GROWING-SEASON AND DORMANT-SEASON FIRE BEHAVIOR AND EFFECTS ON VEGETATION IN THE OUACHITA MOUNTAINS, ARKANSAS

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CHAPTER I

INTRODUCTION

This thesis is composed of 4 distinct manuscripts formatted for submission to 3 scientific journals. Chapter II and III are formatted for the International Journal of Wildland Fire, Chapter IV is formatted for Forest Ecology and Management, and Chapter V for the Wildlife Society Bulletin. Each manuscript is complete as written and requires no additional material for support. Manuscripts are arranged in the order of text, literature cited, tables and figures. Appendixes follow the last manuscript.

CHAPTER II

GROWING-SEASON VERSUS DORMANT-SEASON FIRE BEHAVIOR AND FUEL CONSUMPTION IN THINNED STANDS OF PINE

ABSTRACT. Managers of the pine forests in the southeastern United States have relied primarily on dormant-season fires to meet management objectives, but are beginning to experiment with prescribed fires in different seasons and with varying fire intensities. We observed fire behavior during both growing-season and dormant-season prescribed fires in shortleaf pine (Pinus echinata) stands managed as pine-grassland communities for the endangered red-cockaded woodpecker (Picoides borealis). The Keetch Byram Drought Index during the growing-season was almost 10 times greater than during the dormant season. However, growing-season fires produced discontinuous fire fronts, consumed fuels in a heterogeneous fashion, and burned with less intensity than dormant-season fires. Although potential for escapes was less during growing season fires, high ambient air temperature often resulted in difficult working conditions for burning crews. Effective burning can be achieved during the growing-season, but, managers must be aware of the differences in fire behavior and safety concerns between these two seasons of burning.

Key words: Arkansas, Fire management, Ouachita National Forest, Prescribed fire, Red-cockaded woodpecker, Shortleaf pine.

INTRODUCTION

Fire has a major ecological influence on vegetation in both forested and rangeland communities throughout the world (Christensen 1981; Wright and Bailey 1982; Pyne 1982; 1995). Fire, along with other environmental factors, developed and maintained a mosaic of different ecotypes (Christensen 1981; Singh et al. 1981; Edwards 1984; Waldrop et al. 1992; Pyne 1995; Sparks and Masters 1996). Fire suppression has altered many fire dependent communities often changing plant community structure and composition. For example, fire suppression after settlement in the southeastern United States allowed once open, park-like forested communities to become dense forests, thereby reducing habitat quality for many species of wildlife (Lewis and Harshbarger 1976; Masters 1991; Kreiter 1995; Wilson et al. 1995). Land managers have re-introduced fire to the region primarily for fire hazard reduction, wildlife habitat improvement, endangered species management, control of woody species, seedbed preparation, or for other silviculture reasons.

Managers have until recently largely confined prescribed burning to the dormant season. Managers using prescribed fire are experienced with dormant-season prescriptions, which emphasize winter burns 1 to 3 days after a cold front passes that has delivered 1.3 to 2.5-cm of rain (Mobley et al. 1978). Burning conditions are predictable after the passage of cold fronts because of the presence of a cold air mass, which follows these fronts (Robbins and Myers 1992). Conditions following these fronts are also ideal to meet most silviculture objectives and minimize direct effects on many wildlife species (Robbins and Myers 1992). However, dormant-season fires alone may be ineffective at maintaining habitats of many endemic species over the long-term because they may not mimic natural ecosystem processes (Boerner et al. 1988; Robbins and Myers 1992).

Recent studies indicate that the historic fire regime was one of predominantly late growing-season fires and to a lesser extent dormant-season fires of periodic frequency (Foti and Glenn 1991; Masters et al. 1995). Lightning fires tended to occur with a bimodal distribution, with most occurring during the summer, while aboriginal fires occurred during all seasons, with the majority in late summer and fall (Pyne 1982; Foti and Glenn 1991; Masters et al. 1995). Vegetation composition and structure can be significantly influenced by fire frequency, intensity, and season of burning (Glitzenstein 1995). Therefore, land managers attempting to restore or maintain relicts of natural communities are beginning to mimic presettlement fire regimes by burning in different seasons, with varying intensities and frequencies (Robbins and Myers 1992; Glitzenstein et al. 1995; Masters et al. 1996).

Conventional wisdom in the southern pine forests is that fire during the growing-season will be more intense than dormant-season fires and more greatly influence vegetation (Robbins and Myers 1992; Glitzenstein et al. 1995). However, research and experience with prescribed fire during the growing-season is limited. Land managers are often unaware of differences in fire behavior and common prescription considerations between growing-season and dormant-season prescribed fires. Therefore, managers considering the use of growing-season prescribed fires are faced with uncertain liability risks and perhaps other dangers.

Our primary objective was to compare growing-season and dormant-season fire behavior and fuel consumption in thinned stands of shortleaf pine (Pinus echinata) managed as a pine-grassland community for the endangered red-cockaded woodpecker (Picoides borealis). Our purpose was to determine relative risk from a management standpoint of emulating a presettlement fire regime (see Masters et al. 1995).

METHODS

Study Area

Our study sites were located in Scott County of west-central Arkansas on the Poteau Ranger District of the Ouachita National Forest (ONF). The ONF lies within the 2,280,000 ha Ouachita Mixed Forest Meadow Province and comprises 648,000 ha throughout the Ouachita Mountains in Arkansas and Oklahoma (Neal and Montague 1991; Bailey 1995). The Ouachita mountains are east-west trending, strongly dissected, and range in elevation from 150 to 790 m (Fenneman 1938). The thin and drought prone Ouachita Mountain soils developed from sandstone and shale. A sub-humid to humid climate prevails with hot summers and mild winters.

Our study focused on stands under active management for the endangered red-cockaded woodpecker (Picoides borealis) within the 40,000 ha Pine-bluestem Ecosystem Renewal Area (Wilson et al. 1995; Masters et al. 1996). Management consisted of thinning midstory and codominant pine and hardwood trees followed by dormant-season prescribed burning every three years. We randomly chose 12 stands that had been burned previously in the dormant-season at three year intervals (Table 1).

Pinus echinata (shortleaf pine) was the dominant overstory tree species in all stands. Codominant and intermediate overstory species included Quercus stellata (post oak), Q. marilandica (blackjack oak), Q. alba (white oak), Q. rubra (northern red oak), Q. velutina (black oak), Carya texana (black hickory), and C. tomentosa (mockernut hickory). Woody resprouts and shrubs ($\leq$ 3m) dominated the understory of these stands. The dominant understory woody species and vines included Toxicodendron radicans (poison ivy), Vaccinium pallidum (low-bush huckleberry), Q. stellata, C. tomentosa, Rubus spp. (blackberry), Parthenocissus quinquefolia (Virginia creeper), Ceanothus americanus (New Jersey tea), Vitis rotundifolia (muscadine), Q. alba and P. echinata (Sparks 1996).

Treatments

We applied 4 treatments in a completely randomized fashion, with 2 treatments consisting of growing-season fires, and 2 treatments of dormant-season fires. Treatments were as follows:

(1) Growing-season burn (G30; n = 4);

30 months after previous dormant-season burn;

(2) Dormant-season burn (D36; n = 4),

36 months after previous dormant-season burn;

(3) Growing-season burn (G43; n = 2),

43 months after previous dormant-season burn;

(4) Dormant-season burn (D48; n = 2),

48 months after previous dormant-season burn;

The G43 and D48 treatments differed from G30 and D36 in that experimental prescribed burns were applied after 4 growing seasons and 3 growing seasons after dormant-season burns, respectively.

We conducted growing-season burns between 1200 and 1800 on September 10 to 13, 1994, and October 14 and 15, 1995. We initiated dormant-season burns between 1000 and 1800 on March 31 to April 2, 1995, and March 2 to 4, 1996. We ignited backfires and allowed to burn > 50 m into the stand before igniting strip headfires and sampling fire behavior parameters of the strip headfires.

Stand Characteristics

We characterized canopy species within each stand before burning. We sampled 20-30 points on 2-4 randomly spaced lines perpendicular to the contour. At each sampling location we observed canopy cover using a spherical densiometer (Avery 1967), tree and crown height using a clinometer, crown diameter, and diameter at breast height for the closest tree in each sampling quarter.

Meteorological Data

We measured relative humidity, temperature, cloud cover, and wind speed at sunrise, 1400 hours, and sunset the day before the burn, the day after the burn, and the day of the burn. We also recorded weather observations immediately before igniting the fire, as we observed fire behavior parameters, and immediately upon completion of the fire. We measured wind at 2 m using a totalizing anemometer. We used observed wind speeds to estimate wind speed at 6 m (Albini and Baughman 1979). We used a belt weather kit to determine other weather parameters. Keetch Byram Drought Index data from 1985-1996 for the Oden Ranger District, Arkansas was obtained from the U. S. Forest Service, Ouachita National Forest.

Fuel Sampling

We sampled fuels <1 hour before burning at 3 random locations within each stand. At each location, we harvested all fuels $\leq$ 1.5 m in height in 4 to 10, 0.5 X 0.5-m quadrats at 5 m intervals, and parallel to the firefront. We hand separated fuels into 1-hour ($<$ 0.6 cm-diameter) dead, 1-hour live, and 10-hour (0.6 to 2.5 cm-diameter) dead components. The majority of fuels in the 100-hour class had been consumed by previous burns so we did not sample this category. We weighed fuels immediately after clipping. After burning, we collected fuel residue at locations paired with pre-fire fuel samples by sampling all residual dead and live vegetation less than 2.5 cm in diameter to a height of 1.5 m. All fuel samples were dried at 70 degrees C to a constant weight. Fuel moisture was calculated on a dry weight basis.

We determined fuel energy by selecting 3 random samples of dried fuels from each stand burned during the dormant-season of 1995 and growing-season of 1994 ($n = 24$). We combined 1-hour and 10-hour live and dead fuel components for each pre-burn observation, ground samples to a fine powder and compressed them into 1-g pellets. We then combusted these pellets in a bomb calorimeter to determine high heat of combustion.

Fire Behavior Observations

We recorded rate of spread (ROS), flame length (FL), flame depth (FD), and residence time (RT) at all 3 fuel sampling locations. Before headfire ignition we placed

3 sets of 2 m freestanding stakes, with heights marked at 0.5 m intervals, at 5 m apart and perpendicular to the firefront. Three observers estimated fire behavior parameters by observing and timing the fire as the firefront passed each set of stakes, as described by Rothermel and Deeming (1980). We repeated this procedure $\geq$ 2 times at 3 locations within each stand ($\underline{n} \geq 18$).

We calculated fireline intensity by Byram's (1959) formula (I_B = hwr), where I_B is frontal fire intensity (kW/m), h is net heat of combustion (kJ/kg) obtained by adjusting fuel high heat of combustion for fuel moisture and heat of vaporization, w is fuel consumed (kg/m^2) calculated as pre-burn fuel load minus post-burn residual fuel, and r is rate of spread (m/sec). We estimated the total energy released in the active flame front, or heat per unit area (kJ/m^2) (H_a), by dividing fireline intensity (kW/m) by rate of spread (m/min) (Rothermel and Deeming 1980). We determined reaction intensity (kW/m^2) (I_R), or the rate of energy release per unit area of flaming zone, by dividing fireline intensity (kW/m) by flame depth (m) (Albini 1976; Alexander 1982).

We tested all variables for homogeneity of variance using Levene's test (Snedecor and Cochran 1980). None of these tests were significant, indicating homogeneous variances. We then used a 2 X 2 factorial analysis of variance to test for differences between years, burn season, and for an interaction between year and burn season. We separated means ($\underline{P} \leq 0.05$) with the protected least significant difference test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

High relative humidity and light and variable wind along with the presence of live vegetation caused growing-season fires to be low intensity and burn a given area in a patchy discontinuous fashion. Our dormant-season fires produced greater fireline intensity, heat per unit area, reaction intensity and rate of spread than fires during the growing-season (Table 2). The Keetch Byram Drought Index (KBDI) for the nearby Oden Ranger District (Figure 1) indicates that prescribed fires during the growing season should burn with greater intensity than dormant-season fires because of greater amounts of available fuel (Melton 1989). Melton (1989) noted that an active fire situation develops when KBDI values exceeds 200 and approaches 300 and at KBDI levels between 300 and 500, the fire consumes most of the surface litter and fire intensity increases dramatically (Melton 1989). Fuel moisture was similar between seasons, but dormant-season fires had more 1-hour dead and total fuel than growing-season fires (Table 3). We attribute the increase in fuel load during the dormant season to hardwood leaf fall in late autumn and early winter (Engle and Stritzke 1995). Fuel decomposition is also less during the dormant season because of low temperature and lower relative humidity, thereby allowing accumulated leaf litter to persist throughout the winter (Engle and Stritzke 1995). Furthermore, the majority of standing vegetation during dormant-season fires was dormant or "cured", and served as dead 1-hour time-lag fuels, whereas a large proportion of standing vegetation was actively growing with high moisture content during growing-season fires.

One-hour dead fuel moisture is a primary controlling factor of fire behavior on the fire front (Andrews 1986). One-hour live fuel moisture depends on physiological changes in the plant (Andrews 1986), and can influence ignition and spread patterns depending on the distribution, quantity and moisture content of live vegetation. Therefore, because of sparse and patchily distributed live vegetation, fuel consumption was greater in dormant-season fires (Table 3).

Woody understory species were primarily deciduous, therefore solar radiation and wind exposure to the fuels increased during the dormant season. Increased solar radiation and exposure to wind allowed fuels to dry quickly after precipitation. Large amounts of live herbaceous vegetation and shading from the dense woody shrub layer resulted in discontinuous fire fronts, leaving a mosaic of unburned areas during growing-season fires. In contrast, dormant-season fires produced continuous fire fronts and relatively homogeneous fuel consumption across the stand, leaving very few unburned patches.

Behavior parameters based on flame characteristics were similar for all treatments (Table 2). Unlike other behavior parameters, flame length and depth are difficult to estimate because the flame is unsteady, causing observers to estimate average lengths (Rothermel and Deeming 1980). Also, the correlation of flame length with fireline intensity is not always high nor does it follow a standard function (Clark 1983; Nelson and Adkins 1986; Finney and Martin 1992). Fuels and weather conditions are dynamic and change by season (Table 3), and, both have a major influence on fire behavior.

Dormant-season fires in this study were less intense than fires observed by Masters and Engle (1994) in a nearby study in open Quercus dominated stands. The difference in fire behavior can be contributed to the fact that Masters and Engle (1994) observed fire behavior in a open forest type (% canopy cover=5-24%) with the dominant fuel type consisting of standing dormant grasses. We observed fire behavior in stands with greater canopy cover (% canopy cover = 84%) with fuels dominated by pine needles and hardwood leaf litter with only scattered patches of grass. Pine needles contributed less to fire spread in our fires than did the grass fuels in the fires of Masters and Engle (1994) because, un-weathered conifer needles often act like 10 hour time-lag fuels or greater (Anderson 1990; Hartford and Rothermel 1991). Although the packing ratio was not measured in either study, we believe fuel bed porosity differed greatly between these two studies, with much greater packing of the fuel beds in our study.

Risk Assessment

Growing-season fires have been perceived to produce fires of greater intensity than dormant-season fires (Komarek 1965; Waldrop et al. 1992), but our dormant-season fires were more intense (Table 2). We attempted to burn under conditions necessary to create more severe fire behavior in the growing season of the second year of this study (KBDI > 650), but even these fires were less intense than dormant-season fires (KBDI < 100) (Table 4). We believe our growing-season fires were less intense than the KBDI would indicate because of the relatively large amount of live 1-hour fuels. However, we also believe it is possible for growing-season fires conducted under extreme conditions (i.e. small amounts of live fuels) that accompany unusually dry summers or droughty years to produce higher fireline intensities and potentially have a greater influence on woody vegetation than we observed in our study. We used strip headfires to burn all stands. Fires utilizing other fire ignition techniques (i.e., ring fires) may be more intense than the fires we observed. However, the risk of overstory damage would increase if high intensity fires were used during the growing-season when temperatures are higher and particularly when light winds prevail (Robbins and Myers 1992).

Growing-season fires were generally of low intensity with slower rates of spread, allowing for easily suppressed fires. We observed 18 growing-season fire fronts in 6 stands. Of those, 12 fire fronts had fireline intensities < 345 kW/m, which are within the range of direct attack at the head by persons using hand tools (Rothermel 1983). The other 6 had fireline intensities > 345 kW/m and would require equipment such as plows, dozers, pumpers and retardants for suppression (Rothermel 1983). In comparison, only 1 of the 18 dormant-season fire fronts observed produced a fireline intensity < 345 kW/m.

Growing-season fires had a low potential for escape, so line construction needs and personnel requirements were reduced (Robbins and Myers 1992). However, members of the burn crew were heat stressed in the growing-season fires because of the high ambient air temperatures coupled with high relative humidities creating high heat indices. For example, we burned 1257 with an ambient air temperature of 30 degrees Celsius coupled with 50% relative humidity that produced a heat index of 32 degrees

Celsius in a shaded area. Heat exhaustion, cramps and sunstroke are possible at indices between 32 and 41, and exposure to heat indices greater than 41 is dangerous (Quayle and Doehring 1981; Chang et al. 1996). Furthermore, exposure to sun can increase heat indices by 7 to 9 degrees (Quayle and Doehring 1981; Chang et al. 1996), and exposure to a burning fire would also elevate these indices (Quayle and Doehring 1981). Many days have ambient air temperatures greater than 32 degrees C during the growing season (Figure 1), which produces dangerous heat indices.

Management Implications

Managers must be aware of the implications and risks involved with burning during the growing-season. Common prescriptions for dormant-season (i.e., winter) burning are 1) mid-flame windspeed between 3 and 15 km/h, 2) relative humidity of 30 to 55 percent, and 3) temperature below 16 degrees C (Wade and Lunsford 1989). Seldom do all of the above parameters occur within the acceptable ranges during the growing season. Relative humidity during the growing season tends to be higher because of the influx of moisture from the Gulf of Mexico. Temperatures, which pre-heat fuels, in the growing season are also considerably higher than acceptable ranges for dormant-season fires (Table 4). Winds during the growing season are light and variable, and can change suddenly and unexpectedly with afternoon storms (Robbins and Myers 1992).

Burning during the growing season is often ruled out because of 1) frequent afternoon thunderstorms, making it difficult to predict a burning day, 2) widely scattered rainfall cannot be predicted, so the site must be checked the day of the burn, and 3) high ambient air temperature and lack of steady winds to dissipate heat, thereby increasing the risk of crown damage (Robbins and Myers 1992). These problems can be reduced if the fire officer arrives to the burn area early, observes weather conditions on site, and inspects the fireline for any trouble areas before fire ignition. If crown scorching and fire suppression are major concerns for managers inexperienced with growing-season fires, then small scale fires should be performed initially, allowing managers to gain experience and to modify their prescriptions with minimal risks of escape and timber damage. To reduce crown scorching of pine trees, managers can modify their prescriptions for lower ambient air temperatures and greater windspeeds (see also Wade 1986; Robbins and Myers 1992). Crown scorch and damage to overstory pines is a major consideration for red-cockaded woodpecker management because suitable cavity trees may be limited in some stands.

Growing-season fires produced more smoke because of the large quantity of live vegetation and high fuel moisture. Therefore, managers should exercise added caution when burning near smoke-sensitive areas in the growing season. As the elevated KBDI indicates, larger fuels such as snags, stumps and fallen logs burned for several days after the growing-season burns. The presence of burning snags may increase the potential for escapes if the wind shifts or increases in the days following a growing-season fire. Fire managers inexperienced with growing-season fires may find it difficult to accommodate the patchy burns that growing-season fires produced. Silviculture practices, such as pine plantation burns, often require homogeneous burn patterns that dormant-season fires produced. In contrast, the patchy burning patterns resulting from growing-season fires may benefit many wildlife species because of the mosaic of habitats created (Burrows and Christensen 1991).

CONCLUSIONS

Our results indicate that fires in the growing season behave differently from fires in the dormant season. In comparison, growing-season fires produced low intensity and discontinuous fire fronts leaving a mosaic of burned and unburned areas. Dormant-season fires had a higher potential for escapes than growing-season fires, but resulted in an homogeneous burn pattern. When burning during the growing season, managers should be aware of the chance for wind shifts because of afternoon thunderstorms, excessive smoke, longer burn-out time of larger fuels, and physical stress on personnel conducting the fires.

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Table 1. Stand characteristics at time of growing-season and dormant season fires in the Ouachita Mountains of Arkansas, USA.

Stand, treatment	Fire date	Months since last fire	Stand size (ha)	Stand elevation (m)	Slope (%)	Mean basal area (m^2/ha)	Mean height (m)	Mean DBHa (cm)	Mean crown length (m)	Mean crown diameter (m)	Mean canopy cover (%)
Dormant Season											
1313, D36	3-31-95	36	13.8	305	7	24	15.0	27.9	6.5	5.4	90
1274, D36	4-1-95	36	16.2	336	7	25	16.5	28.2	7.0	5.3	94
1289, D36	4-1-95	36	16.2	335	7	17	15.0	29.1	6.0	5.4	82
1257, D36	4-2-95	36	16.2	305	7	20	15.5	31.5	7.0	6.3	88
1257, D48	3-2-96	48	18.2	335	9	14	17.0	32.6	9.0	7.1	68
1313, D48	3-3-96	48	26.7	305	8	23	15.0	26.9	7.0	4.9	84
Growing Season											
1274, G30	9-10-94	30	24.3	338	3	23	22.0	30.7	10.0	6.1	87
1289, G30	9-11-94	30	13.8	333	8	17	21.0	32.8	9.0	5.9	81
1257, G30	9-12-94	30	16.2	292	13	18	20.5	32.3	9.5	6.1	81
1259, G30	9-13-94	30	16.2	305	9	17	21.5	33.4	10.0	6.5	72
1265, G43	10-14-95	43	16.2	335	4	23	21.5	29.7	9.0	5.7	93
1274, G43	10-15-95	43	17.8	305	15	26	23.0	27.6	10.0	5.2	92

[a] DBH= diameter at breast height.

Table 2. Comparison of growing-season and dormant-season fire behavior parameters, Ouachita National Forest, Arkansas, USA (1995 and 1996).

	Treatment[a]					
	Dormant Season (n = 6)			Growing Season (n = 6)		
Fire Behavior Parameter	Mean	Min	Max	Mean	Min	Max
Flame Length (m)	0.5	0.4	0.8	0.5	0.3	0.8
Flame Depth (m)	0.8	0.5	1.4	0.4	0.2	0.7
Rate of Spread (m/min)	8.5a	4.9	12.6	2.9b	0.6	6.2
Residence Time (Sec)	11	8	15	26	14	54
Fireline Intensity (kW/m)	1,300a	534	2,082	281b	58	691
Heat per Unit Area (kJ/m^2)	8,827a	6,745	10,415	5,803b	5,150	6,668
Reaction Intensity (kW/m^2)	1,955a	905	2,767	618b	394	961

[a] Row means followed by the same letter were not different (P > 0.05).

Table 3. Fuel conditions during growing- and dormant-season prescribed fires on Wildlife Stand Improvement areas in the Ouachita National Forest, USA (1994, 1995, and 1996).

	Treatment[a]			
	Dormant Season (n = 6)		Growing Season (n = 6)	
Fuel Conditions	Mean	Std error	Mean	Std error
Fuel load[c] (kg/ha)				
1 hour live fuels	240b	30	930a	120
1 hour dead fuels	10,030a	740	7,610b	410
10 hour dead fuels	930	60	1,020	180
Total fuel load	11,210a	700	9,600b	540
Post burn residual	5,710	520	5,670	570
Fuel Consumption	5,480a	320	3,910b	180
Fuel Moisture (%)				
1 hour live	125	10	110	3
1 hour dead	20	3	14	2
10 hour dead	30	5	31	3

[a] Row mean followed by the same Row mean followed by the same letter were not different ($P > 0.05$).

Table 4. Mean weather conditions during growing-season and dormant-season prescribed fires. Ouachita National Forest, Arkansas, USA.

Stand, treatment	Fire date	Mean Temperature (C)	Mean Relative Humidity (%)	Mean Wind Speed (km/h)	Mean Cloud Cover (%)	Keetch/Byram Drought Index
Dormant Season						
1313, D36	3-31-95	14	43	5	17	79
1274, D36	4-1-95	20	26	2	55	85
1289, D36	4-1-95	19	34	11	17	85
1257, D36	4-2-95	24	25	5	5	95
1257, D48	3-2-96	14	29	4	3	68
1313, D48	3-3-96	15	38	5	0	71
Growing Season						
1274, G30	9-10-94	27	53	3	19	137
1289, G30	9-11-94	28	53	4	25	155
1257, G30	9-12-94	30	50	7	22	172
1259, G30	9-13-94	30	49	7	20	189
1265, G43	10-14-95	19	30	2	0	659
1274, G43	10-15-95	25	23	3	0	662

Figure 1. Mean Keetch/ Byram Drought Index by month, Oden Ranger District of the Ouachita National Forest for 1985-1996.

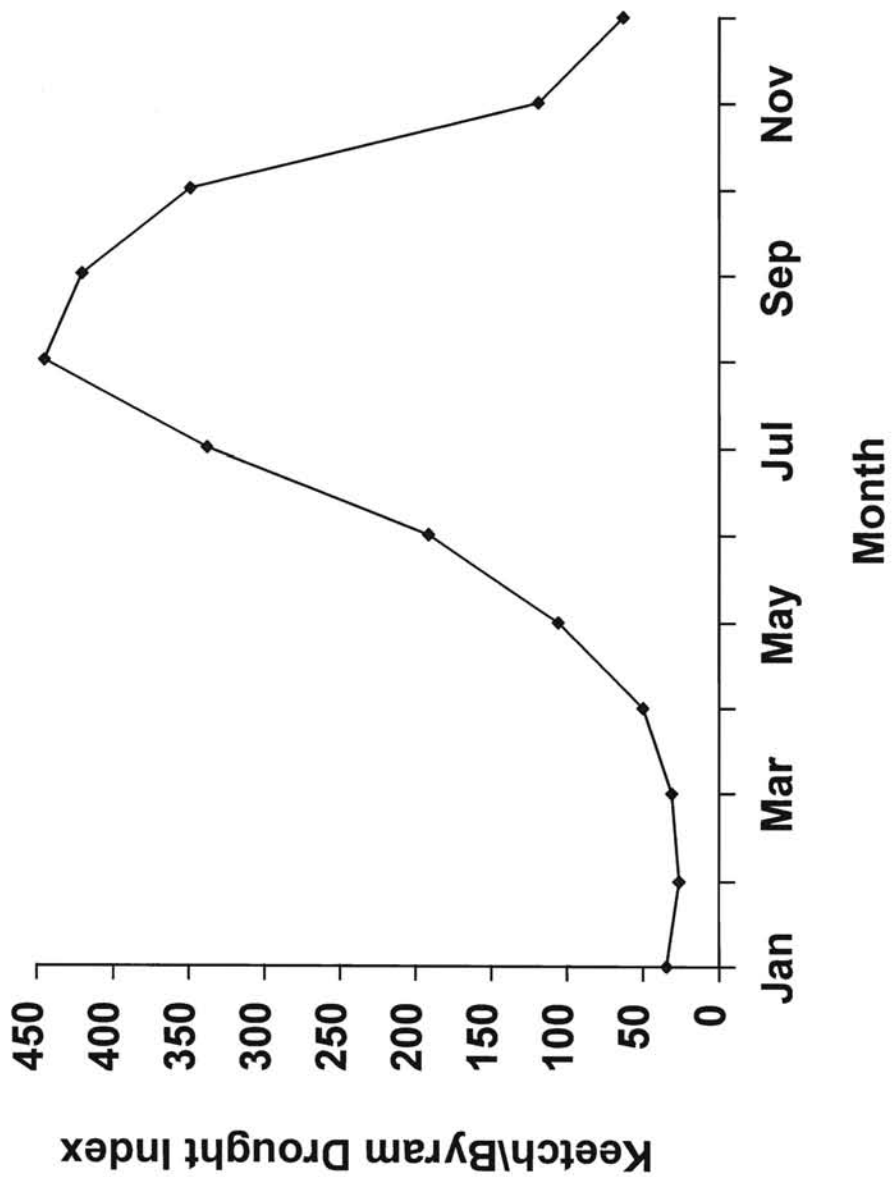
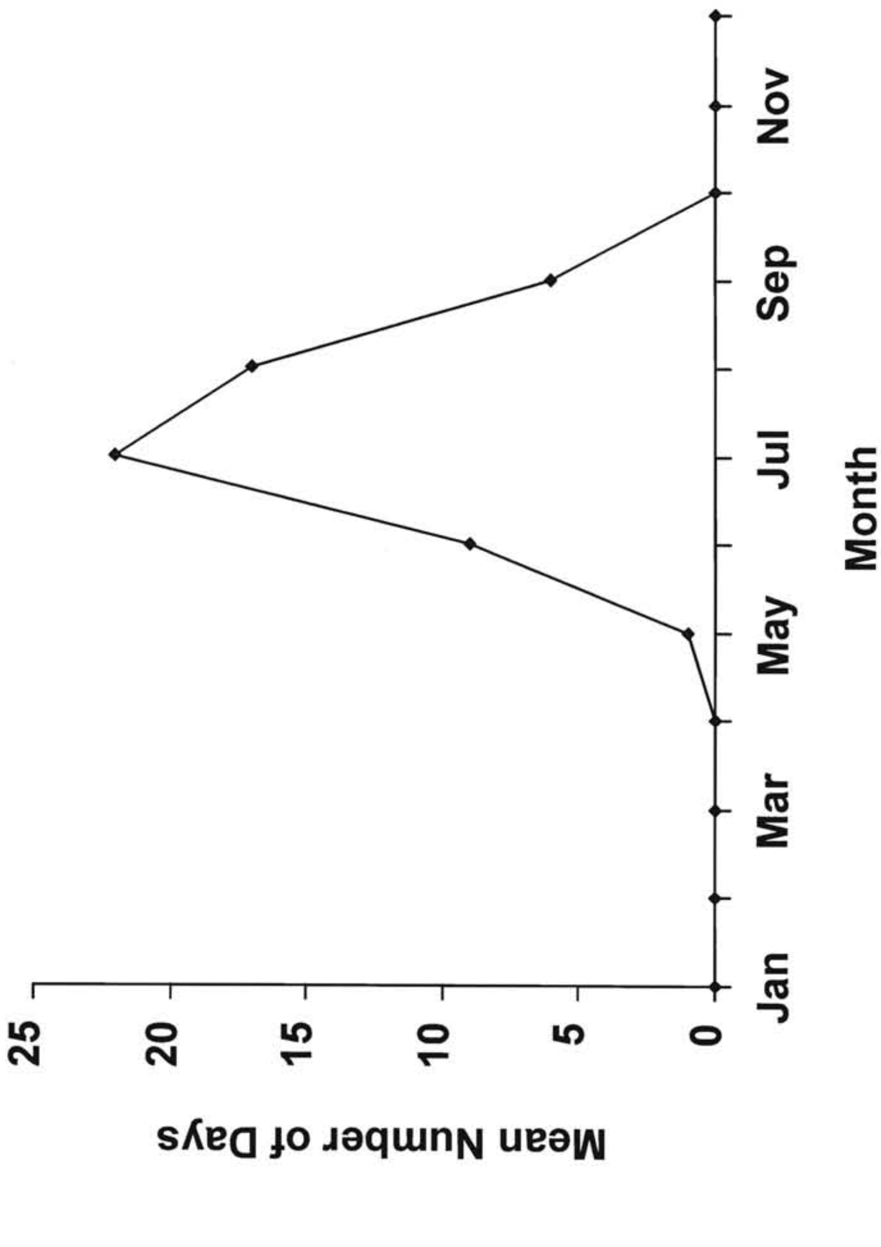

Keetch\Byram Drought Index
450
400
350
300
250
200
150
100
50
0
Jan
Mar
May
Jul
Sep
Nov
Month

Figure 2. Mean number of days by month the ambient air temperature reached 32 degrees C or greater for Waldron, AR 1991-1995.


Mean Number of Days
25
20
15
10
5
0
Jan
Mar
May
Jul
Sep
Nov
Month

CHAPTER III

INFLUENCE OF FIRE SEASON ON ACCURACY OF BEHAVE PREDICTIONS OF FIRE BEHAVIOR

ABSTRACT. We compared predicted fire behavior of 4 standard BEHAVE fuel models and site specific customized models with observed fire behavior in shortleaf pine (Pinus echinata) stands managed for the endangered red-cockaded woodpecker (Picoides borealis). We observed fire behavior in growing-season and dormant-season prescribed fires. Models varied in accuracy depending on fuel loading and season of fire. Therefore, multiple models were required to accurately characterize all fire behavior parameters across fire seasons and fuel loads. When used with the appropriate fuel model, BEHAVE has the potential to predict fire behavior parameters before ignition, ideally limiting risk involved with burning in these seasons. Accurate predictions are important for endangered species management as well as assessment of safety.

Keywords: Fire management; Fire models; Fuel models; Ouachita National Forest; Picoides borealis; Pinus echinata; Prescribed fire; Red-cockaded woodpecker; Shortleaf pine.

INTRODUCTION

Fire is a natural and dynamic force that played a major role in presettlement landscape development in both forest and rangeland communities worldwide (Christensen et al. 1981; Gill 1981; Pyne 1982; Wright and Bailey 1982; Bigalke and Willan 1984; Kruger 1984; Chandler et al. 1983; Sparks and Masters 1996). However, fire control and prevention has altered many of these fire derived communities, often causing many plant and animal species dependent on these communities to decline or become endangered. Land managers throughout the world attempt to restore and maintain relics of these communities by initiating prescribed fire to meet specific objectives such as endangered species management, manipulation of community composition, fire hazard reduction, wildlife habitat improvement, control of woody species, and seedbed preparation (Van Lear 1985; Waldrop et al. 1992; Wilson et al. 1995; Masters et al. 1996).

Computer models utilizing on-site environmental data to predict common fire behavior parameters can be used before fire ignition providing managers with insight on the probability of achieving desired objectives, possibility of escapes, and equipment required to suppress the firefront (Raybould and Roberts 1983; Andrews and Bradshaw 1990). BEHAVE is a wildland fire behavior and fuel modeling system developed by the U.S. Department of Agriculture, Forest Service to provide real-time fire behavior predictions of large scale wildland fires or prescribed natural fires (Burgan and Rothermel 1984; Andrews 1986; Andrews and Chase 1989). However, when used with caution, BEHAVE can be utilized for fire behavior training, dispatch of crews for initial attack and prescribed fire planning (Andrews 1986; Andrews and Chase 1989; Andrews and Bradshaw 1990).

BEHAVE is equipped with 13 standard fuel models and the capability of customizing site-specific models (Andrews 1986; Andrews and Chase 1989). Standard models vary according to fuel type, fuel load, and fuel structure. However, fuels are dynamic and describing them often requires more than one model, depending on management history, the season of fire, fuel bed depth, and subsequent weather conditions. Furthermore, a standard model may not adequately characterize a site, therefore managers may need to modify a model for their particular situation. Managers must be aware of the complexity of fuels, and be capable of choosing the appropriate model for a given situation.

Many researchers are beginning to experiment with fire in different seasons and with fires of varying intensities to accomplish management objectives (Robbins and Myers 1992; Glitzenstein et al. 1995). Fire behavior characteristics may be used to predict the influence on herbaceous and woody vegetation (Engle et al. 1996; Sparks 1996). Accurate fire behavior predictions can thus be used to define burning windows and potential habitat change for management of endangered species such as the red-cockaded woodpecker (Picoides borealis). Currently, research and experience with prescribed fire at times other than the late dormant-season is limited. Therefore, managers are faced with uncertain liability risks from fire escapes, residual smoke and uncertain management outcomes when using prescribed fire for endangered species management. However, fire behavior models such as BEHAVE maybe useful for increasing the efficacy of prescribed fires and reducing liability (Masters and Engle 1994). Predictive fire behavior models such as BEHAVE were developed for use in continuous fine fuels under wildfire situations. Therefore, these models must be validated before fire management decisions are based on predicted outcomes.

Our primary objective was to evaluate the accuracy of BEHAVE's predictions by determining the most appropriate fuel model for thinned stands of shortleaf pine (Pinus echinata), managed as a pine-grassland community for the red-cockaded woodpecker. We also wanted to determine the efficacy of using a single fuel model in different seasons.

METHODS

Study Area

Our study sites were located on the Poteau Ranger District of the Ouachita National Forest (ONF) in Scott County of west-central Arkansas. The ONF lies within the 2,280,000 ha Ouachita Mixed Forest-Meadow Provide and comprises 648,000 ha throughout the Ouachita Mountains in Arkansas and Oklahoma (Neal and Montague 1991; Bailey 1995). The Ouachita mountains are east-west trending, strongly dissected, and range in elevation from 150-790 m (Fenneman 1938). Soils in the Ouachita Mountains developed from sandstone and shales and are thin and drought prone. The climate of the area is semi-humid to humid with hot summers and mild winters.

Our study focused on stands under active management for the endangered red-cockaded woodpecker (Picoides borealis) within the 40,000 ha Pine-bluestem

Ecosystem Renewal Area (Masters et al. 1996; Wilson et al. 1995). Management consisted of thinning midstory and codominant pine and hardwood trees and is known as Wildlife Stand Improvement (WSI). Dormant-season prescribed burning every three years followed WSI. Three-year fire intervals are the most common after WSI, but intervals vary from 1 to 4 years. We randomly chose 12 stands that had been burned previously in the dormant season between 1 to 5 times at 3 year intervals (Table 1).

Pinus echinata (shortleaf pine) was the dominant overstory tree species in all stands (Table 1). Codominant and intermediate overstory species included Quercus stellata (post oak), Q. marilandica (blackjack oak), Q. alba (white oak), Q. rubra (northern red oak), Q. velutina (black oak), Carya texana (black hickory), and C. tomentosa (mockernut hickory). Woody resprouts and shrubs ($\leq$ 3m) dominated the understory of these stands. The dominant understory species included Toxicodendron radicans (Poison ivy), Vaccinium pallidum (Low-bush huckleberry), Q. stellata, Rubus spp. (Blackberry), Parthenocissus quinquefolia (virginia creeper), Ceanothus americanus (New Jersey Tea), Vitis rotundifolia (muscadine), Q. alba and P. echinata (Sparks 1996).

Treatments

We applied 5 treatments in a completely randomized fashion, with 2 treatments consisting of growing-season fires, and 3 treatments of dormant-season fires. Treatments were as follows:

(1) Growing-season burn (G30; n = 4);

30 months after previous dormant-season burn;

(2) Dormant-season burn (D36; n = 4),

36 months after previous dormant-season burn;

(3) Growing-season burn (G43; n = 2),

43 months after previous dormant-season burn;

(4) Dormant-season burn (D48; n = 2),

48 months after previous dormant-season burn;

(5) Dormant-season burn (D12; n = 2),

12 months after previous dormant-season burn.

The G43 and D48 treatments differed from G30 and D36 in that experimental prescribed burns were applied after 4 growing seasons and 3 growing seasons respectively. The G43, D48, and D12 treatments were added to test model flexibility under different fuel loads.

We conducted growing-season burns between 1200 and 1800 on September 10 to 13, 1994, and October 14 and 15, 1995 (Table 1). We initiated dormant-season prescribed fires between 1000 and 1800 on March 31 to April 2, 1995, and March 2 to 4, 1996 (Table 1). We ignited backfires and allowed to burn > 50 m into the stand before igniting strip headfires and sampling fire behavior parameters of the strip headfires.

Fuel Sampling

We sampled fuels <1 hour before burning at 3 random locations within each stand. At each location, we harvested all fuels $\leq$ 1.5 m in height in 4 to 10, 0.5 X 0.5-m quadrats at 5 m intervals, parallel to the firefront. We hand separated fuels into

1-hour (< 0.6 cm-diameter) dead, 1-hour live, and 10-hour (0.6 to 2.5 cm-diameter) dead components. We weighed fuels immediately after clipping. After burning, we collected fuel residue at locations paired with pre-fire fuel samples by sampling all residual dead and live vegetation less than 2.5 cm in diameter to a height of 1.5 m. All fuel samples were dried at 70 degrees C to a constant weight. Fuel moisture was calculated on a dry weight basis. We also determined fuel moisture of 10-hour fuels using standard fuels sticks and a protimeter. Fuel loads varied considerably, while mean fuel moisture was similar across all treatments (Table 2).

We calculated fuel energy by selecting 3 random samples of dried fuels from each stand burned during the dormant season of 1995 and growing season of 1994 (n = 24). We combined 1-hour and 10-hour live and dead fuel components for each pre-burn observation, ground samples to a fine powder and compressed them into 1-g pellets. We then combusted these pellets in a bomb calorimeter to determine high heat of combustion.

Meteorological Data

We measured relative humidity, temperature, cloud cover, and wind speed at sunrise, 1400 hours and sunset the day before the burn, the day after the burn, and the day of the burn. We also recorded weather observations immediately before igniting the fire, as we observed fire behavior parameters, and immediately upon completion of the fire. We measured wind at 2 m using a totalizing anemometer. We used observed wind speeds to estimate wind speed at 6 m (Albini and Baughman 1979). We used a belt weather kit to determine other weather parameters. We verified our observations with weather data from the Poteau Ranger District Headquarters in Waldron, Arkansas and the National Weather Service in Tulsa, Oklahoma, for Fort Smith observations. Weather parameters by treatment are in Table 2.

Stand Characteristics

We characterized the canopy species within each stand before burning. In September, 1994 and March and April, 1995 we sampled 30 points at 30-m intervals on 2 to 4 randomly spaced lines perpendicular to the contour. In October of 1995 and March of 1996 we sampled 20 locations within each stand. At each sampling location we estimated canopy cover with a spherical densiometer (Avery 1967), tree and crown height using a clinometer, crown diameter, and diameter at breast height for the closest tree in each sampling quarter. We estimated mean tree height and the ratio of crown length to tree height and crown length to crown diameter from these observations for use in BEHAVE.

Fire Behavior Observations

We recorded rate of spread (ROS), flame length (FL), flame depth (FD), and residence time (RT) at all 3 fuel sampling locations. Before headfire ignition we placed 3 sets of 2 m freestanding stakes, with referenced heights marked at 0.5 m intervals, at 5 m apart and perpendicular to the firefront. Three observers estimated fire behavior parameters by observing and timing the fire as the firefront passed each set of stakes, as described by Rothermel and Deeming (1980). We repeated this procedure ≥ 2 times at 3 locations within each stand ($n \geq 18$).

We calculated fireline intensity by Byram's (1959) formula (I_B = hwr), where I_B is frontal fire intensity (kW/m), h is net heat of combustion (kJ/kg) obtained by adjusting fuel high heat of combustion for fuel moisture and heat of vaporization, w is fuel consumed (kg/m^2) calculated as pre-burn fuel load minus post-burn residual fuel, and r is rate of spread (m/sec). We estimated the total energy released in the active flame front, or heat per unit area (kJ/m^2) (H_a) by dividing fireline intensity (kW/m) by rate of spread (m/min) (Rothermel and Deeming 1980). We determined reaction intensity (kW/m^2) (I_R), or the rate of energy release per unit area of flaming zone, by dividing fireline intensity (kW/m) by flame depth (m) (Albini 1976; Alexander 1982).

Creating Custom Fuel Models

We used TSTMDL in BEHAVE to create a site specific, static fuel model for each treatment type (n = 5), by adjusting the values of the Southern Rough model (model 7). We used the fuels sampled in each stand to represent fuel load. We calculated depth of the fuel bed in NEWMDL and used this value in TSTMDL. After customizing model 7, we used TSTMDL to test the model against observed fire behavior using environmental data we collected. We fine tuned extinction moisture, fuel load, and fuel depth (Table 3) to produce accurate and consistent results for a variety of environmental conditions.

BEHAVE Predictions

The mathematical model used in BEHAVE is intended primarily for the prediction of fire behavior parameters on the flame front of a headfire carried by fine fuels (Rothermel 1983). Therefore, we only compared observed fire behavior parameters of headfires with BEHAVE predictions. We modeled fire behavior using the SITE module of the FIRE1 program in BEHAVE (Andrews 1986). We were interested in predictions from several possible models, therefore, we used our custom fuel model and standard fuel models 7, 8, 9, and 10 described by Anderson (1982). We used 1-hour fuel moisture from collected fuel samples; 10-hour fuel moisture from fuel sticks and protimeter readings observed on site; we estimated 100 hour fuel moisture based on 1- and 10-hour fuel moisture and weather conditions. We supplied all environmental variables, stand characteristics, and weather observations for each fire sub-sample within a stand as prompted by the SITE module. BEHAVE predicted fireline intensity, heat per unit area, reaction intensity, flame length, and rate of spread for each fire location within all stands.

We used simple linear regression to determine if fuel models in BEHAVE were accurate predictors over the range of observed fire behavior by pairing observed and predicted fire behavior parameters for each fire sub-sample. We tested the slope of the linear regression line (i.e., BEHAVE predicted fire behavior vs observed fire behavior) for equality to 1 with the y-intercept forced to 0. A model was determined accurate when the slope was not significantly different from 1 using a 0.05 significance level. To determine model accuracy at all levels of observed behavior, we inspected the $\underline{r}^2$ for the model and plotted the residuals. We also validated the average accuracy of BEHAVE predictions of flame length and fireline intensity with Fisher's exact test by defining categorical variables from the fire behavior characteristics chart (Rothermel 1983).

RESULTS AND DISCUSSION

Fuels in all stands tended to be heterogenous and discontinuous, with occasional exposed rock, patches of dense grass, deep pine needles, residual thinning slash, and occasional fallen snags. Fuels in the growing-season treatments were even more heterogeneous because of patchy distribution of live understory vegetation.

The SITE module of the FIRE1 program in BEHAVE is based on Rothermel's (1972) model and Albini's (1976) additions. It was developed for predicting fire behavior of wildland fires in relatively homogeneous, porous fuels (Rothermel 1983). The program is intended to characterize fine fuels and describe headfires (Rothermel 1983; Andrews 1986). In discontinuous and heterogeneous fuels the model can produce erroneous predictions (Sneeuwjagt and Frandsen 1977; Brown 1982). Brown (1982) found Rothermel's model accurately predicted rate of spread in sagebrush fuel types, however the model produced erroneous predictions of flame length and intensity. Sneeuwjagt and Frandsen (1977) determined the model was useful in predicting fire behavior in grasslands, but expressed concern about flame length and combustion zone depth inaccuracies. Therefore, part of the variation between observed and predicted fire behavior may be attributed to fuel bed continuity and relative homogeneity.

Reliability of Fuel Models Across Seasons

Fire behavior parameters predicted with standard models were constant for all treatments regardless of fuel loads and season of fire, while observed parameters varied depending on the season of the fire and fuel loads (Figure 1a-e). This constancy is linked to the static nature of these fuel models. Fuels are dynamic and change by seasons and with time since fire (see Sparks et al. 1996). For example, a larger proportion of the fuels are dormant or "cured" during dormant-season fires. Second, woody species in the understory are primarily deciduous, therefore when they are dormant there is an increase in solar radiation and wind exposure on the fuels (Sparks et al. 1996). Each fuel model is designed to function in a specific fuel type; as fuel characteristics change so must the fuel models used to predict fire behavior. Therefore, it is necessary for managers to understand the dynamics of fuels and which fuel model is appropriate for their given situation (Andrews 1986; Andrews and Chase 1989). To appropriately choose a model, managers should use TSTMDL in BEHAVE to validate a model for their particular fuel type (Burgan and Rothermel 1984).

Accuracy of Fuel Models

We examined 4 standard fuel models (i.e., 7, 8, 9, and 10) and a separate model customized for each treatment (Table 3). Model 8 and 9 produced unrealistic predictions for all fire behavior parameters, so we discarded these models from further analysis. None of the models either standard or customized, produced accurate estimates of all fire behavior parameters across all treatments (Figure 1). Models tended to vary in accuracy depending on fuel loading and season of fire. Therefore multiple models were required to accurately characterize all fire behavior parameters across fire seasons and fuel loads. Results on the efficacy of models varied with the different statistical analyses (i.e., regression vs Fisher's exact test). For example, model 7 appears to be the most accurate model on average for predicting reaction intensity in the D12 treatment but, model 10 and the custom model are more accurate when analyzing specific fires (Figure 1e). Model 7 would be effective from a management standpoint, if numerous predictions were obtained throughout the stand, but model 10 and the custom model would be more effective if a limited number of predictions were obtained.

Standard models 7 and 10 produced accurate predictions of flame length for all treatments except the D12 treatment (Figure 1a). However, standard models under estimated fireline intensity and rate of spread in all treatments except for the D12 treatment in which the customized models and model 7 and 10 predicted fireline intensity similar to observed fireline intensity (Figure 1b, 1c). Model 7 produced accurate predictions of heat per unit area more often than other models for growing-season fires, while custom models tended to over-predict heat per unit area (Figure 1d, 1e). Model 7 was most effective at predicting reaction intensity of D12 stands, while model 10 and the custom models proved more effective on average and on an individual basis for all other treatments (Figure 1e). Models produced similar $\underline{r}^2$ values within similar treatments (Table 4).

All models failed to produce accurate predictions for fireline intensity and rate of spread (Figure 1b, 1c). Analysis of residuals indicated that all models tended to over-predict fireline intensity on low intensity fires while under predicting on higher intensity fires. We found an inconsistent relationship between observed and predicted fireline intensity based on low $\underline{r}^2$ values for fireline intensity (Table 4). Observed ROS and fireline intensity may have been greater than predicted because the headfire may have been influenced by backing fires. Strip headfires were set and allowed to burn into backing fires creating a situation similar to a ring fire, a common firing technique in the southeastern United States (Wade and Lunsford 1989). Wind speeds in the actively burning area can increase because of the convection created by ring fires (Wade and Lunsford 1989), we attempted to monitor these winds at 2 m, but were unsuccessful. Therefore, fire behavior may have been influenced by these convection winds not measured in our pre-burn weather observations. Adjustments to BEHAVE may be needed for this influence in small-scale ring fires (Masters and Engle 1994).

Because of the mountainous terrain of the region, wind speeds away from the fire were also variable in all stands, constantly shifting directions and varying intensities. We attempted to monitor this variability but were unsuccessful. Fuel moisture was also quite variable within stands, as a result of live vegetation in the growing season and variable shading from the dense midstory. A portion of the large variation between observed and predicted fire parameters was a result of the inherent variation of the advancing fire front, which varies with fuel moisture, and wind speed (Brown and Davis 1973; Trollope 1984).

In the D12 treatment, BEHAVE failed to produce accurate predictions and high r^2 for nearly all fire behavior parameters (Table 4). Unlike other treatments, this treatment had only one year of fuel build up, with fuels consisting primarily of freshly fallen conifer needles with little cured herbaceous material and hardwood leaf litter. Unweathered conifer needles such as those found in this treatment often act like ten hour time-lag fuels or greater (Anderson 1990). Hartford and Rothermel (1991) noted unweathered organic coatings on freshly cast conifer needles as a likely cause of slow moisture response in the Yellowstone fires.

Management Implications

If BEHAVE can accurately predict fire behavior parameters before ignition, managers can prescribed burn with more efficacy and yet reduce the risks involved. Fireline intensity, heat per unit area and reaction intensity relate to fire effects on vegetation (Van Wagner 1973; Rothermel and Deeming 1980; Alexander 1982; Wright and Bailey 1982; Wade 1986; Engle et al. 1996). Wade (1986), recommended using fireline intensity for correlating fire behavior effects above the flame zone, reaction intensity within the flame zone, and heat per unit area for below ground effects. Flame length, which is related to fireline intensity, is a good predictor of scorch height on conifers (Van Wagner 1973). Fireline intensity, and flame length are also excellent indicators of the difficulty of control, potential for escapes, and equipment required for suppression (Roussopoulos and Johnson 1975; Rothermel 1983; Pyne 1996). With accurate models, prescribed burn practitioners can set goals and identify parameters within which a given heat per unit area, reaction intensity, and fireline intensity will best achieve their management objectives. Practitioners can also determine the equipment required to suppress or maintain the fire fronts using the fire behavior characteristics chart (Rothermel 1983).

Headfires with fireline intensity < 345 kW/m (flame length < 1.2 m) can generally be attacked at the head by persons using hand tools (Rothermel 1983). Headfires with a fireline intensity > 345 kW/m (flame length < 2.5 m) are too intense for direct attack on the head by persons using hand tools and require equipment such as plows, dozers, pumpers and retardant aircraft (Rothermel 1983). Our fires produced intensities and flame lengths in both of these categories (Figure 1a, 1b). In D48 and D36 treatments, models 10 and 7 were more accurate than custom models at predicting flame length within the correct fire behavior classification ($P \leq 0.001$). However, custom models were more accurate than other models at predicting fireline intensity in the D36 and D48 treatments ($P \leq 0.001$).

CONCLUSIONS

BEHAVE can provide accurate predictions of fire behavior for use in defining prescribed burning windows when the proper model is selected. This is particularly important when managing for endangered species because specific fire behavior parameters may be used to predict the influence on habitat variables. However, managers must proceed with caution because the appropriate fuel model varies with season of fire and fuel loading. Therefore, managers must identify or customize the appropriate fuel model. Furthermore, model accuracy varies among fire behavior parameters, so managers should use more than one model to predict relevant fire behavior parameters and to produce a range of fire behavior within which a specific fire may fall. Because fuels vary widely between seasons, managers should interpret predictions with caution, and perform multiple analyses for each burn situation.

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Table 1. Characteristics of stands used to compare BEHAVE predicted and observed fire behavior in the Ouachita Mountains of Arkansas, USA.

Stand, treatment	Fire date	Months since last fire	Stand size (ha)	Stand elevation (m)	Slope (%)	Mean basal area (m^2/ha)	Mean height (m)	Mean DBH (cm)	Mean crown length (m)	Mean crown diameter (m)	Mean canopy cover (%)
1257, D48	3-2-96	48	18.2	335	9	14	17.0	32.6	9.0	7.1	68
1257, D36	4-2-95	36	16.2	305	7	20	15.5	31.5	7.0	6.3	88
1257, D12	3-2-96	12	16.2	305	7	20	16.0	32.5	7.0	6.4	81
1257, G30	9-12-94	30	16.2	292	13	18	20.5	32.3	9.5	6.1	81
1259, G30	9-13-94	30	16.2	305	9	17	21.5	33.4	10.0	6.5	72
1265, G43	10-14-95	43	16.2	335	4	23	21.5	29.7	9.0	5.7	93
1274, G43	10-15-95	43	17.8	305	15	26	23.0	27.6	10.0	5.2	92
1274, D36	4-1-95	36	16.2	336	7	25	16.5	28.2	7.0	5.3	94
1274, D12	3-4-96	12	16.2	336	7	25	16.5	28.2	7.0	5.3	84
1274, G30	9-10-94	30	24.3	338	3	23	22.0	30.7	10.0	6.1	87
1289, D36	4-1-95	36	16.2	335	7	17	15.0	29.1	6.0	5.4	82
1289, G30	9-11-94	30	13.8	333	8	17	21.0	32.8	9.0	5.9	81
1313, D48	3-3-96	48	26.7	305	8	23	15.0	26.9	7.0	4.9	84
1313, D36	3-31-95	36	13.8	305	7	24	15.0	27.9	6.5	5.4	90

NOTE: DBH= diameter at breast height.

Table 2. Range in fuel and weather conditions during prescribed fires on Wildlife Stand Improvement areas in the Ouachita National Forest of western Arkansas.

Parameter	Treatment[a]									
	D36 (n=12)		G30 (n=12)		D48 (n=6)		G43 (n=6)		D12 (n=6)	
	min	max	min	max	min	max	min	max	min	max
Fuel load (kg/ha)										
1 hour live fuels	73	422	320	1890	75	330	363	1010	81	250
1 hour dead fuels	6580	11350	4860	9340	8900	13810	7420	8460	5910	9140
10 hour dead fuels	200	1730	156	2510	340	1570	77	1700	175	1550
Post burn residue	3230	6740	2430	9870	5170	9560	3430	6050	5450	8970
Fuel moisture (%)										
1 hour live	45	163	92	133	114	184	86	127	133	194
1 hour dead	9	45	8	28	12	28	6	15	15	24
10 hour dead	6	55	6	58	28	48	8	62	19	50

Table 2. Continued.

Parameter	Treatment[a]									
	D36 (n=12)		G30 (n=12)		D48 (n=6)		G43 (n=6)		D12 (n=6)	
	min	max	min	max	min	max	min	max	min	max
Weather conditions										
Air temperature (C)	12	24	27	31	12	16	19	26	10	19
6 m wind speed (km/h)	0	13	3	9	2	7	0	5	0	4
Relative humidity (%)	22	48	46	57	26	51	20	31	32	49
Cloud cover (%)	0	70	0	30	0	10	0	0	0	90

[a] D36 = dormant-season burn 36 months after previous dormant-season burn. G30 = growing-season burn 30 months after previous dormant-season burn. D12 = dormant-season burn 12 months after previous dormant-season burn. D48 = dormant-season burn 48 months after previous dormant-season burn. G43 = growing-season burn 43 months after previous dormant-season burn.

Table 3. Fuel model descriptors for standard and custom fuel models used to model fire behavior in the Ouachita Mountains, Arkansas, USA.

		Fuel load (Mton/ha)					Surface to volume ratio (1/cm)				
Model #	Treatments	1-Hour	10-Hour	100-Hour	Live Herb.	Live Woody	1-Hour	Live Herb.	Live Woody	Fuel depth (cm)	Extinction moisture (%)
7	All	2.54	4.20	3.37	0.00	0.83	57	6	51	76.2	40
8	All	3.37	2.25	5.61	0.00	0.00	66	6	6	6.1	30
9	All	6.54	0.93	0.34	0.00	0.00	82	6	6	6.1	25
10	All	6.74	4.49	11.23	0.00	4.49	66	6	49	30.5	25
custom	G30	7.62	1.12	1.01	0.90	1.12	57	6	51	28.96	27
"	D36	8.96	1.12	0.52	0.00	0.83	57	6	51	60.9	45
"	G43	7.84	1.57	0.90	0.90	1.12	57	6	51	29.57	29
"	D12	5.60	0.67	0.45	0.00	0.83	57	6	51	24.38	25
"	D48	9.52	1.90	0.90	0.00	0.83	57	6	51	67.06	40

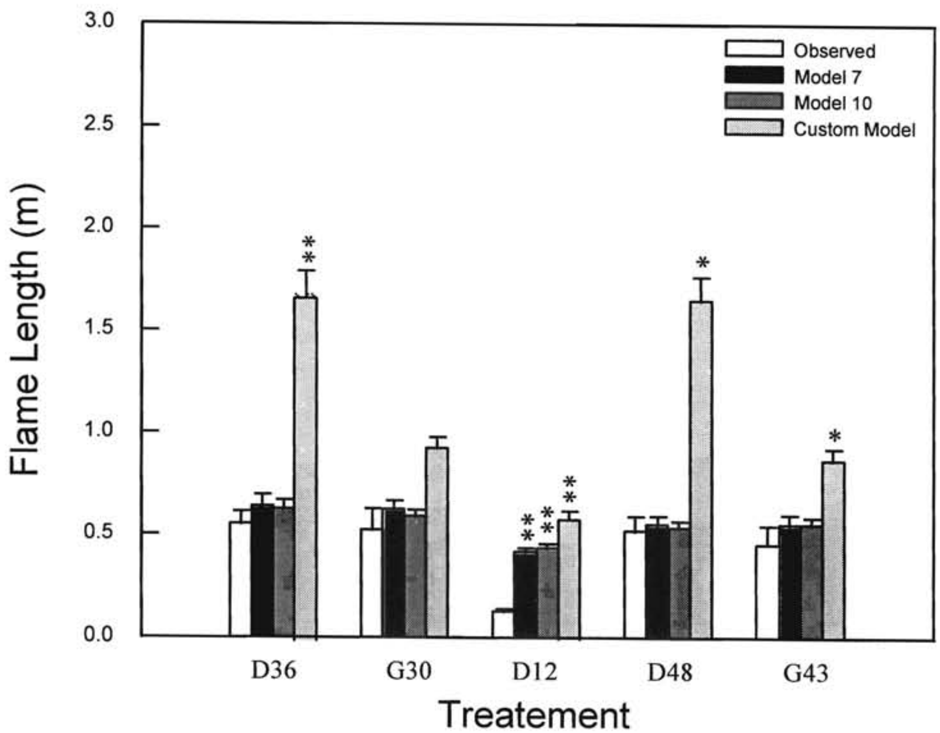
Table 4. R-square values by treatment and fire behavior parameters for linear regression of observed parameters vs predicted parameters, Ouachita Mountains, Arkansas, USA.

Fire Behavior Parameter	Treatment[a], Model Number														
	D36			G30			D12			D48			G43		
	7	10	Cust.	7	10	Cust.	7	10	Cust.	7	10	Cust.	7	10	Cust.
Flame Length (m)	0.90	0.87	0.90	0.72	0.71	0.72	0.95	0.96	0.94	0.90	0.90	0.92	0.93	0.90	0.90
Fireline Intensity (kW/m)	0.75	0.70	0.80	0.63	0.60	0.61	0.19	0.21	0.18	0.72	0.72	0.74	0.77	0.71	0.73
Rate of Spread (m/min)	0.77	0.47	0.85	0.54	0.37	0.54	0.01	.	0.02	0.65	.	0.82	0.84	.	0.72
Heat per Unit Area (kJ/m^2)	0.93	0.93	0.93	0.87	0.87	0.87	0.60	0.61	0.60	0.94	0.94	0.94	0.91	0.91	0.91
Reaction Intensity (kW/m^2)	0.72	0.72	0.71	0.75	0.75	0.75	0.40	0.41	0.40	0.75	0.75	0.75	0.93	0.92	0.93

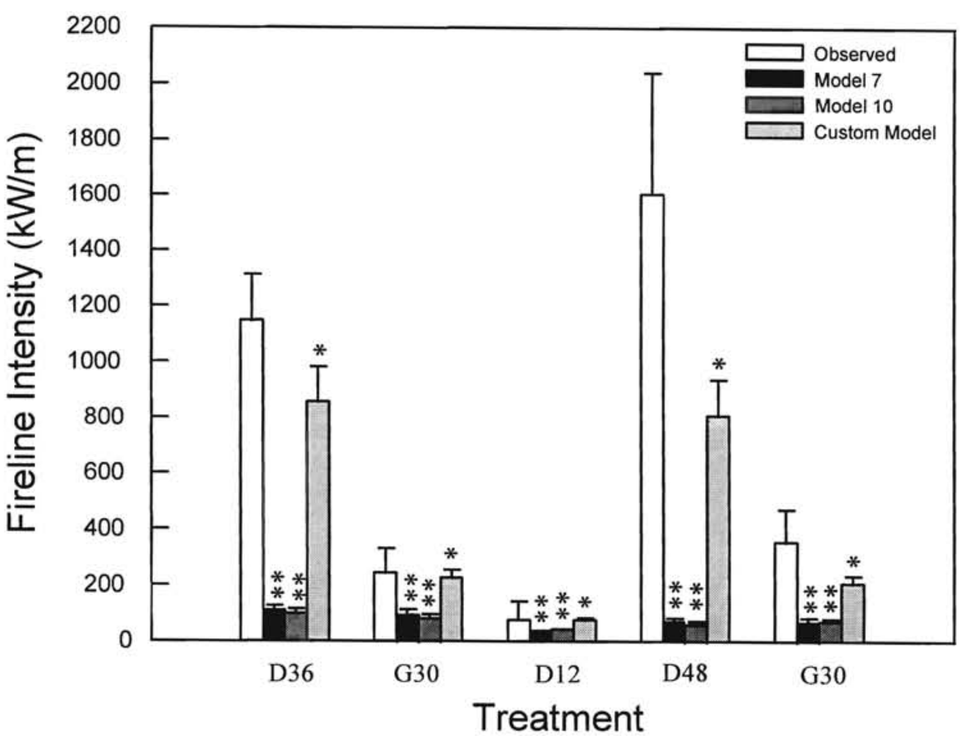
[a] D36 = dormant-season burn 36 months after previous dormant-season burn. G30 = growing-season burn 30 months after previous dormant-season burn. D12 = dormant-season burn 12 months after previous dormant-season burn. D48 = dormant-season burn 48 months after previous dormant-season burn. G43 = growing-season burn 43 months after previous dormant-season burn.

Figure 1. Means and Standard Errors by treatment for (a) flame length (m), (b) fireline intensity (kW/m), (c) rate of spread (m/min), (d) heat per unit area (kJ/m^2) and (e) reaction intensity (kW/m^2). Asterisks indicate regression results (H_o: slope = 1, given Y intercept = 0), * = $\underline{P}$ = 0.05 to 0.001, ** = $\underline{P} \leq 0.001$ and no asterisk indicates a $\underline{P} \geq 0.05$ (that the model prediction accurately represents observed fire behavior). D36 = Dormant-season burn 36 months after previous dormant-season burn ($\underline{n}$ = 12). G30 = Growing-season burn 30 months after previous dormant-season burn ($\underline{n}$ = 12). D12 = Dormant-season burn 12 months after previous dormant-season burn ($\underline{n}$ = 6). D48 = Dormant-season burn 48 months after previous dormant-season burn ($\underline{n}$ = 6). G43 = Growing-season fire 43 months after previous dormant-season burn ($\underline{n}$ = 6). Bars are +1 SE.

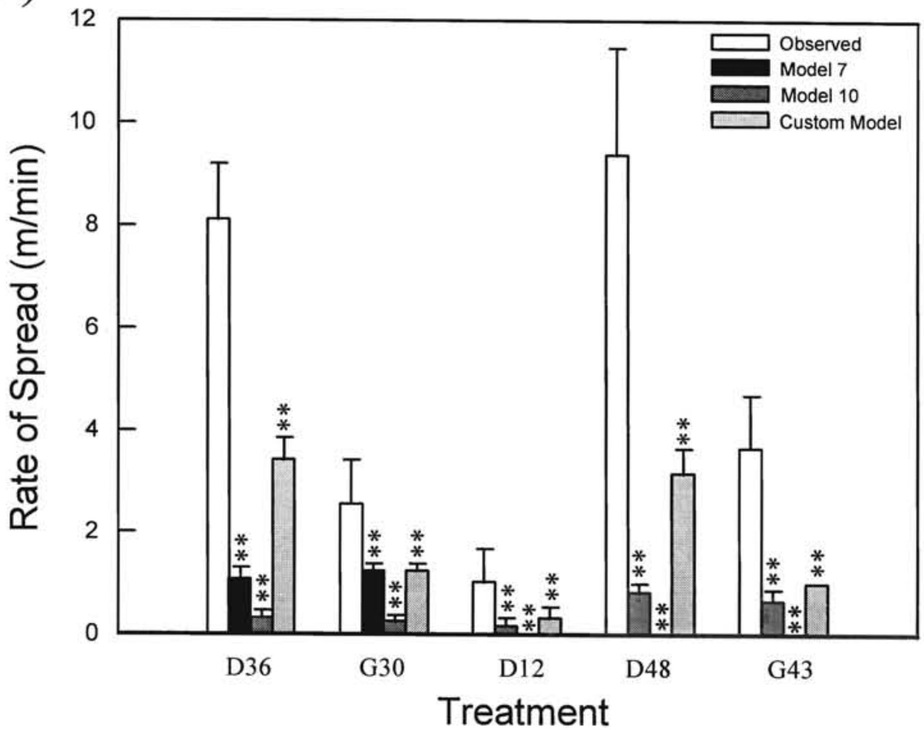
(a)


3.0
2.5
2.0
1.5
1.0
0.5
0.0
Flame Length (m)
Observed
Model 7
Model 10
Custom Model
D36
G30
D12
D48
G43
Treatement

(b)

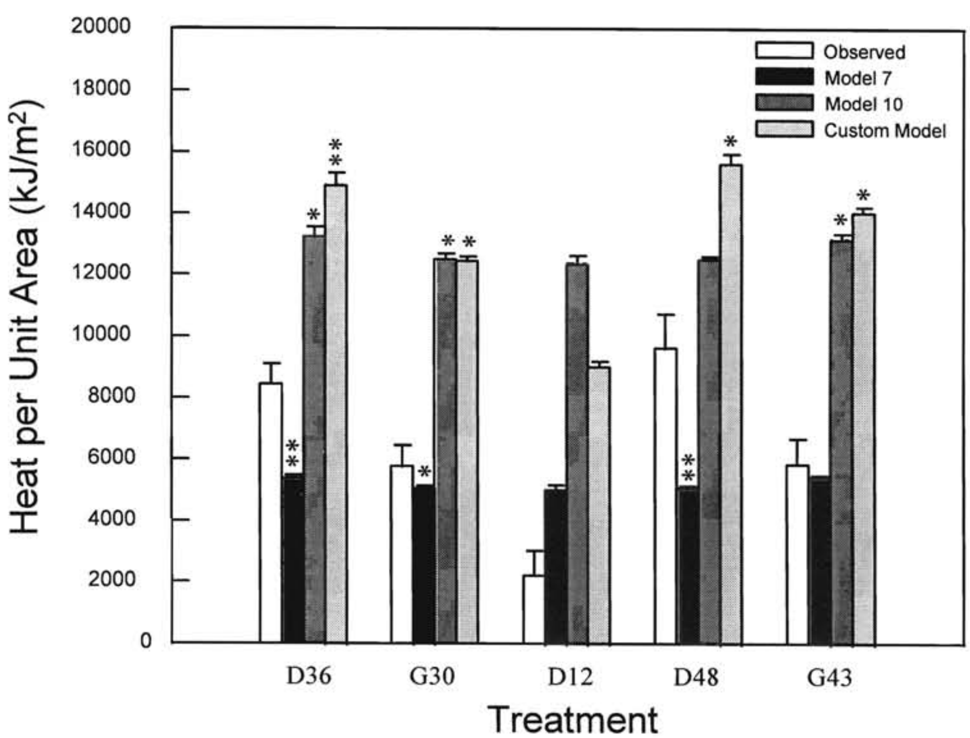

2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Fireline Intensity (kW/m)
Observed
Model 7
Model 10
Custom Model
D36
G30
D12
D48
G30
Treatment

(c)



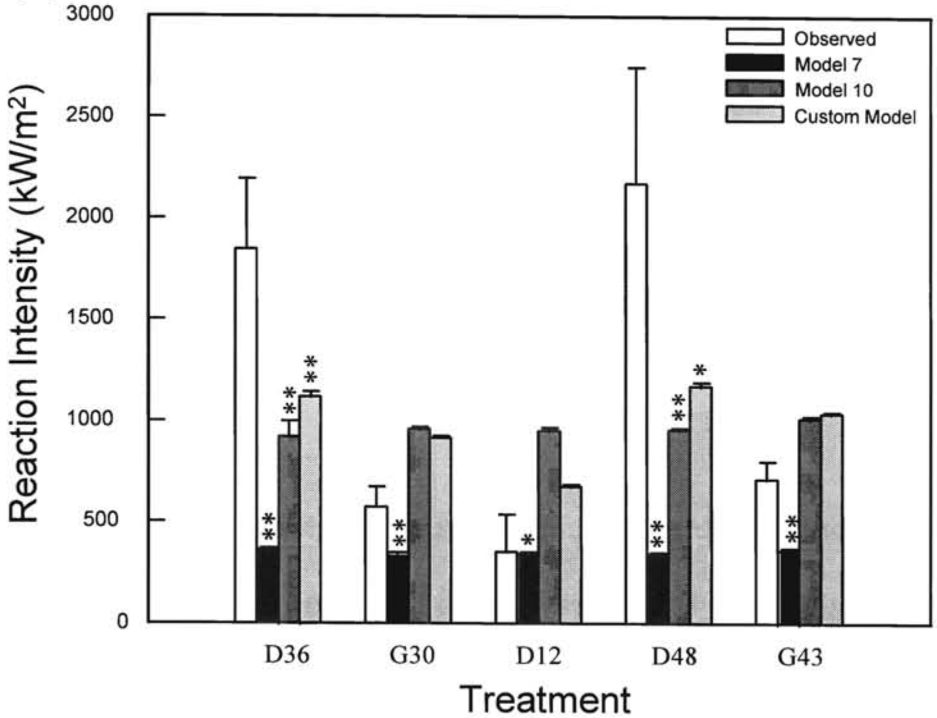
Observed
Model 7
Model 10
Custom Model
Rate of Spread (m/min)
12
10
8
6
4
2
0
D36
G30
D12
D48
G43
Treatment

(d)



Observed
Model 7
Model 10
Custom Model
Heat per Unit Area (kJ/m2)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
D36
G30
D12
D48
G43
Treatment

(e)



Reaction Intensity (kW/m²)
3000
2500
2000
1500
1000
500
0
Observed
Model 7
Model 10
Custom Model
D36
G30
D12
D48
G43
Treatment

CHAPTER IV

EFFECTS OF GROWING-SEASON AND DORMANT-SEASON PRESCRIBED FIRE ON HERBACEOUS VEGETATION IN RESTORED PINE-GRASSLAND COMMUNITIES

Abstract

Fire is essential in pine- (Pinus spp.) grassland communities to maintain open structure. We compared the effects of dormant-season and growing-season prescribed fires on herbaceous species in restored pine-grassland communities in the Ouachita Highlands of western Arkansas. Herbaceous species richness, diversity, and total forb and legume abundance increased following fire. Growing-season burns reduced distribution and abundance of panicums while dormant-season burns increased panicum distribution and abundance. Density of legumes increased following frequent or annual dormant-season fires. However, season of fire influenced the distribution and abundance of fewer than 10% of the species.

Key words: Arkansas, fire frequency, fire season, Ouachita Mountains

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Introduction

Fire in conjuction with other natural disturbances and environmental factors such as topography and climate created and maintained a mosaic of pre-settlement communities including grasslands, savannahs, and forests, throughout the world (Pyne, 1982; Anderson and Brown, 1986; Anderson, 1990; Waldrop et al., 1992). Fire plays a major role in the development and maintenance of plant communities and species dependent on those communities (Connell, 1978; Pickett and White, 1985; Noss and Cooperrider, 1994; Perry, 1994). After disturbance, many species and individuals may become established in an area where they previously did not occur, increasing species richness and relative abundance of individual species in that community (Sousa, 1984). Fire and other disturbances are a major source of temporal and spatial heterogeneity in structure and dynamics of a community (Sousa, 1984; Pickett and White, 1985). Most plant and wildlife species require specific habitats for their survival, and without some form of successional redirection or method of disturbance, these habitats will change (Komarek, 1963; Sparks and Masters, 1996).

Fire played an important role in shaping formerly abundant pine- (Pinus spp.) grassland communities in the southeastern United States (Buckner, 1989; Platt et al., 1988; Waldrop et al., 1992; Masters et al., 1995). These pine-grassland communities consisted of open "park like" pine stands with a distinct grass-dominated herbaceous layer and recurrent woody layer, depending on fire frequency (Komarek, 1965; Masters, 1991a; Waldrop et al., 1992; Masters et al., 1995). Historical accounts before settlement describe an open structure forest with substantial herbaceous material on the forest floor and occasional prairie openings or glades (James, 1823; Featherstonhaugh, 1844; Nuttall, 1980). The accumulation of herbaceous material provided adequate fuels for frequent fires of aboriginal and lightening origin which maintained the open structure of these pine-grassland communities (Komarek, 1965; Buckner, 1989; Foti and Glenn, 1991; Waldrop et al., 1992; Masters et al., 1995).

Similar to other forested communities of the World, settlement in the southeastern U.S. (18th to mid 19th century) altered these landscapes by removing or changing much of the natural vegetation, resulting in fragmented and dissected landscapes (Cottam, 1949; Stearns, 1949; Curtis, 1956; Forman and Godron, 1986; Kreiter, 1995). The frequency and scale of fires in the region declined after settlement because of aboriginal displacement, fragmentation of habitats causing artificial fire breaks, and fire suppression by settlers (Pyne, 1982). This decline in fire activity caused once open pine-grassland communities to become much more dense. Dense forests minimize light reaching the forest floor, thus reducing the herbaceous plant community, understory forage, and habitat quality for many species of wildlife (Lewis and Harshbarger, 1976; Masters, 1991a; Wilson et al., 1995). The endangered red-cockaded woodpecker (Picoides borealis), an endemic of southeastern pine forests, is one example of a species that has declined, in part, as a result of forest densification in southeastern United States.

The U.S. Forest Service has begun to reconstruct or restore pine-grassland communities to benefit both plant and wildlife species dependent on these systems. In the Ouachita National Forest of western Arkansas, the Forest Service uses a program known as Wildlife Stand Improvement (WSI) that consists of thinning midstory and codominant pine and hardwood trees to near pre-settlement basal areas. Currently, WSI treated stands are burned during the dormant season on 3 year intervals to maintain open structure. However, recent studies in the Ouachitas suggest that the historical fire regime was one of predominantly late growing-season fires and to a lesser extent dormant-season burns (Foti and Glenn, 1991; Masters et al., 1995). In order to effectively restore this system, knowledge of the effects of both growing-season and dormant-season prescribed burns is necessary (Masters and Wilson, 1994).

Numerous studies have compared the effects of growing-season and dormant-season fires on vegetation in Coastal Plain regions of Florida, Louisiana, and South Carolina (Grelen, 1975; Hughes, 1975; Lewis and Harshbarger, 1976; Platt et al., 1988; Waldrop et al., 1992; Glitzenstein et al., 1995). Masters (1991a;b) and Masters et al. (1993) described the effects of dormant-season burns of varying frequency on vegetation under a variety of overstory conditions in interior highlands. Masters et al. (1996) described the effects of WSI and dormant-season burns on restored pine-bluestem communities. However, no information is available on the effects of growing-season burns in the Ouachita Mountains. Our main objective was to compare the effects of growing-season and dormant-season burns on herbaceous vegetation richness, diversity, and abundance in WSI treated stands.

Study area

Our study focused on stands under active management for the endangered red-cockaded woodpecker within the 40,000 ha Pine-bluestem Ecosystem Renewal Area, on the Poteau Ranger District of the Ouachita National Forest (ONF) in Scott County Arkansas. The ONF lies within the 2,280,000 ha Ouachita Mixed Forest Meadow Province and comprises 648,000 ha throughout the Ouachita Mountains in Arkansas and Oklahoma (Neal and Montague, 1991; Bailey, 1995). The Ouachita mountains are east-west trending, strongly dissected and range in elevation from 150-790 m (Fenneman, 1938:669). South-facing slopes tend to be dominated by shortleaf pine (Pinus echinata) and more mesic north-facing slopes tend to be dominated by oaks (Quercus spp.), hickories (Carya spp.) and other hardwoods (Johnson, 1986; Foti and Glenn, 1991). Ouachita Mountain soils developed from sandstone and shales and are thin and drought prone. A semi-humid to humid climate prevails with hot summers and mild winters (Smith, 1989).

Shortleaf pine was the dominant overstory tree species in all stands. Codominant and intermediate overstory species included post oak (Quercus stellata), blackjack oak (Q. marilandica, white oak (Q. alba), northern red oak (Q. rubra), black oak (Q. velutina), black hickory (Carya texana), and mockernut hickory (C. tomentosa). Woody sprouts ($\leq$ 3-m) dominated the understory of these stands. The dominant understory woody species and vines included poison ivy (Toxicodendron radicans), low-bush huckleberry (Vaccinium pallidum), post oak, mockernut hickory, blackberry (Rubus spp.), virginia creeper (Parthenocissus quinquefolia), New Jersey tea (Ceanothus americanus), muscadine (Vitis rotundifolia), white oak and shortleaf pine (Sparks 1996).

Methods

Experimental design

Our experimental design encompassed two studies (Study 1 and Study 2) and was completely randomized. In these studies we used 12 stands (13.8 to 26.7 ha) that had been previously subjected to WSI and fire. Study 1 consisted of 3 treatments with 4 replications of each treatment (n = 12). Study 2 used the control and dormant-season fire stands from Study 1 (n = 8). Treatments are as follows:

Study 1

(1) No-burn control (CON1; n = 4);

(2) Growing-season burn, September 1994 (GS1; n = 4);

(3) Dormant-season burn March-April 1995 (DS1; n = 4);

Study 2

(4) Growing-season burn, October 1995 (GS2; n = 2);

(5) Dormant-season burn, March 1996 (DS2; n = 2);

(6) Frequent dormant-season fire, March-April 1995 and March 1996 (FDS; n = 2);

(7) Infrequent dormant-season fire, burned March-April 1995, no-burn 1996 (IFDS; n = 2).

Study 1 and Study 2 dormant-season and growing-season fire treatments differed in that prescribed burns were applied after 3 growing seasons versus 4, respectively, after previous dormant-season fire. Study 2 used the dormant-season fire treatments from Study 1 to determine the effects of fire frequency on the herbaceous community.

Vegetation sampling

We sampled herbaceous vegetation during a two week period in late July 1994 (Study 1 pre-treatment), July 1995 (Study 1 post-treatment; Study 2 pre-treatment), and July 1996 (Study 2 post-treatment). In each stand, we established 30, 1-m x 1-m permanent plots (after Oosting, 1956) at 30-m intervals on 2 to 4 randomly spaced lines perpendicular to the contour (after Masters, 1991a;b). We did not sample within 50-m of any edge to avoid bias from surrounding stands (Mueller-Dombois and Ellenberg, 1974:123). We recorded percent frequency of occurrence and stem density for each herbaceous species within permanent plots, and estimated cover for vascular plants and objects such as rocks, tree boles, and logs. We collected voucher specimens, and verified species identity with the Oklahoma State University Herbarium. We followed the nomenclature of Smith (1988). We deposited voucher specimens in the Oklahoma State University Herbarium.

Data analysis

We calculated species richness, diversity (Shannon-Weaver H') and evenness (J' of Pielou) after Ludwig and Reynolds (1988) at the sample (m^2) and stand scales. In both studies, we summarized herbaceous species by mean density and percent frequency of occurrence for each year and treatment. We classified all plant species according to plant type (e.g., forb, legume, grass etc.) and season of growth (cool vs warm). Season of growth was determined by flowering dates described by the Great Plains Flora Association (1986) with cool season species flowering from November to mid May, and warm season species flowering from mid May through October. To account for pre-treatment differences, we determined the percent change [(post-treatment / pre-treatment) X 100] in density and frequency of occurrence caused by treatments. We tested all variables for homogeneity of variance using Levene's test (Snedecor and Cochran, 1980). These tests indicated homogeneity of variances, so we tested for treatment differences in percent change using a one-way GLM in which treatment was the factor of interest (SAS Inst. Inc., 1985). In Study 1, we used orthogonal contrasts (burn vs no-burn and growing-season fire vs dormant-season fire) and separated treatment means ($\underline{P} \leq 0.05$) with the protected least significant difference test (Steel and Torrie, 1980; Conover and Iman, 1981).

We performed a detrended correspondence analysis (DCA) using CANOCO (ter Braak, 1988), to analyze the species composition data. DCA is a multivariate indirect gradient analysis that uses variation in species abundance data to display species and stand locations in a two-dimensional ordination space (ter Braak, 1986). DCA axes are in units of constant beta-diversity, where one unit is equal to one standard deviation of species turnover (Hill and Gauch 1980). In DCA, changes in location of a stand over time indicate corresponding changes in real or relative species composition of the stand (Wyant et al., 1991). We used DCA to analyze importance values (relative density + relative frequency) to determine changes in stand composition from pre-treatment to post-treatment (after Mueller-Dombois and Ellenberg, 1974; Smith, 1990). We square-root transformed species abundances before analysis.

Results

Response to fire and fire season

We observed more than 150 herbaceous species during these two studies. Fewer than 10% of these species were influenced ($P \leq 0.05$) by season of fire. Dormant-season fires produced a greater frequency of occurrence of Panicum dichotomum (Study 1: $F = 26.9$; $P = 0.0006$, Study 2: $F = 29.7$, $P = 0.0320$) and Scleria triglomerata (Study 1: $F = 15.3$; $P = 0.0035$, Study 2: $F = 19.9$, $P = 0.0467$) than growing-season fires. Density of Panicum dichotomum ($F = 54.5$; $P = 0.0001$) and Scleria triglomerata ($F = 5.6$; $P = 0.0416$) was less after growing-season fires than after dormant-season fires in Study 1.

Although few species were influenced by season of fire, differences ($P \leq 0.05$) in density and frequency of major plant categories were apparent (Tables 1 and 2). Dormant-season fires increased panicum density while growing-season fires greatly reduced total panicum density (Tables 1 and 2). Panicum frequency also declined after growing-season fires in Study 1 (Table 1). Grasses showed a tendency to increase in percent cover following fire (Table 3), but a tendency to decline in density following growing-season fires (Table 2).

Regardless of season, fire increased density of legumes (Tables 1 and 2). Legume species such as Stylosanthes biflora increased in density ($F = 16.9$; $P = 0.0026$) after fire, while other legumes such as Desmodium ciliare ($F = 6.58$; $P = 0.0334$) and Lespedeza procumbens ($F = 8.37$; $P = 0.0179$) increased in frequency of occurrence after fire. Fire also increased density and frequency of occurrence of numerous forbs such as Coreopsis tinctoria, Polygala alba, and Erechtites hieraciifolia, resulting in an increase in total forb density in Study 1 (Table 1). We found that forbs after dormant-season fires occurred more frequently than after growing-season fires and generally increased with fire (Table 1). Cover of herbaceous vegetation was similar for all treatments, but stands burned during the dormant season had more bare ground and exposed rock (Table 3). Warm season species had lower densities in response to growing-season burns than dormant-season burns (Table 1 and 2).

Response to frequent fire

Panicum frequency increased with frequent dormant-season burns (Table 4). However, density of Chasmanthium sessiliflorum declined ($F = 35.6$; $P = 0.0270$) after frequent dormant-season fire. Legume density was greater after frequent dormant-season fires (Table 4). Density of Lespedeza procumbens ($F = 124$, $P = 0.0080$) and Stylosanthes biflora ($F = 124.9$; $P = 0.0079$) was greater after frequent dormant-season fires. Helianthus hirsutus ($F = 33.7$; $P = 0.0284$) frequency of occurrence was also greater after frequent fire. Stand species richness in frequently burned stands remained stable, but declined in control stands (Figure 1).

Community response to fire

Fire and season of fire dramatically influenced community composition in restored pine-grassland stands. Species diversity when compared to un-burned stands was greater ($P \leq 0.05$) after both growing-season and dormant-season prescribed fires. Stand species richness increased after both growing-season and dormant-season fires, while declining in un-burned stands (Figure 1b). Furthermore, post-treatment stand species richness after dormant-season and growing-season fires was greater than the unburned controls in Study 1 (Figure 1a). Sample species richness increased dramatically after dormant-season fires with net change in stand species richness being greatest after dormant-season fires (Figure 2b). Species evenness was similar for all treatments.

Detrended Correspondence Analysis illustrated the nature of change in these stands over time and in response to fire (Figure 3). Axis 1 indicated that year to year variation may be the most important factor in determining species composition of these stands (Figure 3). Axis 2 indicated that location also determines species composition. We could not interpret Axis 3, but Axis 4 may be interpreted as a treatment axis (Figure 3). Control stands shifted to the right on Axis 1 and upward on Axis 4 indicating a year and treatment effect, while dormant-season fire stands shifted right on Axis 1 and down on Axis 4 also indicating a year and treatment effect (Figure 3). Growing-season fire stands shifted directly to the right on Axis 1 indicating that year had an overriding influence on treatment (Figure 3). The shift in stands after treatment indicates a similar change in species composition among the treatments. Axes 1 through 4 had eigenvalues of 0.161, 0.081, 0.056, and 0.042 respectively. Together all axes account for 26.5% of the total variation in species data. With an eigenvalue of only 0.042, and the fact that the apparent "treatment axis" is the 4th axis, it is obvious that the effects of treatment, while perhaps highly significant, is trivial compared with the year-to-year effects and site effects.

Discussion

Treatment response

Burned stands had higher stand species richness and diversity than no-burn controls (Figure 1). These results are similar to many studies that indicate an initial increase in species diversity and richness following fire (Trabaud and Lepart, 1980; Armour et al., 1984). In Study 2, stands in the 2nd growing season since dormant-season fire (IFDS), declined in species richness, indicating that the initial increase in stand richness after fire is short lived (Figure 1 and 2) and may be somewhat influenced by environmental conditions during a given year (Figure 3). The majority of individual species in both studies did not respond favorably to any one treatment, but were common in all treatments. We believe this is because species present in restored pine-grassland communities are well adapted to fire and community changes are small and of short duration. Waldrop et al. (1992) noted that the pine-grassland ecosystem once common throughout the southeastern U.S. was fire derived and fire maintained. Herbaceous species in these restored-pine grassland communities were present in pre-settlement communities that developed under a periodically frequent fire regime during both the dormant and growing seasons (Masters et al., 1995).

Fire does not drastically alter species composition in stands with a recent history of fire. Pre-fire composition is a major factor in determing post-fire composition (Armour et al., 1984; Stickney, 1986; Rego et al. 1991). Adjacent forests without WSI treatment have dense midstories minimizing light from reaching the forest floor, so species richness and abundance of herbaceous species is much less (Masters et al., 1996). We also suggest that post-fire species richness and composition is influenced by fire intensity, which is related to litter consumption and reduction in the stature of woody species.

Stand structure

Prescribed fire plays a major role in determining the vegetation structure and composition in restored pine-grassland communities (Wilson et al., 1995). Understories of stands treated with WSI are characteristically dominated by woody sprouts (> 50,000 stems/ha) that restrict light from reaching the forest floor. Dormant-season fires in these stands on average produce greater fireline intensity than growing-season fires (1,300 kW/m versus < 300 kW/m), and are more effective at maintaining an open forest structure by reducing the stature of woody sprouts (Sparks, 1996; Sparks et al., IN REVIEWa;b).

The effect of a disturbance such as fire on any community or ecosystem depends on the intensity, scale, and frequency (Sousa, 1984; Perry, 1994; Sparks 1996). Dormant-season fires in these stands act as more intense disturbances than growing-season fires, by more effectively reducing stature of the woody community and reducing the litter layer. Increased light penetration due to the reduced stature of the woody understory and reduction of litter after fire provides an opportunity for new herbaceous species to become established, thereby significantly increasing species richness and diversity (Sousa, 1984; Masters, 1991a;b; Masters et al., 1993). But, fire in either season increases light and allows already present species to prosper, thus the increase in density and percent frequency of occurrence of forbs after fire.

Species composition

Herbaceous species actively growing at the time of a fire in grassland systems are more susceptible to injury than species that are dormant or in early stages of development (Towne and Owensby, 1984). Fires during the dormant season reduce cool-season species while favoring many warm-season species (Owensby and Anderson, 1967; Hover and Bragg, 1981; Towne and Owensby, 1984; Hulbert, 1988; Howe, 1994a) In contrast, growing-season fires reduce warm-season species while favoring cool-season species (Hover and Bragg, 1981; Ewing and Engle, 1988; Biondini et al., 1989; Howe, 1994a). Our results in Study 2 followed these other studies, with density of warm-season species being greatest after dormant-season fires (Table 2). Results from Study 1 were inconclusive, which may be attributed to a later burn date within the dormant-season. Growing-season burns may have increased cool-season species had our growing-season fires been conducted earlier in the growing season and before cool-season species initiated new growth. It is important to note that in both studies we attempted to burn earlier in the growing season, but burning conditions (primarily fuel moisture, presence of live vegetation and high relative humidities) were not conducive to fire until later in the growing season.

Several studies have noted that growing-season fires when compared to dormant-season fires and unburned areas increase diversity and richness by increasing the number of annuals and promoting cool-season grasses and forbs (Biondini et al., 1989; Howe, 1994b). Platt et al. (1988) noted that growing-season fires produced more flowering stems than fires in other seasons. Many warm-season grasses such as wiregrass (Aristida stricta) and little bluestem (Schizachrium scoparium) flower profusely after growing-season fires (Lewis, 1964; Robbins and Myers, 1992). Hodgkins (1958) noted that composites and legumes increase in response to growing-season fires. Our results indicate an aggressive response from legumes and forbs (Table 1 and 2), and a larger increase in species richness after dormant-season fires (Figure 1 and 2). Other studies have found similar results (Grelen and Lewis, 1981; Landers, 1981, and White et al. 1991). In Study 2, legume density was greater after frequent dormant-season fires, which are results similar to those of White et al. (1991) who found annual winter fires increased legumes more than periodic summer and winter burns or annual summer burns.

Conclusions

Fire changes woody structure, which influences plant composition in restored pine-grassland ecosystems. Fire increased species richness, diversity, and total abundance of forbs and legumes, while herbaceous species abundance and richness declined in no-burn controls. Increased light and presence of bare ground after fire provide the opportunity for many herbaceous species to become established. Change in species composition and abundance is linked to change in stand structure. Dormant-season fires are more effective than growing-season fires at reducing woody sprouts in the understory and at providing bare ground for colonization. As a result, herbaceous species abundance and richness was greater after dormant-season fires.

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Table 1.[a] Study 1, herbaceous stem density (stems/m^2) and percent frequency of occurrence response to season of fire in restored pine-grassland communities on the Ouachita National Forest, Arkansas, summer 1994 and 1995.

	Treatment[b]								
	No-burn Control		Dormant Season		Growing Season		P > F		
	1995 Mean (SE)	Percent[b] change	1995 Mean (SE)	Percent[b] change	1995 Mean (SE)	Percent[b] change		Contrasts[c]	
Parameter, Group	(n=4)	(n=4)	(n=4)	(n=4)	(n=4)	(n=4)	Treatment	C vs B	D vs G
Density (stems/m^2)									
Grasses	42.7 (1.1)	116	37.4 (6.3)	100	24.8 (5.1)	65	0.3477	0.2806	0.3292
Panicums	17.2 (5.7)	106A	27.5 (6.2)	134A	8.4 (2.2)	23B	0.0194	0.3519	0.0077
Sedges	8.0 (0.9)	73	22.3 (2.4)	129	13.8 (1.8)	81	0.1085	0.1850	0.0872
Legumes	20.8 (7.6)	102B	24.8 (4.1)	198A	23.5 (6.7)	165AB	0.0259	0.0115	0.2864
Forbs	21.0 (1.8)	105B	48.4 (1.2)	226A	29.5 (4.8)	142AB	0.0353	0.0451	0.0625
Cool-season Species	26.8 (3.5)	116	54.0 (5.2)	187	31.6 (4.0)	88	0.1599	0.6160	0.0692
Warm-season Species	82.7 (7.2)	102	106.3 (8.0)	131	68.4 (11.8)	76	0.2005	0.9604	0.0811
Percent Frequency of Occurrence									
Grasses	77 (3)	97	77 (4)	102	69 (6)	88	0.3026	0.8060	0.1364
Panicums	82 (6)	96A	93 (3)	109A	63 (2)	67B	0.0005	0.1874	0.0002
Sedges	58 (3)	95	79 (6)	106	70 (7)	90	0.5019	0.7559	0.2691
Legumes	80 (11)	94	85 (7)	103	88 (10)	115	0.2330	0.1732	0.2922
Forbs	95 (2)	99	99 (1)	105	95 (5)	97	0.1181	0.5692	0.0500
Cool-season Species	93 (2)	99	98 (2)	102	95 (5)	96	0.4027	0.9852	0.1894
Warm-season Species	99 (1)	99	100 (0)	101	98 (3)	101	0.6252	0.3511	0.8828

[a] Row means followed by different letters are different ($P \le 0.05$, Least Significant Difference).

[b] Percent change = [(post treatment (1995) / pre-treatment (1994)) X 100] , presented P > F values are for this category.

[c] Contrasts: C = Control; B = Burned stands regardless of season; D = Dormant-season fires; G = Growing-season fires.

Table 2.[a] Study 2, herbaceous stem density (stems/m^2) and percent frequency of occurrence response to season of fire in restored pine-grassland communities on the Ouachita National Forest, Arkansas, summer 1995 and 1996.

	Treatment[b]				
	Dormant Season		Growing Season		
	1996 Mean (SE)	Percent[b] change	1996 Mean (SE)	Percent[b] change	P > F
Parameter, Group	(n=2)	(n=2)	(n=2)	(n=2)	Treatment
Density (stems/m^2)					
Grasses	47.9 (6.9)	115	16.7 (6.1)	38	0.0724
Panicums	18.6 (10.6)	110	8.4 (5.4)	45	0.0056
Sedges	12.2 (3.7)	142	8.0 (1.7)	104	0.1758
Legumes	29.6 (14.6)	184	23.8 (11.8)	104	0.0451
Forbs	28.7 (1.9)	143	21.4 (0.3)	101	0.1781
Cool-season Species	37.6 (4.4)	124	20.1 (5.6)	88	0.3087
Warm-season Species	101.1 (10.0)	140	58.6 (16.3)	63	0.0451
Percent Frequency of Occurrence					
Grasses	77 (17)	105	67 (3)	84	0.4563
Panicums	78 (5)	100	67 (3)	80	0.1987
Sedges	67 (3)	123	60 (3)	100	0.3352
Legumes	85 (15)	120	93 (0)	110	0.6865
Forbs	98 (2)	102	100 (0)	107	0.4226
Cool-season Species	100 (0)	106	98 (2)	107	0.7863
Warm-season Species	100 (0)	102	100 (0)	100	0.4226

[a] Row means followed by different letters are different ($\underline{P} \leq 0.05$, Least Significant Difference).

[b] Percent change = [(post treatment (1995) / pre-treatment (1994) X 100] , presented $\underline{P} > F$ values are for this category.

Table 3.[a] Post-treatment percent cover in restored red-cockaded woodpecker clusters on the Ouachita National Forest, Arkansas in 1995.

	Treatment						P > F		
	Control (n=4)		Dormant Season (n=4)		Growing Season (n=4)			Contrasts[b]	
Group	Mean	SE	Mean	SE	Mean	SE	Treatment	C vs B	D vs G
Bare Ground	0.1B	0.1	6.4A	0.6	1.4B	0.6	0.0001	0.0001	0.0001
Litter	74.5	2.4	51.3	14.2	73.8	6.3	0.1787	0.3114	0.1149
Rock	0.5B	0.2	3.9A	0.8	1.3B	0.2	0.0019	0.0057	0.0045
Logs	2.9	0.8	2.7	0.5	3.6	0.7	0.6449	0.7773	0.3842
Tree Bole	0.3B	0.1	0.8A	0.2	0.1B	0.1	0.0111	0.3599	0.0042
Cryptogams	1.0	0.5	1.8	1.2	0.1	0.0	0.3233	0.9020	0.1447
Woody Species	24.7	4.1	16.6	3.0	18.0	3.1	0.2609	0.1141	0.7979
Forbs	7.8	1.9	10.4	0.9	9.2	3.0	0.7161	0.4756	0.7180
Grasses	10.9	3.5	5.3	0.8	4.8	1.2	0.1474	0.0582	0.7991

[a] Row means followed by different letters are different ($\underline{P} \leq 0.05$, Least Significant Difference).

[b] Contrasts: C = Control; B = Burned stands regardless of season; D = Dormant-season fires; G = Growing-season fires.

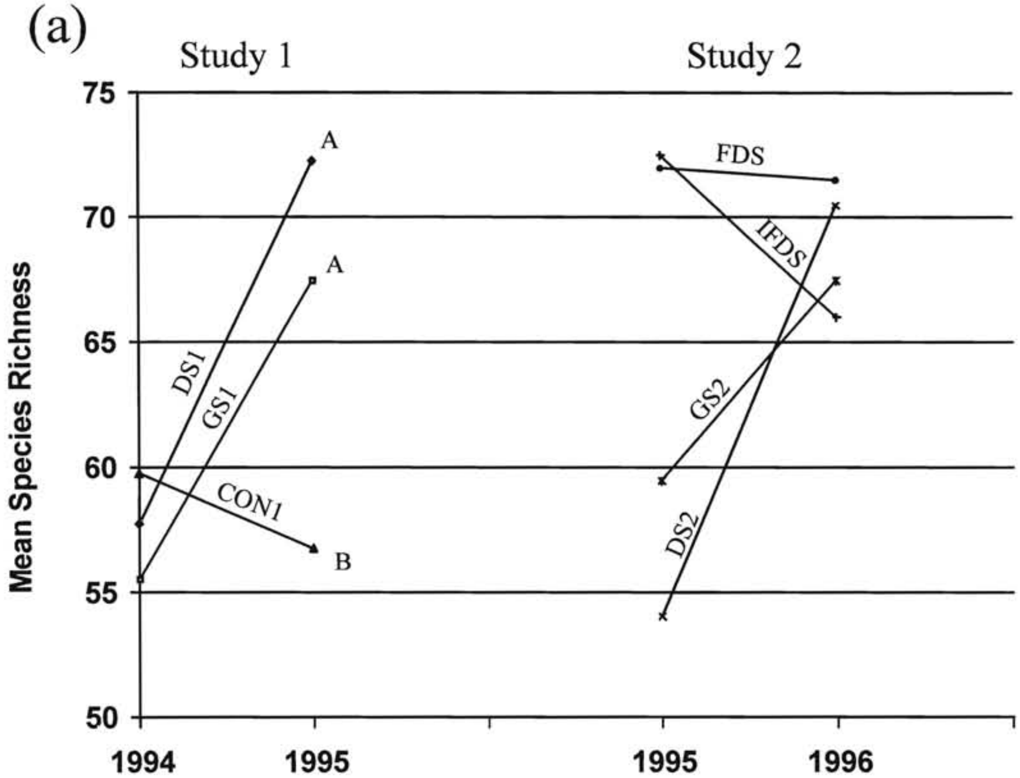
Table 4.[a] Study 2, herbaceous stem density (stems/m^2) and percent frequency of occurrence response to frequent fire in restored pine-grassland communities on the Ouachita National Forest, Arkansas, summer 1995 and 1996.

	Treatment				
	Control		Frequent Fire		
	1996	Percent[b]	1996	Percent[b]	
	Mean (SE)	change	Mean (SE)	change	P > F
Parameter, Group	(n=2)	(n=2)	(n=2)	(n=2)	Treatment
Density (stems/m^2)					
Grasses	57.7 (4.4)	130	32.5 (8.7)	109	0.3744
Panicums	18.9 (8.7)	76	21.5 (2.6)	75	0.9556
Sedges	25.3 (3.0)	96	15.5 (1.1)	86	0.4414
Legumes	17.0 (5.8)	79	32.6 (2.8)	118	0.0234
Forbs	30.9 (5.5)	65	30.2 (1.9)	62	0.8398
Percent Frequency of Occurrence					
Grasses	78 (5)	94	75 (2)	108	0.2951
Panicums	88 (2)	91	88 (2)	100	0.0267
Sedges	82 (2)	106	72 (5)	90	0.3854
Legumes	85 (15)	103	95 (2)	110	0.3906
Forbs	98 (2)	100	98 (2)	98	0.4226

[a] Row means followed by different letters are different ($P \leq 0.05$, Least Significant Difference).

[b] Percent change = [(post treatment (1995) / pre-treatment (1994)) X 100] , presented $P > F$ values are for this category.

Figure 1. (a) Stand species richness by study and treatment, (b) Net-change and standard errors in stand species richness by study and treatment. Means followed by different letters are different ($P \leq 0.05$, Least Significant Difference). CON1 = Study 1, no-burn control; GS1 = Study 1, growing-season burn; DS1 = Study 1, dormant-season burn; GS2 = Study 2, growing-season burn; DS2 = Study 2, dormant-season burn; FDS = Study 2, frequent dormant-season burn; and IFDS = Study 2, infrequent dormant-season burn.


(a)
Study 1
Study 2
Mean Species Richness
75
70
65
60
55
50
1994
1995
1995
1996
DS1
GS1
CON1
A
A
B
FDS
IFDS
GS2
DS2

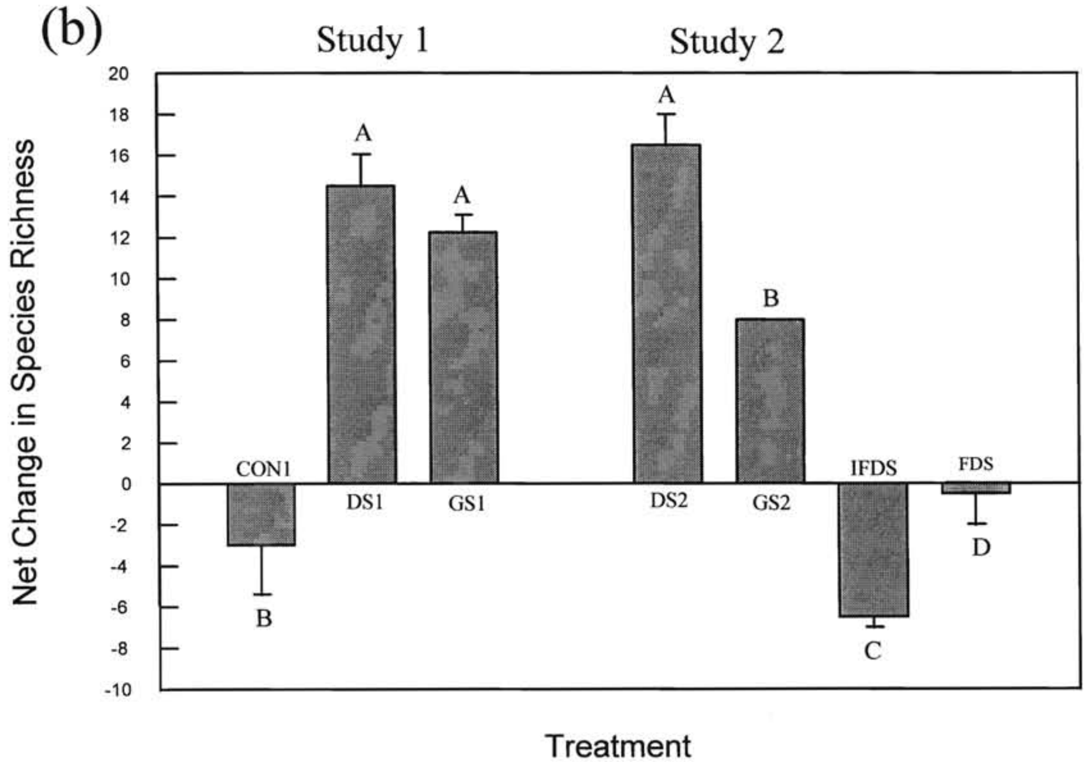

(b)
Study 1
Study 2
Net Change in Species Richness
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
CON1
DS1
GS1
DS2
GS2
IFDS
FDS
A
A
A
B
B
C
D
Treatment

Figure 2. (a) Sample (m^2) species richness by study and treatment, (b) Net-change and standard errors in sample species richness by study and treatment. Means followed by different letters are different ($\underline{P} \leq 0.05$, Least Significant Difference). CON1 = Study 1, no-burn control; GS1 = Study 1, growing-season burn; DS1 = Study 1, dormant-season burn; GS2 = Study 2, growing-season burn; DS2 = Study 2, dormant-season burn; FDS = Study 2, frequent dormant-season burn; and IFDS = Study 2, infrequent dormant-season burn.

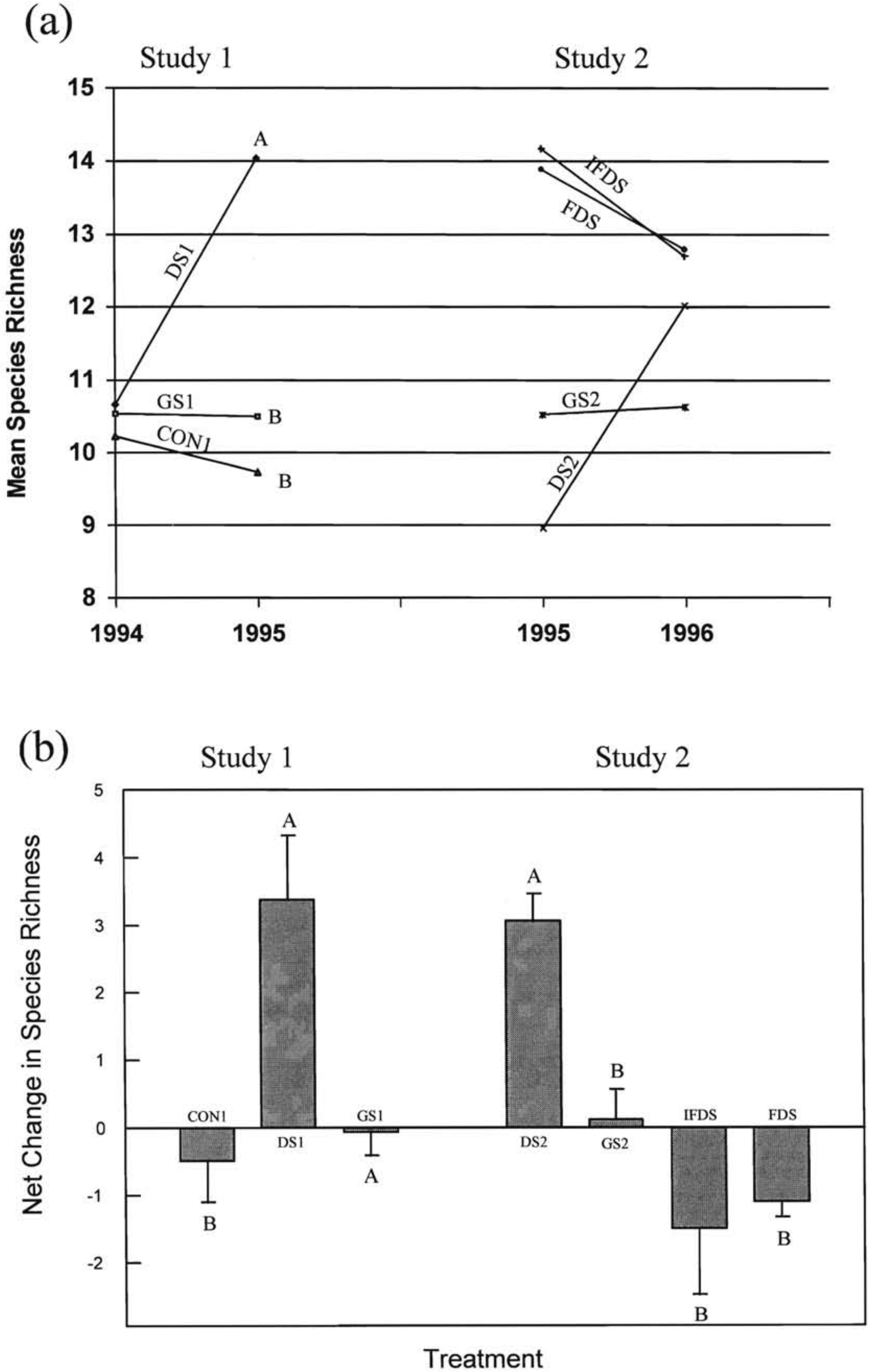
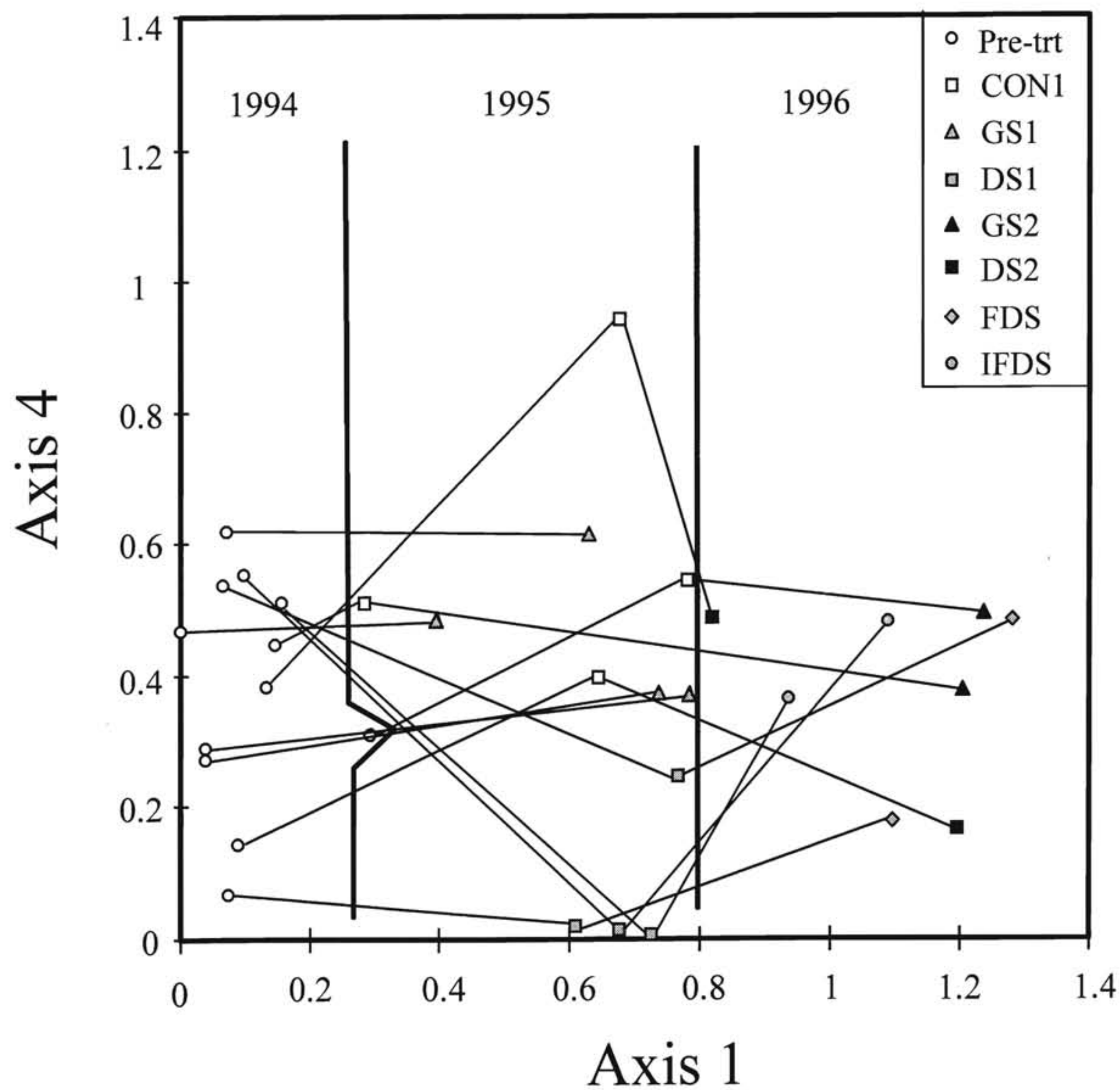

(a)
Study 1
Study 2
Mean Species Richness
15
14
13
12
11
10
9
8
1994
1995
1995
1996
A
DS1
GS1
B
CON1
B
IFDS
FDS
GS2
DS2
(b)
Study 1
Study 2
Net Change in Species Richness
5
4
3
2
1
0
-1
-2
CON1
DS1
GS1
DS2
GS2
IFDS
FDS
A
A
B
A
B
B
B
Treatment

Figure 3. Detrended correspondence analysis of stand importance values by treatment, Ouachita National Forest. Stands are connected by vectors to indicate change from pre-treatment sampling to post-treatment sampling. CON1 = Study 1, no-burn control; GS1 = Study 1, growing-season burn; DS1 = Study 1, dormant-season burn; GS2 = Study 2, growing-season burn; DS2 = Study 2, dormant-season burn; FDS = Study 2, frequent dormant-season burn; and IFDS = Study 2, infrequent dormant-season burn.


1994
1995
1996
Pre-trt
CON1
GS1
DS1
GS2
DS2
FDS
IFDS
Axis 4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Axis 1

CHAPTER V

GROWING-SEASON VERSUS DORMANT-SEASON FIRE FOR WOODY SPECIES MANAGEMENT IN RED-COCKADED WOODPECKER CLUSTERS

Abstract: Control of woody midstory in red-cockaded woodpecker clusters is a major concern throughout southeastern U.S pine forests. Prescribed fire and midstory thinning are the most common management tools used to restore pine-grassland communities and minimize midstory development, however it is unclear which season of fire is most efficient. We compared woody stem control from prescribed fires during both the late growing season (September--October: before leaf fall) and dormant season (March--April: before leaf expansion). We found mortality of woody stems $\geq$ 1-m tall was related to fireline intensity, rate of spread, and heat per unit area. Growing-season fires were less intense than dormant-season fires, and less effective at reducing woody stems $\geq$ 1-m tall in the understory and lower midstory. Because of prolific sprouting, neither growing-season nor dormant-season prescribed fires were effective at reducing stems $<$ 1-m tall. We recommend that studies using prescribed fire should quantify fire behavior rather than using subjective descriptions and should precisely define season of burn.

INTRODUCTION

The endangered red-cockaded woodpecker (Picoides borealis) is endemic to the fire derived or maintained, pine- (Pinus spp.) grassland ecosystem once common throughout the southeastern U.S. (Conner and Rudolph 1989, 1991; Masters et al. 1996). Pine-grassland communities consist of widely spaced pine or mixed pine-hardwood canopies with a distinct herbaceous and grass dominated groundstory (Little and Olmstead 1931, Smith 1986, Waldrop et al. 1992), and a recurrent hardwood shrub layer or midstory on some sites (Masters et al. 1995). After Euro-American settlement these once open communities changed drastically because of habitat loss through timber harvest and fire suppression (Foti and Glenn 1991, Kreiter 1995, Masters et al. 1995). Subsequently, red-cockaded woodpecker populations declined precipitously (Ligon et al. 1986, Conner and Rudolph 1989, 1991; Conner et al. 1991a,b; Kelly et al. 1993, Heppell et al. 1994).

Fire historically maintained open southeastern forest conditions (Buckner 1989, Masters et al. 1995, Kreiter 1995). However, fire suppression following settlement permitted development of dense midstories (primarily hardwoods) and an increase in overall tree density (Conner and Rudolph 1989, Foti and Glenn 1991, Masters et al. 1995, Kreiter 1995). Encroachment of hardwood midstories cause red-cockaded woodpeckers to abandon cavities and even entire clusters (Lennartz et al. 1983, Richardson and Smith 1992). Therefore, removal of midstory and codominant trees within active red-cockaded woodpecker clusters is essential when managing for red-cockaded woodpeckers.

Increased interest in ecosystem management over single species management prompted the U.S.D.A. Forest Service to focus on broader efforts using wildlife stand improvement (WSI) and fire (Masters et al. 1996). WSI consists of thinning midstory and codominant trees to presettlement basal area followed by application of fire at 3-year intervals (Wilson et al. 1995, Masters et al. 1996). The primary objective of WSI and fire is to reconstruct and maintain presettlement forest structure and benefit wildlife and plant species dependent on open forests and fire.

Because woody plants that sprout after thinning are common in southeastern pine forests, periodic dormant-season prescribed fires are used to maintain WSI stands and prevent midstory development. Dormant-season fires in WSI stands topkill the majority of woody stems in the understory and midstory, but these stems are replaced by numerous sprouts (Wilson et al. 1995, Waldrop et al. 1987, 1991; Glitzenstein et al. 1995). Because woody sprouts grow rapidly after fire, stands must be burned every 3 to 4 years to prevent midstory development. With small administrative units (generally < 16 ha) this fire interval limits the area than can be burned on an annual basis. Therefore, interest has increased in using growing-season prescribed fires as a potential method of extending the number of burning days per year and possibly the interval between burns.

Several studies in the Ouachita Highlands have investigated the effects of dormant-season fire frequency on woody understory and midstory species (Masters 1991a,b; Masters et al. 1993, Masters et al. 1996). However, no information is available on the effects of growing-season burns on woody species in the forest understory and midstory of the Ouachita Mountains. Numerous studies performed in the Coastal Plains of the southeast suggest growing-season fires are more effective than dormant-season fires in controlling small hardwoods and sprouts (Brender and Cooper 1968, Chaiken 1952, Ferguson 1961, Grano 1970, Grelen 1975, Hodgkins 1958, Lotti et al. 1960, Trousdell 1970, Waldrop et al. 1987, Boyer 1990).

Our purpose was to evaluate the effects of growing-season and dormant-season prescribed fires on woody structure in restored pine-grassland communities. Our primary objective was to determine which season of fire (growing versus dormant) was most effective at topkilling understory and lower midstory woody species in WSI treated stands. We compared no-burn control WSI stands with WSI stands burned during the growing season and dormant season. A secondary objective was to determine if fire behavior parameters (i.e., flame length, fireline intensity, rate of spread, heat per unit area, and reaction intensity) were related with woody stem response following prescribed fire.

STUDY AREA

Our study was conducted on the Poteau Ranger district of the Ouachita National Forest (ONF) in west-central Arkansas. The ONF lies within the 2,280,000 ha Ouachita Mixed Forest Meadow Province and comprises 648,000 ha throughout the Ouachita Mountains in Arkansas and Oklahoma (Neal and Montague 1991, Bailey 1995). All stands in this study were within the 40,000 ha Pine-bluestem Ecosystem Renewal Area, and were under active management for the endangered red-cockaded woodpecker. Other studies have described the physical features of these stands

(Wilson et al. 1995, Masters et al. 1996, Sparks 1996, Sparks et al. IN REVIEWa).

Forest structure in these stands resemble presettlement pine-grasslands, with shortleaf pine (Pinus echinata) as the dominant overstory species. Codominant and intermediate overstory species included post oak (Quercus stellata), blackjack oak (Q. marilandica, white oak (Q. alba), northern red oak (Q. rubra), black oak (Q. velutina), black hickory (Carya texana), and mockernut hickory (C. tomentosa). The understory and lower midstory of these stands were dominated by numerous woody resprouts ($\leq$ 3-m). Woody species and vines dominating the understory included poison ivy (Toxicodendron radicans), low-bush huckleberry (Vaccinium pallidum), post oak, mockernut hickory, blackberry (Rubus spp.), virginia creeper (Parthenocissus quinquefolia), New Jersey tea (Ceanothus americanus), muscadine (Vitis rotundifolia), white oak and shortleaf pine (Sparks 1996).

METHODS

Experimental Design

Our experimental design included two studies (Study 1 and Study 2) in a completely randomized design. In these studies we used 12 stands (13.8 to 26.7 ha) that had been previously subjected to WSI and fire. Study 1 consisted of 3 treatments with 4 replications of each treatment (n = 12). Study 2 used the control stands from Study 1 (n = 4). Study 1 and Study 2 treatments differed in that prescribed burns were applied after 3 growing seasons versus 4 growing seasons, respectively after the previous dormant-season fire. Treatments are as follows:

Study 1

(1) No-burn control (n = 4);

(2) Dormant-season fire, March--April 1995 (n = 4);

(3) Growing-season fire, September 1994 (n = 4);

Study 2

(4) Dormant-season fire, March 1996 (n = 2);

(5) Growing-season fire, October 1995 (n = 2).

Vegetation Sampling

We sampled woody vegetation during a two week period in July 1994 (pre-treatment, Study 1), July 1995 (post-treatment, Study 1; pre-treatment Study 2), and July 1996 (post-treatment, Study 2). We established 30 permanent plots in each stand at 30-m intervals on 2 to 4 randomly spaced lines perpendicular to the contour (after Oosting 1956, Masters 1991a,b). We did not sample within 50-m of any edge to avoid bias from surrounding stands (Mueller-Dombois and Ellenberg 1974:123). We divided woody understory, shrub, and midstory species into three height classes 0 to 1-m, 1 to 3-m, and > 3-m. We determined species density and composition within these height classes using fixed-radius plots (radius = 3.64-m). We estimated basal area using a 10-factor prism (Avery 1967) and percent canopy cover using a spherical densiometer (Lemmon 1957) at each permanent plot.

Fire Behavior

We used strip headfires to burn each stand at the appropriate dates (see above). Fire behavior was sampled at 3 random locations within a stand. Further description of methods used to sample and calculate fire behavior parameters was reported by Sparks et al. (IN REVIEWa). Fire behavior data are presented in Table 1.

Data Analysis

We calculated species richness, diversity (Shannon-Weaver H') and evenness (J' of Pielou) after Ludwig and Reynolds (1988). In both studies, we summarized woody species by mean density and frequency of occurrence for each year and treatment. We then determined the percent change caused by treatment [(post-treatment / pre-treatment) X 100] to account for pre-treatment differences among stands and tested these variables for homogeneity of variance using Levene's test (Snedecor and Cochran 1980). These tests indicated heterogeneity of variances, so we tested for treatment differences ($P \leq 0.05$) using the Kruskal-Wallis nonparametric test on percent change (SAS Inst., Inc. 1985:651). In Study 1 we used orthogonal contrasts (burn vs no-burn and growing-season fire vs dormant-season fire). We separated mean differences ($P \leq 0.05$) with the protected least significant difference test (Steel and Torrie 1980, Conover and Iman 1981). We used a large population effect (F-ratio = 4.0) to determine power (1-∃). Study 1 power or the probability of a Type II error (failure to reject the null hypothesis) was 0.31 (Critical F = 4.26; df = 2, 9), while study 2 power was 0.22 (Critical F = 18.51; df = 1, 2). We used linear regression on inverse transformed fire behavior parameters to determine if fire behavior was related to total woody stem density ($\geq$ 1-m).

RESULTS AND DISCUSSION

Prescribed fire plays a major role in determining the structure of restored pine-grassland communities (Masters et al. 1996, Wilson et al. 1995). Fire, regardless of season, reduced stature of woody stems, but nearly all woody species in these stands sprouted after fire (Table 2). Species richness, diversity and evenness were not affected by fire or season of fire, because of the tendency for woody species to sprout after fire.

Understory Structure, Stems < 1-m

Stem density in the 0 to 1-m height class did not differ among control and burn treatments or with season of fire (Table 2 and 3). The majority of species in the 0 to 1-m height class were not affected by season of fire. However, in Study 1, stem densities of post oak (Quercus stellata) ($F = 18.6$; $P = 0.0020$) and black oak (Quercus velutina) ($F = 6.0$; $P = 0.0368$) increased after fire regardless of season. Black-jack oak (Quercus marilandica) stem density ($F = 6.5$; $P = 0.0179$) and frequency of occurrence ($F = 57.6$; $P = 0.0001$) declined after fire regardless of season. Our results vary slightly from those of Huddle and Pallardy (1996), who determined Erythrobalanus (black and red oak sub-genus) oak species were more susceptible to mortality after fire than post oaks. This difference may be attributed to the fact that Huddle and Pallardy (1996) combined all Erythrobalanus oak species, while we examined species separately.

<u>**Midstory Structure, Stems > 1-m**</u>

Stem density and frequency of occurrence in the 1 to 3-m height class was less after prescribed fire in either season, but dormant-season fires were more effective than growing-season fires at reducing stems in the 1 to 3-m height class (Table 2). Fire in both seasons caused all woody species $\geq$ 1-m to decline in density and frequency of occurrence ($P < 0.05$). Waldrop et al. (1992) and Waldrop and Lloyd (1991) documented a similar shift in hardwoods after periodic winter and summer fires. Fire maintained WSI stands by reducing stems $\geq$ 1-m. Dormant-season prescribed fires produced higher fire intensities and were generally more effective at controlling stem density and frequency.

As woody species age they develop thick insulative bark and elevate terminal buds (Wade 1986, Waldrop et al. 1992, Huddle and Pallardy 1996), these conditions protect stems > 3-m in the midstory (Table 2 and 3) and common canopy species from fire induced mortality. The potential for mortality of canopy species is greater following late growing-season fires because of higher ambient air temperatures and lower windspeeds (Ferguson 1961, Robbins and Myers 1992).

Studies in Coastal Plain communities of southeastern U.S. suggest growing-season fires are more effective at controlling woody species in the understory and midstory (Ferguson 1961, Grano 1970, Grelen 1975, Hodgkins 1958, Lotti et al. 1960, Trousdell 1970, Waldrop et al. 1987, Boyer 1990, Glitzenstein et al. 1995). These studies conclude successive annual summer fires are extremely effective at killing and reducing woody stem densities. Waldrop and Lloyd (1991) noted that after 20 years of annual "hot" summer fires, hardwood rootstocks began to die and woody stem density declined. It is important to note that Coastal Plains studies were conducted in a different habitat (fuel) type than the Ouachita Highlands where fuel continuity, woody species composition and flammability may be different. These studies also concentrated on the use of frequent fire and early to mid growing-season fires. Early to mid growing-season fires are rarely possible in the Ouachita Highlands because of high fuel moisture, low wind speeds, and presence of substantial amounts of live vegetation. Limited dead fuels, presence of lush vegetation of low flammability, and high percentage of exposed surface rock make it near impossible to perform annual or frequent early to mid summer fires. These conditions restricted this study to periodic, late growing-season fires that may not be as effective as frequent or early growing-season fires achieved in other regions of southeastern U.S. If land managers are unable to achieve burning targets on three year intervals, annual fires would further compound the problem.

Response of woody species to fire varies with the timing of fires within a season (Robbins and Myers 1992). For example, the increase of woody stems between 0 and 1-m in Study 2 may be attributed to the timing of fire within the dormant season (Table 3). Fires in Study 1 were at the time of bud break for many of the woody species (late March-early April), while dormant-season fires in Study 2 were a month earlier. Fires early in the growing season (i.e., late in the dormant season), immediately after leaf expansion, are believed most effective for weakening and killing deciduous trees because carbohydrate root reserves are at their lowest point (Woods et al. 1959, Boyer

1990, Waldrop and Lloyd 1991). When fires are conducted annually over a long period of time, carbohydrate reserves diminish and root systems begin to die (Waldrop et al. 1987, Waldrop and Lloyd 1991). However, periodic winter and summer fires and annual winter fires provide at least one full growing season for sprouts to replenish depleted carbohydrate reserves before the next burning event (Waldrop and Lloyd 1991). Without long term, annual growing-season fires it is questionable whether fire alone can reduce stem density of hardwood sprouts (Waldrop and Lloyd 1991).

Woody Response to Fire Behavior

Changes to vegetation caused by fire depend on fire behavior, season of fire, fire frequency, number of successive fires and previous stand conditions (Waldrop and Lloyd 1991, Masters et al. 1993). Dormant-season fires in these stands tend to produce greater fire intensities than growing-season fires (Table 1). Dormant-season fires topkill a larger proportion of woody stems $\geq$ 1-m than growing-season fires, and thus are more effective at maintaining an open forest structure by reducing stature of woody stems (Table 2 and 3). Fire regardless of season was not effective at reducing the number of stems $<$ 1-m, and often resulted in an increase in stems (Table 2 and 3).

Fire intensity influences woody understory and lower midstory structure. We found a discrete relationship between stem density and observed fire behavior parameters. The best model ($\underline{r}^2 = 0.79$; $\underline{F} = 37.8$; $\underline{P} = 0.0001$) was for stem density and the inverse of fireline intensity (Kw/m) (Figure 1a). Other parameters that influenced woody stem density were the inverse of rate of spread (m/min) and the inverse of reaction intensity (KW/m^2) (Figure 1b and 1c). As fire intensity increases, stems $\geq$ 1-m decline, creating a more open forest structure, an important consideration for pine-grassland restoration.

Fire behavior parameters such as fireline intensity, reaction intensity, and rate of spread relate to fire effects on vegetation (Van Wagner 1973, Rothermel and Deeming 1980, Alexander 1982, Wright and Bailey 1982, Wade 1986, Engle et al. 1996). Natural resource managers can utilize results from studies such as ours to determine desired fire behavior parameters required to meet specific objectives. Furthermore, managers can increase the efficiency of their burning program by using computer software such as BEHAVE to predict fire behavior parameters before fire ignition (Sparks et al. IN REVIEWb). Computer models such as BEHAVE utilize on-site environmental variables to predict fire behavior before fires are initiated, thus providing managers with insight on the probability of achieving desired objectives (Raybould and Roberts 1983, Andrews and Bradshaw 1990, Masters and Engle 1994, Sparks et al. IN REVIEWb). Land managers can also use these programs to define "windows" of acceptable burning conditions (i.e., fuel moisture, temperature, relative humidity, and windspeed) to meet their objectives (Andrews and Bradshaw 1990).

MANAGEMENT IMPLICATIONS

The majority of studies comparing the effects of growing-season and dormant-season fires did not quantify fire behavior. We strongly recommend that managers and researchers quantify fire behavior rather than use general descriptive terms such as "low", "moderate", and "high" intensity fires, or "hot" and "cool" fires. Fire behavior in the Ouachita Highlands may vary from that of the Coastal Plains because of highly discontinuous fuel beds caused by exposed surface rock, steep slopes, and strongly dissected landscapes. Furthermore, understory woody species composition and fuel flammability in the Ouachita Highlands may be considerably different than those in Coastal Plain regions.

Growing-season fires in these stands burned with low intensities and heterogenous fire fronts creating a mosaic of burned and unburned areas (Sparks et al. IN REVIEWa). Therefore, growing-season fires were not as efficient at reducing stature of woody stems in the understory or lower midstory. Stems spared by growing-season fires and by future fires may begin to develop a midstory, and reduce habitat quality for red-cockaded woodpeckers. However, numerous other wildlife species may benefit from the mosaic of habitats created by patchy burning patterns of growing-season fires (Burrows and Christensen 1991). The goal of WSI and fire is not to eliminate, but to reduce stature of hardwoods, because the recurrent hardwood shrub layer present in restored pine-grassland communities is important to other species of wildlife such as the prairie warbler (Dendroica discolor) (Wilson et al. 1995).

Managers must be aware of potential for damage or mortality of canopy species (i.e., pine) following growing-season fires (Ferguson 1961, Robbins and Myers 1992). Red-cockaded woodpecker cavity trees may be limiting in many stands, therefore crown scorch and damage to overstory pines is a major consideration (Sparks et al. IN REVIEWa). To overcome these problems, managers can modify prescriptions to include lower ambient air temperatures, higher fuel moisture, and greater windspeeds (Wade 1986, Robbins and Myers 1992, Sparks et al. IN REVIEWa). Our results indicate that there is no silvicultural advantage to using growing-season fires for woody stem control, because all dormant-season fires (i.e., the lowest intensity dormant-season fire) were more effective at reducing stems $\geq$ 1-m (Figure 1). From an ecological perspective both seasons of fire most likely play an important role. We also see little advantage to burning stands with intense fires ($\geq$ 345 kW/m), because the majority of stem kill on stems $\geq$ 1-m is reached before this point and equipment required to suppress the fire front increases dramatically (Rothermel 1983). Fire fronts with fireline intensities $<$ 345 kW/m are within the range of direct attack at the head by persons using hand tools, while fire fronts with fireline intensities $>$ 345 kW/m would require equipment such as plows, dozers, pumpers and retardants for suppression (Rothermel 1983). High fireline intensities also create safety hazards for personnel.

Current policy of natural resource management agencies in many areas of southeastern U.S. restrict the use of prescribed fires between April 1 and June 30 each year in deference to ground nesting birds. Burning late in the dormant season or extremely early in the growing-season (April--May) may be an effective alternative to mid to late growing-season fires, but the effects on ground nesting birds should be quantified first. Fireline intensity should be relatively high because lush vegetation is limited and dead fuels abundant. Several studies suggest reduced sprouting after fires during this phenological stage (i.e., budding and leaf expansion) (Grano 1955, Woods et al. 1959, Robbins and Myers 1992, Glitzenstein et al. 1995). It is also possible for managers to increase the number of restored hectares with minimal effort by burning larger tracts in a single burn unit rather than scattered small units. Larger burn units also more nearly mimic presettlement landscape level burns (Masters et al. 1995).

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Table 1. Comparison of growing-season and dormant-season fire behavior parameters, Ouachita National Forest, Arkansas, USA 1995 and 1996 (data from Sparks et al. IN REVIEWa).

	Treatment[a]					
	Dormant Season (n = 6)			Growing Season (n = 6)		
Fire Behavior Parameter	Mean	Min	Max	Mean	Min	Max
Flame Length (m)	0.5	0.4	0.8	0.5	0.3	0.8
Flame Depth (m)	0.8	0.5	1.4	0.4	0.2	0.7
Rate of Spread (m/min)	0.5A	4.9	12.6	2.9B	0.6	6.2
Residence Time (Sec)	11	8	15	26	14	54
Fireline Intensity (kW/m)	1,300A	534	2,082	281B	58	691
Heat per Unit Area (kJ/m^2)	8,827A	6,745	10,415	5,803B	5,150	6,668
Reaction Intensity (kW/m^2)	1,955A	905	2,767	618B	394	961

[a] Row means followed by the same letter were not different ($P > 0.05$).

Table 2.[a] Study 1, woody stem density (stems/m^2) and percent frequency of occurrence by height class to season of fire in red-cockaded woodpecker clusters on the Ouachita National Forest, Arkansas, 1994 and 1995.

	Treatment						P > F		
	No-Burn Control		Dormant Season		Growing Season				
Parameter, Height Class	1995 Mean (SE) (n=4)	Percent[b] change	1995 Mean (SE) (n=4)	Percent[b] change	1995 Mean (SE) (n=4)	Percent[b] change	Treatment	Contrasts[c] C vs B	D vs G
Stem Density									
0-1-m	62,921 (7,066)	99	62,532 (9,416)	106	76,293 (9,023)	128	0.3009	0.2503	0.2938
1-3-m	4,563 (250)	99A	916 (121)	20C	2,668 (616)	43B	0.0008	0.0004	0.0424
≥ 3-m	546 (360)	156	216 (78)	53	201 (122)	35	0.2524	0.1175	0.6472
Percent Frequency of Occurrence									
0-1-m	100 (0)	100	100 (0)	100	100 (0)	100	1.0000	1.0000	1.0000
1-3-m	100 (0)	100A	56 (8)	56C	92 (4)	92B	0.0001	0.0002	0.0016
≥ 3-m	8 (3)	208	3 (1)	33	6 (3)	61	0.5770	0.3080	0.9628

[a] Row means followed by different letters are different ($P \leq 0.05$, Least Significant Difference).

[b] Percent change = [(post treatment (1995) / pre-treatment (1994)) X 100].

[c] Contrasts: C = Control; B = Burned stands regardless of season; D = dormant-season fires; G = growing-season on fires.

Table 3.[a] Study 2, woody stem density (stems/m^2) and percent frequency of occurrence by height class to season of fire in red-cockaded woodpecker clusters on the Ouachita National Forest, Arkansas, 1995 and 1996.

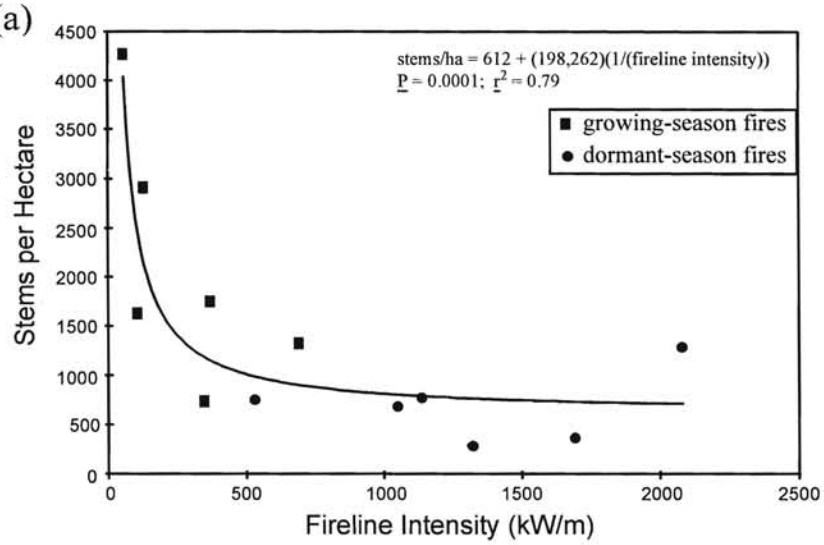
	Treatment				
	Dormant Season		Growing Season		
Height Class	1995 Mean (SE) (n=4)	Percent[b] change	1995 Mean (SE) (n=4)	Percent[b] change	P > F Treatment
Stem Density					
0-1-m	90,227 (11,881)	162	89,070 (5,790)	131	0.1056
1-3-m	2,137 (210)	48	1,503 (295)	32	0.1056
≥ 3-m	124 (124)	38	309 (62)	12	0.7643
Percent Frequency of Occurrence					
0-1-m	100 (0)	100	100 (0)	100	1.0000
1-3-m	50 (17)	50	78 (18)	78	0.5528
≥ 3-m	2 (2)	17	5 (2)	50	0.7643

[a] Row means followed by different letters are different ($P \leq 0.05$, Least Significant Difference).

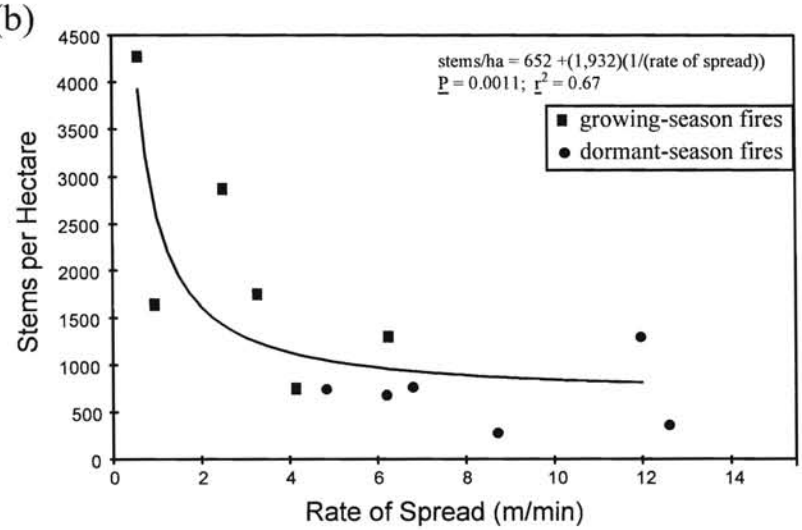
[b] Percent change = [(post treatment (1995) / pre-treatment (1994)) X 100].

Figure 1. Fire behavior parameters versus total stem density (stems/ha) $\geq$ 1-m for each stand and season of fire (a) fireline intensity (kW/m), (b) rate of spread (m/min), and (c) reaction intensity (kW/m^2), Ouachita National Forest, Arkansas. Circles are growing-season fires and squares are dormant-season fires. Each symbol represents the mean value observed for a stand.

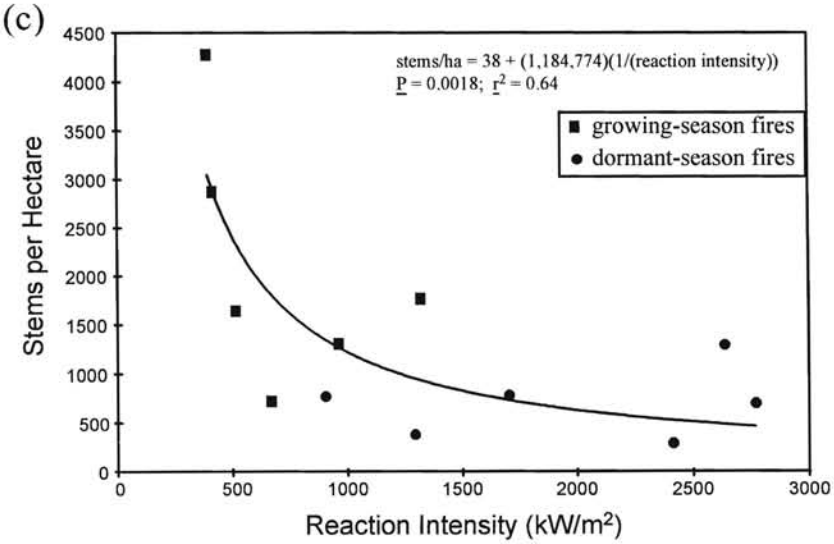
(a)


stems/ha = 612 + (198,262)(1/(fireline intensity))
P = 0.0001; r² = 0.79
growing-season fires
dormant-season fires
Stems per Hectare
Fireline Intensity (kW/m)

(b)


stems/ha = 652 +(1,932)(1/(rate of spread))
P = 0.0011; r² = 0.67
growing-season fires
dormant-season fires
Stems per Hectare
Rate of Spread (m/min)

(c)


stems/ha = 38 + (1,184,774)(1/(reaction intensity))
P = 0.0018; r² = 0.64
growing-season fires
dormant-season fires
Stems per Hectare
Reaction Intensity (kW/m²)

APPENDIXES

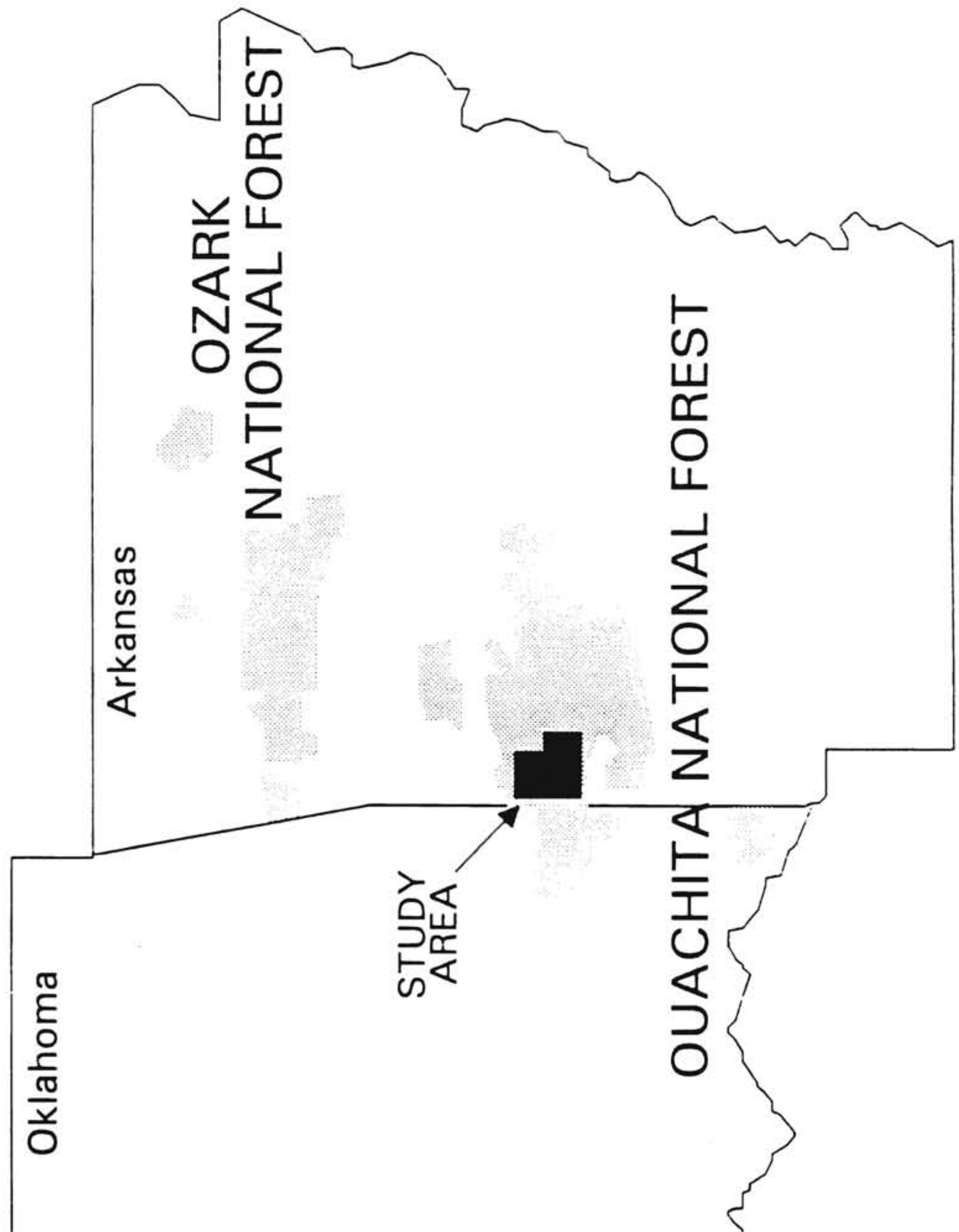
APPENDIX A

STAND CHARACTERISTICS AND LOCATION

Table 1. Stand characteristics and history prior to treatment, Ouachita National Forest, Arkansas.

Stand	Treatment	Size (Ha)	Year of WSI	Times Burned
1257C	WSI-C	18.21	1990	3
1274C	WSI-C	17.81	1980	5
1313C	WSI-C	26.71	1985	2
1265C	WSI-C	16.19	1980	5
1289G	WSI-G	13.76	1989	2
1257G	WSI-G	16.19	1990	3
1274G	WSI-G	24.28	1989	1
1259G	WSI-G	16.19	1990	3
1313D	WSI-D	13.76	1985	2
1257D	WSI-D	16.19	1990	3
1274D	WSI-D	16.19	1980	3
1289D	WSI-D	16.19	1989	2

Figure 1. Map of the pine-bluestem renewal area, Ouachita National Forest, Arkansas.


Oklahoma
Arkansas
OZARK
NATIONAL FOREST
OUACHITA NATIONAL FOREST
STUDY
AREA

APPENDIX B

HERBACEOUS SPECIES RESPONSE TO SEASON OF FIRE

Table 1.[a] Herbaceous species response (stems/m^2) to season of fire in WSI stands, Ouachita National Forest, Arkansas.

	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
Group, Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Grasses												
Andropogon gerardii	2.33	0.57	2.87	0.78	2.96	1.58	2.78	1.37	2.11	1.07	2.80	1.52
Andropogon gyrans	3.42	1.84	4.27	3.40	2.62	1.12	3.08	1.13	2.63	1.00	1.46	0.46
Aristida spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.27	0.27
Chasmanthium sessiliflorum	9.76	4.57	9.27	3.07	6.00	3.30	10.50	4.91	7.92	2.80	2.98	1.67
Danthonia spicata	2.97	0.92	4.94	1.51	9.29	4.66	3.29	0.96	1.77	0.52	1.94	0.72
Gymnopogon ambiguus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.06	0.00	0.00
Manisuris cylindrica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.09	0.09
Muhlenbergia schreberi	0.00	0.00	0.00	0.00	0.00	0.00	1.81	1.11	0.00	0.00	0.00	0.00
Muhlenbergia spp.	2.93	1.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paspalum sp.	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Schizachyrium scoparium	23.80	9.01	22.80	8.67	18.10	5.76	19.90	4.80	21.60	0.56	14.80	2.81
Sorghastrum nutans	0.01	0.01	0.59	0.51	0.49	0.29	0.00	0.00	0.07	0.07	0.45	0.27
Sporobolus asper	0.07	0.07	0.28	0.28	0.33	0.19	1.27	1.27	0.00	0.00	0.06	0.06
Sporobolus spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04	0.91	0.77	0.06	0.06
Tridens flavus	0.00	0.00	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.38	0.00	0.00
Panicums												
Panicum acuminatum	0.00	0.00	0.00	0.00	0.00	0.00	1.87	1.28	13.80	4.62	1.64	0.88
Panicum anceps	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00
Panicum boscii	1.01	0.37	0.89	0.37	0.69	0.39	3.48	1.61	2.92	0.46	1.61	0.48
Panicum dichotomum	3.23B	0.58	3.90B	0.54	10.0A	1.36	3.49AB	1.25	5.85A	1.09	1.46B	0.63
Panicum laeviatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00
Panicum linearifolium	0.00	0.00	0.00	0.00	0.00	0.00	3.52	1.93	2.68	1.09	0.36	0.16
Panicum rigidulum	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.29	0.29	0.00	0.00
Panicum spp.	11.10B	2.10	15.90B	0.79	24.50A	4.16	4.80	4.14	1.27	0.66	3.33	1.53
Panicum virgatum	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.62	0.62	0.00	0.00
Sedges												
Carex latebracteata	0.12	0.12	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.00	0.00
Carex spp.	0.17	0.09	0.03	0.03	0.03	0.03	2.44	0.93	8.14	1.18	6.91	1.95
Scleria spp.	8.08	2.35	10.6	4.90	8.00	1.12	1.15	1.11	0.19	0.13	2.23	1.86
Scleria triglomerata	3.94B	0.48	12.1A	4.60	9.10A	0.87	4.44B	0.40	13.90A	1.86	4.65B	1.94

Table 1. (Continued).[a]

Group, Species	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Legumes												
Amphicarpa bracteata	0.45	0.32	0.32	0.17	0.65	0.38	0.38	0.12	0.43	0.21	1.21	0.42
Baptisia nuttalliana	0.03	0.02	0.03	0.02	0.00	0.00	0.02	0.01	0.16	0.09	0.02	0.02
Cassia fasciculata	0.76	0.49	0.40	0.21	2.05	1.17	0.25B	0.15	1.46A	0.32	0.22B	0.10
Clitoria mariana	1.46	0.66	1.62	0.72	2.00	0.53	1.29	0.43	1.84	0.77	1.76	0.55
Crotalaria sagittalis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Desmodium canescens	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06
Desmodium ciliare	3.34	1.87	0.68	0.41	1.43	0.68	3.73	1.68	3.32	1.17	6.32	2.26
Desmodium cuspidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.01	0.01
Desmodium laevigatum	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.24	0.01	0.01	0.07	0.04
Desmodium marilandicum	0.75	0.39	0.57	0.32	0.15	0.11	0.93	0.57	0.16	0.06	0.52	0.51
Desmodium paniculatum	0.00	0.00	0.13	0.13	0.08	0.08	0.00	0.00	0.06	0.03	0.01	0.01
Desmodium rotundifolium	0.08	0.03	0.19	0.11	0.13	0.05	0.03	0.03	0.00	0.00	0.06	0.04
Desmodium spp.	0.38	0.14	0.32	0.06	0.17	0.08	0.00	0.00	0.03	0.03	0.01	0.01
Desmodium viridiflorum	0.92	0.51	0.33	0.17	0.29	0.10	0.79	0.29	1.95	0.51	1.12	0.54
Galactia regularis	0.36	0.10	0.47	0.14	0.17	0.03	0.38	0.09	0.35	0.09	0.19	0.08
Lespedeza cuneata	0.00	0.00	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.00	0.01	0.01
Lespedeza hirta	0.16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00
Lespedeza intermedia	0.17	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.15	0.00	0.00
Lespedeza procumbens	3.18	0.49	2.07	0.18	3.30	1.37	3.54	1.13	3.12	0.86	3.03	1.17
Lespedeza repens	2.73	1.41	3.44	1.50	2.02	0.47	3.46	2.06	4.55	0.69	4.33	1.51
Lespedeza spp.	0.07A	0.03	0.00B	0.00	0.00B	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lespedeza striata	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lespedeza violacea	1.02	1.02	0.11	0.11	0.00	0.00	1.55	0.87	0.61	0.28	2.09	0.96
Lespedeza virginica	0.21	0.14	0.16	0.13	0.08	0.08	0.37	0.22	0.56	0.32	0.42	0.37
Rhynchosia latifolia	0.17	0.17	0.01	0.01	0.08	0.06	0.00	0.00	0.01	0.01	0.20	0.20
Schrankia nuttallii	0.13	0.07	0.04	0.03	0.09	0.03	0.00	0.00	0.01	0.01	0.10	0.10
Strophostyles umbellata	0.12	0.06	0.13	0.13	0.18	0.10	0.11	0.07	0.27	0.20	0.13	0.08
Stylosanthes biflora	6.28	5.48	1.65	0.37	1.56	0.58	3.67	2.87	5.28	2.24	1.63	0.61
Tephrosia virginiana	0.30	0.30	0.02	0.02	0.11	0.11	0.00	0.00	0.06	0.06	0.00	0.00
Ferns												
Polystichum acrostichoides	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Pteridium aquilinum	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00

Table 1. (Continued).[a]

	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
Group, Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Forbs												
Acalypha gracilens	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.08	0.39	0.14	0.10	0.04
Acalypha sp.	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agalinis fasciculata	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ambrosia artemisiifolia	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Antennaria parlinii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.39
Antennaria spp.	2.39	0.48	2.22	0.43	4.98	1.54	2.83	0.83	2.53	0.96	3.13	0.95
Aristolochia serpentaria	0.00	0.00	0.17	0.08	0.08	0.03	0.03	0.03	0.02	0.02	0.03	0.03
Asclepias variegata	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01
Asclepias verticillata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Aster ageria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
Aster anomalus	0.68	0.44	1.94	1.47	0.19	0.08	0.54	0.10	1.19	0.75	0.38	0.15
Aster azureus	0.02	0.02	0.00	0.00	0.00	0.00	0.14	0.10	0.00	0.00	0.02	0.01
Aster ericoides	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aster linariifolius	0.20	0.20	0.09	0.09	0.00	0.00	0.33	0.33	0.16	0.09	0.25	0.25
Aster paludosus	0.19	0.13	0.38	0.15	0.15	0.03	0.03B	0.03	0.52A	0.19	0.11AB	0.04
Aster patens	0.60	0.20	2.11	1.25	0.56	0.20	0.71	0.18	1.14	0.40	0.77	0.21
Aster spp.	0.04	0.04	0.05	0.05	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Aster subulatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Cirsium carolinianum	0.33	0.26	0.23	0.12	0.17	0.06	0.15	0.05	1.10	0.49	0.45	0.14
Cirsium horridulum	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cirsium spp.	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Cocculus carolinus	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.01
Conyza canadensis	0.05	0.05	0.00	0.00	0.00	0.00	0.00B	0.00	0.00B	0.00	0.34A	0.20
Coreopsis grandiflora	0.00	0.00	0.03	0.03	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Coreopsis lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Coreopsis palmata	1.01	0.39	0.45	0.21	0.22	0.14	3.86A	2.34	2.17A	0.44	0.40B	0.20
Coreopsis spp.	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coreopsis tinctoria	0.53	0.18	0.59	0.17	0.33	0.14	0.11B	0.05	1.82A	0.90	0.90A	0.26
Crotonopsis elliptica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Cunila origanoides	0.25AB	0.18	0.31A	0.12	0.00B	0.00	0.26	0.17	0.99	0.73	0.00	0.00
Echinacea pallida	0.08	0.08	0.08	0.03	0.07	0.05	0.05	0.03	0.24	0.11	0.23	0.14
Echinacea purpurea	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Elephantopus tomentosus	0.37	0.37	0.01	0.01	0.00	0.00	0.30	0.27	0.17	0.16	0.08	0.08
Erechtites hieraciifolia	0.00	0.00	0.01	0.01	0.00	0.00	0.00C	0.00	14.40A	1.46	0.37B	0.14
Erigeron annuus	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01

Table 1. (Continued).[a]

Group, Species	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Forbs (Continued)												
Polygonum scandens	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.14	0.14
Potentilla simplex	0.08	0.06	0.00	0.00	0.00	0.00	0.08	0.05	0.09	0.09	0.19	0.19
Potentilla spp.	0.00	0.00	0.23	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pycnanthemum albescens	0.13	0.13	0.03	0.03	0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.00
Pycnanthemum tenuifolium	0.20	0.20	0.08	0.08	0.00	0.00	0.00	0.00	0.05	0.05	0.24	0.24
Rudbeckia amplexicaulus	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Rudbeckia grandiflora	0.28	0.13	0.26	0.12	0.16	0.06	0.44	0.23	0.54	0.52	0.60	0.22
Rudbeckia hirta	0.09	0.04	0.27	0.13	0.06	0.03	0.02B	0.01	0.86A	0.40	0.22AB	0.16
Ruellia humilis	0.06	0.03	0.12	0.07	0.14	0.07	0.00B	0.00	0.01B	0.01	0.18A	0.07
Ruellia pedunculata	0.43	0.37	0.15	0.12	0.16	0.05	0.08B	0.06	0.35AB	0.28	0.25A	0.05
Ruellia strepens	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.01	0.01	0.03	0.03
Salvia lyrata	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00
Sanicula canadensis	0.00	0.00	0.01	0.01	0.24	0.19	0.03	0.03	0.03	0.03	0.59	0.37
Scutellaria ovata	0.04	0.04	0.00	0.00	0.00	0.00	0.02	0.01	0.50	0.36	0.93	0.36
Scutellaria parvula	0.02	0.02	0.03	0.03	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Senecio spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.02	0.02
Sisyrinchium angustifolium	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.06	0.00	0.00	0.15	0.09
Solidago caesia	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.25	0.23	0.04	0.04
Solidago hispida	0.49	0.35	0.57	0.29	0.37	0.18	0.06B	0.04	1.79A	0.50	0.00B	0.00
Solidago odora	0.01	0.01	0.03	0.02	0.10	0.06	0.22	0.13	0.58	0.34	0.26	0.14
Solidago radula	0.68	0.35	2.22	0.83	0.63	0.14	0.55	0.25	1.20	0.77	0.67	0.21
Solidago spp.	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Solidago ulmifolia	1.69	0.33	1.67	0.76	1.32	0.30	1.86	0.38	1.70	0.47	2.06	0.63
Tradescantia ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01
Triodanus leptocarpa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09
Unknown Forb #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Unknown Forb 100	0.04	0.04	0.02	0.01	0.13	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Forb 2b	0.04	0.03	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Forb 4	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown forb	0.01	0.01	0.11	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Unknown forb 108	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unkown onetwo	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00
Unknown three	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.04	0.03
Unkown Seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
Verbesina helianthoides	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.04	0.04

Table 1. (Continued).[a]

Group, Species	Pre-treatment (1994)[b] WSI-C Mean	SE	WSI-D Mean	SE	WSI-G Mean	SE	Post-treatment (1995)[b] WSI-C Mean	SE	WSI-D Mean	SE	WSI-G Mean	SE
Forbs (Continued)												
Polygonum scandens	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.14	0.14
Potentilla simplex	0.08	0.06	0.00	0.00	0.00	0.00	0.08	0.05	0.09	0.09	0.19	0.19
Potentilla spp.	0.00	0.00	0.23	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pycnanthemum albescens	0.13	0.13	0.03	0.03	0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.00
Pycnanthemum tenuifolium	0.20	0.20	0.08	0.08	0.00	0.00	0.00	0.00	0.05	0.05	0.24	0.24
Rudbeckia amplexicaulus	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Rudbeckia grandiflora	0.28	0.13	0.26	0.12	0.16	0.06	0.44	0.23	0.54	0.52	0.60	0.22
Rudbeckia hirta	0.09	0.04	0.27	0.13	0.06	0.03	0.02B	0.01	0.86A	0.40	0.22AB	0.16
Ruellia humilis	0.06	0.03	0.12	0.07	0.14	0.07	0.00B	0.00	0.01B	0.01	0.18A	0.07
Ruellia pedunculata	0.43	0.37	0.15	0.12	0.16	0.05	0.08B	0.06	0.35AB	0.28	0.25A	0.05
Ruellia strepens	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.01	0.01	0.03	0.03
Salvia lyrata	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00
Sanicula canadensis	0.00	0.00	0.01	0.01	0.24	0.19	0.03	0.03	0.03	0.03	0.59	0.37
Scutellaria ovata	0.04	0.04	0.00	0.00	0.00	0.00	0.02	0.01	0.50	0.36	0.93	0.36
Scutellaria parvula	0.02	0.02	0.03	0.03	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Senecio spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.02	0.02
Sisyrinchium angustifolium	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.06	0.00	0.00	0.15	0.09
Solidago caesia	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.25	0.23	0.04	0.04
Solidago hispida	0.49	0.35	0.57	0.29	0.37	0.18	0.06B	0.04	1.79A	0.50	0.00B	0.00
Solidago odora	0.01	0.01	0.03	0.02	0.10	0.06	0.22	0.13	0.58	0.34	0.26	0.14
Solidago radula	0.68	0.35	2.22	0.83	0.63	0.14	0.55	0.25	1.20	0.77	0.67	0.21
Solidago spp.	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Solidago ulmifolia	1.69	0.33	1.67	0.76	1.32	0.30	1.86	0.38	1.70	0.47	2.06	0.63
Tradescantia ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01
Triodanus leptocarpa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09
Unknown Forb #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Unknown Forb 100	0.04	0.04	0.02	0.01	0.13	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Forb 2b	0.04	0.03	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Forb 4	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown forb	0.01	0.01	0.11	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Unknown forb 108	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unkown onetwo	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00
Unknown three	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.04	0.03
Unkown Seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
Verbesina helianthoides	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.04	0.04

Table 1. (Continued).[a]

	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
Group, Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Forbs (Continued)												
<u>Viola</u> <u>palmata</u>	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.32	0.27	0.07	0.05
<u>Viola</u> <u>pedata</u>	0.23	0.11	0.08	0.03	0.28	0.12	0.09	0.03	0.23	0.20	0.30	0.14
<u>Viola</u> <u>sagittata</u>	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<u>Viola</u> <u>sororia</u>	0.06	0.05	0.02	0.01	0.04	0.03	0.00B	0.00	0.13A	0.06	0.00B	0.00

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormasnt-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing-season prescribed fire, September 1994.

Table 2.[a] Herbaceous species response (stems/m^2) by treatment in WSI stands, Ouachita National Forest, Arkansas, Summer 1996.

	Treatment[b]							
	WSI-CD		WSI-CG		WSI-DC		WSI-DD	
Group, Species	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
Grasses								
Andropogon gerardii	7.72	4.25	0.15	0.12	0.78	0.58	4.25	3.85
Andropogon gyrans	1.63	0.53	0.02	0.02	4.70	2.37	5.73	5.33
Chasmanthium sessiliflorum	2.70	2.70	7.75	1.95	10.45	4.52	7.92	6.35
Danthonia spicata	5.63	4.97	0.00	0.00	2.42	0.18	2.33	1.43
Manisuris cylindrica	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00
Muhlenbergia schreberi	0.00	0.00	0.00	0.00	0.00	0.00	1.18	1.18
Muhlenbergia spp.	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Schizachyrium scoparium	30.18	4.02	7.47	5.47	37.58	6.95	11.07	5.60
Sorghastrum nutans	0.00	0.00	0.00	0.00	1.25	1.25	0.00	0.00
Sporobolus asper	0.00	0.00	1.27	1.27	0.03	0.03	0.00	0.00
Sporobolus spp.	0.00B	0.00	0.00B	0.00	0.33A	0.13	0.00B	0.00
Panicums								
Panicum acuminatum	4.93	4.90	3.05	2.55	6.55	3.58	9.92	1.18
Panicum anceps	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00
Panicum boscii	2.68	2.15	0.63	0.10	1.82	0.28	2.08	0.45
Panicum dichotomum	4.98	0.08	2.78	1.85	5.73	2.20	3.65	0.82
Panicum laeviatum	0.00	0.00	0.72	0.72	0.00	0.00	0.00	0.00
Panicum linearifolium	3.40	2.57	0.62	0.55	3.30	1.93	4.02	1.92
Panicum scoparium	1.73	1.73	0.70	0.07	1.10	0.70	0.53	0.10
Panicum spp.	2.63	1.03	0.58	0.22	1.23	0.43	1.87	1.50
Sedges								
Carex latebracteata	0.03	0.03	0.00	0.00	0.02	0.02	0.00	0.00
Carex spp.	5.40	1.23	5.75	1.18	11.83	2.00	9.18	0.82
Scleria oligantha	0.43	0.43	0.00	0.00	0.00	0.00	0.00	0.00
Scleria spp.	0.35	0.22	0.00	0.00	0.22	0.22	0.00	0.00
Scleria triglomerata	6.02AB	1.78	2.25B	0.55	13.23A	0.73	6.33AB	0.23
Ferns								
Polystichum acrostichoides	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Pteridium aquilinum	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Legumes								
Amphicarpa bracteata	0.83	0.83	0.45	0.28	0.08	0.08	1.38	0.02
Baptisia nuttalliana	0.10	0.10	0.02	0.02	0.12	0.12	0.15	0.15
Cassia fasciculata	0.58	0.55	0.22	0.15	1.30	0.63	0.60	0.03
Clitoria mariana	0.87	0.77	1.25	0.35	1.03	1.03	2.52	1.32
Crotalaria sagittalis	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.02
Desmodium canadense	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Desmodium canescens	0.40	0.40	0.05	0.05	0.00	0.00	0.00	0.00
Desmodium ciliare	4.43	0.97	2.97	2.77	0.58	0.58	5.08	3.12
Desmodium laevigatum	0.10	0.07	0.12	0.12	0.32	0.32	0.97	0.10
Desmodium marilandicum	1.63	1.60	0.00	0.00	0.22	0.22	0.20	0.20
Desmodium paniculatum	0.00B	0.00	0.00B	0.00	0.02AB	0.02	0.38A	0.25
Desmodium spp.	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Desmodium viridiflorum	2.20	2.20	2.80	0.97	1.50	1.27	0.52	0.05
Galactia regularis	0.33	0.27	0.15	0.02	0.22	0.12	0.30	0.20
Lespedeza intermedia	0.05	0.05	0.00	0.00	0.32	0.32	0.00	0.00
Lespedeza procumbens	9.48	5.52	3.48	0.25	1.55	1.02	5.17	1.87
Lespedeza repens	5.42	4.08	6.88	4.72	4.30	0.77	8.45	3.22
Lespedeza striata	0.10	0.07	0.00	0.00	0.03	0.03	0.00	0.00
Lespedeza violacea	0.30	0.27	0.00	0.00	1.20	1.20	0.03	0.03
Lespedeza virginica	0.40	0.37	0.08	0.08	0.78	0.35	0.38	0.18
Rhynchosia latifolia	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Schrankia nuttallii	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00

Table 2. (Continued)[a].

	Treatment[b]							
	WSI-CD		WSI-CG		WSI-DC		WSI-DD	
Group, Species	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
Legumes (Continued)								
Strophostyles umbellata	0.15	0.05	0.02	0.02	0.73	0.73	0.17	0.10
Stylosanthes biflora	1.98	0.42	5.18	4.75	2.52	1.52	6.28	2.72
Tephrosia virginiana	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00
Forbs								
Acalypha gracilens	0.28	0.28	0.80	0.60	0.27	0.27	0.73	0.40
Acalypha virginica	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
Ambrosia artemisiifolia	0.03	0.03	0.07	0.07	0.00	0.00	0.00	0.00
Antennaria spp.	3.18	0.68	1.33	0.87	3.50	2.67	3.20	2.03
Aristolochia serpentaria	0.08	0.08	0.00	0.00	0.00	0.00	0.03	0.00
Asclepias variegata	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Aster anomalus	1.17	0.70	0.43	0.13	1.68	1.52	0.85	0.85
Aster azureus	0.47	0.47	0.07	0.07	0.05	0.05	0.00	0.00
Aster linariifolius	0.85	0.85	0.00	0.00	0.40	0.13	0.02	0.02
Aster paludosus	0.15	0.15	0.02	0.02	0.85	0.82	0.07	0.03
Aster patens	0.97	0.53	0.48	0.15	1.05	0.45	0.82	0.32
Aster subulatus	0.08A	0.02	0.00B	0.00	0.00B	0.00	0.32A	0.22
Cirsium carolinianum	0.32	0.08	1.03	0.47	0.60	0.13	1.58	1.18
Cocculus carolinus	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Conyza canadensis	0.02	0.02	0.08	0.08	0.12	0.05	0.02	0.02
Coreopsis palmata	0.75	0.42	1.63	0.83	1.52	0.08	4.33	0.47
Coreopsis tinctoria	0.20	0.13	0.17	0.17	1.42	0.92	1.28	1.08
Coreopsis verticillata	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02
Cunila origanoides	0.57	0.57	0.13	0.00	1.20	0.60	0.15	0.15
Echinacea pallida	0.00	0.00	0.20	0.20	0.28	0.28	0.02	0.02
Elephantopus tomentosus	0.00	0.00	0.52	0.52	0.18	0.18	0.00	0.00
Erechtites hieraciifolia	1.60	0.33	1.27	1.20	0.02	0.02	0.15	0.12
Erigeron strigosus	0.00	0.00	0.02	0.02	0.02	0.02	0.00	0.00
Eupatorium altissimum	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Euphorbia corollata	0.15	0.15	0.00	0.00	0.03	0.03	0.02	0.02
Galium pilosum	0.32	0.05	0.80	0.80	0.67	0.67	0.63	0.37
Galium spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20
Geum canadense	0.03	0.03	0.02	0.02	0.02	0.02	0.12	0.02
Gnaphalium obtusifolium	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Gnaphalium purpureum	0.10	0.10	0.00	0.00	0.17	0.13	0.10	0.10
Hedyotis longifolia	0.53	0.20	0.12	0.02	0.12	0.12	0.17	0.13
Helianthus hirsutus	3.48	1.42	2.58	0.22	4.27	1.17	4.53	0.83
Heterotheca graminifolia	2.52	2.52	0.00	0.00	1.77	0.00	0.00	0.00
Hieracium gronovii	0.22	0.08	0.08	0.02	0.38	0.18	0.13	0.03
Hieracium longipilum	0.03	0.03	0.03	0.03	0.12	0.12	0.08	0.02
Ipomoea pandurata	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Lactuca canadensis	0.20	0.10	0.05	0.05	0.07	0.07	0.32	0.22
Liatris aspera	0.05	0.05	0.17	0.13	0.08	0.05	0.02	0.02
Liatris squarrosa	0.05	0.05	0.05	0.05	0.00	0.00	0.07	0.07
Lobelia appendiculata	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.02
Lobelia spicata	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.02
Mentha spp.	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00
Monarda russeliana	1.23	1.23	2.60	1.60	0.88	0.88	4.03	2.13
Monarda stipitatoglandulosa	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Oxalis stricta	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.02
Oxalis violacea	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Parthenium integrifolium	0.00	0.00	0.08	0.08	0.08	0.08	0.05	0.05
Phlox divaricata	0.05	0.05	0.00	0.00	0.03	0.03	0.00	0.00
Phlox spp.	0.83	0.53	0.70	0.37	0.28	0.02	0.50	0.07
Physalis virginiana	0.07	0.07	0.30	0.20	0.00	0.00	0.02	0.02
Polygala alba	0.03	0.03	0.00	0.00	0.07	0.07	0.02	0.02
Potentilla simplex	0.18	0.12	0.13	0.13	0.00	0.00	0.05	0.05

Table 2. (Continued)[a].

Group, Species	WSI-CD MEAN	WSI-CD SE	WSI-CG MEAN	WSI-CG SE	WSI-DC MEAN	WSI-DC SE	WSI-DD MEAN	WSI-DD SE
Forbs (Continued)								
Pycnanthemum tenuifolium	0.03	0.03	0.00	0.00	0.07	0.07	0.00	0.00
Rudbeckia amplexicaulus	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
Rudbeckia grandiflora	0.27	0.27	0.52	0.22	0.00	0.00	1.00	1.00
Rudbeckia hirta	0.03	0.03	0.23	0.17	0.32	0.25	0.50	0.27
Ruellia humilis	0.07	0.07	0.03	0.03	0.00	0.00	0.00	0.00
Ruellia pedunculata	0.10	0.07	0.17	0.00	0.07	0.00	0.67	0.43
Salvia lyrata	0.00	0.00	0.30	0.30	0.10	0.10	0.02	0.02
Sanicula canadensis	0.07	0.07	0.25	0.02	0.02	0.02	0.10	0.07
Scutellaria ovata	0.82	0.78	0.15	0.15	0.13	0.13	0.07	0.07
Senecio spp.	0.10	0.10	0.00	0.00	0.02	0.02	0.02	0.02
Sisyrinchium angustifolium	0.07	0.07	0.18	0.05	0.00	0.00	0.02	0.02
Solidago caesia	0.27	0.27	0.00	0.00	0.00	0.00	0.05	0.05
Solidago canadensis	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08
Solidago hispida	1.17	1.13	0.20	0.17	0.53	0.53	0.00	0.00
Solidago odora	0.33	0.33	0.03	0.03	0.70	0.07	0.02	0.02
Solidago radula	1.42AB	0.35	0.42C	0.02	3.55A	1.08	0.95BC	0.25
Solidago spp.	0.63	0.50	0.12	0.12	1.03	1.00	0.02	0.02
Solidago ulmifolia	1.92	0.62	1.83	0.80	2.10	0.97	1.58	0.52
Tradescantia ohiensis	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Triodanus leptocarpa	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00
UNK Matela	0.00	0.00	0.18	0.08	0.00	0.00	0.05	0.05
Unknown forb	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Unkown Seeds	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00
Viola palmata	0.10	0.10	0.00	0.00	0.00	0.00	0.05	0.05
Viola pedata	0.08	0.08	0.23	0.23	0.07	0.03	0.23	0.20
Viola sagittata	0.00	0.00	0.10	0.03	0.00	0.00	0.05	0.05
Viola sororia	0.13	0.13	0.03	0.03	0.00	0.00	0.00	0.00
Viola spp.	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996. WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996.

Table 3.[b] Percent frequency of occurence of herbaceous species to season of prescribed fire in WSI stands on the Ouachita National Forest, Arkansas.

Group, Species	Pre-treatment (1994)[b]			Post-treatment (1995)[b]		
	WSI-C	WSI-D	WSI-G	WSI-C	WSI-D	WSI-G
Grass						
Andropogon gerardii	9.2	10.0	10.0	12.5	14.2	9.2
Andropogon gyrans	16.7	20.0	20.0	14.2	20.8	15.0
Andropogon virginicus	0.0	0.8	0.0	0.0	0.0	0.0
Aristida spp.	0.0	0.0	0.0	0.0	0.8	1.7
Chasmanthium sessiliflorum	30.8	30.0	19.2	31.7	32.5	13.3
Danthonia spicata	16.7	27.5	24.2	18.3B	32.5A	11.7B
Gymnopogon ambiguus	0.0	0.0	0.0	0.0	1.7	0.0
Manisuris cylindrica	0.0	0.0	0.0	0.0	0.8	1.7
Muhlenbergia schreberi	0.0	0.0	0.0	1.7	0.0	0.0
Muhlenbergia spp.	1.7	0.0	0.0	0.0	0.0	0.0
Paspalum sp.	0.8	0.0	0.0	0.0	0.0	0.0
Schizachyrium scoparium	47.5	50.8	45.0	42.5	49.2	48.3
Sorghastrum nutans	0.8	2.5	3.3	0.0	0.8	2.5
Sporobolus asper	0.8	1.7	3.3	1.7	0.0	0.8
Sporobolus spp.	0.0	0.0	0.0	2.5	4.2	0.8
Tridens flavus	0.0	0.0	0.8	0.0	0.0	0.0
Panicum						
Dicanthelium spp.	52.5	61.7	76.7	8.3	3.3	13.3
Panicum acuminatum	0.0	0.0	0.0	19.2B	59.2A	10.0B
Panicum anceps	0.0	0.8	0.0	0.0	0.8	0.0
Panicum boscii	14.2	15.8	16.7	41.7A	38.3A	24.2B
Panicum dichotomum	47.5	50.8	62.5	45.8A	57.5A	30.0B
Panicum laeviatum	0.0	0.0	0.0	0.0	1.7	0.0
Panicum linearifolium	0.0	0.0	0.0	19.2AB	27.5A	4.2B
Panicum rigidulum	0.0	0.0	0.0	1.7	1.7	0.0
Panicum spp.	40.8	40.0	35.8	15.8	10.8	10.8
Panicum virgatum	0.0	0.0	0.8	0.0	0.8	0.0
Sedge						
Carex latebracteata	1.7	0.0	0.0	0.8	1.7	0.0
Carex spp.	2.5	0.8	0.8	25.0B	59.2A	42.5AB
Scleria spp.	40.0	45.8	52.5	10.0	1.7	15.8
Scleria triglomerata	38.3	53.3	62.5	39.2B	62.5A	38.3B
Fern						
Polystichum acrostichoides	0.0	0.0	0.0	0.8	0.0	0.0
Pteridium aquilinum	0.0	0.0	0.0	0.8	0.0	0.0
Legume						
Amphicarpa bracteata	10.0	7.5	16.7	9.2	11.7	12.5
Baptisia nuttalliana	1.7	1.7	0.0	1.7	7.5	0.8
Cassia fasciculata	15.0	10.0	27.5	10.0	15.0	14.2
Clitoria mariana	41.7	35.8	45.8	36.7	41.7	48.3
Crotalaria sagittalis	0.0	0.0	0.0	0.0	0.0	0.8
Desmodium canescens	0.0	0.0	0.0	0.0	0.0	1.7
Desmodium ciliare	22.5	8.3	14.2	19.2	20.0	28.3
Desmodium cuspidatum	0.0	0.0	0.0	0.0	3.3	0.8
Desmodium laevigatum	0.0	0.0	0.0	3.3	0.8	2.5
Desmodium marilandicum	10.8	5.8	4.2	7.5	10.0	2.5
Desmodium paniculatum	0.0	0.8	0.8	0.0	1.7	0.8
Desmodium rotundifolium	3.3	3.3	7.5	1.7	0.0	2.5
Desmodium spp.	15.0	10.0	9.2	0.0	0.8	0.8
Desmodium viridiflorum	12.5	9.2	10.8	9.2	23.3	15.0
Galactia regularis	19.2	16.7	10.8	18.3	20.0	14.2
Lespedeza cuneata	0.0	0.0	0.8	0.0	0.0	0.8
Lespedeza hirta	0.8	0.0	0.0	0.0	1.7	0.0
Lespedeza intermedia	4.2	0.0	0.0	0.0	2.5	0.0

Table 3. (Continued).[b]

Group, Species	Pre-treatment (1994)[b] WSI-C	WSI-D	WSI-G	Post-treatment (1995)[b] WSI-C	WSI-D	WSI-G
Legumes (Continued)						
Lespedeza procumbens	25.8	25.0	32.5	25.0	18.3	20.8
Lespedeza repens	32.5	43.3	41.7	24.2	35.8	33.3
Lespedeza spp.	2.5	0.0	0.0	0.0	0.0	0.0
Lespedeza striata	0.0	0.8	0.0	0.0	0.0	0.0
Lespedeza violacea	3.3	2.5	0.0	14.2	12.5	15.0
Lespedeza virginica	5.8	3.3	2.5	8.3	8.3	3.3
Rhynchosia latifolia	0.8	0.8	3.3	0.0	0.8	3.3
Schrankia nuttallii	2.5	2.5	2.5	0.0	0.8	0.8
Strophostyles umbellata	7.5	2.5	8.3	2.5	10.8	9.2
Stylosanthes biflora	20.8	20.8	20.0	18.3	20.8	20.0
Tephrosia virginiana	0.8	0.8	0.8	0.0	0.8	0.0
Forbs						
Acalypha gracilens	0.0	0.0	0.0	3.3B	22.5A	9.2AB
Agalinis fasciculata	0.0	0.8	0.0	0.0	0.0	0.0
Ambrosia artemisiifolia	0.8	0.0	0.0	0.0	0.0	0.8
Antennaria parlinii	0.0	0.0	0.0	0.0	0.0	0.8
Antennaria spp.	20.0	15.0	27.5	18.3	15.8	24.2
Aristolochia serpentaria	0.0	8.3	7.5	0.8	0.8	1.7
Asclepias variegata	0.0	0.0	0.8	0.8	0.8	2.5
Asclepias verticillata	0.0	0.0	0.0	0.0	0.8	0.0
Aster anomalus	22.5	28.3	9.2	29.2	30.0	14.2
Aster azureus	0.8	0.0	0.0	6.7	0.0	1.7
Aster ericoides	1.7	0.0	0.0	0.0	0.0	0.0
Aster linariifolius	3.3	1.7	0.0	2.5	4.2	1.7
Aster paludosus	6.7	7.5	10.0	1.7	5.8	5.0
Aster patens	20.8	29.2	20.8	21.7	27.5	23.3
Aster spp.	2.5	0.8	0.0	0.0	0.8	0.0
Aster subulatus	0.0	0.0	0.0	0.0	0.0	1.7
Cirsium carolinianum	11.7	10.0	9.2	11.7	22.5	17.5
Cirsium horridulum	0.0	0.8	0.0	0.0	0.0	0.0
Cocculus carolinus	0.0	0.0	1.7	0.0	0.0	0.8
Conyza canadensis	0.8	0.0	0.0	0.0B	0.0B	10.0A
Coreopsis grandiflora	0.0	0.8	0.0	1.7	0.0	0.0
Coreopsis lanceolata	0.0	0.0	0.0	0.0	0.8	0.0
Coreopsis palmata	5.0	8.3	1.7	6.7	10.0	3.3
Coreopsis spp.	0.0	0.8	0.0	0.0	0.0	0.0
Coreopsis tinctoria	9.2	8.3	7.5	4.2B	15.0A	18.3A
Crotonopsis elliptica	0.0	0.0	0.0	0.0	0.8	0.0
Cunila origanoides	6.7	6.7	0.0	7.5	8.3	0.0
Echinacea pallida	1.7	4.2	1.7	2.5	5.8	2.5
Echinacea purpurea	0.0	0.0	0.8	0.0	0.0	0.0
Elephantopus tomentosus	4.2	0.8	0.0	3.3	4.2	1.7
Erechtites hieraciifolia	0.0	0.8	0.0	0.0C	86.7A	15.8B
Erigeron annuus	0.8	0.0	0.0	1.7	0.0	0.8
Erigeron spp.	0.0	0.0	0.0	0.0	0.8	0.0
Eupatorium altissimum	0.8	0.0	0.0	0.0	0.0	0.0
Eupatorium serotinum	0.0	0.0	0.0	0.8	0.0	0.0
Eupatorium sp.	0.8	0.0	0.0	0.0	0.0	0.0
Euphorbia corollata	1.7	0.0	0.0	0.0	0.8	0.0
Galium pilosum	0.8	0.8	0.0	0.8	0.0	0.0
Galium spp.	8.3	9.2	10.8	10.8	12.5	8.3
Gnaphalium obtusifolium	0.8	0.0	5.8	0.8	0.8	0.0
Gnaphalium purpureum	0.0	0.0	0.0	1.7	4.2	0.8
Hedyotis longifolia	6.7	19.2	10.8	3.3	5.8	3.3
Hedyotis spp.	0.0	0.0	0.0	0.8	0.0	0.0
Helianthus hirsutus	44.2	45.0	51.7	52.5	50.8	55.0
Heterotheca graminifolia	12.5	8.3	0.0	10.0	14.2	2.5
Hieracium gronovii	15.8	20.8	15.0	19.2	20.0	14.2

Table 3. (Continued).[b]

Group, Species	Pre-treatment (1994)[b] WSI-C	WSI-D	WSI-G	Post-treatment (1995)[b] WSI-C	WSI-D	WSI-G
Forbs (Continued)						
Hieracium longipilum	0.0	0.0	0.0	0.0	3.3	0.0
Lactuca canadensis	10.0	13.3	13.3	9.2	14.2	9.2
Lactuca serriola	0.0	0.8	0.0	0.0	0.0	0.8
Liatris aspera	4.2	1.7	0.0	9.2	9.2	3.3
Liatris pycnostachya	0.0	0.0	0.0	0.0	2.5	0.0
Liatris squarrosa	1.7	0.8	0.0	1.7	3.3	0.0
Lobelia appendiculata	0.0	0.0	0.0	0.8	6.7	5.0
Lobelia spicata	3.3	2.5	0.8	0.0	0.8	0.8
Mentha spicata	0.0	0.0	0.0	0.8	0.0	0.0
Monarda russeliana	26.7	30.8	33.3	29.2	35.8	36.7
Monarda spp.	2.5	1.7	0.0	0.0	0.0	0.0
Monarda stipitatoglandulosa	0.0	0.0	0.8	0.8	0.0	1.7
Oxalis stricta	2.5	1.7	1.7	1.7	2.5	3.3
Oxalis violacea	0.0	0.0	0.0	0.0	0.8	0.0
Parthenium integrifolium	3.3	5.0	0.0	2.5	5.0	2.5
Phlox divaricata	5.8	5.0	7.5	10.8	9.2	23.3
Phlox sp.	0.0	0.0	0.0	0.0	2.5	8.3
Physalis virginiana	0.8	0.8	0.0	3.3	11.7	9.2
Phytolacca americana	0.8	0.0	0.0	0.0	0.0	0.0
Plantago lanceolata	0.8	0.0	0.0	0.0	0.0	0.0
Polygala alba	0.8	0.0	0.0	0.0B	5.8A	2.5A
Polygala sp.	0.8	0.0	0.0	0.0	0.0	0.0
Polygonum scandens	0.0	0.0	0.0	0.8	0.0	0.8
Potentilla simplex	2.5	0.0	0.0	2.5	0.8	0.8
Potentilla spp.	0.0	4.2	0.0	0.0	0.0	0.0
Prunella vulgaris	0.0	0.0	0.8	0.0	0.0	0.0
Pycnanthemum albescens	0.8	1.7	0.8	0.0	0.0	0.0
Pycnanthemum tenuifolium	0.8	1.7	0.0	0.0	0.8	0.8
Rudbeckia amplexicaulus	0.0	0.0	0.8	0.0	0.0	0.0
Rudbeckia grandiflora	8.3	5.8	3.3	8.3	5.0	6.7
Rudbeckia hirta	4.2	6.7	4.2	1.7	10.0	7.5
Ruellia humilis	4.2	5.8	9.2	0.0B	0.8B	8.3A
Ruellia pedunculata	5.8	8.3	9.2	4.2	11.7	8.3
Ruellia strepens	0.0	0.0	0.0	2.5	0.8	0.8
Salvia lyrata	0.0	0.0	0.0	0.8	0.0	0.0
Sanicula canadensis	0.0	0.8	6.7	0.8	1.7	6.7
Scutellaria ovata	3.3	0.0	0.0	1.7	9.2	18.3
Scutellaria parvula	0.8	1.7	3.3	0.0	0.0	0.0
Senecio spp.	0.0	0.0	0.0	0.0	1.7	1.7
Sisyrinchium angustifolium	0.0	0.0	0.0	1.7	0.0	4.2
Solidago caesia	0.0	0.0	0.0	4.2	4.2	2.5
Solidago hispida	12.5	10.8	9.2	1.7B	27.5A	0.0B
Solidago odora	0.8	1.7	1.7	6.7	8.3	6.7
Solidago radula	20.8	28.3	15.8	18.3	20.8	20.8
Solidago spp.	0.8	0.0	0.0	0.0	0.8	0.8
Solidago ulmifolia	41.7	43.3	35.0	49.2	40.0	35.0
Tradescantia ohiensis	0.0	0.0	0.0	0.0	0.8	0.8
Triodanus leptocarpa	0.0	0.0	0.0	0.0	0.0	2.5
Unknown Forb #3	0.0	0.0	0.0	0.0	0.0	0.8
Unknown Forb 100	0.8	1.7	4.2	0.0	0.0	0.0
Unknown Forb 2b	3.3	2.5	0.0	0.0	0.0	0.0
Unknown Forb 4	0.8	0.0	0.0	0.0	0.0	0.0
Unknown forb	0.8	6.7	2.5	0.0	0.0	0.8
Unknown forb 108	0.0	0.8	0.0	0.0	0.0	0.0
Unkown onetwo	0.0	0.0	0.0	2.5	0.0	0.0
Unknown three	0.0	0.0	0.0	1.7	0.0	2.5
Unknown Seeds	0.0	0.0	0.0	0.8	0.0	0.0
Verbesina helianthoides	0.0	0.0	0.8	0.0	0.0	0.8
Viola palmata	0.0	0.0	0.0	0.8	9.2	4.2

Table 3. (Continued).[b]

Group, Species	Pre-treatment (1994)[b]			Post-treatment (1995)[b]		
	WSI-C	WSI-D	WSI-G	WSI-C	WSI-D	WSI-G
Forbs (Continued)						
Viola pedata	7.5	5.8	9.2	5.0	3.3	11.7
Viola sagittata	1.7	0.0	0.0	0.0	0.0	0.0
Viola sororia	2.5	1.7	2.5	0.0B	5.0A	0.0B

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormasnt-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing season prescribed fire, September 1994.

Table 4. Percent frequency of occurence of herbaceous species to season of prescribed fire in WSI stands on the Ouachita National Forest, Arkansas, summer 1996.

	Treatment[b]			
Group, Species	WSI-CD	WSI-CG	WSI-DC	WSI-DD
Grass				
Andropogon gerardii	20.0	3.3	3.3	16.7
Andropogon gyrans	15.0	1.7	20.0	23.3
Chasmanthium sessiliflorum	8.3	46.7	40.0	31.7
Danthonia spicata	28.3	0.0	23.3	23.3
Manisuris cylindrica	0.0	0.0	1.7	0.0
Muhlenbergia schreberi	0.0	0.0	0.0	1.7
Muhlenbergia spp.	0.0	1.7	0.0	0.0
Schizachyrium scoparium	51.7AB	26.7B	58.3A	30.0B
Sorghastrum nutans	0.0	0.0	1.7	0.0
Sporobolus asper	0.0	1.7	1.7	0.0
Sporobolus spp.	0.0B	0.0B	5.0A	0.0B
Panicum				
Dicanthelium spp.	10.0	1.7	1.7	1.7
Panicum acuminatum	25.0	26.7	56.7	56.7
Panicum anceps	0.0	0.0	1.7	0.0
Panicum boscii	30.0	20.0	21.7	30.0
Panicum dichotomum	46.7	41.7	65.0	46.7
Panicum laeviatum	0.0	1.7	0.0	0.0
Panicum linearifolium	18.3BC	6.7C	33.3A	31.7AB
Panicum scoparium	11.7	11.7	13.3	16.7
Panicum spp.	13.3	10.0	18.3	8.3
Sedges				
Carex latebracteata	1.7	0.0	1.7	0.0
Carex spp.	45.0BC	41.7C	61.7A	51.7AB
Scleria oligantha	1.7	0.0	0.0	0.0
Scleria spp.	10.0	0.0	3.3	0.0
Scleria triglomerata	45.0BC	40.0C	63.3A	56.7AB
Ferns				
Polystichum acrostichoides	0.0	1.7	0.0	0.0
Pteridium aquilinum	0.0	1.7	0.0	0.0
Legumes				
Amphicarpa bracteata	18.3	15.0	6.7	25.0
Baptisia nuttalliana	3.3	1.7	5.0	5.0
Cassia fasciculata	15.0	6.7	16.7	13.3
Clitoria mariana	25.0	45.0	35.0	45.0
Crotalaria sagittalis	0.0	1.7	0.0	1.7
Desmodium canadense	3.3	0.0	0.0	0.0
Desmodium canescens	3.3	1.7	0.0	0.0
Desmodium ciliare	16.7	30.0	10.0	18.3
Desmodium laevigatum	3.3	3.3	3.3	10.0
Desmodium marilandicum	6.7	0.0	3.3	3.3
Desmodium paniculatum	0.0	0.0	1.7	3.3
Desmodium spp.	1.7	1.7	0.0	0.0
Desmodium viridiflorum	13.3	26.7	10.0	15.0
Galactia regularis	20.0	10.0	13.3	16.7
Lespedeza intermedia	1.7	0.0	5.0	0.0
Lespedeza procumbens	25.0	30.0	15.0	26.7
Lespedeza repens	28.3	43.3	38.3	53.3
Lespedeza striata	6.7	0.0	1.7	0.0
Lespedeza violacea	6.7	0.0	15.0	3.3
Lespedeza virginica	13.3	1.7	15.0	8.3
Rhynchosia latifolia	0.0	0.0	1.7	0.0
Schrankia nuttallii	0.0	1.7	0.0	0.0
Strophostyles umbellata	8.3	1.7	20.0	6.7

Table 4. (Continued).[a]

Group, Species	Treatment[b] WSI-CD	WSI-CG	WSI-DC	WSI-DD
Legumes (Contiued)				
Stylosanthes biflora	15.0	23.3	18.3	35.0
Forbs				
Acalypha gracilens	15.0	35.0	16.7	26.7
Acalypha virginica	0.0	1.7	0.0	0.0
Ambrosia artemisiifolia	1.7	1.7	0.0	0.0
Antennaria spp.	25.0	16.7	10.0	15.0
Aristolochia serpentaria	5.0	0.0	0.0	3.3
Asclepias variegata	0.0	0.0	0.0	1.7
Aster anomalus	38.3	13.3	36.7	25.0
Aster azureus	13.3	6.7	5.0	0.0
Aster linariifolius	5.0	0.0	5.0	1.7
Aster paludosus	3.3	1.7	6.7	5.0
Aster patens	26.7	20.0	31.7	28.3
Aster subulatus	3.3	0.0	0.0	6.7
Cirsium carolinianum	13.3	25.0	18.3	31.7
Cocculus carolinus	0.0	0.0	0.0	1.7
Conyza canadensis	1.7	1.7	5.0	1.7
Coreopsis palmata	3.3C	8.3B	3.3C	16.7A
Coreopsis tinctoria	8.3	3.3	15.0	15.0
Coreopsis verticillata	0.0	1.7	1.7	1.7
Cunila origanoides	8.3	5.0	10.0	5.0
Echinacea pallida	0.0	6.7	3.3	1.7
Elephantopus tomentosus	0.0	5.0	1.7	0.0
Erechtites hieraciifolia	41.7	26.7	1.7	10.0
Erigeron strigosus	0.0	1.7	1.7	0.0
Eupatorium altissimum	0.0	0.0	0.0	1.7
Euphorbia corollata	5.0	0.0	1.7	1.7
Galium pilosum	10.0	8.3	6.7	16.7
Galium spp.	0.0	0.0	0.0	1.7
Geum canadense	1.7	1.7	1.7	10.0
Gnaphalium obtusifolium	0.0	1.7	0.0	0.0
Gnaphalium purpureum	1.7	0.0	8.3	5.0
Hedyotis longifolia	11.7	6.7	3.3	6.7
Helianthus hirsutus	50.0	53.3	43.3	56.7
Heterotheca graminifolia	20.0	0.0	21.7	0.0
Hieracium gronovii	11.7	8.3	23.3	8.3
Hieracium longipilum	3.3	1.7	5.0	8.3
Ipomoea pandurata	0.0	0.0	0.0	1.7
Lactuca canadensis	11.7	5.0	6.7	15.0
Liatris aspera	1.7	6.7	5.0	1.7
Liatris squarrosa	1.7	5.0	0.0	1.7
Lobelia appendiculata	1.7	0.0	0.0	1.7
Lobelia spicata	1.7	0.0	0.0	1.7
Mentha spp.	0.0	1.7	0.0	0.0
Monarda russeliana	21.7	40.0	18.3	43.3
Monarda stipitatoglandulosa	1.7	0.0	0.0	0.0
Oxalis stricta	0.0	1.7	0.0	1.7
Oxalis violacea	0.0	0.0	0.0	1.7
Parthenium integrifolium	0.0	3.3	5.0	1.7
Phlox divaricata	1.7	0.0	3.3	0.0
Phlox spp.	30.0	28.3	15.0	26.7
Physalis virginiana	3.3	11.7	0.0	1.7
Polygala alba	1.7	0.0	3.3	1.7
Potentilla simplex	3.3	5.0	0.0	1.7
Pycnanthemum tenuifolium	1.7	0.0	1.7	0.0
Rudbeckia amplexicaulus	0.0	1.7	0.0	0.0
Rudbeckia grandiflora	3.3	15.0	0.0	8.3
Rudbeckia hirta	3.3	3.3	11.7	13.3

Table 4. (Continued).[a]

Group, Species	Treatment[b] WSI-CD	WSI-CG	WSI-DC	WSI-DD
Forbs (Continued)				
Ruellia humilis	5.0	1.7	0.0	0.0
Ruellia pedunculata	5.0	10.0	6.7	21.7
Salvia lyrata	0.0	1.7	1.7	1.7
Sanicula canadensis	3.3	13.3	1.7	3.3
Scutellaria ovata	10.0	6.7	8.3	3.3
Senecio spp.	3.3	0.0	1.7	1.7
Sisyrinchium angustifoli	1.7	5.0	0.0	1.7
Solidago caesia	6.7	0.0	0.0	3.3
Solidago canadensis	0.0	0.0	0.0	3.3
Solidago hispida	16.7	5.0	15.0	0.0
Solidago odora	3.3	1.7	15.0	1.7
Solidago radula	31.7AB	15.0C	56.7A	28.3BC
Solidago spp.	11.7	5.0	13.3	1.7
Solidago ulmifolia	56.7	53.3	53.3	38.3
Tradescantia ohiensis	1.7	0.0	0.0	0.0
Triodanus leptocarpa	0.0	1.7	0.0	0.0
UNK Matela	0.0	5.0	0.0	1.7
Unknown forb	0.0	0.0	1.7	0.0
Unkown Seeds	0.0	1.7	0.0	0.0
Viola palmata	1.7	0.0	0.0	3.3
Viola pedata	5.0	8.3	3.3	6.7
Viola sagittata	0.0	3.3	0.0	1.7
Viola sororia	1.7	1.7	0.0	0.0
Viola spp.	1.7	0.0	0.0	0.0

[a] Row means follwed bythe same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996; WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996.

Table 5. Effects of fire season on species richness, diversity, and evenness of herbaceous plants in experimental stands, Ouachita National Forest, Arkansas, July 1994-1996.

YEAR	STAND	TREATMENT[a]	Species Richness		Species Diversity		Species Evenness	
			(Stand)	(m^2)	H'[b]	N2[b]	E1[b]	E5[b]
Pre-Treatment								
94	1257C	WSI-C	52	9	2.93	9.79	0.74	0.50
94	1265C	WSI-C	78	14	3.22	15.13	0.74	0.59
94	1274C	WSI-C	53	9	3.09	15.68	0.78	0.70
94	1313C	WSI-C	56	9	2.65	6.30	0.66	0.40
94	1257D	WSI-D	53	9	3.05	14.41	0.77	0.67
94	1274D	WSI-D	60	11	3.19	16.21	0.78	0.65
94	1289D	WSI-D	63	12	3.10	13.41	0.75	0.59
94	1313D	WSI-D	55	11	2.78	9.88	0.69	0.59
94	1257G	WSI-G	55	11	3.04	14.33	0.76	0.67
94	1259G	WSI-G	57	12	2.89	10.47	0.71	0.56
94	1274G	WSI-G	51	8	2.68	10.42	0.68	0.69
94	1289G	WSI-G	59	12	2.94	13.13	0.72	0.68
Year One								
95	1257C	WSI-C	53	10	3.00	11.40	0.75	0.55
95	1265C	WSI-C	68	12	3.09	12.99	0.73	0.57
95	1274C	WSI-C	51	9	3.06	15.12	0.78	0.70
95	1313C	WSI-C	55	8	2.89	8.34	0.72	0.43
95	1257D	WSI-D	65	14	3.19	15.57	0.76	0.63
95	1274D	WSI-D	79	14	3.31	17.97	0.76	0.65
95	1289D	WSI-D	76	16	3.39	18.62	0.78	0.61
95	1313D	WSI-D	69	12	3.06	10.89	0.72	0.48
95	1257G	WSI-G	69	12	3.34	18.18	0.79	0.63
95	1259G	WSI-G	69	12	3.22	15.23	0.76	0.59
95	1274G	WSI-G	64	7	3.26	17.45	0.78	0.66
95	1289G	WSI-G	69	11	3.28	16.19	0.77	0.60
Year Two								
96	1257CD	WSI-CD	71	13	3.24	15.64	0.76	0.59
96	1265CG	WSI-CG	76	12	3.14	13.69	0.73	0.57
96	1274CG	WSI-CG	59	10	3.30	19.85	0.81	0.72
96	1313CD	WSI-CD	70	11	3.04	9.82	0.72	0.44
96	1257DD	WSI-DD	66	12	3.30	19.60	0.79	0.71
96	1274DD	WSI-DD	77	13	3.28	18.66	0.76	0.69
96	1289DC	WSI-DC	69	14	3.17	13.40	0.75	0.54
96	1313DC	WSI-DC	63	12	2.90	8.42	0.70	0.44

[a] WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormasnt-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing season prescribed fire, September 1994; WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996; WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996.

[b] H' = Shannon Weaver index of diversity, N2 = number of abundant species, E1 = J' of Pielou, E5 = Modified Hill's ratio.

APPENDIX C

WOODY SPECIES RESPONSE

TO SEASON

OF FIRE

Table 1.[a] Woody species response (stems/ha) to season of fire in WSI stands, Ouachita National Forest, Arkansas.

	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
Group, Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Woody, Trees												
Acer rubrum	1,030	587	962	540	257	206	1,019	605	949	599	297	234
Amelanchier arborea	208	73	103	39	113	81	181	106	241	132	152	69
Carya texana	144	102	107	96	663	488	776	274	1,431	676	2,549	880
Carya tomentosa	2,133	373	2,914	796	3,159	1,028	1,435	447	1,678	1,000	1,116	550
Celtis occidentalis	14	8	6	6	25	15	8	6	6	6	16	12
Cercis canadensis	0	0	0	0	10	10	0	0	0	0	0	0
Chionanthus virginicus	4	2	64	39	47	23	14	8	167	121	91	48
Cornus florida	1,299	873	1,824	819	1,678	1,166	1,287	877	2,156	1,072	1,728	1,143
Diospyros virginiana	0	0	4	2	0	0	4	4	0	0	0	0
Fraxinus americana	4	4	16	16	41	19	4	4	0	0	25	20
Juniperus virginiana	0	0	0	0	4	4	0	0	0	0	0	0
Liquidambar styraciflua	0	0	8	8	0	0	0	0	0	0	0	0
Morus rubra	14	9	4	4	6	4	16	14	12	7	14	14
Nyssa sylvatica	472	445	887	549	70	21	332	326	912	447	54	22
Ostrya virginiana	192	113	16	12	10	10	138	93	8	6	2	2
Pinus echinata	2,473	1,181	4,740	2,772	3,618	3,195	1,711	828	3,498	3,040	1,017	990
Prunus mexicana	523	313	237	147	476	194	385	240	515	282	566	329
Prunus serotina	700	440	356	38	402	208	597	369	548	269	597	331
Quercus alba	1,878	1,498	1,048	400	1,299	847	1,855	1,361	945	396	1,151	696
Quercus falcata	41	41	72	48	194	69	16	16	16	16	12	12
Quercus marilandica	1,474	311	1,588	465	2,053	663	920A	225	78C	34	408B	90
Quercus nigra	31	23	39	12	99	46	21	15	51	19	8	6
Quercus phellos	8	6	8	6	2	2	2	2	0	0	0	0
Quercus rubra	373	209	82	82	262	180	167	72	124	52	103	21
Quercus stellata	6,182	863	6,480	451	6,089	847	5,206B	612	8,473A	816	7,574A	593
Quercus velutina	624	245	350	127	616	193	1,110	306	2,576	512	2,483	837
Sassafras albidum	0	0	0	0	0	0	4	4	0	0	0	0
Ulmus alata	1,497	728	1,036	355	1,575	602	1,419	705	1,400	538	2,525	1,012
Viburnum rufidulum	859	470	124	37	196	61	910	501	117	69	764	541
Totals												
0-1 m	18,361	2,594	18,740	2,725	17,715	2,739	15,740B	1,965	25,560A	4,335	21,310A	229
1-3 m	3,791	445	4,295	773	5,212	961	3,758A	246	334C	76	1,923B	550
> 3 m	25	19	41	17	37	26	41	23	10	5	19	11
TOTAL	22,177	2,639	23,077	2,003	22,964	2,130	19,539	2,163	25,904	4,372	23,252	357

Table 1. (Continued).[a]

	Pre-treatment (1994)[b]						Post-treatment (1995)[b]					
	WSI-C		WSI-D		WSI-G		WSI-C		WSI-D		WSI-G	
Group, Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Woody, Shrubs												
Callicarpa americana	0	0	8	8	4	4	0	0	23	23	0	0
Ceanothus americanus	2,611	1,413	1,147	202	2,446	1,132	2,685	1,552	3,348	430	5,177	2,808
Crataegus crusgalli	43	25	62	37	91	66	72	38	56	32	99	76
Crataegus marshallii	89	56	31	13	305	172	68	37	41	41	115	43
Crataegus pruinosa	10	10	2	2	27	17	21	21	10	10	35	35
Crataegus spathulata	45	30	6	6	0	0	2	2	19	11	4	4
Crataegus uniflora	23	23	4	4	4	2	0	0	23	14	0	0
Euonymous americanus	2	2	0	0	0	0	0	0	0	0	0	0
Hypericum densiflorum	62	62	0	0	0	0	14	14	0	0	49	29
Hypericum hypericoides	754	408	1,032	557	614	89	593A	375	23B	11	449A	285
Ilex decidua	10	10	0	0	25	16	0	0	0	0	0	0
Rhamnus caroliniana	0	0	0	0	0	0	0	0	0	0	0	0
Rhus aromatica	45AB	31	0B	0	645A	400	78	56	185	185	698	434
Rhus copallina	507	197	958	209	1,100	390	391B	162	2,187A	371	1,415AB	502
Rhus glabra	126	61	33	17	241	121	107	61	119	62	257	137
Ribes sp.	8	5	39	39	2	2	0	0	0	0	0	0
Rosa carolina	1,460	1,287	785	580	459	394	585	383	303	215	463	269
Rosa multiflora	10	10	0	0	154	90	710	710	0	0	58	50
Sambucus canadensis	0	0	0	0	0	0	0	0	0	0	0	0
Symphoricarpos orbiculatus	0	0	0	0	2	2	6	4	8	8	4	2
Vaccinium arboreum	1,931	1,035	1,347	398	1,528	607	1,779	794	1,256	411	1,678	716
Vaccinium pallidum	9,297	8,817	4,789	6,315	848	501	9,332	8,839	1,120	579	474	439
Vaccinium stamineum	103	50	235	208	121	46	595	173	3,511	3,382	801	361
Totals												
0-1 m	16,712	9,255	12,835	7,740	7,831	790	16,663	8,798	12,167	4,638	11,599	2,846
1-3 m	424	72	342	132	785	327	377	75	64	53	177	56
> 3 m	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	17,136	9,269	13,176	7,764	8,615	670	17,039	8,833	12,231	4,642	11,776	2,843
Woody, Vines												
Berchemia scandens	45	45	0	0	4	4	33	33	0	0	0	0
Lonicera japonica	0	0	4	2	4	4	0	0	0	0	0	0
Lonicera spp.	2	2	0	0	0	0	2	2	0	0	0	0
Parthenocissus quinquefolia	2,349	1,611	1,194	485	3,406	2,379	2,310	1,310	1,343	530	3,548	952
Rubus spp.	6,645	3,590	2,650	967	5,397	1,895	4,909	1,543	3,295	1,125	9,151	3,594

Table 1. (Continued).[a]

Group, Species	Pre-treatment (1994)[b] WSI-C Mean	SE	WSI-D Mean	SE	WSI-G Mean	SE	Post-treatment (1995)[b] WSI-C Mean	SE	WSI-D Mean	SE	WSI-G Mean	SE
Woody, Vines (Continued)												
Smilax bonanox	1,831	346	1,439	369	1,987	671	2,275	182	1,614	583	2,010	627
Smilax glauca	41	25	6	6	10	10	262	187	200	130	134	115
Smilax rotundifolia	142	77	521	312	206	116	4B	2	175A	134	10B	8
Smilax spp.	340	142	19	11	82	47	0	0	0	0	0	0
Toxicodendron radicans	20,262	9,419	22,469	12,926	26,614	12,817	18,512	8,690	15,707	8,497	26,905	10,664
Vitis aestivalis	142	67	243	84	198	62	284	81	276	98	344	209
Vitis palmata	2	2	0	0	8	8	0	0	0	0	0	0
Vitis rotundifolia	1,534	761	1,822	424	1,038	200	2,360	1,076	2,319	362	1,668	145
Totals												
0-1 m	32,784	13,764	29,707	13,445	38,166	13,757	30,519	10,098	24,802	9,241	43,359	10,009
1-3 m	552	152	651	238	772	288	428	102	126	32	406	114
> 3 m	0	0	10	10	16	6	4	2	0	0	4	2
TOTAL	33,335	13,850	30,368	13,677	38,955	13,750	30,951	10,192	24,928	9,259	43,769	10,107

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing season prescribed fire, September 1994.

Table 2.[a] Woody species response (stems/ha) by treatment in WSI stands, Ouachita National Forest, Arkansas, Summer 1996.

	Treatment[b]							
	WSI-CD		WSI-CG		WSI-DC		WSI-DD	
Group, Species	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
Woody, Trees								
Acer rubrum	1,594	1,594	964	799	1,672	972	350	243
Amelanchier arborea	272A	107	70AB	37	29BC	21	0C	0
Bumelia lanuginosa	54	54	0	0	0	0	0	0
Carya texana	78	78	111	62	264	0	49	33
Carya tomentosa	2,483	1,281	3,097	99	1,903	1,219	5,210	572
Celtis occidentalis	16	16	0	0	0	0	33	33
Chionanthus virginicus	0	0	8	8	107	107	54	54
Cornus florida	103	54	4,114	2,261	2,426	1,726	1,717	1,404
Fraxinus americana	0	0	8	8	62	62	0	0
Liquidambar styraciflua	140	140	16	16	21	21	0	0
Morus rubra	0B	0	37A	12	0B	0	0B	0
Nyssa sylvatica	1,211	1,128	29	12	1,660	309	16	16
Ostrya virginiana	62	37	29	4	305	305	45	45
Pinus echinata	6,976	6293	54	29	4,559	4,122	663	12
Prunus mexicana	1,623	1,441	1,141	194	511	156	527	453
Prunus serotina	680	169	1,952	1,623	284	210	424	29
Quercus alba	3,735	3,554	605	605	951	844	1,598	1,277
Quercus falcata	0B	0	0B	0	86A	21	0B	0
Quercus marilandica	91	91	91	91	2,092	239	198	115
Quercus nigra	21	21	41	41	54	12	45	45
Quercus phellos	124A	82	0B	0	12AB	12	0B	0
Quercus rubra	861	367	469	264	194	78	16	8
Quercus stellata	7,541	1,371	11,082	712	10,918	1231	9,489	1,095
Quercus velutina	2,244	457	1,651	647	383	37	2,401	1,075
Ulmus alata	1,413	482	3,748	2,306	1,775	1,009	733	99
Viburnum rufidulum	1,219A	16	115AB	8	156AB	58	66B	16
Totals								
0-1 m	31,880	7,862	28,614	6,828	28,210	1211	23,309	1,738
1-3 m	659	124	803	441	2,191	165	325	128
>3 m	0	0	16A	8	21A	4	0B	0
Total	32,539	7,985	29,433	7,277	30,422	1,042	23,635	1,866
Woody, Shrubs								
Ceanothus americanus	9,942	9,661	3,760	1,355	2,051	395	7,532	2,335
Crataegus crus-galli	12	12	12	12	70	70	0	0
Crataegus marshallii	181	156	140	115	0	0	58	25
Crataegus pruinosa	119	21	124	124	0	0	91	91
Hypericum hypericoides	202	169	54	54	37	37	45	45
Rhus aromatica	78	78	4	4	0	0	0	0
Rhus copallina	1,326	857	898	99	1,738	82	1,787	848
Rhus glabra	74	74	329	33	8	0	95	95
Rosa carolina	5,469	5,131	243	136	906	906	354	41
Symphoricarpos orbiculatus	8	8	0	0	0	0	16	16
Vaccinium arboreum	24,174	23,186	3,315	1,413	2,166	824	1,343	527
Vaccinium pallidum	0	0	0	0	13,504	13,496	2,282	2,282
Vaccinium stamineum	74	74	585	486	78	45	346	346
Totals								
0-1 m	41,442	7,648	9,176	1,145	20,464	14,731	13,895	6,466
1-3 m	218	218	288	99	95	29	62	62
>3 m	0	0	0	0	0	0	0	0
Total	41,661	7,429	9,464	1,046	20,558	14,760	13,957	6,527

Table 2. (Continued).[a]

Group, Species	Treatment[b] WSI-CD MEAN	WSI-CD SE	WSI-CG MEAN	WSI-CG SE	WSI-DC MEAN	WSI-DC SE	WSI-DD MEAN	WSI-DD SE
Woody, Vines								
Parthenocissus quinquefolia	2,170	1,791	4,699	3,562	894	531	3,958	572
Rubus spp.	4,044	3,089	10,905	1,738	3,406	984	4,592	2,879
Smilax bona-nox	2,244	671	1,701	424	2,644	346	869	449
Smilax glauca	268	259	284	144	350	243	25	25
Smilax rotundifolia	0	0	0	0	144	144	54	54
Toxicodendron radicans	6,968	1,013	29,742	1,911	8,290	5,383	22,819	13,751
Vitis aestivalis	115	82	367	12	297	91	399	350
Vitis palmata	4	4	0	0	0	0	0	0
Vitis rotundifolia	1,252	568	3,723	3,583	3,418	1,137	3,043	54
Totals								
0-1 m	16,906	3,628	51,281	107	19,072	4,468	35,627	17,910
1-3 m	156	156	140	33	371	181	132	115
>3 m	4	4	0	0	0	0	0	0
Total	17,066	3,789	51,421	74	19,442	4,650	35,759	18,026

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996; WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996.

Table 3.[a] Percent frequency of occurence of woody species to season of prescribed fire, in WSI stands on the Ouachita National Forest, Arkansas.

Group, Species	Pre-treatment (1994)[b]			Post-treatment (1995)[b]		
	WSI-C	WSI-D	WSI-G	WSI-C	WSI-D	WSI-G
Woody, Trees						
Acer rubrum	26.7	29.2	15.8	25.8	25.0	15.0
Amelanchier arborea	20.0	9.2	9.2	12.5	10.0	14.2
Carya texana	11.7	7.5	28.3	50.8	50.0	73.3
Carya tomentosa	83.3	85.0	85.8	70.0	47.5	36.7
Celtis occidentalis	2.5	0.8	1.7	1.7	0.8	1.7
Cercis canadensis	0.0	0.0	0.8	0.0	0.0	0.0
Chionanthus virginicus	1.7	3.3	5.8	2.5	8.3	11.7
Cornus florida	22.5	42.5	34.2	28.3	31.7	32.5
Diospyros virginiana	0.0	1.7	0.0	1.7	0.0	0.0
Fraxinus americana	0.8	1.7	9.2	0.8	0.0	4.2
Juniperus virginiana	0.0	0.0	1.7	0.0	0.0	0.0
Liquidambar styraciflua	0.0	0.8	0.0	0.0	0.0	0.0
Morus rubra	4.2	1.7	1.7	4.2	1.7	1.7
Nyssa sylvatica	14.2	22.5	9.2	9.2	20.0	5.0
Ostrya virginiana	7.5	4.2	2.5	13.3	2.5	0.8
Pinus echinata	45.0	56.7	43.3	36.7	23.3	17.5
Prunus mexicana	23.3	18.3	25.0	21.7	14.2	17.5
Prunus serotina	35.0	25.8	35.0	34.2	23.3	32.5
Quercus alba	31.7	40.0	32.5	39.2	35.8	38.3
Quercus falcata	2.5	5.0	10.0	0.8	2.5	2.5
Quercus marilandica	47.5	55.8	70.8	39.2A	4.2C	20.0B
Quercus nigra	4.2	10.0	11.7	4.2	9.2	2.5
Quercus phellos	1.7	2.5	0.8	0.8	0.0	0.0
Quercus rubra	25.0	3.3	23.3	7.5	9.2	15.0
Quercus stellata	95.8	96.7	96.7	91.7	97.5	96.7
Quercus velutina	44.2	30.0	36.7	68.3	65.0	77.5
Sassafras albidum	0.0	0.0	0.0	0.8	0.0	0.0
Ulmus alata	65.0	57.5	65.0	65.8	53.3	66.7
Viburnum rufidulum	19.2	19.2	15.0	25.8	10.8	22.5
Woody, Shrubs						
Callicarpa americana	0.0	0.8	0.8	0.0	0.8	0.0
Ceanothus americanus	58.3	47.5	62.5	61.7	54.2	60.0
Crataegus crus-galli	7.5	13.3	11.7	12.5	5.8	8.3
Crataegus marshallii	10.0	6.7	15.8	8.3	3.3	8.3
Crataegus pruinosa	1.7	0.8	3.3	4.2	0.8	4.2
Crataegus spathulata	4.2A	0.8AB	0.0B	0.8	1.7	0.8
Crataegus uniflora	4.2	0.8	1.7	0.0	5.0	0.0
Euonymous americanus	0.8	0.0	0.0	0.0	0.0	0.0
Hypericum densiflorum	1.7	0.0	0.0	0.8	0.0	1.7
Hypericum hypericoides	25.8	34.2	20.8	20.8A	2.5B	14.2A
Ilex decidua	0.8	0.0	2.5	0.0	0.0	0.0
Rhus aromatica	2.5	0.0	10.0	3.3	0.8	9.2
Rhus copallina	47.5	61.7	56.7	46.7B	70.0A	60.8AB
Rhus glabra	10.8	7.5	22.5	8.3	12.5	20.0
Ribes sp.	2.5	1.7	0.8	0.0	0.0	0.0
Rosa carolina	10.8	5.0	3.3	10.0	3.3	5.0
Rosa multiflora	0.8	0.0	2.5	1.7	0.0	1.7
Symphoricarpos orbiculatus	0.0	0.0	0.8	1.7	0.8	1.7
Vaccinium arboreum	36.7	40.0	39.2	30.0	34.2	25.8
Vaccinium pallidum	18.3	25.0	5.8	20.8	18.3	7.5
Vaccinium stamineum	5.8	6.7	6.7	25.0	19.2	17.5

Table 3. (Continued)[a]

Group, Species	Pre-treatment (1994)[b] WSI-C	WSI-D	WSI-G	Post-treatment (1995)[b] WSI-C	WSI-D	WSI-G
Woody, Vines						
Berchemia scandens	0.8	0.0	0.8	0.8	0.0	0.0
Lonicera japonica	0.0	1.7	0.8	0.0	0.0	0.0
Parthenocissus quinquefolia	44.2	33.3	53.3	49.2	28.3	63.3
Rubus spp.	59.2	69.2	69.2	60.8	70.8	75.8
Smilax bonanox	63.3	55.0	71.7	70.0	70.8	74.2
Smilax glauca	8.3	1.7	1.7	18.3	17.5	12.5
Smilax rotundifolia	10.8	28.3	14.2	1.7	12.5	4.2
Smilax spp.	12.5	4.2	5.8	0.0	0.0	0.0
Toxicodendron radicans	60.0	61.7	71.7	57.5	60.8	71.7
Vitis aestivalis	18.3	29.2	19.2	23.3	25.0	20.0
Vitis palmata	0.8	0.0	2.5	0.0	0.0	0.0
Vitis rotundifolia	43.3	49.2	47.5	50.0	42.5	40.0

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing season prescribed fire, September 1994.

Table 4.[a] Percent frequency of occurence of woody species to season of prescribed fire, in WSI stands on the Ouachita National Forest, Arkansas, summer 1996.

Group, Species	Treatment[b]			
	WSI-CD	WSI-CG	WSI-DC	WSI-DD
Woody, Trees				
Acer rubrum	13.3	12.5	16.7	7.5
Amelanchier arborea	9.2A	3.3B	1.7C	0.0D
Bumelia lanuginosa	0.8	0.0	0.0	0.0
Carya texana	4.2	2.5	8.3	5.0
Carya tomentosa	38.3	45.8	35.0	46.7
Celtis occidentalis	0.8	0.0	0.0	0.8
Chionanthus virginicus	0.0	0.8	0.8	3.3
Cornus florida	1.7	20.8	15.8	17.5
Fraxinus americana	0.0	0.8	4.2	0.0
Liquidambar styraciflua	0.8	0.8	0.8	0.0
Morus rubra	0.0	2.5	0.0	0.0
Nyssa sylvatica	10.0	1.7	19.2	1.7
Ostrya virginiana	1.7	1.7	0.8	1.7
Pinus echinata	20.8	4.2	17.5	6.7
Prunus mexicana	15.0	20.0	10.0	14.2
Prunus serotina	10.8	25.0	10.8	11.7
Quercus alba	21.7	11.7	15.8	16.7
Quercus falcata	0.0	0.0	1.7	0.0
Quercus marilandica	0.8	2.5	25.8	5.8
Quercus nigra	1.7	4.2	4.2	1.7
Quercus phellos	1.7	0.0	0.8	0.0
Quercus rubra	20.8	16.7	7.5	1.7
Quercus stellata	46.7	49.2	50.0	49.2
Quercus velutina	30.8	29.2	12.5	30.8
Ulmus alata	23.3	40.0	30.8	20.8
Viburnum rufidulum	8.3	9.2	7.5	4.2
Woody, Shrubs				
Callicarpa americana	0.0	0.0	0.0	0.8
Ceanothus americanus	29.2	34.2	15.8	37.5
Crataegus crus-galli	0.8	0.8	4.2	0.0
Crataegus marshallii	5.0	5.0	0.0	1.7
Crataegus pruinosa	5.0	6.7	0.0	4.2
Hypericum hypericoides	1.7	1.7	1.7	0.8
Rhus aromatica	1.7	0.8	0.0	0.0
Rhus copallina	22.5	30.0	34.2	29.2
Rhus glabra	3.3	10.8	1.7	2.5
Rosa carolina	8.3A	5.0B	0.8C	3.3B
Symphoricarpos orbiculatus	0.8	0.0	0.0	0.8
Vaccinium arboreum	27.5	20.0	21.7	9.2
Vaccinium pallidum	0.0	0.0	15.8	5.0
Vaccinium stamineum	1.7	3.3	1.7	2.5
Woody, Vines				
Parthenocissus quinquefolia	17.5	32.5	9.2	20.8
Rubus spp.	23.3	44.2	34.2	35.0
Smilax bonanox	30.8	41.7	33.3	31.7
Smilax glauca	12.5	14.2	15.0	1.7
Smilax rotundifolia	0.0	0.0	4.2	2.5
Toxicodendron radicans	14.2	46.7	30.0	31.7
Vitis aestivalis	5.0	12.5	12.5	13.3
Vitis palmata	0.8	0.0	0.0	0.0
Vitis rotundifolia	15.8	18.3	20.8	24.2

[a] Row means followed by the same letter or without letters were not different (LSD) ($P \leq 0.05$).

[b] WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife

Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996; WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996.

Table 5. Effects of fire season on species richness, diversity, and evenness of woody plants in experimental stands, Ouachita National Forest, Arkansas, July 1994-1996.

YEAR	STAND	TREATMENT[a]	Species Richness		Species Diversity		Species Evenness	
			(Stand)	(m^2)	H'[b]	N2[b]	E1[b]	E5[b]
Pre-Treatment								
94	1257C	WSI-C	36	15	2.77	12.35	0.77	0.76
94	1265C	WSI-C	42	20	2.11	4.33	0.57	0.46
94	1274C	WSI-C	43	18	2.20	4.15	0.58	0.39
94	1313C	WSI-C	38	14	2.31	4.95	0.64	0.43
94	1257D	WSI-D	35	13	2.42	7.69	0.68	0.65
94	1274D	WSI-D	42	21	1.79	2.59	0.48	0.32
94	1289D	WSI-D	39	17	2.29	5.14	0.63	0.46
94	1313D	WSI-D	36	16	2.54	6.41	0.71	0.46
94	1274G	WSI-G	46	19	1.83	2.81	0.48	0.35
94	1257G	WSI-G	40	17	2.57	7.48	0.70	0.54
94	1259G	WSI-G	42	19	2.74	10.45	0.73	0.66
94	1289G	WSI-G	41	20	2.30	5.47	0.62	0.50
Year One								
95	1257C	WSI-C	42	16	2.91	13.66	0.78	0.73
95	1265C	WSI-C	39	19	2.30	5.42	0.63	0.49
95	1274C	WSI-C	34	17	1.97	3.23	0.56	0.36
95	1313C	WSI-C	38	15	2.23	4.23	0.61	0.39
95	1257D	WSI-D	34	10	2.55	9.06	0.72	0.68
95	1274D	WSI-D	40	13	2.16	4.00	0.58	0.39
95	1289D	WSI-D	34	13	2.56	7.64	0.73	0.56
95	1313D	WSI-D	35	12	2.74	10.14	0.77	0.63
95	1257G	WSI-G	35	14	2.70	9.90	0.76	0.64
95	1259G	WSI-G	37	14	2.55	8.32	0.71	0.62
95	1274G	WSI-G	42	18	2.06	3.40	0.55	0.35
95	1289G	WSI-G	39	15	2.14	4.68	0.59	0.49
Year Two								
96	1257CD	WSI-CD	35	12	2.56	8.72	0.72	0.64
96	1257DD	WSI-DD	26	8	2.37	7.82	0.73	0.70
96	1265CG	WSI-CG	35	16	2.38	7.27	0.67	0.64
96	1274CG	WSI-CG	35	13	2.29	5.42	0.64	0.50
96	1274DD	WSI-DD	38	14	2.39	5.93	0.66	0.50
96	1289DC	WSI-DC	36	15	2.58	8.38	0.72	0.60
96	1313CD	WSI-CD	36	10	2.07	4.06	0.58	0.44
96	1313DC	WSI-DC	35	13	2.52	6.78	0.71	0.50

[a] WSI-CD = Wildlife Stand Improvement--dormant-season prescried fire, March 1996; WSI-CG = Wildlife Stand Improvement--growing-season prescribed fire, October 1995; WSI-DC = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995, no burn in 1996; WSI-DD = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995 and 1996; WSI-C = Wildlife Stand Improvement--no burn control; WSI-D = Wildlife Stand Improvement--dormant-season prescribed fire, March 1995; WSI-G = Wildlife Stand Improvement--growing season prescribed fire, September 1994.

[b] H' = Shannon Weaver index of diversity, N2 = number of abundant species, E1 = J' of Pielou, E5 = Modified Hill's ratio.

APPENDIX D

FUELS OF PRESCRIBED FIRES ON THE OUACHITA NATIONAL FOREST, ARKANSAS

Table 1. Mean fuel energy (kj/kg) sampled prior to growing-season (September 1994) and dormant-season (March 1995) prescribed fires, in Ouachita National Forest, Arkansas.

	Fire 1		Fire 2		Fire 3	
	Pre-Burn	Post-burn	Pre-burn	Post-burn	Pre-burn	Post-burn
Stand						
1257D	17021.98	18154.89	18519.68	19105.83	19069.70	17269.50
1257G	17623.87	17276.33	17793.44	17160.52	14915.81	17750.06
1259G	15476.50	15250.80	14467.57	17785.07	18666.72	16137.27
1274D	17349.22	19520.03	18110.76	14311.95	17400.09	14380.23
1274G	18254.87	18965.95	17111.79	17904.98	17031.74	14300.73
1289D	16788.91	16004.46	18442.85	17685.21	16988.15	15954.55
1289G	16286.74	19894.21	15768.91	18591.78	16555.40	18818.45
1313D	18702.23	18174.48	18250.01	15146.42	18304.36	18617.19

Table 2. Mean fuel conditions during prescribed fires in Wildlife Stand Improvement stands, Ouachita National Forest of western Arkansas.

	Percent Moisture			Fuel Load Kg/ha			
Stand, Fire	1 hr dead	1 hr live	10 hr dead	1 hr dead	1 hr live	10 hr dead	Post-burn residual
1257CD 1	23	184	37	10,070	294	350	5,980
1257CD 2	24	135	48	12,030	198	340	6,900
1257CD 3	24	114	39	13,805	188	1565	6,485
1257D 1	16	120	28	9,960	200	687	4,472
1257D 2	11	63	14	10,013	153	1,727	6,740
1257D 3	9	45	6	10,728	160	200	6,673
1257G 1	11	101	18	9,344	1,074	2,511	6,820
1257G 2	11	121	43	8,656	732	1,902	9,868
1257G 3	12	121	53	9,102	1,053	1,029	8,520
1259G 1	14	101	22	8,080	1,072	1,056	5,712
1259G 2	8	113	40	7,668	889	728	4,892
1259G 3	10	115	31	8,888	1,416	848	6,240
1265CG 1	13	104	40	7,293	423	350	5,153
1265CG 2	14	127	36	8,460	827	857	6,053
1265CG 3	10	127	19	8,083	363	1,703	5,200
1274CG 1	10	113	51	7,613	495	77	5,747
1274CG 2	6	86	8	7,423	650	643	5,627
1274CG 3	11	110	17	7,527	1,007	703	3,433
1274D 1	12	128	26	9,247	73	1,080	3,993
1274D 2	15	117	15	8,413	307	1,140	5,147
1274D 3	16	120	14	6,767	283	577	6,107
1274G 1	15	105	23	7,896	870	1,212	6,256
1274G 2	25	117	29	6,136	942	1,573	4,564
1274G 3	8	102	11	4,864	816	280	2,432
1289D 1	22	143	29	8,180	220	1,380	4,987
1289D 2	45	117	55	6,580	263	963	3,273
1289D 3	20	163	45	8,260	380	1,113	3,233

Table 2. Continued.

Stand, Fire	Percent Moisture 1 hr dead	1 hr live	10 hr dead	Fuel Load Kg/ha 1 hr dead	1 hr live	10 hr dead	Post-burn Residual
1289G 1	28	92	29	8,492	1,018	1,752	5,304
1289G 2	12	94	40	5,940	1,227	883	4,227
1289G 3	24	100	58	5,592	1,892	156	6,028
1313CD 1	28	128	33	13,305	330	910	9,555
1313CD 2	21	114	28	8,895	75	960	5,165
1313CD 3	12	153	38	13,465	145	1,070	8,015
1313D 1	19	113	26	9,300	422	474	4,336
1313D 2	18	138	33	10,180	366	1,436	5,448
1313D 3	29	143	31	11,352	200	720	6,300

APPENDIX E

OBSERVED AND PREDICTED FIRE BEHAVIOR

Table 1. Mean fire behavior parameters observed for dormant-season and growing-season prescribed fires, Ouachita National Forest, Arkansas, 1994-1996.

Fire Season, Stand	Fire Type	Date	Fire Behavior Parameters: Rate of Spread m/min	Flame Length (meters)	Flame Depth (meters)	Residence Time (seconds)
Dormant-season						
1257CD		3-2-96				
	Headfire		11.95	0.52	0.91	9.67
1257D		4-2-95				
	Backfire		0.28	0.17	0.02	8.50
	Headfire		8.78	0.54	0.53	7.98
1257DD	Headfire	3-2-96	0.27	0.12	0.09	18.11
1274D		4-1-95				
	Backfire		1.06	0.35	0.30	19.50
	Headfire		4.86	0.38	0.70	10.67
1274DD	Headfire	3-4-96	1.80	0.13	0.15	17.54
1289D		4-1-95				
	Backfire		0.41	0.23	0.04	10.19
	Headfire		12.62	0.75	1.42	12.55
1313CD	Headfire	3-3-96	6.84	0.51	0.56	15.34
1313D		3-31-95				
	Backfire		0.24	0.14	0.04	9.39
	Headfire		6.20	0.54	0.45	12.27
Growing-Season						
1257G		9-12-94				
	Backfire		0.43	0.45	0.11	13.00
	Headfire		0.95	0.26	0.17	26.33
1259G		9-13-94				
	Backfire		0.36	0.24	0.10	17.00
	Headfire		6.23	0.79	0.70	13.62
1265CG		10-14-95				
	Headfire		3.20	0.38	0.39	17.33
1274CG		10-15-95				
	Headfire		4.13	0.52	0.52	19.88
1274G		9-10-94				
	Backfire		0.13	0.15	0.05	28.00
	Headfire		0.59	0.43	0.17	54.00
1289G		9-11-94				
	Backfire		0.26	0.21	0.11	.
	Headfire		2.49	0.59	0.36	22.00

Table 2. Observed and predicted fire behavior parameters of headfires, for prescribed fires in the Ouachita National Forest, Arkansas 1994-1996.

Stand, Fire	Observed Parameters: Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)	Predicted Parameters: Model Number	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)
1289D 1	0.59	15.2	1812	7137	1693	7	0.8	2	155	5147	347
1289D 1						50	2.1	5	1278	14419	1078
1289D 1						8	0.2	0	5	1845	151
1289D 1						9	0.4	1	34	3713	400
1289D 1						10	0.7	1	118	12596	965
1289D 2	0.75	10.6	1296	7312	1296	7	0.9	2	195	5235	353
1289D 2						50	2.2	6	1506	14540	1087
1289D 2						8	0.2	0	5	1853	152
1289D 2						9	0.4	1	37	3724	401
1289D 2						10	0.8	1	150	12814	981
1289D 3	0.90	12.0	1976	9871	898	7	0.6	1	80	5157	347
1289D 3						50	1.6	3	699	14610	1092
1289D 3						8	0.1	0	3	1864	153
1289D 3						9	0.3	0	21	3740	403
1289D 3						10	0.5	0	66	12589	964
1274D 1	0.39	3.0	504	10113	788	7	0.6	1	98	5399	364
1274D 1						50	1.7	3	799	15107	1129
1274D 1						8	0.1	0	3	1914	157
1274D 1						9	0.3	0	22	3807	410
1274D 1						10	0.6	0	82	13021	997
1274D 2	0.39	7.1	921	7739	1738	7	0.4	0	45	5362	361
1274D 2						50	1.2	2	385	14883	1112
1274D 2						8	0.1	0	2	1888	155
1274D 2						9	0.3	0	16	3769	406
1274D 2						10	0.5	0	53	13021	997
1274D 3	0.35	4.5	177	2383	190	7	0.4	0	43	5359	361
1274D 3						50	1.2	2	373	14896	1113
1274D 3						8	0.1	0	2	1890	155
1274D 3						9	0.3	0	15	3772	407
1274D 3						10	0.5	0	52	12996	995
1313D 1	0.83	7.1	1166	9911	4665	7	0.7	1	120	5010	337
1313D 1						50	1.7	4	845	13575	1014
1313D 1						8	0.1	0	3	1784	146
1313D 1						9	0.3	0	23	3594	387

Table 2. (Continued).

Stand, Fire	Observed Parameters: Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m²)	Reaction Intensity (kW/m²)	Predicted Parameters: Model Number	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m²)	Reaction Intensity (kW/m²)
1313D 1						10	0.6	0	101	12376	948
1313D 2	0.44	6.9	1231	10701	1758	7	0.5	1	58	4976	335
1313D 2						50	1.3	2	444	13665	1021
1313D 2						8	0.1	0	2	1792	147
1313D 2						9	0.3	0	15	3620	390
1313D 2						10	0.5	0	55	12335	945
1313D 3	0.35	4.6	752	9741	1879	7	0.4	0	36	4896	330
1313D 3						50	1.1	1	291	13402	1002
1313D 3						8	0.1	0	2	1775	146
1313D 3						9	0.2	0	12	3555	383
1313D 3						10	0.4	0	41	12132	929
1257D 1	0.40	10.1	1636	9766	2517	7	0.7	1	125	5824	392
1257D 1						50	1.9	4	1082	16695	1248
1257D 1						8	0.2	0	5	2120	174
1257D 1						9	0.4	0	30	4188	451
1257D 1						10	0.7	0	103	14014	1073
1257D 2	0.80	11.6	1694	8738	3388	7	0.8	2	170	6001	404
1257D 2						50	2.0	4	1229	16848	1259
1257D 2						8	0.2	0	5	2133	175
1257D 2						9	0.4	0	30	4213	454
1257D 2						10	0.8	1	167	15190	1163
1257D 3	0.41	4.7	604	7746	1343	7	0.9	2	201	6054	408
1257D 3						50	2.1	5	1364	16864	1260
1257D 3						8	0.2	0	5	2131	175
1257D 3						9	0.4	0	32	4211	454
1257D 3						10	0.9	1	215	15725	215
1257DD 1	0.13	0.3	6	1090	43	7	0.4	0	36	5220	352
1257DD 1						76	0.6	0	74	9253	688
1257DD 1						8	0.1	0	2	1873	154
1257DD 1						9	0.3	0	15	3755	405
1257DD 1						10	0.4	0	44	12722	974
1257DD 2	0.14	0.3	10	1864	107	7	0.4	0	44	5435	366
1257DD 2						76	0.6	1	88	9577	713
1257DD 2						8	0.1	0	2	1959	161

Table 2. (Continued).

Stand, Fire	Observed Parameters: Flame Length (m)	Observed: Rate of Spread (m/min)	Observed: Fireline Intensity (kW/m)	Observed: Heat/ Unit Area (kJ/m^2)	Observed: Reaction Intensity (kW/m^2)	Predicted Parameters: Model Number	Predicted: Flame Length (m)	Predicted: Rate of Spread (m/min)	Predicted: Fireline Intensity (kW/m)	Predicted: Heat/ Unit Area (kJ/m^2)	Predicted: Reaction Intensity (kW/m^2)
1257DD 2						9	0.3	0	18	3894	420
1257DD 2						10	0.5	0	51	13116	1004
1257DD 3	0.10	0.2	0	0	0	7	0.4	0	28	4781	322
1257DD 3						76	0.5	0	60	8662	644
1257DD 3						8	0.1	0	2	1780	146
1257DD 3						9	0.3	0	13	3586	387
1257DD 3						10	0.4	0	31	11524	883
1313CD 1	0.41	2.9	384	7953	1201	7	0.5	1	65	4910	331
1313CD 1						80	1.5	3	674	14921	1116
1313CD 1						8	0.1	0	2	1775	145
1313CD 1						9	0.3	0	15	3560	384
1313CD 1						10	0.5	0	61	12163	931
1313CD 2	0.31	3.4	439	7704	798	7	0.6	1	76	5030	339
1313CD 2						80	1.7	3	785	15282	1144
1313CD 2						8	0.1	0	2	1795	147
1313CD 2						9	0.3	0	17	3633	392
1313CD 2						10	0.6	0	73	12456	954
1313CD 3	0.80	14.2	2561	10821	3123	7	0.6	1	86	4899	330
1313CD 3						80	1.8	4	971	15129	1132
1313CD 3						8	0.1	0	3	1789	147
1313CD 3						9	0.3	0	21	3617	390
1313CD 3						10	0.6	0	73	12218	936
1257CD 1	0.58	10.1	1275	7604	1020	7	0.4	0	35	5112	344
1257CD 1						80	1.3	2	472	16250	1216
1257CD 1						8	0.1	0	2	1871	153
1257CD 1						9	0.3	0	15	3752	404
1257CD 1						10	0.4	0	37	12539	960
1257CD 2	0.62	14.1	2143	9095	2552	7	0.7	1	114	5189	350
1257CD 2						80	2.1	5	1352	16175	1210
1257CD 2						8	0.1	0	4	1859	152
1257CD 2						9	0.3	0	24	3735	403
1257CD 2						10	0.6	0	90	12682	971
1257CD 3	0.38	11.7	2827	14546	4349	7	0.5	1	55	5269	355
1257CD 3						80	1.5	2	600	16316	1221

Table 2. (Continued).

Stand, Fire	Observed Parameters: Flame Length (m)	Observed: Rate of Spread (m/min)	Observed: Fireline Intensity (kW/m)	Observed: Heat/ Unit Area (kJ/m²)	Observed: Reaction Intensity (kW/m²)	Predicted Parameters: Model Number	Predicted: Flame Length (m)	Predicted: Rate of Spread (m/min)	Predicted: Fireline Intensity (kW/m)	Predicted: Heat/ Unit Area (kJ/m²)	Predicted: Reaction Intensity (kW/m²)
1257CD 3						8	0.1	0	2	1868	153
1257CD 3						9	0.3	0	15	3748	404
1257CD 3						10	0.5	0	56	12897	988
1274DD 1	0.17	4.2	403	5772	1222	7	0.4	0	35	4980	336
1274DD 1						76	0.5	0	70	8942	665
1274DD 1						8	0.1	0	2	1796	147
1274DD 1						9	0.3	0	13	3635	392
1274DD 1						10	0.4	0	43	12365	947
1274DD 2	0.12	0.5	22	2600	276	7	0.5	1	55	4929	332
1274DD 2						76	0.7	1	102	8914	663
1274DD 2						8	0.1	0	2	1809	148
1274DD 2						9	0.3	0	17	3662	395
1274DD 2						10	0.5	0	50	12278	940
1274DD 3	0.10	0.7	22	1939	446	7	0.4	0	29	5032	339
1274DD 3						76	0.6	0	73	9027	672
1274DD 3						8	0.1	0	2	1810	148
1274DD 3						9	0.3	0	13	3663	395
1274DD 3						10	0.4	0	41	12454	954
1259G 1	1.10	9.3	947	6141	1029	7	0.9	2	200	5206	351
1259G 1						25	1.3	2	422	12686	933
1259G 1						8	0.2	0	5	1822	149
1259G 1						9	0.4	1	34	3678	396
1259G 1						10	0.8	1	160	12861	985
1259G 2	0.54	3.9	368	5607	708	7	0.8	2	166	5156	347
1259G 2						25	1.2	2	361	12619	928
1259G 2						8	0.2	0	4	1817	149
1259G 2						9	0.4	0	30	3671	396
1259G 2						10	0.7	1	132	12692	972
1259G 3	0.77	5.5	757	8255	1147	7	0.7	1	113	5147	347
1259G 3						25	1.0	1	256	12606	927
1259G 3						8	0.1	0	3	1816	149
1259G 3						9	0.3	0	22	3670	396
1259G 3						10	0.6	0	96	12666	970
1257G 1	0.33	1.4	228	9685	1084	7	0.5	1	65	5187	349

Table 2. (Continued).

Stand, Fire	Observed Parameters: Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)	Predicted Parameters: Model Number	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)
1257G 1						25	0.8	1	159	12693	933
1257G 1						8	0.1	0	2	1822	149
1257G 1						9	0.3	0	16	3681	397
1257G 1						10	0.5	0	67	12826	982
1257G 2	0.24	0.7	28	2278	156	7	0.8	2	141	5133	346
1257G 2						25	1.1	2	317	12627	928
1257G 2						8	0.1	0	4	1822	279
1257G 2						9	0.4	0	28	3681	397
1257G 2						10	0.7	1	113	12626	967
1257G 3	0.22	0.7	40	3487	308	7	0.6	1	81	5139	346
1257G 3						25	0.9	1	201	12638	929
1257G 3						8	0.1	0	3	1824	150
1257G 3						9	0.3	0	21	3684	397
1257G 3						10	0.6	0	77	12636	968
1289G 1	0.28	0.8	110	8595	613	7	0.5	1	65	5158	347
1289G 1						25	0.8	1	154	12576	924
1289G 1						8	0.1	0	2	1803	148
1289G 1						9	0.3	0	14	3635	392
1289G 1						10	0.5	0	69	12822	982
1289G 2	0.20	0.4	33	5270	325	7	0.6	1	97	5152	347
1289G 2						25	0.9	1	218	12595	926
1289G 2						8	0.1	0	3	1802	148
1289G 2						9	0.3	0	18	3645	393
1289G 2						10	0.6	0	90	12795	980
1289G 3	1.30	6.3	243	2306	300	7	0.5	1	66	4995	336
1289G 3						25	0.8	1	168	12380	910
1289G 3						8	0.1	0	2	1796	147
1289G 3						9	0.3	0	18	3631	391
1289G 3						10	0.5	0	62	12363	947
1274G 1	0.53	0.7	68	6145	241	7	0.6	1	74	5085	343
1274G 1						25	0.8	1	176	12517	920
1274G 1						8	0.1	0	2	1797	147
1274G 1						9	0.3	0	16	3635	392
1274G 1						10	0.6	0	71	12582	963

Table 2. (Continued).

Stand, Fire	Observed Parameters					Predicted Parameters					
	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)	Model Number	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)
1274G 2	0.37	0.5	53	6138	409	7	0.5	1	70	5062	341
1274G 2						25	0.8	1	171	12494	919
1274G 2						8	0.1	0	2	1800	148
1274G 2						9	0.3	0	16	3641	393
1274G 2						10	0.5	0	67	12506	958
1274G 3	0.40	0.6	53	5390	530	7	0.5	1	63	4850	327
1274G 3						25	0.7	1	120	10902	801
1274G 3						8	0.1	0	2	1675	137
1274G 3						9	0.2	0	8	2862	308
1274G 3						10	0.5	0	48	10590	811
1274CG 1	0.48	6.4	393	3689	756	7	0.6	1	95	5542	373
1274CG 1						60	1.0	1	269	14391	1060
1274CG 1						8	0.1	0	3	1954	160
1274CG 1						9	0.3	0	23	3868	417
1274CG 1						10	0.6	0	86	13383	1025
1274CG 2	0.46	3.5	271	4708	630	7	0.6	1	75	5581	376
1274CG 2						60	0.9	1	229	14381	1059
1274CG 2						8	0.1	0	3	1939	159
1274CG 2						9	0.3	0	21	3845	414
1274CG 2						10	0.6	0	89	13767	1054
1274CG 3	0.63	2.5	369	8726	616	7	0.7	1	103	5504	371
1274CG 3						60	1.0	1	268	14273	1051
1274CG 3						8	0.1	0	3	1934	159
1274CG 3						9	0.3	0	20	3836	414
1274CG 3						10	0.6	0	84	13334	1021
1265CG 1	0.17	1.5	108	4408	568	7	0.4	0	41	5363	361
1265CG 1						60	0.7	1	136	13893	1023
1265CG 1						8	0.1	0	2	1872	153
1265CG 1						9	0.3	0	14	3745	404
1265CG 1						10	0.5	0	53	13123	1005
1265CG 2	0.22	1.1	110	6140	576	7	0.4	0	36	5305	357
1265CG 2						60	0.7	1	126	13824	1018
1265CG 2						8	0.1	0	2	1873	154
1265CG 2						9	0.3	0	14	3746	404

Table 2. (Continued).

	Observed Parameters					Predicted Parameters					
Stand, Fire	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)	Model Number	Flame Length (m)	Rate of Spread (m/min)	Fireline Intensity (kW/m)	Heat/ Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)
1265CG 2						10	0.4	0	45	12861	985
1265CG 3	0.75	7.1	880	7490	1128	7	0.6	1	83	5288	356
1265CG 3						60	0.9	1	218	13787	1015
1265CG 3						8	0.1	0	3	1867	153
1265CG 3						9	0.3	0	19	3738	403
1265CG 3						10	0.6	0	73	12835	983

APPENDIX F

WEATHER DURING PRESCRIBED FIRES ON THE OUACHITA NATIONAL FOREST, ARKANSAS

Table 1. Mean weather parameters recorded during growing-season and dormant season burns, September 1994, March 1995, October 1995, March 1996, Ouachita National Forest, Arkansas.

	Weather Parameters					
Stand, Fire	Time	Ambient Temperature C	Relative Humidity	Wind Speed m/s	Cloud Cover Percent	Sky Description
1257CD						
1	1130	54.00	32.00	0.25	10.00	1.00
2	1329	59.00	29.00	1.17	0.00	1.00
3	1430	60.00	26.00	0.48	0.00	1.00
1257D						
1	1026	72.33	29.67	0.83	5.00	1.00
2	1118	75.00	23.00	.	5.00	1.00
3	1224	75.91	22.18	0.86	5.00	1.00
1257DD						
1	1709	55.00	32.00	0.05	0.00	1.00
2	1754	53.00	37.00	0.05	0.00	1.00
3	1830	50.00	.	0.00	70.00	1.00
1257G						
1	1287	85.50	51.50	1.04	25.00	3.00
2	1414	86.00	51.00	1.30	20.00	3.00
3	1577	85.86	47.86	1.16	20.00	3.00
1259G						
1	1333	88.00	48.00	1.44	30.00	3.00
2	1522	85.00	49.00	1.29	30.00	3.00
3	1712	85.50	48.75	0.75	2.50	3.00
1265CG						
1	1345	66.00	28.00	0.00	0.00	1.00
2	1430	66.50	29.50	.	0.00	1.00
3	1545	67.00	31.00	0.70	0.00	1.00
1274CG						
1	1360	76.00	19.50	0.79	0.00	1.00
2	1430	79.00	25.00	0.15	0.00	1.00
3	1530	78.00	27.00	0.91	0.00	1.00
1274D						
1	1520	70.00	24.00	0.69	70.00	1.00
2	1620	68.00	28.00	0.00	45.00	1.00
3	1640	68.00	28.00	.	40.00	1.00
1274DD						
1	1320	66.00	49.00	0.00	70.00	1.00
2	1430	66.00	32.00	0.60	90.00	1.00
3	1550	66.00	32.00	0.00	85.00	1.00
1274G						
1	1473	80.00	57.00	0.56	20.00	3.00
2	1630	82.00	51.00	0.48	25.00	3.00
3	1730	81.00	46.00	0.48	0.00	3.00
1289D						
1	1119	64.00	39.00	1.84	0.00	1.00
2	1215	69.00	34.00	2.16	0.00	1.00
3	1315	69.12	28.00	1.55	50.00	1.00
1289G						
1	1309	82.00	54.00	0.56	25.00	3.00
2	1451	83.00	51.40	0.61	25.00	3.00
3	1582	83.25	54.00	0.65	25.00	3.00
1313CD						
1	1400	58.00	51.00	0.68	0.00	1.00
2	1439	60.00	30.00	0.68	0.00	1.00
3	1547	58.00	32.00	1.02	0.00	1.00
1313D						
1	1456	56.00	46.00	1.11	30.00	3.00
2	1662	59.00	38.00	0.66	10.00	1.00
3	1764	54.00	48.00	0.00	0.00	1.00

APPENDIX G

A PARTIAL LIST OF PLANTS OCCURING ON THE OUACHITA NATIONAL FOREST ARKANSAS

Table 1. Herbaceous and woody plants known to occur in experimental stands, Ouachita National Forest, 1996. Nomenclature after Smith (1988), "An Atlas and Annotated List of the Vascular Plants of Arkansas".

GROUP Scientific Name	Common Name
Grasses	
Andropogon gerardii	Big bluestem
Andropogon gyrans	Elliott bluestem
Andropogon virginicus	Broomsedge
Aristida spp.	Three-awn
Chasmanthium latifolium	Inland sea oats
Chasmanthium sessiliflorum	Sessile uniola
Danthonia spicata	Poverty oatgrass
Gymnopogon ambiguus	Bearded skeletongrass
Manisuris cylindrica	Carolina Jointtail
Muhlenbergia schreberi	Nimblewill muhly
Muhlenbergia spp.	Muhly
Paspalum sp.	Paspalum
Schizachyrium scoparium	Little bluestem
Sorghastrum nutans	Indian Grass
Sporobolus asper	Tall dropseed
Sporobolus spp.	Dropseed
Tridens flavus	Purple top
Panicum virgatum	Switchgrass
Sedges	
Carex latebracteata	Waterfall sedge
Carex spp.	Unknown sedge
Rynchospora spp.	Beakrush
Scleria oligantha	Nut rush
Scleria spp.	Nut rush
Scleria triglomerata	Tall nut grass
Ferns	
Polystichum acrostichoides	Christmas fern
Pteridium aquilinum	Bracken fern

Table 1. (Continued).

GROUP Scientific Name	Common Name
Legumes	
Amphicarpa bracteataea	Hog peanut
Baptisia nuttalliana	Nuttall's wild indigo
Cassia fasciculata	Partridge pea
Clitoria mariana	Butterfly pea
Crotalaria sagittalis	Rattlebox
Desmodium canadense	Tick trefoil
Desmodium canescens	Hoary tick trefoil
Desmodium ciliare	Sm-leaved tick trefoil
Desmodium cuspidatum	Lg-bracted tick trefoil
Desmodium laevigatum	Beggar's lice
Desmodium marilandicum	Tick trefoil
Desmodium paniculatum	Panicled tick trefoil
Desmodium rotundifolium	Prostrate tick trefoil
Desmodium spp.	Tick trefoil
Desmodium strictum	Stiff tick trefoil
Desmodium viridiflorum	Tick trefoil
Galactia regularis	Downy-milk-pea
* Lespedeza cuneata	Serecia lespedeza
Lespedeza hirta	Bush lespedeza
Lespedeza intermedia	Intermediate lespedeza
Lespedeza procumbens	Prostrate lespedeza
Lespedeza repens	Reclining lespedeza
Lespedeza spp.	Unknown lespedeza
* Lespedeza stipulacea	Korean lespedeza
* Lespedeza striata	Japanese lespedeza
Lespedeza violacea	Violet lespedeza
Lespedeza virginica	Slender lespedeza
Psoralea simplex	Scurf-pea
Rhynchosia latifolia	Snoutbean
Schrankia nuttallii	Sensitivebriar
Strophostyles umbellata	Trailing wild bean
Stylosanthes biflora	Pencil flower
Tephrosia virginiana	Goat's rue

Table 1. (Continued).

GROUP Scientific Name	Common Name
Forbs	
Acalypha gracilens	3-seeded mercury
Acalypha sp.	3-seeded mercury
Acalypha virginica	3-seeded mercury
Agalinis fasciculata	Gerardia
Agrimonia rostellata	Agrimony
Allium canadense	Wild onion
Ambrosia artemisiifolia	Common ragweed
Ambrosia bidentata	Lanceleaf ragweed
Anemone quinquefolia	Wood anenome
Antennaria parlinii	Pussy's toes
Antennaria plantaginifolia	Pussy's toes
Antennaria spp.	Pussy's toes
Aristolochia serpentaria	Virginia snakeroot
Aristolochia tomentosa	Pipe-vine
Asclepias quadrifolia	Milkweed
Asclepias spp.	Milkweed
Asclepias variegata	Milkweed
Asclepias verticillata	Whorled milkweed
Aster ageria	Aster ageria
Aster anomalus	Aster
Aster azureus	Azure aster
Aster ericoides	Wreath aster
Aster linariifolius	Stiff-leaf aster
Aster paludosus	Aster paludosus
Aster patens	Spreading aster
Aster spp.	Aster
Aster subulatus	Aster
Aureolaria grandiflora	Gerardia
Cirsium altissimum	Tall thistle
Cirsium carolinianum	Carolina thistle
Cirsium horridulum	Yellow Thistle
Cirsium spp.	Thistle
Clematis versicolor	Leather flower
Cocculus carolinus	Carolina moonseed
Conyza canadensis	Horseweed
Coreopsis grandiflora	Tickseed

Table 1. (Continued).

GROUP Scientific Name	Common Name
Forbs (Continued)	
Coreopsis lanceolata	Lance-leaved coreopsis
Coreopsis palmata	Tickseed
Coreopsis spp.	Tickseed
Coreopsis tinctoria	Plains tickseed
Coreopsis verticillata	Tickseed
Croton capitatus	Woolly croton
Crotonopsis elliptica	Crotonopsis
Cunila origanoides	Dittany
* Daucus carota	Queen Anne's lace
Diodia teres	Poor joe
Dioscorea sp.	Wild yam
Echinacea augustifolia	Coneflower
Echinacea pallida	Pale coneflower
Echinacea purpurea	Coneflower
Elephantopus tomentosus	Tobacco weed
Engelmannia pinnatifida	Cutleaf daisy
Erechtites hieraciifolia	Fireweed
Erigeron annuus	Daisy fleabane
Erigeron spp.	Fleabane
Erigeron strigosus	Rough fleabane
Eryngium yuccifolium	Rattlesnake master
Eupatorium altissimum	Tall throughwort
Eupatorium rugosum	White snakeroot
Eupatorium serotinum	Late boneset
Eupatorium spp.	Eupatorium
Euphorbia commutata	Wood spurge
Euphorbia corollata	Flowering spurge
Euphorbia cyathophora	Wild poinsettia
Fragaria virginiana	Wild strawberry
Galium circaezans	Wild Licorice
Galium pilosum	Hairy bedstraw
Galium spp.	Bedstraw
Geranium carolinianum	Carolina cranesbill
Geranium maculatum	Spotted cranesbill
Geum canadense	White avens
Glandularia canadensis	Rose vervain

Table 1. (Continued).

GROUP Scientific Name	Common Name
Forbs (Continued)	
Glechoma hederacea	Ground ivy
Gnaphalium obtusifolium	Fragrant cudweed
Gnaphalium purpureum	Purple cudweed
Hedyotis longifolia	Long-leaved bluets
Hedyotis spp.	Bluets
Helianthus hirsutus	Rough-leaf sunflower
Heliantus mollis	Ashy sunflower
Heterotheca graminifolia	Grass-leaved golden aster
Heterotheca spp.	Golden aster
Hieracium gronovii	Hawkweed
Hieracium longipilum	Hawkweed
Ipomoea pandurata	Wild potato vine
Lactuca canadensis	Wild lettuce
* Lactuca serriola	Wild lettuce
Liatris aspera	Rough blazing star
Liatris pycnostachya	Button snakeroot
Liatris spp.	Blazing star
Liatris squarrosa	Scaly blazing star
Linum medium	Flax
Lobelia appendiculata	Lobelia
Lobelia spicata	Lobelia, Highbelia
Ludwigia alternifolia	Bushy seedbox
Matelea decipiens	Climbing milkweed
* Mentha spicata	Spearmint
Mentha spp.	Mint
Monarda citriodora	Lemon balm
Monarda fistulosa	Wild bergamot
Monarda russeliana	Horsemint
Monarda spp.	Bergamot
Monarda stipitatoglandulosa	Monarda
Monarda virgata	Bergamot
* Nepeta cataria	Catnip
* Oxalis corniculata	Creeping lady's sorrel
* Oxalis stricta	Yellow-woodsorrel
Oxalis violacea	Violet wood sorrel

Table 1. (Continued).

GROUP Scientific Name	Common Name
Forbs (Continued)	
Parthenium integrifolium	Wild quinine
Passiflora lutea	Passion flower
Pedicularis canadensis	Lousewort
Penstemon arkansanus	Arkansas beard-tongue
Phlox divaricata	Blue phlox
Phlox drummondii	Annual phlox
Phlox pilosa	Prairie phlox
Phlox spp.	Phlox
Physalis virginiana	Ground cherry
Phytolacca americana	Pokeweed
Plantago lanceolata	English plantain
Plantago patagonica	Wooly plantain
Plantago spp.	Plantain
Polygala alba	Milkwort
Polygala sp.	Milkwort
Polygonatum biflorum	Solomon's seal
Polygonum scandens	Hedge smartweed
Polygonum spp.	Smartweed
Potentilla simplex	Cinquefoil
Potentilla spp.	Cinquefoil
Prunella vulgaris	Heal-all
Pycnanthemum albescens	Mountain mint
Pycnanthemum muticum	Mountain mint
Pycnanthemum tenuifolium	Slender mountain mint
Rudbeckia amplexicaulus	Clasping coneflower
Rudbeckia grandiflora	Large coneflower
Rudbeckia hirta	Black-eyed susan
Ruellia humilis	Wild petunia
Ruellia pedunculata	Wild petunia
Ruellia spp.	Wild petunia
Ruellia strepens	Wild petunia
* Rumex crispus	Dock
Sabatia angularis	Rose pink
Salvia lyrata	Cancer weed
Sanicula canadensis	Black snakeroot

Table 1. (Continued).

GROUP Scientific Name	Common Name
Forbs (Continued)	
Scutellaria elliptica	Skullcaps
Scutellaria ovata	Heart-leaved skullcap
Scutellaria parvula	Smaller skullcap
Scutellaria spp.	Skullcap
Senecio spp.	Groundsel
Silphium laciniatum	Compass plant
* Sisymbrium officinale	Hedge mustard
Sisyrinchium angustifolium	Blue eyed grass
Solanum carolinense	Horse nettle
Solidago caesia	Bluestem goldenrod
Solidago canadensis	Canada goldenrod
Solidago hispida	Goldenrod
Solidago odora	Fragrant goldenrod
Solidago radula	Rough goldenrod
Solidago spp.	Goldenrod
Solidago ulmifolia	Elm-leaf goldenrod
Thalictrum thalictroides	Rue anemonoe
Thaspium barbinode	Thaspium
Thelsperma filifolium	Green thread
* Torilis arvensis	Hedge parsley
Tradescantia ohiensis	Ohio spiderwort
Trifolium spp.	Clover
Triodanis leptocarpa	Venus'looking glass
Valerianella spp.	Corn salad
* Verbascum thapsus	Mullein
Verbena urticifolia	White vervain
Verbesina helianthoides	Crownsbeard
Vernonia baldwinii	Ironweed
Vicia spp.	Vetch
Viola palmata	3-lobed violet
Viola pedata	Bird's foot violet
Viola sagittata	Arrow-leaved violet
Viola sororia	Missouri violet
Viola spp.	Violet
Zizia aurea	Golden alexanders

Table 1. (Continued).

GROUP Scientific Name	Common Name
Woody Plants	
Acer negundo	Box elder
Acer rubrum	Red maple
Acer saccharum	Silver maple
Amelanchier arborea	Downy serviceberry
Ampelopsis arborea	Pepper vine
Berchemia scandens	Rattan vine
Bumelia lanuginosa	Chittamwood
Callicarpa americana	Beauty berry
* Campsis radicans	Trumpet vine
Carpinus caroliniana	American hornbeam
Carya glabra	Pignut hickory
Carya spp.	Hickory
Carya texana	Black hickory
Carya tomentosa	Mockernut hickory
Ceanothus americanus	New Jersey tea
Celtis laevigata	Sugarberry
Celtis occidentalis	Common hackberry
Cercis canadensis	Redbud
Chionanthus virginicus	Fringe tree
Cornus drummondii	Rough-leaved dogwood
Cornus florida	Flowering dogwood
Crataegus crus-galli	Cockspur hawthorn
Crataegus marshallii	Parsley hawthorn
Crataegus pruinosa	Frosted hawthorn
Crataegus spathulata	Pasture hawthorn
Crataegus uniflora	Hawthorn
Diospyros virginiana	Persimmon
Euonymous americanus	Strawberrybush
Fraxinus americana	White ash
Hypericum densiflorum	St. Johns wort
Hypericum hypericoides	St. Andrews cross
Ilex decidua	Decidous holly
Juniperus virginiana	Eastern redcedar
Liquidambar styraciflua	Sweetgum
* Lonicera japonica	Japanese honeysuckle
Lonicera sempervirens	Trumpet honeysuckle

Table 1. (Continued).

GROUP Scientific Name	Common Name
Woody plants (Continued)	
Lonicera spp.	Coral honeysuckle
Magnolia tripetala	Umbrella magnolia
Morus rubra	Red mulberry
Nyssa sylvatica	Blackgum
Ostrya virginiana	Ironwood
Parthenocissus quinquefolia	Virginia creeper
Pinus echinata	Shortleaf pine
Prunus mexicana	Mexican plum
Prunus serotina	Wild black cherry
Quercus alba	White oak
Quercus falcata	Southern red oak
Quercus marilandica	Black-jack oak
Quercus nigra	Water oak
Quercus phellos	Willow oak
Quercus rubra	Northern red oak
Quercus stellata	Post oak
Quercus velutina	Black oak
Rhamnus caroliniana	Indian cherry
Rhus aromatica	Fragrant sumac
Rhus copallina	Winged sumac
Rhus glabra	Smooth sumac
Ribes sp.	Currant
Rosa carolina	Wild rose
Rosa multiflora	Multiflora rose
Rubus spp.	Blackberry
Sambucus canadensis	Elderberry
Sassafras albidum	Sassafras
Smilax bona-nox	Greenbrier
Smilax glauca	Cat greenbrier
Smilax rotundifolia	Greenbrier
Smilax spp.	Greenbriar
Symphoricarpos orbiculatus	Coral berry
Toxicodendron radicans	Posion ivy
Ulmus alata	Winged elm
Ulmus americana	American elm
Vaccinium arboreum	Farkleberry

Table 1. (Continued).

GROUP Scientific Name	Common Name
Woody plants (Continued)	
Vaccinium pallidum	Low-bush huckleberry
Vaccinium stamineum	Deerberry
Viburnum rufidulum	Rusty black haw
Vitis aestivalis	Summer grape
Vitis cinerea	Grayback grape
Vitis palmata	Cat grape
Vitis rotundifolia	Muscadine

Note: * = Introduced, naturalized, or exotic species.

VITA

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Master of Science

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