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Effect of prescribed burning on the composition and structure of forest vegetation in the ozarks of Northwest Arkansas

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ABSTRACT

Prescribed burning (also referred to as controlled or hazard reduction burning) is widely used as a management technique in forests throughout the Ozark Mountains in northwest Arkansas. However, the nature and magnitude of the changes that result from prescribed burning are still incompletely known. In the present study, the effects of prescribed burning were assessed in five study areas located along the Buffalo National River. Data on the structure and composition of forest vegetation were collected from twenty10 by 10 m plots (10 in burned areas and 10 in unburned areas) in each study area. Statistically significant differences were noted between burned (first value) and unburned (second value) plots for percent grass cover (1.50 vs 0.75), tree volume (26.90 vs 16.80 m^3) and numbers of forbs (203 vs 136), seedlings (161 vs 95), saplings (156 vs 163), shrubs/vines (306 vs 257) and trees (2540 vs 4268) per hectare. Although fire has been reported to suppress the invasion of mesic species (beech and sugar maple) in oak-hickory forests, only one of the five study sites had enough beech saplings present to show that fire can significantly reduce the number of saplings of this species in the understory (12 vs 33). However, the overall results indicate that prescribed burning does not seem to have any readily apparent negative effects on forests if carried out in a proper manner. Jmp statistical software and chi-square were used to analyze data for the existence of significant differences between the burned and unburned sites. Site similarities and dissimilarities were also derived through a dendrogram.

Key words: Fire, forest vegetation, Ozark Mountains ecoregion, prescribed-burning.

INTRODUCTION

Prescribed burning (also referred to as controlled or hazard reduction burning) is widely used as a management technique in forests throughout the Ozark Mountains in northwest Arkansas. Walkinstick and Liechty (2009) and Abrams (1985) listed the primary uses of prescribed burning within the Ozarks as hazard reduction, plant community restoration, creating a desirable habitat for wildlife, enhancing tree regeneration and eliminating unwanted trees to reduce competition pressure. However, the overall effects of prescribed burning on forest ecosystems continue to be debated, especially with respect to possible changes in species composition and essential ecosystem functions such as productivity, nutrient cycling and carbon storage (DeBano et al. 1979, DeBano and Klopatek 1988, Nearya et al. 1999, Peterson and Reich 2001, Guyette and Spetich 2003, Foti 2004, Guyette and Stambaugh 2004, Guyette et al. 2006, Jenkins and Jenkins 2006). Many of the questions relating to the use of prescribed burning as a forest management tool remain unanswered because the appropriate studies have yet to be carried out.

The overall objective of the research described herein was to determine the effects of prescribed burning on the composition and structure of forest ecosystems in one portion of northwest Arkansas, with primary emphasis directed towards assessing possible changes in plant cover and species composition of each stratum of vegetation (trees, small trees, saplings, seedlings, shrubs/vines and herbaceous plants). In addition, the effect of prescribed burning on the relative abundance and regeneration potential of seedlings and saplings of the more important tree species was evaluated.

We hypothesized that prescribed burning has effect on the composition and structure of forest vegetation.

GENERAL STUDY AREA

The general study area falls within the Ozark Mountains ecoregion, which encompasses northern Arkansas, the southern half of Missouri along with a small part of Oklahoma and southeastern Kansas, and has a total area of approximately 108,332 km^2 (Karstensen 2010). The data reported in this paper were collected from five study areas located along the Buffalo River where the latter cuts through the Springfield Plateau. The Buffalo River has national importance since it was the first river in the United States to be designated as a National River (http://www.nps.gov/buff/index.htm, Petersen and Reich 2001). This portion of the Ozarks consists of a series of plateaus, ridges, valleys and streams, with an elevation range of 111 to 725 m. Latitude and longitude of the five study areas ranged from 35.09 to 36.07 N and 92.80 to 93.39 W, respectively. Average annual precipitation is approximately 114 cm, and temperatures generally range from 18 to 38 ºC. Braun (1950) described the forests of the Ozark Mountains as oak-hickory (*Quercus-Carya*), with oak generally more abundant than hickory. The more important oaks are black oak (*Quercus velutina* Lam.), northern red oak (*Q. rubra* L.), chinquapin oak (*Q. muehlenbergii* Engelm), post oak *(Quercus stellata* Wangenh.), blackjack oak (*Quercus marilandica* Münchh.) and white oak (*Q. alba* L.), whereas the most important hickories are bitternut (*Carya cordiformis* [Wangenh.] K.Koch, shagbark hickory (*C. ovata* [Mill.] K. Koch) and mockernut hickory (*C. alba* [L.] Nutt. et Elliott). These occur in association with other trees such as red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marshall), white ash (*Fraxinus americana* L.), elm (*Ulmus* spp.), black walnut (*Juglans nigra* L.), black gum (*Nyssa sylvatica* Marsh.) and red cedar (*Juniperus virginiana* L.).

Prescribed burning as a forest management tool in the general study area has been taking place since 1998, with the individual study areas having different fire frequencies with slight variations in intensity, depending upon the amount of litter on the forest floor and weather conditions. Prescribed burning was carried out on one occasion (2004) at Boxley, on three occasions (2000, 2004 and 2009) at Erbie, on three occasions (2001, 2005 and 2012) at Pruitt, on four occasions (1998, 2002, 2006 and 2010) at Gene Rush and on five occasions (1999, 2000, 2002, 2006 and 2010) at Cash Bend.

MATERIALS ND METHODS

The five study areas were selected by United States Park Service personnel, and each area was considered to be representative of a forest type found along a different section of the Buffalo National River (Fig. 1). In each of the five study areas, 20 permanent 10 by 10 m (0.01 ha) plots were systematically selected and established. Ten of these were in a portion of the study area subjected to prescribed burning (burned plots) and 10 were in a portion where prescribed burning had not taken place (unburned plots). The availability of an area of forest within which paired sites (i.e., burned and unburned) characterized by generally similar vegetation, soils, topography, aspect and age of the dominant trees present was the most important consideration in the selection of study areas. Four of these (Erbie, Cash Bend, Gene Rush and Pruitt) were located in a conservation area or a commercial timber harvest area, whereas one (Boxley) was located in a wilderness area. Summary data on the study areas are presented in Table 1. Figures 2 and 3 show a representative burned and unburned plots respectively.

The series of 10 by 10 m square plots in the burned or unburned portion of a particular study site were established along a longitudinal transect, with the individual plots located at least 100 m apart. All plots were placed in areas characterized by relatively uniform topography and vegetation, so that the distance separating two adjacent plots was sometimes much more than 100 m. As such, transects varied in length from 1000 to 2600 m. Once the plot location had been selected, slope inclination was determined with a clinometer, aspect with a compass and the exact coordinates determined with a portable GPS unit.

The center of each 10 by 10 m plot was marked with a metal stake with an attached numbered aluminum tag to allow resampling at some future date. For sampling purposes the outside boundary of the plots and subplots were delimited with a fiberglass measuring tape. Quantitative data on the composition and structure of vegetation were collected using standard sampling methods (e.g., Stephenson and Adams 1986), where DBH (diameter at breast height) measurements were taken at a distance of approximately 1.37 m above the ground.

Within the 10 by 10 m plot, data were obtained for all trees (stems $\geq$ 10 cm DBH), small trees (stems $\geq$ 2.5 DBH but <10 cm DBH) and saplings (stems < 2.5 cm DBH but $\geq$ 1.0 m tall). Seedlings (stems of tree species <1 m tall) and shrubs/vines (other woody stems) were tallied in one 5 by 5 subplot in each larger plot. The subplot represented one quarter of the larger plot and the particular subplot sampled was selected with the use of a random numbers table. Each larger plot also contained sixteen 1 m by 1 m nested plots (delimited with a sampling frame), with four nested plots in each of the four 5 by 5 m subplots. The nested plots were used to obtain cover values for herbaceous plants (forbs and graminoids), bryophytes and lichens. Cover values were determined with the use of the cover class rating scale described by Daubenmire (1968). Any additional species of vascular plants not encountered within the nested plots but observed to be present within larger 10 by 10 m plot were recorded. Later, data collected in the field were used to calculate values of relative abundance (stems <2.5 cm DBH), relative cover (herbaceous plants, bryophytes and lichens) and importance value indices (stems $\geq$2.5 cm DBH) in the manner described by Stephenson and Adams (1986). Nomenclature used herein follows the Checklist of the Vascular Plants of Arkansas (Gentry et al. 2013). Jmp statistical software, important values and chi-square were used to analyze data for significant differences between the burned and unburned sites.

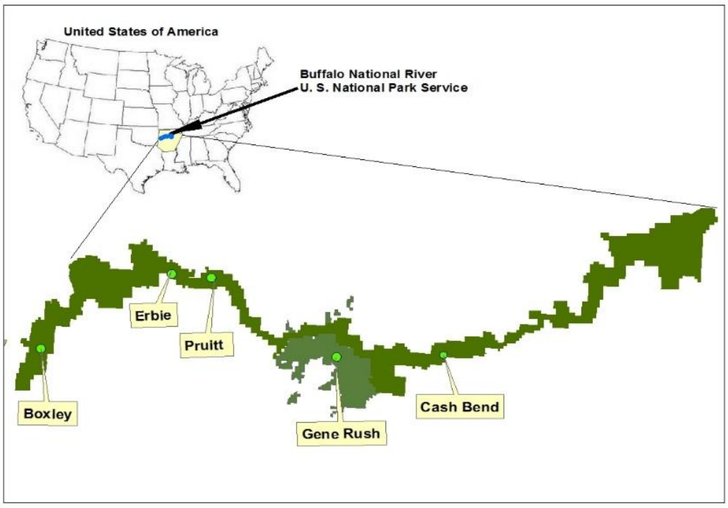


Fig. 1. Map of study cite.

RESULTS AND DISCUSSION

Overall results from the five study areas are summarized in Table 2 and Figure 4. These data indicate that significant differences existed between burned and unburned sites for certain parameters in some study areas. The values for number of tree species, number of stems, average tree height, tree basal area and volume for burned and unburned areas varied considerably among the five sets of study plots. However, this undoubtedly reflects, at least in part, the considerable variability that exists among the five study areas. Importance values for trees on the burned and unburned plots are listed in Table 3, whereas numbers of saplings, seedlings and shrubs/vines are provided in Tables 4 and 5. As a general observation, differences in both numbers of stems and species composition in all of these strata are likely the result of enhanced regeneration of fire tolerant species such as black walnut, Carolina buckthorn (*Frangula caroliniana* [Walter] A. Gray), mockernut hickory, red maple, American hornbeam (*Carpinus caroliniana* Walter), black gum, winged elm (*Ulmus alata* Michx.), pine (*Pinus* spp.) and post oak.

Some of these species, such as the oaks, hickories and black gum, regenerate as a result of the root system sending up new growth after the original stem is killed by fire, whereas the saplings of other species such as red cedar and sugar maple die off completely when burned. For species in the first group, fire probably created new openings to

Fig. 2. A main burned Pruitt study plot (10 m by 10 m) with nested plots (subplots).

Fig. 3. A main unburned Pruitt study plot (10 m by 10 m) with nested plots (subplots).

be exploited. However, fire generally eliminated and/or discouraged the establishment of fire intolerant species such as American beech (*Fagus grandifolia* Ehrh), pawpaw (*Asimina triloba* [L.] Dunal), sassafras (*Sassafras albidum* [Nutt.] Nees) and dogwood (*Cornus florida* L.). Average tree height was higher in burned sites (13.7 vs 11.9 m), probably because the unburned sites had retained more of the smaller diameter, shorter understory trees, which lowered the average height. The number of tree species was also generally lower (6 vs 8 for average site values) in burned study sites (Table 2).

Numbers of saplings (Table 4) were slightly lower for burned sites (156 vs 163 for average site values), probably because some thin-barked saplings were killed by the fire. In contrast, numbers of seedlings were significantly higher (about double [161 vs 95]) on burned sites (Table 5), likely because more seeds germinated in the surface litter-free mineral soils under reduced competition and enhanced availability of nutrients derived from the ash generated by the fire.

The shrub/vine stratum, which generally receives more light when the understory is thinned by fire, is characterized by plants that grow relatively close to the ground. This includes semi-woody species of blackberry (*Rubus*) and wild grape (*Vitis*) along with soft-stemmed Virginia creeper (*Parthenocissus quinquefolia* [L.] Planch.) and poison ivy (*Toxicodendron radicans* [L.] Kuntze). Since fire undoubtedly opened up the lower strata, thus enhancing regeneration, numbers of shrubs/vines were significantly higher in burned sites, with river-bank grape **(***Vitis riparia* Michx.) *and* poison ivy having the highest and lowest variance, respectively (Table 4). On unburned sites, populations of poison ivy were highest at forest edges, presumably due to the availability of sunlight.

Not all shrub/vine species responded the same to fire, since fire intolerant species such as Virginia creeper had fewer mature stems in burned sites, probably because of stem death due to the heat from the fire. However, fire appears to encourage the establishment of blackberry, blueberry (*Vaccinium* spp.) and sumac (*Rhus* spp.), along with such herbaceous species as prostrate tick trefoil (*Desmodium rotundifolium* [Michx.] DC.), shrubby bush clover (*Lespedeza bicolor* Turez.) and shining bedstraw (*Galium concinnum* Torr. & A. Gray).

Data for forbs are listed in Table 6. Among the more common species were trillium (*Trillium* spp.), false Solomon's seal (*Maianthemum racemosum* [L.] Link), Mayapple (*Podophyllum peltatum* L.) and ebony spleenwort (*Asplenium platyneurron* [L.] Britton, Sterns & Poggens). The latter was especially common on rocky sites. Certain species of grasses and sedges (*Carex* spp.) dominated in some study areas, regardless of whether particular study sites were burned or unburned. Prominent examples were Bosc's panic grass (*Dichanthelium boscii* [Pom.] Gould & C. A. Clark) on sites with fertile deep soils and prairie drop seed (*Sporobolus heterolepsis* [A. Gray] A. Gray), poverty oat grass (*Danthonia spicata* [L.] P. Beauv. ex. Roem. & Schult.) and bearded shorthusk (*Brachyelytrum erectum* [Schreb.] P. Beauv.) on sites located on north-facing slopes. Tapered rosette grass (*Dichanthelium accuminatum* [Sw.] Gould & C. A. Clark) and cypress panic grass (*Dichanthelium dichotomum* [L.] Gould) were found across all study areas. The overall mean grass cover value was significantly higher in burned sites (1.50 vs 0.75) compared to unburned sites (Table 2), probably due to reduced competition and ash from the burning that facilitated grass growth in burned areas. In general, cover values for grasses and forbs did not show evidence of a significant relationship with elevation or a response to the number of occasions on which a particular study area had been burned, but they appeared to be strongly correlated with tree density. Burned sites had significantly higher cover values for forbs (2.52 vs 2.07) and higher stem numbers (almost double [203 vs 136]) (Table 2), once again presumably due to enhanced growth that resulted from the ash generated by the fire.

Table 1. Summary of the characteristics of the five study areas.

Characteristic	**PRUITT**	**BOXLEY**	**CASH BEND**	**ERBIE**	**GENE RUSH**
Latitude (N)	36.07	35.95	35.97	35.09	35.98
Longitude (W)	-93.15	-93.38	-92.80	-93.20	-92.94
Area (hectares)	102	101	531	264	1194
Slope range (%)	0 to 30	0 to 30	0 to 30	0 to 30	0 to 30
Elevation (m)	244 to 366	335 to 482	152 to 311	250 to 305	207 to 381
Aspect	South (Some N & E)	West (Some N & S)	Level	North & Northwest	Level
Year(s) burned	2001, 2005 & 2012	2004	1999, 2000, 2002, 2006 & 2010	2000, 2004 & 2009	1998, 2002, 2006 & 2010
General forest type	Mixed hardwood & glades	Mixed hardwood	Mixed hardwood	Mixed hardwood	Mixed hardwood

Table 2. Summary of cover values, numbers of stems and characteristics of trees and saplings for burned and unburned plots for each study site with mean and Chi square values.

Parameter		PRUITT		BOXLEY		CASH BEND		ERBIE		GENE RUSH		Mean		X^2
(Mean values)		**BURN**	**UNBU**	**BURN**	**UNBU**	**BURN**	**UNBU**	**BURN**	**UNBU**	**BURN**	**UNBU**	**BURN**	**UNBU**	**Value**
Cover values	Bryophytes	0.72	0.89	0.93	0.98	0.60	1.13	0.68	0.65	1.08	1.13	0.80	0.95	0.3
	Grasses	1.70	0.90	0.60	0.95	1.03	0.45	3.40	0.73	0.79	0.72	1.50	0.75	11.4*
	Forbs	2.18	1.35	2.82	2.35	2.23	2.13	2.58	1.93	2.80	2.58	2.52	2.07	0.9
Number of	Seedlings	120	91	296	87	182	146	147	106	56	44	161	95	539.3*
	Forbs	199	120	231	204	165	86	251	125	168	143	203	136	259.5*
	Saplings	77	153	295	275	134	99	160	134	111	154	156	163	68.6*
	Shrub/vines	101	96	70	85	79	41	34	25	22	10	306	257	55.8*
	Tree spp.	3	6	8	11	6	6	6	9	3	4	6	8	0.5
	Trees per ha	2000	4400	2860	4460	4140	6160	1740	2600	1960	3720	2540	4268	699.6*
Average tree height (m)		12	6	7	8	5	5	9	8	8	5	8.2	6.4	0.5
Average tallest tree (m)		39	29	32	32	28	33	27	29	26	18	13.7	11.9	0.3
Tree basal area (m^2/ha)		10.3	3.6	1.3	0.9	0.8	0.7	1.6	1.3	4.7	2.2	2.7	1.7	2.4
Tree volume (m^3/ha)		15.4	28.2	40.4	13.4	0.1	4.6	0.9	13.6	77.6	24.1	26.9	16.8	6.1*

Note: BURN = burned sites and UNBU = unburned sites.
X^2 = Chi square value
* = Significant difference

Overall cover values for bryophytes were not significantly different, although they were slightly lower (0.80 vs 0.95) on burned sites, probably because (1) fire consumed coarse woody debris (bryophyte substrates) on which most bryophytes occur, (2) directly killed some bryophytes and (3) slowed recovery of bryophytes that were not completely killed by the fire. Cover values for bryophytes were lowest in Cash Bend and highest at Boxley. Both sites had been burned four times, implying that factors other than fire influenced bryophyte cover. Topography probably played a role, as low-lying Cash Bend and Gene Rush, both bottomland study areas, had higher bryophyte cover than the other, more upland sites.

The data on species composition of the tree stratum in the five study areas (Table 3) indicates that the forests on these sites can be characterized as oak-hickory forest, thus conforming to the classification proposed by Braun (1950). Oaks, including white oak, post oak, red oak and black oak, along with mockernut hickory dominated the tree stratum. Tree basal area was slightly higher in burned sites (30.4 vs 29.8 m^2/ha) but the difference was not significant. This difference was probably due to the deaths (thinning) of some small trees that enhanced an increase in the girth of the remaining trees. This difference was not significant, implying that fire had minimal impact on tree diameter. However, tree volume was somewhat lower on burned sites (213.4 vs 257.8 m^3/ha; Table 2) probably due to the death/thinning of some individual stems. Fire opened up forest canopy, allowing more light to reach the forest floor and thus resulted in the development of more undergrowth as well as reducing the "mesiphication" that causes the proliferation of mesic species such as maple and beech but encourages the establishment of oaks and hickories. The data obtained in this study show that seedlings of white ash, red and black oak, hickory, ironwood and dogwood were significantly more numerous on burned versus unburned sites. Less significant increases in seedlings for burned over unburned plots were noted for other tree species. The seedlings counts for sugar maple and beech, the two species most often associated with mesiphication, were more numerous on burned sites, but the numbers are so low as to be effectively meaningless. A significant number of

Table 3. Importance values for trees given for each burned and unburned site with averages and totals ranked with burned site total.

	BURNED							UNBURNED						
Species	PR	BO	CB	GR	ER	Total	Mean	PR	BO	CB	GR	ER	Total	Mean
Quercus alba	8.7	10.4	15.1	19.2	12.8	66.2	13.2	6.5	5.1	21.5	53.5	5.4	92.0	18.4
Quercus stellata	12.8		30.1	3.4	8.7	55.0	11.0	22.1		10.2	5.5	3.4	41.2	8.3
Quercus rubra		11.7		35.8		47.5	9.5		9.0			5.5	14.5	2.9
Juniperus virginiana	13.7			5.1	12.0	30.8	6.2	12.0	0.6	1.4	0.9	1.5	16.4	3.3
Quercus velutina		17.9	5.9	1.7		25.5	5.1		12.2	35.5		21.8	69.5	13.9
Cornus florida	9.2	0.4	1.2	12.3		23.1	4.6	5.8	0.7	4.0	9.5	5.2	25.2	5.1
Carya texana			8.8	5.2	8.8	22.8	4.6			7.9		6.4	14.3	2.9
Frangula caroliniana	11.7		2.8		6.2	20.7	4.1	11.8		0.5		5.2	17.5	3.5
Carya tomentosa		4.5	6.4		9.6	20.5	4.1				11.4	4.5	15.9	3.2
Platanus occidentalis					19.1	19.1	3.8							
Pinus echinata	10.1			6.5		16.6	3.3	7.9					7.9	1.6
Acer rubrum		14.9	0.1	1.5		16.5	3.3	0.5	0.8		3.1	1.2	5.6	1.1
Sassafras albidum		4.5	8.4	1.0		13.9	2.8	0.5		1.9	3.7	2.1	8.2	1.7
Quercus marilandica	13.6					13.6	2.7							
Ulmus alata	2.4	0.2	5.7		3.5	11.8	2.4	2.0	1.3	12.4	0.8	15.6	32.1	6.4
Carpinus caroliniana		10.2	0.1		0.6	10.9	2.2	1.5	7.0		2.0		10.5	2.1
Liquidambar styraciflua	1.1	8.0				9.1	1.8		0.1				0.1	
Carya spp.	9.0					9.0	1.8	8.5	3.3	3.2			15.0	3.0
Juglans nigra			7.3			7.3	1.5		9.6			0.6	10.2	10.0
Acer saccharum		1.6			4.9	6.5	1.3		3.0			2.6	5.6	1.1
Other species	7.9	14.5	3.3	6.8	11.6	48.6	10.7	21	50.3	0.7	6.4	16.4	94.8	20.3
Total	100	100	100	100	100	500	100	100	100	100	100	100	500	100

Note: PR = PRUITT, BO = BOXLEY, CB = CASH BEND, GR = GENE RUSH, ER = ERBIE.

Importance values given by the sum of relative basal area and relative abundance expressed as percentages and divided by two.
Others: In a descending order;
Fraxinus Americana, Quercus muehlenbergii, Fagus sylvatica, Magnolia acuminate, Carya cordiformis, Ulmus rubra, Cercis canadensis, Castanea ozarkensis, Carya ovate, Amelanchier canadensis, Ulmus americana, Vaccinium spp., Fraxinus quadrangulata, Viburnum rufidulum, Celtis occidentalis, Vaccinium arboretum, Fraxinus pennsylvanica, Lindera benzoin, Morus rubra, Diospyros virginiana, Hamamelis virginiana, Asimina triloba, Carya laciniosa, Celtis tenuifolia, Dirca palustris, Prunus americana, Prunus serotina, and Quercus falcate

beech saplings were present in the Boxley study area, and there were noticeably fewer beech saplings in burned plots at Boxley. Abrams (1998) stated that there is a general slow decline in oak dominance but an increase in red maple and certain other species in the eastern United States. The results reported herein support the often assumed utility of prescribed burns to enhance advanced reproduction by less tolerant but commercially valuable species of oak, but they do not provide evidence that burning also suppresses the invasion of tolerant beech and maple, simply because so few saplings and seedlings of these species were present in the study plots, with the one exception being the Boxley study area, where burning was associated with a reduction in beech.

Table 4. The number of twenty common saplings and the five shrub/vines species in the five burned and unburned study sites.

Saplings				Shrub/vines		
Species	BUR	UNB	Growth form	Species	BUR	UNB
Cornus florida	16	118	Small tree	*Toxicodendron radicans*	101	96
Carya alba	76	90	Tree	*Vitis riparia*	79	41
Vaccinium angustifolium	94	88	Shrub	*Parthenocissus quinquefolia*	70	85
Quercus velutina	79	75	Tree	*Smilax rotundifolia*	34	25
Frangula caroliniana	41	72	Tree	*Rubus flagellaris*	22	10
Sassafras albidum	106	66	Small tree	-	-	-
Quercus alba	39	33	Tree			
Nyssa sylvatica	29	33	Tree			
Fagus grandifolia	12	33	Tree			
Fraxinus sp.	21	31	Tree			
Acer rubrum	31	20	Tree			
Ulmus alata	33	18	Small tree			
Prunus americana	5	16	Tree			
Viburnium prunifolium	14	15	Shrub			
Acer saccharum	11	14	Tree			
Prunus serotina	18	13	Tree			
Cercis canadensis	23	12	Small tree			
Ostrya virginiana	33	11	Tree			
Vibunum rufidulum	8	11	Shrub			
Asimina triloba	0	11	Small tree			
Others	75	29		-	-	-
Total	777	814			306	257

NOTE: BUR = BURNED, UNB = UNBURNED and other species are listed in a descending order:
Burned:
Carya cordiformis, Vaccinium arboretum, Fraxinus quadrangulata, Morus rubra, Juniperus virginiana, Quercus stellata, Diospyros virginiana, Crataegus laevigata, Lindera benzoin, and Crataegus insidiosa.
Unburned:
Lonicera japonica, Quercus stellata, Carya cordiformis, Crataegus laevigata, Crataegus insidiosa, Diospyros virginiana, Morus rubra, Fraxinus quadrangulata, Lindera benzoin, Celtis occidentalis, and *Rhus copallina*

Diversity on the study plots was estimated by use of Simpson's reciprocal index (1/D), a measure of species diversity in an ecosystem where the higher the value, the more diverse the community. The results obtained from the study indicated that fire increased the diversity of forbs, seedlings, and saplings with diversity indices of 26.4, 17.4 and 14.5, respectively (Tables 7, 8 and 9). Tree diversity was slightly lowered by fire but the difference was not significant. The calculated 1/D showed considerable variation among plant growth forms and study sites, ranging from negative 4.70 to 0.80. The results otherwise represent two competing tendencies, the elimination of species by fire and the encouragement of an increased addition of species by the opening up of habitats and the removal of competition.

There are aspects other than plant species diversity in forest ecology that can be affected by prescribed burning. Boyles and Aubrey (2006) stated that many forest-dwelling vertebrates such as cavity-roosting bats benefit from the effects of fire on vegetation. However, in the present study, cavities made by woodpeckers (*Picoides borealis* Vieillot) were found only on unburned sites. This may suggest that prescribed burning may reduce the numbers of woodpeckers that create cavities in tree trunks in the general study area. Fire scars and wood cavities at the bases of trees generally occurred on the uphill side of trees because the accumulation of surface litter on the upper slope at the base of a trunk resulted in a "hot spot" during burning, thus causing extensive damage to both phloem cells and xylem vessels. Basal cavities caused by such fire scars could be used by small mammals, providing a benefit for the wildlife community.

Table 5. Total number and species of dominant seedlings in the five unburned and burned study sites.

Species	**BURNED**	**UNBURNED**	**Growth form**
Quercus alba	57	66	Tree
Ulmus alata	85	44	Small tree
Frangula caroliniana	83	43	Tree
Carya alba	66	43	Tree
Quercus velutina	83	41	Tree
Sassafras albidum	70	36	Tree
Acer rubrum	51	30	Tree
Cornus florida	53	28	Tree
Nyssa sylvatica	27	23	Tree
Acer sp.	95	20	Tree
Fraxinus sp.	43	19	Tree
Prunus serotina	136	18	Tree
Unknown others	9	15	Tree and shrubs
Cercis canadensis	37	14	Small tree
Juniperus virginiana	26	11	Tree
Liquidamber styraciflua	11	10	Tree
Salix nigra	18	8	Small tree
Prunus Americana	8	7	Tree
Quercus muehlenbergii	14	7	Tree
Rhus sp.	173	7	Shrub
Pinus echinata.	17	5	Tree
Others	237	25	
Totals	**1385**	**515**	

Others in a descending order:
Burned:
Juglans nigra, Viburnum prunifolium, Ostrya virginiana, Quercus rubra, Viburnum rufidulum, Lonicera japonica, Acer saccharinum, Amelanchier arborea, Asimina triloba, Crataegus laevigata, Morus rubra, and *Vaccinum* spp.
Unburned:
Crataegus laevigata, Ostrya virginiana, Lindera benzoin, Lonicera japonica, Quercus rubra, Asimina triloba, Viburnum rufidulum, Juglans nigra, Viburnum prunifolium, Amelanchier arborea, Morus rubra, Vaccinum sp., Diospyros virginiana, Acer saccharinum, Fagus grandifolia, and Castanea ozarkensis.

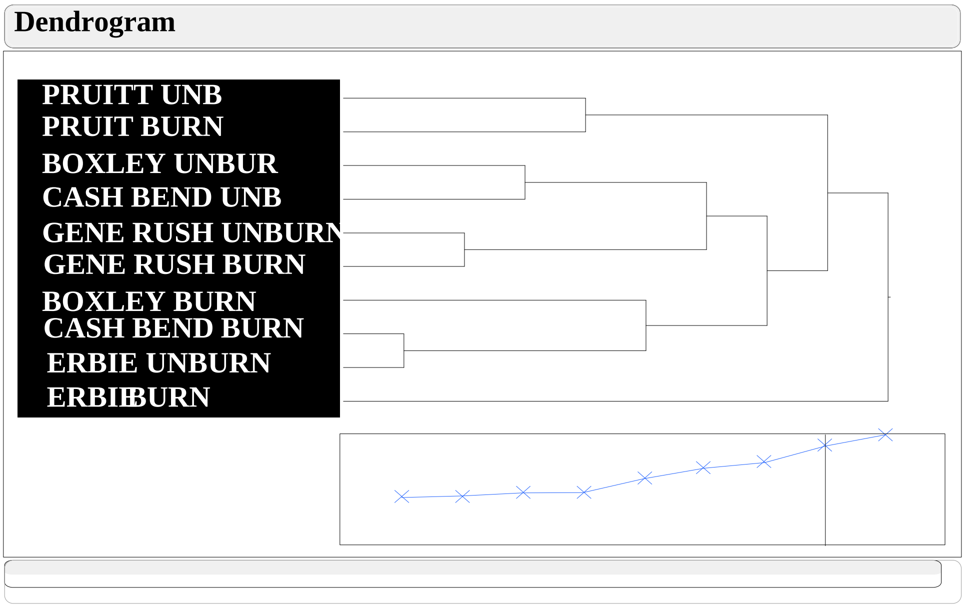
Prescribed burning encourages the development of undergrowth, but the results depend upon site conditions. As this study reveals, fire generally enhances the regeneration of forbs, opens up the forest floor (allowing shade intolerant species to become established), kills saplings (reducing their numbers), reduces bryophyte cover, adding ash from the burning that take place, and opening up lower strata of vegetation (thus reducing competition and encouraging the establishment of tree seedlings, grasses and forbs. However, fire has little effect on trees other than thinning some individual stems.

Wherever prescribed burning is not carried out, the undergrowth can become depleted and or smothered by the accumulation of coarse woody debris. The non-availability of undergrowth (browse and forage) in areas that have not been burned for many years can cause wildlife such as elk and deer to damage trees through debarking. In the general study area, there were some species of rare plants such as leatherwood (*Dirca palustris* L.)

and rattlesnake plantain (*Goodyera pubescens* [Willd.] R. Br.) that occurred only on unburned sites and thus might not be tolerant of fire. As such, reconnaissance and assessment of fuel conditions may be required before implementation of future prescribed fire along the Buffalo National River. However, if carried out in a proper manner, prescribed burning ("prescribed fire") clearly yields some desired outcomes, including such things as improved habitat, reduced completion among and within species, reduced fire hazards, restored ecosystem conditions and preparation of the site for other types operations.

The sites' hierarchical clustering (Fig.1 dendrogram) reveal that burned Erbie site is an outlier while Pruitt site is on the extreme of the cluster. The two sites are completely different hence need different management practices.

Fig 4. Sites hierarchical clustering using jmp software.



No. of clusters	Distance	Leader	Joiner
9	1.711681504	CASH BEND BURN	ERBIE UNBURN
8	1.768962403	GENE RUSH UNBURN	GENE RUSH BURN
7	1.875951532	BOXLEY UNBUR	CASH BEND UNB
6	1.886474942	PRUITT UNB	PRUIT BURN
5	2.378396296	BOXLEY BURN	CASH BEND BURN
4	2.751991021	BOXLEY UNBUR	GENE RUSH UNBURN
3	2.951284767	BOXLEY UNBUR	BOXLEY BURN
2	3.531296596	PRUITT UNB	BOXLEY UNBUR
1	3.930976424	PRUITT UNB	ERBIE BURN

CONCLUSION

The study results confirm that prescribed burning has effect on the composition and structure of forest vegetation hence we reject the null hypothesis. However, the significant effects are generally positive and helpful for the management of forests. These outcomes indicate that it is worthwhile to use prescribed burning as a forest management tool within the Buffalo National River, but such operations need to continue in a careful and professional way. However, some observed minor variations between sites may have been due to different management treatments at each site.

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