EFFECTS OF PRESCRIBED FIRE ON VEGETATION AND FUEL LOADS IN LONGLEAF PINE STANDS IN THE BLUESTEM RANGE

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Abstract—Three longleaf pine (*Pinus palustris* Mill.) sites in the bluestem (*Andropogon* spp. and *Schizachyrium* spp.) range were selected in Louisiana for a 40-month study: a shelterwood, a small pole stand, and a newly planted clearcut. On each site, two treatments were applied: check and prescribed fires (PF). Prescribed fires were conducted in May 2001 and June 2003. Overstory basal area increased in the shelterwood and small-pole stand regardless of treatment. In August 2004, the checks had 39 percent and the PF plots had 15 percent cover in arborescent plants. Initially, grass cover was similar on both treatments (45 percent average), but in August 2004, grass cover was 16 percent on the checks and 28 percent on the PF plots. The decrease in grass cover was likely associated with increasing basal area in the overstory and changes in arborescent plant cover in the understory. Prescribed fire reduced dead fuel load over the 40 month period.

INTRODUCTION

Before European settlement, longleaf pine (*Pinus palustris* Mill.) forests occupied as much as 37 million ha across the Southeastern United States and constituted the most extensive ecosystem in North America (Landers and others 1995, Brockway and others 2005). Across that vast area, longleaf pine depended on natural or anthropogenic fires, because without fire, other pines and hardwoods would eventually succeed the species (Wahlenberg 1946, Haywood and others 2001, Brockway and others 2005). Extensive exploitation, as well as fire protection implemented during the 1920s and a bias against longleaf pine as a regeneration source allowed invasive hardwoods and other southern pines to replace longleaf across its natural range (Barnett 1999). By 1996, only 1.2 million ha of longleaf pine forest remained (Outcalt and Sheffield 1996).

Currently, several state and federal agencies, non-governmental organizations, and private individuals are restoring longleaf pine across the Southern United States (Brockway and others 2005). The desired future condition is a park-like longleaf pine overstory with few midstory hardwoods except in riparian and other moist areas, and a rich and diverse ground cover of herbaceous and low woody plants that can be maintained by frequent surface fires. Thus, prescribed fire is an essential ecological process in the effort to restore and maintain the longleaf pine-bluestem (*Andropogon* spp. and *Schizachyrium* spp.) range (Landers and others 1995, Barnett 1999, Haywood and others 2001, Brockway and others 2005). To develop further information on fire dynamics in such ranges in the West Gulf Coastal Plain, I studied the effects of prescribed fire on fuel load and vegetation over a 40-month period.

METHODS

Study Sites

The three study sites are within longleaf pine-bluestem ranges on the Kisatchie National Forest in central LA. Study Site 1 (block 1) is a longleaf pine shelterwood. Originally, the site was a mixed pine and hardwood stand that periodically had been prescribed burned. The loblolly pines (*P. taeda* L.) were harvested and the hardwoods were deadened in 2000 to create the shelterwood. It was underplanted with longleaf pine seedlings in November 2000 although a heavy crop of natural regeneration was present. The understory was sparse grass, low brush, and other taxa. Study Site 2 (block 2) was a recent clearcut. Originally, the site was a periodically burned loblolly pine and hardwood stand that had been harvested in 2000. It too was planted with longleaf pine seedlings in November 2000. The plant cover was a grass rough with scattered low brush. The soils at Sites 1 and 2 are Kolin and Gore silt loams, respectively. Site 3 (block 3) is a periodically burned small pole stand of longleaf pine with a grass rough understory that originated from direct seeding. The soil is a Ruston fine sandy loam.

Study Establishment and Measurements

Each of the three sites (blocks) was 10 ha in size, and each block was divided into three areas. Two areas within each block were randomly selected to receive prescribed fire conducted in May 2001 and June 2003. The third area was the check, which received no fire or other disturbance during the study. Within each of the three areas, a 0.10-ha plot was established for making fuel and vegetation measurements. In April 2003, overstory trees (stems > 10-cm d.b.h.) were inventoried and diameter at breast height (d.b.h.) measured on Blocks 1 and 3; total height and d.b.h. of overstory trees were measured again in February 2005. Using the 2005 measurements, I calculated volume per tree with Baldwin and Saucier's (1983) formulas for longleaf pine.

Four 10-m^2 subplots were randomly selected and established within each main plot. In August 2004, all understory trees and shrubs over 1.4 m tall with a d.b.h. less than 25 mm were inventoried on the 10 m^2 subplots, and d.b.h. was measured. Initially, I attempted to study midstory vegetation changes using the 10-m^2 subplots; however, the midstory trees were too scattered, nullifying this plan.

A 1-m^2 subplot was randomly nested within each 10-m^2 subplot; therein, percentage of cover was estimated for plants no taller than 1.4 m. These cover estimates were made to the nearest percent for nine taxa—trees, shrubs, blackberry (*Rubus* spp.), ferns, forbs, grasses, grass-likes, legumes, and woody vines—during July 2001, June 2003, July 2003, and August 2004.

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Fuel load was measured on four randomly established 2 by 5 m fuel-sample plots within each 0.10-ha main plot and the fuel-sample plots were distinct from the subplots used to inventory vegetation. Each fuel-sample plot was divided into ten 1-m^2 subplots. On each sample date, a 1-m^2 subplot was randomly selected for sampling fuel load without replacement. Fuel samples were collected before and 6 weeks after each prescribed fire on all three treatments. The sampled fuels were separated into five fuel classes considered available for burning based on Deeming and others (1977) fire-danger-rating system. The five fuel classes were as follows: (1) living foliage of all plants within 2 m of the ground; (2) living blackberry canes, woody stems, and vines no more than 6 mm in diameter within 2 m of the ground; (3) 1 hour time-lag dead fuels (surface litter and duff to a 0 to 6 mm depth and small roundwood and stubble no more than 6 mm in diameter); (4) 10-hour time-lag dead fuels (litter from a 6 to 25 mm depth and roundwood and stubble between 6 and 25 mm in diameter); and (5) 100 hour time-lag dead fuels (litter from a 25 mm to 100 mm depth and roundwood between 26 and 75 mm in diameter). In addition, in the post burn samples, two additional fuel classes were collected—(6) needlecast after the fire and (7) regrowth of vegetation—to keep these classes from biasing how much fuel had been consumed in the fires. Sampled fuels were dried at 80 °C for 72 h in a forced-air oven and weighed. The differences in pre-burn and post burn fuel samples (not including needlecast or regrowth following the burn) were used with a best estimate of rate-of-spread to calculate Byram's fire intensity on the prescribed fire (PF) plots as described by Haywood (1995).

Prescribed burning was conducted by strip headfiring the treatment areas once baseline backfires had been established. Overall, the prescribed fires in 2001 averaged 211 kJ/s/m (table 1), which was 22 percent higher than the 173 kJ/s/m intensity recommended as a maximum for prescribed fires (Deeming and others 1977). Average fire intensity was 467 kJ/s/m in 2003. Although above recommended levels, the fire intensities in both years were not greater than fire intensities reported in other longleaf pine-bluestem ranges (Haywood 2002).

Data Analysis

The statistician reviewing this paper suspected that there were site-by-treatment interactions, which nullified the block effect and would leave no degrees of freedom for Error Mean Squares in the analyses. Therefore, I do not present statistical results, although I will discuss trends in the data based on prior, albeit inappropriate, analyses. In those earlier analyses, I compared overstory stocking and basal area measurements in April 2001 and February 2005 and volume per ha in 2005. In August 2004, I also compared number of stems and basal area per ha and average d.b.h. of understory trees and shrubs greater than 1.4 m tall with a d.b.h. less than 25 mm. Percent cover of understory vegetation was compared on the following dates: post-burn in June 2001, preburn in June 2003, post-burn in July 2003, and post-burn in August 2004. For the percent cover comparisons, I grouped cover into three taxa–arborescent vegetation (trees, shrubs, and blackberry), grasses, and others (ferns, forbs, grass-likes, legumes, and woody vines).

For fuel loads, the ovendried mass of live stems and foliage both followed the same pattern of treatment response throughout the study; and so, the two classes of live fuels were combined. Thereafter, live fuels, 1-hour time-lag dead fuels, 10-hour time-lag dead fuels, and 100-hour time-lag dead fuels were compared in May and June 2001, June and July 2003, and August 2004.

Table 1—Fire intensities by site and time of burning

Sites	May 2001	June 2003
	(kJ/s/m)	*(kJ/s/m)*
Shelterwood	1	531
Small pole stand	426	544
Clearcut	206	327

RESULTS

Overstory Vegetation

Number of overstory trees per ha did not change much from April 2001 to February 2005 on the shelterwood. Across both treatments, the average number of trees increased in the small pole stand from 163 to 595 trees/ha because of ingrowth over this period (table 2). Average basal area/ha increased during this period from 7 m^2/ha to 8 m^2/ha in the shelterwood stand and from 1.4 m^2/ha to 7.2 m^2/ha in the small pole stand. In 2005, total volume of longleaf pine was 74 m^3/ha in the shelterwood stand and 35 m^3/ha in the small pole stand with little differences between the check and PF plots.

Understory Vegetation

After the first prescribed fire, percent cover of understory vegetation had been little affected by burning. For the check and PF treatments, cover of all plants totaled 95 and 91 percent, respectively. Following the second fire, the PF treatment had less grass and arborescent plant cover than the checks, averaging 41 and 21 percent on the checks and 26 and 4 percent on the PF plots, respectively (fig. 1). The shift in arborescent plant cover after the second prescribed fire was still evident in August 2004. Grass cover did not return to preburn percentages by August 2004 on either treatment, and grass cover was less on the check than PF plots at that date. Initially on the checks, grasses dominated

Table 2—Number of overstory trees and basal area per hectare

Stands/ treatments	April 2001 Stocking	April 2001 Basal area	February 2005 Stocking	February 2005 Basal area
	(trees/ha)	*(m^2/ha)*	*(trees/ha)*	*(m^2/ha)*
Shelterwood				
Check	60	9.8	60	10.6
PF*	50	4.3	50	4.9
Small Poles				
Check	140	1.2	630	7.6
PF	185	1.6	560	6.8

* PF-prescribed fire was applied in May 2001 and June 2003.

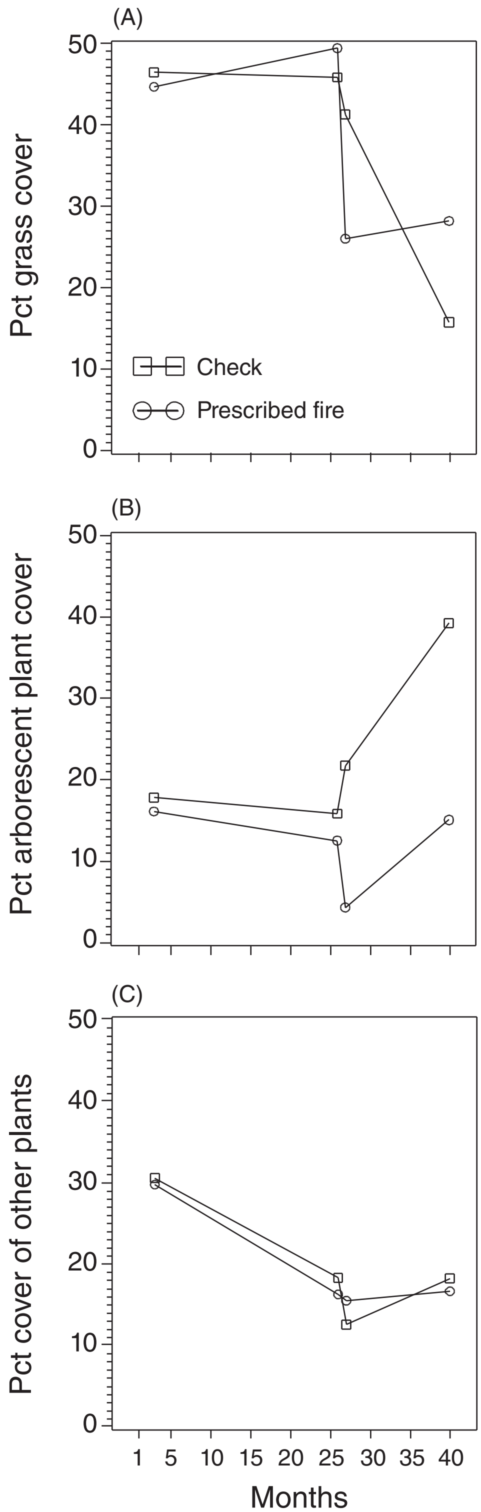

Figure 1—Percent cover of grasses (A), arborescent plants no more than 1.4 m tall (B), and other plants--ferns, forbs, grass-likes, legumes, and woody vines (C), which were measured post burn in June 2001, preburn in June 2003, post burn in July 2003, and post burn in August 2004.

the cover, but by August 2004, arborescent plants dominated the cover. On the PF plots, grasses still covered more area than the arborescent plants at the end of the study. Cover of the other understory plants decreased throughout the study, and was similar between the check and PF plots on each measurement date.

In August 2004, the PF plots had fewer and smaller understory trees and shrubs than the checks (table 3). However, there were no large differences in stocking and average diameter between treatments. Basal area combines the effects on stocking and d.b.h. into one variable. Differences in basal area between the check and PF treatments suggested that prescribed burning might be reducing understory tree and shrub cover.

Fuel Loads

Before the first prescribed fire was conducted, the mass of live fuels (stems and foliage) averaged 711 kg/ha on the two treatments (fig. 2). After the first fire, mass of live fuels increased on both treatments, but the increase was greater on the checks. Before the second prescribed fire, the mass of fuels was again similar on both treatments and averaged 1 574 kg/ha. The second fire greatly reduced the mass of live fuels from 1 550 kg/ha to only 14 kg/ha, while the mass of live fuels on the checks increased from 1 600 kg/ha to 2 332 kg/ha over the next 6 weeks. In August 2004, there was again no important difference in the mass of live fuels between the two treatments, which averaged 2 722 kg/ha. Thus, despite a major short-term change in live fuels on the PF plots after the second burn, the live fuels recovered on PF plots by the end of the study.

In May 2001, the preburn mass of 1 hour time-lag dead fuels was 2 369 kg/ha on check plots and 2 657 kg/ha on PF plots (fig. 2). The first prescribed fire reduced the mass of 1 hour fuels, but there was also a decrease in 1-hour fuels on the check plots. 1-hour fuels accumulated on both treatments before the second prescribed fire to an average of 3 224 kg/ha. The second fire reduced fuels on the PF plots (488 kg/ha) compared to the checks (3 071 kg/ha). In August 2004, there was still a difference in mass of 1-hour fuels, the check and PF plots having 2 591 and 1 493 kg/ha, respectively. Over the course of the study, the checks averaged 2 728 kg/ha and PF plots averaged 1 669 kg/ha of 1-hour fuels.

In May 2001, the preburn mass of 10-hour time-lag dead fuels was 1 929 kg/ha on the check plots and 3 259 kg/ha on the PF plots (fig. 2). Following the first prescribed fire,

Table 3—Number of stems, d.b.h., and basal area per hectare of understory trees and shrubs greater than 1.4 m tall with a d.b.h. less than 25 mm in August 2004

Treatments	Stocking	dbh	Basal area
	(stems/ha)	*(mm/stem)*	*(m^2/ha)*
Check	1500	15	0.75
PF*	1250	10	0.21

* PF-prescribed fire was applied in May 2001 and June 2003.

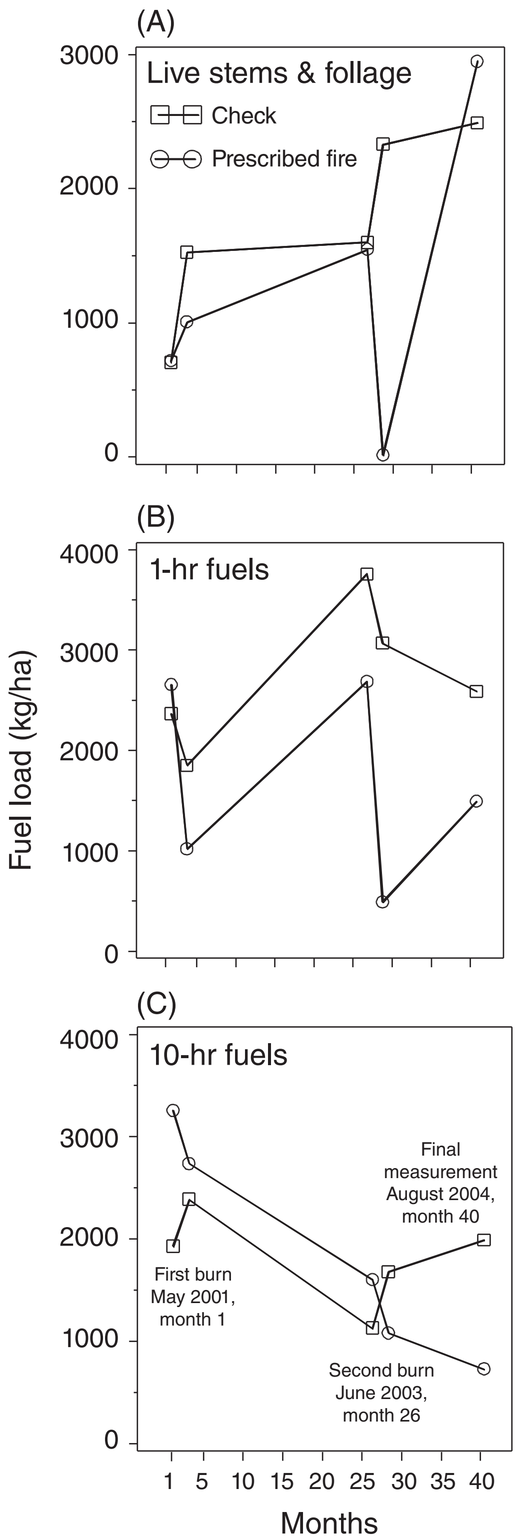

Figure 2—Fuel loads (kg/ha) for the live stems and foliage (A), 1-hr time-lag dead fuels (B), and 10-hr time-lag dead fuels (C) that were measured preburn in May 2001, post burn in June 2001, preburn in June 2003, post burn in July 2003, and post burn in August 2004.

10-hour fuels were reduced on the PF plots while increasing on the checks. In June 2003, the preburn mass of 10-hour fuels was similar on both treatments and averaged 1 365 kg/ha. Burning again reduced the mass of 10-hour fuels, while the mass of 10-hour fuels increased on the checks. In the final measurement, there was more mass of 10-hour fuels on the checks (1 990 kg/ha) than on the PF plots (727 kg/ha).

The mass of 100-hour time-lag dead fuels decreased over the course of the study. The 100-hour fuels averaged 3 701 kg/ha in May 2001 and 1 586 kg/ha in August 2004.

DISCUSSION

Prescribed fires were intense but not greater than similar fires in other longleaf pine-bluestem ranges (Haywood 2002). Fire did not change overstory composition, and basal area increased on both treatments. Prescribed fire is a way to reduce understory arborescent vegetation, remove litter, and create conditions where herbaceous productivity can increase in forest stands (Grelen and Enghardt 1973, Haywood and others 2001). However, in this study, the percent cover of grasses, ferns, forbs, grass-likes, legumes, and woody vines decreased 43 percentage points on the checks and 30 percentage points on the PF plots (fig. 1).

An increase in overstory basal area may be causing the adverse change in herbaceous plant cover (Grelen and Enghardt 1973). In the shelterwood and small pole stands, overstory basal area increased by an average of 3.6 m^2/ha on the checks and 2.9 m^2/ha on the PF plots by the end of the study (table 2). In addition, changes in understory arborescent plant cover are likely affecting herbaceous plant cover (Haywood and others 1998, Haywood and others 2001). Arborescent cover increased by 21 percentage points on the checks but decreased one percentage point on the PF plots from 2001 to 2004 (fig. 1), and at the end of the study, understory basal area was 0.75 m^2/ha on the checks and 0.21 m^2/ha on the PF treatments (table 3). Prescribed burning therefore had an immediate effect on understory arborescent vegetation as shown in figure 1. Although arborescent vegetation naturally recovers between fires (Haywood and others 2000), its coverage remained constant over the study period even as arborescent cover continued to increase on the checks. Prescribed fire kept understory arborescent vegetation under control; although no long-term visual change occurred. Controlling the cover of arborescent vegetation likely lessened its adverse effect on grass cover as seen in figure 1. Smothering of plants is also a likely factor as litter continues to accumulate on the unburned check plots (Grelen and Enghardt 1973). Regardless, it is most likely that differences in overstory and understory arborescent plant cover between treatments are reflected in differences in grass cover between treatments.

Although live fuels were reduced immediately following the second prescribed fire, they rebounded rapidly and had a net increase on the sites regardless of treatment (fig. 2). The increase in live fuels appears counter to the plant cover results (fig. 1). However, much of the live fuels were herbaceous plants that grew throughout the 2004 growing season, and increasing plant stature increases its mass without a corresponding increase in area shaded by the plant. The same is true for the arborescent plants.

The 1-hour and 10-hour time-lag dead fuels decreased on PF plots by 3 695 kg/ha while increasing on checks by 283 kg/ha over the course of the study (fig. 2). Fire apparently was reducing dead fuel loads in these longleaf pine stands.

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