OAK WOODLAND RESTORATION IN THE MISSOURI OZARKS: TWO CASE STUDIES EXAMINING RESPONSES OF GROUND FLORA VEGETATION TO PRESCRIBED FIRE

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Absract—Prescribed fire and thinning are two primary tools for restoring overgrown oak and oak-pine woodlands in Missouri. We wanted to examine woodland restoration efforts and determine if we were meeting our goals of promoting herbaceous ground flora cover and richness. We examined herbaceous responses to fire at two restoration sites in the Missouri Ozarks. At the first research site (Fourche Creek), we compared ground flora responses following fall and spring burning. At the second site (Rocky Creek), we examined ground flora responses following harvest treatments and three prescribed fires. At Fourche Creek, herbaceous richness and cover was not different for all treatments prior to burning. In 2011 after two prescribed burns, both fall and spring burn treatments had higher herbaceous richness and cover when compared to the unburned control. Both burn treatments also had lower sapling density in 2011 when compared to the control. Despite distinct structural differences in the overstory at Rocky Creek, there were no differences in cover and richness of herbaceous ground flora pre- and post-burning. High variability within and among treatments for the herbaceous community at Rocky Creek was likely due to environmental factors not accounted for within this study. Overall, these two case studies present evidence that fire is sufficient to increase cover and richness of native ground flora species, and that herbaceous communities can vary greatly across large restoration units with varied topography and soil conditions.

INTRODUCTION

Wildland fire shaped the structure and composition of eastern oak woodlands of the United States prior to Euro-American settlement (Ryan and others 2013). Following intense exploitive harvesting and fire suppression in the early 20th century, woodland composition shifted towards mesic species with a subsequent decline in fire-tolerant species such as oak (*Quercus* spp.) and pine (*Pinus* spp.) (Nowacki and Abrams 2008). Recent efforts in the last two decades have aimed at using thinning and prescribed fire to halt the progression of mesophication and restore oak and oak-pine woodlands to pre-settlement conditions (McIver and others 2013).

In the Missouri Ozarks, pre-settlement woodlands were characterized as open with low densities of understory shrubs and a diverse and abundant ground flora (Batek and others 1999, Ladd 1991, Nelson 1997, Nigh 1992). Early travelers often noted the open woodland conditions with lush herbaceous understory free from underbrush (Houck 1908, Schoolcraft 1821), which was maintained by widespread fires ignited by American Indians (Guyette and others 2002). After decades of fire suppression, contemporary Ozark woodlands have increased in composition of fire-intolerant species and experienced dramatic increases in tree densities (Hanberry and others 2012, Hanberry and others 2014).

One objective for reintroducing fire to a landscape is to benefit native species that are promoted with periodic fires, thereby improving the resiliency of woodland natural communities to change caused by disturbance and climate change (Nelson 2005). Since the mid-1980s, natural resource agencies across Missouri began implementing prescribed fire in an effort to restore overgrown woodlands to their pre-settlement character (Hartman 2005, Neuwald and Templeton and others 2013). The main objectives of restoration efforts include controlling the woody understory and increasing the vigor and abundance of native ground flora (Hartman 2005, Nelson 2005). Projects on state owned land have used silvicultural treatments along with landscape-scale prescribed fire on three to five year intervals in an effort to restore open woodland conditions and stimulate growth of herbaceous cover (Hartman and Heumann 2003, Kinkead and others 2013, McMurray and others 2007). This study examines woodland restoration efforts at Fourche Creek and Rocky Creek Conservation Areas in the Missouri Ozarks.

OBJECTIVES

Our project focused on restoration efforts in an oak-dominated woodland at Fourche Creek Conservation Area (CA) and a pine-oak woodland at Rocky Creek CA. For the Fourche Creek project, we wanted answers for two questions: 1) Are there differences in

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herbaceous responses between early dormant season (fall) and late dormant season (spring) burning following two prescribed fires? and, 2) Do the fall and spring prescribed fires help control the woody understory? For the Rocky Creek project, we wanted to know if, 1) Following different harvest treatments, is there a difference in immediate ground flora response? and, 2) Will there be differences in ground flora responses following burning at sites with different structural characteristics?

STUDY AREA

The two study sites are located within the Ozarks Highland Ecoregion in Missouri (Nigh and Schroeder 2002). The Fourche Creek Project (FCHE) is located in Ripley County within the Oak Woodland Dissected Plain. This area is characterized by flat to gently rolling topography dominated by oaks (mainly *Quercus stellata* and *Q. velutina*) and hickories (*Carya* spp.). The Rocky Creek Project (RCKY) was established in Shannon County within the Current River Oak-Pine Woodland/ Forest Hills. This area features gently rolling dissected plains to rugged topography near major streams. Pine-oak woodlands generally dominate the landscape, especially on ridgetops and upper slopes. Dominant canopy species in this region include hickories (*Carya glabra, C. texana, C. tomentosa*), oaks (*Quercus alba*, *Q. coccinea*, *Q. stellata*, and *Q. velutina*), and shortleaf pine (*Pinus echinata*).

METHODS

We evaluated three prescribed fire treatments at FCHE: early dormant season burning (fall), late dormant season burning (spring), and no burn (control). We implemented the fall prescribed fires on 11/10/05 and 11/8/09. The spring burns occurred on 3/28/06 and 4/9/2010. The three treatment units ranged from 3.3 to 5.5 ha.

Managers initiated harvest treatments at the RCKY project in 2003 before researchers had a chance to collect baseline data, but we still wanted to determine if pre-burn overstory structure would affect herbaceous species response to fire. We evaluated four harvest treatments that occurred in 2003 and 2004: intermediate thinning with timber stand improvement (ITSI), shelterwood harvest (SW), uneven-aged management (UAM), and a non-commercial woodland thinning (NCW). We added a fifth treatment, pine-ITSI (PITSI), within the ITSI treatment because the overstory composition within this particular study area was predominantly shortleaf pine, whereas the other sites had higher proportions of oaks. See table 1 for more detailed descriptions of harvesting treatments. All harvest sites at RCKY are within the same burn unit (267 ha), and were burned in March 2006 (date unspecified), January 2009 (date unspecified), and 4/8/2011.

We established three circular permanent plots for each treatment. Within each 0.1 ha plot, we sampled all woody vegetation ≥ 10 cm DBH (overstory). Within a 0.01 ha subplot located at plot center, we measured all woody vegetation <10 cm DBH and ≥1.4 m tall (sapling). We sampled vegetation cover for herbaceous and woody species (<1.4 meters in height) in three 1-m^2 quadrats distributed at 5.64 meter intervals along the four cardinal directions (n=12).

For both studies we wanted to investigate differences in ground flora among all treatments before (2005) and after the application of fire (2011). Specifically, we wanted to determine if the treatments affected the richness (plot-level) and cover (quadrat-level) of herbaceous species. At FCHE, we also evaluated the density of saplings (<2.74 m in height) in 2005 and 2011. To examine overstory structure at RCKY, we evaluated basal area (m^2 /ha) and quadratic mean diameter (cm) in 2005 and 2011. All hypotheses were tested using one-way ANOVA, and means were compared using Fisher's least significant difference test. Because our sample size was small, we set $\alpha = 0.10$ to test for significant effects.

Table 1—Description of treatments at the Rocky Creek project (RCKY). ITSI = intermediate thinning with timber stand improvement. NCW = non-commercial woodland thinning. PITSI = intermediate thinning with timber stand improvement with a relatively high component of overstory shortleaf pine (*Pinus echinata*). SW = shelterwood. UAM = uneven-aged management

Treatment	Description
ITSI	Thinned to 13.8 m^2/ha
NCW	Cut all woody vegetation <15.2 cm DBH
PITSI	Thinned to 13.8 m^2/ha
SW	Retain 4.6 - 9.2 m^2/ha residual basal area
UAM	Group openings and thinning using Law and Lorimer (1989) method

RESULTS

Fourche Creek Project (FCHE)

Herbaceous richness—In 2005, prior to spring and fall burning, herbaceous richness ranged from 12 to 16 species per plot (fig. 1), although no significant difference was found among treatments (ANOVA; F-value = 0.75; $p = 0.51$). In 2011, herbaceous richness in burned treatments was significantly higher than in the control (ANOVA; F-value = 6.67; $p = 0.03$). For spring and fall burning treatments, there were 35 and 39 species per plot, respectively. For the control treatment, there were 24 species per plot.

Herbaceous cover—Prior to burning in 2005, there were no significant differences in herbaceous cover among treatments (fig. 2). Herbaceous cover during this sampling period was 5 percent for all treatments (ANOVA; F-value = 0.01; $p = 0.99$). In 2011, herbaceous cover in the burn treatments was significantly higher than in the control (ANOVA; F-value = 22.74; $p < 0.001$). Herbaceous cover was 13 percent for fall burning and 14 percent for spring burning, while cover in the control was 3 percent.

Sapling density—In 2005, the sapling density in spring burn sites was higher than in both control and fall burn sites (fig. 3). There were 15 stems per plot for the spring treatment, whereas the control and fall treatments each averaged 7 stems per plot (ANOVA; F-value = 12.80; $p < 0.01$). In 2011 the control had significantly higher sapling density than spring and fall treatments (ANOVA; F-value 14.18; $p < 0.01$). The control treatment had 28 stems per plot, in contrast to much lower stem density in spring (2) and fall (4) treatments.

Rocky Creek Project (RCKY)

Herbaceous richness—For herbaceous richness, there were no significant differences among harvest treatments for both 2005 (ANOVA; F-value = 0.67, $p = 0.63$) and 2011 (ANOVA; F-value = 0.64 $p = 0.65$), likely due to high amount of variability within treatments (fig. 4). In 2005, herbaceous species richness ranged from 5 species per plot for NCW to 14 species per plot for ITSI. In 2011, the NCW treatment again had the lowest species richness among all treatments (13), while the SW treatment had the highest species richness (22).

Herbaceous cover—For both sampling years, there were no significant differences among treatments for herbaceous cover (2005-ANOVA; F-value = 0.41; $p = 0.80$; 2011-ANOVA; F-value = 1.34; p-value = 0.33) (fig. 5). In 2005, herbaceous cover ranged from 1.7 percent to 4.3 percent at all sites. In 2011, herbaceous cover ranged from 2.3 percent to 8.9 percent.

Basal area—In 2005, basal area by treatment can be separated into two groups (fig. 6). The "low" basal area group contains the NCW (10.5 m^2/ha) and SW (4.8 m^2/ha) treatments. The basal areas for these treatments were significantly lower than the other three treatments (ANOVA; F-value 7.32; $p < 0.01$). The "high" basal group contains the other three treatments. Basal areas in this group were not significantly different from one another at 17.6 (PITSI), 17.9 (UAM), and 20.4 (ITSI) m^2/ha.

From 2005 to 2011 there were small changes in basal area (fig. 6). Basal area for SW (4.5 m^2/ha) was significantly lower than all other treatments (ANOVA; F-value =8.58; $p < 0.01$). Basal area (m^2/ha) for ITSI (20.4) was the highest, but it was not significantly different from PITSI (17.6) and UAM (14.6). The basal area for NCW increased to 12.7 m^2/ha in 2011, but it was not statistically different from PITSI or UAM.

Quadratic mean diameter (QMD)--Much like basal area in 2005, quadratic mean diameter (QMD; cm) can be separated into two groups (fig. 7). The "small" QMD group contains ITSI, PITSI, and UAM. QMDs in this group range from 21.1 cm to 22.5 cm. QMDs in this group are not significantly different from each other, but they are significantly smaller than the "large" group (ANOVA; F-value = 12.36; $p < 0.001$). The "large" QMD group contains NCW (29.6 cm) and SW (28.2 cm). The QMD for these two treatments were not significantly different from each other.

The QMD in 2011 differed among treatments (ANOVA; F-value = 6.67; $p < 0.01$). The SW and NCW QMDs were still the highest (31.7 cm and 30.1 cm, respectively), but unlike in 2005, NCW was not different from UAM (25.2 cm). As in 2005, there was no difference in QMD for ITSI (22.7 cm), PITSI (22.9 cm), and UAM (25.2 cm).

DISCUSSION

Fourche Creek (FCHE)

Many studies have shown that fire is effective at increasing herbaceous richness in oak and oak-pine woodlands of the eastern United States (Arthur and others 1998, Elliott and others 1999, Kinkead and others 2012, Masters 1991, McGee and others 1995, Nuzzo and others 1996, Phillips and others 2007, Sparks and others 1998, Taft 2003, Wilhelm and Masters 1994). Increasing herbaceous richness in the understory is a cornerstone objective in the goal of restoring oak and pine-oak woodlands in the Missouri (Hartman 2005, Nelson 2005). Our results confirm that fall and spring burning at Fourche Creek is effective at increasing herbaceous richness during oak woodland restoration.

It was no surprise that herbaceous cover was higher after fall and spring burning at FCHE when compared

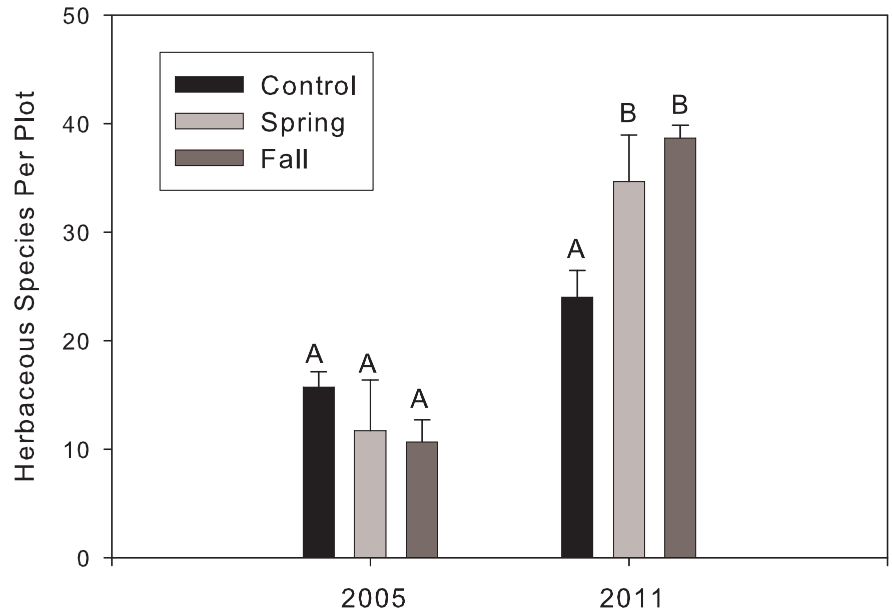

Figure 1—Herbaceous richness (mean + SE) at the Fourche Creek project (FCHE) in 2005 (pre-treatment) and 2011. The fall prescribed fires were implemented on 11/10/05 and 11/8/09. The spring burns occurred on 3/28/06 and 4/9/2010. Significant differences of means within years are denoted by different letters (α = 0.10).

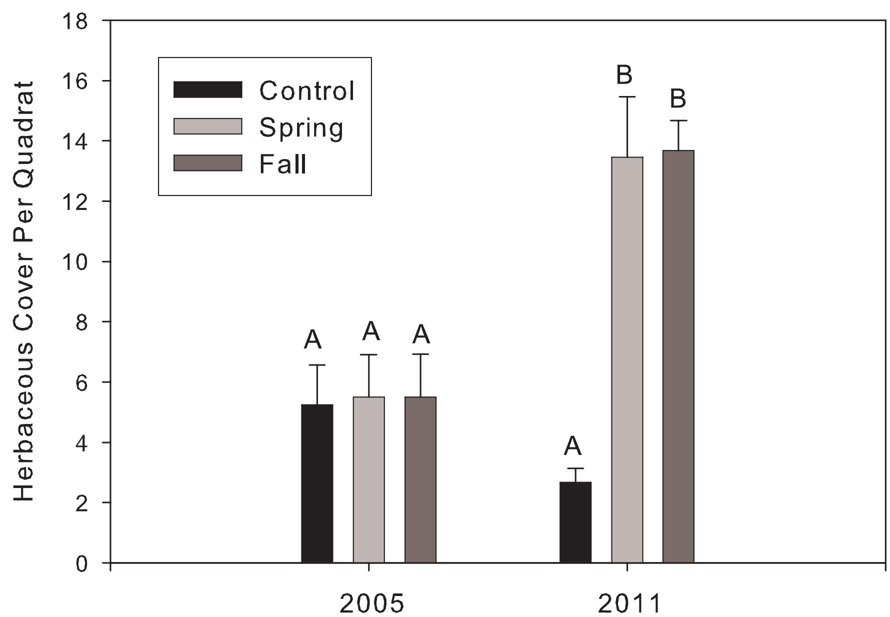

Figure 2—Herbaceous cover (mean + SE) at the Fourche Creek project (FCHE) in 2005 (pre-treatment) and 2011. The fall prescribed fires were implemented on 11/10/05 and 11/8/09. The spring burns occurred on 3/28/06 and 4/9/2010. Significant differences of means within years are denoted by different letters (α = 0.10).

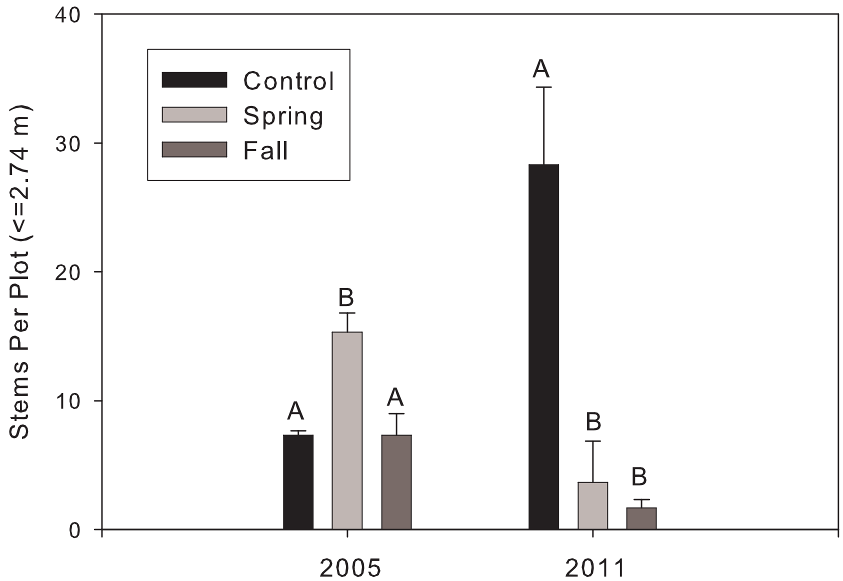

Figure 3—Sapling stem density (mean + SE) at the Fourche Creek project (FCHE) in 2005 (pre-treatment) and 2011. The fall prescribed fires were implemented on 11/10/05 and 11/8/09. The spring burns occurred on 3/28/06 and 4/9/2010. Significant differences of means within years are denoted by different letters (α = 0.10).

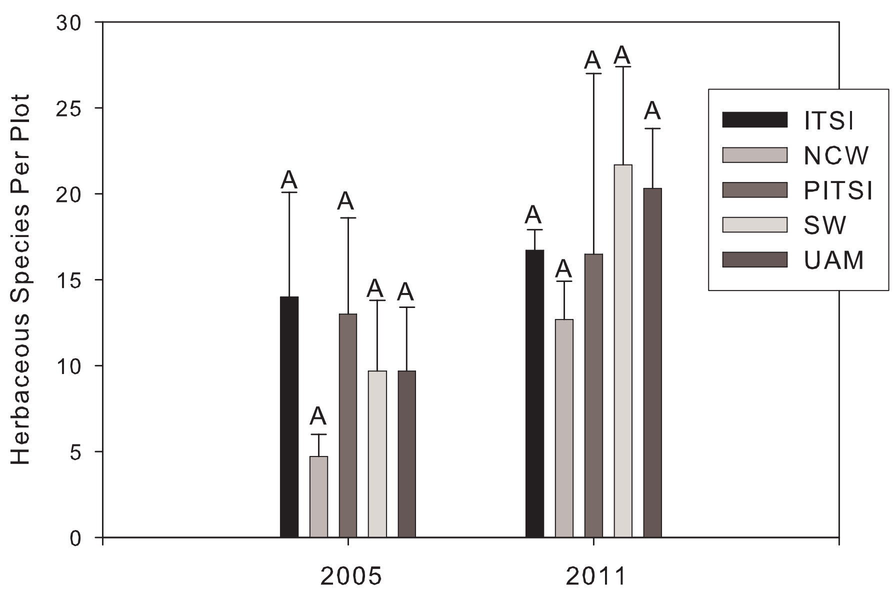

Figure 4—Herbaceous richness (mean + SE) at the Rocky Creek project (RCKY) in 2005 (post-harvest, pre-fire) and 2011. Harvesting occurred in 2003 and 2004. All treatment sites at RCKY are within the same burn unit, and were prescribed fire in March 2006 (date unspecified), January 2009 (date unspecified), and 8 April 2011. Significant differences of means within years are denoted by different letters (α = 0.10). ITSI = intermediate thinning with timber stand improvement. NCW = non-commercial woodland thinning. PITSI = intermediate thinning with timber stand improvement with a relatively high component of overstory shortleaf pine (*Pinus echinata*). SW = shelterwood. UAM = uneven-aged management.

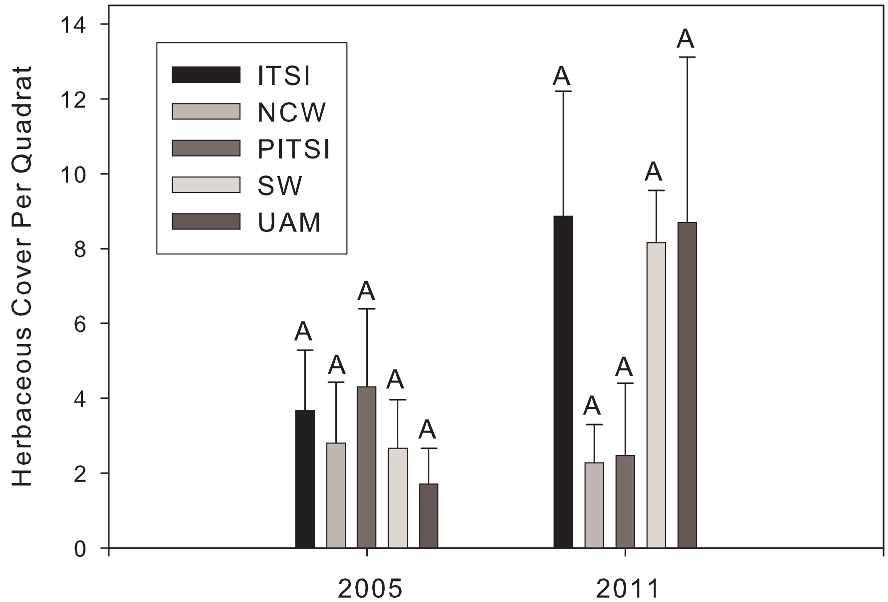

Figure 5—Herbaceous cover (mean + SE) at the Rocky Creek project (RCKY) in 2005 (post-harvest, pre-fire) and 2011. Harvesting occurred in 2003 and 2004. All treatment sites at RCKY are within the same burn unit, and were prescribed fire in March 2006 (date unspecified), January 2009 (date unspecified), and 8 April 2011. Significant differences of means within years are denoted by different letters (α = 0.10). ITSI = intermediate thinning with timber stand improvement. NCW = non-commercial woodland thinning. PITSI = intermediate thinning with timber stand improvement with a relatively high component of overstory shortleaf pine (*Pinus echinata*). SW = shelterwood. UAM = uneven-aged management.

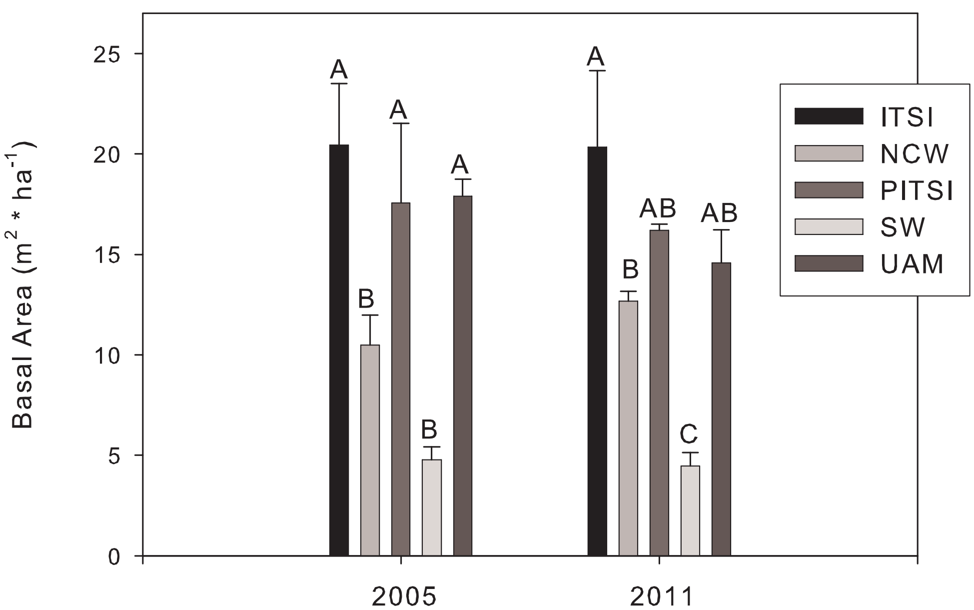

Figure 6—Basal area (mean + SE) at the Rocky Creek project (RCKY) in 2005 (post-harvest, pre-fire) and 2011. Harvesting occurred in 2003 and 2004. All treatment sites at RCKY are within the same burn unit, and were prescribed fire in March 2006 (date unspecified), January 2009 (date unspecified), and 8 April 2011. Significant differences of means within years are denoted by different letters (α = 0.10). ITSI = intermediate thinning with timber stand improvement. NCW = non-commercial woodland thinning. PITSI = intermediate thinning with timber stand improvement with a relatively high component of overstory shortleaf pine (*Pinus echinata*). SW = shelterwood. UAM = uneven-aged management.

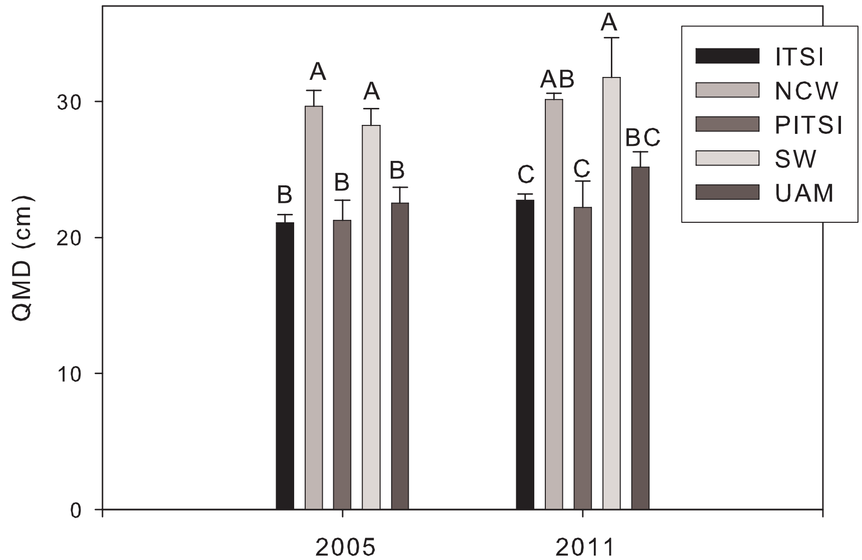

Figure 7—Quadratic mean diameter (mean + SE) at the Rocky Creek project (RCKY) in 2005 (post-harvest, pre-fire) and 2011. Harvesting occurred in 2003 and 2004. All treatment sites at RCKY are within the same burn unit, and were prescribed fire in March 2006 (date unspecified), January 2009 (date unspecified), and 8 April 2011. Significant differences of means within years are denoted by different letters ($\alpha = 0.10$). ITSI = intermediate thinning with timber stand improvement. NCW = non-commercial woodland thinning. PITSI = intermediate thinning with timber stand improvement with a relatively high component of overstory shortleaf pine (*Pinus echinata*). SW = shelterwood. UAM = uneven-aged management.

to unburned sites. Numerous studies in oak dominated woodlands have shown that use of prescribed fire leads to increases in herbaceous ground flora cover (DeSelm and Clebsch 1991, Elliott and others 1999, Kuddes-Fischer and Arthur 2002, Masters 1991, Nuzzo 1996, Phillips and others 2007, Taft 2003). Results from other restoration sites in the Missouri Ozarks have also reported increased herbaceous cover following prescribed fire (Hartman and Heumann 2003, Kinkead and others 2013, McMurray and others 2007, Sasseen and Muzika 2004).

Top-killing of saplings causes an immediate decrease in woody cover following prescribed fires (Bacone and Post 1986, Glitzenstein and others 2003), but re-sprouting from species such as red maple (*Acer rubrum*) and sassafras (*Sassafras albidum*) often leads to increased density following prescribed fire (Ducey and others 1996, Phillips and others 2007). Studies in the Missouri Ozarks have also shown that fire is effective at top-killing saplings, and periodic burning leads to lower densities of saplings in burned oak and oak-pine woodlands (Blake and Schuette 2000, Hartman and Heumann 2003). Our results from FCHE confirm that multiple fires in spring or fall lead to lower density of saplings when compared to similar unburned sites. The relatively low density of saplings in the burned areas, along with the prescribed fires, likely influenced the herbaceous response (Hartman and Heumann 2003).

Rocky Creek (RCKY)

The findings from the RCKY project are difficult to interpret because of several problems with the study design. First, baseline data was not collected prior to harvest treatments. Second, control plots were not established outside of the burning area. And lastly, sampling plots were established across three different Ecological Landtypes (Nigh and Schroeder 2002) which include ultic chert uplands, exposed sandstone backslopes, and upland loess fragipans. It is reasonable to expect variability in herbaceous cover and richness ground flora within these different Ecological Landtypes due to variability in landforms, soil types, and geologic parent material.

One would posit that different structural differences in the overstory would lead to variability in herbaceous responses among treatments. Instead we found wide variability of herbaceous responses within and among treatments. As stated earlier, this could be attributed to location of plots within different Ecological Landtypes both within and among treatments.

For some harvest treatments, there did appear to be an increase in herbaceous richness and cover following burning, although this was not statistically tested. As we said earlier, many studies have shown that prescribed fire is effective at stimulating ground flora, including our FCHE study. Although we did not see differences in cover and richness among harvest treatments, one might suggest that regardless of harvest treatment, prescribed fire may be effective at stimulating herbaceous ground flora.

CONCLUSION

Prescribed fire appears to be an effective tool for meeting common objectives of oak woodland restoration. Following multiple prescribed fires, we saw an increase in herbaceous richness and cover at two oak restoration sites in the Missouri Ozarks. Prescribed fire may also be effective at top-killing saplings, which likely enhances sunlight reaching the ground flora and further stimulates the growth of herbaceous species. Following harvest treatments and prescribed fire, variability within sites could not be accounted for with overstory metrics, while environmental factors may be driving variability in herbaceous responses within and among treatments. Future monitoring efforts will continue to track changes in vegetation responses following multiple fires.

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