forest in 2003.

Treatment	**Total Stems <10 cm. (4.0 in.)[a]**		**Total Stems 10 cm-1.4 m (4 in-4.59 ft.)[b]**		**Percent of Herbaceous Vegetation[c]**	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
Control	4200 (1135)A	6207 (673)A	13528 (2357)A	17948 (3245)A	4.25 (0.63)A	2.13 (0.49)A
Prescribed Fire Alone	7253 (2485)A	7076 (986)A	15789 (5571)A	26889 (4712)A	3.37 (0.52)A	4.03 (0.57)A
Wildlife Thinning	4006 (3194)A	7329 (2997)A	15409 (2846)A	20149 (6357)A	7.39 (3.56)A	1.84 (0.43)A
Wildlife Thinning With Prescribed Fire	5026 (1159)A	6199 (486)A	13621 (12591)A	29335 (19214)A	2.58 (1.06)A	1.94 (0.21)A
Shelterwood	6722 (985)A	5642 (783)A	16540 (967)A	21887 (16521)A	2.60 (0.46)A	5.01 (1.01)A

Means with the same letter in the same column are not different (P>0.05).

[a]ANOVA statistics: (P=.4556)

[b]ANOVA statistics: (P=.3748)

[c]ANOVA statistics: (P=.2457)

than in the other treatments and the control (Table 14, 15). The percentage of sound acorns removed from collection baskets by wildlife was approximately 25% (Table 14).

Table 14. Mean (± SE) acorn production within 3 silvicultural treatments at Chuck Swan State Forest in 2003.

Treatment	**Mass of Sound ($oz./ft^2$)[a]**	**Sound (ft^2)[b]**	**Unsound (ft^2)[c]**	**Percent Sound**	**Crown Area (ft^2)[d]**
Control (n=10)	.04 (.02)A	.18 (.07)A	.53 (.33)A	25.00	935.30 (135.39)A
Shelterwood (n=10)	.02 (.01)A	.13 (.08)A	.22 (.12)A	36.80	1022.00 (175.86)A
Wildlife Thinning (n=10)	.07 (.04)A	.36 (.23)A	.94 (.39)A	27.60	1076.62 (173.06)A

Means with the same letter in the same column are not different (P>0.05).

[a]ANOVA statistics: (P=.1055)

[b]ANOVA statistics: (P=.2282))

[c]ANOVA statistics: (P=.3498)

[d]ANOVA statistics: (P=.1520)

Table 15. Acorns removed from baskets by wildlife at Chuck Swan State Forest in 2003.

Acorns set out	**Acorns removed**	**Percent of predation**
43	11	25.59

CHAPTER IV

DISCUSSION

Treatment effects on overstory

The results that basal and canopy cover were reduced with shelterwood cutting and wildlife thinning were not unexpected as a primary goal of these treatments was to reduce the number of stems and open up the main canopy. The measurements of basal area obtained with the 10 factor prism and dbh tape revels the mean residual basal area achieved was a bit higher than the target residual basal areas of 11 m^2-13 m^2/ha (50 ft^2-60 ft^2/ ac). However, the basal areas measured were reasonably close to the target values, particularly in the case of basal area measured with the 10 factor prism.

It is interesting that basal area measured with the 10 factor prism was consistently lower than basal area calculated from dbh measurements. Basal area derived from dbh measurements is likely to be more accurate than basal area measured with the prism due to the fact that decisions concerning whether a tree is in or out of the plot must be made when using the prism, whereas no judgements are necessary beyond reading the tape when measuring each stem with a dbh tape. Although the prism method of measuring basal area is much more rapid and efficient than measuring the dbh of all stems in a plot, it appears prism basal area measurements may tend to underestimate true basal area.

Due to the girdling technique, more snags were expected in the wildlife thinning treatments than in the other treatments. The snags will likely provide cavities and food for birds, mammals and amphibians such as salamanders, toads, and frogs for many years (Scott et al. 1977). As many as 66 species of wildlife use snags in this region of Tennessee, including the pileated woodpecker, wood duck, barred owl, gray squirrel, raccoon, and great crested flycatcher. These species all use snags for reproduction, roosting, and foraging. Even when snags become down wood, they still provide wildlife foraging, nesting, cover, and protection from predators (Titus 1985). Black bears in the Southern Appalachians have been known to use hollow down snags for den sites to hibernate and give birth during the winter (Beeman and Eagar 1977). Although few snags on the study sites were large enough for black bear use, wildlife thinning in stands with larger diameters could produce these.

Direct effect of the treatments on the overstory initiated a chain of indirect events in the understory. Site factors such as moisture regime, fertility, and aspect broadly determine the set of plant species that are adapted to the site, whereas natural disturbances and disturbances in the form of silvicultural treatments such as shelterwood cutting, wildlife thinning, and prescribed fire further shape species composition and structure, especially in the understory. Effects of treatments on overstory structure affect all strata below the overstory, which includes saplings and shrubs forming the middlestory, and herbaceous species, shrubs, and tree regeneration in the understory. The structure of the middlestory and taller vegetation such as shrubs in the understory also influence the development of vegetation in the understory. Seed dispersal from outside the stand determines what new species may arrive following treatment, and amounts of seed dispersed (e.g., white oak acorns) are related to canopy structure.

Regeneration of oak and woody competitors

The lack of significant differences in the number of regenerating oak across treatments suggests that the oak species on the study sites have not yet responded strongly to the treatments. The data collected suggests a pattern of greater mean number of red oak stems in the < 10 cm (4 in) and 10 cm – 1.4 m (4 in – 4.59 ft) height classes in the prescribed fire alone and wildlife thinning treatments. However, none of these differences were statistically significant. Before you can expect significant oak regeneration, sufficient fruit production must occur. This did not happen in 2001 and 2002 (Basinger 2003).

Although differences were not significant, the greater mean number of grape stems sampled in the treatments with prescribed fire suggest grape may have been stimulated by prescribed fire on the study sites. Previous research has demonstrated a positive response of grape in areas with frequent fire, including oak communities (Paulsell 1957, DeSelm et al. 1974, Grelen 1975). In an experiment involving different frequencies of prescribed fire, grape was more abundant on plots burned every 5 years in late winter than in unburned plots (DeSelm et al. 1974).

Lower numbers of black cherry in the treatments with prescribed fire than control illustrates its sensitivity to fire (Lorimer 1985). The reason for lower numbers of black cherry in the treatments without prescribed fire is less clear. The greater abundance of sassafras in the <2.54 cm and > 1.4 m tall (<1 in > 4.59 ft tall) size class in the wildlife thinning and wildlife thinning with prescribed fire treatments than in the remaining treatments and control suggests opening the canopy and prescribed burning favored this species. Sassafras is a fire-adapted species (Burns and Honkala 1990). Post-fire regeneration of sassafras occurs in several forms, such as root suckering or germination from the existing seedbank. Earlier in this study, Jackson (2002) described a strong response of sassafras to burning. The abunndance of sumac in the 10 cm–1.4 m (4 in–4.59 ft) size class in the wildlife thinning with prescribed fire treatment than in the control and wildlife thinning treatment indicates fire also stimulated this species. In an earlier study (Scheiner et al. 1981), found sumac species had high frequencies 3 years post-fire. Sumac seeds are apparently resistant to high temperature, and fire may stimulate germination (Marks 1979). Greater mean numbers of yellow poplar in all treatments compared with the controls was not surprising given the intolerance of this species to shade (Burns and Honkala 1990) and the additional light availability within the treatments. Seeds of yellow poplar remain viable in the litter and duff for years and germinate readily following a fire (Shearin et al. 1972). Thus, follow-up prescribed fires are required to suppress young seedlings (Shearin et al. 1972). The significant increases in mean numbers of flowering dogwood in the shelterwood treatment, and blackgum in the shelterwood and wildlife thinning with prescribed treatments suggest reduced competition with overstory vegetation, and perhaps understory vegetation stimulated these species as well.

The increases in potential competitors of oak, combined with the lack of significant increases in oak three years post-treatment, suggests competition between these species and regenerating oaks is substantial. Many of these species are shade intolerant and well-adapted to disturbance (Burns and Honkala 1990) and may be better equipped to take advantage of the rapidly increased abundance of light and other resources for the first few years following treatment implementation than oak. In the case of the treatments with prescribed fire, repeated prescribed burning may be necessary to cause a significant shift toward greater oak abundance. It is also possible that more time is needed for oak regeneration to build up in the understory, which can be directly related to mast production.

Understory vegetation composition and structure

The lack of differences in percent cover of individual herbaceous species and combined herbaceous cover was likely the result of high variability in the distribution of various species both within and between replicate stands. The paucity of herbaceous vegetation among treatments may have been a result of competition from woody vegetation. Herbaceous cover can be out-competed by shrubs where fire is suppressed (Thor and Nichols 1973, Taylor 1973). Further, the study sites at Chuck Swan State Forest were moderately productive, and competition between the predominantly woody understory in these stands and herbaceous cover was likely intense.

Although differences in the cover of Japanese grass were not significant, there was a pattern in which mean cover of this species was greater in the shelterwood treatment. One factor that differentiates the shelterwood treatment from the remaining treatments is soil disturbance. Japanese grass in the shelterwood was mainly observed along the skid trails created during treatment implementation, and these trails may have provided favorable conditions for the establishment and spread of this invasive species. Japanese grass is known to rapidly colonize disturbed soil along trails, roads, and ditches (Miller 2004).

The result that all treatments except prescribed fire alone increased foliage density as measured with the density board in the 0-50 cm (0-19.68 in) and 51-101 cm (19.69 – 39.8 in) sections above ground indicates vegetation structure for wildlife was enhanced by the shelterwood, wildlife thinning, and wildlife thinning with prescribed fire treatments. The fact that similar increases in foliage density did not occur in the prescribed fire alone treatment suggests overstory reduction was more important in increasing structure than prescribed fire.

Basinger (2003) suggested that by year two following treatment implementation, there was a pattern in which soft mast production appeared to be increased by the prescribed fire alone, shelterwood, and wildlife thinning with prescribed fire treatments. The lack of differences in percent cover of soft mast species in year three indicates that these species had not yet appreciably increased in abundance. Continued monitoring of soft mast species is warranted due to their importance to wildlife (Miller and Miller 1999), and it has been demonstrated that burning enhances berry production for black bears in southern Appalachians (Hamilton 1981).

Effects of deer browsing

The lack of differences in vegetation susceptible to deer browsing between fenced and unfenced plots may have several explanations. First, the fences were only in place for three growing seasons, which may not have been a sufficient time period for differences in plant species abundance and composition to become evident. In an exclosure study conducted in an area of Michigan's Upper Peninsula where deer are overabundant, only slight differences in plant morphological characteristics were evident, and no differences in composition were apparent within and outside exclosures after five years (Kraft et al. 2004). Second, deer populations in the vicinity of the study sites may have been lower during the first three years of this study than in recent years (John Mike, personal communication).

White oak acorn production

Differences were not statistically significant, but the pattern in which crown area and sound acorn production were greatest in the wildlife thinning treatment suggests this treatment may prove to be most beneficial for white oak acorn production. A wildlife thinning properly conducted releases the crowns of favored stems to grow freely, whereas those in a shelterwood may or may not be released. The removal of 25% of sound acorns from collection baskets by wildlife, and an observation of a white-footed mouse in one of the mast baskets, indicates underestimates of true sound acorn production may occur during sampling with mast collection devices. Beck (1977) reported insects and mammals predated approximately 50% of the sound acorns in mast baskets. When food availability is high acorn predation is low, when food availability is low, acorn predation can be expected to increase.

Continued monitoring of acorn production by these white oaks is warranted due to potential effects of year-to-year variation in factors such as weather and insect populations that influence sound acorn production. Acorn production is sporadic from year-to-year (Sharp 1958). Low acorn production is influenced by late spring freezes, temperature, wind, humidity and summer droughts (Van Dersal 1940, Sharp and Sprague 1967), and the proportion of sound acorns can also depend on the populations of insects such as acorn weevils. Most species of oak only produce a good mast crop one out of five years in the Southern Appalachians (Van Dersal 1938, Goodrum et al. 1971, Beck 1977, Burns and Honkala 1990, Smith 1993). In years in which acorn production is low, most of the acorns are consumed by insects such as *Curculio* weevils, rodents, birds and other mammal species (Sork et al. 1993, Williams 1989). Thus, strong competition between turkeys and other wildlife species for acorns likely occurs during these years. Genetics and location play an important role. A study in Pennsylvania indicated that only 30% of mature oaks produce acorns even in good years (Galford, et al. 1991). As a result of genetics, mast years are as variable between individuals within a species as between oak species.

CHAPTER V

CONCLUSION

Oak regeneration and woody competitors

Based on the 2003 data, the response of yellow poplar, sassafras, black cherry, blackgum, and sumac to the treatments was stronger than the response of oak after three growing seasons. Repeated burning or perhaps selective treatment of competing hardwood stems using chemical or mechanical methods may be necessary. Burning at approximately the same time overstory treatments were implemented particularly enhanced the abundance of sassafras and yellow poplar, which likely increased their abundance due to germination from the seedbank and heavy sprouting. In the shelterwood-burn technique (Brose et al. 1999), implementation of prescribed fire is recommended 3-5 years after cutting in order to avoid this situation. Competitors of oak are allowed to sprout and germinate from the seedbank, and are then set back with prescribed fire. Testing of this technique is underway in a related portion of the overall project at Chuck Swan State Forest.

Understory composition and development of understory structure

Treatments did not significantly affect composition of herbaceous species, and this was likely a result of the low overall abundance of herbaceous species and high variability in the herbaceous composition within and between replicate stands. Understory structure up to 101 cm (39.8 in) was significantly increased by the shelterwood, wildlife thinning, and wildlife thinning with prescribed fire treatments. However, this structure was mainly comprised of woody species. As is the case for oak regeneration, additional burning or chemical and mechanical methods may be necessary to shift the understory composition toward herbaceous species.

Deer browsing

Effects of deer browsing were not detected by analyses of the effects of fencing on vegetation susceptible to deer browsing. More direct sampling of deer browsing, such as tallies of browsed stems or classification of browse damage on stems may be needed to detect effects of browsing in the first few years after treatment. Additional time may reveal differences between fenced and unfenced plots, particularly if local deer populations increase.

Acorn production

Mean values for white oak acorn production and crown size were highest in the wildlife thinning treatment. Differences in the means were not significant in 2003, but a trend may be emerging. Further monitoring of these trees should continue to overcome the effects of factors producing year-to-year variation in acorn production.

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APPENDIX

Scientific and common names of species of interest in this project.

PLANT SPECIES

Common Name	Scientific Name
red maple	*Acer rubrum*
sugar maple	*Acer saccharum*
hogpeanut	*Amphicarpa bracteata*
hickory	*Carya spp.*
flowering dogwood	*Cornus florida*
beggarslice	*Desmodium glutinosum*
wild yam	*Dioscorea villosa*
American beech	*Fagus grandifolia*
yellow poplar	*Liriodendron tulipifera*
honeysuckle	*Lonicera spp.*
Japanese grass	*Microstegium vimineum*
blackgum	*Nyssa sylvatica*
sourwood	*Oxydenrum arboreum*
Virginia creeper	*Parthenocissus quinquefolia*
black cherry	*Prunus serotina*
white oak	*Quercus alba*
chestnut oak	*Quercus montana*
black/red oak	*Quercus spp.*
sumac	*Rhus spp.*
sassafras	*Sassafras albidum*
greenbrier	*Smilax glauca*
poison ivy	*Toxicodendron radicans*
grapevine	*Vitis spp.*
Virginia pine	*Pinus virginiana*
persimmon	*Diospyros virginiana*

ANIMAL SPECIES

Scientific Name	Common Name
white-tailed deer	*Odocoileus virginianus*
black bear	*Ursus americanus*
pileated woodpecker	*Dryocopus pileatus*
wood duck	*Aix sponsa*
barred owl	*Strix varia*
grey squirrel	*Sciurus carolinensis*
raccoon	*Procyon lotor*
great crested flycatcher	*Myiarchus crinitus*
wild turkey	*Meleagris gallopavo*

VITA

Daniel Stuart Gordon was born in Miami, Florida on April 4, 1975. He graduated from Miami, Killian Sr. High in 1993. Daniel then attended Pellissippi State Community College in Knoxville, Tennessee where he graduated with an A.S. degree in Business. Transferring to University of Tennessee, Knoxville, Daniel earned a B.S. degree in Wildlife and Fisheries Science with a Forestry minor. After working for a few years, Daniel attended Graduate School at the University of Tennessee where he earned a Master of Science degree in Forestry. Daniel is currently pursing employment in the southern United States.