SEEDLING RESPONSE TO INITIAL OAK WOODLAND RESTORATION TREATMENTS ON THE OZARK NATIONAL FOREST

Jamie L. Schuler, Don C. Bragg, Eric Heitzman, and Jason Milks

Abstract.—Over the last century, the range of oak woodland ecosystems has diminished as woodlands have become more closed-canopy forests. A century of fire suppression efforts has all but eliminated the frequent ground fires necessary to maintain the open canopy characteristics of oak woodland ecosystems. Restoration efforts are underway to return some of the closed-canopy forests to a more open woodland condition. A combination of two prescribed burns followed by a noncommercial thinning treatment (largely thin-to-waste) was used on three sites in the Boston Mountains of Arkansas within the Ozark National Forest between 1999 and 2003. The development of regeneration was assessed 3 years following the thinning treatment. Relative to untreated control sites, the restoration treatment greatly enhanced the development of reproduction. Total stem density was greatest on the upper slope positions of treated sites. Oak reproduction was greatest on the upper slopes on both treated and control sites. For all species combined and oak-only reproduction, the density of stems ≥4 feet was much greater on treated sites. The rapid response of reproduction to the combined burning and thinning treatment will necessitate continued prescribed burning to maintain the open-canopy structural characteristics of oak woodlands. Almost 350 stems acre⁻¹ of oak species are present in the ≥4-foot size class, which is likely adequate to maintain an oak presence in these ecosystems.

INTRODUCTION

Oak woodlands represent a transitional community between prairie and forest. Woodlands are characterized as having fewer and more widely spaced trees than forests and a diverse understory of prairie grasses and forbs that are typically maintained by frequent burning (Nuzzo 1986, Taft 1997). Only a small fraction of the original oak woodland areas remains in the United States (Nuzzo 1986) due to changes in historic fire regimes (Abrams 1992). Changes in the historic fire regime and the vegetation structure have caused shifts in plant communities and reduced species diversity. Increases in fire-intolerant plant species, higher stem densities on droughty soils, and the loss of plant and animal species associated with more open plant communities have raised concerns about ecosystem resiliency as well (Ozark-St. Francis National Forest [OSFNF] 2011).

All of the Arkansas Ozarks, and most of what is now the Ozark-St. Francis National Forest, overlap the historical range of oak woodlands. Foti (2004) used information derived from General Land Office notes from the early 1800s to the mid-1800s to describe the forest structure from the Lower Boston Mountains in west-central Arkansas to the Ozark Highlands Plateau, which stretches into

Footnotes:
1Associate Professor (JLS), University of Arkansas-Monticello, 110 University Ct., Monticello, AR 71656; Research Forester (DCB), U.S. Forest Service, Southern Research Station; Assistant Professor (EH), West Virginia University, Division of Forestry and Natural Resources; and Private Lands Project Manager (JM), the Nature Conservancy, Little Rock, AR. JLS is corresponding author: to contact, call 304-293-3896 or email at jamie.schuler@mail.wvu.edu. Current address: Assistant Professor, West Virginia University, Division of Forestry and Natural Resources, P.O. Box 6125, Morgantown, WV 26506.
southern Missouri. He concluded that closed-canopy forests in this region covered only 22 to 38 percent of the landscape (Foti 2004), with overstories generally dominated by red and white oaks (*Quercus* spp.).

The relative openness of these forests was shaped by ground fires that were a common occurrence in this region. Using fire history information pieced together from areas within the southern Ozarks, several sources indicate periods before the early 1900s when fire hot enough to scar trees occurred every 1 to 8 years (Guyette and Spetich 2003, Jurney and Stahle 2004). Forests that developed since this period now have structural characteristics very different from the original woodlands described by early settlers and surveyors. The landscape is now characterized by steep, densely forested hills of oak and hickory (*Carya* spp.), interspersed with shortleaf pine (*Pinus echinata* Mill.) (Anderson et al. 2003). Fire exclusion in the Boston Mountains during the 20th century has also contributed to the development of a dense understory and midstory of shade-tolerant, fire-intolerant tree species (Beilman and Brenner 1951, Penfound 1962).

Lack of a frequent-fire regime coupled with a dense multi-tiered canopy is not conducive to the sustained recruitment of oak seedlings (Franklin et al. 2003, Loftis 2004, Van Lear 2004). In fact, these conditions have contributed to reduced oak regeneration in the region. Additionally, oak decline has had a profound influence on the OSFNF (Heitzman 2003) and has caused significant mortality to mature oak. Together, infrequent fires, the decline of the oak overstory, and an aggrading non-oak understory have created a great deal of uncertainty for maintaining oak woodland ecosystems across the landscape.

One of the challenges to managing oak woodland ecosystems is the lack of management targets for the understory vegetation. For example, little information is available to specify desired woody stem densities, although some have suggested from 10 to 50 percent total cover (e.g., Nelson 2005) for oak woodlands/savannas. Currently, the generalized desired conditions for woodlands are: 60 feet$^2$/acre$^{-1}$ overstory basal area with >70 percent as oak or oak-pine, 50 percent of overstory trees ≥14 inches in diameter at breast height (d.b.h.), <150 stems acre$^{-1}$ in trees ≥2 inches, >50 stems acre$^{-1}$ as oak or oak-pine (2 to 7 inches in d.b.h.), shrub cover less than 30 percent, and ground layer cover >8 percent (Ozark-St. Francis National Forest 2011).

To address these concerns the OSFNF implemented a large-scale program designed to restore oak woodland structural characteristics by using density reduction treatments and frequent prescribed burning. This paper reports on the hardwood regeneration responses 3 years following the thinning treatment relative to adjacent, undisturbed portions of the OSFNF.

---

STUDY AREA

Six study sites in the Boston Mountains of Arkansas were chosen (Table 1). Five were located on the Bayou Ranger District and one was located on the Buffalo Ranger District of ONF. All six sites were dominated by south- to west-facing aspects, less than 25 percent slope, and stony and gravelly silt loam soils in the Nella-Enders-Mountainberg associations (Typic Paleudults, Typic Hapludults, and Lithic Hapludults) (Vodrazka et al. 1981). Study site elevations ranged from 1,425 to 2,165 feet above sea level.

Three sites were chosen as treated areas, and three were chosen as control areas. The treated sites (Mulberry Mountain, Lick Hollow, and County Line) were located in Pope and Searcy Counties, Arkansas. Each treated site was burned twice between 1999 and 2003, and thinned in summer 2003. Control sites (Raspberry Mountain, Sulphur Creek, and Falling Water) were chosen from stands within 15 miles of treated sites and had no history of cutting or burning in at least 80 years. No pretreatment measurements were taken on any of the sites. However, the control sites, which were selected for their similarities to the treated sites in soils, aspect, slope, size, and species assemblage, averaged 94 feet² acre⁻¹ and 333 stems acre⁻¹ for stems ≥2.5 inches in d.b.h. 1 year following the thinning treatments (Table 2). Dominant species were various hickories, white oaks (including post oak [Q. stellata Wangenh.]), and red oaks (both northern red [Q. rubra L.] and black oak [Q. velutina Lam.]).
METHODS

For the treated sites, all burns were conducted during the dormant season (February through early March). Fires were ignited by using grid-pattern aerial ignition and backing fire with hand ignition from established fire lines. The burned sites were subsequently thinned with chainsaws to 30-50 feet$^2$ acre$^{-1}$. Felled trees were left in the woods and used for public firewood collection (see Milks 2005 for a more detailed description).

Ten 0.10-acre overstory plots were systematically established along an elevational gradient on each of three slope positions per site: upper slope, middle slope, and lower slope (30 plots per site). Across all sites, the mean difference in elevation between upper and lower slope transects was 353 feet. Transect lengths varied from about 490 to 3,280 feet, depending on the size and shape of the site. Plots were equally spaced along each transect.

Three 0.001-acre circular plots were located 25 feet from each overstory plot center at 120° intervals (i.e., 30 plots per slope position) to quantify understory vegetation. All woody stems taller than 1 foot and less than 1.0 inch in d.b.h. were tallied by species, height class, and stem origin (sprout or non-sprout). Height classes were defined as 1.0 to 1.9 feet tall (class 1), 2.0 to 2.9 feet tall (class 2), 3.0 to 3.9 feet tall (class 3), and 4.0 feet tall and above (class 4).

DATA ANALYSIS

Hardwood regeneration was analyzed as a split plot with whole plots arranged in a completely randomized design by using a SAS version 9.2 mixed model procedure (SAS Institute, Cary, NC). Treatments were defined as the whole plot factor. Slope position (upper, middle, and lower) was considered the subplot factor. Mean seedling density of hardwood regeneration was compared between treated and control sites, and among slope positions. Significance for all tests was evaluated by using alpha = 0.05. A Tukey-Kramer adjustment was used for multiple comparison testing.

RESULTS

Three years following the thinning treatments, average seedling density for all species ranged from 3,578 to 9,044 stems acre$^{-1}$ across treatments and slope positions (Table 3). As expected, treated sites have higher stem densities than nontreated sites (P = 0.0061). On control sites, the three slope positions were similar in terms of total stem density, averaging 3,938 stems acre$^{-1}$. On the treated sites, total stem density increased with increasing slope position and averaged more than twice the number of stems relative to control sites (trt*pos interaction, P = 0.0354) (Table 3).

For all species combined, the number of stems per height class interacted with treatment (P < 0.0001) (Fig. 1). The greatest numbers of seedlings were found in height class 4 on the treated sites. Ninety percent of the seedlings in this largest size class were considered moderately tolerant to tolerant of shade. Red maple (*Acer rubrum*) was the most frequently encountered shade-tolerant species with an occurrence of 28 percent. Additionally, 30 percent of the seedlings in height class 4 were of sprout origin. The vast majority of the seedlings on the control sites were in the smallest height class regardless of slope position.
Red and white oak stem densities ranged from 294 to 1,456 stems acre\(^{-1}\) among treatment and slope position combinations (Table 3), which accounted for up to 17 percent of the total stem density. Treatment effects were not significant (\(P = 0.1110\)) whereas slope position influenced stem density (\(P = 0.0177\)). On average, more stems were located on high slope positions (1,167 stems acre\(^{-1}\)) compared to lower slopes (347 stems acre\(^{-1}\)). Neither position differed from mid-slope positions (761 stems acre\(^{-1}\)). Oak stem density also varied by height class between the treatments (\(P = 0.0231\), Trt*HC interaction) (Fig. 2). Control sites had fewer stems in the taller height classes; treated sites had high stem densities in the smallest and largest classes. However, this result was not entirely due to increased sprouting. Sprout-origin oak seedlings represented 5, 9, 17, and 11 percent of the total oak seedling density for height classes 1 to 4, respectively.

### Table 3.—Mean seedling densities by slope position for sites being restored by using burning and thinning treatments (treated) relative to untreated reference sites in the Boston Mountains of Arkansas, 2006

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Position</th>
<th>All species(^{†}) (stems ac(^{-1}))</th>
<th>All oak species (stems ac(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Lower</td>
<td>4,544 b</td>
<td>400</td>
</tr>
<tr>
<td>Control</td>
<td>Middle</td>
<td>3,578 b</td>
<td>422</td>
</tr>
<tr>
<td>Control</td>
<td>Upper</td>
<td>3,608 b</td>
<td>878</td>
</tr>
<tr>
<td>Treated</td>
<td>Lower</td>
<td>5,451 ab</td>
<td>294</td>
</tr>
<tr>
<td>Treated</td>
<td>Middle</td>
<td>6,378 ab</td>
<td>1,100</td>
</tr>
<tr>
<td>Treated</td>
<td>Upper</td>
<td>9,044 a</td>
<td>1,456</td>
</tr>
</tbody>
</table>

\(^{†}\) Stem densities under the “all species” heading followed by the same letter are not significantly different at alpha = 0.05. The interaction among treatment and position was not significant for the oak species.

![Figure 1](image_url)

**Figure 1.**—The distribution of regenerating stems (all species) by height class for sites being restored by using burning and thinning treatments (treated) relative to untreated reference sites in the Boston Mountains of Arkansas. Stem densities were determined 3 years after the thinning treatment was applied. Values followed by the same letter were not significantly different at alpha = 0.05.
DISCUSSION

The structural characteristics of oak woodlands have been changing over the last century due to altered disturbance regimes. Sites that historically were characterized as woodlands have now formed closed canopies with midstory and understory layers that are also well established. Burning and thinning treatments as conducted here are a first step in the oak woodland restoration process and have increased understory light levels, reduced competition, and promoted a vigorous seedling response.

Obviously, the manipulation of the overstory to reduce canopy cover was the easiest objective to fulfill. In time, however, some recruitment into the overstory will be necessary for the continued sustainability of these ecosystems. For example, the prescribed burns conducted in this study resulted in about 15 percent wounding and 1.5 percent mortality across all oak stems (Milks 2005). Additional mortality should be expected from lightning, windthrow, and other abiotic and biotic factors. Additional oak stems will be needed to fill these gaps over time.

Although understory woody stem density following burning and thinning was somewhat lower than similar stands regenerated by using shelterwood reproduction methods (Graney and Murphy 1995, Graney and Rogerson 1985), probably due to the two fires prior to thinning, stem densities are more than adequate to meet recruitment objectives. Burning and thinning shifted the distribution of stems among the height classes, and resulted in more stems in the largest height classes, whereas the largest seedling pool on control sites occurred in the smallest height class (Fig. 1). This increase probably resulted from more favorable light conditions and a compensatory response from top-killed seedlings (Kruger and Reich 1993).

The increased available light coupled with a reduction in competition from other seedlings (at least short-term) may give oaks a competitive advantage over the faster-growing shade-tolerant
species (Johnson et al. 2009, Loftis 2004, Van Lear 2004). Even though oak seedling numbers were increased on height classes 2 to 4 compared to control sites, height class 4 (≥4 feet tall) had the only significant increase (Fig. 2). Though not documented, this increase is likely an artifact of a wider permissible range of stem sizes (i.e., 4 feet tall to 1.0 inch in d.b.h.) and ingrowth. Sprouting is an especially important mechanism of oak regeneration in the Ozark Mountains (Johnson et al. 2009, Loftis 2004, Van Lear 2004), but relatively low percentages were actually observed. This finding, however, may be related to our ability to detect sprouting on small seedlings.

Regardless of the reason, it appears that enough large oak seedlings (≥4 feet tall) are present (about 350 stems acre⁻¹) to develop into the targeted minimum of 50 stems acre⁻¹ in the 2- to 7-inch d.b.h. size class. The next concern will be how to reduce stem densities without jeopardizing the recruitment of these oak seedlings. Without additional disturbances, the remaining woody understory will continue to persist and develop into midstory and overstory positions. The understory may grow 3 to 4 feet over the next 5 years under current stocking levels (Graney and Rogerson 1985). Within another decade, some stems will exceed a threshold where high-intensity fires can top-kill stems (Maslen 1989).

Subsequent prescribed burns should favor the maintenance and recruitment of oaks over fire-intolerant non-oak species that may otherwise outcompete smaller oaks (Blake and Schuette 2000, Johnson et al. 2009, Peterson and Reich 2001). This process increases the probability that some oaks can move into the upper canopy positions (Johnson et al. 2009, Loftis 2004, Van Lear 2004). The repeated burns may also help xerify the site, making it less favorable for establishing mesic hardwoods (Johnson et al. 2009, Loftis 2004).

Other management options include the targeted use of selective and nonselective herbicides to reduce woody stem cover and increase cover of grasses and forbs. For example, a growing-season application of sulfometuron methyl broadcasted over the top of a regenerating upland oak stand resulted in reduced stem densities and depressed height growth on certain non-oak species without affecting any of the oak component (Schuler and Stephens 2010). Additionally, directed applications of systemic herbicides (e.g., glyphosate) can be very effective but limited by the inherent efficiency at which large areas can be treated.

CONCLUSIONS

The burning and thinning treatments appear to be a successful technique to quickly modify mature, closed-canopy upland hardwood forests to more closely mimic the structural characteristics of oak woodlands. Repeated fires or some other intervention will be required to reduce the woody understory to keep the overstory canopies open. After two burns and one thinning, fire-tolerant species (e.g., oak) are increasing in density in the larger height classes, which further typifies the woodland structural characteristics.

ACKNOWLEDGMENTS

The authors would like to recognize the support provided by the Arkansas Forest Resources Center and a cooperative agreement with the U.S. Department of Agriculture, Forest Service, Southern Research Station.
LITERATURE CITED


The content of this paper reflects the views of the authors(s), who are responsible for the facts and accuracy of the information presented herein.