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Prescribed fire effects on structure in uneven-aged stands of loblolly and shortleaf pines

Michael D. Cain, T. Bently Wigley, and Derik J. Reed

Abstract Structure was assessed in uneven-aged stands of loblolly (*Pinus taeda*) and shortleaf pine (*P. echinata*) that were subjected to prescribed winter burns on cycles of 0, 3, 6, and 9 years. Vegetation assessments were made in late summer of 1990, 10 years after a single hardwood control treatment (basal injection of nonpine woody plants >2.5 cm in groundline diameter with Tordon® 101 R); 1 year after the fourth 3-year burn cycle; 4 years after the second 6-year burn cycle; and 1 year after the second 9-year burn cycle. Compared to unburned controls, prescribed burning tended to increase ($P \leq 0.008$) percent ground cover from graminoids and composites. For understory woody plants that were >1 m tall but <2.5 cm diameter breast height (dbh), American beautyberry (*Callicarpa americana)* had the greatest percent ground cover on burned and unburned plots. Horizontal cover between 0- and 3-m height tended to average less ($P \leq 0.002$) with more frequent prescribed burning and with shorter time since burning. There were no burn treatment differences in density ($P = 0.199$, $\beta = 0.853$) or basal area ($P = 0.477$, $\beta = 0.898$) for sapling-size stems (2.5-8.9 cm dbh), but species diversity of saplings was lower ($P = 0.002$) on plots prescribe burned at 3-year intervals as compared to other treatments.

Key words burning cycle, cutting cycle, *Pinus echinata, Pinus taeda,* plant diversity, prescribed burning, selection silviculture

In forest management, timing, intensity, and frequency of prescribed burns are not only critical to successful stand establishment and development, but they also indirectly impact wildlife by changing food and cover (Davis 1959, Wade and Lunsford 1989). Fire can be used to enhance the establishment of herbaceous vegetation and stimulate resprouting in forest stands by top-killing woody species. However, little is known about the effects of fire on structure in uneven-aged stands of loblolly (*Pinus taeda*) and shot-deaf pine (*P. echinata*).

In response to public concerns about the ecological consequences of even-aged management, some national forests in the southeastern United States have dramatically increased planned acreages under uneven-aged management by using single-tree and group-selection cutting (U.S. Dep. Agric. For. Serv. 1990). In the selection system, some trees are harvested regularly as individuals or in groups, with total volume cut at any 1 time being roughly equal to the growth that has occurred since the last harvest (Reynolds et al. 1984, Baker et al. 1996). Uneven-aged management has also been recommended for private nonindustrial forest landowners (Baker and Murphy 1982). In the southeastern United States, nearly 75% of the timberland area with economic opportunities to increase net annual timber growth are on these nonindustrial, private ownerships (U.S. Dep. Agric. For. Serv. 1988).

This study was initiated to examine the effects of

Address for Michael D. Cain: USDA Forest Service, Southern Research Station, Monticello, AR 71656-3516, USA. Present address for T. Bently Wigley: NCASI, Department of Aquaculture, Fisheries, and Wildlife, Clemson University, Clemson, SC 29634-0362, USA. Address for T. Bently Wigley and Derik J. Reed during this research: School of Forest Resources, Arkansas Agricultural Experiment Station, University of Arkansas, Monticello, AR 71656, USA.

various prescribed winter-burn-return intervals on structure in uneven-aged loblolly and shortleaf pine stands. We tested the hypothesis that burning on cycles of 3, 6, and 9 years would result in measurable changes in stand structure and, thereby, impact wildlife habitat. Although an abundance of information is available on wildlife habitat structure in even-aged pine stands, comparable studies have not been conducted on habitat structure in regulated, uneven-aged stands of southern pines (Harlow and Van Lear 1981, 1987).

Methods

Study area

The study was conducted in southeastern Arkansas at 33" 02' N mean latitude and 91" 56' W mean longitude. Elevation of the area is about 40 m with nearly level topography. Soils are predominantly Bude and Providence silt loam (Glossaquic and Typic Fragiudalfs, respectively) with an impervious layer at 46-102 cm that impedes internal drainage (U.S. Dep. Agric. 1979). These soils have a site index of 27 m for loblolly pine at base age 50 years. Annual precipitation averages 140 cm, with seasonal extremes being wet winters and dry autumns.

The study encompasses 3 16-ha units that had been managed for pine timber production using single-tree selection from the late 1930s to the late 1960s, with complete exclusion of fire. Hardwoods were periodically controlled by girdling in early years of selection management and later by stem injection and mist-blowing with herbicides. From 1970 until 1980, pines were not harvested, and competing vegetation was not controlled. At the time of study installation in 1980, basal area of merchantable-sized pines (>8.9 cm dbh) ranged from 18 to 29 m^2/ha. Density of the submerchantable component (≤8.9 cm dbh) averaged 77 stems/ha for pines and 12,355 rootstocks/ha for hardwoods.

Plot layout and prescribed burning

We divided each 16-ha unit into 16 (100- x 100-m) plots. Interior measurement plots of 0.65 ha (80 x 80 m) were surrounded by lo-m-wide isolation strips. Four contiguous l-ha plots comprised a 4-ha burn treatment. An unburned control and burning intervals of 3, 6, and 9 years were randomly assigned to the 4-ha burn treatments within each of the 3 16-ha units. Prescribed burning was conducted during the dormant season at these specified intervals to address the need for competition control and development of natural pine regeneration.

Within each burn treatment, residual merchantable pine basal areas of 9, 14, 18, and 23 m^2/ha were assigned to the l-ha plots at random, resulting in a randomized-block, split-plot design. These basal-area treatments included the practical range of residual density thought to be suitable for selection management of loblolly-shortleaf pine stands (Murphy and Shelton 1994). For the present investigation, we examined the 4 burning intervals (unburned, 3-yr, 6-yr, and 9-yr cycles) at 2 basal-area levels (9 and 14 m^2/ha).

We initiated uneven-aged regulation using the basal area-maximum diameter-quotient (BDq) technique (Farrar 1984), and harvested pines on 6-year cycles. The "q" in BDq is defined as the constant ratio of the number of trees in a given 2.54-cm (l-inch) dbh class to the number in the adjacent, larger 2.54-cm dbh class for balanced uneven-aged stands. The "q" was set at 1.2, and the maximum dbh class was 56 cm.

We installed study plots during autumn 1980. All plots, except those in the unburned controls, were prescribe burned beginning in January 1981. We used backfires and flank fires to manage the prescribed burns. In the spring of 1981, all hardwoods >2.5 cm in groundline diameter (gld), including those on unburned control plots, were basally injected with Tordon® 101R (0.03 kg/L picloram and 0.12 kg/L 2,4-D; DowElanco, Indianapolis, Ind.). Dosage rates were 1 ml of undiluted herbicide per 2.5 cm of gld. (Note: The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.)

Plots were harvested to their assigned residual basal areas during the summer of 1982. A second cycle cut was completed during the winter of 1987, using the same marking criteria developed for the initial harvest.

In addition to the initial prescribed burn, subsequent burn treatments were as follows: 3 prescribed fires on the 3-year cycle (Ian 1984, Jan-Feb 1987, Dec 1989); 1 prescribed fire on the 6-year cycle (Ian-Feb 1987); and 1 prescribed fire on the 9-year cycle (Dec 1989). Fuel and weather conditions during all prescribed burns were reported by Cain (1993). Fuel and weather conditions during the 1989 burns are presented here for reader information (Table 1).

Measurements and data analysis

During August and September of 1990, we systematically located 10 sampling points at which we sampled habitat variables in each 0.65-ha interior plot. In a 5- x 5-m plot, we identified woody stems by species and measured the dbh of these stems to the nearest centimeter if they were 2.5-8.9 cm dbh. Stem counts were used to compute a Shannon diversity index

Table 1. Fuel and weather conditions during the 1989 prescribed winter burns that preceded uneven-aged pine stand-structure assessments in southeastern Arkansas.

Fuel and weather variables	Burn cycles 3-yr	9-yr
Date of burn (day/month/yr)	04/12/89	05/12/89
Days since last precipitation	11	12
Time of burning (hr CST)	1100-1900	1000-1500
Air temperature (°C)	11-14	13-21
Relative humidity (%)	22-12	38-26
Wind direction	SW	W
Wind speed (km/hr)	21	16
Fine fuel moisture[a] (%)	6	10
Mean fireline intensity[b] (KW/m)	268	208
Range in fireline intensity (KW/m)	214-336	55-464
Type of burn	back and flank fires	

[a] Determined from fuel-moisture sticks at midday.
[b] $I = 5.67L_f^{2.17}$, where L_f = Ocular estimates of flame length (Byram 1959).

(Shannon and Weaver 1949), an equitability component (Pielou 1975), and species importance.

In a nested 2- x 2-m plot, we counted species and estimated percent cover of woody stems >1 m tall but <2.5 cm dbh. Also in the 2- x 2-m plot we estimated percent cover of all woody vegetation, vines, bare ground, organic debris (i.e., leaf litter), and down woody material >10 cm in diameter. In a nested 1- x 1-m plot, we estimated percent cover for 7 categories of vegetation <1 m tall: composites, forbs-ferns, graminoids, legumes, shrubs, tree seedlings, vines, and all vegetation combined.

At each of the 10 sample points we estimated percent horizontal cover using a density board (Nudds 1977). From a distance of 15 m, we estimated percent cover for zones at 0-1 m, 1-2 m, and 2-3 m on the board. From a stepladder at a height of 3 m, we estimated vertical canopy cover of the midstory and overstory using a densiometer. We used cover values in the 4 height zones to compute a foliage height diversity index (MacArthur and MacArthur 1961). Finally, at each sample point we measured the total height of the nearest overstory pine to 0.3 m. We used analysis of variance (ANOVA; SAS Inst. Inc. 1989) to test for differences in habitat variables among burn treatments. Percentage data were arcsine transformed before analysis. Tukey's HSD procedure was used for mean separation. Statistical significance was accepted at the $\alpha \leq 0.05$ probability level. Using PASS 6.0 (Hintze 1996), we calculated effect size and performed statistical power $(1 - \beta)$ analysis on all ANOVA's to evaluate potential type II error. Because basal area and basal area x burning interaction were nonsignificant in analyses of variance, basal areas were pooled within burn treatments for the reported analyses.

Results

Ground-level components

For vegetation <1 m tall, total cover on 3-year and 9-year burn plots averaged 19 percentage points higher ($P = 0.005$) compared to unburned controls (Table 2). On plots where burning had not been conducted for 4 years (6-yr cycle), total ground-level vegetation was not different than on unburned controls or 9-year burn plots (Table 2).

Vines were the principal ground-level component, averaging 24% cover (Table 2), but there were no differences ($P = 0.407$, $\beta = 0.903$) among burn treatments. Graminoids were the second most important herbaceous component across treatments, with cover on 3-year burn plots averaging 8.5 percentage points higher ($P = 0.008$) than on control or 6-year burn plots. Like grasses, ground cover from composites tended to increase as a result of frequent or recent burning on 3-year and 9-year cycles. Composite cover in the latter 2 treatments averaged 12 percentage points higher ($P < 0.001$) than controls or 6-year burn plots (Table 2). We found no differences ($P = 0.727$, $\beta = 0.931$) among burn treatments in percent cover from tree seedlings (Table 2). Likewise, differences among burn treatments were nonsignificant for percent cover from shrubs ($P = 0.726$, $\beta = 0.931$) forbs-ferns ($P = 0.112$, $\beta = 0.836$) and legumes ($P = 0.494$, $\beta = 0.913$; Table 2).

The most recent prescribed burns on 3-year and 9-year cycles resulted in a mean reduction in cover from organic debris of 15 percentage points ($P = 0.001$) when compared to control and 6-year burn plots (Table 2). The presence of bare soil and cover from down wood >10 cm in diameter averaged <5% within burn treatments, and there were no differences ($P = 0.238$ to 0.276, with $\beta = 0.877$ to 0.884, respectively) among treatments (Table 2).

Woody plants and vines >1 m tall but <2.5 cm dbb

Total cover from woody plants and vines that were >1 m tall but <2.5 cm dbh averaged 34% (Table 3). In September 1990, mean cover from these woody plants and vines was 18 percentage points higher ($P = 0.016$) on control plots and 6-year burn plots than on 3-year burn plots.

Two shrubs, American beautyberry (*Callicarpa americana*) and shining sumac (*Rhus copallina*), and 2 trees, red maple (*Acer rubrum*) and flowering

Table 2. Percent cover from ground-level components on an unburned control and 3 prescribed-burn treatments (1981-1989) in uneven-aged pine stands in southeastern Arkansas.

Ground-level component	Control	Burn cycles 3-yr (% cover)	6-yr	9-yr	MSE	P > F	Effect size	Power
Vegetation <1 m tall								
Total cover	56.5A[a]	76.2C	60.1 AB	74.9BC	0.0118	0.005	0.90	0.386
Vines	25.7	22.9	18.7	27.0	0.0101	0.407	0.36	0.097
Graminoids	13.3A	22.9B	15.5A	16.0AB	0.0035	0.008	0.84	0.345
Tree seedlings	7.0	6.7	8.7	8.7	0.0079	0.727	0.24	0.069
Forbs-ferns	6.6	12.2	7.0	17.1	0.0178	0.112	0.54	0.164
Shrubs	6.3	7.9	9.5	8.2	0.0090	0.726	0.24	0.069
Composites	1.7A	16.1B	3.0A	13.38	0.0110	<0.001	1.31	0.703
Legumes	0.6	1.9	0.5	0.9	0.0060	0.494	0.32	0.087
Nonvegetative component								
Organic debris	31.6A	14.68	26.4A	14.3B	0.0072	0.001	1.08	0.533
Bare soil	2.5	3.9	4.9	1.2	0.0087	0.238	0.44	0.123
Down wood >1 O-cm diam	3.0	1.9	0.7	2.4	0.0056	0.276	0.42	0.116

[a] Within-row means followed by the same letter are not different at $P \leq 0.05$.

dogwood (*Cornus florida*), contributed the most cover from woody plants that were >1 m tall but <2.5 cm dbh (Table 3). Out of 15 species of woody plants in these size classes, 4 differed in percent cover among burn treatments after the 1990 growing season (Table 3). Cover from red maples was 5 percentage points less on control and 3-year burn plots than on 6-year burn plots (P = 0.002). Similarly, cover from water oak (*Quercus nigra*) was 3 percentage points lower on the 3-year burn plots than on 6-year burn plots (P = 0.050). Sweetgum (*Liquidambar styraciflua*) cover averaged 2.5 percentage points higher on 6-year burn plots than on 9-year burn plots (P = 0.040). Lastly, American holly (*Ilex opaca*) had about 3 percentage points more cover on control plots compared to the 3-year or 9-year burn plots (P = 0.020). Although statistically significant, mean differences of ≤5% are probably unimportant ecologically.

The most prevalent vines in terms of percent cover were Japanese honeysuckle (*Lonicera japonica*), blackberry (*Rubus* spp.), greenbrier (*Smilax* spp.), and wild grape (*Vitis* spp.). None of the individual species averaged >10.1% cover within any burn treatment (Table 3), and none of the vines differed (P > 0.05, β > 0.842) in mean cover among the burn treatments.

Horizontal and vertical cover

Mean horizontal cover in these uneven-aged stands was greatest in height zones of 0- 1 m (>96%) and 1-2 m (>79%), and least in height zones of 2-3 m (<50%; Table 4). Plots which were burned most often, at 3-year intervals, tended to average less horizontal cover compared to other treatments. In the 0- to l-m zone, 3-year burn plots averaged 7 percentage points less cover (P = 0.002) than other burn treatments.

Compared to unburned controls, dormant-season fires in the winter of 1989-1990 reduced (P < 0.001) horizontal cover in the 1- to 2-m strata by 39 percentage points on 3-year burn plots and by 18 percentage points on 9-year burn plots (Table 4). Also, 3-year burn plots had 31 percentage points less cover than 6-year burn plots, which had not been burned for 4 years.

Horizontal cover in the 2- to 3-m height zone was also significantly influenced by burn treatments (P < 0.001; Table 4). For this stratum, cover on control plots was >3 times as great as on 3-year bum plots. Also, cover on 9-year bum plots averaged 29 percentage points less than on control plots but was more than twice as great as the cover on 3-year bum plots.

The greatest percent vertical cover, >3 m in height, occurred on 9-year burn plots (Table 4). Yet, the mean difference between the greatest cover (9-yr bum plots) and the least cover (control plots) was only 15 percentage points (P = 0.032). Because of the relatively low basal area of pine in these uneven-aged stands, differences in vertical cover are likely attributable to the location' at which cover was assessed in relation to the pine overstory and not to the effects of burning.

Frequency of prescribed bums appears to have a significant impact on foliage height diversity (FHD; Table 4). Compared to the mean of all other treat-

Table 3. Percent cover from woody plants and vines >1 m tall but <2.5 cm dbh on an unburned control and 3 prescribed-burn treatments (1981-1989) in uneven-aged pine stands in southeastern Arkansas.

Type of cover and species[a]	Control	3-yr	6-yr	9-yr	MSE	P > F	Effect size	Power
	Burn cycles (% cover)							
Total cover	38.1A[b]	22.3B	41.5A	34.9AB	0.0116	0.016	0.77	0.292
Woody plants								
Acer rubrum	0.9B	0.9B	6.2A	2.7AB	0.0053	0.002	1.00	0.467
Callicarpa americana	9.7	4.2	10.5	10.6	0.0119	0.061	0.62	0.201
Cornus florida	3.2	0.3	1.7	0.3	0.0091	0.292	0.41	0.113
Diospyros virginiana	0.5	1.8	1.7	0.7	0.0076	0.576	0.29	0.080
Ilex opaca	2.7A	0.0B	0.7AB	0.2B	0.0045	0.020	0.74	0.276
Liquidambar styraciflua	0.8AB	0.7AB	2.7A	0.2B	0.0056	0.040	0.67	0.229
Nyssa sylvatica	0.2	1.0	1.0	0.5	0.0023	0.390	0.37	0.099
Ostrya virginiana	0.7	0.0	0.0	0.8	0.0035	0.336	0.39	0.106
Pinus taeda	0.7	1.5	1.9	0.0	0.0079	0.348	0.39	0.104
Quercus alba	0.7	0.2	1.2	0.7	0.0064	0.783	0.21	0.065
Q. nigra	1.0AB	0.4B	3.4A	0.7AB	0.0053	0.050	0.64	0.213
Q. velutina	0.5	0.8	1.2	0.2	0.0046	0.460	0.34	0.091
Rhus copallina	1.7	3.9	3.2	2.6	0.0101	0.416	0.36	0.095
Sassafras albidium	0.9	0.3	1.5	1.7	0.0038	0.244	0.44	0.122
Vaccinium spp.	1.4	1.0	3.2	0.5	0.0052	0.105	0.55	0.168
Vines								
Ampelopsis arborea	0.7	1.6	0.7	1.4	0.0054	0.633	0.27	0.076
Berchemia scandens	3.1	1.7	4.9	1.9	0.0108	0.151	0.51	0.147
Lonicera japonica	10.1	5.6	9.7	7.0	0.0114	0.209	0.46	0.130
Rubus spp.	5.5	6.7	9.4	5.3	0.0088	0.357	0.38	0.103
Smilax glauca	1.5	4.2	4.5	1.3	0.0099	0.125	0.53	0.158
S. rotundifolia	2.4	0.7	3.5	2.3	0.0092	0.458	0.34	0.091
Toxicodendron radicans	1.2	2.3	3.4	1.3	0.0118	0.410	0.36	0.096
Vitis spp.	2.9	2.9	6.0	2.3	0.0067	0.146	0.51	0.149

[a] Includes only species with percent cover averaging ≥0.4.
[b] Within-row means followed by the same letter are not different at $P \leq 0.05$.

ments, FHD index was reduced 22% by burning at 3-year intervals ($P < 0.001$). When burning was done at 6-year and 9-year intervals, FHD index was no different from unburned controls.

Total height for pine overstory trees averaged 25 m (Table 4). For this variable, there was no difference among burn treatments ($P = 0.360$, $\beta = 0.897$).

Woody vegetation 2.5-8.9 cm dbh

Basal area of the sapling component (stems with 2.5-8.9 cm dbh) averaged 0.44 m^2/ha (Table 5), but 8 months after the 3-year and 9-year burn cycles, no difference occurred in mean basal area among treatments ($P = 0.477$, $\beta = 0.898$). Sapling density averaged 332 stems/ha (Table 5), but again there were no differences among treatment means ($P = 0.199$, $\beta = 0.853$).

The Shannon diversity index for saplings was lowest on 3-year burn plots (Table 5) where fires occurred most frequently. Compared to other treatments, burning at 3-year intervals reduced sapling diversity by 72% ($P = 0.002$). Similarly, the evenness of saplings (equitability component) on 3-year burn plots was 55% less ($P = 0.004$) than on the other treatments, that averaged 0.92 (Table 5).

Species importance

Out of a possible importance value (IV) of 300, 10 species of woody plants with 2.5-8.9 cm dbh had a mean IV 210. Across all treatments, loblolly pine had the highest average IV for sapling-sized species (Table 6). In general, 3-year burn plots had fewer woody species in these size classes compared to the other 3 treatments. Out of the 10 most important species, only 5 were present on the 3-year burn plots; whereas, the other 3 treatments had 29 of the top 10 species.

On control plots, 6-year burn plots, and 9-year burn plots, species listed as 'others' had a total IV that was higher than any individual species (Table 6). Frequent burning apparently eliminated fire-sensitive species from the community. On 3-year burn plots,

Table 4. Horizontal and vertical cover on an unburned control and 3 prescribed-burn treatments (1981-1989) in uneven-aged pine stands in southeastern Arkansas.

Cover type	Burn cycles: Control	3-yr	6-yr	9-yr	MSE	$P > F$	Effect size	Power
Horizontal cover (%)								
O-l m	98.8A[a]	91.1B	98.3A	98.3A	0.0065	0.002	1.02	0.486
l-2 m	95.1A	56.6C	87.4AB	77.2B	0.0137	<0.001	1.64	0.886
2-3 m	73.7A	20.8C	55.6AB	44.8B	0.0207	<0.001	1.46	0.799
Vertical cover (%)								
>3 m	57.0B	57.3AB	60.0AB	72.3A	0.0097	0.032	0.69	0.244
Foliage height diversity index[b]	1.01A	0.778	0.99A	0.95A	0.0050	<0.001	1.32	0.714
Total height canopy pines (m)	23.5	25.8	23.6	27.0	15.2765	0.360	0.38	0.103

[a] Within-row means followed by the same letter are not different at $P \leq 0.05$

[b] Foliage height diversity index =

$$-\sum p_i \ln p_i$$

Where p_i is the proportion of the foliage which lies in the i^{th} of the chosen canopy layers.

loblolly pine had the highest average IV when compared to all other species.

Discussion

Results of this investigation indicate that the length of return intervals and recency of prescribed winter burns are important in changing vegetation structure in the understory and midstory of uneven-aged loblolly and shortleaf pine stands (Fig. 1). These changes also impact wildlife habitat by modifying shelter and forage for a broad range of wildlife species (Schemnitz 1980). Concomitantly, Hermann (1995) concluded that rigid fire regimes that have ≥1 year between burns, applied over many decades, are likely to produce changes in habitat structure.

In this investigation, vines comprised the greatest percentage of ground cover for vegetation <1 m tall, but there were unimportant differences among burn treatments. The 4 vines that had the greatest ground cover-Japanese honeysuckle, blackberry, wild grape, and greenbrier-were species that have been determined to be valuable for wildlife in southern forests (Oefmger and Halls 1974). These 4 vines also have a medium to high deer-preference rating as browse species (Matthews and Glasgow 1981).

The only category of low-ground vegetation that exhibited a substantial response to prescribed burning were composites, which are indicators of early

Table 5. Characteristics of woody vegetation 2.5-8.9 cm dbh on an unburned control and 3 prescribed-burn treatments (1981-l 989) in uneven-aged oine stands in southeastern Arkansas.

Measurement variables	Burn cycles: Control	3-yr	6-yr	9-yr	MSE	$P > F$	Effect size	Power
Basal area (m^2/ha)	0.59	0.26	0.50	0.42	0.1031	0.477	0.38	0.102
Density (stems/ha)	453	153	393	327	4.97E04	0.199	0.50	0.147
Shannon Diversity Index[a]	1.37A[b]	0.388	1.39A	1.34A	0.1752	0.002	1.03	0.487
Equitability component[c]	0.91 A	0.41 B	0.90A	0.95A	0.0604	0.004	0.90	0.390

[a] Shannon Diversity Index:

$$H' = \sum_{i=1}^{S} p_i \ln p_i$$

Where S is the number of species, and p_i is the proportion of the total number of individuals consisting of the i^{th} species.

[b] Within-row means followed by the same letter are not different at $P \leq 0.05$.

[c] Equitability component:

$$H' = \frac{H'}{H' \ maximum}$$

Where H' is the diversity value from the Shannon function, and H' maximum is the logarithm of the number of species (*S*).

Table 6. Importance values for woody vegetation 2.5-8.9 cm dbh on an unburned control and 3 prescribed-burn treatments (1981-l 989) in uneven-aged pine stands in southeastern Arkansas.

Species”	Burn cycles			
	Control	3-yr	6-yr	9-yr
	(importance value[b])			
Acer rubrum	**16.3**	**0.0**	**22.8**	**12.8**
Aralia spinosa	17.9	17.9	14.7	12.1
Cornus florida	64.3	0.0	0.0	43.5
Liquidambar styraciflua	20.2	40.3	53.8	9.6
Pinus taeda	14.3	188.7	14.8	24.9
Quercus alba	35.6	12.4	12.3	31.1
Q. falcata	0.0	15.7	34.6	8.3
Q. nigra	10.0	0.0	36.5	27.9
Rhus copallina	14.6	0.0	10.9	16.2
Sassafras albidum	16.5	0.0	28.7	11 .o
Others[c]	90.3	25.1	70.8	102.7
Total	300.0	300.1	299.9	300.1

[a] Species that are listed had mean importance values ≥10.

[b] Importance value = relative basal area + relative density + relative frequency.

[c] Other species present and their importance values by burn cycles (control, 3-yr, 6- yr, 9-yr): *Carya* spp. (0, 0, 6.8, 5.8), *Cephalanthus occidentalis* (0, 0, 6.5, 0), *Diospyros virginiana* (0, 12.4, 11.7, 5.8), *Hamamelis virginiana* (0, 0, 19.7, 0), *Ilex decidua* (0, 0, 0, 6.2), *1. opaca* (24.5, 0, 0, 8.8), *Ligustrum* spp. (0, 0, 0, 8.6), *Morus rubra* (6.1, 0, 0, 0), *Nyssa sylvatica* (0, 12.7, 0, 13.8), *Ostrya virginiana* (5.1, 0, 0, 23.5), *Quercus phellos* (14.7, 0, 0, 5.8), *Q. stellata* (0, 0, 4.8, 0), *Q. velutina* (16.3, 0, 4.6, 6.01, *Rhamnus caroliniana* (7.6, 0, 0 , 0), *Rhus glabra* (0, 0, 7.7, 0), *Ulmus alata* (10.7, 0, 9.0, 18.4), *Vitis* spp. (5.3, 0, 0, 0).

succession on disturbed areas. Seeds from some composites are important to songbirds and small mammals (Martin et al. 1951). In addition, many composites are eaten by white-tailed deer (***Odocoileus virginianus***) and other browsers (Buckner et al. 1979, Felix et al. 1986).

Although we found no differences in sapling density or in percent ground cover from tree seedlings <1 m tall, long-term assessments have shown that prescribed winter burns tend to stimulate sprouting of hardwoods and to increase their density in southern pine forests (Hodgkins 1958, Cain 1985*a*). Huntley and McGee (1981) found that prescribed burns in winter and spring not only increased the quantity of available deer browse from top-killed hardwoods but also increased browse quality.

Wolters et al. (1982) investigated the effects of 3-year-rotation winter burns in uneven-aged pine-hardwood stands located in north-central Louisiana. They theorized that fire-stimulated hardwood sprouts limited forage production, but we found no such trend in the present study. Lay (1956) found that prescribed burns in pine-hardwood stands in southeast Texas reduced browse for 2 years, but burning increased herbaceous forage for at least 3 years and caused little change in total forage production. Likewise, Hodgkins (1958) reported that frequent burning in southern pine forests causes the development and maintenance of a comparatively lush undergrowth of herbs, with grasses as the dominant component. Our most recent burns (3- and 9-yr cycles) also resulted in a higher percent cover from graminoids and composites (Fig. 1). Chen et al. (1977) found that repeated burn treatments in southern pine forests in Alabama were effective in maintaining succulent browse and stimulating the growth of herb species that were considered beneficial to white-tailed deer, northern bobwhite ***(Colinus virginianus)***, and wild turkey ***(Meleagris gallopavo)***.

The only ground-level component, other than vegetation, to be influenced by winter fire in the present study was organic debris. A reduction in leaf and needle litter is expected following prescribed burning because it is this component that carries the fire. Leaf litter is important to ground foragers such as the brown thrasher (*Toxostoma rufum*). Cade (1986) described optimum habitat conditions for the brown thrasher as 280% ground cover by litter ≥1 cm deep. Litter is also important to herpetofauna. Although a cycle-harvest took place in November 1987, percent cover from down woody debris >10 cm dbh was minimal in these uneven-aged stands 3 years later and was not affected by prescribed burning.

For woody plants that were >1 m tall but <2.5 cm dbh, American beautyberry and shining sumac had the highest percent cover, and differences among burn treatments were unimportant. Thill et al. (1990) reported that, in central Louisiana, fruits of American beautyberry were the main mast used by white-tailed deer in autumn. A few species of woody plants in this size class exhibited significant changes (usually a decline) in percent cover as a result of burning, but differences between burn treatments were ≤5% and were considered unimportant.

Horizontal cover in the lowest height zone (O-l m) was least affected by prescribed fire, except at the most intensive treatment level (3-yr burn cycle). Long-term effects of fire on horizontal cover were evident in the 1- to 2-m and the 2- to 3-m height zones, where a reduction in percent cover tended to be positively correlated

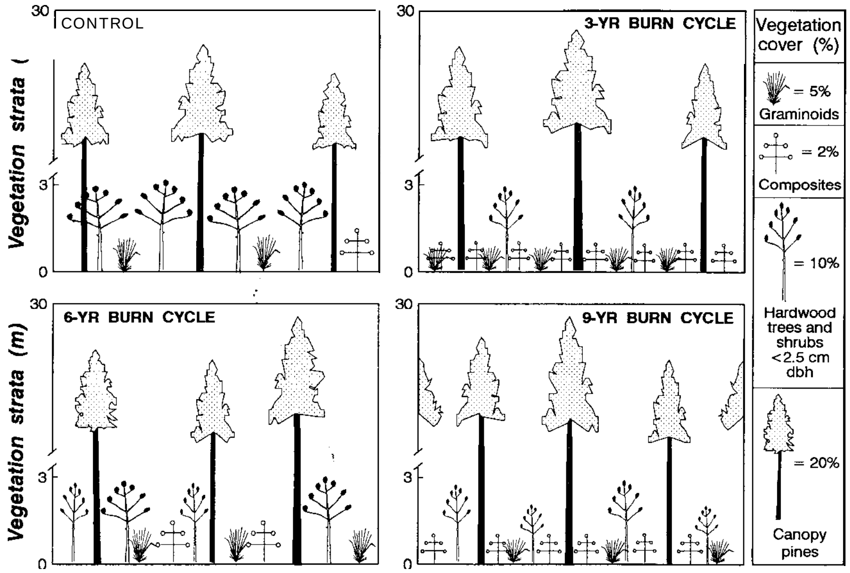

Fig. 1. Illustration of typical uneven-aged stand structure in relation to statistically significant differences in vegetation cover by burn treatments.

identified on the 3-year burn plots, as compared to 17 species on the 6-year burn plots and control plots, and 20 species on the 9-year burn plots. Although these were the only species to attain sapling size, they were not the only species present. These findings are consistent with the literature-recurring winter fires tend to control the size of hardwood competition but not hardwood density (Lotti et al. 1960, Ferguson 1961, Brender and Cooper 1968).

Natural plant succession from shade-intolerant to shade-tolerant species may be altered by the length of a burn cycle. For sapling-sized stems, flowering dogwood, a shade-tolerant species, dominated control plots and 9-year burn plots. In contrast, 2 shade-intolerant species, loblolly pine and sweetgum, were dominant on 3-year and 6-year burn plots, respectively.

with frequency of burning. This might be expected because winter burns reduce the size of vegetation but seldom destroy the rootstocks (Cain 1985*a*).

Because fire affects different cover strata, prescribed burning may improve habitat for some wildlife while degrading habitat for others. For example, research on the relationships between fire and bird density in coastal scrub and slash pine (*Pinus elliottii*) flatwoods in Florida suggests that the numbers of ground-dwelling birds may increase after fires, but burning as frequently as every 7 years has a negative effect on shrub-dwelling birds (Breininger and Smith 1992).

Compared to all other treatments, prescribed burning at 3-year intervals significantly reduced foliage height diversity index. This is important because species diversity of birds is positively correlated with foliage height diversity (MacArthur and MacArthur 1961). Odum (1989) reported changes in 30 species of passerine bird populations as vegetation changed from grass to shrubs to pines in ecological succession.

Sapling diversity declined as the frequency of prescribed burning increased. However, the 3-year burn cycle resulted in significantly less diversity compared to other treatments. The evenness with which individual species were divided among all species was also least on a 3-year burn cycle.

The importance of sapling-size species was least uniform in the 3-year burn plots. The general tendency was for species richness of sapling-size stems to decline as the frequency of prescribed burning increased. For example, 7 species of sapling size were

Prescribed burning on a 3-year cycle is most likely to maintain an understory of small woody plants. However, Lay (1956) reported that frequent burning at 2-year and 3-year intervals reduced understory soft mast production in pine-hardwood stands of southeast Texas. He suggested that such burns are likely to have negative impacts on wildlife species that are highly dependent on mast-producing plants. For pine seedlings to become established and grow, this vertical zone must be sparsely occupied by competing vegetation.

The importance of sapling-size loblolly pines on the 3-year burn plots may be misleading. Loblolly pines that are <3.8 cm in gld or <2.4 m tall are likely to be killed by prescribed winter burns (Cain 1985*b*). Consequently, it is unlikely that uniform prescribed burns on a 3-year cycle will allow natural pine regeneration to become established and grow to a size that is resistant to fire. The high IV of pine saplings on the 3-year burn plots is attributed to nonuniform burns in the early years of the original silviculture study, which allowed patches of pine regeneration to escape the fires. When considering a program of prescribed burning to sustain uneven-aged stands of loblolly and shortleaf pines, more attention should be given to density, quadrat stocking, and size of established pine regeneration and to expected pine seedcrops, rather than the prosecution of rigid burning schedules (Cain 1993).

Management implications

Prescribed fires have effects on wildlife species through modification of stand structure. Prescribed winter burns change plant succession in uneven-aged pine stands by reducing the size of understory hardwood trees and shrubs and enhancing the growth of herbaceous vegetation. Even though woody plants are topkilled by prescribed fires, sprouts become more accessible to wildlife as browse. Furthermore, without periodic burns or other techniques for controlling the size of understory woody plants in uneven-aged pine stands, wildlife habitat would likely diminish for most game species.

The effects of prescribed fire on wildlife habitat structure in uneven-aged pine stands should be weighed in conjunction with the effects of fire on pine timber production. Uneven-aged silvicultural systems provide for the periodic extraction of forest products and are beneficial to wildlife species that require a well-developed stand structure. Additional research on uneven-aged pine stands is needed to address the effects of repeated burns on individual wildlife species, including ungulates, understory birds, tree-canopy birds, and terrestrial herpetofauna. It is important for managers to recognize that rigid burning schedules of <5 years in uneven-aged stands do not allow for a time frame in which natural loblolly and shortleaf pine regeneration can become established and grow to a size that is resistant to fire.

From the standpoint of using prescribed fire to facilitate the establishment and growth of pine regeneration in uneven-aged stands of loblolly and shortleaf pines, Cain (1994) recommended a series of annual or biennial burns to keep the submerchantable-sized hardwoods in check. The last burn in a series should be timed to coincide with a better-than-average pine seedcrop and with site disturbance from cycle-harvest activities. The last burn in a series should be completed by early autumn, before the majority of pine seeds have disseminated. If stand regeneration is a priority, additional burns should be postponed until pine regeneration is well distributed with 2494 stems/ha that are >2.4 m in height or >3.8 cm in gld to withstand subsequent prescribed winter burns (Cain 1993).

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