MULTIPLE TREATMENTS YIELD EARLY SUCCESS IN A SHORTLEAF PINE WOODLAND RESTORATION PROJECT IN THE MISSOURI OZARKS

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Abstract--Shortleaf pine woodland communities were more extensive in the southeastern Missouri Ozarks prior to Euro-American settlement than today. In 2000, the Missouri Department of Conservation initiated a shortleaf pine woodland restoration project on state land in the Ozarks of southeast Missouri at an area called the Midco Pine Flats Restoration Area. The purpose of this investigation was to evaluate shortleaf pine woodland restoration efforts at Midco over the 14-year period from 2000-2013. Our analysis suggested that treatments impacting both the overstory and understory, including mechanical release of both planted and natural pine regeneration, yielded the best short-term results. In contrast, the failure of burning alone to significantly enhance both pine and woodland ground flora in the short-term highlights the importance of canopy disturbance to increase light to the understory to restore this woodland natural community. Increased competition from regenerating hardwood species appeared to limit both pine recruitment and woodland herbaceous cover expansion. Future release treatments will likely be needed to promote shortleaf pine and woodland flora at this and similar sites where shortleaf pine woodland restoration is a management goal.

INTRODUCTION

Prior to Euro American settlement, shortleaf pine (*Pinus echinata*) was a dominant tree species of the southeastern Missouri Ozarks, where it grew in pure stands and in mixtures with hardwood species (Hanberry and others 2012). At the time of settlement in the Missouri Ozarks, shortleaf pine grew as part of a shifting landscape mosaic of forest and woodland natural communities shaped by ecological site variation and frequent fire (Ladd 1991, Batek and others 1999, Hanberry and others 2012).

Woodlands are terrestrial communities dominated by trees, with sparse midstory and understory tree layers (Nelson 2010). Although woodlands can have high variability in overstory tree density, the canopies of woodlands are generally more open than forest canopies. This open structure allows for a conspicuous ground layer of diverse forb, grass, and sedge species (Nelson 2010). Historical shortleaf pine woodland communities likely supported a rich understory of about 300 species of forbs, grasses, and sedges (Ladd and others 2007). With frequent fire, understory woody stems would be suppressed, and grasses would become dominant in the understory (Masters 2007). Historic accounts describe the ground layer of shortleaf pine woodlands as composed of blueberry shrubs (*Vaccinium* spp.), bluestem grasses (*Andropogon gerardii* and *Schizachyrum scoparium*), and other herbaceous perennials associated with high light intensities (Ladd and others 2007).

Multiple historical factors have led to the loss of shortleaf pine woodland communities from the Missouri Ozarks. Extensive logging from 1880-1920 targeted the removal of shortleaf pine (Cunningham and Hauser 1989) and caused an immediate loss of mature trees, which, in turn, diminished the seed source for new pine seedlings. Associated with extensive logging and human population density was an increase in fire frequency and intensity (Guyette and others 2002), which acted as a barrier to the recruitment of shortleaf pine beyond the seedling stage (Guyette and others 2007). Although fire can facilitate shortleaf pine seedling establishment by reducing litter depth and woody competition (Little and Moore 1949), recurrence at too frequent intervals can prohibit shortleaf pine from reaching a size large enough to resist top-kill (Dey and Hartman 2005). Shortleaf pine is one of only a few North American pine species capable of basal sprouting (Lawson 1990), but shortleaf pine sprout growth is less vigorous than that of co-occurring oak species. In concert, extensive pine harvesting and frequent fire diminished shortleaf dominance, while simultaneously increasing the dominance of oak species. Finally, active fire suppression starting in the 1940s enabled an accumulation of midstory and overstory trees on sites that previous supported more open canopies

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Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

(Hanberry and others 2013). The resulting forests, dominated by oak species, did not admit enough light to the understory for light-demanding woodland ground flora species to survive and reproduce or for shade-intolerant shortleaf pine regeneration to persist, grow, and eventually recruit into the canopy. Collectively, these factors reduced the extent of pine woodland communities in the southeastern Missouri Ozarks, making these natural communities some of the most imperiled in the state.

In 2000, the Missouri Department of Conservation (MDC) initiated a shortleaf pine woodland community restoration project on state land in the Ozarks of southeastern Missouri at an area called the Midco Pine Flats Restoration Area (Midco). This area experienced severe and widespread red oak decline – mainly black oak (*Quercus velutina*) and scarlet oak (*Q. coccinea*) – in the mid to late-1990s, prompting MDC managers to prescribe extensive salvage harvesting and to critically consider alternative management options for mitigating future oak decline. With the predominance of dry sites at Midco, pine-dominated communities were thought to be more appropriate for much of the area than forests dominated by red oak species. Shifting composition from red oak to shortleaf pine would lower the vulnerability of these communities to red oak decline (Law and others 2004; Blizzard and others 2007) and restore an imperiled Missouri natural community.

The purpose of this investigation was to evaluate shortleaf pine woodland restoration efforts at Midco over the last 14 years and to determine if treatments have yielded early success. Specifically, we are interested in identifying the treatment that has produced the greatest gains in shortleaf pine abundance, woodland herbaceous plant richness and abundance, and overall floristic quality.

METHODS

Midco is a 2,233-acre site located on Peck Ranch Conservation Area (PRCA). PRCA is located in the Current River Subsection of the Ozark Highlands Section (Nigh and Schroeder 2002). Most of Midco falls within the Current River Oak-Pine Woodland/Forest Hills landtype association (LTA) and the rest within the Current River Pine-Oak Woodland Dissected Plain LTA (Nigh and Schroeder 2002). Topography is predominantly rolling with elevation ranging from 625-970 feet. Soils are mainly dry to dry-mesic, cherty Ultisols and Alfisols derived within residuum of sandstone and dolomite and have low base saturation.

Midco was established as an adaptive restoration project with the primary objective of developing a high-quality shortleaf pine woodland community. An additional objective of this study is to evaluate the use of prescribed fire, mechanical release, and herbicide release treatments as restoration tools. The first wave of restoration at Midco was a salvage harvest of dead and dying red oak throughout Midco from 1998-2003. The intensity of overstory removal varied substantially depending on local variation in the severity of red oak decline and presence of species targeted for retention (shortleaf pine, white oak (*Quercus alba*), and post oak (*Q. stellata*). Nearly all of Midco received a prescribed burn from 2001-2002. Since this first wave of extensive burning, treatments have been applied adaptively and selectively to portions of the project area in need of management action, including: partial overstory removal (2003), site preparation slashing and planting of shortleaf pine seedlings (2004-2007), mechanical release of shortleaf pine (2009 and 2011), herbicide release (2006 and 2009), and prescribed fire (2007 and 2010-2013). Monitoring plots (n=24) were used to help guide adaptive management at Midco. As a result of low sample size and targeted application of treatments, the network of monitoring plots does not cover the full range of treatments implemented to date. For this investigation, monitoring plots were partitioned into three categories based on treatment history: 1) burn only (n=5), 2) harvest and burn (HB; n=4), and 3) harvest, burn, and mechanical release (HBR; n=6). Most of the plots falling into HBR group were also treated with site preparation slashing after salvage harvesting and planted with shortleaf pine seedlings on a spacing of 12 feet x 12 feet. Unfortunately, the source of pine regeneration was not tracked in these monitoring plots so we were unable to determine the relative contribution of artificial versus natural pine regeneration.

The data for this study comes from 15, 0.2-acre vegetation monitoring plots that were randomly established in 2000. The diameter at breast height (dbh; taken at 4.5 feet) and species of all woody plants ≥ 4.5 feet tall and rooted within the 0.2-acre plot were recorded. Woody vegetation < 4.5 feet tall and herbaceous plants were captured using 12, 10.8 square-foot quadrats nested within each 0.2-acre plot; quadrats were located at 16.4-foot intervals along four transects radiating in cardinal directions from the plot center. All vascular plant species within each quadrat were identified to species and assigned to one of seven percent cover classes (<1, 1-5, 5-25, 25-50, 50-75, 75-95, and 95-100). Monitoring plot data were collected in 2000, 2002, 2006, 2009, and 2013.

Multiple response variables were used in this study to assess the treatments. The abundance of shortleaf pine relative to that of all tree species was calculated separately for four size classes: 1) overstory (dbh ≥ 4.5 inches), 2) large sapling (0.5 inch ≥ dbh < 4.5 inches), 3) small sapling (≥ 4.5 feet tall, dbh < 0.5 inch), and 4) seedling (< 4.5 feet tall). For overstory pine, relative density (stems per acre) and relative basal area were calculated as percentages of total tree density and basal area, respectively. For the other size classes, only relative density was calculated. All herbaceous species were placed into one of four ecologically-based guilds: forest, woodland, generalist, and ruderal (Unpublished data. Susan Farrington. 2009. Natural History Biologist, Missouri Dept. of Conservation, 550 Joe Jones Blvd, West Plains, MO 65775). The woodland guild is composed of species that are more abundant in open-canopied woodlands and on drier exposed slopes, while the forest guild species are more abundant on shady, mesic, protected slopes in the Ozarks. Generalist species may occur on all sites, and ruderals are associated with recent disturbance. Shrubs and woody vines were placed into separate guilds. Each species was assigned to only one guild; tree seedlings were not included in the ground flora analysis. Ground flora species richness was calculated at the plot level by summing all of the species recorded in the 12 quadrats. Frequency was calculated at the plot level as the number of quadrats in which a species was recorded. We calculated Importance Values (IV) at the plot level for each guild group as the sum of the relative cover (based on cover class midpoints) and relative frequency of all species in each guild. The IV sums to 200 percent, but was re-scaled to 100 percent for ease of interpretation.

We used the Floristic Quality Index (FQI) to assess the floristic integrity (Ladd and Thomas, 2015). This index is based on assigning each species a coefficient of conservatism (CC) – a rating on a scale of 1-10 based on the species' tolerance for human disturbance and obligate predilection for intact habitats. Species with low CC values are weedy; species with high CC are more restricted to specific habitats and do not readily colonize disturbed ground. FQI is calculated by multiplying the mean CC by the square root of species richness.

We used PROC TTEST in SAS to test for differences among treatments within an inventory year and PROC MEANS to test for differences over time within each treatment individually. Because we were mainly interested in pine dynamics over the 14-year timeframe of this study, we limited our analysis of shortleaf pine relative abundance to data in 2000 and 2013. However, since ground flora often increase in richness and cover soon after disturbance, we also included data from 2006 to capture this short-term response. PROC MEANS was used to test for differences over time at the site level (i.e., all plots pooled together). Square-root or log transformations were used to meet distributional assumptions when necessary. Significance was set at $p=0.05$ for all analyses.

The control plots used by Rimer (2004) were not maintained as such, so we were not able to use them in this analysis. We summarized pretreatment conditions using data from a set of plots that had not yet been treated in 2000.

RESULTS

Tree Community Response

Prior to the start of restoration at Midco, mean basal area and stem density of the overstory were 77.1 square feet per acre and 136 stems per acre, respectively (data not shown). The overstory was dominated by oak species with red oak species (mainly black and scarlet oaks) constituting over half of the total basal area. In contrast, shortleaf pine accounted for approximately 10 percent of overstory basal area and stem density. White oak species (principally white and post oaks) comprised a much larger portion of total stem density of the large sapling layer than either red oak species or shortleaf pine. No shortleaf pine stems were recorded in the small sapling layer, and less than 1 percent of the seedling layer was shortleaf pine.

As expected, overstory basal area and stem density in plots treated with salvage harvesting were lower than in the burn only plots in 2000, mainly due to lower basal area of red oak species in harvested plots (figs. 1A and 1B). By 2013, basal area declined to 15 square feet per acre in HBR plots, which was driven largely by decreasing red oak basal area. Shortleaf pine basal area of all treatment groups increased over the 14-year period, while overstory density increased in harvested plots but not the burn only plots. No statistically significant differences ($p<0.05$; table 1) in the relative basal area (RBA) or relative density (RD) of overstory shortleaf pine were detected among treatment groups at the start of restoration in 2000. Overstory shortleaf pine basal area and stem density increased during the study period with the largest increases in HBR plots (figs. 1A and 1B). Pine RBA and RD for all plots combined was significantly greater in 2013 than in 2000 ($p=0.0245$ and 0.0480, respectively).

The densities of large and small saplings of all tree species increased substantially in the HBR plots (figs. 2A and 2B). Large saplings of shortleaf pine in these plots increased dramatically over the 14 years and, by 2013, averaged over 50 percent (122 stems per acre) of all large saplings at the plot level. RD of large pine saplings in the HBR plots increased significantly over the study period ($p=0.0171$; table 1) and was significantly higher than the burn only plots in 2013 ($p=0.0241$). Large sapling RD also significantly increased from 2000 to 2013 across all plots ($p=0.0125$). By 2013, RD of large pine saplings in the HB plots reached 25 percent (22 stems per acre), which was driven more by a large decrease in red oak density than increasing pine abundance. Pine only made up a small component of the small sapling and seedling layers of all treatments with the largest RD in HB plots in 2013

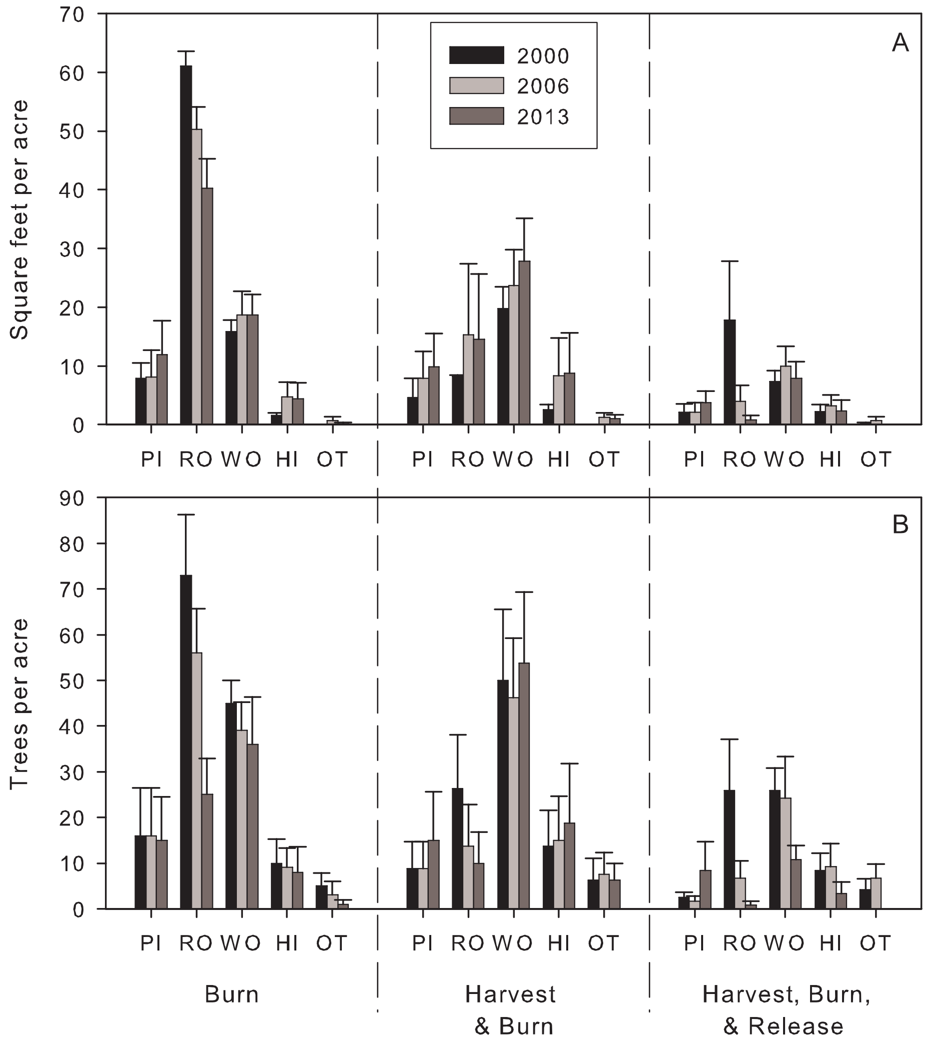

Figure 1—Mean basal area (A) and stem density (B) of five species within three treatment groups in the overstory of Midco in 2000, 2006, and 2013. Error bars equal one standard error. Species are: PI=shortleaf pine, RO=red oak group, WO=white oak group, HI=hickories, and OT=other (mainly black cherry, blackgum, sassafras, sumacs and maples).

(9.3 percent and 9.8 percent, respectively). Meanwhile, there were 5-6 fold increases in the density of other woody species (mainly black cherry (*Prunus serotina*), blackgum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), sumac (*Rhus* spp.), and maple (*Acer* spp.)) in the seedling layer of harvested plots, where they comprised over 14,000 stems per acre, or > 65 percent of all seedling stems, by 2013 (fig. 2C).

Ground Flora Response

Prior to treatments, woodland species were infrequently recorded and had low cover (data not shown). There was an average of 3.5 woodland guild species per 0.2-acre plot. The cover of the woodland guild averaged 1 percent per quadrat. The average IV of the woodland guild was 26 percent and the average FQI was 13.9 per plot.

By 2013, 27 new species (excluding tree species) were recorded that were not recorded in 2000. These new species were primarily native woodland flora such as bastard toadflax (*Comandra umbellata*), largebract tick trefoil (*Desmodium cuspidatum*), smooth tick trefoil (*D. laevigatum*), Maryland tick clover (*D. marilandicum*), Arkansas bedstraw (*Galium arkansanum*), hairy bedstraw (*G. pilosum*), hairy bush clover (*Lespedeza hirta*), prairie bush clover (*L. frutescens*), beebalm (*Monarda bradburiana*), hairy skullcap (*Scutellaria elliptica*), dropseed (*Sporobolus clandestinus*), and bashful bulrush (*Trichophorum planifolium*). New species in the study site also included two non-natives: Kentucky bluegrass (*Poa pratensis*) and sericea lespedeza (*Lespedeza cuneata*). A few woodland species were recorded in 2000 but were not found in 2013, including St. Andrew's cross (*Hypericum*

Table 1—Mean relative basal area (RBA) and relative density (RD) of shortleaf pine within four size classes by three treatment groups and for all groups combined at the start of restoration (2000) and the end of the 14-year study period (2013). Treatment group means within a size class and year, excluding "All groups", followed by a different letter are statistically different (p<0.05). In the 2013 column only, a mean followed by a plus (+) indicates a significant increase (p<0.05) over the study period for that treatment group

Size class	Treatment	2000	2013
Overstory RBA	Burn	8.7	14.4
	HB	13.7	18.6
	HBR	15.4	35.1
	All groups	12.6	22.7 +
Overstory RD	Burn	7.3	14.0
	HB	13.2	18.2
	HBR	10.9	34.3
	All groups	10.5	22.2 +
Large sapling RD	Burn	0.0	7.1b
	HB	4.4	25.0
	HBR	0.0	53.6 a +
	All groups	1.5	28.6 +
Small sapling RD	Burn	0.0	0.0
	HB	0.0	9.3
	HBR	0.0	2.9
	All groups	0.0	4.1
Seedling RD	Burn	3.8	1.6
	HB	0.0	9.8
	HBR	0.3	1.2
	All groups	1.4	12.6

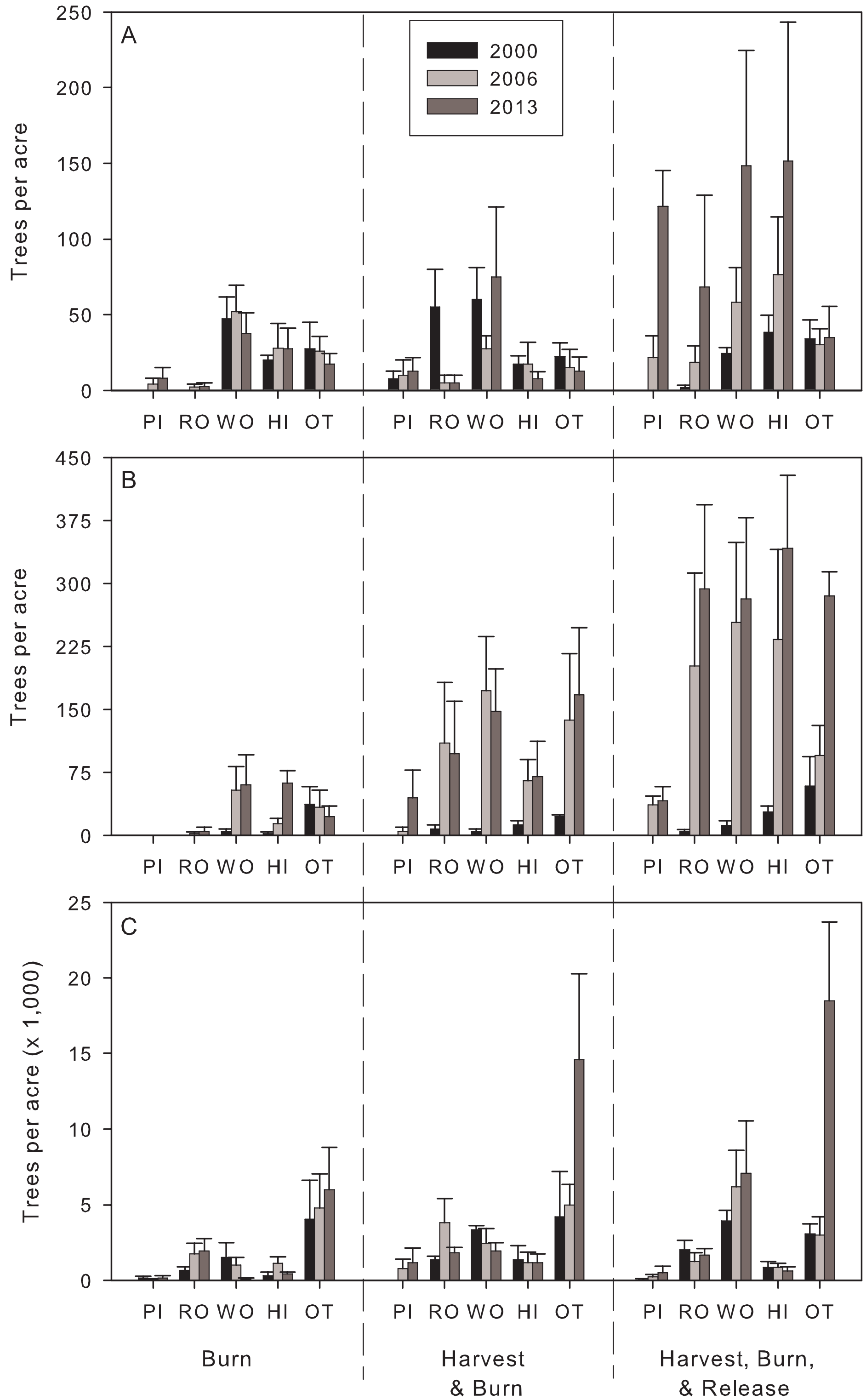

Figure 2—Mean stem density of large saplings (A), small saplings (B), and seedlings (C) of five species within three treatment groups in 2000, 2006, and 2013. Error bars equal one standard error. Species are: PI=shortleaf pine, RO=red oak group, WO=white oak group, HI=hickories, and OT=other (mainly black cherry, blackgum, sassafras, sumacs and maples).

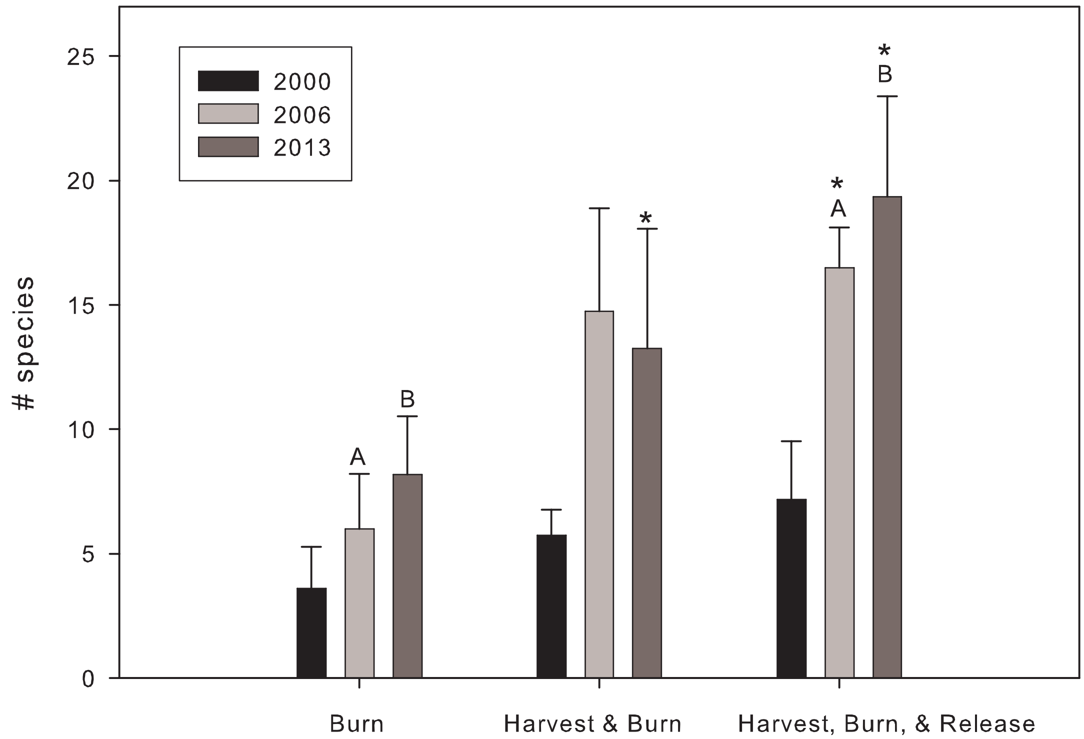

Figure 3—Woodland guild richness; bars are treatment means and error bars are one standard error. Within each year, the same letter indicates a significant difference between treatments. Within each treatment type, asterisks indicate a significant difference from the mean in 2000.

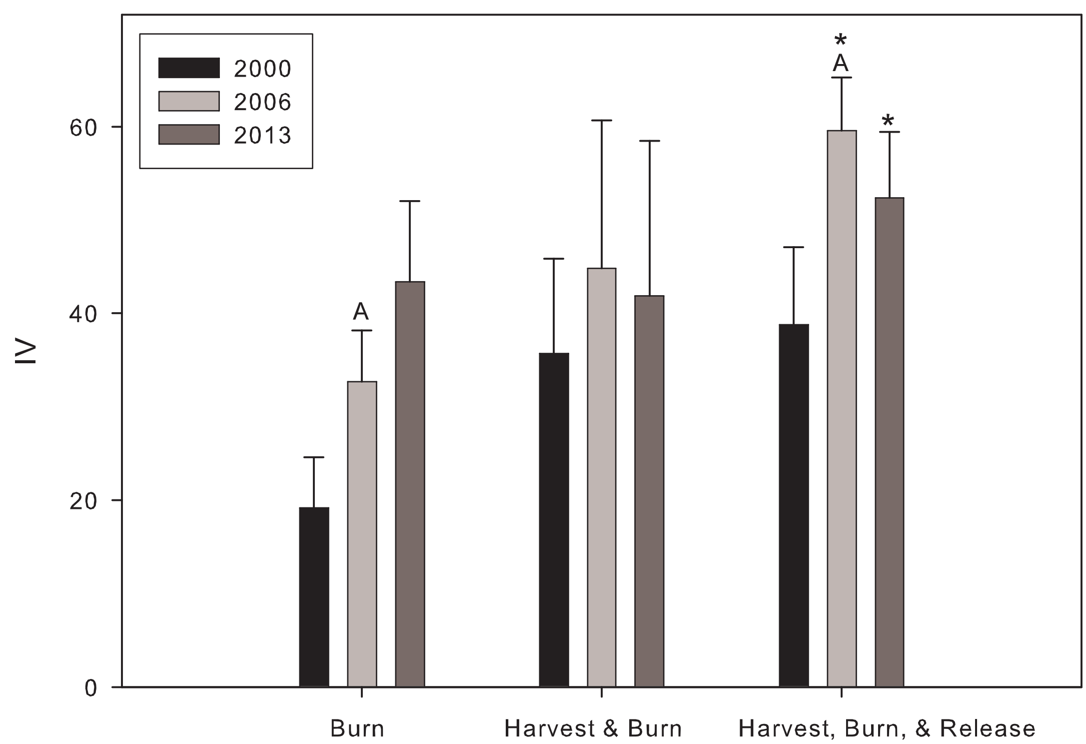

Figure 4—Woodland guild importance value (IV); bars are treatment means and error bars are one standard error. Within each year, the same letter indicates a significant difference between treatments. Within each treatment type, asterisks indicate a significant difference from the mean in 2000.

hypericoides), orange dwarf dandelion (*Krigia biflora*), sensitive brier (*Mimosa quadrivalvis*), and bird's foot violet (*Viola pedata*).

In 2000, woodland guild richness, woodland guild IV, and FQI were similar among the treatments (figs. 3, 4, and 5). Woodland guild richness remained low in the burn treatment, but increased significantly in the HB treatment in 2013 (p=0.0168), and in the HBR treatment in 2006 (p=0.0002) and in 2013 (p=0.0062) (fig. 3). The HBR plots gained significantly more woodland species than the burn plots in 2006 (p=0.0035) and 2013 (p=0.0506). Only the HBR treatment significantly increased the woodland IV in 2006 (p=0.0092) and 2013 (p=0.0472) (fig. 4). Pooling all plots together, the woodland IV increased significantly for the entire Midco restoration area in 2006 (40 percent IV, p=0.0007) and 2013 (44 percent IV, p=0.0048). Although we did not find significant changes in floristic quality between the treatments, the HBR treatment increased FQI in 2006 (p=0.0037) and 2013 (p=0.0303) (fig. 5). Pooling all plots together, FQI increased significantly for the entire Midco research area in 2006 (p=0.0003) and 2013 (p=0.0048).

DISCUSSION

Restoring the composition and structure of historic shortleaf pine woodland natural communities will likely require a long-term commitment of management resources on many sites in the Missouri Ozarks, especially where pine is a relatively minor component. At Midco, overstory pine made up < 10 percent of total basal area and < 5 percent sapling and seedling density at the start of this restoration project. Therefore, it is important to view the results of this study as early findings of a long-term restoration effort at Midco.

Despite significant increases in the pine RBA of all plots over the 14-year study period, the absolute BA of pine was still fairly low, ranging from 4 square feet per acre for HBR plots to 12 square feet per acre for burn plots. Recent estimates of pre-settlement structure of Ozark oak-pine woodlands suggest that basal area may have ranged from 80-130 square feet per acre (Hanberry and others 2014). A more conservative target for natural community management developed for the Mark Twain National Forest recommends that stocking of woodlands should fall between 30 percent and 90 percent, which corresponds to 30-125 square feet per acre (quadratic mean diameter of 7-22 inches) for upland central hardwood stands (Gingrich 1967). Applying this more conservative target, restoring overstory pine basal area to at least 30 square feet per acre will take time, especially areas treated with only prescribed fire.

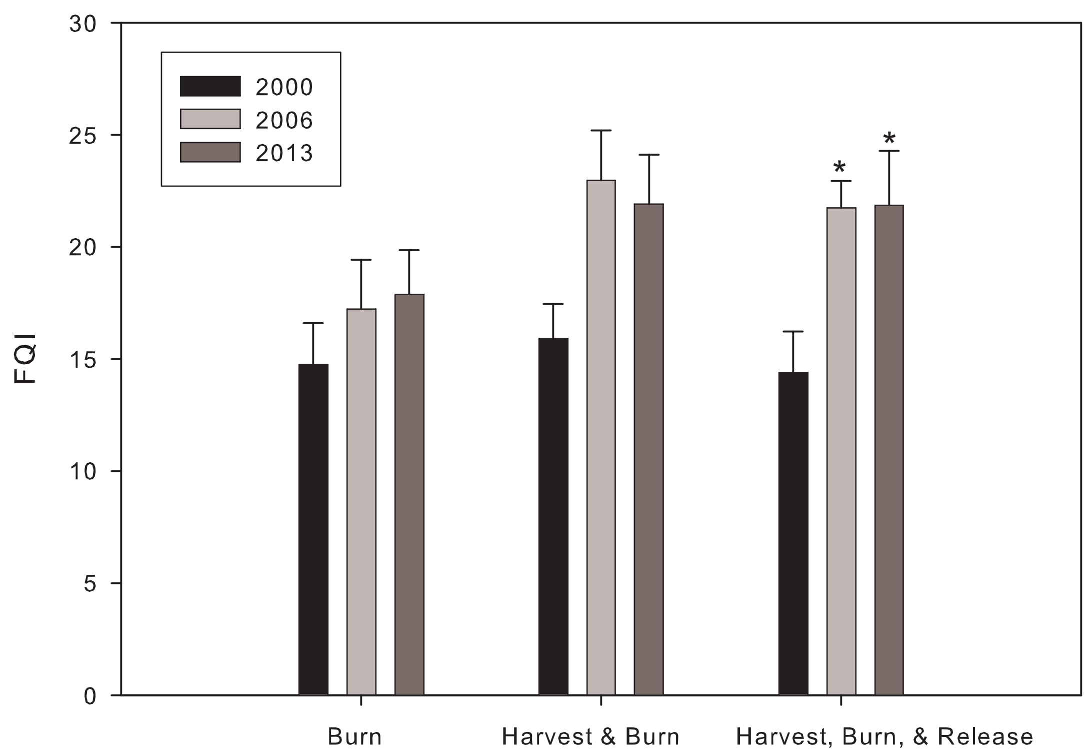

Figure 5—Floristic quality index (FQI); bars are treatment means and error bars are one standard error. Asterisks indicate a significant difference from the mean in 2000 within the same treatment type.

The greatest early gains in shortleaf pine densities occurred in the most heavily disturbed plots; those treated with harvesting, burning, and mechanical release. On these plots, the absolute and relative densities of large pine saplings increased to 122 stems per acre and 54 percent, respectively, by 2013. Most of this resulted from a pulse of ingrowth that took place between 2006 and 2013, which added 100 stems per acre compared to just 20 between 2000 and 2006. This pulse was likely initiated by mechanical release in 2009 and 2011. By 2013, burn only and HB plots supported just 8 and 13 large pine saplings per acre. HBR plots were also the most open stands based on basal area, which declined to only 15 square feet per acre. Shortleaf pine is a shade-intolerant species capable of rapid height growth of free-to-grow seedlings and saplings (Waldrop and others 1989). A higher rate of pine advancement into the large sapling class of the HBR plots was likely an outcome of both competitor release and lower overstory density. Most of the HBR plots also occur within areas treated with site preparation slashing and subsequently planted with nursery-grown shortleaf pine seedlings. Unfortunately, we were unable to determine the relative contribution of artificial versus natural pine regeneration in this study. However, it is likely the early success of HBR in promoting large sapling pine was likely facilitated by deliberate mechanical competition control around both artificial and natural shortleaf pine regeneration.

Our results suggest that a few burns alone (without the addition of mechanical treatments) were not sufficient to increase seedling or sapling shortleaf pine during the first 14 years of this project. Other studies have also shown that a single or even a few burns may not yield a desired understory vegetation response when starting with a mature, undisturbed forest. Elliott and Vose (2005) found that a single, low severity prescribed fire did not increase shortleaf pine establishment in a mature, southern Appalachian forest, which they partially attributed to a lack of fire-induced mortality of overstory trees and, consequently, a poor understory light environment for pine regeneration. Burn-only plots did have the highest pine BA but also maintained the highest total overstory basal area (>75 square feet per acre). According to Brinkman and Smith (1968), a minimum of 6-8 mature trees per acre is enough to regenerate shortleaf pine on suitable seedbeds using the seed-tree method. On average, burn-only plots had 16 overstory shortleaf pine per acre, suggesting that there was adequate density of seed producers for regeneration. Shortleaf pine germination is also limited by deep leaf litter (Grano 1949, Stambaugh and Muzika 2007), and it may take a series of burns to improve a seedbed for light-seeded species (Elliott and Vose 2005). Since shortleaf pine produces a good seed crop every 3-10 years (Lawson 1990), it is possible that transient improvement of the seedbed from fire was not followed by a good seed crop. This suggests that pine recruitment in the burn-only plots was limited more by seed availability, seedbed suitability, and light environment than the density of mature pine. Repeated burning may have also limited new pine establishment by killing pine seedlings.

The ground flora community responded positively to all restoration treatments, with the magnitude of response related to the intensity of treatments. Burning without additional treatment gradually increased the woodland composition and floristic quality, but the response over the 14 year period was not statistically significant. The effect of the HB treatment was statistically similar to both the burn and HBR treatments. HBR was the most effective in changing the species composition to woodland flora and increasing the floristic quality. Our findings are similar to those of Rimer (2004), who also found a significant increase in FQI on Midco in 2002 after burning and thinning.

CONCLUSIONS

Monitoring and evaluation are integral to a full understanding of the effectiveness of ecological restoration projects. Our analysis of monitoring data from Midco indicated that the treatments which caused the most intense disturbance, impacting both the overstory and understory, and also deliberately released both planted and natural pine regeneration, yielded the best short-term results. In contrast, the failure to enhance both pine regeneration and woodland ground flora after just a few burns highlights the importance of canopy disturbance to increase light to the understory for promoting a shortleaf pine woodland natural community. Elliott and Vose (2005) also concluded that mechanical overstory removal will likely be necessary to establish and recruit shortleaf pine in mature stands. Competition from hardwoods can also limit shortleaf pine regeneration and woodland herbaceous cover expansion. Pine seedling and small sapling densities in this study were vastly out-numbered by broadleaf shrubs and trees. This suggests that future release treatments will likely be needed to promote pine recruitment and the maintenance of woodland flora. However, the benefits of more intensive approaches should be weighed against the higher financial costs associated with more intensive treatment.

ACKNOWLEDGMENTS

We thank the many people who have been involved with restoration efforts at Midco over the years, including Kim Houf, Ryan Houf, George Kipp, Preston Mabry, Mike Norris, Rhonda Rimer, Carrie Steen, Terry Thompson, and John Tuttle. We also thank Ben Knapp, Aaron Stevenson, and Dawn Henderson for reviewing an earlier draft of this paper.

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