

OVERSTORY TREE STATUS FOLLOWING THINNING AND BURNING TREATMENTS IN MIXED PINE-HARDWOOD STANDS ON THE WILLIAM B. BANKHEAD NATIONAL FOREST, ALABAMA

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Abstract—Prescribed burning and thinning are intermediate stand treatments whose consequences when applied in mixed pine-hardwood stands are unknown. The William B. Bankhead National Forest in northcentral Alabama has undertaken these two options to move unmanaged, 20- to 50-year-old loblolly pine (*Pinus taeda* L.) plantations towards upland hardwood-dominated stands. Our study of their management employs a randomized complete block design with a three by three factorial treatment arrangement and four replications of each treatment. Treatments are three residual basal areas (50 square feet per acre, 75 square feet per acre, and an untreated control) with three burn frequencies (frequent burns once every 3 to 5 years, infrequent burns once every 8 to 10 years, and an unburned control). To date, only one burn cycle has been completed (all burn units burned once). Stands were thinned from June through December, and burned in December through March. We measured the overstory response to these treatments 1 year after implementation. Pretreatment basal area ranged between 952 and 163 square feet per acre; harvesting reduced basal areas to 51 square feet per acre and 68 square feet per acre in the 50 and 75 retention treatments, respectively. The percentage of total basal area that was loblolly pine remained relatively unchanged posttreatment (47.4 percent pretreatment and 46.5 percent posttreatment). Oak basal area (*Quercus alba* L., *Q. prinus* L., *Q. falcata* Michx., *Q. rubra* L., *Q. velutina* Lam., and *Q. coccinea* Münchh.) increased slightly posttreatment, from 7 percent of total stand basal area to 10 percent. Harvested stands had a 30-percent reduction in percent canopy cover, and light penetration through the canopies ranged from 5 to 25 percent pretreatment to 29 to 60 percent posttreatment. The cool, slow moving burns had no discernable effect on the overstory trees.

INTRODUCTION

Decline and death of southern yellow pines (*Pinus* spp.) due to the southern pine beetle (*Dendroctonus frontalis* Zimmermann) has been detrimental to the health of portions of the William B. Bankhead National Forest (BNF), located in northcentral Alabama. On the BNF, the district ranger and staff have worked with a formal forest liaison board to gain interest and acceptance of the new Forest Health and Restoration Project (FHRP) (U.S. Department of Agriculture Forest Service 2003) to be implemented under traditional Forest Service authorities. Involved parties wished to have a scientific assessment of the effectiveness of the BNF's current management techniques, as detailed in their most recent Land and Resource Management Plan. A goal of this management was to initiate a series of processes that would move mixed hardwood-pine stands towards those dominated by upland hardwood species. Generally, a combination of various techniques (herbicide treatments, prescribed fire, thinning, and shelterwood regeneration harvests) applied at intervals (depending on vegetation response and site characteristics) may have the most profound effect on community structure and composition (Franklin and others 2003, Loewenstein and Davidson 2002, Lorimer 1992, Nowak and others 2002). However, the interactions of these techniques are largely unknown.

Prescribed burning and thinning are intermediate treatments that when applied in oak (*Quercus* spp.)-dominated stands can improve forest health, increase the abundance and size of oak regeneration, and control species composition. This large-scale study was designed to assess the effectiveness of silvicultural techniques used to restore and maintain

upland oak-dominated ecosystems in the northern portion of the BNF. Our objectives for this paper are to summarize the first-year response of the overstory tree species, and to explore changes in canopy composition, structure, and light penetration induced by thinning and burning.

METHODS

Study Area

The BNF, established by proclamation in 1914, has a long history of repeated logging and of soil erosion caused by poor farming practices during the Depression era. The 180,000-acre BNF is in the Strongly Dissected Plateau subregion of the Southern Cumberland Plateau, within the Southern Appalachian Highlands (Smalley 1979). Base age 50 site indices for loblolly pine (*P. taeda* L.); red oaks (*Q. rubra* L., *Q. velutina* Lam., *Q. coccinea* Münchh., and *Q. falcata* Michx.); and white oaks (*Q. alba* L. and *Q. prinus* L.) are 75 feet, 65 feet, and 65 feet, respectively (Smalley 1979).

Study Design

The BNF study employed a randomized complete block design with a three by three factorial treatment arrangement in four blocks. The treatments were three residual basal area (BA) treatments (heavy thin leaving 50 square feet per acre, light thin leaving 75 square feet per acre, and an untreated control) with three prescribed burn frequencies (frequent burns every 3 to 5 years, infrequent burns every 8 to 10 years, and an unburned control; table 1). Each treatment was replicated 4 times, for a total of 36 treatment units. Treatments are representative of management practices described in the BNF's FHRP for restoring oak forests and woodlands (U.S. Department of Agriculture Forest Service 2003).

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Table 1—Thinning and burning treatment implementation schedule (month-yr), by block, for study stands on the William B. Bankhead National Forest, Alabama

Treatment	Harvest goal	Harvest date				Burn return frequency	Burn date			
		Block 1	Block 2	Block 3	Block 4		Block 1	Block 2	Block 3	Block 4
<i>number</i>	<i>feet²/acre</i>					<i>years</i>				
1	0					0				
2	0					10	Feb-06	Dec-06	Jan-07	Mar-08
3	0					3	Feb-06	Jan-07	Mar-07	Jan-08
4	50	Aug-05	Jun-06	Jul-06	Jun-07	0				
5	75	Aug-05	Jun-06	Jul-06	Nov-07	0				
6	50	Aug-05	Aug-06	Dec-06	Sep-07	3	Jan-06	Jan-07	Jan-07	Feb-08
7	75	Aug-05	Dec-06	Dec-06	Sep-07	3	Jan-06	Jan-07	Mar-07	Feb-08
8	50	Sep-05	Dec-06	Aug-06	Oct-07	10	Mar-06	Dec-06	Jan-07	Mar-08
9	75	Sep-05	Dec-06	Jul-06	Oct-07	10	Mar-06	Dec-06	Jan-07	Mar-08

Criteria for stand selection were based on species composition, stand size, and stand age. Treatment units for the study were located on upland sites currently supporting 20- to 50-year-old loblolly pine plantations with a pronounced hardwood component in the understory. Treatment units were at least 22 acres in size with BAs ranging from 95 to 163 square feet per acre.

Commercial thinning was conducted by marking from below smaller trees or trees that appeared diseased or damaged. Hardwoods were preferentially retained. Thinning treatments were completed prior to the initiation of the burning treatments (thinning conducted from June through December). Prescribed burning was conducted during the dormant season (December through March) using backing fires and strip headfires to ensure that only surface fire occurred. See table 1 for treatment implementation schedule.

Field Techniques

We established five 0.2-acre vegetation measurement plots in each treatment unit (stand) and measured plots prior to and one growing season after treatment implementation. All plot centers were permanently marked with rebar, flagging, and GPS coordinates. We permanently tagged all trees >5.5 inches diameter at breast height (d.b.h.) with aluminum tags. Tree distance and azimuth to plot center were recorded. We measured and recorded tree species; d.b.h. (diameter tape, to the nearest 0.1 inch); canopy cover (hand-held spherical densiometer, five measurements at each plot, one 10 feet from plot center in each cardinal direction and one at plot center); and damage (enumerated number of epicormic branches, recorded number of wounds on the lower bole and measured length and height of each wound with a ruler to the nearest inch). Photosynthetically active radiation (PAR) was

measured using two synchronized ceptometers (AccuPAR LP-80, Decagon Devices, Inc., Pullman, WA). One ceptometer was placed in full sunlight and the second ceptometer was used to record light in each stand along predesignated transects. Additional canopy characteristics were assessed using hemispherical photographs taken at plot centers and analyzed using HemiView Version 2.1 (Delta-T Devices, Cambridge, United Kingdom). A global site factor (GSF) was obtained from analysis of hemispherical photographs taken at each vegetation plot center. All data were gathered pretreatment and posttreatment.

We sampled fuel loading using line transects and employed electronic recording devices and temperature sensitive paints to quantify fire behavior during burns (Clark and Schweitzer this proceedings). We revisited plots once near the end of the growing season to document recruitment and tree growth.

Statistical Analysis

We used analysis of variance (ANOVA) to test differences and interactions at the stand level. All analyses were performed in SAS (2000). ANOVA was performed using time of treatment implementation as block, harvest intensity, and prescribed burn interval as treatments, and the mean of vegetation plot measurements by stand as replicates. If no interaction existed, treatment effects were assessed separately using Tukey's studentized range test on main effect means using a $P < 0.05$ level of significance.

RESULTS

Overstory Composition and Structure

We measured 10,448 trees with diameters that ranged from 5.6 to 24.3 inches. Twenty-three different species were identified in these plots. There were three pine species,

dominated by loblolly, with a smaller portion of Virginia (*P. virginiana* Mill.) and shortleaf (*P. echinata* Mill.). Other species included upland oaks (chestnut oak, white oak, northern red oak, scarlet oak, black oak, and southern red oak); yellow-poplar (*Liriodendron tulipifera* L.); red maple (*Acer rubrum* L.); and black cherry (*Prunus serotina* Ehrh.). We found no significant differences for BA ($P = 0.3116$) and stems per acre (SPA) ($P = 0.5801$) among the nine treatments prior to treatment implementation. BA in the study stands ranged from 95 to 163 square feet per acre (standard deviation 16, $n = 36$), and SPA were 191 to 379 stems per acre (std 48, $n = 36$) (see tables 2 and 3). Pretreatment stand BA was dominated by loblolly pine, which accounted for 87 percent of the BA and 85 percent of the SPA. Data are presented by block to assist research partners who are engaged in other aspects of this large study. The percent of total BA and SPA for upland oaks was 7 and 8, for yellow-poplar 6 and 5, and for both red maple and black cherry 2 and 3, respectively.

The prescribed burning had no effect on overstory composition and structure (species diversity as a percentage of total BA) ($P = 0.6697$), and there were no burn by thinning interactions ($P = 0.7040$). Only one fire has been implemented to date. Fires burned 70 percent of our plots, had a mean maximum temperature of 220 °F, spread at a rate of 10 feet per minute, and were not intense (heat index, the sum of temperature above 90 °F averaged 21,000 °F).²

The thinning treatments resulted in three significantly different BA and SPA groups. Unthinned stands had 132 square feet

per acre of BA and 286 SPA, the light thinned had 68 square feet per acre and 113 SPA, and the heavy thinned stands had 51 square feet per acre and 84 SPA. Although the light thinned stands resulted in 7 square feet per acre less BA than was the goal, the overall objective of creating three distinct residual BA groups was achieved. The majority of the reduction in BA came from the removal of pine; in the light thinning, pine BA was reduced from 118 to 85 square feet per acre, and in the heavy thinning from 113 to 40 square feet per acre. Some hardwood BA was also affected by the thinning treatments. For the upland oaks, light thinning reduced total BA from 8 to 7 square feet per acre and heavy thinning from 9 to 7 square feet per acre. Yellow-poplar BA was similarly reduced, from 8 to 4 square feet per acre in light thinned stands and from 8 to 2 square feet per acre in heavy thinned stands.

These young stands contained predominately smaller diameter trees, and thinning targeted those trees in the 6- to 12-inch diameter classes. There were few tallied trees of any species with a d.b.h. >18 inches for the 24 stands that were thinned. For both the heavy and light thinned treatments, pine SPA in the 6-inch d.b.h. class was reduced 90 percent and 6-inch oak by 38 percent. There was a 78-percent reduction in 8-inch pine and a 65-percent reduction in 10-inch pines (fig. 1). Oak in the 8-inch class declined 17 percent and 10-inch oak was reduced by 42 percent (fig. 2).

Damage

In the thinned stands, 12 percent of the residual trees had damage attributable to logging activities. There was no

Table 2—Basal area for trees >5.5 inches d.b.h., pre- and posttreatment averages by block, for study stands on the William B. Bankhead National Forest, Alabama

Treatment	Pretreatment					Posttreatment				
	Block 1	Block 2	Block 3	Block 4	Block average	Block 1	Block 2	Block 3	Block 4	Block average
	----- square feet per acre -----									
1	124	128	128	148	132	128	135	132	152	137
2	109	113	131	139	123	108	125	133	145	128
3	144	95	123	125	122	151	106	132	132	130
4	108	131	148	140	132	48	60	50	56	53
5	116	137	125	153	133	55	73	67	73	67
6	111	128	124	147	128	51	51	41	55	50
7	102	134	141	147	131	60	58	63	75	64
8	125	150	146	107	132	55	51	49	42	49
9	112	163	137	146	139	58	62	88	78	72

² Stacy Clark. 2009. Unpublished data. Research Forester, U.S. Forest Service, Southern Research Station, P.O. Box 1568, Normal, AL 35762.

Table 3—Stems per acre of trees >5.5 inches d.b.h., pre- and posttreatment averages by block, for study stands on the William B. Bankhead National Forest, Alabama

Treatment	Pretreatment					Posttreatment				
	Block 1	Block 2	Block 3	Block 4	Block average	Block 1	Block 2	Block 3	Block 4	Block average
----- stems per acre -----										
1	299	274	237	251	265	299	274	235	247	264
2	241	268	266	347	281	228	268	259	344	275
3	325	280	372	307	321	323	280	372	305	320
4	191	313	360	322	297	66	81	91	103	85
5	218	237	253	379	272	88	93	104	137	106
6	234	280	261	335	278	88	80	70	95	83
7	218	329	297	328	293	104	92	114	119	107
8	303	306	328	262	300	103	72	84	82	85
9	328	365	237	295	306	133	112	129	126	125

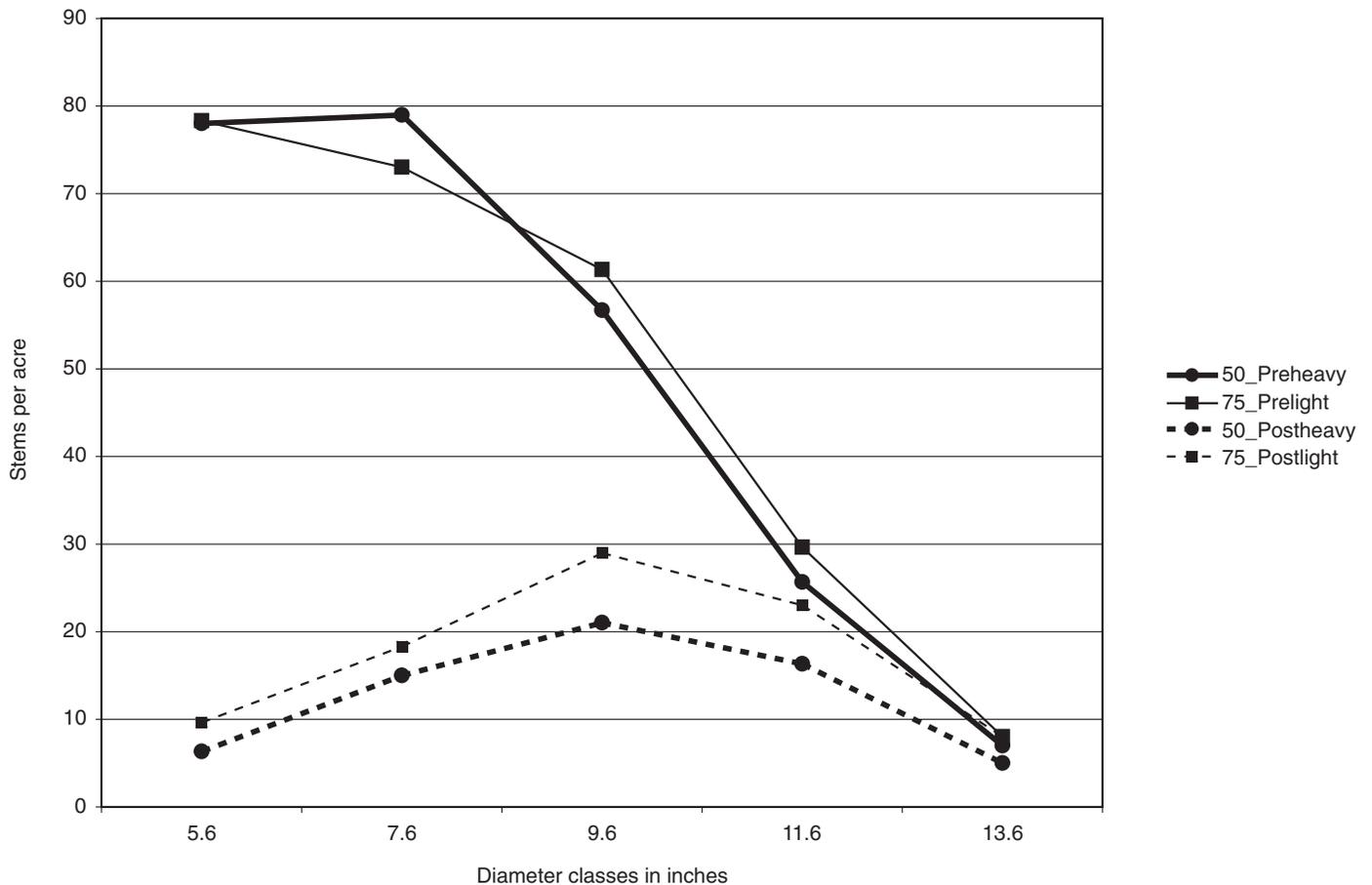


Figure 1—Pre- and posttreatment pine stems per acre for light (75 square feet per acre retention goal) and heavy (50 square feet per acre) thinning treatments on study stands in the William B. Bankhead National Forest, Alabama.

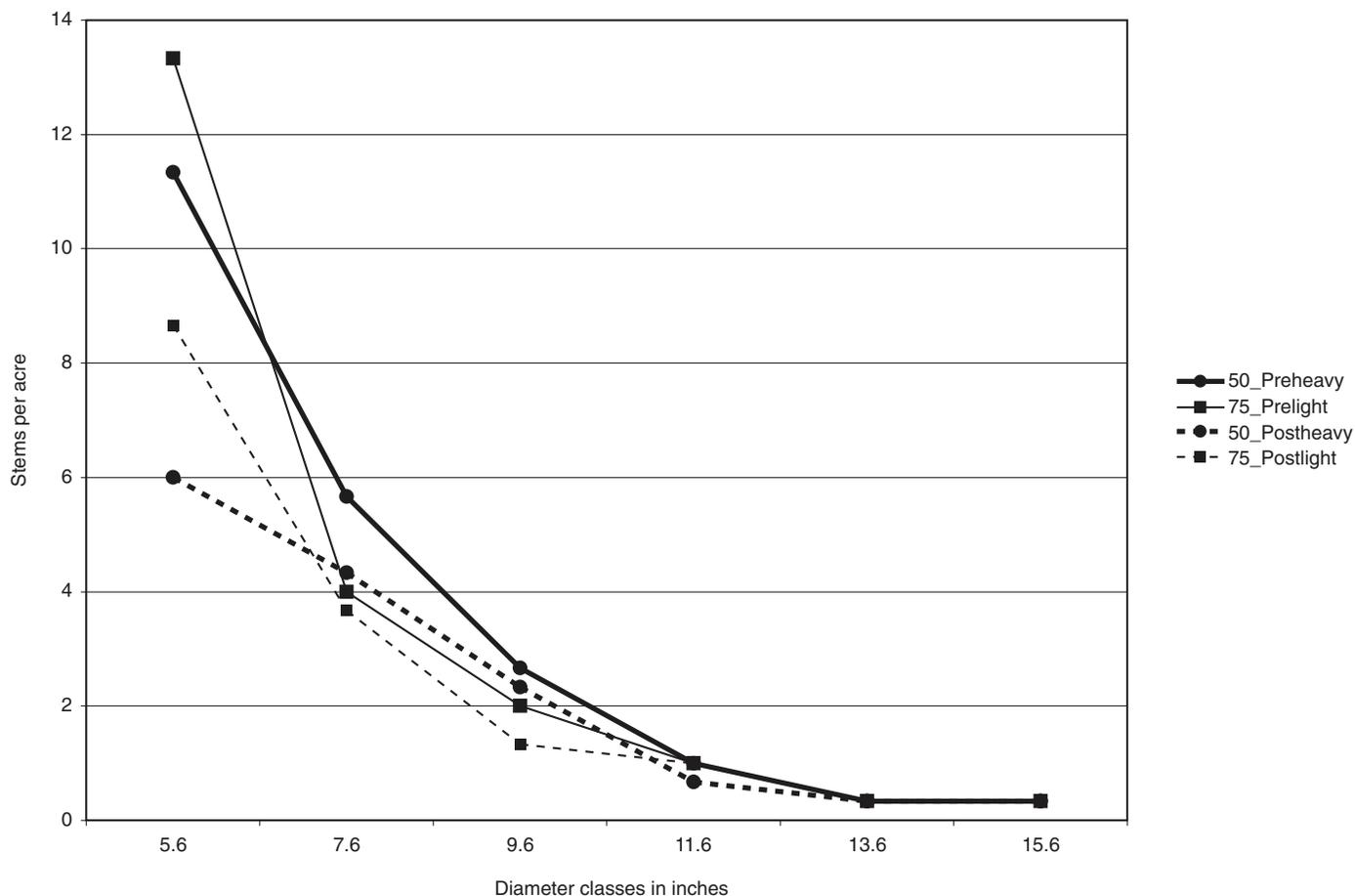


Figure 2—Pre- and posttreatment oak stems per acre for light (75 square feet per acre retention goal) and heavy (50 square feet per acre) thinning treatments on study stands in the William B. Bankhead National Forest, Alabama.

difference in the frequency of damage between the light and heavy thinned stands, with the light thinned stands having an average of 12 wounded residual SPA and the heavy having 10 wounded residual SPA ($P = 0.1316$). Epicormic branching was assessed for the residual hardwood species only. There was no significant difference among the three harvest treatments for the number of residual hardwood SPA that displayed epicormic branching ($P = 0.6995$). In the light thinned treatment, 24 percent of the residuals had some epicormic branching, which averaged 21 branches per tree. In the heavy thinned treatment, 41 percent of hardwood residuals epicormically branched, averaging 18 branches per tree. On average, 57 percent of hardwood stumps sprouted after 1 growing season; sprouting stumps averaged 11 sprouts with an average height of 3 feet.

Canopy Cover

We estimated the change in the light environment in the understory using three methods. Densimeter-derived canopy cover estimates, averaging 93 percent, did not differ among the stands prior to harvest ($P = 0.3427$). Postharvest cover for the control stands (93 percent) was significantly greater

than the light (68 percent) and heavy thinned (66 percent) stands (Tukey $P = 0.0016$). The amount of PAR penetrating these canopies showed a similar trend. Ceptometer data, representing the amount of full sun penetrating the canopy relative to readings obtained in the open, showed that PAR was similar for the light (43 percent of full sun) and heavy thinned stands (52 percent of full sun) posttreatment, and the treated stands differed from the control (9 percent of full sun) (Tukey $P < 0.0001$). The GSF also corresponds with the percentage of total PAR reaching a site relative to a site in the open. There were no GSF differences among treatments prior to harvest ($P = 0.0862$). Postharvest GSF was greater for the light (33 percent) and heavy (38 percent) thinned stands compared to the control (23 percent) (Tukey $P = 0.0039$).

DISCUSSION

Thinning was used in these stands to accelerate natural succession and move the stands towards a species composition dominated by upland hardwoods. Hardwood encroachment into these unmanaged pine plantations commenced following stand initiation 20 to 50 years ago. Additional management objectives included improving

productivity and forest health. Thinning can also increase stand structural diversity and plant and wildlife diversity (Maas-Hebner and others 2005). Congruent studies being carried out by faculty and graduate students at Alabama A&M University will be used to document how these habitat changes impact wildlife.

Intermediate stand treatments such as thinning, and as in this study, prescribed fire, focus their effects on the residual stand. That said, every entry into a hardwood stand should also consider the impact on reproduction. For this paper, we only report on the residual overstory composition and structure; we are documenting the midstory and reproduction response and will report on those elsewhere.

One growing season postfire may not have allowed sufficient time to document any effects on the survival of the residual overstory trees. Waldrop and others (2008) found that hardwood trees had a delayed response to fire, while Arthur and others (1998) found that overstory trees were not damaged by fire. Chiang and others (2008) reported significant fire-related tree mortality in treatments that had experienced prescribed fire; other prescribed fire studies have reported no effect on overstory trees due to the fire itself (Blake and Schuette 2000, Blankenship and Arthur 2006, Franklin and others 2003). Prescribed fire at such low intensities was not expected to have any discernable impact on overstory tree composition or structure in our study. Our fires consumed unconsolidated leaf litter and fine woody fuels (1- and 10-hour fuel) only. Fires in this study were not intense enough to cause scarring on trees 5.6 inches d.b.h. or greater. Other studies have shown scarring due to fire, highly correlated with fire intensity and tree size (Guyette and Stambaugh 2004, Hutchinson and others 2008, McEwan and others 2007, Smith and Sutherland 1999).

Canopy-reducing disturbances influence all tiers of forest structure. Some have shown that large reductions in canopy cover followed by prescribed fire facilitated regeneration of desirable *Quercus* species (Brose and others 1999, Ellsworth and McComb 2003). Changes in cover and light are transient and will alter vegetation response, including seedling recruitment (Chiang and others 2005, Iverson and others 2004). In this study, we did document a change in light penetrating the canopy. Harvesting disturbance which facilitated this increase in light will also stimulate the growth of preexisting saplings, and their growth may narrow the window for reproduction response (Domeke and others 2007). Changes in the size structure of these managed stands may limit the recruitment of light-demanding species as well.

CONCLUSION

Thinning combined with prescribed burning is being examined in mixed pine-hardwood stands in the Southern Cumberland Plateau. The process of moving these stands towards upland-hardwood dominated composition has commenced. The initial response documented in this project was the creation of three different residual BAs. Changes in overstory composition, canopy cover, and subsequent below canopy

light levels resulted primarily from the thinning, as the low intensity burns had no discernable impact on the overstory stratum. These treatments will certainly have an impact on other stratum dynamics, such as midstory sprouting and seedling recruitment. The consequences of repeated fires on the dynamics of these stands will be explored.

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