The Effect of Controlled Burns on Abundance of Woody Species in Appalachian Pine-Oak Forests at Buck Mountain, West Virginia

Authors: Edgar, B.E., and Griscom, H.P.

Source: Natural Areas Journal, 37(1) : 30-38

Published By: Natural Areas Association

URL: https://doi.org/10.3375/043.037.0106

RESEARCH ARTICLE

•

The Effect of Controlled Burns on Abundance of Woody Species in Appalachian Pine-Oak Forests at Buck Mountain, West Virginia

B.E. Edgar[1]

[1]Division of Community Forestry
527 West Jefferson Street, Suite 606
Louisville, KY 40202

H.P. Griscom[2,3]

[2]James Madison University
Biology Department, MSC 7801
Harrisonburg, VA 22807

•

---

[3] Corresponding author: griscohp@jmu.edu; 540-568-5525

Natural Areas Journal 37:30–999

ABSTRACT: Each year, the US Forest Service uses prescribed fires within the George Washington and Jefferson National Forest (GWJNF). Burns are prescribed in the growing (late April–October) and dormant season (November–mid-April). The goal of the burns is to reinstate the natural fire regime, returning forests to their original species composition. Currently in GWJNF, Appalachian pine-oak forests are experiencing an increase in fire-intolerant species, while *Quercus* species and *Gaylussacia brachycera*, an endangered shrub species, are declining. In the summer of 2014, a vegetation survey was conducted on Buck Mountain, West Virginia, to determine if there was a significant difference between dormant- and growing-season burns compared to a no-burn control. A total of 60 plots (15 per treatment) was established within a site burned once (in the dormant season), a site burned twice (dormant season burn followed by a growing-season burn), a site burned twice (both dormant season), and a site protected from fire (control). We hypothesized that burns would have differing effects on woody vegetation, depending on fire treatment and species' shade tolerance. We predicted that *Quercus* species and *G. brachycera* would increase after a growing season burn. We found that *Quercus* species regeneration, as well as *G. brachycera*, were more abundant at burn sites, regardless of season. Our results suggest that seasonality of burns did not affect oak and *G. brachycera* regeneration at Buck Mountain. Future vegetation monitoring is needed to determine if time intervals between burns affects regeneration of desired species rather than the season of burn.

Index terms: fire, *Gaylussacia brachycera*, oak regeneration, prescribed burn, season of burn

INTRODUCTION

Fire is a natural disturbance regime that greatly influences the vegetation composition, development, and structure of a forest (Bond et al. 2005; Lafon et al. 2005; Hoss et al. 2008; Aldrich et al. 2010). Fires create a mix of successional stages, thus increasing plant diversity and forage production for birds and other wildlife. Patterns of fire periodicity, seasonality, intensity, and area determine the natural disturbance regime of a landscape (Lafon et al. 2005). Historically, fires caused by lightning strike in the southeastern United States were low in severity but relatively high in frequency, occurring in late spring or early summer (Schmidt et al. 2002; Lafon et al. 2005; Knapp et al. 2009). Traditionally, Native Americans used fires for various uses, such as to improve wildlife habitat and drive game (Van Lear and Waldrop 1989; Lafon et al. 2005). European settlers also used fires to clear lands for agricultural purposes (Johnson and Hale 2001; Nowacki and Abrams 2008).

However, beginning in the 1920s fire suppression policies were established to protect forested lands (Stephens and Ruth 2005; Nowacki and Abrams 2008). Suppressing the natural disturbance regime has resulted in altered forest composition (Stephens and Ruth 2005; Fowler and Konopik 2007; Nowacki and Abrams 2008). One such change in composition is a rise in abundance of *Acer rubrum* L. and other shade-tolerant plant species (Lorimer 1984; Abrams 1992; Hutchinson et al. 2008; Fei et al. 2011; Brose et al. 2012). To return forests to their original state, land managers, including the US Forest Service (USFS), started prescribing burns in the 1940s (Johnson and Hale 2001; Fowler and Konopik 2007). In Appalachian pine-oak forests, prescribed burns are intended to restore and maintain fire-dependent pines and oaks as the dominant species in the canopy.

Every 3–25 years in the George Washington National Forest, controlled burns are either conducted during the growing season (late April–October) or dormant season (November–mid-April). Dormant-season burns occur before hardwood tree species have leafed out, so leaf litter is exposed to sunlight, creating model burning conditions, and the direct impacts to nesting birds is reduced (Brennan et al. 1998; Knapp et al. 2009). For these reasons the majority of burns have been conducted by the USFS in the dormant season. To recover from burns, plants rely on stored carbohydrates to resprout and grow (Knapp et al. 2009). Plants usually have the lowest levels of carbohydrates in the early growing season due to higher energy expenditure (Knapp et al. 2009). If a growing-season burn were conducted during this active time plants might recover at a slower rate than if burns were conducted during the dormant season

(Knapp et al. 2009). However, unlike the majority of plants, certain tree species, such as *Quercus* L., have large taproots with stored carbohydrates, allowing them to be competitive after growing-season burns (Brose et al. 1999).

Quercus species and woody shrubs are declining in Appalachian pine-oak forests due to increasing competition from fire-intolerant species. After the Chestnut Blight decimated *Castanea dentata* Marshall (Borkh.) (American chestnut) in the early 1900s, *Quercus* assumed the role of the foundation species in hardwood forests of the southeastern United States (McShea et al. 2007; Alexander et al. 2008). *Quercus* species are considered relatively slow growing, mid-shade tolerant, and fire resistant (Abrams 1992; Burns and Honkala 1990; Green et al. 2010). *A. rubrum*, a competitor of oaks, is a shade-tolerant and fire-sensitive species, as well as a vigorous stump sprouter and seeder (Burns and Honkala 1990; Arthur et al. 1998; Signell et al. 2005; Green et al. 2010). Fire-intolerant species, such as *A. rubrum*, can outcompete *Quercus* spp. in mesic, dense shade environments (Brose and Van Lear 1998; Signell et al. 2005; Brose et al. 2012). Unlike *Quercus* spp., *A. rubrum* has epigeal germination, where root collars and dormant buds are above ground, making the species susceptible to fires, especially repeated fires (Burns and Honkala 1990; Brose 2010). *Nyssa sylvatica* Marshall (black gum), another common tree in Appalachian pine-oak forests, is also fire sensitive (Arthur et al. 1998; Elliot and Vose 2005; Signell and Abrams 2006), shade tolerant, and has epigeal germination like *A. rubrum* (Burns and Honkala 1990).

Other common species found in Appalachian pine-oak forests are of the Ericaceae family. Ericaceous species are beneficial for wildlife foraging; increasing their population size with fire may benefit fauna. Specifically, growing-season burns have shown to increase percent cover of *Gaylussacia baccata* (Wangenh.) K. Koch (black huckleberry) and *Vaccinium* spp. L. (blueberry species) (Elliot et al. 1999). However, Arthur et al. (1998) found dormant-season burns also promoted *Vaccinium pallidum* Aiton, but decreased percent cover of *G. baccata*. *Gaylussacia brachycera* (Michx.) A. Gray (box huckleberry), a species of interest, is considered to be imperiled or endangered in the southeastern United States. Prescribed burning could be beneficial to *G. brachycera*, a slow-growing plant (Pooler et al. 2006), by reducing fast-growing competitors.

Land managers need to understand the effects of growing- and dormant-season burns on vegetation, given the interest by the USFS to promote oak regeneration and conflicting recommendations from the literature (Brose and Waldrop 2014). Many studies have found *Quercus* seedlings and saplings to be most abundant after a single growing-season burn compared to a dormant-season burn (Brose and Van Lear 1998; Brose et al. 1999; Brose 2010). However, this may be species- and age-specific. Elliot et al. (1999) found only *Q. montana* Willd. and *Q. coccinea* Münchh. saplings benefited from a growing-season burn; *Q. alba* L., *Q. velutina* Lam., and *Q. rubra* L. saplings did not benefit. Interestingly, Brose and Van Lear (1999) found growing-season burns caused more damage to *Quercus* adult trees than did dormant-season burns due to high temperatures reaching and killing trunk cells.

With regard to *A. rubrum*, an oak competitor, single growing-season burns have shown to reduce saplings and seedlings (Brose and Van Lear 1998; Elliot et al. 1999; Brose 2010). Green et al. (2010) suggest that burns occurring in the later growing season could potentially reduce *A. rubrum* seedlings, and lower the growth of surviving maples. During the later growing season *A. rubrum* are more physiologically active, thus the additional stress of burning on a seedling could hinder growth (Green et al. 2010). Unlike growing-season burns, the effect of dormant-season burns is unclear as research has shown that these burns both promote *A. rubrum* (Teuke and Van Lear 1982; Arthur et al. 1998) and reduce *A. rubrum* regeneration (seedlings and saplings) (Alexander et al. 2008).

Frequency of prescribed burning is another factor that may affect vegetation outcomes. Studies with single dormant-season burns have conflicting results regarding oak regeneration. Teuke and Van Lear (1982) found that *Quercus* saplings significantly decreased post dormant-season burn. With regard to seedlings, a single dormant-season burn has been found to both increase (Teuke and Van Lear 1982; Brose and Van Lear 1998) and decrease *Quercus* seedlings (Johnson 1974; Alexander et al. 2008). In Brose and Waldrop's (2014) review of the Johnson (1974) study, the authors suggested excessive deer browse and original small seedling sizes, as well as the timing of the Johnson (1974) study, could explain the decrease in seedlings. Prior to the late dormant-season burn, small seedlings could have expanded leaves, thus increasing seedling mortality post burn (Brose and Waldrop 2014).

Repeated burns have been found to favor *Quercus* seedlings (Dey and Hartman 2005), but not saplings (Arthur et al. 2015). Arthur et al. (1998) found two burns had the highest frequency of *Q. montana* seedlings. Multiple burns favor oak regeneration by reducing competitors of oaks over a single prescribed burn (Dey and Hartman 2005). However, after 3–4 burns seedlings may suffer (Green et al. 2010). A fire-free period is needed for *Quercus* seedlings and saplings to reach into the overstory (Fan et al. 2012).

Repeated burns also decrease seedlings and saplings of the oak competitor, *N. sylvatica* (Arthur et al. 1998; Dey and Hartman 2005; Fan et al. 2012), and *A. rubrum* (Arthur et al. 1998; Green et al. 2010; Arthur et al. 2015). However, Alexander et al. (2008) found repeated burns did not reduce *A. rubrum* regeneration greater than a single burn. Burning too frequently or severely may expose mineral seedbeds, which favor smaller-seeded species, such as *A. rubrum* (Arthur et al. 2015).

We conducted a vegetation survey to determine if there was a significant difference between dormant- and growing-season burns compared to a no-burn control with regard to woody vegetation abundance. We hypothesized that prescribed burns would have differing effects on woody vegetation, depending on fire treatment and shade tolerance of the species of interest.

We predicted that *Quercus* seedlings and saplings and understory shrub species, *G. brachycera*, *G. baccata*, and *Vaccinium* spp., would increase after a growing-season burn due to the decrease in competition from shade- and fire-intolerant species. We predicted oak competitor *A. rubrum* would decrease post growing-season burn as well (Brose and Van Lear 1998; Elliot et al. 1999; Brose 2010). We also predicted repeated burns would result in greater abundance of regeneration of *Quercus* spp. (Arthur et al. 1998; Dey and Hartman 2005; Fan et al. 2012) and a decrease in *N. sylvatica* (Arthur et. al. 1998; Dey and Hartman 2005; Fan et al. 2012).

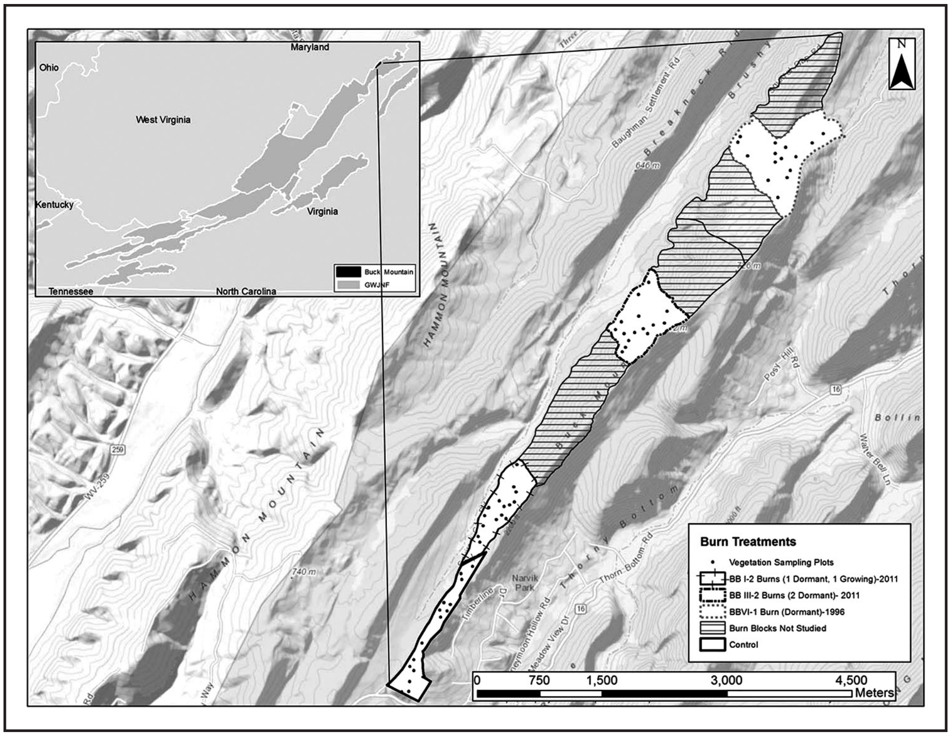

Figure 1. Map of study site with burn treatments and vegetation sampling plots on Buck Mountain, West Virginia. Buck Mountain is located in the George Washington National Forest.

METHODS

Study Site

The field study was conducted June through July 2014 on Buck Mountain in Hardy County, West Virginia. Buck Mountain is located in the Lee Ranger District of the George Washington National Forest (GWNF) and is designated as a Special Biological Area to protect the endangered *G. brachycera*.

Xeric pine-oak forests are present on Buck Mountain. Overstory composition was dominated by *N. sylvatica, Pinus rigida* Mill., and *Q. montana.* The woody understory was primarily composed of *Quercus ilicifolia* Wangenh. and *Hamamelis virginiana* L. In the shrub layer, mainly *Vaccinium* spp., *G. brachycera*, *G. baccata, Gaultheria procumbens* L., and *Kalmia latifolia* L. were present.

Buck Mountain consists of seven burn blocks (Figure 1); we used three of them and created a control treatment for this study. The area of the control treatment was created based on the property lines of the GWNF, and had similar aspect and forest type as the burn blocks. Specifically, we sampled vegetation from burn blocks I (23 ha), III (32 ha), and VI (49 ha). Burn block I was burned twice. The first burn was prescribed in March (dormant season) (D) of 1987. The second burn was prescribed 24 years later, in May (growing season) (G) of 2011, and was high in severity. Burn block III also had two prescribed burns. The first burn was prescribed in mid-April (dormant season) (D) of 1998, and was low in severity. The second burn was conducted 13 years later, in November (dormant season) (D) of 2011, and was moderate in severity. In 1996, burn block VI had one dormant-season burn (D) prescribed in November that was low in severity. A control treatment (C) (22 ha) was created adjacent to burn block I; the area had no history of prescribed fire or wildfire.

Fifteen circular plots were randomly placed within each burn block using the Create Random Points tool in ArcGIS. Plots were 40 m in diameter (area = 1257 m^2) and at least 50 m apart. Plots ranged from 566 m to 691 m in elevation. A majority of the plots had a northwest-facing aspect, ranging in slope from 2° to 32°. Plot centers had to be at least 30 m from the edge of each burn treatment. Eight plots had to be moved in the field due to close proximity to the edge of the treatment or hazardous field conditions.

Vegetation Sampling

Using a nested subplot design we counted adult trees, tree saplings (woody understory tree species), tree seedlings, and shrub species. We measured diameter at breast height (dbh) and identified tree species within the 1257 m^2 area of the plot (20-m radius; 1/8th ha plot). An individual qualified as an adult tree if the dbh was greater than or equal to 5 cm. Snags (dead, standing trees) were also counted and measured in the 1257-m^2 area. Tree saplings and woody understory tree species were identified within the 625-m^2 area of the subplot (14.1-m radius; 1/16th ha plot). An individual was considered a sapling or woody understory tree species greater than 1 m in height with dbh less than 5 cm. Tree seedlings were identified within the 125-m^2 area of the subplot (6.3-m radius; 1/80th ha plot). Seedlings were less than 1 m in height. Individual shrub stems were identified and counted within the 3-m^2 area of the subplot (1-m radius). A shrub was defined as a short, woody plant with several branching stems.

Data Analysis

Species abundances for trees, saplings, seedlings, and shrubs were calculated from the vegetation sampling. Total density (individuals/ha) was then calculated for selected species of canopy trees, tree saplings, tree seedlings, and shrubs. Using dbh measurements of selected canopy tree species, basal area (m^2/ha) was also calculated. ANOVA or Kruskal–Wallis tests were used (IBM SPSS Statistics 22) to analyze differences between species (density and basal area) within a treatment. Shrub and seedling abundance data were transformed using the square root function.

The Kruskal–Wallis test was used when data were not normal. If Kruskal–Wallis tests revealed significant differences between species within a treatment, post hoc tests were performed to determine species differences within a treatment. However, if data were normal ANOVA analysis was performed. If ANOVA analyses showed significant differences between species within a treatment, a post hoc Tukey test was performed to identify differences between individual species. Importance values (IV) for selected canopy tree species were also calculated using the equation: (relative density + relative basal area)/2.

RESULTS

Effect of Fire on the Canopy

N. sylvatica, *Q. montana*, and *P. rigida* had the greatest importance values in the canopy on Buck Mountain across all treatments (Table 1). *Q. montana* maintained co-dominance with *P. rigida* in the canopy at the site burned twice in the dormant season (DD) (IV = 0.33, basal area = 9.32), and the single dormant-season burn site (D) (IV = 0.31, basal area per ha = 7.94) (Table 1, Figure 2).

Oak competitor *N. sylvatica* dominated or co-dominated the canopy at the control site (C) (IV = 0.50, basal area = 7.57) and the site burned twice (DG) (IV = 0.30, basal area = 3.84) (Table 1, Figure 2). The two-burn site (DG) had a total basal area of 17.92 (m^2/ha), the lowest total basal area of all the burn sites compared to the control which had the greatest total basal area of 22.61 (m^2/ha) (Table 2). *A. rubrum* was infrequently found at all sites in the canopy. Snags were greatest at the burn site with a growing season burn (DG) (Figure 2).

Effect of Fire on the Understory

The effect of burning on tree regeneration in the woody understory varied depending on species (Figure 3). Overall species density differed significantly within a treatment (Table 3). In the woody understory layer, few individuals were found at any of the sites. On average, there was a total of 1087 individuals/ha at each site. Oak competitor *N. sylvatica* was negatively affected by burning. Only at the control site (C) were *N. sylvatica* saplings significantly more abundant than other woody understory species. However, within burn treatments, *Q. ilicifolia* had the greatest density (individuals/ha) and was significantly more abundant than other species at the two-burn site (DG), except for *H. virginiana* ($F = 18.44$, $P \leq 0.05$) (Table 3, Figure 3).

At Buck Mountain, seedlings were much more abundant compared to woody understory species, with the most seedlings found in the control site (C) (15,563 individuals/ha) (Figure 4). *A. rubrum*, although rare in the canopy and woody understory layer, had a significantly greater seedling density (individuals/ha) than other species in the control site (C) ($F = 36.831$, $P \leq 0.05$) (Table 3, Figure 4). On the other hand, *Quercus* species were significantly more abundant compared to seedlings of other species in the single burn (D) ($F = 29.355$, $P \leq 0.05$) and the two dormant-season burns site (DD) ($F = 33.27$, $P \leq 0.05$) (Table 3, Figure 4). Interestingly, a slightly different pattern emerged at the other twice-burned site (DG). Here, *Quercus* species and *N. sylvatica* co-dominated the seedling layer (Figure 4).

Effect of Fire on Ericaceae

All species in Ericaceae (*K. latifolia*, *Vaccinium* spp., and *G. brachycera*) were more abundant on burn sites, except for *G. procumbens* (winterberry). Oak competitor *K. latifolia* was more abundant at burn sites compared to the control, but not significantly so (Figure 5). Desired shrubs, such as *Vaccinium* spp., were most abundant at the dormant-season burn site (D) (Figure 5). In the control (C), *Vaccinium* species were least abundant while *G. procumbens* was the most abundant shrub species (Figure 5). Another desired shrub species, *G. baccata*, was most abundant post two burns (DD and DG) and least abundant at the 1996 burn site (D) (Figure 5).

The endangered shrub *G. brachycera* also appeared to be positively affected by burning. However, few significant differences were found at sites due to the nature of the plant. *G. brachycera* was found in large patches, consisting of clones, or was absent, creating variability. However, the pattern that emerged was that *G. brachycera* proliferated at the burn sites; *G. brachycera* was either the dominant or co-dominant shrub species at the burn sites. At the burn sites densities of *G. brachycera* ranged from 303,333 to 165,556 individual stems/ha compared to just 56,222 individual stems/ha at the control (Figure 5).

DISCUSSSION

Prescribed burns had differing effects on woody vegetation at Buck Mountain, depending on the fire- and shade-tolerance of the species. At the burn sites *Q. montana*, *N. sylvatica,* and *P. rigida* were the more dominant canopy species compared to the control where *N. sylvatica* dominated (Table 1). Snags were most prevalent at the growing-season burn site (DG); perhaps high temperatures in the trunks of the adult trees caused cell death (Brose and Van Lear 1999). *A. rubrum*, a common competitor of oak, was not common in either the canopy or sub canopy and consequently, there was not an abundant source of seeds. Surprisingly, few saplings of any species were found on the mountain. Deer herbivory may have decreased sapling densities. After a burn, woody vegetation produces new shoots that are more palatable, thus attracting deer to newly burned sites (Halisey and Wood 1976).

On the other hand, seedlings were abundant

Table 1. Importance values (IV) and standard deviations (± SD) for selected canopy tree species in the no-burn and burn treatments. Tree species were selected if importance value (IV) ≥ 0.01. *Quercus* spp. represents the combined value for *Q. rubra* and *Q. velutina* trees. Numbers in parentheses rank species of importance. Numbers bolded are the dominating tree species in the canopy at each site. Importance values were calculated using the equation: (relative density + relative basal area)/2. Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

	Control (C)		2 Burns (DG) 2011		2 Burns (DD) 2011		1 Burn (D) 1996	
Species	**IV**	**SD**	**IV**	**SD**	**IV**	**SD**	**IV**	**SD**
A. rubrum	0.02 (6)	± 0.01	0.02 (4)	± 0.04	0.02 (5)	± 0.03	0.01 (6)	± 0.02
N. sylvatica	**0.50 (1)**	± 0.08	**0.30 (1)**	± 0.17	0.21 (3)	± 0.17	0.24 (3)	± 0.08
P. rigida	0.12 (3)	± 0.08	**0.30 (1)**	± 0.15	**0.31 (1)**	± 0.27	**0.28 (2)**	± 0.22
P. strobus	0.01 (7)	± 0.03	0.00 (6)	± 0.01	0.00 (7)	± 0.01	0.00 (7)	± 0.01
Q. montana	0.19 (2)	± 0.11	0.10 (3)	± 0.08	**0.33 (2)**	± 0.22	**0.31 (1)**	± 0.21
Quercus spp.	0.09 (4)	± 0.06	0.01 (5)	± 0.02	0.01 (6)	± 0.03	0.05 (5)	± 0.04
Snag	0.05 (5)	± 0.02	0.27 (2)	± 0.16	0.11 (4)	± 0.08	0.06 (4)	± 0.03

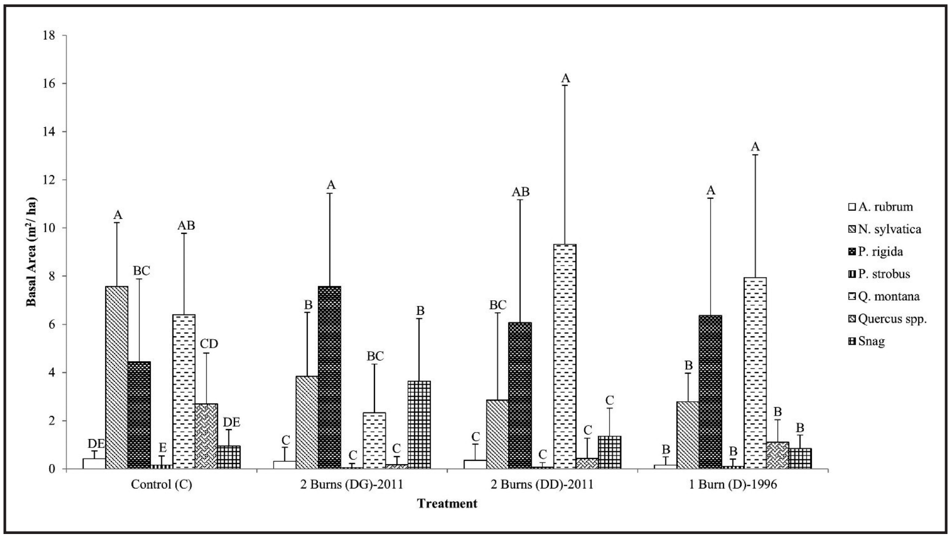

Figure 2. Basal area (m^2/ha) for selected canopy tree species at burn treatments ($n = 60$). Tree species were selected if importance value (IV) ≥ 0.01. *Quercus* spp. represents *Q. rubra* and *Q. velutina* trees. Different letters indicate significant differences between species within treatments (ANOVA; $P \leq 0.05$; + SD). Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

at Buck Mountain, especially in the control with *A. rubrum* significantly dominating the seedling layer ($F = 36.831$, $P \leq 0.05$) (Table 3, Figure 4). Conversely, at all the burn sites, *Quercus* spp. seedlings significantly dominated or co-dominated the seedling layer ($P \leq 0.05$) (Figure 4). Fires create gaps in the canopy, and *Quercus* seedlings rely on these gaps for light to grow and outcompete competitors (Alexander et al. 2008; Elliot and Vose 2010). On Buck Mountain, desired species (*Quercus* seedlings, *G. brachycera*, *G. baccata*, and *Vaccinium* spp.) appeared to benefit from burning, regardless of season. In general, regeneration of undesired species (*A. rubrum* and *N. sylvatica*) was lower on burned sites, except for *K. latifolia*.

Oak Regeneration

An increase in oak regeneration is a management goal of the USFS since mast-producing species are a food source for wildlife. In addition, *Q. ilicifolia* communities are decreasing in the southeastern United States, thus are a species of special concern (Barden 2000). We predicted oak regeneration would benefit the greatest from a growing-season burn (Brose and Van Lear 1998; Brose et al. 1999; Elliot et. al. 1999; Brose 2010). This is because oak competitors, such as *A. rubrum,* are also greatly reduced (Brose and Van Lear 1998; Elliot et al. 1999; Brose 2010). However, in this study, seasonality of burns was irrelevant to *Quercus* spp. seedling density. Frequency of burns was more important with the greatest abundance of *Quercus* spp. at the sites burned twice (DG and DD). Hallisey and Wood (1976) also found that *Q. ilicifolia* was the product of periodic fires. Other *Quercus* spp. have been found to benefit from repeated burns (Arthur et al. 1998; Dey and Hartman 2005; Fan et al. 2012). Arthur et al. (1998) found *Q. montana* seedlings benefited greatly from two burns. Hutchinson et al. (2005) state periodic fires maintain canopy gaps, thus increase light levels and prevent the establishment of shade-tolerant species. Therefore, repeated prescribed burns are needed to promote the regeneration of *Q. ilicifolia* and other *Quercus* species, which are mid-shade tolerant.

Oak Competitors

In Appalachia, shade-tolerant species, such as *A. rubrum* and *N. sylvatica*, have been dominating canopies on sites with a lack of fire. We predicted that a growing-season

Table 2. Total density (individuals/ha) and total basal area (m^2/ha) for selected canopy tree species of the burn treatments (*n* = 60). Tree species were selected if importance value (IV) ≥ 0.01. Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

Treatments	Total density (individuals/ ha)	Total basal area (m^2/ha)
Control (C)	896	22.61
2 Burns (DG) 2011	714	17.92
2 Burns (DD) 2011	571	20.43
1 Burn (D) 1996	647	19.31

burn would reduce *A. rubrum* regeneration the most (Brose and Van Lear 1998; Elliot et al. 1999; Brose 2010). However, although seedlings were numerous, few *A. rubrum* saplings were found at any site; on average there were only four individuals/ ha on Buck Mountain (Figure 3). Perhaps, at this xeric pine-oak site with more light reaching the understory, *A. rubrum* seedlings are not as competitive. Due to higher light levels, more light-demanding species, such as *Q. ilicifolia*, may outcompete *A. rubrum* in the understory. Fire, in general, reduced *A. rubrum* seedlings, but seasonality of the burn was not important. *A. rubrum* seedlings were significantly less abundant than *Quercus* spp. seedlings at burn sites compared to the control site (F = 36.831, $P \leq 0.05$) (Table 3, Figure 4).

Contrary to *A. rubrum*, we predicted that seasonality would not affect *N. sylvatica*, but repeated burns would decrease regeneration (Arthur et. al. 1998; Dey and Hartman 2005; Fan et al. 2012). In this study, *N. sylvatica* was significantly less abundant than *Quercus* spp. at both the two dormant-season burns site (DD) ($F = 33.27$, $P \leq 0.05$) and the single dormant-season burn site (D) ($F = 29.355$, $P \leq 0.05$) (Table 3, Figure 4). *N. sylvatica* seedling density was lowest at the single dormant-season burn treatment (D) with 309 individuals/ ha compared to the control with 1632 individuals/ha (Figure 4). However, since the site was burned 18 years ago, time could have also influenced the reduction of the species by allowing other tree species to outcompete *N. sylvatica*. At the single dormant-season burn treatment (D), long time length until sampling could have also influenced the other species found in the treatment.

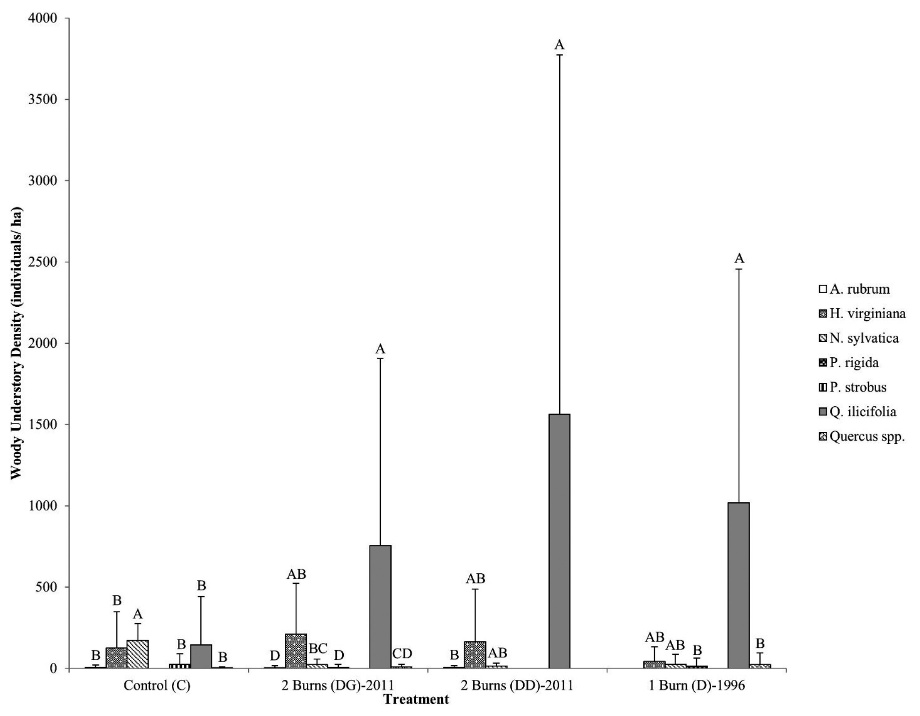

Figure 3. Density (individuals/ha) for selected woody understory species at burn treatments (*n* = 60). Species selection was based off of importance and dominance in the woody understory layer. *Quercus* spp. represents *Q. rubra* and *Q. velutina* saplings. Different letters indicate significant differences between species within treatments (Kruskal–Wallis; $P \leq 0.05$; + SD). Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

Desired Shrub Species

To increase desired shrub species, such as *G. brachycera*, *G. baccata*, and *Vaccinium* spp., we predicted a growing-season burn was best for regeneration since Elliot et al. (1999) found an increase in ericaceous species with a growing-season burn in North Carolina. In addition, Arthur et al. (1998) found dormant-season burns negatively affected *G. baccata* in Kentucky. On Buck Mountain, we found a positive effect of fire on *G. brachycera, G. baccata,* and *Vaccinium* spp. *G. brachycera* dominated or co-dominated in the burn sites, but not significantly due to the high variability between plots (Figure 5). *G. procumbens*, a fire-sensitive species (Moola and Vasseur 2009), was the only shrub species with lower density on burned sites compared to the control site (Figure 5).

Future Studies and Management

The US Forest Service should continue to burn on Buck Mountain to promote oak and *G. brachycera* regeneration. Our results suggest that seasonality of burns did not affect oak and *G. brachycera* regeneration at Buck Mountain. Dormant-season burns are not detrimental to oak or *G. brachycera* regeneration, even though the natural fire regime of the area is in the growing season (Lafon et al. 2005; Knapp et al. 2009). Also, if dormant-season burns pro-

Table 3. *P* values, *F* values and degrees of freedom (df) for basal area (m^2/ha) of canopy trees, seedling density (individuals/ha), and shrub density (individual stems/ha) at all four treatments. Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

Basal area (m^2/ha)	***df***	***F***	***P***
Control (C)	6	26.16	<0.001
2 Burns (DG) 2011	6	23.723	<0.001
2 Burns (DD) 2011	6	15.016	<0.001
1 Burn (D) 1996	6	20.027	<0.001
Seedling density (individuals/ha)	***df***	***F***	***P***
Control (C)	5	36.831	<0.001
2 Burns (DG) 2011	5	18.44	<0.001
2 Burns (DD) 2011	5	33.27	<0.001
1 Burn (D) 1996	5	29.355	<0.001
Shrub density (individual stems/ha)	***df***	***F***	***P***
Control (C)	4	7.901	<0.001
2 Burns (DG) 2011	4	2.018	0.101
2 Burns (DD) 2011	4	4.184	0.004
1 Burn (D) 1996	4	5.575	0.001

tect nesting game birds and are easier to implement, then the USFS should continue their practice of dormant-season burning in locations floristically similar to Buck Mountain.

Future vegetation monitoring is needed to determine if time intervals between burns affect regeneration of desired species rather than the season of burn. Sampling at different time intervals between burns can determine the ideal burning time for maximum regeneration of *Quercus* and desired shrub species. Due to the lack of information on the life history of species and scarcity of *G. brachycera* populations, the USFS should continue to monitor *G. brachycera* patches on Buck Mountain.

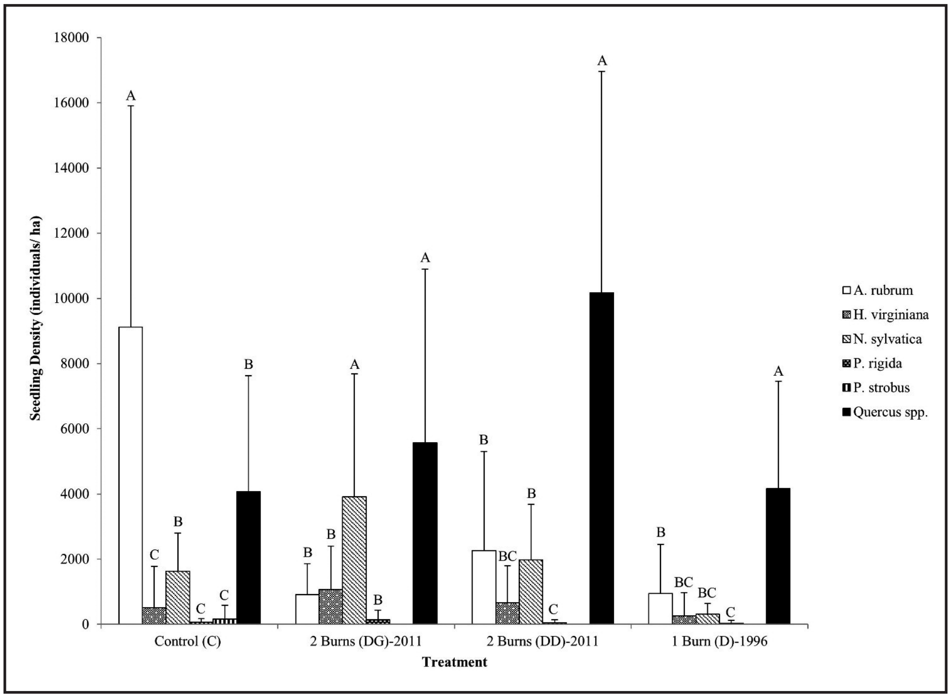

Figure 4. Density (individuals/ha) for selected tree seedling species at burn treatments (*n* = 60). Species selection was based off of importance and dominance in the seedling layer. *Quercus* spp. represents *Q. alba, Q. ilicifolia, Q. montana, Q. rubra*, and *Q. velutina* seedlings. Many seedlings were underdeveloped, thus exact species identification was not feasible. Different letters indicate significant differences between species within treatments (ANOVA; $P \leq 0.05$; + SD). Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

ACKNOWLEDGMENTS

We would like to thank field assistants Dakota Kobler, Sarah Maher, Kevin Tomlinson, and Rebecca Sanders for their dedication to the mountain. Also, we would like to acknowledge committee members Dr. Conley McMullen and Dr. Bruce Wiggins, as well as the USFS, specifically Sami Schinnell and Tom Ledbetter, for their guidance of this project. Lastly, we would like to thank the James Madison University

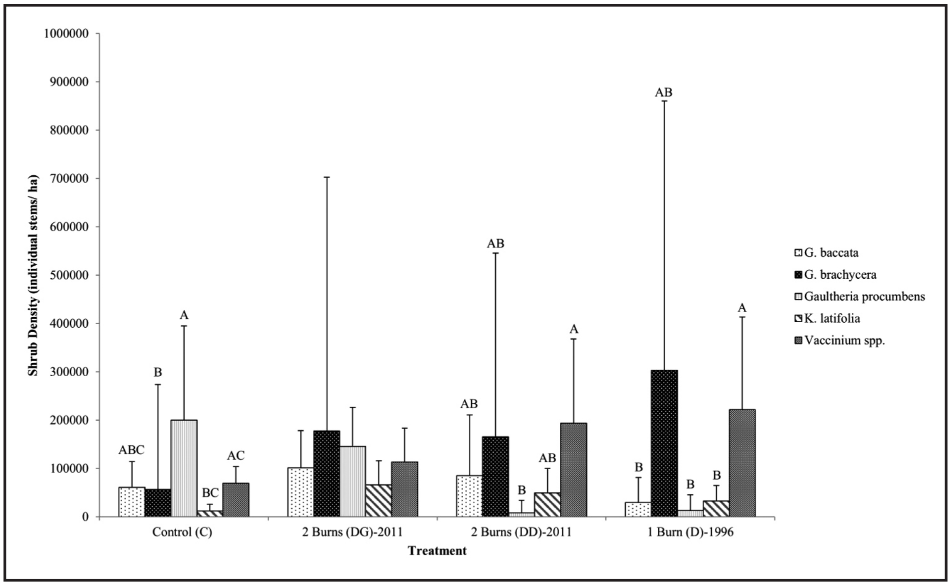

Figure 5. Density (individual stems/ha) for selected shrub species at burn treatments (*n* = 60). Species selection was based off of importance and dominance in the shrub layer. Different letters indicate significant differences between species within treatments (ANOVA; $P \leq 0.05$; + SD). Treatments: C = no-burn, DG = 1 dormant-season burn followed by growing-season burn, DD = dormant-season burn followed by dormant-season burn, D = 1 dormant-season burn.

Biology Department and Graduate School for funding.

Barry Edgar received her master's degree in Biology from James Madison University. Barry is a Forestry Assistant for Louisville Metro Government.

Heather Griscom, Ph.D., is an Associate Professor of Biology at James Madison University. Her current research focuses on seedling regeneration ecology, succession, and restoration in central Appalachia.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests in eastern North America. BioScience 42:346-353.

Aldrich, S.R., C.W. Lafon, H.D. Grissino-Mayer, G.G. DeWeese, and J.A. Hoss. 2010. Three centuries of fire in montane pine-oak stands on a temperate forest landscape. Applied Vegetation Science 13:36-46.

Alexander, H.D., M.A. Arthur, D.L. Loftis, and S.R. Green. 2008. Survival and growth of upland oak and co-occurring competitor seedlings following single and repeated prescribed fires. Forest Ecology and Management 256:1021-1030.

Arthur, M.A., B.A. Blankenship, A. Schoregendorfer, D.L. Loftis, and H.D. Alexander. 2015. Changes in stand structure and tree vigor with repeated prescribed fire in an Appalachian hardwood forest. Forest Ecology and Management 340:46-61.

Arthur, M.A., R.D. Paratley, and B.A. Blankenship. 1998. Single and repeated fires affect survival and regeneration of woody and herbaceous species in an oak-pine forest. Journal of the Torrey Botanical Society 125:225-236.

Barden, L.S. 2000. A common species at the edge of its range: Conservation of bear oak (*Quercus ilicifolia*) and its low elevation rocky summit community in North Carolina (USA). Natural Areas Journal 20:85-89.

Bond, W.J., F.I. Woodward, and G.F. Midgley. 2005. The global distribution of ecosystems in a world without fire. New Phytologist 165:525-538.

Brennan, L.A., R.T. Engstrom, W.E. Palmer, S.M. Herman, G.A. Hurst, L.W. Burger, and C.L. Hardy. 1998. Whither wildlife without fire? Transactions of the North American Wildlife and Natural Resources Conference 63:402-414.

Brose, P.H. 2010. Long-term effects of single prescribed fires on hardwood regeneration in oak shelterwood stands. Forest Ecology and Management 260:1516-1524.

Brose, P.H., and D.H. Van Lear. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research 28:331-339.

Brose, P., and D. Van Lear. 1999. Effects of seasonal prescribed fires on residual overstory trees in oak-dominated shelterwood stands. Southern Journal of Applied Forestry 23:88-93.

Brose, P.H., and T.A. Waldrop. 2014. Making sense out of confusion: A review of fire-oak papers published in the past 50 years. Pp. 12-24 *in* T.A. Waldrop, ed., Proceedings, Wildland Fire in the Appalachians: Discussions among Managers and Scientists. General Technical Report SRS-199, USDA Forest Service, Asheville, NC.

Brose, P., D. Van Lear, and R. Cooper. 1999. Using shelterwood harvests and prescribed fire to regenerate oak stands on productive upland sites. Forest Ecology and Management 113:125-141.

Brose, P.H., C. Dey, R.J. Philips, and T.A. Waldrop. 2012. A meta-analysis of fire-oak hypothesis: Does prescribed burning promote oak reproduction in eastern North America? Forest Science 59:322-334.

Burns, R.M., and B.H. Honkala. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654, USDA Forest Service, Washington, DC.

Dey, C., and G. Hartman. 2005. Returning fire to Ozark highland forest ecosystems: Effects on advance regeneration. Forest Ecology and Management 21:37-53.

Elliott, K.J., R.L. Hendrick, A.E. Major, J.M. Vose, and W.T. Swank. 1999.Vegetation dynamics after a prescribed fire in the southern Appalachians. Forest Ecology and Management 114:199-213.

Elliot, K.J., and J.M. Vose. 2005. Effects of understory prescribed burning on shortleaf pine (*Pinus echinata* Mill.)/mixed-hardwood forests. Journal of the Torrey Botanical Society 132:236-251.

Elliott, K.J., and J.M. Vose. 2010. Short-term effects of prescribed fire on mixed oak forests in the southern Appalachians: Vegetation response. Journal of the Torrey Botanical Society 137:49-66.

Fan, Z., Z. Ma, D.C. Dey, and S.D. Roberts. 2012. Response of advance reproduction of oaks and associated species to repeated prescribed fires in upland oak-hickory forests, Missouri. Forest Ecology and Management 266:160-169.

Fei, S., N. Kong, K.C. Steiner, W.K. Moser, and E.B. Steiner. 2011. Change in oak abundance in the eastern United States from 1980 to 2008. Forest Ecology and Management 262:1370-1377.

Fowler, C., and E. Konopik. 2007. The history of fire in the southern United States. Human

Ecology Review 14:165-176.

Green, S.R., M.A. Arthur, and B.A. Blankenship. 2010. Oak and red maple seedling survival and growth following periodic prescribed fire on xeric ridgetops on the Cumberland Plateau. Forest Ecology and Management 259:2256-2266.

Hallisey, D.M., and G.W. Wood. 1976. Prescribed fire in scrub oak habitat in central Pennsylvania. The Journal of Wildlife Management 40:507-516.

Hoss, J.A., C.W. Lafon, H.D. Grissino-Mayer, S.R. Aldrich, and G.G. DeWeese. 2008. Fire history of a temperate forest with an endemic fire-dependent herb. Physical Geography 29:424-441.

Hutchinson, T.F., E.K. Sutherland, and D.A. Yaussy. 2005. Effects of repeated prescribed fires on the structure, composition, and regeneration of mixed-oak forests in Ohio. Forest Ecology and Management 218:210-228.

Hutchinson, T.F., R.P. Long, R.D. Ford, and E. Kennedy Sutherland. 2008. Fire history and the establishment of oaks and maples in second-growth forests. Canadian Journal of Forest Research 38:1184-1198.

Johnson, A.S., and P.E. Hale. 2001. The historical foundations of prescribed burning for wildlife: A Southeastern perspective. Pp. 11-23 *in* W.M. Ford, K.R. Russell, and C.E. Moorman, eds., The role of fire in nongame wildlife management and community restoration: Traditional uses and new directions. General Technical Report NE-288, USDA Forest Service, Newtown Square, PA.

Johnson, P.S. 1974. Survival and growth of northern red oak seedlings following a prescribed burn. Research Note NC-177, USDA Forest Service, St. Paul, MN.

Knapp, E.A, B.L. Estes, and C.N. Skinner. 2009. Ecological effects of prescribed fire season: A literature review and synthesis for managers. General Technical Report PSW-GTR-224, USDA Forest Service, Albany, CA.

Lafon, C.W., J.A. Hoss, and H.D. Grissino-Mayer. 2005. The contemporary fire regime of the central Appalachian Mountains and its relation to climate. Physical Geography 26:126-146.

Lorimer, C.G. 1984. Development of the red maple understory in northeastern oak forests. Forest Science 30:3-22.

McShea, W.J., W.M. Healy, P. Devers, T. Fearer, F.H. Koch, D. Stauffer, and J. Waldon. 2007. Forestry matters: Decline of oaks will impact wildlife in hardwood forests. Journal of Wildlife Management 71:1717-1728.

Moola, F.M. and L. Vasseur. 2009. The importance of clonal growth to the recovery of *Gaultheria procumbens* L. (Ericaceae) after forest disturbance. Plant Ecology 202:319-337.

Nowacki, G.J., and M.D. Abrams. 2008. The demise of fire and "mesophication" of forests in the eastern United States. BioScience 58:123-138.

Pooler, M.R., R.I. Dix, and R.J. Griesbach. 2006. Genetic diversity among accessions of the endangered box huckleberry (*Gaylussacia brachycera*) based on AFLP markers. Journal of the Torrey Botanical Society 133:439-448.

Schmidt, K.M., J.P. Menakis, C.C. Hardy, W.J. Hann, and D.L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report RMRS-GTR-87, USDA Forest Service, Fort Collins, CO.

Signell, S.A., and M.D. Abrams. 2006. Influence of rocky landscape features and fire regime on vegetation dynamics in Appalachian *Quercus* forests. Journal of Vegetation Science 17:675-685.

Signell, S.A., M.D. Abrams, J.C. Hovis, and S.W. Henry. 2005. Impact of multiple fires on stand structure and tree regeneration in central Appalachian oak forests. Forest Ecology and Management 218:146-156.

Stephens, S.L., and L.W. Ruth. 2005. Federal forest-fire policy in the United States. Ecological Applications 15:532-542.

Teuke, M., and D.H. Van Lear. 1982. Prescribed burning and oak advance regeneration in the southern Appalachians. Georgia Forest Research Paper 30, Georgia Forestry Commission, Macon, GA.

Van Lear, D.H. and T.A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. General Technical Report SE-54, USDA Forest Service, Asheville, NC.