Vegetative Response to 37 Years of Seasonal Burning on a Louisiana Longleaf Pine Site

James D. Haywood, Finis L. Harris, and Harold E. Grelen (retired) *USDA Forest Service, Southern Research Station, Kisatchie National Forest, and Southern Research Station, Pineville LA 71360, respectively; and* **Henry A. Pearson** *(Emeritus Scientist) Trinity Valley Community College, Athens, TX 75751.*

ABSTRACT: ***From 1962 through 1998, 20 prescribed burns were applied in a natural stand of longleafpine (*****Pinus** palustris ***Mill.) to determine the effects of variousfire regimes on theforestplant community. The original longleaf seedlings regeneratedfrom the 1955 seed crop and were growing in a grass-dominated cover when the study began. By 1999, prescribed burning in March and May resulted in a significantly greater stocking of longleafpine (203 trees/ac) than on the unburned and July burned treatments (72 trees/ac) (a = 0.05). Fire arrested the growth of natural loblolly pine*** (P. taeda ***L.) and hardwoods, but loblolly pines and hardwoods of at least 4 in. dbh added 70*** ft^2***/ac of basal area on the unburned plots. Thus, total woody basal area was significantly greater on the unburned (117*** ft^2***/ac) and May burned (132*** ft^2***/ac) treatments than on the July burned treatment (66*** ft^2***/ac); basal area was intermediate on the March burned treatment (97*** ft^2***/ac). Pine volume was 4,315, 2,870, 2,652, and 1,970*** ft^3 ***inside-bark/ac on the May burned, March burned, unburned, and July burned treatments, respectively, but these differences were not statistically significant*** (P ***= 0.06). There was only 1 I lb/ac of herbaceous plants on the*** unburned ***plots. Herbaceous plants averaged 993 lb/ac on the three burned treatments, withpinehill bluestem*** (Schizachyrium scoparium ***var.*** divergens ***[Hack] Gould} being the most common herbaceousplant. We believe the chief influence ofbuming in this natural longleafpineforest was not on pine yield but how fires influenced overall stand structure and species composition. South. J. Appl. For. 25(3):122–130.***

Key Words: ***Pinus palustris*** Mill., ***Pinus taeda*** L., ***Schizachyrium scoparium*** var. ***divergens*** [Hack] Gould, control burning, stand structure, species composition, and vegetation control.

Restoring longleaf pine (***Pinus palustris*** Mill.) plant communities within their historical ranges is an objective of many public land managers in the southern United States as a way to arrest the progressive decline of nearly 200 associated taxa of vascular plants and several vertebrate species (Brockway et al. 1998). Periodic burning of longleafpine forests regardless of season is recommended to help control hardwoods and unwanted pine species, bum off needles infected with brown-spot needle blight, caused by ***Mycosphaerella dearnessii*** Barr. (Boyer 1975), and hopefully improve conditions for herbaceous plant development (Brockway and Lewis 1997, Glitzenstein et al. 1995, Grelen 1976, 1983, Robbins and Myers 1989).

The effects of a single burn can be transitory (Haywood 1995, Olson and Platt 1995). Thus, a series of prescribed bums is recommended, and periodic burning later in the growing season may more effectively reduce hardwood vegetation than periodic burning near the beginning of the growing season (Chen et al. 1975, Grelen 1975, Lotti 1956, Lotti et al. 1960, Robbins and Myers 1989).

We are currently conducting two research studies that address the issue of long-term continual prescribed burning at different times of the year for the restoration of longleaf pine communities. One was established in 1972 on a wet pine site that had been direct-seeded to longleaf pine (Haywood and Grelen 2000), and this study, established in 1962, in an upland stand of naturally regenerated longleaf pine. Originally, this research was a simulated grazing study (Grelen and Epps 1967). Eventually, the objective of this long-term research shifted to determining how biennial prescribed burning in March, May, or July influenced pines, hardwoods, and herbaceous vegetation as the natural plant communities developed. Unburned conditions were also evaluated. Grelen (1975) reported on the first 12 yr of research in this study.

NOTE: James D. Haywood can be reached at (318) 473-7226; Fax: (3 18) 473-7273; E-Mail: dhaywood@fs.fed.us. Manuscript received May 5, 2000, accepted October 16, 2000.

Materials And Methods

Study Area

The study area is within the humid, temperate, Coastal Plain and flatwoods province of the West Gulf Region of the southern United States (McNab and Avers 1994) and is suitable for the restoration of a loamy dry-mesic upland longleaf pine forest (Turner et al. 1999). It is located within boundaries of the Kisatchie National Forest in central Louisiana about 19 miles south-southwest of Alexandria (approximately 92°30′W longitude, 3 1°N latitude) at an average elevation of 170 ft above sea level. Slopes vary from 1 to 8%.

Climate is subtropical with mean January and July temperatures of 47° and 82°F, respectively (Louisiana Office of State Climatology 1999). Annual precipitation averages 60 in. with more than 38 in. during the 250-day growing season, which is from March 10 to November 15 (the spring and fall dates with a 50% probability of a frost).

Major soils on the site include the Ruston (fine-loamy, siliceous, thermic, Typic Paleudult); McKamie (fine, mixed, thermic, Vertic Hapludalf); and Gore (fine, mixed, thermic, Vertic Paleudalf) series (John C. Novosad, Soil Scientist, Kisatchie National Forest, personal communication, 1992). The Ruston is a well-drained, moderately permeable, upland soil with few limitations for growing trees (Kerr et al. 1980). The McKamie is a well-drained, very slowly permeable upland soil. The Gore is a moderately well drained, very slowly permeable soil of lower slopes. The clay content in the upper portion of the McKamie and Gore soils can limit productivity. All three soils are best suited for pine management. The Ruston is the most productive and the Gore the least productive of the three soils.

The 7 ac study area lies less than 0.5 mile from two hardwood-pine intermittent drainages. The original stand of pines and hardwoods was clearcut in the 1920s. A cover of perennial grasses under scattered pines and hardwoods was maintained by periodic burning for open-range grazing. The original pine seedling stand regenerated from the 1955 seed crop that came from the occasional residual longleaf pine trees within and nearby the study area (Grelen 1975). Residual loblolly pines were also occasionally found in the area. Managed grazing began in 1956, and the complete site was last burned in 1961.

When this study began in 1962, grass-stage longleaf seedlings were abundant (Grelen 1975). Waxmyrtle or southern bayberry (*Myrica cerifera* L.), shining sumac (***Rhus copallina*** L.), and American beautyberry (***Callicarpa americana*** L.) were the most common shrubs. Herbaceous vegetation was predominantly pinehill bluestem (*Schizachyrium* ***scoparium*** var. *divergens* [Hack] Gould) and slender bluestem ***(S. tenerum Nees).***

Treatments

In early 1962, the 7 ac study area was fenced to exclude livestock. Sixteen contiguous plots were laid out, each one separated by a 10-ft-wide fire line. Individual plots were 104 by 104 ft or 0.25 ac. The 16 plots were divided among 4 blocks in a randomized complete block design. Blocking was based on slope, but each block contained a mixture of soils. The most common soil was Ruston in block 1, McKamie in block 2, Gore in block 3, and equal amounts of Ruston and McKamie in block 4.

In early 1962, all pine and hardwood trees and shrubs above grass height (about 1 ft tall) were severed and removed to help create uniform cover conditions over the entire research area. However, scattered loblolly and longleaf pines outside of the study area and loblolly pines within the drainages continued to be seed sources. Four treatments were randomly assigned to the plots in each block as follows:

1. Unburned (1962 to present). Burning was discontinued after the broadcast burn of the entire area in 196 1. As part of the original simulated grazing study, these plots were annually mowed in March 1962 and 1963 to about 4 in. above ground with a tractor-drawn machine, then to near ground level with a hand-operated mower (Grelen and Epps 1967). After cutting, the residue was raked and removed. After 1963, no further treatments were applied (Grelen 1975).

2. March burns. These plots were included in the 1961 burn. In 1962 through 1964, these plots were prescribed burned annually on or as near March 1 as weather and fuel conditions permitted. Because fuels did not accumulate sufficiently between annual bums, it was decided to biennially burn the plots on or near March 1 beginning in 1966 (Grelen 1975). Thus, 20 burns were applied over a 37 yr period from 1962 through 1998.

3. May burns. Plot treatments and burning schemes were the same as for the March burned plots, except the plots were burned on or as near May 1 as weather and fuel conditions permitted.

4. July burns. Plot treatments and burning schemes were the same as for the March burned plots, except the plots were burned on or as near July 15 as weather and fuel conditions permitted from 1962 through 1964. The burning date was changed to July 1 in 1966 (Grelen 1975).

After treatments in 1962 and 1963, all plots were about equally devoid of plant material, which served the initial purpose of the study to isolate fire effects other than herbage removal (Grelen and Epps 1967). The unburned plots were no longer treated after 1963 when the objective of the study changed to determining how repeated burning influenced woody and herbaceous vegetation on natural longleaf pine-bluestem range (Grelen 1975).

Plots were burned with backfires and strip headfires, and all burns were completed as planned. Because dates rather than burning conditions were prescribed and cumulative effects of decades of burning were measured rather than the effect of a single burn, no fuel or daily weather data were recorded. Our principal concern was the long-term cumulative effects of repeated burning on plant development, which is analogous to the effects of the climate on cumulative growth, rather than transitory vegetation responses to a single burn (Olson and Platt 1995). Pinehill and slender bluestem provided most of the fine fuels through age 12 (Grelen 1975), but pine needles were a significant source of fine fuel in later years.

Measurements and Data Analysis

In September 1999, total height and dbh of all pines (longleafand loblolly) 4.0 in. or greater indbh were measured in the central 0.1 ac of each plot and 15 to 19 months after the last burns. These data were used to calculate total inside-bark stem volume. Volumes for loblolly pine were calculated from a 0.5 ft stump height using Baldwin and Feduccia's (1987) formula. For longleaf pines with at least a 5.0 in. dbh, volumes were calculated from a 0.4 ft stump height, and for the 4.0 to 4.9 in. dbh longleaf pines, volumes were calculated from a 0.1 ft stump height using Baldwin and Saucier's (1983) formulas.

In November 1999, total height and dbh of all hardwoods with a stem 4.0 in. or greater in dbh were measured in each 0.1 ac plot. These measurements were made 16 to 20 months after the last biennial burns.

On each of the 16 plots, 9 systematically located, permanently marked 2.4 ft^2 subplots were established in a 3 by 3 grid pattern in the central 0.1 ac of each plot for evaluating herbaceous vegetation. At each subplot in September 1999, all of the herbaceous species were ocularly inventoried to determine species composition. Then, the four most common plants were assigned a ranking (1—most common to 4-fourth most common). The herbaceous vegetation was clipped to groundline, ovendried at 176°F, and weighed. The inventories and samples were taken 15 to 19 months after the last burn. The delay before data collection gave the understory vegetation enough time to recover so valid treatment comparisons could be made.

On each of the 16 plots, five circular 0.001 ac subplots (milacres) were established for evaluating understory shrubs and tree seedlings and saplings less than 4.0 in. dbh, which included plants under 4.5 ft in height. A milacre was placed within the center of each quarter and in the center of each 0.1 ac plot. At each milacre in September 1999, pines, hardwoods, and shrubs were counted by species and height and crown width were measured to the nearest 0.1 ft to determine species composition and stature. Woody vines were also counted by species on each milacre.

Plot means were compared using analyses of variance for a randomized complete block design with four blocks of each of the four treatments (a = 0.05) (Steel and Torrie 1980). Pine variables analyzed were per acre values for number of stems, basal area, and volume and mean tree values for dbh, height, and volume for only longleaf pine or for longleaf plus loblolly pine. Treatment comparisons were made with Duncan's Multiple Range Tests when significant treatment effects were found (a = 0.05). We did not compare variables for hardwoods 4.0 in. or greater in dbh because this size class was only found on the unburned plots.

Understory woody vegetation stem count, height, and crown width and herbaceous plant productivity were also analyzed (a = 0.05). However, there were such large differences in treatment means that a logarithmic transformation [log (Y)] was used to equalize variances (Steel and Torrie 1980). A $\log(Y + 1)$ transformation was used for the understory pine counts because several plots had no pine seedlings. Nonparametric analyses were also done to compare treatment means, but the nonparametric tests had similar results to the logarithmic transformation analyses.

Results

Pines

In this natural stand of pines at least 4 in. dbh, stocking of longleaf pine trees was significantly greater on the March and May burned treatments (203 stems/ac) than on the unburned and July burned treatments (72 stems/ac) (Table 1). Longleaf pine basal area and volume on the May burned treatment (132 ft^2/ac and 4,3 15 ft^3/ac) was significantly greater than on the unburned and July burned treatments (56 ft^2/ac and 1,735 ft^3/ac). Longleaf pine basal area on the March burned treatment was significantly greater than the basal area on the unburned plots, and there were no significant differences in longleaf pine volume among the unburned, March burned, and July burned treatments.

The reduced volume on the March burned treatment resulted because the longleafpines were significantly smaller on this treatment than on the other three treatments: tree

Table 1. Means for stand and tree characteristics for either longleaf pine or all pines following 37 yr of prescribed burning in a natural longleaf pine stand in Louisiana.

Taxa and treatments	Stocking (stems/ac)	Basal area (ft^2/ac)	Volume production (ft^3/ac)	Mean total height (ft)	Mean dbh (in.)	Mean tree volume (ft^3)
Longleaf pine only						
Unburned	55b'	46.6c	1,500b	79a	12.7a	27.3a
March bums	210a	97.3ab	2,870ab	70b	8.8c	13.8b
May burns	195a	131.7a	4,315a	80a	10.9b	22.0a
July burns	88b	65.6bc	1,970b	70b	11.4ab	22.1a
Error mean squares	2,023	837.8	921,321	9.202	1.075	22.024
All pines						
Unburned	78b'	80.3a†	2,652a†	81a	13.8a	34.1a
March bums	210a	97.3a	2,870a	70b	8.8c	13.8c
May burns	195a	131.7a	4,315a	80a	10.9b	22.0b
July burns	88b	65.6a	1,970a	70b	11.4b	22.1b
Error mean squares	2,200	1,020.3	1,116,487	7.997	0.960	17.805

* Withii columns and by taxon, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (a = 0.05).
† P values for stand basal area and stand volume differences among treatments were 0.078 and 0.063, respectively.

Table 2. Vegetation characteristics for hardwoods 4 in. or greater in dbh on the unburned portion of a natural stand of longleaf pine in Louisiana after 37 yr.

Species	Stocking (stems/ac)	Basal area (ft^2/ac)	Mean total height (ft)	Mean dbh (in.)
Acer rubrum	5	0.9	52	5.7
Cornus florida	52	8.8	39	5.4
Ilex opaca	15	2.2	34	5.1
Liquidambar styraciflua	5	0.6	25	4.5
Prunus serotina	18	8.3	68	8.8
Quercus falcata	12	7.1	58	9.8
Q. marilandica	40	7.4	43	5.7
Q. stellata	5	0.6	43	4.6
Sassafras albidum	3	0.4	48	5.4
Totals	155	36.3	—	—

volume was 14 ft^3 for the March burned treatment compared to an average of 24 ft^3 on the unburned, May burned, and July burned treatments (Table 1). Total height of longleaf pines on the unburned and May burned treatments (80 ft) was significantly greater than on the March and July burned treatments (70 ft), but average dbh on the unburned and July burned treatments (12 in.) was significantly greater than average dbh on the March burned treatment (9 in.).

Biennial prescribed burning controlled the natural loblolly pine regeneration, but the unburned plots had 23 loblolly pine trees per acre that originated from parent trees near the study area. These loblolly pines averaged 16 in. dbh, 84 ft tall, and 50 ft^3 of volume. They added 34 ft^2/ac of basal area and 1,152 ft^3/ac of volume to the unburned plots.

When all pines were considered, there were no significant differences in stand basal area and stand volume among the four treatments, although the *P* value was 0.08 for basal area and 0.06 for volume (Table 1). This was in part due to changes in size of the average pine tree. With the inclusion of loblolly pine, pine trees on the unburned plots (34 ft^3/tree) were significantly larger than those on the three burned treatments (19 ft^3/tree).

Hardwoods

Biennial prescribed burning suppressed the development of hardwoods. As a result, midstory hardwoods (stems 24.0 in. dbh) were only found on the unburned plots, where these hardwoods numbered 155/ac and added 36 ft^2/ac of basal area (Table 2). Total height averaged 42 ft, and dbh averaged 6 in. The four most common species, in terms of basal area, were flowering dogwood (*Cornus florida* L.) (8.8 ft^2/ac), black cherry (***Prunus serotina*** Ehrh.) (8.3 ft^2/ac), blackjack oak (***Quercus marilandica*** Muenchh.) (7.4 ft^2/ac), and southern red oak (Q. *falcata* Michx.) (7.1 ft^2/ac). These four species numbered 122 stems/ac or 79% of all midstory hardwoods. The next most common species was American holly (*Ilex opaca* Ait.) with only 2.2 ft^2/ac of basal area.

When hardwoods were included with pines, the total number of trees 4 in. or greater in dbh was similar among the unburned (233 trees/ac), March burned (210 trees/ac), and May burned (195 trees/ac) treatments. These three treatments still had significantly more trees than the July burned treatment (88 trees/ac). Total basal area of all trees 4 in. or greater in dbh was similar on the May burned (132 ft^2/ac) and unburned (117 ft^2/ac) treatments, and these two treatments had significantly more total basal area than the July burned treatment (66 ft^2/ac). Total basal area on the March burned treatment was intermediate (97 ft^2/ac).

Woody Understory Vegetation

Understory pine seedlings were nearly all below 4.5 ft tall. No longleaf pine seedlings were found on the unburned plots (Table 3). There were fewer loblolly pine seedlings on the unburned plots (300 stems/ac) than on the three burned treatments (5,233 stems/ac). However, after means were logarithmically transformed, there were no significant differences in the number of longleaf or loblolly pine seedlings among the three burned treatments. Similarly, woody vine counts ranged from 300 stems/ac on the March burned treatments to 6,800 stems/ac on the unburned plots, but there were no significant treatment differences.

Understory hardwoods and shrubs were significantly more common on the March burned treatment (15,350 stems/ac) than on the other two burned treatments (3,675 stems/ac) (Table 3). The unburned plots (8,000 stems/ac) had more hardwoods than the May bum treatment (2,950 stems/ac). The total height of the understory hardwoods was significantly greater on the unburned and March burned treatments than on the May and July burned treatments. Crown width was not significantly different among the four treatments.

The representative understory hardwoods on all treatments were blackjack oak and sassafras (***Sassafras albidum*** [Nutt.] Nees) (Table 4). Both species were found in the midstory of the unburned plots (Table 2). Sassafras was especially common in the understory of the March burned

Table 3. Vegetation characteristics for understory woody plants lass than 4 in. dbh following 37 yr of prescribed burning in a natural stand of longleaf pine in Louisiana.

	Stocking (stems/ac)				Hardwoods* (ft)	
Treatments	Longleaf	Loblolly	Vines	Hardwoods*	Mean total height	Mean crown width
Unburned	0b†	300b	6,800a	8,000ab	3.0a	1.5a
March bums	5,050a	1,000a	300a	15,350a	2.1a	1.1a
May burns	16,800a	5,400a	4,050a	2,950c	1.1b	0.8a
July burns	18,300a	9,300a	450a	4,400bc	1.2b	0.8a
Error mean squares ††	4.760	5.167	1.417	0.527	0.054	0.095

* Includes shrubs.

† Within columns, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (a = 0.05).

†† A logarithmic transformation [log(Y)] of plot means was used to equalize variances (Steel and Torrie 1980). A log(Y + 1) transformation was used for the understory pine counts because several plots had no seedlings.

Table 4. Understory hardwoods and shrubs less than 4.0 in. dbh commonly found in a natural longleaf pine stand in Louisiana after 37 yr of prescribed burning.

Taxa	Unburned	March bums	May burns	July burns
Hardwood trees				
Acer rubrum				
Stems/ac	50	—*	—	—
Mean total height (ft)	1.0	—	—	—
Mean crown width (ft)	0.5	—	—	—
Ilex opaca				
Stems/ac	200	—	—	—
Mean total height (ft)	5.6	—	—	—
Mean crown width (ft)	2.6	—	—	—
Prunus serotina				
Stems/ac	300	—	—	—
Mean total height (ft)	0.8	—	—	—
Mean crown width (ft)	0.6	—	—	—
Quercus falcata				
Stems/ac	—	—	150	—
Mean total height (ft)	—	—	1.2	—
Mean crown width (ft)	—	—	0.7	—
Q. marilandica				
Stems/ac	50	200	200	50
Mean total height (ft)	0.5	1.0	0.9	1.5
Mean crown width (ft)	0.5	1.0	0.9	1.0
Sassafras albidum				
Stems/ac	300	2,800	250	50
Mean total height (R)	4.2	2.7	1.2	2.0
Mean crown width (ft)	1.7	1.3	0.8	1.0
Shrubs				
Ascyrum hypericoides				
Stems/ac	—	50	500	400
Mean total height (ft)	—	0.5	1.0	1.8
Mean crown width (R)	—	0.5	0.5	0.5
Ilex vomitoria				
Stems/ac	2,100	—	—	—
Mean total height (ft)	4.0	—	—	—
Mean crown width (ft)	1.7	—	—	—
Myrica cerifera				
Stems/ac	3,100	2,100	750	850
Mean total height (ft)	2.2	1.6	1.0	1.2
Mean crown width (ft)	1.1	1.1	1.0	0.9
Rhus copallina				
Stems/ac		3,150	100	1,050
Mean total height (ft)	—	2.1	1.3	1.8
Mean crown width (ft)	—	1.2	1.0	1.1
Rubus spp.				
Stems/ac	—	2,900	100	400
Mean total height (ft)	—	2.5	1.5	1.2
Mean crown width (ft)	—	1.1	0.5	0.7
Vaccinium spp.				
Stems/ac	650	550	—	—
Mean total height (ft)	2.2	1.4	—	—
Mean crown width (ft)	1.2	1.0	—	—

* Taxon was not found on the milacre subplots of this treatment.

treatment. Red maple (*Acer rubrum* L.) and black cherry were inventoried in the midstory and understory of the unburned plots but were not inventoried in the under-story of the three burned treatments (Table 4). Another midstory hardwood, southern red oak, was inventoried in the understory of only the May burned plots.

Although flowering dogwood, sweetgum (*Liquidambar styraciflua* L.), and post oak (Q. *stellata* Wangenh.) were found in the midstory of the unburned plots, they were not inventoried in the understory, nor were they found on the three burned treatments (Tables 2 and 4).

American holly and yaupon ***(I. vomitoria* Ait.)** were found in the understory of the unburned plots but were absent in the burned plot inventories (Table 4). Both of these species were above average in height (Tables 3 and 4). Conversely, St. Andrewscross ***(Ascyrum hypericoides*** L.), shining sumac, and blackberry (***Rubus*** spp.) were shaded out under the unburned plot canopies but were inventoried in the understory of all three burned treatments (Table 4). Waxmyrtle was found in the understory of all four treatments. Burning in March resulted in a greater number of waxmyrtle, shining sumac, and blackberry stems than burning in May or July. Blueberries ***(Vaccinium*** spp.) were inventoried on the unburned and March burned treatments but not on the May nor July burned treatments.

Herbaceous Vegetation

Biennial burn treatments had significantly more herbaceous plants (993 lb/ac) than the unburned plots (11 lb/ac) (P = 0.002). There were no significant differences among the three burning treatments, with the March, May, and July burned plots producing 839, 907, and 1,232 lb/ac, respectively.

The only herbaceous species inventoried on the unburned plots was partridgeberry (*Mitchella repens* L.). Not even the shade-tolerant uniola grasses (*Chasmanthium* spp.) were present here. However, over 80 species of herbaceous plants were inventoried on the burned treatments.

In terms of distribution across the three burned treatments, the most common taxon was pinehill bluestem, which was the dominant plant on 55 (May burned) to 88% (July burned) of the subplots (Table 5). Slender bluestem was either the most common or third most common herbaceous plant on a small percentage of the burned treatments, but none of the other grasses were as evenly distributed as these two bluestems.

Swamp sunflower (*Helianthus angustifolius* L.), and grassleaf goldaster (*Heterotheca graminifolia* [Michx.] Shinners) were the most common composite species on the three burned treatments (Table 5). The most common legume and other forb were weak tephrosia (*Tephrosia onobrychoides* Nutt.) and white mountainmint (*Pycnanthemum albescens* T. & G.), respectively. Another species commonly found on just the March and July burned treatments was small noseburn (*Tragia smallii* Shinners). Bracken fern (*Pteridium aquilinum* var. *pseudocaudatum* [Clute] Heller) was also a common species on all three burned treatments.

Table 5. Herbaceous plants most commonly found following 37 yr of prescribed burning in a natural longleaf pine stand in Louisiana.

Taxa	Occurrence as dominant plants* (%)		
	March bums	May bums	July bums
Grasses			
Andropogon gerardii	3’	—††	—
A. elliottii		$3^{\dagger}$	$5^{\S}$
Aristida spp.	$8^{\S}$	—	$3^{\dagger}$
Dichanthelium spp.		$5^{\dagger}$	$5^{\S}$
Leptoloma cognatum	—	$3^{\dagger}$	
Panicum spp.	$8^{\dagger}$		$3^{\dagger}$
Paspalum spp.	—	3’	$5^{\S}$
Schizachyrium scoparium var. *divergens*	$68^{\dagger}$	$55^{\dagger}$	88’
S. tenerum	$5^{\|}$	$8^{\dagger}$	$3^{\dagger}$
Sorghastrum avenaceum	$3^{\dagger}$	—	
Grasslike plants			
Scleria ciliata	$3^{\dagger}$	$8^{\|}$	—
Composites			
Helianthus angustifolius		$3^{\dagger}$	3’
Helianthus silphiodes	3’	$5^{\dagger}$	$5^{\S}$
Heterotheca gramintfolia	$3^{\dagger}$	$14^{\S}$	$5^{\S}$
Solidago salicina		$3^{\dagger}$	—
Vernonia texana		$3^{\dagger}$	
Legumes			
Rhynchosia difformis	—	$3^{\dagger}$	—
Tephrosia onobrychoides	8”	$8^{\S}$	$8^{\S}$
Other forbs			
Hypoxis hirsuta		$3^{\dagger}$	—
Pycnanthemum albescens	–$3^{\dagger}$	$3^{\dagger}$	$3^{\#}$
Tragia smallii	$3^{\dagger}$	—	$3^{\|}$
Ferns			
Lygodium japanicum	$3^{\dagger}$	—	$3^{\S}$
Pteridium aquilinum var. *pseudocaudatum*	$3^{\|}$	$3^{\S}$	$3^{\S}$

* Control treatment not reported because of low occurrence of herbaceous vegetation.
† Taxon was the most common on this percentage of herbaceous subplots.
†† Taxon was not commonly found on this burning treatment.
§ Second most common taxon on this percentage of herbaceous subplots.
‖ Third most common taxon on this percentage of herbaceous subplots.
\# Fourth most common taxon on this percentage of herbaceous subplots.

Discussion

Understory Plant Communities

In our 37 yr study, prescribed burning influenced woody plant composition. Fire prevented red maple, black cherry, American holly, and yaupon from becoming established in the midstory. However, the more open canopy on the burned plots allowed St. Andrewscross, shining sumac, and blackberry to persist in the understory while these species were shaded out on the unburned plots. Certain species were found in the understory of all treatments: blackjack oak, known to tolerate fire (Grelen 1976); sassafras, which is intolerant and susceptible to fire damage but sprouts readily (Leonard 1977); and waxmyrtle, which survives burning by readily sprouting from the root collar (Halls 1977). Blueberries, an important genus for wildlife (Dale and Hughes 1977), were inventoried on the unburned and March burned treatments but not on the May or July burned treatments.

Control burning can be used to manage herbaceous vegetation (Grelen and Epps 1967). When fire was biennially applied, loblolly pine and hardwood growth and stature were reduced, and litter did not accumulate sufficiently to suppress herbaceous plants. The canopy remained more open and sufficient sunlight reached the forest floor to sustain a productive, species-rich herbaceous plant community. The large difference in herbaceous plant productivity between the unburned and burned treatments is probably indicative of the difference in light intensity near the forest floor between the unburned plots that had 36 ft^2/ac of hardwoods and the burned plots that had no hardwood midstories and thus a more open canopy. It was not because of differences in total basal area of all trees 4 in. or greater in dbh because total basal area among the unburned (117 ft^2/ac), March burned (97 ft^2/ac), and May burned (132 ft^2/ac) treatments were not significantly different.

Still, the inverse relationship between longleaf pine basal area and herbaceous plant productivity is well known (Grelen and Lohrey 1978), and this was probably a factor in the minor herbage yield differences among the burning treatments. The July burned treatment, which produced the most herbaceous plants, had significantly less basal area than the May burned treatment. However, the May burned treatment produced slightly more herbaceous plants than the March burned treatment, although the May burned plots had the greatest basal area. This discrepancy probably occurred because of a greater number of understory hardwoods on the March burned plots than on the May burned plots. The adverse effect that understory woody vegetation has on herbaceous plants has been shown in other upland longleaf pine forests (Haywood and Harris 1999).

On the burned treatments, the common occurrence of pinehill bluestem, big bluestem (*Andropogon gerardii* Vitm.), and threeawn (*Aristida* spp.) grasses; Texas ironweed (*Vernonia texana* [A. Gray] Small); and weak tephrosia indicate a well-developed understory for a loamy dry-mesic upland longleaf pine forest (Turner et al. 1999). Small noseburn is indicative of sandy dry longleaf uplands and is probably found on sandier intergrades of Ruston soil within the study area. Other common species in this study, swamp sunflower, grassleaf goldaster, and bracken fern, are also commonly found on longleaf pine uplands of the Kisatchie National Forest (Haywood and Harris 1999).

Pine Regeneration

A large number of pine seedlings were inventoried under the natural forest canopy, as noted on other burned forest landscapes (Haywood et al. 1998a). However, these small pine seedlings fail to develop because the overstory trees shade the seedlings and compete aggressively for water and nutrients. Shading is especially a factor on the unburned plots, which had 31% of their basal area in hardwoods. Also, the continual application of fire reduces the number of surviving longleaf and loblolly pine seedlings, but their numbers recover between burns (Haywood et al. 1998a).

If grass-stage longleaf pine seedlings develop in open ranges of established grass cover as were common in the West Gulf Region -when this study began in the early 1960s, the seedlings reach sufficient girth to tolerate burning. However, once the longleaf pine seedlings emerge from the grass stage, they are highly vulnerable to damage and mortality caused by fire until the seedlings are 4 to 6 ft tall (Bruce 195 1).

Open-range conditions are rare today. Consequently, forest managers wishing to restore upland mixed pine or mixed pine-hardwood forests to pure longleaf pine often have stands with poorly developed herbaceous plant communities. When these sites are regenerated to longleaf pine, following harvesting and site preparation, they will not burn because they do not have the necessary fine fuels to carry a fire across the site. Since conditions found on the untreated plots are often closer to what forest managers confront today, the restoration of upland forests from mixed pine or pine-hardwood to pure longleaf pine will not always be a simple process.

Without fine fuels, one is practically unable to burn longleaf seedling stands, and as a result, aggressive hardwood sprouts and seedlings of other pine species encroach. Longleaf seedlings are in danger of being overtopped since they often seldom initiate height growth for the first 3 to 6 yr as the root system develops (Harlow and Harrar 1969). The bunch of needles at the surface resembles a clump of grass; hence the term "grass stage" is used to describe this juvenile period of growth. Once seedlings have a well-developed root collar (at least 1 in. diameter), they are able to emerge from the grass stage, but by this time the rapidly developing brush may have occupied the site.

Long-Term Influence of Fire

Early in this study of natural forest development, Grelen (1975) reported that biennial burning in May resulted in larger longleaf pine saplings than biennial burning in either March or July. The positive relationship between May burning and greater longleaf pine stature has continued through 37 yr. However, the May burned treatment was not statistically better than the March burned treatment in affecting longleaf pine basal area or volume per acre. Burning in July was the least effective technique. When both longleaf and loblolly pines were considered, the unburned plots produced nearly as much pine volume as the March burned treatment and more than the July burned treatment.

Thus, the chief influence of burning in this natural stand was not on long-term pine yield but on how it influenced overall stand structure and species composition. Without the continual use of fire, a forest canopy developed with a basal area divided comparatively among longleaf (40% of basal area) and loblolly pine (29% of basal area) overstory trees and hardwood midstory trees (31% of basal area). Beneath this canopy was a well-developed understory of woody plants and vines, but the deep shade and accumulation of litter nearly eliminated herbaceous vegetation and pine regeneration.

Conversely, continued burning can maintain pure longleaf pine forests, defined as at least 80% of the overstory tree number, basal area, or volume being longleaf pine (Helms 1998). Stand conditions are such that with periodic application of fire, it is possible for longleaf pines to naturally regenerate into harvested openings or naturally occurring gaps in the overstory. The loblolly pine seed source should be removed within and near longleaf pine stands to keep this species from naturally regenerating into openings as well.

Management Implications

We believe that on most upland sites, a series of preharvest treatments are needed to ensure the restoration of longleaf pine and associated plant communities. The treatments would mostly involve prescribed burning and thinning prior to final overstory removal (Haywood and Harris 1999). These treatments are necessary to establish a herbaceous plant community under the existing overstory before final harvest.

Prescribed burning should be the first treatment applied as fire is considered a necessary management tool for preparing sites for longleaf pine regeneration (Boyer 1993, Croker and Boyer 1975, Smith 1961, Wahlenberg 1946). Implementing a timely fire regime is needed for fuel reduction and reducing midstory trees and shrubs.

However, to accomplish complete midstory control, herbicides or mechanical means may have to be used where vegetation is too large to control with prescribed burning. Also, a herbicide or mechanical treatment may be required where managers must restore certain plant communities as quickly as possible because the effects of a single prescribed burn are often transitory, and a series of burns over many years must be completed and maintained to have lasting changes in plant communities (Brockway et al. 1998, Haywood 1995, Olson and Platt 1995).

As the midstory is controlled and accumulated litter removed, grasses and forbs will naturally reestablish on forested uplands in the West Gulf Region (Haywood et al. 1998b). This herbaceous plant cover supports low-intensity burns with minimal smoke. The continued implementation of fire is essential and should be applied when woody stems start to become reestablished in the understory. Frequency of burns depends on site productivity and the desired or existing plant community.

Thinning treatments remove the immediate loblolly pine seed source and reduce canopy cover allowing more sunlight to reach the forest floor. This further favors the natural recovery of herbaceous vegetation (Grelen and Lohrey 1978). Once a herbaceous understory is in place, the overstory can be harvested and longleaf pine seedlings planted. Or if longleaf pines of seed-producing size are present, a natural regeneration system could be used employing either shelterwood, shelterwood with reserves, or group selection methods. The latter two methods maintain mature trees on the site. This may be the most ecologically beneficial provided the distribution of the mature trees is controlled to favor longleaf pine recruitment in openings (Grace and Platt 1995, Palik et al. 1997). Brockway and Outcalt (1998) recommend group selection with the openings being 130 to 165 ft in diameter (0.3 to 0.5 ac). This provides enough open space for the intolerant longleaf pine seedlings to develop without intensive intraspecific competition with adult longleaf pines for light, water, and nutrients.

Regardless of regeneration technique, as the stand canopy becomes more open in character, the recovering grass-dominated herbaceous plant community intermixed with pine needles will provide fuels for prescribed fires to control hardwoods and loblolly pine seedlings and promote the establishment of the longleaf pine regeneration. At this stage of stand development, spring burns will best help establish longleaf pine (Haywood and Grelen 2000, Grelen 1975). Although not all of the desired herbaceous plants may now be found in the stand, over time the desired species should reestablish themselves in the West Gulf Region (Haywood et al. 1998a, 1998b).

Literature Cited

BALDWIN, V.C., JR., AND D.P. FEDUCCIA. 1987. Loblolly pine growth and yield prediction for managed West Gulf plantations. USDA For. Serv. Res. Pap. SO-236.27 p.

BALDWIN, V.C., JR., AND J.R. SAUCIER. 1983. Aboveground weight and volume of unthinned, planted longleafpine on West Gulf forest sites. USDA For. Serv. Res. Pap. SO-191.25 p.

BOYER, W.D. 1975. Brown-spotinfectiononreleasedandunreleasedlongleaf pine seedlings. USDA For. Serv. Res. Pap. SO-108.9 p.

Boyer, W.D. 1993. Long-term development of regeneration under longleaf pine seedtree and shelterwood stands. South. J. Appl. For. 17(1):10–15.

BROCKWAY, D.G., AND C.E. LEWIS. 1997. Long-term effects of dormant-season prescribed fire on plant community diversity, structure and productivity in a longleaf pine wiregrass ecosystem. For. Ecol. Manage. 96:167–183.

BROCKWAY, D.G., AND K.W. OUTCALT. 1998. Gap-phase regeneration in longleaf pine wiregrass ecosystems. For. Ecol. Manage. 106: 125-139.

BROCKWAY, D.G., K.W. OUTCALT, AND R.N. WILKINS. 1998. Restoring longleaf pine wiregrass ecosystems: Plant cover, diversity and biomass following low-rate hexazinone application on Florida sandhills. For. Ecol. Manage. 103:159–175.

BRUCE, D. 1951. Fire, site, and longleaf height growth. J. For. 49: 25-28.

CHEN, M.Y., E.J. HODGKINS, AND W.J. WATSON. 1975. Prescribed burning for improving pine production and wildlife habitat in the hilly Coastal Plain of Alabama. Auburn Univ., Alabama Agric. Exp. Sta. Bull. 473. 19 p.

CROKER, T.C., JR., AND W.D. BOYER. 1975. Regenerating longleaf pine naturally. USDA For. Serv. Res. Pap. SO-105. 21 p.

DALE, E.E., JR., AND R. HUGHES. 1977. Blueberries/*Vaccinium* spp. P. 117-122 *in* Southern fruit-producing woody plants used by wildlife, L.K. Halls (ed.). USDA For. Serv. Gen. Tech. Rep. SO-16.

GLITZENSTEIN, J.S., W.J. PLATT, AND D.R. STRENG. 1995. Effects of fire regime and habitat on tree dynamics in North Florida longleaf pine savannas. Ecol. Monogr. 65(4):441-476.

GRACE, S.L., AND W.J. PLATT. 1995. Neighborhood effects on juveniles in an old-growth stand of longleafpine, *Pinus palustris*. Oikos 72:99–105.

GRELEN, H.E. 1975. Vegetative response to twelve years of seasonal burning on a Louisiana longleaf pine site. USDA For. Serv. Res. Note SO-192. 4 p.

GRELEN, H.E. 1976. Responses of herbage, pines, and hardwoods to early and delayed burning in a young slash pine plantation. J. Range Manage. 29:301–303.

GRELEN, H.E. 1983. May burning favors survival and early height growth of longleaf pine seedlings. South. J. Appl. For. 7(1): 16–20.

GRELEN, H.E., AND E.A. EPPS, JR. 1967. Season of burning affects herbage quality and yield on pine-bluestem range. J. Range Manage. 20:403–404.

GWEN, H.E., AND R.E. LOHREY. 1978. Herbage yield related to basal area and rainfall in a thinned longleafplantation. USDA For. Serv. Res. Note SO-232. 4 p.

HALLS, L.K. 1977. Southern bayberry/*Myrica cerifera* L. P. 57-58 *in* Southern fruit-producing woody plants used by wildlife, Halls, L.K. (ed.). USDA For. Serv. Gen. Tech. Rep. SO-16.

HARLOW, W.M., AND E.S. HARRAR. 1969. Textbook of dendrology. McGraw-Hill Book Company, New York. 5 12 p.

HAYWOOD, J.D. 1995. Prescribed burning and hexazinone herbicide as release treatmentsinasapling hardwood-loblollypinestand. New For. 10:39–53.

HAYWOOD, J.D., W.D. BOYER, AND F.L. HARRIS. 1998a. Plant communities in selected longleaf pine landscapes on the Catahoula Ranger District, Kisatchie National Forest, Louisiana. P. 86-91 *in* Proc. Ninth Bienn. South. Silvi. Res. Conf., Waldrop, T.A. (ed.). USDA For. Serv. Gen. Tech. Rep. SRS-20.

HAYWOOD, J.D., A. MARTIN, JR., H.A. PEARSON, AND H.E. GRELEN. 1998b. Seasonal biennial burning and woody plant control influence native vegetation in loblolly pine stands. USDA For. Serv. Res. Pap. SRS-14. 8 p.

HAYWOOD, J.D., AND H.E. GRELEN. 2000. Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. South. J. Appl. For. 24(2):86–92.

HAYWOOD, J.D., AND F.L. HARRIS. 1999. Description of vegetation in several periodically burned longleaf pine forests on the Kisatchie National Forest. P. 217-222 *in* Proc. Tenth Bienn. South. Silvic. Res. Conf., Haywood, J.D. (ed.). USDA For. Serv. Gen. Tech. Rep. SRS-30.

HELMS, J.A. (ED.). 1998. The dictionary of forestry. Soc. of Am. For., Bethesda, MD. 210 p.

KERR, A., JR., ET AL. 1980. Soil survey of Rapides Parish, Louisiana. USDA Soil Conserv. Serv. and For. Serv. and Louisiana State Univ. Agric. Exp. Sm. 87 p. and 114 maps.

LEONARD, R.G. 1977. Sassafras/Sassafras *albidum* (Nutt.) Nees. P. 91-92 *in* Southern fruit-producing woody plants used by wildlife, Halls, L.K. (ed.). USDA For. Serv. Gen. Tech. Rep. SO-16.

LOTTI, T. 1956. Eliminating understory hardwoods with summer prescribed fires in Coastal Plain loblolly pine stands. J. For. 54:191–192.

LOTTI, T., R.A. KLAWITTER, AND W.P. LEGRANDE. 1960. Prescribed burning for understory control in loblolly pine stands of the Coastal Plain. USDA For. Serv., Sta. Pap. No. 116. 19 p.

LOUISIANA OFFICE OF STATE CLIMATOLOGY. 1999. Louisiana monthly climate review. South. Reg. Climate Cent., Dep. Geogr. and Anthropol., Louisiana State Univ. Vol 19.98 p.

MCNAB, W.H., AND P.E. AVERS (COMPS.). 1994. Ecological subregions of the United States: Section descriptions. USDA For. Serv. Admin. Publ. WO-WSA-5. 267 p.

OLSON, M.S., AND W.J. PLATT. 1995. Effects of habitat and growing season fires on resprouting of shrubs in longleaf pine savannas. Vegetatio 119:101–118.

PALIK, B.J., R.J. MITCHELL, G. HOUSEAL, AND N. PEDERSON. 1997. Effects of canopy structure on resource availability and seedling responses in a longleaf pine ecosystem. Can. J. For. Res. 27:1458–1464.

ROBBINS, L.E., AND R.L. MYERS. 1989. Seasonal effects of prescribed burning in Florida: A review. The Nature Conserv. Fire Manage. and Res. Prog., Tallahassee, FL. 86 p.

SMITH, L.F. 1961. Tree percent on burned and unburned longleaf seedbeds. J. For. 59:201–203.

STEEL R.G.D., AND J.H. TORRIE. 1980. Principles and procedures of statistics a biometrical approach. Ed. 2. McGraw-Hill, New York. 633 p.

TURNER, R.L., J.E. VAN KLEY, L.S. SMITH, AND R.E. EVANS. 1999. Ecological classification system for the national forests and adjacent areas of the West Gulf Coastal Plain. The Nature Conserv., Nacogdoches, TX. 305 p.

WAHLENBERG, W.G. 1946. Longleaf pine its use, ecology, regeneration, protection, growth, and management. Charles Lathrop Pack For. Found. and USDA For. Serv., Washington, DC. 429 p.