EARLY IMPACTS OF FIRE AND CANOPY GAPS ON SEEDLING AND SAPLING LAYERS: EVIDENCE FOR REVERSING MESOPHICATION?

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Abstract—Two prescribed fires and reductions in mid and overstory canopies by herbicide may be starting to reverse the mesophication trend in oak-dominated stands. Before treatment, the sapling layer was about 360 stems per acre and of that, approximately 20 percent was striped maple. The relative abundances of several mesic species increased after treatment (birch and red maple); however, the relative abundance of seedlings of other mesic species showed a temporary reduction after one fire; yellow-poplar seedling abundance dropped after two fires. The relative abundance of non-oak tree seedlings categorized as dry-mesic to xeric (e.g., hickory, sassafras) did increase after the two prescribed fires. Prescribed fire and mid- or overstory reduction treatments occurred at the same time in our study, with little to no existing advanced oak regeneration available to take advantage of favorable conditions created by the treatments. However, our results suggested fire reduced low shade (striped maple) but also shows the disadvantage of creating post-disturbance competitors for oaks (increases in birch and red maple). Two levels of canopy reduction by herbicide treatment conferred no immediate advantage to oak seedlings when combined with fire. For the oak seedlings 2 years post fire, the manipulation of the canopy and midstory by herbicide has not resulted in any benefit over fire alone. We expect that the species composition and structure of the seedling and sapling layers will show greater differences at 5 or 10 years post-fire. In this analysis of almost immediate post-treatment effects, there has not been enough time for oak saplings to develop.

INTRODUCTION

The removal of fire, closed forest canopies, and overabundance of white-tailed deer (*Odocoileus virginianus*) from the eastern hardwood forests has led to an alternative vegetation stable state termed mesophication, whereby shade-tolerant and fire-sensitive tree species, particularly those less prone to herbivory dominate the understory (Campbell and others 2006, Collins and Carson 2003, Nowacki and Abrams 2008). The increase in shade-tolerant and fire-sensitive species in the understory creates shade that leads to a cool and moist microclimate. In turn, these species also tend to produce fuels that are thin, flat, moist, and that rapidly decompose thereby reducing fuel needed to carry a biologically impactful fire (Nowacki and Abrams 2008).

Even with management actions, oak regeneration and eventual accession to the canopy has often proven elusive and less than successful. Oak forests have dominated the Eastern United States for thousands of years (Davis 1981, Watts 1979), yet studies of existing old-growth and second-growth oak-dominated forests show that the replacement of oak overstories with mesic shade-tolerant species such as sugar maple (*Acer saccharum*) and pioneer species like red maple (*A. rubrum*) are now commonly occurring (Abrams and Downs 1990, Hart and Grissino-Mayer 2009, McGee 1986, Nowacki and Abrams 1992). Although oak seedlings may still be found in the understory and in gap openings, oaks no longer appear to have the ability to persist in the understory as they had in the past (i.e., as much as 54 years on average for northern red oak (*Quercus rubra*)) due to competition for light and herbivory pressure, or become competitive when light conditions are favorable (Kochenderfer and Ford 2008, Rentch and others 2003).

Other factors besides the reduction in fire-return intervals also have occurred in these forests including clearing for agriculture, extensive exploitative logging and slash fires (Stephenson 1993), and the loss of key species from forest disease and insect pathogens (Woods and Shanks 1959). In general, current forests exist under altered conditions from those the original forests developed under, with current forests developing with higher white-tailed deer densities (Rooney 2001), reduced fire frequency (Nowacki and Abrams 2008),

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denser overstory, less flammable understories (Nowacki and Abrams 2008), and smaller canopy gaps (Clebsch and Busing 1989). These have further contributed to depauperate understories dominated by a few tree species that are simultaneously browse-tolerant, shade-tolerant, and fire sensitive (Kain and others 2011, Nuttle and others 2013).

Understory fire has been suggested as a way to change midstory light levels and to favor oak (Lorimer 1989). Generally, oak is a poor competitor on high and medium quality sites, a fact that seems counter-intuitive in view of its current dominance in most Eastern forests (Lorimer 1989). Oaks are not well adapted to low light conditions, although seed will germinate in shade (Crow 1988), and self-replacing oak forests are generally limited to the more xeric sites (Abrams 1992). Oaks do possess many ecophysiological factors that indicate adaptation to fire, such as thick bark on mature trees, ability to form seedling-sprouts hypogeally, ability to stump sprout, deep root system, compartmentalization of stem injuries, and rot resistance (Abrams 1992). Successful oak regeneration relies on advanced reproduction, often as seedling-sprouts and not true seedlings (Johnson and others 2009a).

Fire does top-kill oak seedlings and sprouts, so reduction in their numbers is common immediately after a fire (Brose and others 2014). However, repeated burning and resprouting of oaks and their competitors is expected to create conditions whereby competitors such as red maple and yellow-poplar (*Liriodendron tulipifera*) deplete energy reserves and seed banks faster than oaks due to physiological differences (Lorimer 1985). These insights on fire and oak forest development have led to the increased interest in application of prescribed fire where oaks dominate the overstory.

The mesophication of the eastern forests is an example of the theory of alternative stable states. Applying this theory to fire-adapted forests, it can be argued that the shift caused by the removal of a disturbance regime combined with various other proximate factors is more rapid and harder to reverse on more mesic sites (Nowacki and Abrams 2008). With these regional trends in mind, the effects of fire and canopy reduction on oak regeneration were incorporated in a long-term study on the Fernow Experimental Forest (FEF) in east central West Virginia. The broader study involved the use of prescribed fire and snag creation to create or maintain habitat for tree-roosting bats (Ford and others 2016, Johnson and others 2009b) with no consideration for present or future timber values. Fire and canopy gaps are hypothesized to combat the mesophication occurring in eastern oak forests, particularly those on more mesic locations. If reversal of mesophication is occurring in the study area, the early effects should be discernable in the seedling and sapling layers. We tested the hypothesis that the species composition of seedlings and saplings has been shifted toward more dry-mesic to xeric species with subsequent decreases in mesic species following two prescribed fires and the creation of canopy gaps.

STUDY AREA

Our research was conducted at the Fernow Experimental Forest (FEF) (fig. 1), an ~4,700-acre experimental forest located in the Unglaciated Allegheny Mountains subsection of the Appalachian Plateau Physiographic Province in Tucker County, West Virginia (Cleland and others 2007). The study site is Compartment 45 located in the John B. Hollow watershed of the FEF and is referred to as the “John B. Hollow study”. Elevations at the study site range from about 2000 to 2600 feet. The underlying geology of the study site is mostly shale and sandstone of the Hampshire formation. Mean annual total precipitation on the FEF is about 57 inches, with maximum average monthly precipitation occurring in June and minimum monthly precipitation in October. Mean annual temperature is 48.5° F, ranging from –0.4°F in January to 69°F in July (Kochenderfer 2006). The FEF was initially logged from 1903 to 1911 with nearly complete removal off all merchantable trees (Schuler and Fajvan 1999). Although the overstory of the FEF is broadly described as mixed mesophytic (Braun 1950), within the study site, the overstory was dominated by northern red oak, chestnut oak (*Q. prinus*), sugar maple, red maple, and yellow-poplar (*Liriodendron tulipifera*) with oak species having larger average diameter at breast height (DBH). In 2006, before treatments were applied, total basal area in the overstory (trees over 5 inches DBH) was about 132 square feet per acre.

METHODS

We conducted spring burns in 2007 and 2008 in Compartment 45 (299 acres), including all sample plots each year (fig. 1). Strip-head-fire techniques were used during the burns with ignition by hand-held drip torches. Since the overarching focus of the study was wildlife habitat (Johnson and others 2009b), greater fire intensity was allowed than if production of timber products were a management goal. No measures of fire intensity were taken, however the resulting mosaic of fire severity includes patches where overstory mortality occurred and other areas with little fire damage (cove or riparian areas). Within the burn unit, a total of 60 randomly located ~66 ft (20 m) radius plots were established and three treatments were assigned in a completely randomized design. After the second prescribed fire in 2008, 49 plots were determined to have been burned; our analysis includes only those 49 plots. On 19 plots, all overstory trees (> 5 inches DBH, with the exception of oak or hickory [*Carya* spp.]; retained as day-roosts for the endangered Indiana bat *Myotis sodalis*; Johnson and others 2010) were deadened with stem-injection application of glyphosate herbicide during the growing

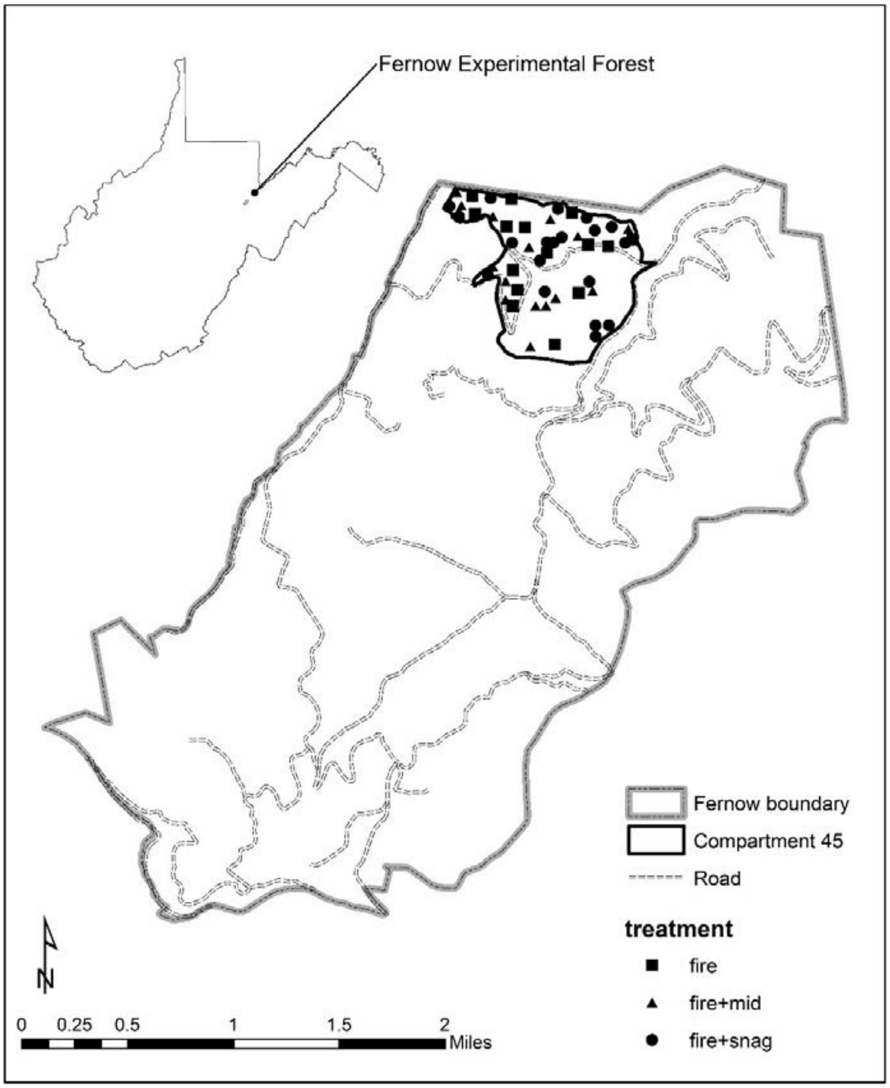

Figure 1—General location of study area with plot locations by treatment type.

season in 2007; this treatment is referred to as fire+snag in this analysis. All midstory trees (5 to 11 inches DBH, with the exception of oak or hickory) were removed by herbicide on another 15 plots (fire+mid treatment). In both these treatments, trees that were not killed by the 2007 application of herbicide were treated again in 2008. We are considering the herbicide treatment to be conducted once (2007) in the sample design and statistical analysis. On the remaining 15 plots no over- or midstory trees were treated with herbicide (fire treatment; fig. 1).

At each plot center, a 1/100th acre plot was established to tally woody vegetation 1 to 5 inches in DBH. Species, DBH, crown class, origin (seedling or sprout), and quality were recorded for each stem. In the four cardinal directions from the main plot center, four milacre plots were established to sample the seedling regeneration. On these plots, woody vegetation <1 inch DBH and > 6 inches in height was tallied by species, height class, and origin (seedling or sprout).

Statistical Analysis

Seedling relative abundance was calculated for all tree and shrub species by plot (an average of the 4 milacre subplots); no vine species were included in the seedling calculations and blackberry (*Rubus* spp.) was excluded. To test for the effect of prescribed fire and overstory reduction on the species composition of the seedling layer, species were assigned to either mesic or dry-mesic to xeric categories, or were considered separately. Table 1 lists the species considered for each category and those species assessed separately.

Table 1—Species groups used in analysis

Species group	Species/genera
Other mesic trees	White ash (*Fraxinus americana*)
	Dogwood (*Cornus florida*)
	Basswood (*Tilia americana*)
	Sugar maple (*Acer saccharum*)
	Black cherry (*Prunus serotina*)
	Fire cherry (*P. pensylvanica*)
	Serviceberry (*Amelanchier* spp.)
	Frasier magnolia (*Magnolia fraseri*)
	Cucumber tree (*M. acuminata*)
	American beech (*Fagus grandifolia*)
	Hophornbeam (*Ostrya virginiana*)
	Hornbeam (*Carpinus caroliniana*)
Other dry-mesic to xeric trees	Sourwood (*Oxydendrum arboreum*)
	Blackgum (*Nyssa sylvatica*)
	Black locust (*Robinia pseudoacacia*)
	Sassafras (*Sassafras albidum*)
	American chestnut (*Castanea dentata*)
	Hickory (*Carya* spp.)
	White pine (*Pinus strobus*)
Mesic shrubs	Witch hazel (*Hamamelis virginiana*)
	Wild hydrangea (*Hydrangea arborescens*)
	Sumac (*Rhus typhina*)
	Spicebush (*Lindera benzoin*)
	Rhododendron (*Rhododendron* spp.)
	Mapleleaf viburnum (*Viburnum acerifolium*)
	Deciduous holly (*Ilex montana*)
	Hercules club (*Aralia spinosa*)
	Elderberry (*Sambucus* spp.)
Dry-mesic to xeric shrub	Minniebush (*Menziesia pilosa*)
	Blueberry (*Vaccinium* spp.)
	Mountain laurel (*Kalmia latifolia*)
	Azalea (*Azalea* spp.)
As individual species or genera	Birch (*Betula alleghaniensis* and *B. lenta*)
	Yellow-poplar (*Liriodendron tulipifera*)
	Striped maple (*A. pensylvanicum*)
	Red maple (*A. rubrum*)
	Oak (*Quercus* spp.)

For the sapling layer, stems per acre and basal area per acre were calculated. Preliminary analyses showed that assessing individual species or descriptive groups of species did not result in conclusive statistical assessment due to low numbers of saplings. Stems per acre by species or species group were calculated for descriptive statistics. The other mesic species category included: eastern hemlock (*Tsuga canadensis*), American beech, black cherry, and sugar maple. The other dry-mesic to xeric category included: black locust, blackgum, and sourwood.

We used a repeated measures completely randomized, generalized linear model with pseudo-maximum likelihood estimation via PROC GLIMMIX (SAS 2012) in a two factor design. Year (2006, 2007, 2008, and 2010) and overstory treatment were the explanatory variables with treatments defined as fire, fire+mid, and fire+snag based on the random assignment of herbicide treatments to the plots. The associated interactions of year and treatment were fixed effects in the model. Pre-treatment year is 2006, with treatments applied in 2007 (fire and herbicide) and 2008 (second fire), with 2010 as most recent post-treatment measurement. We used the exponential distribution with logarithmic link function because relative density data displayed a negative exponential distribution (SAS 2012). In the repeated measures model, covariance structures of autoregressive, heterogeneous autoregressive, or variance components were used depending on response variable to account for the correlation of repeated measures over time. Least square means are displayed; the Tukey-Kramer method was used to adjust p values for multiple orthogonal comparisons. Comparisons between years and among treatments were also made through contrasts of the means of fire only treatment with the means of the other fire and snag creation treatments combined. Contrasts of interest were: 2006 fire vs. 2006 both fire+mid and fire+snag and 2010 fire vs. 2010 both fire+mid and fire+snag.

RESULTS

Although the changes in the overstory were not addressed statistically in this analysis, the herbicide and fire treatments did reduce the overstory basal area. By 2010, basal area in the fire only plots had increased slightly to about 139 square feet per acre, reduced to about 110 square feet per acre in the fire+mid treatment plots, and been reduced to about 79 square feet per acre in the fire+snag treatment plots.

Total stems per acre in saplings were reduced from around 360 stems per acre before treatment to 33 to 205 per acre (depending on treatment) in 2010 (fig. 2a). All treatments showed significant reductions in numbers of stems per acre from 2006 to 2010 ($p=0.0015$ for fire, $p<0.0001$ for fire+mid, and $p=0.0175$ for fire+snag). The fire+mid plots had the lowest mean stems per acre in 2010 but did not differ significantly from other treatments when adjustments were made for multiple comparisons.

Total basal area in saplings of all species followed roughly the same pattern as for stems per acre and was reduced by the treatments (fig.2b), however only the basal area in fire+mid plots was reduced significantly from 2006 to 2010 ($p<0.0001$). For the fire only and fire+snag plots, basal area per acre was not significantly different before treatment and 2010 ($p=0.1442$ for fire only and $p=0.4510$ for fire+snag). In 2010, the basal area in the fire+mid plots averaged only 1.3 square feet per acre but when adjusted for multiple comparisons, there were no differences between treatments in 2010. For both stems per acre and basal area per acre, no significant differences were found in 2010 between the fire plots and the two other treatments combined.

The absolute numbers of birch and red maple saplings declined with fire and mid- or overstory reductions, with slight reductions in relative abundances as well (table 2). There were no yellow-polar or oak (all species combined) saplings in the plots after treatment. Striped maple saplings were reduced in absolute and relative abundance after treatments were applied, dropping to zero in 2008 but increasing to 2 stems per acre in 2010. Surprisingly, saplings categorized as dry-mesic to xeric (other than oaks) also dropped in abundance with treatments although their relative abundance increased slightly. Similarly, saplings of mesic species (other than those already considered) also dropped in absolute numbers but their relative abundance increased after treatments.

Total seedlings increased from about 24,000 per acre before management actions (all treatments combined) to about 41,000 to 49,000 after treatment (table 3; fig 3a) with differences found from 2006 to 2010 for all three treatments combined ($p=0.0009$). Higher stems per acre were found in plots in 2010 where the mid- or overstory was also reduced although differences among treatments were not statistically significant in 2010. The relative abundance of seedlings of all oak species was reduced by all treatments from 2006 to 2010 ($p=0.0004$ for fire, $p=0.0002$ for fire+mid, and $p<0.0001$ for fire+snag), however there was a slight recovery 2 years after the second fire (fig. 3b). In terms of absolute numbers, the number of oak seedlings is about half the pre-treatment level (table 3).

The relative abundance of dry-mesic to xeric shrubs were reduced post treatment compared to pre-treatment levels ($p<0.0001$ for fire, $p=0.0005$ for fire+mid, and $p=0.0177$ for fire+snag), however this group of species only made up approximately 2-4 percent of all seedlings before fire and canopy gaps were created (fig. 3c). In contrast, the seedlings of tree species categorized as dry-mesic to xeric (other than oak species) increased

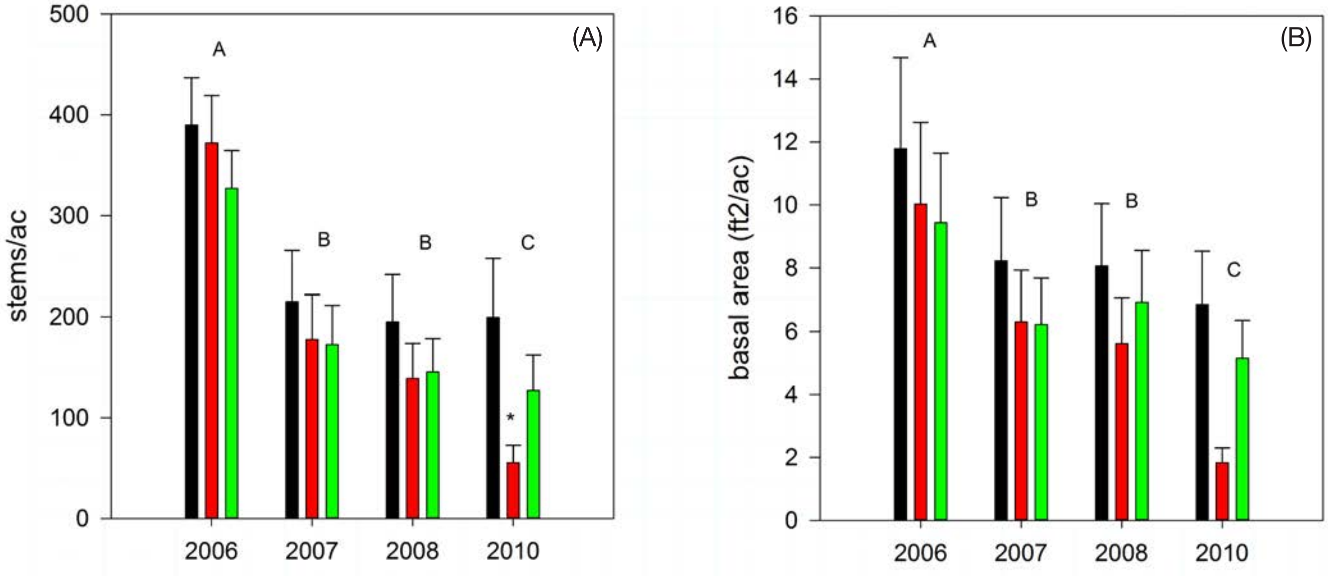

Figure 2—Comparison of least square mean (±SE) of total sapling density (a) and total sapling basal area (b) by treatment and year. Means between years with the same letter are not statistically different (α = 0.05).

Table 2—Sapling species composition as mean stems per acre (percent total in parenthesis) on the John B. Hollow study site, Fernow Experimental Forest, West Virginia, 2006-2010

Species or group	2006	2007	2008	2010
Birch	20.4 (5.6)	4.1 (2.9)	4.1 (3.4)	6.1 (7.0)
Yellow-poplar	2.0 (0.6)	0.0	0.0	0.0
Striped maple	71.4 (19.8)	6.1 (4.4)	0.0	2.0 (2.3)
Red maple	51.0 (14.1)	32.7 (23.5)	14.3 (12.1)	12.2 (14.0)
Other mesic	175.5 (48.6)	75.5 (54.4)	79.6 (67.2)	53.1 (60.5)
All oaks	0.0	2.0 (1.5)	0.0	0.0
Other dry-mesic to xeric	40.8 (11.3)	18.4 (13.2)	20.4 (17.2)	14.3 (16.3)
Total	361.2	138.8	118.4	87.8

Table 3—Seedling species composition as mean stems per acre (percent total in parenthesis) on the John B. Hollow study site, Fernow Experimental Forest, West Virginia, 2006-2010

Species or group	2006	2007	2008	2010
Birch	270.5 (1.2)	65.1 (0.4)	51.4 (0.1)	3,630.1 (9.0)
Yellow-poplar	407.5 (1.8)	6,126.7 (35.9)	10,729.5 (24.7)	5,301.4 (13.1)
Striped maple	3,434.9 (15.0)	2,256.8 (13.2)	1,455.5 (3.4)	1,106.2 (2.7)
Red maple	2,476.0 (10.8)	3,239.7 (19.0)	5,845.9 (13.5)	11,887.0 (29.3)
Other mesic trees	2,287.7 (10.0)	1,003.4 (5.9)	4,332.2 (10.0)	3,688.4 (9.1)
All oaks	8,664.4 (38.0)	1,804.8 (10.6)	2,260.3 (5.2)	4,438.4 (11.0)
Other dry-mesic to xeric trees	537.7 (2.4)	1,164.4 (6.8)	12,708.9 (29.3)	8,058.2 (19.9)
Mesic shrubs	390.4 (1.7)	123.3 (0.7)	452.1 (1.0)	866.4 (2.1)
Dry-mesic to xeric shrubs	4,356.2 (19.1)	1,291.1 (7.6)	5,568.5 (12.8)	1,547.9 (3.8)
Total seedlings	22,825.3	17,075.3	43,404.1	40,524.0

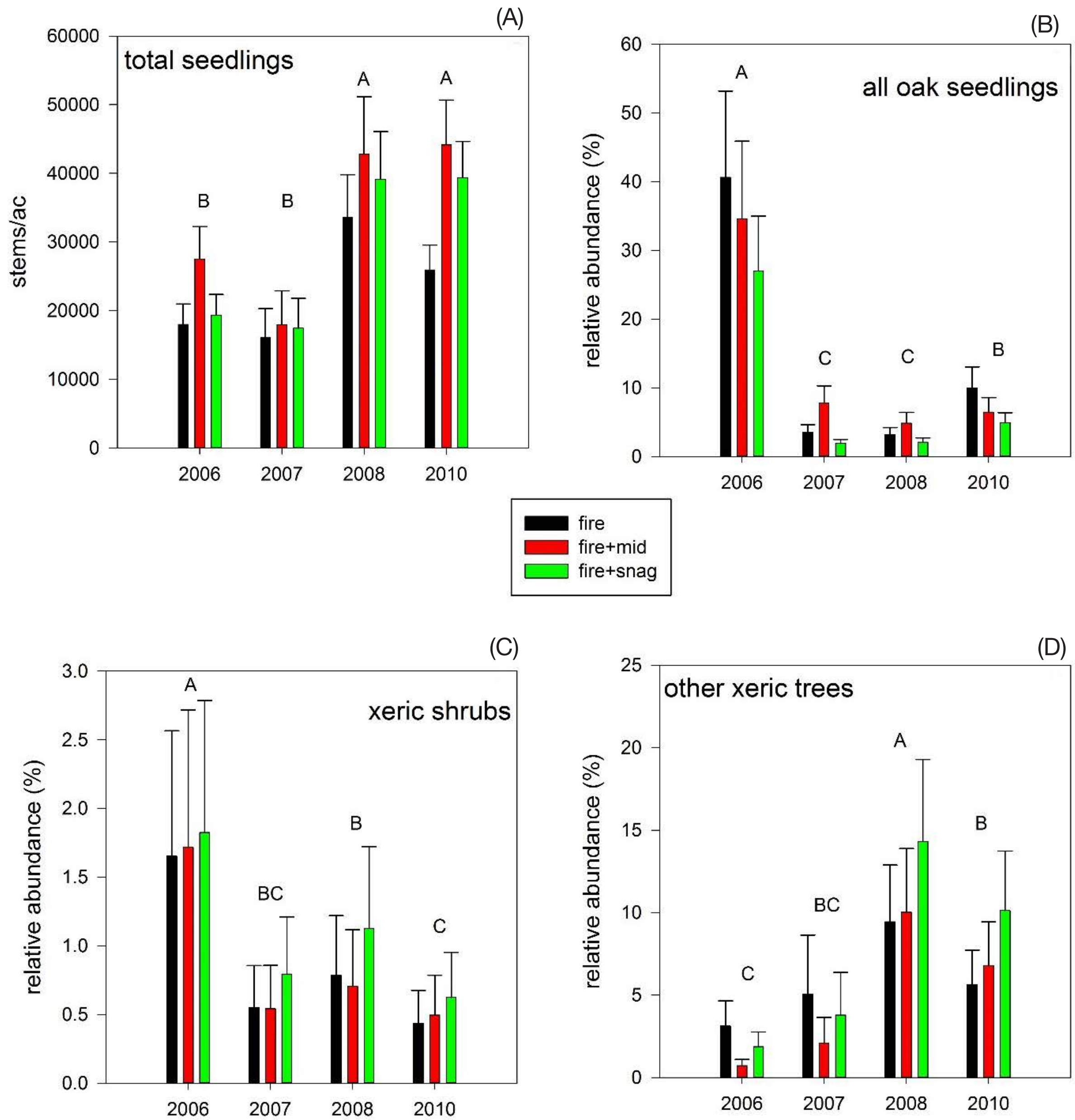

Figure 3—Least square means (±SE) of total (a), oak (b), dry-mesic to xeric shrubs (c), and other dry-mesic to xeric tree species (d) seedlings by year and treatment. Means between years with the same letter are not statistically different (α = 0.05).

in relative abundance after the two fires and snag creation, increasing from about 1-3 percent abundance to 9–11 percent in 2010 (*p* <0.0001 for all treatments combined; p=0.0021 for fire+mid) (fig. 3d). There were no statistically significant differences among treatments in any year. This species group increased in absolute numbers (averaged for all treatments) as well, going from about 500 stems per acre in 2006 to over 8,000 in 2010 (table 3).

Birch seedling relative abundance increased dramatically after treatments (*p*<0.0001 all treatments combined) with the greatest increase found in fire+snag plots, although no statistically significant differences among treatments were found in 2010 (fig. 4a). Relative abundances of yellow-poplar increased with treatments in 2007 (p=0.0004 for fire, p<0.0001 for fire+mid and fire+snag plots), but are showing decreases after the second prescribed fire (fig. 4b). As happened in the sapling layer, striped maple seedling relative abundances were reduced by prescribed fire (p<0.0001 for fire, p=0.0001 for fire+mid and fire+snag), dropping from around 13 to 16 percent before treatment to 1 to 2 percent in 2008 and 2010 (fig. 4c). In contrast, red maple seedling relative abundances increased over time (*p*<0.0001 for all treatments combined) and there were no differences between treatments or within treatments over time (fig. 4d).

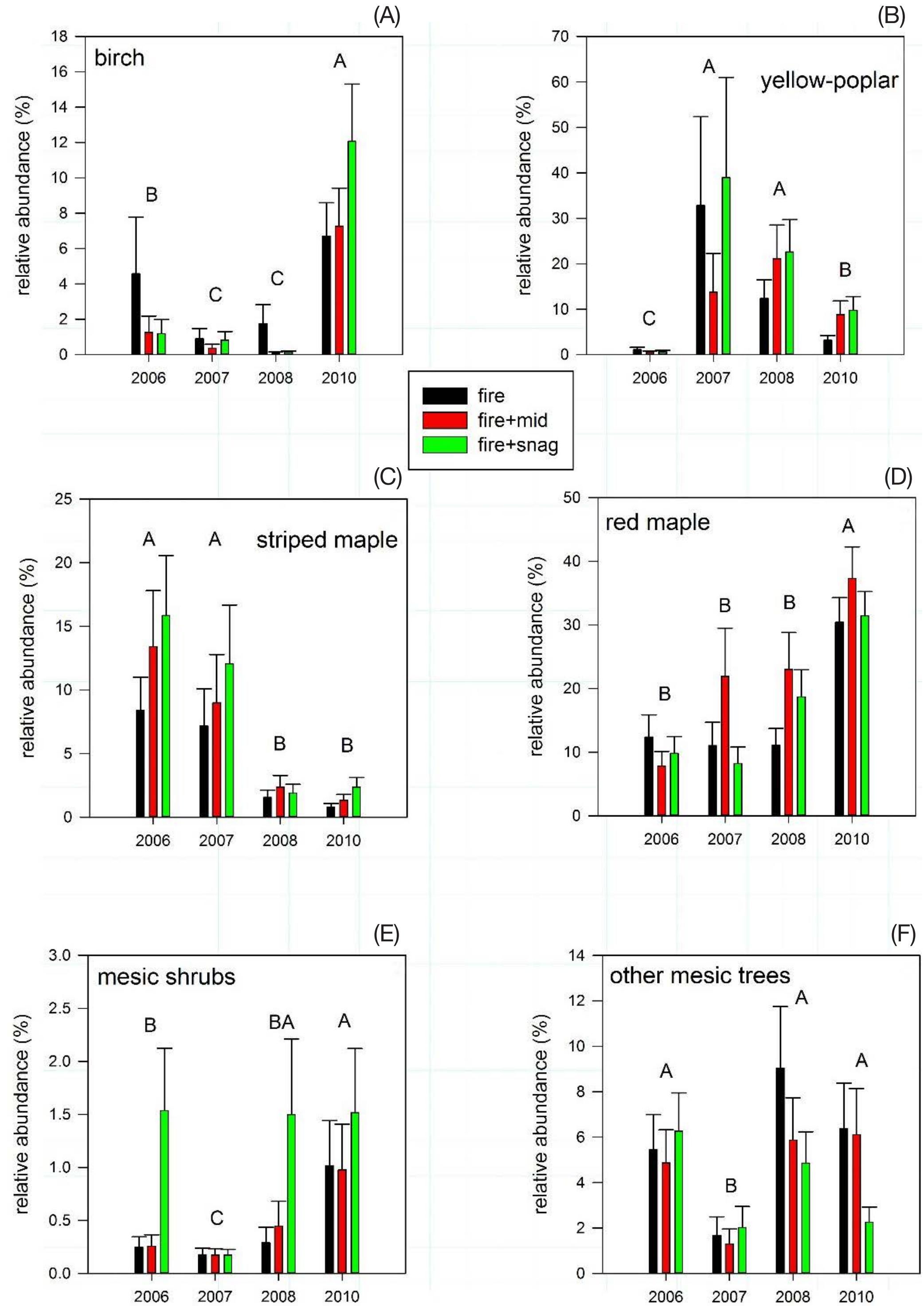

Figure 4—Least square means (±SE) of birch (a), yellow-poplar (b), striped maple (c), red maple (d), mesic shrubs (e), and other mesic to xeric tree species (f) seedlings by year and treatment. Means between years with the same letter are not statistically different (α = 0.05).

The relative abundances of species categorized as mesic shrubs increased over time (p=0.0006 for all treatments combined) and with fire+mid treatment in particular (p=0.0057), however, like the dry-mesic to xeric category, mesic shrubs made up a small proportion of the seedling layer even after treatment (fig. 4e). Seedlings of mesic tree species decreased in relative abundance after the first fire ($p<0.0001$) and recovered to pre-treatment levels by 2010, although still < 10 percent of the species composition (fig. 4f). In 2010 the lowest relative abundance for this group was found in the fire+snag plots although no differences between treatments in year 2010 were statistically significant. For seedling groups, no significant differences were found in 2010 between the fire plots and the two other treatments combined.

DISCUSSION

We do find some evidence that two prescribed fires and reductions in mid and overstory canopies by herbicide may be starting to reverse the mesophication trend in these stands. Before treatment, the sapling layer was about 360 stems per acre and of that, approximately 20 percent was striped maple. The dense shade created by striped maple saplings has been removed from the stands as was found on a nearby study site on Canoe Run. After two prescribed fires, the species composition of the sapling layer showed only slight change, but similar to the John B. Hollow study, the stems per acre of saplings was reduced by nearly 90 percent (Schuler and others 2010, 2013). In the John B. Hollow study, sapling species considered dry-mesic to xeric are holding steady in relative abundance (table 2).

Whereas the relative seedling abundances of several mesic species increased after treatment (birch and red maple) the relative abundance of seedlings of other mesic species showed a temporary reduction after one fire and yellow-poplar seedling abundance dropped after two fires. These effects were also found on the nearby Canoe Run study, although two prescribed fires had reduced red maple seedling densities on that site (Schuler and others 2013). The lowest relative abundance of seedlings of mesic tree species (other than birch, yellow-poplar, and red maple) was found in fire+snag plots which is consistent with the hypothesis that fires and canopy gaps are reversing mesophication in these stands.

The relative abundance of tree seedlings categorized as dry-mesic to xeric (other than oaks) did increase after the two prescribed fires. Although there were no differences among treatments in 2010, higher abundances were found in fire+snag plots which, on average, showed the lowest overstory basal area per acre in 2010. Although oak seedling relative abundances were reduced by prescribed fires, other dry-site species appear to be responding to the treatments.

Our results are similar to a prescribed fire study in southeastern Ohio in a very similar forest type where areas were burned either two times or four times although no canopy gaps were created. Early results there found that fires reduced the sapling layer, which was mainly composed of shade tolerant species, and that oak and hickory seedling abundances were not affected by fire (Hutchinson and others 2005a). Similar to our findings in West Virginia, red maple abundances decreased immediately after fire only to rebound within 2 years and yellow-poplar seeding abundances responded with the opposite trend of increasing after fire only to decrease two years post-fire (Hutchinson and others 2005a). In an analysis of the herbaceous layer of the Ohio study, sassafras was found to be an indicator of burned plots (Hutchinson and others 2005b). This species was tallied in the dry-mesic to xeric category in our study and showed a large increase in response to two prescribed fires.

Because oak regeneration requires advanced reproduction, management actions such as prescribed fire can target the pre-disturbance buildup of low, dense shade (Brose and others 2008). Also, post-disturbance, the oak advanced regeneration faces competition from species with regeneration strategies such as seed banking or having lightweight seed that rapidly invades a disturbed area (Schuler and others 2010). Prescribed fire and mid- or overstory reduction treatments occurred at the same time in our study, with little to no existing advanced oak regeneration available to take advantage of possible favorable conditions created by the treatments. However, our results do show the advantage of fire in reducing low shade (striped maple) but also shows the disadvantage of creating post-disturbance competitors for oaks (increases in birch and red maple). Our results further support the findings of others on the need for repeated fires to confer a competitive advantage on oak regeneration and for careful consideration of the timing of management actions (Brose and others 2014, Johnson and others 2009a). Successful oak regeneration incorporating prescribed fire is difficult to predict because the process involves the variable and interconnected factors of species life history traits (both of oaks and competitors), the pre-burn condition of the oak seedlings or seedling-sprouts, and the variability inherent in fire as a management tool (Alexander and others 2008).

Perhaps these modest movements away from mesophication are a function of time since treatment. The latest measurements included in this analysis are from 2010, which was only 2 years post-fire. While the two levels of canopy reduction through herbicide conferred no immediate advantage to oak seedlings when combined with fire, these treatments did create wildlife habitat by direct snag creation. For the oak seedlings 2 years post fire, the manipulation of the canopy and midstory by herbicide has not resulted in any benefit over fire alone. We expect that the species composition and structure of the seedling and sapling layers will show greater differences at 10 or more years post-fire. In this analysis of almost immediate post-treatment effects, there has not been enough time for oak saplings to develop. We will also be assessing these stands for the need for another fire as others have found more than two fires are needed for oaks to remain competitive (Hutchinson and others 2012) especially given the mesic nature of the study area.

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