



**National Park Service
Ozark Highlands Cluster
Fire Ecology Annual Report
Calendar Year 2007**

Summary

2007 was a very successful year for the Ozark Highlands fire ecology program. This year our monitoring crew consisted of two seasonal biological science techs and three SCA interns as I exhausted my seasonal certificate during hiring. The SCAs did an excellent job and were critical to our program's accomplishing all of our fire effects plot work. The fire ecologist and lead monitor read 35 immediate postburn plots in cluster park units while the fire effects monitoring crew reread/installed 61 FMH plots at Ozark NSR, Buffalo NR, Pea Ridge NMP, and Hot Springs NP. In addition, 67 CBI plots were read within three burn units at Ozark NSR. Fire Ecologist Dan Swanson gave presentations at the George Wright Society Conference in Duluth, MN, and the Mark Twain NF / Northern Research Station Fire Workshop in Rolla, MO, on the "Effect of Prescribed Fire on Herbaceous Diversity and Cover in Upland Oak-hickory-pine forests at ONSR". The fire ecologist and lead fire effects monitor, Erin Yeoman, were involved in approximately 18 prescribed burns totaling 2900 acres during the months of March and April at area parks. Dan and Erin did go on one wildfire assignment each during last summer's busy fire season. Erin worked on the Blackcat wildfire in Montana as a crew boss (T) in August while Dan was a squad boss (T) in northern California on the Cherry and Moonlight wildfires in September.

Table 1. Fire Effects Plot Workload 2007

Park	Monitoring Unit	Type of Plot (FMH, photo point, other)	Pre-burn	Immed. Post	Postburn (1-20 yrs)	Total Plots within Mon. Type
Ozark NSR	Glade/Woodland Transition	Modified FMH forest plot	2	2	7	20
Ozark NSR	Dry Mesic Woodland Oak/Hickory	FMH forest plot	0	4	10	14
Ozark NSR	Dry Woodland Oak/Hickory/Pine	FMH forest plot	3	9	14	19
Ozark NSR	Various	Fuels	0	0	0	61
Ozark NSR	Various	CBI	0	0	67	101
Buffalo NR	Glade/Woodland Transition	FMH Forest plot	0	15	8	10
Buffalo NR	Dry Woodland Oak/Hickory/Pine	FMH Forest plot	0	15	7	17
Buffalo NR	Open Fields	FMH Grass plot	0	0	0	2
Pea Ridge NMP	Oak Hickory forest/Woodland	FMH Forest plot	0	0	0	6
Pea Ridge NMP	Post Oak – Black Jack Oak Woodland	FMH Forest plot	0	2	2	6
Pea Ridge NMP	Restored Prairie/Fields/Glades	FMH Grass plot	0	0	0	2
Hot Springs NP	Dry Woodland Pine-oak	FMH Forest plot	3	2	4	4
Hot Springs NP	Wildland-urban interface	Mechanical thinning plot	0	0	0	4
Total			8	49	119	266

Table 2. Fire Ecology Staffing 2007

Monitor	Starting Date	Ending Date	# of Pay Periods	Training and Development	Fire Assignments
Dan Swanson Fire Ecologist	NA	Permanent, full time	26	Botany, LANDFIRE, Fire history workshop	Cherry and Moonlight WF, CA, 18 days
Erin Yeoman, Lead Monitor	1/7/07	10/27/07	21	botany	Blackcat WF, MT, 18 days
T.J. Hilton, monitor	5/20/07	9/29/07	10	botany	
Charles Aldridge, monitor	6/24/07	9/29/07	7	botany	
Andrew Miller, SCA monitor	5/20/07	8/18/07	7	botany	
Greg Mitchell, SCA monitor	5/20/07	8/18/07	7	botany	
Stephanie Wagner, SCA monitor	5/20/07	8/18/07	7	botany	

Table 3. Management Objectives and Monitoring Results 2006

Park	Monitoring Unit	Management Objective	Monitoring Results	Objective Achieved
Ozark National Scenic Riverways	Glade/Transition	Reduce the density of pole trees (2.5-15 cm dbh) by at least 40% within two growing seasons after 2 nd burn ; (80% C.I.)	29% Decrease	No n=13, 2 fires
		Increase the average number of species (per quadrat) in the herbaceous layer by at least 40% within two growing seasons after the second burn (90% C.I.)	110% Increase	No n=13, 2 fires
	Dry-Mesic Woodland (Oak/Hickory/Pine)	Reduce the density of pole trees (2.5-15 cm dbh) by at least 30% within two growing seasons after 2 nd burn; (80% C.I.)	49% Decrease	Yes n=9, 2 fires
		Increase the average number of species (per quadrat) in the herbaceous layer by at least 20% within two growing seasons after the second burn (90% C.I.)	52% Increase	No n=9, 2 fires
	Dry Woodland (Oak/Hickory/Pine)	Reduce the density of pole trees (2.5-15 cm dbh) by at least 30% within two growing seasons after 2 nd burn; (80% C.I.)	51% Decrease	Yes n=11, 2 fires
		Increase the average number of species (per quadrat) in the herbaceous layer by at least 40% within two growing seasons after the second burn (90% C.I.)	67% Increase	No n=11, 2 fires
Buffalo National River	Glade/Transition	Increase the average number of native species in the herbaceous layer by at least 40% within two growing seasons after the second burn; (90% C.I.)	No Change ¹	NA n=6, 2 fires
		Reduce pole density (2.5 – 15 cm dbh) by 60% after 10 years of burning; (80% C.I.)	12% Decrease ¹	NA n=6, 2 fires
		Reduce new growth eastern red cedar by 95% after three consecutive burns (90% C.I.)	34% Decrease ¹	NA n=6, 2 fires
	¹ one season after 2 nd burn treatment			
	Dry Woodland	Reduce tree density to open vista with a target density of 74 trees/hectare after 20 years (80% C.I.)	286 tph ¹	NA n=7, 2 fires
		Reduce pole density (2.5-15 cm dbh) by 60% after 10 years of burning; (80% C.I.)	52% Decrease ¹	NA n=7, 2 fires

		Reduce live stems/acre by 60 % over 10 years of burning (90% C.I.) ¹ one season after 2 nd burn treatment	42% Decrease ¹	NA n=7, 2 fires
	Open Fields/Cane Communities	Open fields - Maintain/restore/introduce native grass species and increase percent cover of native species by 25% after three prescribed burn applications (80% C.I.) Cultural/historic - Maintain historical farmstead openings, establish monitoring photopoints, maintain woody species density at 90% of preburn level within open fields over 10 years of burning (80% C.I.) Cane communities - maintain or increase size of cane community after 10 years of burning (90% C.I.)	NA	NA
Pea Ridge National Military Park	E. Red Cedar/Mixed Hardwood/Old Fields/Disturbed Sites	Reduce mean density of pole-sized trees (2.5-15cm dbh) by 30-40% after four burns; (80% C.I.) Increase mean density of oak seedlings and/or resprouts by 300-500% after four burns; (80% C.I.) Increase mean percent cover of native herbaceous species by 50-70% after four burns. (80% C.I.)	NA	NA
	Oak Hickory Forest/Woodland	Reduce mean density of pole-sized trees (2.5-15cm dbh) by 50-70% after four burns; (80% C.I.) Increase mean density of oak seedlings and/or resprouts by 300-500% after four burns. (80% C.I.)	11% Decrease 24% Increase	NA n=3, 1 fire NA n=3, 1 fire
	Post oak-blackjack oak savannah/woodland	Reduce mean density of pole-sized trees (2.5-15cm dbh) by 50-70% after four burns; (80% C.I.) Increase mean percent cover of native herbaceous species by 60-100% after four burns (80% C.I.)	No Change No Change	NA n=3, 1 fire NA n=3, 1 fire
	Restored Prairies/Fields/Glades	Reduce mean percent cover of live trees, shrubs, and woody vines by 75-85% after four burns; (80% C.I.) Reduce the mean percent cover of non-native species by 30-40% after four burns (80% C.I.)	NA	NA

Ozark Highlands Fire Ecologist Accomplishments

In April I gave presentations at the George Wright Society Conference in Duluth, MN, and the Mark Twain NF / Northern Research Station Fire Workshop in Rolla, MO, on the “Effect of Prescribed Fire on Herbaceous Diversity and Cover in Upland Oak-hickory-pine forests at ONSR”. I was involved in Beta testing of the newly released FFI program late summer into fall and provided feedback on the following modules: main program, protocol manager, pda, and ArcGIS. I travelled to Boise in August for a week of hard core testing. Fire effects data analysis from the second prescribed burn treatment within the Lower Wilderness at Buffalo NR was completed this winter. Fire effects data showed that two dormant season prescribed burns continue to significantly decrease pole density. Herbaceous cover and species diversity within the dry woodland monitoring type are both significantly increasing due to fire. This summer my lead monitor and I trained our fire effects crew in the protocols of CBI. Sixty-seven CBI plots were conducted in four prescribed burns at Ozark NSR. Analysis showed approximately 95% of our prescribed burns were in the low severity class and a one-way analysis of variance using Tukey’s comparison of severity class groups showed that there was a significant difference of CBI scores between the low and low-moderate as well as low and moderate severity class groups but not among the low-moderate to moderate severity classes.

Table 4 Fire Ecologist Accomplishments/Focus Areas

Category	Percent Time	Accomplishments and/or areas of activities
Planning	17%	Determining fire effects plot / CBI location and establishment in monitoring types at OZAR, BUFF, PERI, and HOSP. Determining fire effects travel costs to area parks. Training of field crew in FMH, FRCC and CBI protocols Revision of OZAR fire effects monitoring plan
Presentations	5%	Park staff, public meetings, and training
NPS Meetings/ task groups	15%	FFI Beta testing, GMP meetings, OZAR safety committee meetings
Interagency work	2%	CBI, Completion of an ArcGIS Interagency Fire Tower Zone Map
Fire Assignments	11%	FEMO on 8 RX fires (8 operational periods), FFT2 on 4 RX fires (4 operational periods), FFT2 on 10 WF (10 operational periods), Squad boss (T) on 2 WF (13 operational periods)
Research	1%	Literature review of Ozark Highlands fire ecology research
Data entry	1%	Estimated amount of time spent entering data from paper to PC
Data Mgmt	6%	Error checking and species list management
Data analysis	15%	OZAR, BUFF, PERI, and HOSP fire effects data analysis
Supervision/Admin	10%	Hiring, supervision, travel, payroll, etc
Training	4%	Botany training, Fire history workshop, Land Fire workshop, fire refresher
Monitoring Field work	10%	Trips to BUFF, PERI, HOSP for data collection
Miscellaneous	3%	Writing burn reports

Table 5 Fire effects crew accomplishments and area of focus.

Category	Percent Time	Notes
FMH plots	50%	Time spent collecting plot data; including preparation time.
WUI plots	0%	
CBI plots	5%	Plots conducted on four prescribed burn units within OZAR
Other plot work	2%	Live/dead fuel moisture monitoring
Fire Assignments	12%	Lead was on 22 RX fires and 9 WF.
Fuels Project work	0%	Fuels project work
Data entry	12%	100% of 2007 fire effects data entered by Oct. 1
Data Mgmt conversion	5%	Preparing species lists and error checking
Data analysis	3%	Summarized fuel loading data for each park unit
Supervision/Admin	4%	Travel, payroll, etc
Training	7%	Botany, CBI, FMH protocols

Ozark National Scenic Riverways

Using Landsat Satellite Imagery and Composite Index Plots to Assess Burn Severity

Introduction

Composite burn index plots (CBI) were conducted in the field on four burn units at Ozark National Scenic Riverways to validate remote sensing imagery and relate radiometric change to actual fire effects on the ground. Landsat 5 satellite imagery was used for burn area assessment which provides data acquisition over the same area every 16 days. Landsat allows one to compare both pre-fire and post-fire conditions when evaluating the magnitude of fire-caused change at a 30 m pixel resolution. An extended assessment was requested to assess delayed mortality and survivorship of burned vegetation as well as provide a good

view of the burn perimeter. The pre-fire landsat scene was from July 6, 2006 and post-fire scene was from July 25, 2007. Angel Ridge, Booming Shoals, Campbell Point, and Beaver Pond had prescribed fire applied to them between March 22 and March 27, 2007. Since burning was completed during the dormant season, the post-fire landsat scene and CBI field plot monitoring were completed the same year. CBI protocols have the user assess fire effects across strata independently and include three strata for the understory and two for the overstory. Understory strata include: 1.) substrates; 2.) herbs, low shrubs and trees less than 1 meter; and 3.) tall shrubs and trees 1 to 5 meters. Overstory strata include intermediate trees (subcanopy) and big trees (upper canopy). A total of sixty-six CBI plots were completed in August and September 2007.

Results

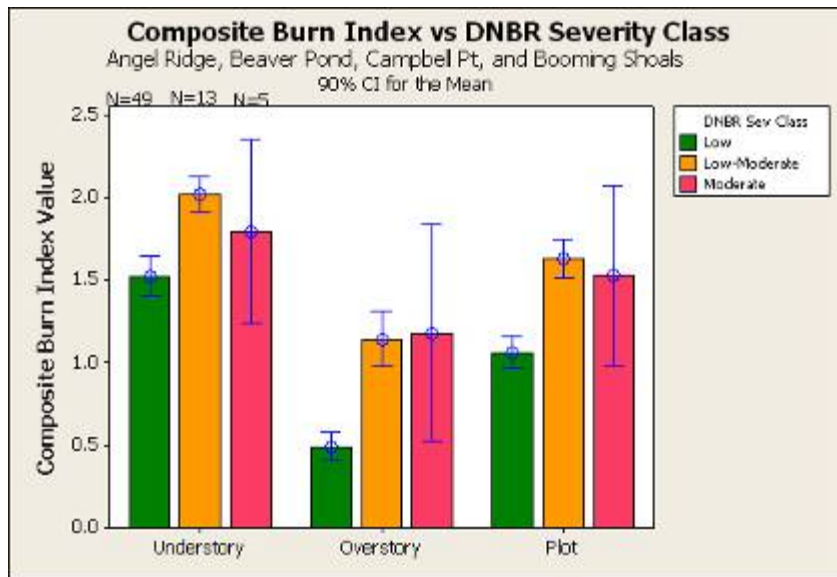
CBI plots were completed in the field using the range of differenced normalized burn ratio values found throughout the four burn units. Differenced normalized burn ratio (DNBR) pixel values were categorized into burn severity classes in order to field validate the satellite imagery. DNBR pixel values from -26 to 150 were classified as low, 151 to 250 as low-moderate, and 251 to 650 as moderate. Maximum DNBR values for each burn unit were 401 for Angel Ridge, 182 for Booming Shoals, 174 for Campbell Pt, and 250 for Beaver Pond. Table 6 shows the percentage of each burn unit that is categorized within each DNBR severity class using Landsat 5 satellite imagery following March 2007 prescribed burns.

Table 6

Burn Unit	DNBR Severity Class Categories		
	Low	Low-Mod	Moderate
Angel Ridge	89%	7%	3%
Booming Shoals	98%	< 1%	0%
Campbell Pt	98%	< 1%	0%
Beaver Pond	96%	3%	0%

The CBI burn severity scale has a range from 0 to 3.0 where 1.0 is low, 1.5 is low-moderate, 2.0 is moderate, 2.5 moderate-high, and 3.0 is high. First, I looked at all the burn units together (67 plots) and assigned DNBR severity class groups based on the Landsat 5 satellite imagery. CBI plots had overall plot means of $1.06 \pm .10$, $1.63 \pm .11$, and $1.53 \pm .55$ for the low, low-moderate, and moderate DNBR severity classes respectively (Figure 1). A one-way analysis of variance using Tukey's comparison of severity class groups showed a significant difference of CBI scores between low and low-moderate as well as low and moderate severity class groups, but not between low-moderate to moderate severity classes.

Figure 1. Mean and 90% CI CBI scores by strata from the DNBR severity classes observed on the Angel Ridge, Beaver Pond, Campbell Point, and Booming Shoals burn units.



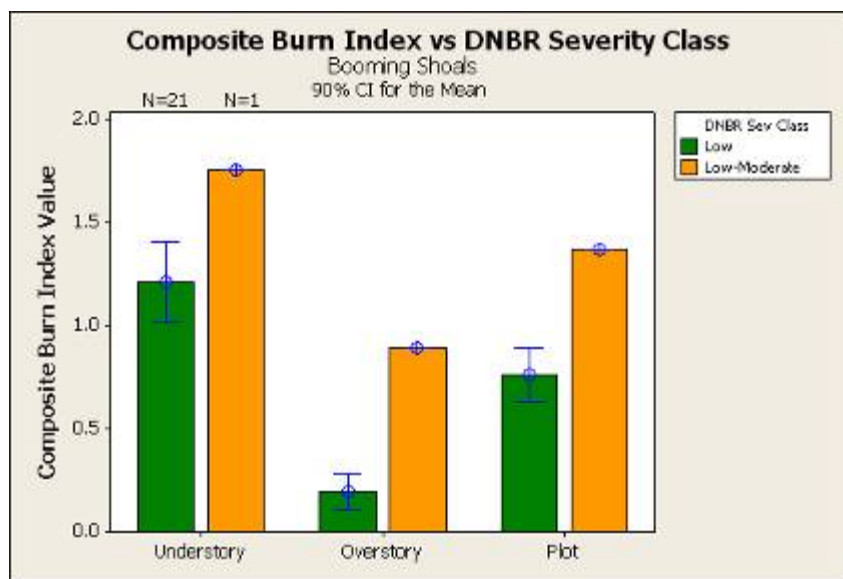
Understory CBI scores were on average higher than plot means for each DNBR severity class, likely due to prescribed burns moving through hardwood leaf litter with flame lengths between 0.5 – 3 feet resulting in direct flame contact and scorching to lower strata. CBI plots had understory plot means of $1.52 \pm .12$, $2.02 \pm .22$, and $1.80 \pm .56$ respectively for the low, low-moderate, and moderate DNBR severity classes (Figure 1). A one-way analysis of variance using Tukey's comparison of severity class groups showed that there was a significant difference of CBI scores between the low and low-moderate class groups but not among the low-moderate to moderate and low to moderate severity classes. Overstory CBI scores are on average lower than the overall plot mean per DNBR severity class since the prescribed burn is a surface fire with small flame lengths, and trees are normally still dormant. CBI plots had overstory plot means of $0.49 \pm .09$, $1.15 \pm .17$, and $1.18 \pm .66$ respectively for the low, low-moderate, and moderate DNBR severity classes (Figure 1). A one-way analysis of variance using Tukey's comparison of severity class groups showed that there was a significant difference of CBI scores between the low and low-moderate and low and moderate class groups but not among the low-moderate to moderate classes.

CBI vs DNBR Severity Class by Burn Unit

Booming Shoals

Next, I looked the relationship between CBI score and DNBR severity class for each burn unit. Booming Shoals had a total of 22 CBI plots sampled with 21 of those in the low DNBR severity class and one in the low-moderate class. With 98% of the unit within the DNBR low severity class there wasn't much opportunity to place any CBI plots within the low-moderate DNBR severity class. CBI plots had overall plot means of $0.76 \pm .13$ and 1.37 for the low and low-moderate DNBR severity classes (Figure 2). CBI plots had understory plot means of $1.21 \pm .20$ and 1.75 for the low and low-moderate DNBR severity classes. Overstory plot means were $0.19 \pm .09$ and 0.89 for the low and low-moderate DNBR severity classes.

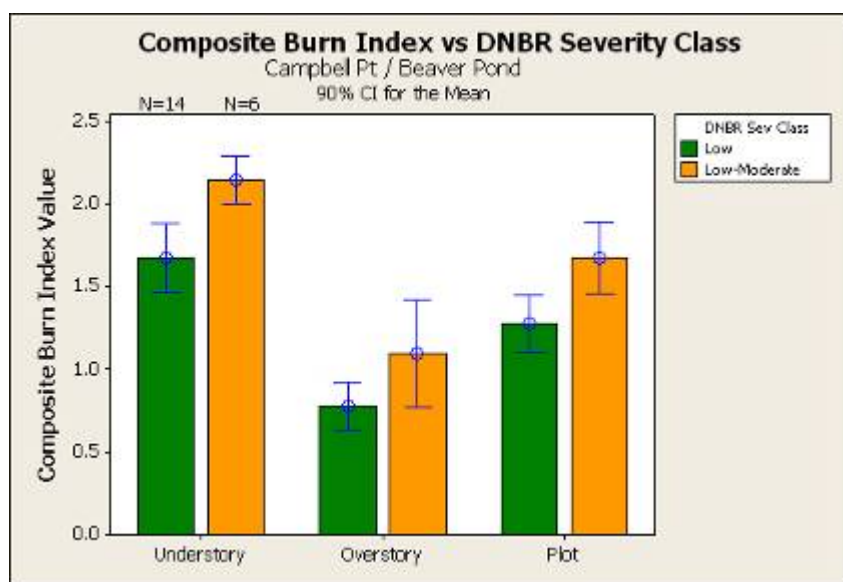
Figure 2. Mean and 90% CI CBI scores by strata from the DNBR severity classes observed on the Booming Shoals burn unit.



Campbell Point / Beaver Pond

Campbell Point and Beaver Pond had a total of 20 CBI plots sampled with 14 of those in the low DNBR severity class and 6 in the low-moderate class. CBI plots had overall plot means of $1.28 \pm .18$ and $1.68 \pm .22$ for the low and low-moderate DNBR severity classes (Figure 3). CBI plots had understory plot means of $1.68 \pm .21$ and $2.15 \pm .15$ for the low and low-moderate DNBR severity classes. Overstory plot means were $0.78 \pm .14$ and $1.09 \pm .32$ for the low and low-moderate DNBR severity classes.

Figure 3. Mean and 90% CI CBI scores by strata from the DNBR severity classes observed on the Campbell Point and Beaver Pond burn units.

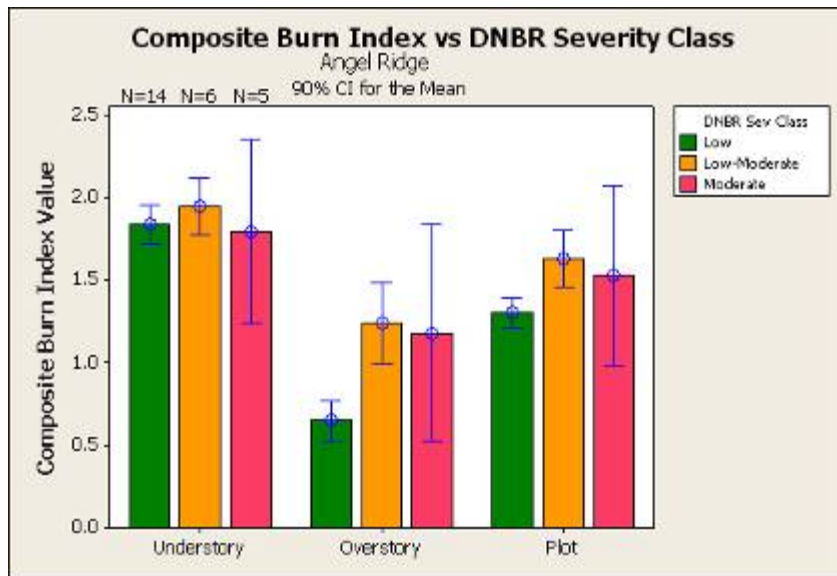


Angel Ridge

Angel Ridge had a total of 25 CBI plots sampled with 14 of those in the low DNBR severity class, 6 in the low-moderate class, and 5 in the moderate class. CBI plots had overall plot means of $1.31 \pm .09$, $1.63 \pm .17$, and $1.53 \pm .55$ for the low, low-moderate, and moderate DNBR severity classes (Figure 4). CBI

plots had understory plot means of $1.84 \pm .12$, $1.95 \pm .18$, and $1.80 \pm .56$ for the low, low-moderate, and moderate DNBR severity classes. Overstory plot means were $0.65 \pm .12$, $1.24 \pm .24$, and $1.18 \pm .66$ for the low, low-moderate, and moderate DNBR severity classes.

Figure 4. Mean and 90% CI CBI scores by strata from the DNBR severity classes observed on the Angel Ridge Burn unit.



Glade / Woodland Transition Monitoring Type

I looked at relative change in overstory and pole density as well as species richness after two prescribed burns.

Effect of Prescribed Fire on Overstory and Pole Tree Density

There was an average 37% decrease in pole density in the glade / woodland transition monitoring type but these results were below the target of a 40% decrease ($p > .20$) (Figure 5). Statistically, there is an 80% certainty that there is at least a 29% decrease in pole trees pre-burn to second growing season after the second prescribed burn. Overstory tree density has significantly increased by at least 12% ($p < .20$) throughout this period indicating that dormant season prescribed burns don't have high enough intensity to decrease density within this monitoring type (Figure 6). Basal area is also significantly increasing within the overstory size class even after two prescribed burns. We will be revising our fire management plan to allow growing season burns in order to decrease overstory stand density. In addition, Eastern red cedar pole-size trees decreased an average of 33% in density but fell short of the objective of a 40% decrease ($p > .20$) (Figure 7). There is an 80% certainty that density of eastern red cedar pole trees decreased by at least 20%.

Figure 5 Relative change in pole tree density (DBH 2.5 – 15.0 cm) within the glade / woodland transition monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents (# of prescribed burns and the # of growing seasons after burn) Bars represent 80% confidence intervals.

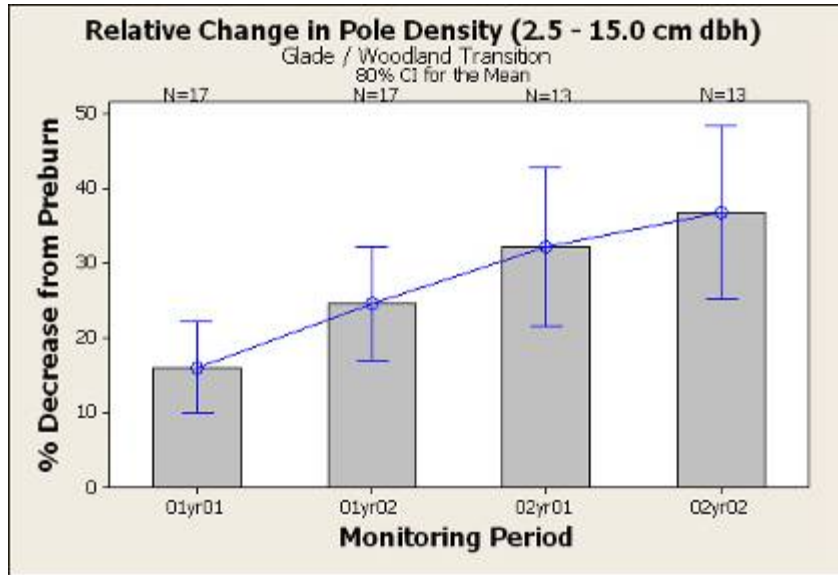


Figure 6 Relative change in overstory tree density (DBH $\geq$ 15.0 cm) within the glade / woodland transition monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.

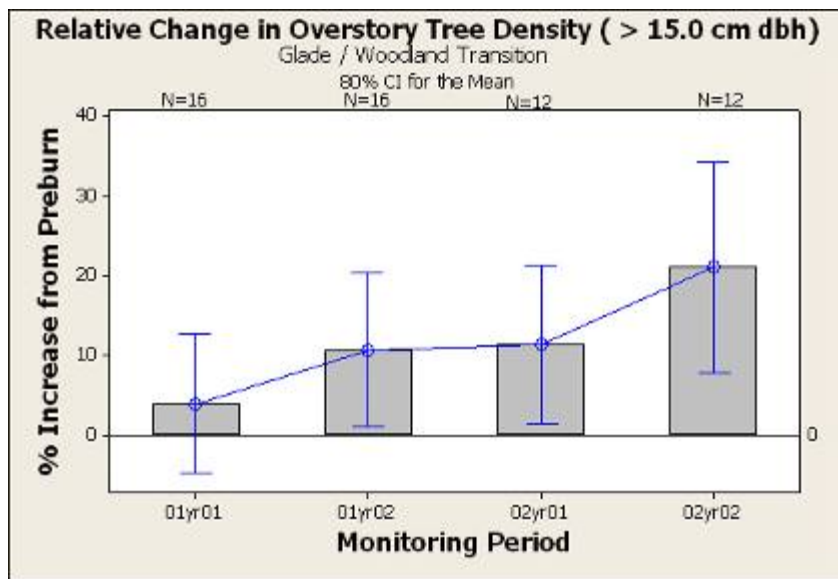
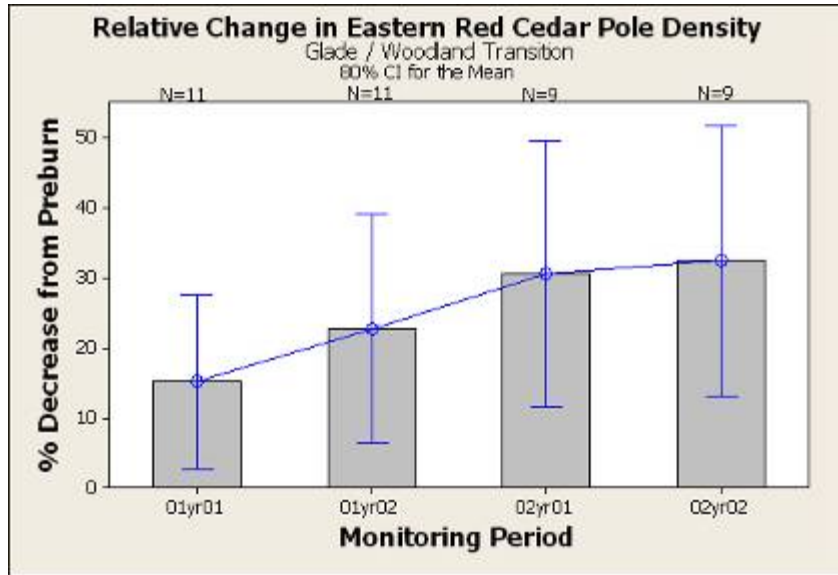


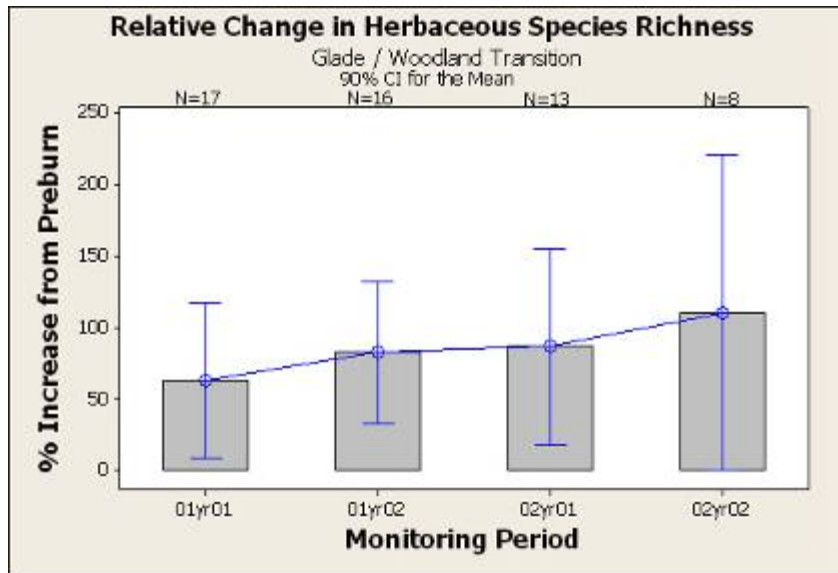
Figure 7 Relative change in cedar pole tree density (DBH 2.5 - 15.0 cm) within the glade / woodland transition monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.



Effect of Prescribed Fire on Herbaceous Species Richness

I also analyzed the change in herbaceous species richness pre-burn to second growing season after second burn. Figure 8 shows an average 110% increase in species richness but was insignificant ($p > .10$) and fell short of the 40% target. There was a 90% certainty that species richness increased by at least 27%.

Figure 8 Relative change in herbaceous species richness within the glade / woodland transition monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 90% confidence intervals.



Dry Mesic Woodland Monitoring Type

I looked at relative change in overstory and pole density and species richness after two prescribed burns.

Effect of Prescribed Fire on Overstory and Pole Tree Density

Pole tree density significantly decreased an average of 55% ($p < .20$), with an 80% certainty that the decline is at least 49%, and was well above the objective of a 30% decline (Figure 9). Nearly all the decrease in density occurred within the small pole size class (2.5 – 8.5 cm dbh). Large pole size trees (≥ 8.5 to 15.0 cm dbh) have thicker bark providing greater insulation and fire resistance than small poles. Figure 10 shows that there is no significant difference in large pole density following two burns. Overstory tree density also did not significantly decline after two burns.

Figure 9 Relative change in pole tree density (DBH 2.5 - 15.0 cm) within the dry-mesic woodland monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.

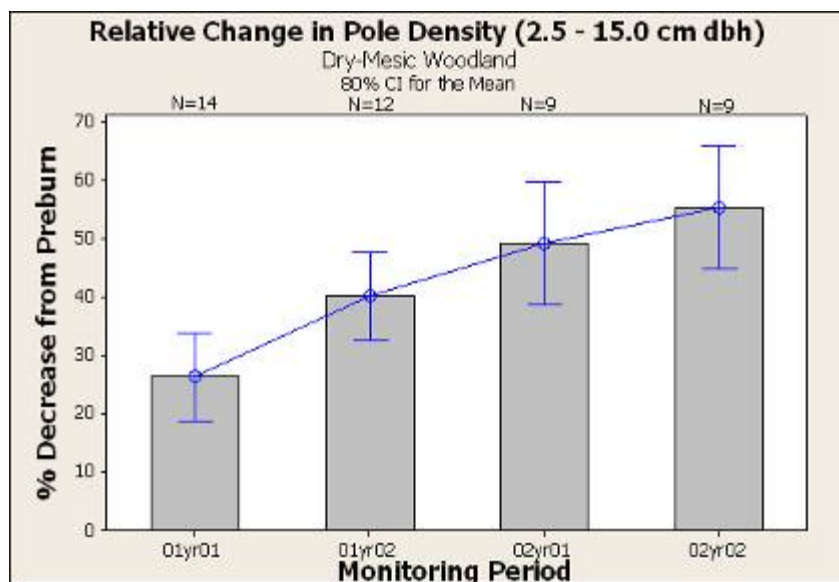
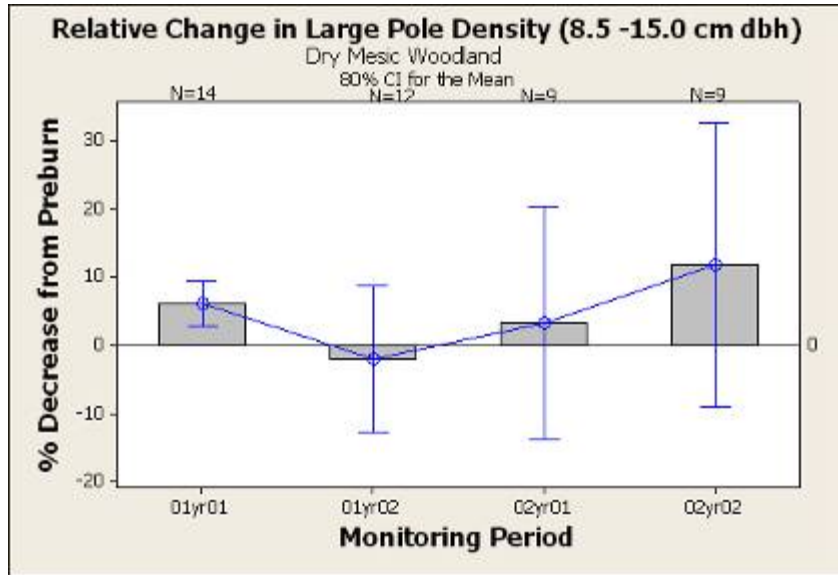


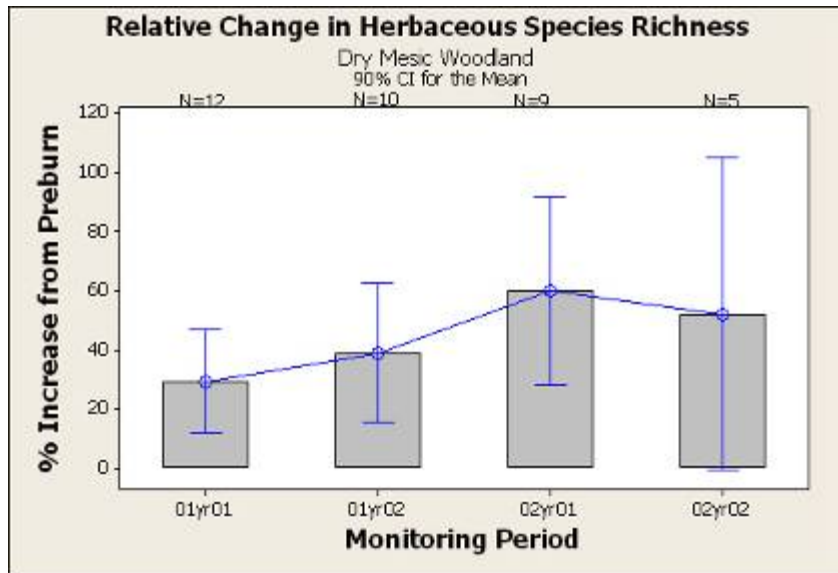
Figure 10 Relative change in large pole tree density (DBH 8.5 - 15.0 cm) within the dry-mesic woodland monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.



Effect of Prescribed Fire on Herbaceous Species Richness

Herbaceous species richness values increased by an average of 52% but was insignificant ($p > .10$), below the target of 20% (Figure 11). There is a 90% certainty that a 14% increase in species richness occurred.

Figure 11 Relative change in herbaceous species richness within the dry mesic woodland monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 90% confidence intervals.



Dry Woodland Monitoring Type

I looked at relative change in overstory and pole density and species richness after three prescribed burns.

Effect of Prescribed Fire on Overstory and Pole Tree Density

Pole tree density decreased by an average of 70% ($p < .20$) from pre-burn to one growing season after third burn and far surpassed the objective of a 30% decline (Figure 12). There is an 80% certainty that the decrease is at least 62%. Figure 13 shows that overstory tree density also significantly decreased by at least 10% ($p < .20$) following three burns.

Figure 12 Relative change in pole tree density (DBH 2.5 - 15.0 cm) within the dry woodland monitoring type after three prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.

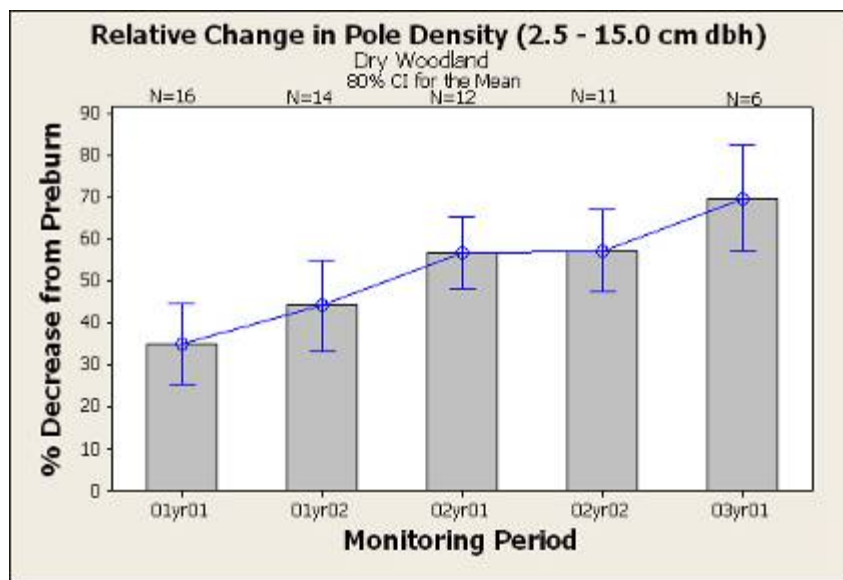
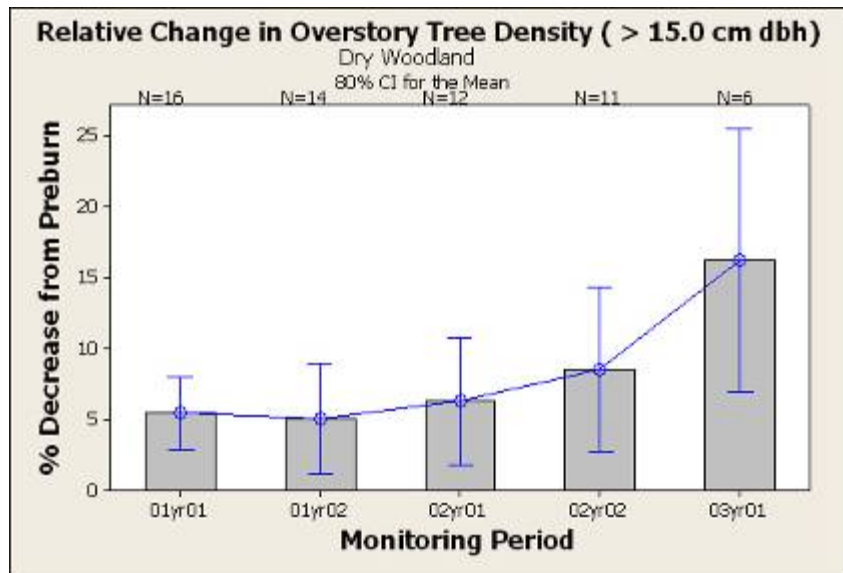


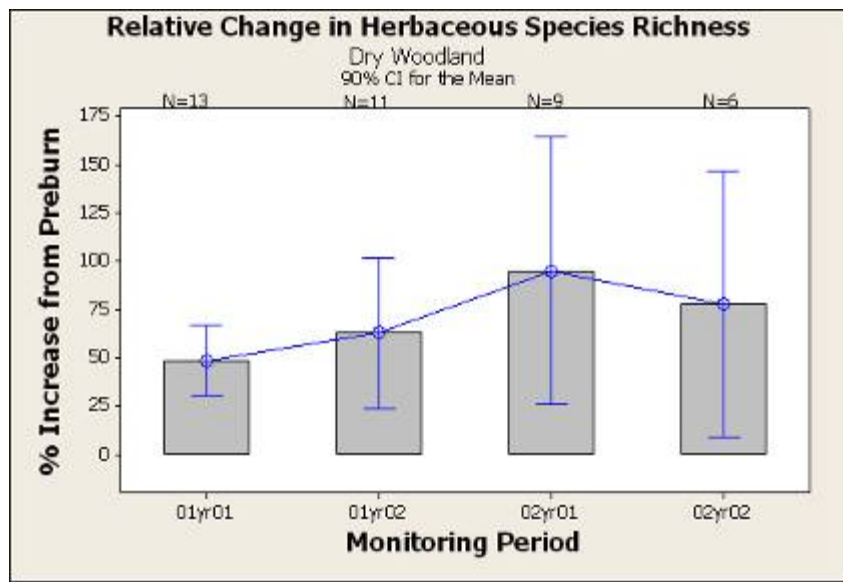
Figure 13 Relative change in overstory tree density (DBH ≥ 15.0 cm) within the dry woodland monitoring type after three prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.



Effect of Prescribed Fire on Herbaceous Species Richness

Herbaceous species richness increased 78% from pre-burn to two years post second burn but was insignificant for meeting the 40% increase objective ($p > .10$) (Figure 14). There is a 90% certainty that the herbaceous species richness increased at least 27 %.

Figure 14 Relative change in herbaceous species richness within the dry woodland monitoring type after two prescribed burns at Ozark National Scenic Riverways. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 90% confidence intervals.



Buffalo National River

Introduction

The effect of two prescribed burns on overstory, pole, and eastern red cedar seedling density was monitored at Buffalo National River within the Lower Wilderness burn unit. Seven dry woodland and eight glade / transition permanent monitoring plots were installed during the summer of 2001 and 2002. Analysis was completed on all of the dry woodland plots and six of the glade / transition plots (since two glades didn't burn during the first treatment and were thus excluded for analysis). The prescribed burns were conducted on March 10, 2004, and March 6, 2007. These were the first two prescribed burns conducted in this wilderness area.

Results & Discussion

Effect of Prescribed Fire on Overstory, Pole, and Eastern Red Cedar Seedling Density

Dry Woodland Monitoring Type

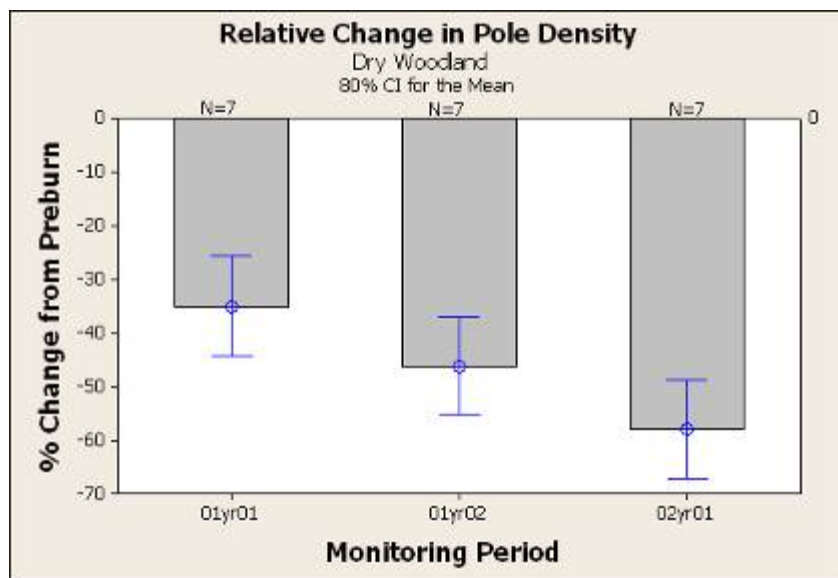
Overstory density within the dry woodland monitoring type did not change (80% confidence interval on the mean) following two prescribed burns, with tree densities staying at 286 trees per hectare (tph) (Table 7). The monitoring objective calls to decrease overstory tree density to 121 trees per hectare after twenty years of restoration. Significant decreases in overstory tree density will not occur unless we initiate growing season burns. Prescribed burns during the late winter and early spring only bring mortality to the pole tree size class. Burning in April and May or late August into September are the best times to increase overstory mortality since bud break typically occurs in early April, and late summer occasionally brings drought conditions which places stress on the trees.

The monitoring objective for pole trees is to be 80% sure of detecting a 60% decrease in density after 10 years. Following two prescribed burns in four years, pole density significantly decreased (80% confidence interval of the mean) at least 52%, from approximately 1971 (± 134 SE mean) to 863 (± 175 SE mean) trees per hectare. Nearly all pole density reduction can be attributed to a decrease in the small pole size class (≥ 2.5 and < 8.5 cm dbh) where there was at least a 63% reduction in density. This corresponds to research showing low intensity surface fires are successful in killing most hardwood stems less than 12 cm dbh (Reich et al, 1990; Waldrop and Lloyd, 1991; Barnes and Van Lear, 1998). A positive relationship exists between increasing stem diameter and survival after burning since it is directly related to bark thickness and tree height (Hare, 1965; Loomis, 1973; Hengst and Dawson, 1994; Regelbrugge and Smith, 1994; Guyette and Stambaugh, 2004). The red oak and white oak groups had at least a 53% and 59% significant reduction in small pole density one growing season after the second burn treatment while hickories decreased by at least 67%. With two more burns in the next six years, we will likely achieve a 60% reduction in pole density as mortality has continued to increase following each prescribed burn (Figure 15).

Table 7. Mean pre-burn and post-burn densities of overstory and pole trees within the dry woodland monitoring type after two late winter/early spring prescribed burns.

Dry Woodland Monitoring Type	Average Density (TPH)		Significant Difference Pre – 2 nd Postburn $\alpha = 0.20$
Species	Pre-burn	1 st Growing Season after 2 nd RX Burn	
Overstory ≥ 15.0 cm	286	286	No
Pole ≥ 2.5 - < 15.0 cm	1971	863	Yes; $\geq 52\%$ ↓
Large pole ≥ 8.5 - < 15.0 cm	343	309	No
Small pole ≥ 2.5 - ≤ 8.5 cm	1629	554	Yes; $\geq 63\%$ ↓
Red Oak group – small pole	326	137	Yes; $\geq 53\%$ ↓
White Oak group – small pole	246	149	Yes; $\geq 59\%$ ↓
Hickories – small pole	326	103	Yes; $> 67\%$ ↓

Figure 15 Relative change in pole tree density (DBH ≥ 2.5 and < 15.0 cm) within the dry woodland monitoring type after two prescribed burns at Buffalo National River. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.



Glade & Transition Monitoring Type

Pole density

The monitoring objective for pole trees is to be 80% sure of detecting a 60% decrease in density after 10 years. Following two prescribed burns in four years, pole density significantly decreased (80% confidence interval of the mean) by at least 12% (Figure 16). All decreases in pole density can be attributed to the small pole (≥ 2.5 and < 8.5 cm dbh) size class. Large poles (≥ 8.5 and < 15.0 cm dbh) actually significantly increased (80% confidence interval of the mean) in density at least 20% following the two burns (Table 8).

Figure 16 Relative change in pole tree density (DBH ≥ 2.5 and < 15.0 cm) within the glade and transition monitoring type after two prescribed burns at Buffalo National River. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 80% confidence intervals.

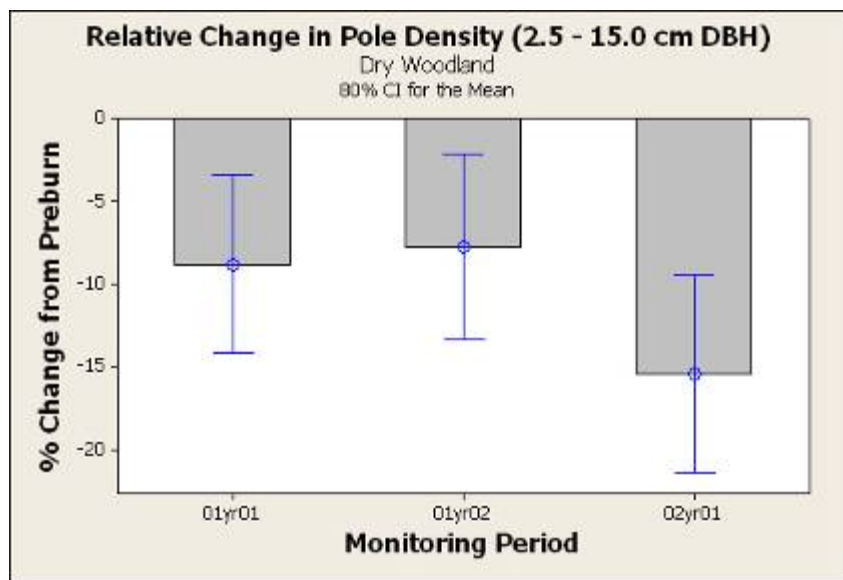


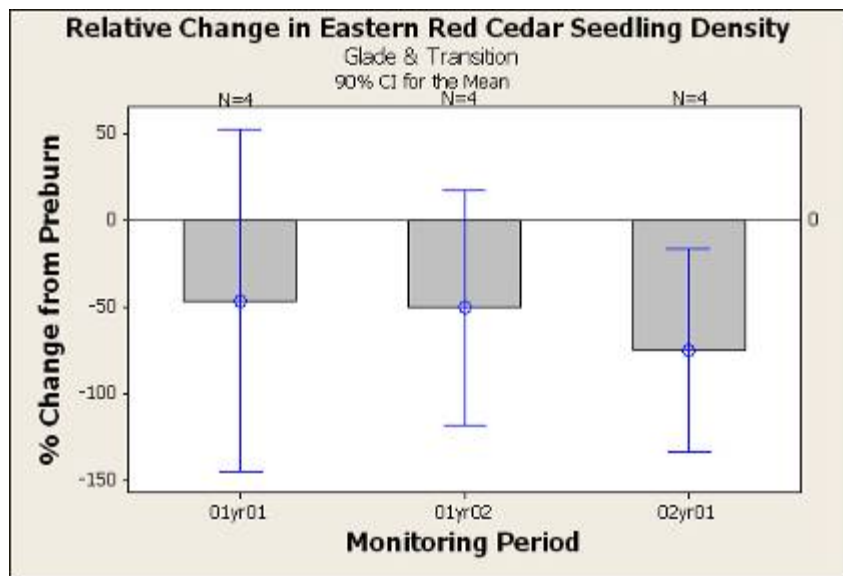
Table 8. Mean pre-burn and post-burn densities of pole trees within the glade & transition monitoring type after two late winter/early spring prescribed burns.

Glade & Transition Monitoring Type	Average Density (TPH)		
Species	Pre-burn	1 st Growing Season after 2 nd RX Burn	Significant Difference Pre – 2 nd Postburn $\alpha = 0.20$
Pole ≥ 2.5 - < 15.0 cm	1680	1407	Yes; $\geq 12\%$ ↓
Large pole ≥ 8.5 - < 15.0 cm	207	280	Yes; $\geq 20\%$ ↑
Small pole ≥ 2.5 - ≤ 8.5 cm	1473	1127	Yes; $\geq 14\%$ ↓
Red Oak group – small pole			
White Oak group – small pole			
Hickories – small pole			

Eastern Red Cedar Seedling Density

The monitoring objective states we want to be 90% sure of a 95% reduction of eastern red cedar seedlings after three consecutive burning events. Following two prescribed burns in four years, seedling density significantly decreased (80% confidence interval of the mean) by at least 34% (Figure 17). Only six of the eight fire effects plots had eastern red cedar seedlings at preburn condition and only two plots had greater than 2 seedlings. This leads to a high degree of relative change with only small decreases in seedling number and a high variability around the mean. A third prescribed burn will probably decrease the amount of eastern red seedlings further.

Figure 17 Relative change in eastern red cedar seedling density (DBH < 2.5 cm) within the glade and transition monitoring type after two prescribed burns at Buffalo National River. X axis represents # of prescribed burns and the # of growing seasons after burn. Bars represent 90% confidence intervals.



Effect of Prescribed Fire on Native Herbaceous Plant Cover

Dry Woodland Monitoring Type

The monitoring objective for herbaceous cover is to be 90% sure of detecting a 20% absolute increase in cover after two prescribed burns. Following two prescribed burns in four years, herbaceous cover significantly increased (90% confidence interval of the mean) by at least 3%. Forb and grass cover significantly increased by 1 and less than 1% respectively. Average percent herbaceous cover (forbs and grass lifeforms) was 8% prior to the first burn and 20% the first growing season following the second burn (Figure 18). Average forb cover increased from 6 to 17% while average grass cover increased from 1 to 3% following two burns. Therefore, nearly all of this percent increase in herbaceous cover can be attributed to an increase in forbs (Figure 19). We are well short of achieving this objective, most likely due to inadequate incident light reaching the woodland floor and thereby suppressing growth of forbs and grasses. Overstory density has not significantly changed after two burns, and therefore available light hasn't sufficiently increased.

Figure 18. Average percent herbaceous cover following two prescribed burns at Buffalo National River within the dry woodland monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.

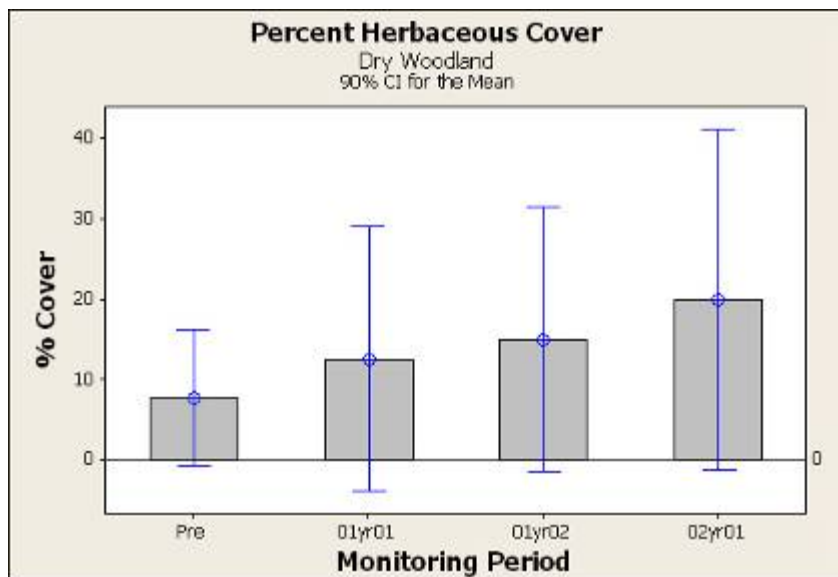
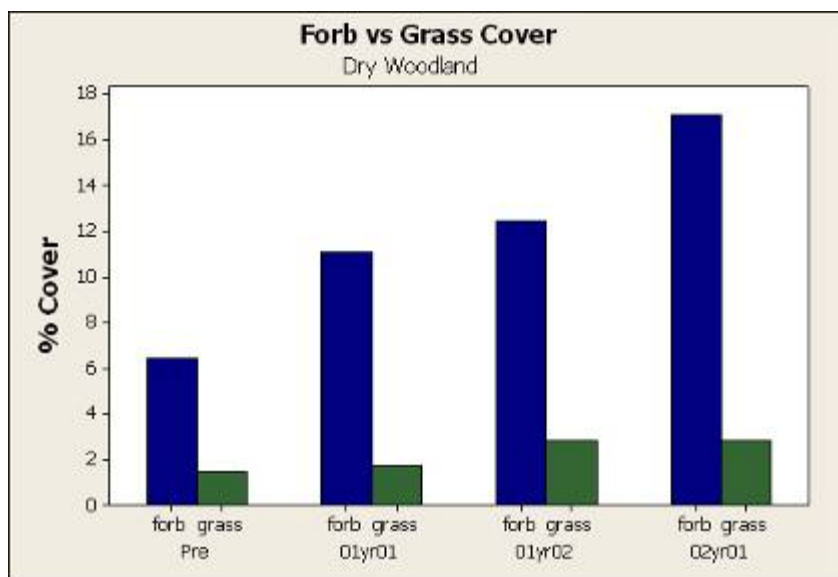


Figure 19. Average percent forb and grass cover following two prescribed burns at Buffalo National River within the dry woodland monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.



Glade & Transition Monitoring Type

The monitoring objective for herbaceous cover is to be 90% sure of detecting a 10% absolute increase in cover after two prescribed burns. Following two prescribed burns in four years, herbaceous cover significantly decreased (90% confidence interval of the mean) by at least 4%. Forb and grass cover significantly decreased by 3 and 6% respectively. Average percent herbaceous cover increased from 42% to 51% following one prescribed burn and then decreased to 35% the first growing season following the second burn (Figure 20). Average forb cover increased from 9 to 19% following one burn and then decreased to 11% after two burns. Average grass cover increased from 37 to 41% after one burn and then decreased to 27% after two burns (Figure 21). Decreases in forb and grass cover after the second prescribed burn are probably attributed to a hard freeze that occurred April 8-9 after green-up had already occurred. Vegetation had broke bud two to three weeks earlier than average this spring due to an

extremely warm March. All existing vegetation died and it was at least a month before new growth was reinitiated. In addition, glade/transition plots were monitored in early June and therefore much of the herbaceous layer hadn't fully recovered yet. At Ozark National Scenic Riverways, average herbaceous cover in the glade and transition monitoring type increased 3% following two prescribed burns up through 2006 and this increasing trend in herbaceous cover is expected at Buffalo NR during the second growing season (2008) after this treatment.

Figure 20. Average percent herbaceous cover following two prescribed burns at Buffalo National River within the glade and transition monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.

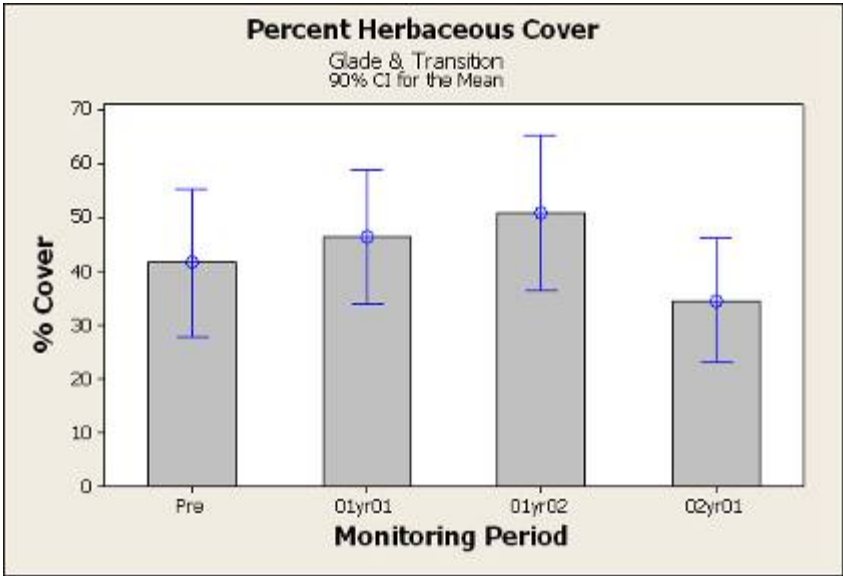
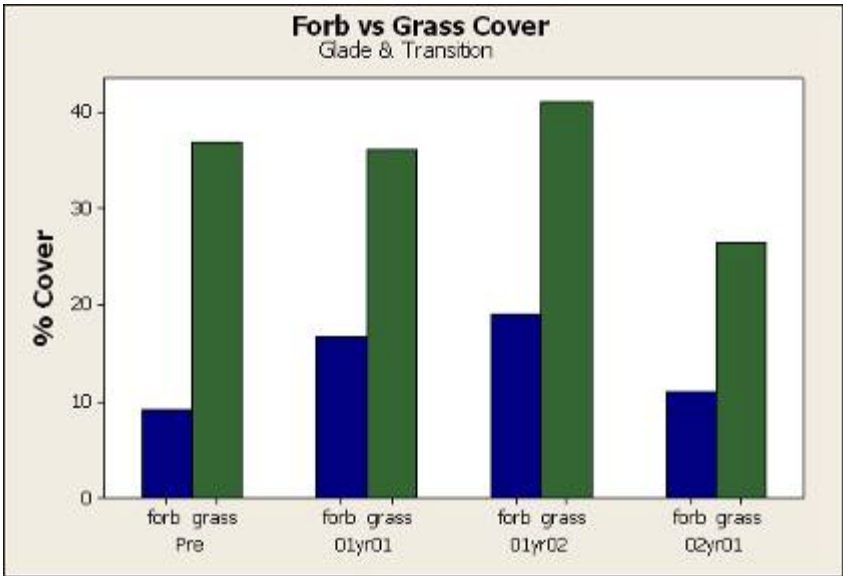


Figure 21 Average percent forb and grass cover following two prescribed burns at Buffalo National River within the glade and transition monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.



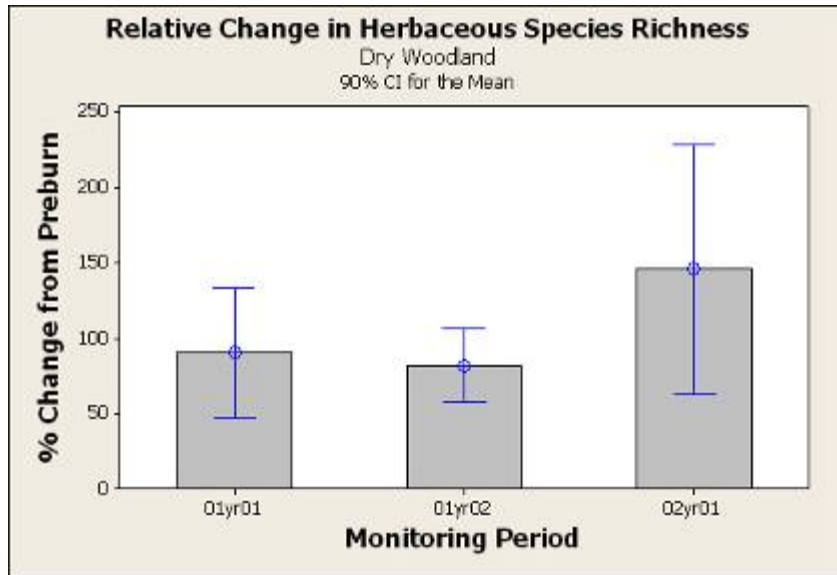
Effect of Prescribed Fire on Herbaceous Diversity

Dry Woodland Monitoring Type

The monitoring objective for herbaceous diversity is to be 90% sure of detecting a 40% relative increase in herbaceous species richness after two prescribed burns. Following two prescribed burns in four years,

herbaceous species richness significantly increased (90% confidence interval of the mean) by at least 85% (Figure 22). We are currently meeting the monitoring objective even though there is a large variability around the mean. This increasing trend in diversity should continue as more light reaches the ground floor with each prescribed burn due to declines in pole density.

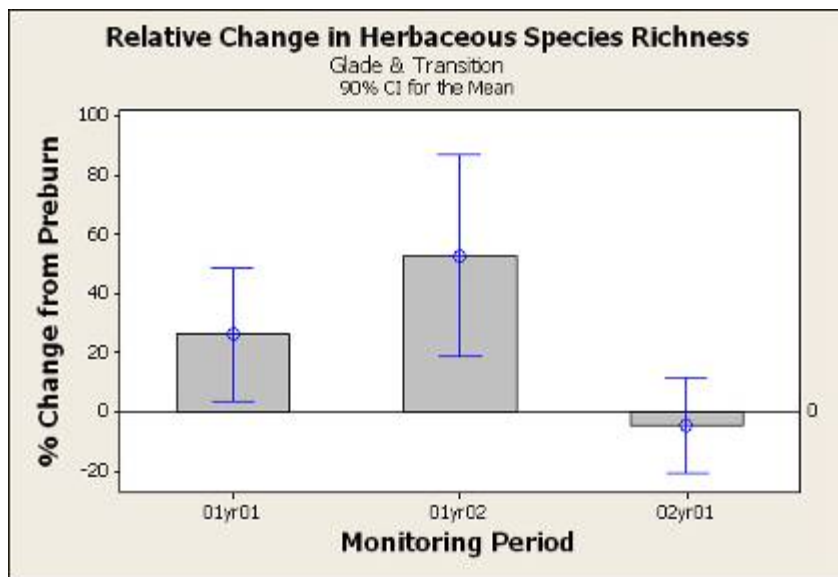
Figure 22. Relative change in herbaceous species richness following two prescribed burns at Buffalo National River within the dry woodland monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.



Glade & Transition Monitoring Type

The monitoring objective for herbaceous cover is to be 90% sure of detecting a 40% relative increase in herbaceous species richness after two prescribed burns. Following two prescribed burns in four years, herbaceous species richness was not significantly changed (90% confidence interval of the mean) from preburn conditions (Figure 23). Species richness failed to increase after the second prescribed burn, probably due to the hard freeze on April 8-9. A lot of perennial herbs had already begun growing at this point and the freeze was a major set-back. Since the glade/transition plots were monitored in early June, plant species diversity was likely underrepresented in early June when the plots were read. I believe summer 2008 reads will again show an increasing trend in species richness.

Figure 23. Relative change in herbaceous species richness following two prescribed burns at Buffalo National River within the Glade & Transition monitoring type. X axis represents # of prescribed burns and the # of growing seasons after burn.



Pea Ridge National Military Park

Post Oak - Blackjack Oak Woodland Monitoring Type

Five plots from three burn units were used to assess the effect of one prescribed fire on pole density, herbaceous plant cover, and fuel loading.

Effect of Prescribed Fire on Overstory and Pole Tree Density

The monitoring objective for pole trees is to be 80% sure of detecting a 50% decrease in density following four prescribed burns. After one prescribed burn, overall pole density significantly decreased (80% confidence interval of the mean) at least 3%, from approximately 768 (± 178 SE mean) to 704 (± 158 SE mean) trees per hectare. However, this significant decrease occurred only in the small pole class (2.5 – 8.5 cm dbh), where at least a 6% decrease was observed. Overstory density (≥ 15.0 cm dbh) stayed at 354 tph following one application of fire.

Effect of Prescribed Fire on Herbaceous Plant Cover

The monitoring objective for herbaceous plant cover is to be 80% sure of detecting a 60% increase following four prescribed burns. Herbaceous plant cover did not significantly change from the preburn average of 22% following one prescribed burn. Higher incident light due to overstory and midstory mortality is needed to reach the monitoring objective (a 60% increase). Growing season burns would bring higher mortality to the overstory and midstory and allow for faster restoration of these woodland communities.

Effect of Prescribed Fire on Fuel loadings

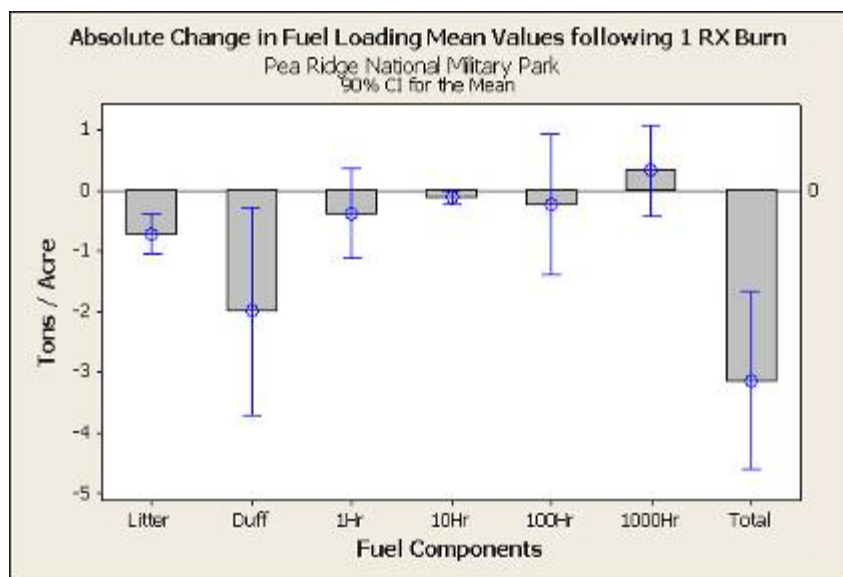
Analysis was done using five fire effects plots located within three burn units at Pea Ridge NMP. Fuel loading component summaries for pre- and post-burns can be seen in table 9. Initial mean total pre fuel loading was 11.26 (± 1.78 SE mean) tons per acre, with litter and duff fuel loading accounting for 12% and 51%, respectively, of the total fuel load. Following one prescribed burn, total fuel loading significantly decreased 30% to 8.13 (± 1.83 SE mean) tons per acre. The fuel components significantly reduced pre- to post-burn were litter, duff, and 10 hr (90% confidence interval on the mean) (Figure 24).

Although significant, 10 hr fuels only slightly decreased by 0.12 tons per acre. Litter depth decreased from 0.85 to 0.41 inches following the burn while duff decreased from 0.52 to 0.34 inches.

Table 9. Pea Ridge NMP fuel loading summary following one prescribed burn – pre and postburn

Burn Unit Status	Fuel Loading (tons / acre)							Litter and Duff Depth (inches)	
	1-hr	10-hr	100-hr	1000-hr	Total	Litter	Duff	Litter	Duff
Pre	.71	.50	1.63	1.35	11.26	1.39	5.69	.85	.52
Post	.32	.38	1.39	1.67	8.13	.67	3.70	.41	.34

Figure 24. Absolute change in fuel loading (tons / acre) following one prescribed burn at Pea Ridge National Military Park.



Hot Springs National Park

Introduction

The effect of applying only one prescribed burn treatment on overstory and pole density was monitored at Hot Springs National Park. Tree density was monitored in two burn units to ensure prescribed burning was meeting objectives for pole reduction. The North Mountain and Sugarloaf Mountain burn units, 15 acres and 66 acres respectively, were selected for the monitoring as these were the first two burns completed within the park in the past twenty years. The North Mountain burn unit was burned on April 12, 2006, with the year one post-burn read completed on September 19, 2006. The Sugarloaf Mountain burn unit was burned on March 20, 2007, with the year one post-burn read completed on September 18, 2007.

Results & Discussion

Overstory density did not significantly decrease (90% confidence interval on the mean) but showed a trend downward from 385 (± 54 SE mean) to 318 (± 67 SE mean) trees per hectare (tph) (Table 10). The red oak group (Scarlet, red, black jack, and bluejack) significantly decreased slightly 2% following the burn. Hickories (Black, mockernut, and pignut) significantly decreased at least 11%. Shortleaf pine was insignificantly changed from a pre-burn density of 95 tph. The white oak group (White and post oak)

showed a slight downward trend from 73 (± 21 SE mean) to 60 (± 26 SE mean) trees. Black gum, red maple, and black cherry overstory densities remained statistically unchanged following one burn. Shortleaf pine, hickories, and the white oak group were three species with the highest relative percentage of overstory trees after one burn: 28%, 19%, and 19%, respectively.

Table 10. Mean pre-burn and post-burn density of overstory trees by species (≥ 15.0 cm dbh) after one late winter/early spring prescribed burn.

Species	Average Density (TPH)		Significant Difference Pre – post $\alpha = 0.10$
	Pre-burn	Post-burn	
All overstory	385	318	No
Shortleaf pine	95	90	No
Red Oak group	58	38	Yes; $\geq 2\%$ ↓
White Oak group	73	60	No
Hickories	85	60	Yes; $\geq 11\%$ ↓
Black gum	30	28	No
Red maple	5	5	No
Black cherry	7.5	5	No

Pole trees significantly decreased (90% confidence interval of the mean) at least 47% following one prescribed burn from approximately 720 (± 54 SE mean) to 250 (± 85 SE mean) trees per hectare (Table 11). Most of this pole density reduction can be attributed to a decrease in the small pole size class (≥ 2.5 and < 8.5 cm dbh), with a 74% reduction in density. This corresponds to research showing low intensity surface fires are successful in killing most hardwood stems less than 12 cm dbh (Reich et al, 1990; Waldrop and Lloyd, 1991; Barnes and Van Lear, 1998). A positive relationship exists between increasing stem diameter and survival after burning since it is directly related to bark thickness and tree height (Hare, 1965; Loomis, 1973; Hengst and Dawson, 1994; Regelbrugge and Smith, 1994; Guyette and Stambaugh, 2004). White oaks showed no significant change in pole density after burning from the preburn value of 60 tph. Hickories represented the highest proportion of pole trees within the plots at 40%, but also had a significant density decrease of at least 60%. There was high mortality of fire intolerant and shade loving hardwood species, as black cherry, Carolina buckthorn, and American plum all significantly decreased by 100%. Sweet gum also is showing a downward trend in density. Shortleaf pine was totally absent from the pole class in any of the plots that were sampled. This is probably due to lack of fire for over sixty years and a high density of overstory and midstory trees that shade the ground, preventing pine regeneration.

Table 11. Mean pre-burn and post-burn density of pole trees by species (≥ 2.5 cm and <15.0 cm dbh) after one late winter/early spring prescribed burn.

Species	Average Density (TPH)		Significant Difference Pre-post $\alpha=0.10$
	Pre-burn	Post-burn	
All Poles	720	250	Yes; 47% ↓
Large Pole ≥ 8.5 - <15.0 cm	290	180	Yes; 10% ↓
Small Pole ≥ 2.5 - <8.5 cm	430	70	Yes; 74% ↓
Shortleaf pine	Not present	Not present	
Red oak group	40	10	Yes; 4% ↓
White oak	60	50	No
Hickories	290	80	Yes; 60% ↓
Black gum	50	50	No
Red maple	Not present	Not present	
Black cherry	120	0	Yes; 100% ↓
Sweet gum	30	10	No
Carolina buckthorn	30	0	Yes; 100% ↓
American plum	40	0	Yes; 100% ↓

Prior to the prescribed burn, small and large pole trees comprised the highest relative densities of any size class (Figure 25). Within the overstory trees, small and medium diameter classes comprised the highest relative percentage. There is an inverse exponential relationship between increasing diameter class and tree density. Following one prescribed burn, the large pole and small overstory classes had the greatest number of trees per class (Figure 26).

Figure 25. Pre-burn density (trees per hectare) of pole and overstory trees by diameter class (cm dbh): Small pole (≥ 2.5 - <8.5), large pole (≥ 8.5 - <15.0), small overstory (≥ 15.0 - <25.0), medium (≥ 25.0 - <35.0), medium-large (≥ 35.0 - <45.0), large (≥ 45.0 - <55.0), and very large (≥ 55.0)

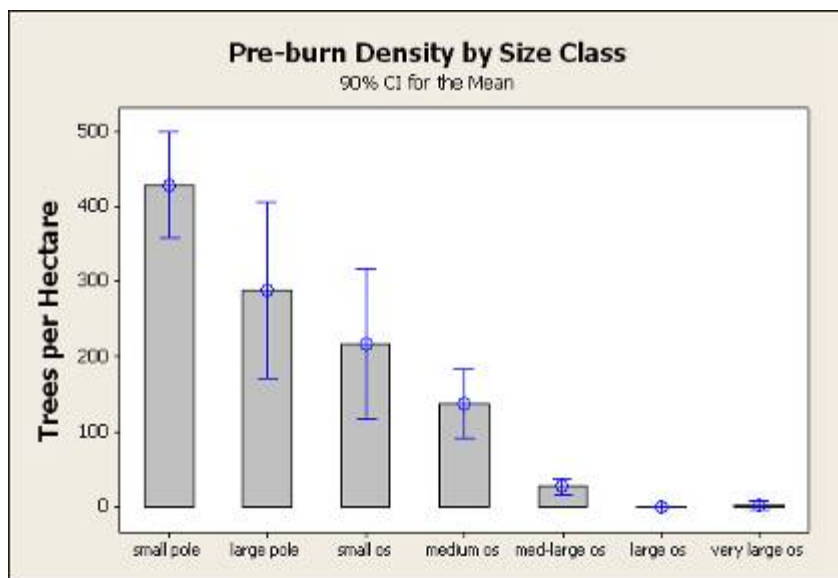
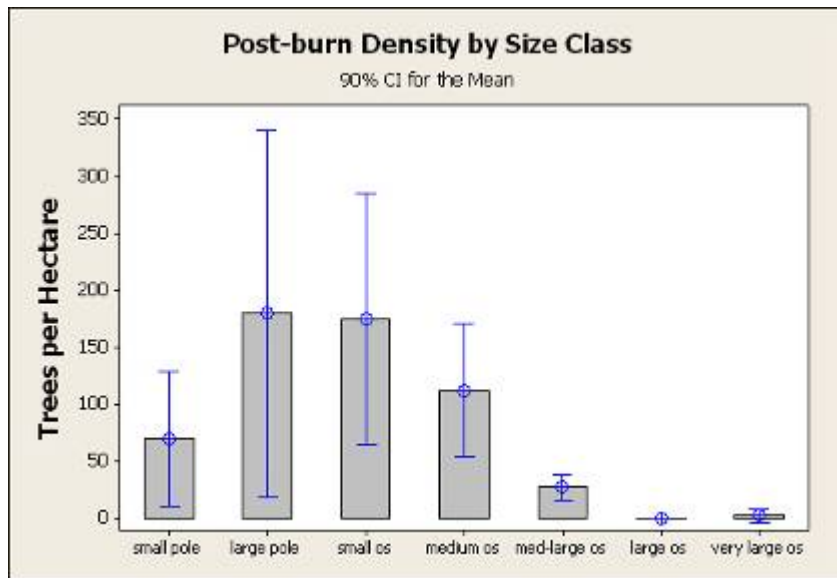


Figure 26. Post-burn density (trees per hectare) of pole and overstory trees by diameter class (cm dbh): Small pole (≥ 2.5 - < 8.5), large pole (≥ 8.5 - < 15.0), small overstory (≥ 15.0 - < 25.0), medium (≥ 25.0 - < 35.0), medium-large (≥ 35.0 - < 45.0), large (≥ 45.0 - < 55.0), and very large (≥ 55.0)



Effect of Prescribed Fire on Herbaceous Plant Cover

Herbaceous cover following one prescribed burn increased from 2 to 4% but wasn't significant. Panicum species showed the greatest increase in cover but wasn't statistically significant. Herbaceous vegetative cover is directly associated with the amount of incident light that reaches the floor of the woodland. Due to past fire suppression, overstory and midstory density is much higher than would have been seen pre-European settlement. As midstory and overstory mortality occurs with successive burns, increases in herbaceous cover will follow. Growing season burns are recommended to expedite the restoration process and to increase the seasonality of burning.

Effect of Prescribed Fire on Fuel loadings

Analysis was done using the North Mountain and Sugarloaf Mtn burn unit data together to increase sample size. Summaries for each individual burn unit and/or the two units combined can be seen in table 12. Initial mean total pre-fuel loading was 13.41 (± 1.76 SE mean) tons per acre, with litter and duff fuel loading accounting for 10% and 56%, respectively of the total fuel load. The fuel components significantly reduced pre- to post-burn were litter, duff, 10 hr, and 100 hr (90% confidence interval on the mean) (Figure 27). Although significant, 10 hr fuels only slightly decreased by 0.05 tons per acre and 1 hr fuels had no change in fuel loading following one burn. This is probably attributed to the fact that even though some of these smaller fuel components were consumed in the burn, additional fuels in these size classes fell to the ground as small seedlings and pole trees died. Litter depth decreased from 0.82 to 0.08 inches following the burn while duff decreased from 0.69 to 0.36 inches. Trends in 1000 hr fuels were higher, probably due to some mortality in larger diameter class trees. Total fuel loading trended downward after one burn but was insignificant probably due to the small sample size. In order to significantly decrease total fuel loading in the future, prescribed burns will need to be on the hotter and drier end of the burn prescription. The North Mountain burn was conducted with relative humidities between 56 and 65%, resulting in fairly high fine dead fuel moistures of 10%. The Sugarloaf burn unit had relative humidities between 43 and 50%, with greater than 50% cloud cover.

Table 12. North Mtn and Sugarloaf Mtn fuels summary – pre and postburn

Burn Unit Status	Fuel Loading (tons / acre)							Litter and Duff Depth (inches)	
	1-hr	10-hr	100-hr	1000-hr	Total	Litter	Duff	Litter	Duff
North Mtn Pre	0.02	0.08	0.80	2.83	14.33	1.16	9.43	0.71	0.87
Sugarloaf Mtn Pre	0.18	0.33	1.16	3.75	12.50	1.49	5.58	0.92	0.52
Combined Pre	0.10	0.21	0.98	3.29	13.41	1.33	7.51	0.82	0.69
North Mtn Post	0.01	0.03	0.14	5.69	10.81	0.10	4.85	0.06	0.44
Sugarloaf Mtn Post	0.21	0.30	0.77	3.09	7.58	0.16	3.05	0.10	0.28
Combined Post	0.11	0.16	0.46	4.39	9.19	0.13	3.95	0.08	0.36

Figure 27 Changes in fuel loading components at Hot Springs National Park following one prescribed burn within the North Mountain and Sugarloaf Mountain burn units.

