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

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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

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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.[2] 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.

[2]Ozark-St. Francis National Forest, Bayou Ranger District. 2001. Restoring forest ecosystem health in the wildland/urban interface on the Bayou Ranger District: implementing the OSFNF land and resource management plan with the federal wildland fire management policy and program review. Unpublished paper. 21 p. On file with Ozark-St. Francis National Forest, Bayou Ranger District, 12000 SR 27, Hector, AR 72843.

Table 1.—Description of study sites and treatments

Study sites	County	Acreage	Years burned	Year thinned
Treated				
Mulberry Mountain	Pope	185	2000, 2003	2003
Lick Hollow	Pope	494	1999, 2002	2003
County Line	Searcy	125	2000, 2003	2003
Control				
Raspberry Mountain	Pope	119	N/A	N/A
Sulphur Creek	Pope	74	N/A	N/A
Falling Water	Newton	205	N/A	N/A

Table 2.—Average stand density and basal area of stems ≥2.5 inches in d.b.h. for untreated control sites in the Boston Mountains of Arkansas, 2004

Species	Stems ac^{-1}	Basal area (ft^2 ac^{-1})
Hickory (*Carya* spp.)	106	17
White oaks (*Q. alba, Q. stellata*)	111	49
Blackgum (*Nyssa sylvatica*)	27	5
Red maple (*A. rubrum*)	23	2
Shortleaf pine (*P. echinata*)	8	6
Red oaks (*Q. rubra, Q. velutina*)	14	11
Miscellaneous	32	4
Total	322	94

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 $feet^2$ $acre^{-1}$ 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 120º 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 nonsprout). 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.

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

Treatment	Position	All species[†] (stems ac^{-1})		All oak species (stems ac^{-1})
Control	Lower	4,544	b	400
Control	Middle	3,578	b	422
Control	Upper	3,608	b	878
Treated	Lower	5,451	ab	294
Treated	Middle	6,378	ab	1,100
Treated	Upper	9,044	a	1,456

[†]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.

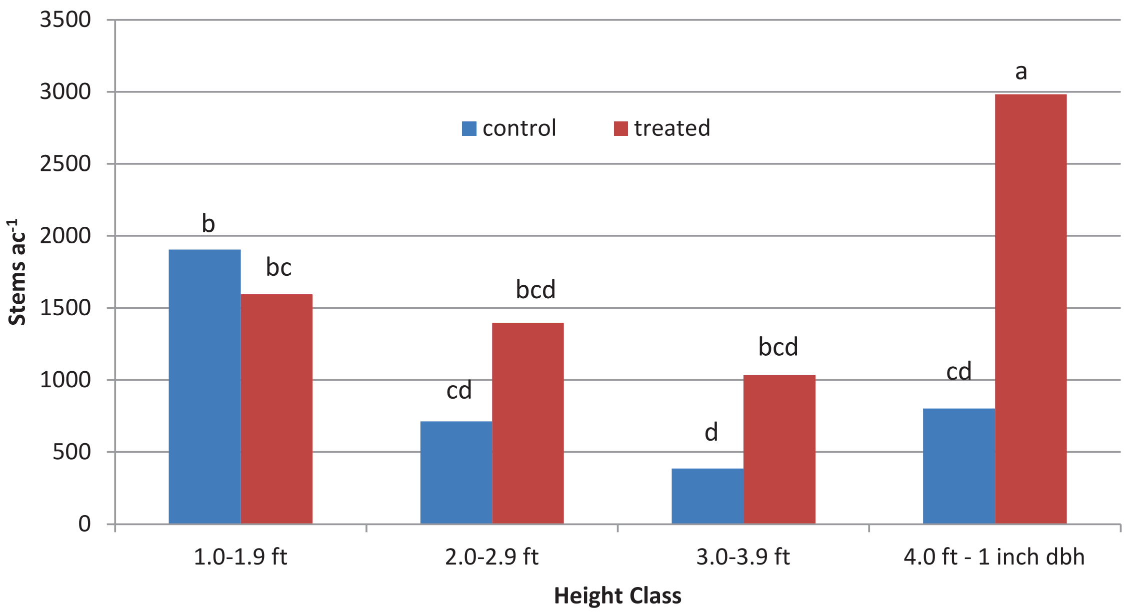

Figure 1.—The distribution of regenerating stems (all species) by height class for sites being restored by using burning and thinning treatments (treated) relative to untreated reference sites in the Boston Mountains of Arkansas. Stem densities were determined 3 years after the thinning treatment was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

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.

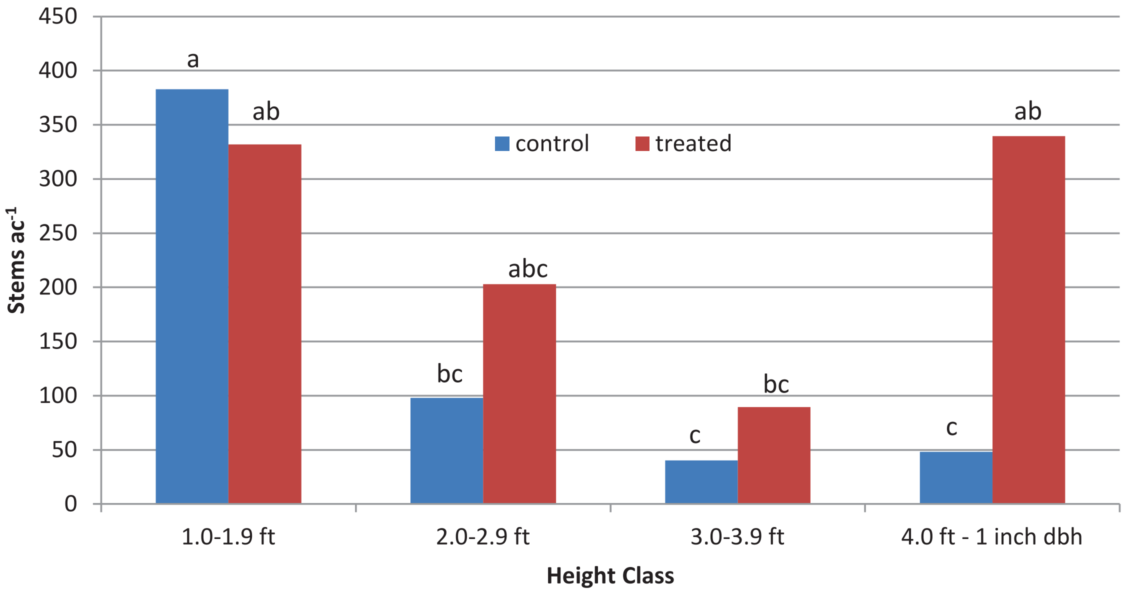

Figure 2.—The distribution of regenerating stems (oak-only) by height class for sites being restored by using burning and thinning treatments (treated) relative to untreated reference sites in the Boston Mountains of Arkansas. Stem densities were determined 3 years after the thinning treatment was applied. 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 aboitic 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.

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LITERATURE CITED

Abrams, M.D. 1992. **Fire and the development of oak forests.** BioScience. 42: 346-353.

Anderson, M.; Andre, J.; Morales, M.; Simon, S.; Whitsell, T. 2003. **Collaborative partnerships and landscape-scale restoration on the Bayou Ranger District in the Interior Highlands of Arkansas.** In: Second international wildland fire ecology and fire management congress; 2003 November 16-20; Orlando, FL. Boston, MA: American Meteorology Society: 1-13.

Beilman, A.; Brenner G. 1951. **The recent intrusion of forests in the Ozarks.** Annals of the Missouri Botanical Garden. 38: 261-282.

Blake, J.G.; Schuette, B. 2000. **Restoration of an oak forest in east-central Missouri: early effects of prescribed burning on woody vegetation.** Forest Ecology and Management. 139: 109-126.

Foti, T.L. 2004. **Upland hardwood forests and related communities of the Arkansas Ozarks in the early 19th century.** In: Spetich M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability; 2002 October 7-10; Fayetteville, AR. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 21-29.

Franklin, S.B.; Roberston, P.A.; Fralish, J.S. 2003. **Prescribed burning effects on upland *Quercus* forest structure and function.** Forest Ecology and Management. 184: 315-335.

Graney, D.L.; Murphy, P.A. 1995. **Shelterwood cutting and understory control increase growth of oak, ash, and cherry reproduction in northern Arkansas.** In: Edwards, M.B., comp. Proceedings of the 8th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture, Forest Service: 479-488.

Graney, D.L.; Rogerson, T.L. 1985. **Growth of oak, ash, and cherry reproduction following overstory thinning of upland hardwood stands in the Boston Mountains of Arkansas.** In Dawson, J.O.; Majerus, K.A., eds. Proceedings of the 5th Central Hardwood Forest conference. Urbana-Champaign, IL: University of Illinois: 4-10.

Guyette, R.; Spetich, M. 2003. **Fire history of oak-pine forests in the lower Boston Mountains, Arkansas.** Forest Ecology and Management. 180: 463-474.

Heitzman, E. 2003. **Effects of oak decline on species composition in a northern Arkansas forest.** Southern Journal of Applied Forestry. 27: 264-268.

Johnson, P.S.; Shifley, S.R., Rogers, R. 2009. **The ecology and silviculture of oaks.** 2nd ed. New York: CABI Publishing. 600 p.

Jurney, D.H.; Stahle, D.W. 2004. **Old-growth wooded pasture in the Ozarks.** In: Spetich M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability; 2002 October 7-10; Fayetteville, AR. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 42-52.

Kruger, E.L.; Reich, P.B. 1993. **Coppicing affects growth, root:shoot relations and ecophysiology of potted *Quercus rubra* seedlings.** Physiologia Plantarum. 89: 751-760.

Loftis, D. 2004. **Upland oak regeneration and management.** In: Spetich M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability; 2002 October 7-10; Fayetteville, AR. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 163-167.

Maslen, P. 1989. **Response of immature oaks to prescribed fire in the North Carolina Piedmont.** Gen. Tech. Rep. SO-74. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 259-266.

Milks, J. 2005. **Hardwood response to oak woodland restoration in the Boston Mountains of Arkansas.** Monticello, AR: University of Arkansas-Monticello. 59 p. M.S. thesis.

Nelson, P.W. 2005. **The terrestrial natural communities of Missouri.** Jefferson City, MO: Missouri Department of Conservation. 550 p.

Nuzzo, V.A. 1986. **Extent and status of Midwest oak savanna: presettlement and 1985.** Natural Areas Journal. 6: 6-36.

Ozark-St. Francis National Forest [OSFNF]. 2011. **Ozark Highlands ecosystem restoration proposal.** 47 p. Available at http://www.fs.fed.us/restoration/CFLR/documents/2011Proposals/Region8/OzarkStFrancis/OzarkHighlandsEcosystemRestorationCFLRGrant.pdfhttp://www.fs.fed.us/restoration/CFLR/documents/2011Proposals/Region8/OzarkStFrancis/OzarkHighlandsEcosystemRestorationCFLRGrant.pdf. (Accessed November 1, 2011).

Penfound, W.T. 1962. **The savanna concept in Oklahoma.** Ecology. 143: 774-775.

Peterson, W.P.; Reich, P.B. 2001. **Prescribed fire in oak savannah: fire frequency effects on stand structure and dynamics.** Ecological Applications. 11: 914-927.

Schuler, J.L.; Stephens, J. 2010. **Releasing red oak reproduction using a growing season application of Oust.** In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 201-205.

Taft, J.B. 1997. **Savanna and open-woodland communities.** In: Schwartz, M.W., ed. Conservation in highly fragmented landscapes. Chicago, IL: Chapman and Hall: 24-54.

Van Lear, D. 2004. **Upland oak ecology and management.** In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability; 2002 October 7-10; Fayetteville, AR. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 65-71.

Vodrazka, F.M.; Winfrey, A.L.; Arnold, T.H.; Glass, J.M.; Hudson, E. 1981. **Soil survey of Pope County, Arkansas.** Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 128 p.