RESTORING UPLAND FORESTS TO LONGLEAF PINE: INITIAL EFFECTS ON FUEL LOAD, FIRE DANGER, FOREST VEGETATION, AND BEETLE POPULATIONS

James D. Haywood, Tessa A. Bauman, Richard A. Goyer, and Finis L. Harris[1]

Abstract—Without fire in the Southeastern United States, loblolly pine (*Pinus taeda* L.) often becomes the overstory dominant on sites historically dominated by longleaf pine (*P. palustris* Mill.). Beneath the loblolly pine canopy a mature midstory and understory develops of woody vegetation supporting draped fuels. The resulting deep shade and accumulation of litter nearly eliminates herbaceous vegetation. To avoid this outcome, on most upland sites a series of treatments can ensure the restoration of longleaf pine plant communities and lessen the danger of wildfires. Burning in heavy fuels, however, may injure and weaken pine trees, favoring detrimental insects, such as bark beetles. This Joint Fire Science Program project was established to study how several management options affect fuel load, fire danger, vegetation, and beetle populations in loblolly pine, mixed pine, and longleaf pine stands. We report first and second growing-season results.

INTRODUCTION

In the Southeastern United States, forest fuels accumulate, and without fire management, understory vegetation can shift from grasses to woody plants with significant numbers of highly flammable shrubs supporting draped fuels (Haywood and Grelen 2000, Haywood and others 2001). We believe this shift in vegetation increases fire intensity, which makes fire fighting more hazardous and costly and places property and natural resources in greater danger. To lessen risk, many forest managers are trying to increase the use of fire and species-specific thinning in upland forest landscapes. Their goal is to ultimately restore existing upland hardwood and loblolly pine (*Pinus taeda* L.) forests to native fire-dependent longleaf pine (*P. palustris* Mill.). The desired future condition is pure longleaf overstories [where 80 percent or more of the basal area is longleaf pine (Helms 1998)], with few hardwoods except in riparian and other moist areas, and a rich and diverse ground cover of herbaceous and low woody plants.

There are problems with using fire. Fire can adversely affect both individual longleaf pine trees and stand health (Boyer 1987, Boyer and Miller 1994). For us, a prime concern is a reduced resistance to bark beetles in fire-stressed stands. In particular, southern pine beetle (*Dendroctonus frontalis*) and Ips engraver beetle (*Ips* spp.) are the most destructive group of insects in the pine forests of the Southern United States. Additionally, ambrosia beetles (*Platypoididae*) are often attracted to fire-stressed stands and are vectors of known and suspected root pathogens. Longleaf pines tolerate fire and have high resin flow rates that make them more resistant to bark beetle attack than other southern pines. Still, the effects of fire on the interaction of insect pests and longleaf pine health are largely unknown. This lack of knowledge is a major concern given the high fuel loads and mixed composition of many upland stands currently undergoing fire-aided restoration efforts. Once the desired future condition is achieved, we expect that frequently applied low-intensity fire will not be as damaging as fires in stands laden with heavier fuels.

The effects of a single prescribed burn are often transitory, and a series of burns over many years must be completed to have lasting changes in plant communities (Olson and Platt 1995). Thus, mechanical methods may be required where managers must restore certain plant communities quickly. Mechanical brush control may also be needed where midstory vegetation is too large to control with burning (Haywood and Harris 1999, Haywood and others 2001). In this Joint Fire Science Program project, we evaluate the outcome of several management schemes involving fire and mechanical treatment in upland loblolly pine forests being restored to longleaf pine in the west Gulf Coastal Plain. We consider changing fuel conditions, fire danger, vegetative composition, and beetle populations.

CLIMATE AND FOREST HISTORY

Our sites lie within the humid, temperate, Coastal Plain, and flatwoods province of the west gulf region of the Southeastern United States. We study loamy dry-mesic uplands where longleaf pine forests once dominated (Turner and others 1999). They are located within the boundaries of the Kisatchie National Forest in central Louisiana at an average elevation of 30 to 60 m above sea level. Slopes vary from 1 to 10 percent. The area's climate is subtropical; mean temperatures in January are 8 °C and in July are 28 °C. Annual precipitation averages 1525 mm with > 965 mm during the 250-day growing season, from March 10 to November 15 (the spring and fall dates with a 50-percent probability of a frost) (Louisiana Office of State Climatology 2001).

The original longleaf pine forests were cut beginning in the 1920s. Although some small stands of longleaf pine remained, most of the area vegetation consisted of perennial grasses under scattered pines and hardwoods maintained by periodic burning for open-range grazing. In the 1950s managers excluded hogs and regulated cattle grazing. Eventually, natural and planted stands of hardwoods and pines reforested much of the landscape.

[1] Research Forester and Biological Science Technician, USDA Forest Service, Southern Research Station, Pineville, LA 71360; Professor, Louisiana State University, LSU Agricultural Center, Baton Rouge, LA 70803; and Silviculturist, USDA Forest Service, Ouachita National Forest, Hot Springs, AR 71902, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

METHODS

We established four demonstration sites in this landscape that represent stages in the change from loblolly pine to longleaf pine: a loblolly pine stand, two mixed pine stands, and a seedling and sapling longleaf pine plantation. Each of the demonstration sites is about 8 ha. We divided each into three parts and randomly assigned three treatments: (1) check—no treatment, (2) biennial prescribed burning beginning in May 2001, and (3) biennial prescribed burning and mechanical woody plant control (MWPC) in July 2002. In treatment 3, MWPC plots were prescribed burned as in treatment 2, and the understory vegetation was cut to within 5 cm of the ground with a machine-mounted horizontal-shaft drum shredder (Woodgator®). Due to dry soil conditions in May 2001, a burning root breached the fireline at the loblolly pine site, and a portion of the check treatment area was accidentally burned.

Plot Layout and Measurement

A 0.10-ha main plot was established within each of the treatment areas. In April 2001, woody plants > 10-cm diameter at breast height (d.b.h.) (height of stem 1.4 m above groundline) were measured and inventoried by species. The overstory and midstory vegetation was again examined in July 2001, 6 weeks after the burns. Trees and shrubs 2.5 to 10 cm d.b.h. were measured on four 10-m^2 subplots, randomly selected and permanently established within each main plot. Eight understory vegetation classes comprise trees and shrubs < 2.5 cm d.b.h.: blackberry, woody vines, ferns, forbs, grasses, grasslikes, and legumes. Cover for each class was estimated to the nearest percent on a 1-m^2 subplot nested within each 10-m^2 subplot.

To determine changes in available fuels, four 2- by 5-m fuel subplots were randomly selected and permanently established within each main plot. Each fuel subplot was divided into ten 1-m^2 subplots for sampling without replacement. Fuel samples were collected on one subplot per fuel subplot a month before the May 2001 prescribed burns. A second subplot was sampled 6 weeks after the burns. Fuel samples were divided into five classes considered available for combustion based on Deeming and others' (1977) fire danger rating system: (1) living foliage of all trees, shrubs, vines, grasses, and forbs within 2 m of the ground; (2) living blackberry canes, woody stems, and vines < 6-mm in diameter within 2 m of the ground; (3) 1-hour time-lag dead fuels [surface litter and duff (0- to 6-mm in depth) and roundwood and stubble < 6-mm in diameter]; (4) 10-hour time-lag dead fuels (litter from 6- to 25-mm in depth and roundwood and stubble between 6- and 25-mm in diameter); and (5) 100-hour time-lag dead fuels (litter from 25- to 100-mm in depth and roundwood between 26- and 75-mm in diameter). The sampled fuels were ovendried and weighed.

Beetles were collected over the whole 8-ha treatment area; thus an unburned check was available at the loblolly pine site. Beetle responses to fire were investigated using both flight interception and pitfall traps, with both ethyl alcohol and turpentine as attractants. Ten traps were placed within each of the three treatments per demonstration site. Trapping was conducted 3 to 4 weeks pretreatment and 6 to 8 weeks posttreatment. Beetles were collected and counted weekly, and the number of beetles collected was compared to determine if a significant change in beetle abundance occurred due to treatment. Additionally, trees were monitored at periodic intervals throughout the study to determine rates of beetle attack and subsequent decline in health.

Data Analysis

For burned vs. unburned treatments, fuel loads were compared using a completely randomized analysis of variance (ANOVA) model ($\alpha = 0.05$) (Steel and Torrie 1980). Using covariate analyses did not change interpretation of results. The fuel-load values were the natural log transformation of the ovendried weight (kg/ha) of either the living or dead fuels. Live fuels are foliage, small living stems, and regrowth 6 weeks after burning; dead fuels are 1-hour, 10-hour, and 100-hour time-lag fuels and needle cast 6 weeks after burning. For each forest type (loblolly pine, mixed pine, or longleaf pine plantation), percent cover of the eight understory vegetation classes was also compared between the burned vs. unburned treatments. The percentage data was arcsine transformed before analysis using a two-factor ANOVA.

Three guilds, or groups, of beetles were used in the analyses: ambrosia beetles, bark beetles (*Hylastes tenuis* and *salebrosus, I. grandicollis* and *arulsus,* and *D. terebrans*), and weevils (*Cossonus corticola*, *Hylobius pales*, and *Pachylobius picivorus*). The southern pine beetle was not collected during 2001 and 2002. By guild and in toto, beetle numbers were compared by site and treatment for the prescribed burns in 2001 and the MWPC treatments in 2002 using SAS Mixed Procedure analysis ($\alpha = 0.05$) (Littell and others 2002). The sites included in these analyses were the loblolly pine and mixed pine stands.

RESULTS AND DISCUSSION

Fuel Loads and Fire Danger

For the May 2001 burns, fire intensity was 550 kJ/second/m in the loblolly pine, 1391 kJ/second/m in the mixed pine, and 467 kJ/second/m in the longleaf pine plantation stands. These burns were three to eight times more intense than the 173 kJ/second/m intensity recommended by Deeming and others (1977) as a maximum for prescribed burns.

The average preburn weight of the living available fuels (foliage and stems) was similar across all sites and averaged 1548 kg/ha. Fire greatly affected these two fuel classes. At the loblolly pine, mixed pine, and young longleaf pine plantation sites, ovendried weight of foliage was reduced by 89, 96, and 63 percent, respectively; ovendried weight of stems was reduced by 95, 99, and 95 percent, respectively (fig. 1). However, within 6 weeks postburn, regrowth replaced 17, 12, and 58 percent of the preburn living fuels on the three sites, respectively. Needle cast from the burns occurred at all sites, but most significantly at the mixed pine sites where the fire intensity was greatest. The weight of 1-hour time-lag dead fuels was reduced by 62 percent across all sites. Overall, burning reduced total available fuel load from an average of 9198 kg/ha to 4124 kg/ha, but needle cast and regrowth replaced 1015 kg/ha of available fuel by 6 weeks after the burns. Still, the burns greatly reduced the fire danger by removing over half of the available fuels.

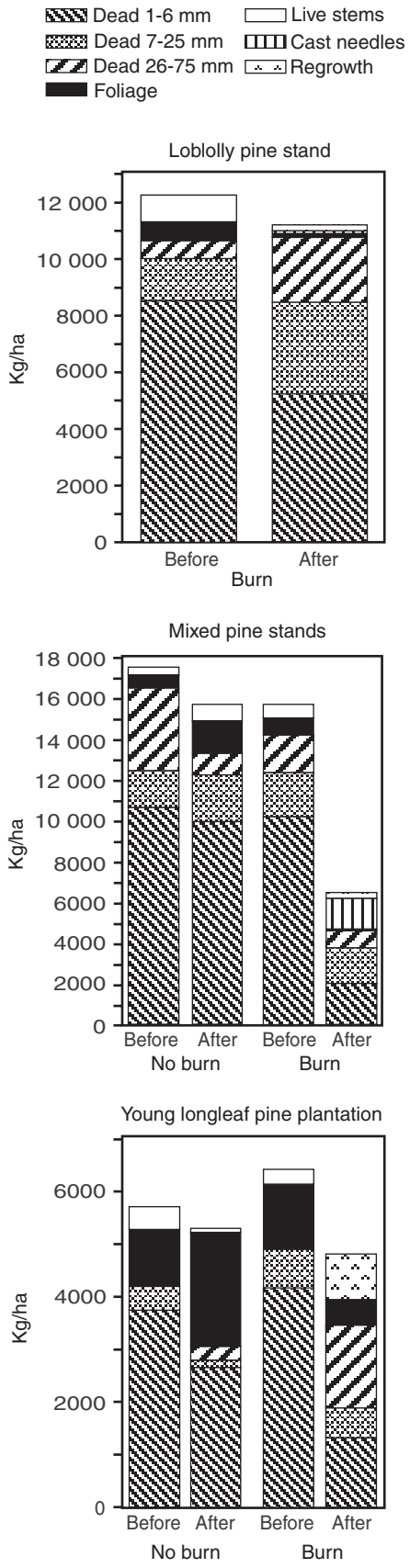

Figure 1—Changes in fuel classes (kg/ha ovendried weight) on the unburned and burned portion of each forest type. Fuel classes were sampled 1 month before the May 2001 burns and 6 weeks after burning.

Vegetation

Prescribed burning did not affect the overstory and midstory vegetation. The loblolly pine site consisted of several tree species in the canopy, but > 80 percent of the basal area was loblolly pine (table 1). The mixed pine sites were also predominately loblolly pine, but loblolly pine was not dominant in the midstory. Longleaf pine was the only

Table 1—Characteristics of the three forest types[a]

Stand type, canopy position	D.b.h.	Basal area
	inches	*ft² per acre*
Loblolly pine		
Overstory		
Pinus taeda	13.4	83 (81%)[b]
P. palustris	16.5	7 (7%)
Liquidambar styraciflua	6.7	4
Prunus serotina	10.3	3
Cornus florida	5.5	3
Nyssa sylvatica	6.2	2
Midstory		
Pinus taeda	3.8	0.23
L. styraciflua	1.0	0.01
Carya tomentosa	1.8	0.03
Mixed pine		
Overstory		
Unburned stand		
Pinus taeda	17.5	72 (72%)
P. palustris	15.7	18 (18%)
Quercus falcata	14.3	6
Q. marilandica	4.8	1
Prunus serotina	10.0	1
Nyssa sylvatica	8.5	1
Burned stand		
Pinus taeda	15.4	79 (81%)
P. palustris	13.1	15 (15%)
Q. falcata	5.2	< 1
Q. marilandica	5.3	2
Q. stellata	5.3	1
L. styraciflua	6.5	< 1
Midstory		
Unburned		
Q. falcata	2.0	0.05
Burned		
Q. marilandica	3.1	0.12
Longleaf pine plantation		
Overstory		
Unburned stand		
P. palustris	4.2	6.0
Burned stand		
P. palustris	4.1	7.7
Midstory		
Unburned stand		
P. palustris	2.6	0.7
Burned stand		
P. palustris	2.9	0.6

[a] Overstory and midstory vegetation was unaffected by burning.

[b] By stand type, percent of the total basal area in the overstory.

species in the overstory and midstory of the longleaf pine plantation.

After the burn at the loblolly pine site, remaining understory trees, shrubs, blackberry, and woody vines shaded 42 percent of the ground (fig. 2). At the mixed pine sites, burning reduced understory tree, shrub, blackberry, and vine cover by 74 percent, but the coverage of forbs and ferns increased after burning. Rapid recovery of forbs and ferns normally follows prescribed burning. In the seedling and sapling longleaf pine plantation, grasses dominated the understory vegetation, and burning had little effect on the relative importance of the plant taxa. The burn reduced overall ground cover from 97 to 85 percent in the longleaf pine plantation.

Beetles

After the May 2001 burns, there were significantly fewer ambrosia beetles collected than either bark beetles or weevils overall (fig. 3). The burned loblolly pine site had greater numbers of collected beetles than all other sites, and 76 percent of the beetles collected at the loblolly pine site were weevils. The majority of the weevils were *C. corticola*, which is an associate of the southern pine beetle (Goyer and others 1980). In general, more bark beetles and weevils were captured in burned stands than in check stands, but these differences were not significant. Too few ambrosia beetles were collected to determine response trends.

After MWPC in July 2002, one of the mixed pine sites had significantly more beetles captured than the other two sites (fig. 3). Only the number of weevils significantly differed among sites or between check and MWPC treatments.

MANAGEMENT IMPLICATIONS

We concluded that a single burn did not greatly change overall fuel conditions or the composition of the understory vegetation, but single burns rarely do (Olson and Platt 1995). Still, our burns initially reduced available fuel load by 55 percent, and this reduction temporarily lowered the risk of catastrophic wildfire destroying natural resources and property or endangering lives.

The beetles we found not only directly attack pine trees but may be vectors of pathogenic fungi (Goyer and others 1980). Burning increased bark beetle and weevil activity on all sites (fig. 3). Although statistically insignificant, these results suggest that if bark beetles are active, particularly the southern pine beetle, burning should be postponed in overstocked stands. Burning is also ill-advised where fuel loads are high and significant crown scorch and charring are expected. Of particular concern would be fires that move too slowly through abundant fuels at the base of trees, resulting in basal scarring, cambial death, and root damage. MWPC did not generally affect the abundance of beetles on these pine sites.

We expect that additional burning with or without MWPC will not greatly change the overstory vegetation. However, we believe a conscientious management plan implementing both fire and MWPC in stands should eventually create a grass-dominated fuel bed that favors low-intensity rapid fires and thereby reduces tree injury and beetle attack.

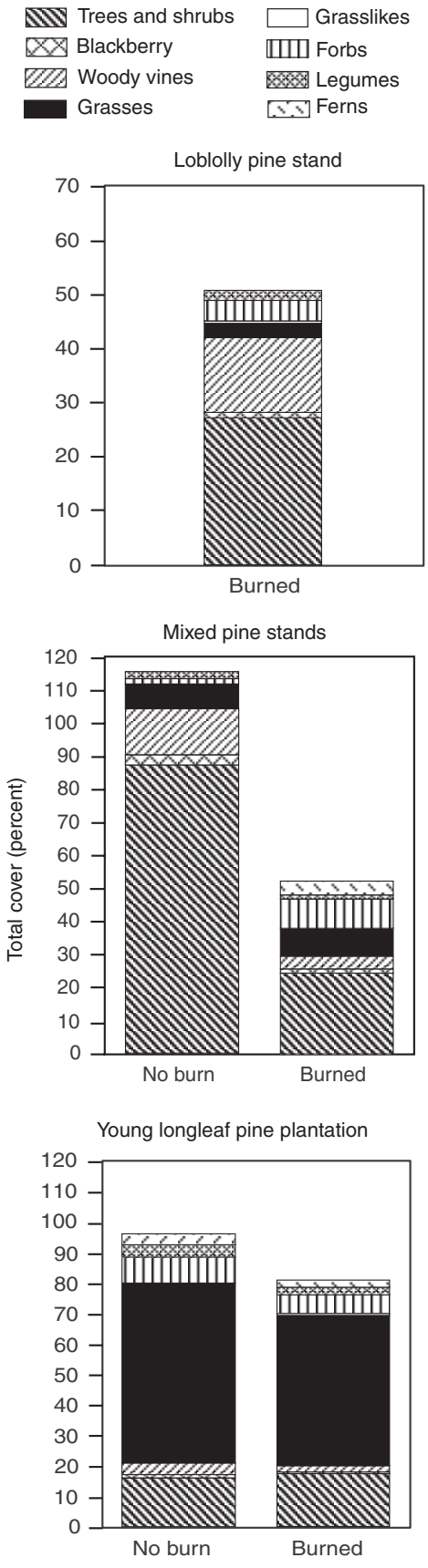

Figure 2—Percent cover of the understory vegetation by taxa on the burned and unburned portions of each forest type 6 weeks after the May 2001 burns.

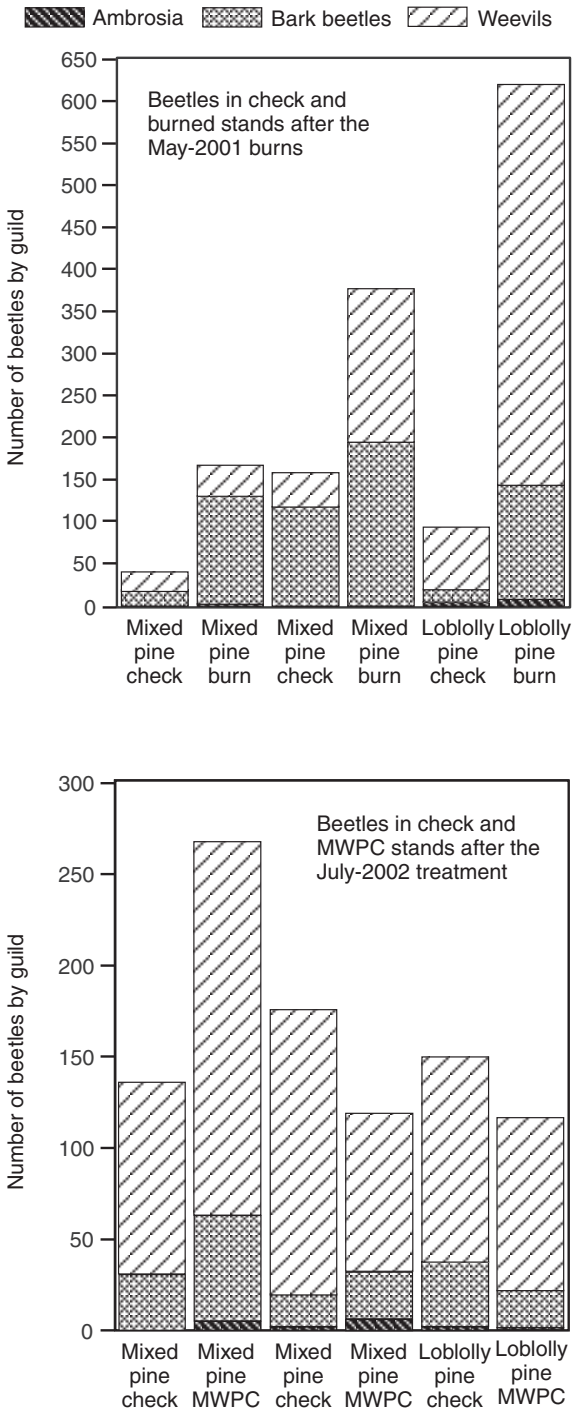

Figure 3—Number of beetles captured by guild after prescribed burning in May 2001 (top) and mechanical woody plant control (MWPC) in July 2002 (bottom).

In the general landscape, we recommend that loblolly pine stands be thinned and repeatedly prescribed burned; as well, MWPC should be applied to restore rich herbaceous plant communities dominated by grasses. After that, these sites should be clearcut and planted to longleaf pine. Prescribed burning should continue after planting, beginning in the second growing season, to maintain longleaf pine plantations with grass-dominated understories.

Longleaf pine naturally develops uneven-aged stand structures, and widespread uneven-aged landscapes are again possible if reserves of longleaf pine are intermixed with gap openings or regenerated areas. We recommend that mixed pine sites be thinned and burned with MWPC used to reduce the stature of understory brush. Eventually, the loblolly pine should be harvested in these mixed pine stands and the longleaf pine retained as a seed source. To ensure timely regeneration, longleaf seedlings should be planted under the retained longleaf pine. Prescribed burning should again be applied beginning in the second growing season after planting. This practice should result in the desired uneven-aged structure with longleaf pine-dominated overstories and rich herbaceous plant communities in the understories.

ACKNOWLEDGMENTS

The Joint Fire Science Program, Boise, ID, funds this project.

LITERATURE CITED

Boyer, W.D. 1987. Volume growth loss: a hidden cost of periodic prescribed burning in longleaf pine? Southern Journal of Applied Forestry. 11(3): 154-157.

Boyer, W.D.; Miller, J.H. 1994. Effect of burning and brush treatments on nutrient and soil physical properties in young longleaf pine stands. Forest Ecology and Management. 70: 311-318.

Deeming, J.E.; Burgan, R.E.; Cohen, J.D. 1977. The national fire-danger rating system—1978. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 p.

Goyer, R.A.; Lenhard, G.J.; Nebeker, T.E.; Jarrard, L.D. 1980. How to identify common insect associates of the southern pine beetle. Agric. Handb. 563. Washington, DC: U.S. Department of Agriculture, Forest Service. 25 p.

Haywood, J.D.; Grelen, H.E. 2000. Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. Southern Journal of Applied Forestry. 24(2): 86-92.

Haywood, J.D.; Harris, F.L. 1999. Description of vegetation in several periodically burned longleaf pine forests on the Kisatchie National Forest. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 217-222.

Haywood, J.D.; Harris, F.L.; Grelen, H.E.; Pearson, H.A. 2001. Vegetative response to 37 years of seasonal burning on a Louisiana longleaf pine site. Southern Journal of Applied Forestry. 25(3): 122-130.

Helms, J.A. 1998. The dictionary of forestry. Bethesda, MD: The Society of American Foresters. 210 p.

Littell, R.C.; Milliken, G.A.; Stroup, W.W.; Wolfinger, R.D. 2002. SAS system for mixed models. Cary, NC: SAS Institute. 656 p.

Louisiana Office of State Climatology. 2001. Louisiana monthly climate review. Baton Rouge, LA: Southern Regional Climate Center, Department of Geography and Anthropology, Louisiana State University. 120 p. Vol. 21.

Olson, M.S.; Platt, W.J. 1995. Effects of habitat and growing season fires on resprouting of shrubs in longleaf pine savannas. Vegetatio. 119: 101-118.

Steel, R.G.D.; Torrie, J.H. 1980. Principles and procedures of statistics. 2d ed. New York: McGraw-Hill Book Co. 633 p.

Turner, R.L.; Van Kley, J.E.; Smith, L.S.; Evans, R.E. 1999. Ecological classification system for the national forests and adjacent areas of the west Gulf Coastal Plain. Nacogdoches, TX: The Nature Conservancy; Stephen F. Austin State University. 305 p.