IMPACTS OF GROWING-SEASON PRESCRIBED BURNS IN THE FLORIDA PINE FLATWOODS TYPE

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Abstract—A considerable amount of experience and knowledge has been gained in the application of growing-season burning in pine communities across the Southeast. However, there is still concern that burning during this season will cause increased tree mortality and/or growth loss. Pine flatwoods stands in south Florida with 3 years of fuel accumulation were burned during the growing season using rather aggressive head-firing techniques. Crown scorch ranged from a low of 16 percent to a high of 83 percent. The lowest crown scorch occurred on treatment units burned mostly with flanking fires. Although scorch was quite high in some units, mortality was not significantly increased by growing-season burns. The probability of mortality and growth loss can be minimized by using firing techniques that produce less intense burns and by avoiding burns during the late growing season or when trees are already stressed.

INTRODUCTION

The pine flatwoods were a predominate ecosystem of the Southeastern Coastal Plain (Sargent 1884) prior to European influx. They were most abundant in Florida, occupying 50 percent of the area (Stout and Marion 1993). Pine flatwoods, a cryptic term, is based on the lack of relief and the open pine-dominated tree layer composed of longleaf (*Pinus palustris* Mill.), slash (*P. elliottii* Engelm.), south Florida slash (*P. elliottii* var. *densa* Little & Dorman), and pond pine (*P. serotina* Michx.) (Abrahamson and Hartnett 1990). Saw palmetto [*Serenoa repens* (Bartr.) Small], gallberry (*Ilex glabra* L.), and grasses are typical understory dominates.

Some of the annually shed resinous needles from overstory pines become entangled in the emergent understory vegetation. Saw palmetto and the predominant shrubs have waxy leaves that will burn quite easily. Coupled with the suspended needle fall and accumulation of dead grass, this creates a very flammable condition (Landers 1991). Florida has more thunderstorm days than anywhere else in the United States, and therefore a very high incidence of lightning strikes (Chen and Gerber 1990). Historically, this combination of rapid accumulation of pyrogenic vegetation and an abundant ignition source resulted in a fire frequency of 1 to 3 years (Frost 1998). Thus, pine flatwoods vegetation has evolved with and is dependent upon frequent low-intensity fires.

Because pine flatwoods are quite productive, understory fuels accumulate quickly, which can lead to severe wildfires (Davis and Cooper 1963). Forestry organizations initially attempted to quell these wildfires by detection and rapid attack to extinguish them. This worked for a time, but as fuel levels increased it became obvious that fires could not always be stopped, especially during periodic droughts. Research and practical application began to demonstrate the usefulness of fire to control fuel buildup, thereby reducing the probability of destructive wildfires. It was also recognized that fire had beneficial effects for forestry and the ecosystem when applied under controlled conditions. Thus, we entered an era of application of prescribed burns by trained professionals to obtain desired management objectives (Wade and Lunsford 1989).

Most of these prescribed burns were done during the dormant season when weather and fuel moisture conditions were generally favorable for fuel reduction burns. It was known, however, that growing-season burns could be more effective at controlling understory shrubs and invading hardwoods (Lotti 1956). More recently, research has shown that growing-season burns not only more closely mimic natural ignitions, especially in the early part of the growing season during the normal spring drought, but they also have important ecological benefits (Robbins and Myers 1992, Streng and others 1993). Based on this information and knowledge gained through adaptive management, most natural resource agencies had begun a program of growing-season burning by 1990 (e.g., Ferguson 1998). Although practitioners have gained a considerable amount of experience in applying growing-season burns, some burns still result in considerable crown scorch and sometimes tree mortality. The overall objective of this study, part of the nationwide fire and fire surrogate study (Weatherspoon 2000) is to develop realistic management options that can be used to treat fuels and restore flatwoods ecosystems. This paper covers the effectiveness of growing-season burns for reducing fuel loads without causing unacceptable damage to overstory trees.

METHODS

Study Site

The study is located about 25 km southeast of Sarasota, FL (27°14′N., 82°19′W.) in the Myakka River State Park. The climate is subtropical, characterized by high temperatures and humidity, declining only moderately during the winter. Moisture is abundant with most rainfall arriving as convective afternoon thunderstorms during the summer or wet season. The terrain is nearly level with slopes typically

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< 1 percent and an elevation of < 15 m above sea level. The soils, developed from unconsolidated marine sediments, are dominated by the Myakka series (Aquods). Myakka soils are wet, often poorly drained sands with an organic-stained subsoil layer occurring at a depth of 60 cm.

The park is managed by the Division of Recreation and Parks under the Florida Department of Environmental Protection. Both longleaf pine, which is near the southern limit of its range here, and south Florida slash pine stands occur in the park, with the latter dominating the southern region. These flatwoods systems are dominated by ascendant saw palmetto beneath a canopy of scattered pines, live oak (*Quercus virginiana* Mill.), and sabal palm [*Sabal palmetto* (Walt.) Lodd. ex Schultes]. The systems under management by Myakka River State Park are representative of all stages of succession possible within flatwoods. Destructive wildfires can be expected in this southern rough fuel complex found in flatwoods and Florida dry prairie when normal fire-return intervals of 3 to 5 years are exceeded. To keep fuel levels in check, park personnel have been burning much of the site on a 3-year rotation since the early 1980s.

Layout and Experimental Design

The basic design was a randomized block with three blocks and five treatment units in each. The blocks were different locations that contain a representative sample of conditions found in these flatwoods systems. Block 1 was a relatively dry site with an overstory dominated by slash pine, mostly a north Florida variety from a former plantation, with smaller amounts of natural longleaf pine. Block 2 was also a relatively dry area, but it does become wet during the peak of the late summer rainy season. It was dominated by natural longleaf pine. Block 3 was a relatively wet site that dries out during the dormant dry period but can be quite wet, with water at or above the soil surface during a good portion of the summer rainy period. South Florida slash pine dominated the overstory of stands in block 3. All areas had been prescribed burned 3 years prior to study establishment.

Each treatment unit consisted of a core area of 12.25 ha and a surrounding 20-m buffer, giving a total size of 15.2 ha. Within each treatment unit, there were 36 grid points on 50- by 50-m spacing. The exact configuration varied for the different treatment units to fit site conditions, but a typical layout consisted of a 6- by 6-grid arrangement. Within each treatment unit, there were 10 rectangular 20- by 50-m subplots established between selected grid points. These subplots were systematically located to sample the range of conditions found on treatment units.

Treatments

The plan was to collect pretreatment data during 2000, apply burn treatments to three randomly selected units in each block, and keep the other two units as controls. However, all units in block 2 were burned before pretreatment data collection by an escaped prescribed burn from an adjacent area. Selected units in other blocks were burned as planned in 2001. All units had a 3-year fuel accumulation and were burned during the growing season using ground ignition by hand crews.

Data Collection and Analyses

Before burning, all overstory trees [> 10 cm in diameter at breast height (d.b.h.)] were sampled on the 20- by 50-m subplots. Stand structure and composition were determined by recording species, d.b.h., status (live or dead), total height, height to live crown, height to dead crown, and crown condition. The entire treatment unit was surveyed at least three times per year to track tree mortality. Species, d.b.h., height, and cause of mortality were collected for recently dead trees.

Understory fuel, which is composed of grasses, forbs, and shrubs, is a very significant component of the total fuel in flatwoods. Amounts were determined by clipping from a 1- by 1-m area from a randomly selected location in each 20- by 50-m subplot. Litter samples, which included 1-hour and 10-hour timelag fuels, then were collected from the same area. All material was bagged by type, dried at 85 °C, and weighed. This was done at the end of the growing season before and after burns.

Just before each burn, samples of live shrubs, palmetto, grass, 1-hour litter (dead foliage and twigs 0.01 to 6.0 mm), and 10-hour litter (twigs 6.01 to 25 mm) were collected adjacent to 10 randomly selected grid points in a burn unit. These samples were sealed in plastic bags, weighed, dried, and reweighed to determine fuel-moisture content. Rate of fire spread was determined by recording the time it took fire to burn across a treatment unit. Flame heights were estimated across the unit using grid point poles of known height. Following prescribed burn treatments, data for crown scorch height, live crown height, and total tree height were collected from each 20- by 50-m subplot.

Crown scorch data were compared between blocks with analysis of variance. Tree mortality in percent was transformed using the square root of arcsine. This transformed value was analyzed using pretreatment annual mortality rate as the covariate. Differences in pretreatment fuel loadings were determined by analysis of variance and posttreatment by analysis of covariance using pretreatment values as the covariate. Because there were no pretreatment data for block 2, these analyses were done for blocks 1 and 3 only.

RESULTS

Study areas had open savanna stands typical for this region, as shown by the low stocking and basal area (table 1). The average diameter of trees in the old plantation on block 1 was slightly smaller, which resulted in a lower basal area. Stocking was significantly higher in block 3, because two treatment units averaged nearly 75 trees/ha.

Prescribed burns were predominately head fires, although some flank fires were set along control lines or resulted from shifting wind directions (table 2). Temperatures were relatively high, while relative humidity and windspeeds were moderate. Flame lengths were moderate for all burns, but rates of spread were quite rapid and intensities high in

Table 1—Characteristics of pines > 10-cm d.b.h. on study sites at the Myakka River State Park, FL

Block	D.b.h.	Height	Basal area	Height to live crown	Density
	cm	*m*	*m^2/ha*	*m*	*trees/ha*
1	23.2	16.0	1.6	11.2	38
2	26.8	14.8	2.2	—	38
3	27.9	15.8	3.2	10.2	56

D.b.h. = diameter at breast height.
— = no data collected prior to burning.

both blocks 1 and 3. The drought index ranged from low for block 1 to moderate for block 3. Block 1 was burned during a brief dry period following 2 months of frequent rainfall. The old firelines still contained pockets of standing water on the day of the burn. Conversely, blocks 2 and 3 were burned a few days after some significant rainfall that followed a long dry period. Fuel moisture levels for most fuels were slightly lower in block 3 (table 3).

At the end of the growing season before burning, fuels were dominated by litter and saw palmetto on both burn and control units (table 4). Live shrubs also contained a moderate level of potential fuel, while dead shrubs and grass were minor components. The only significant difference between pretreatment conditions was that control units had more dead shrubs on average than those units assigned to receive burn treatments. One growing season after the burns, litter and saw palmetto were significantly lower on burned treatments. Dead shrub fuel increased following burning, and it appears that live shrub fuel was decreased, but the change was not significant. Total fuel loads were less on burned areas than on the controls.

Crown scorch varied by location within blocks. In block 1 the least amount of scorch (34 percent) occurred in treatment unit 5, which was the unit with the lowest elevation, and the most scorch (67 percent) occurred in treatment unit 1, which had the highest elevation. In block 2 the units that burned in early afternoon had about twice as much scorch (50 percent) as those that burned in late afternoon (25 percent). In block 3 the most scorch (83 percent) occurred in unit 4; scorch was about the same in units 1 and 5, at 63 percent. Overall, crown scorch was lowest in block 2, intermediate in block 1, and highest in block 3 (fig. 1).

Pretreatment tree mortality was uniformly low across block 3 (fig. 2B), but seemed to increase slightly within two

Table 3—Fuel-moisture levels prior to prescribed burns at study sites in Myakka River State Park, FL

Fuel type	Block 1	Block 3
	- - - - *percent* - - - -	
Saw palmetto	121	114
Live shrubs	121	123
Grass	87	69
Litter		
Foliage	27	26
1-hour twigs	29	19
10-hour twigs	25	19

Table 4—Understory and forest floor fuel loading before and after prescribed burning or no treatment at Myakka River State Park, FL

	Pretreatment		Posttreatment	
Fuel type	Control	Burn	Control	Burn
	- - - - - - - - - - - - *g/m^2*	- - - - - - - - - - - -		
Saw palmetto	306a[a]	225a	239b	146a
Live shrubs	132a	137a	138a	74a
Dead shrubs	29b	2a	14a	43b
Grass	44a	84a	35a	25a
Litter[b]	337a	292a	384b	129a
Total	848a	770a	931b	417a

[a] Within a row for each time period numbers followed by the same letter are not significantly different at the 0.05 level.
[b] Litter includes both 1- and 10-hour fuels on the forest floor.

Table 2—Conditions on day of prescribed burns, firing technique, fire behavior, and intensity at study sites at the Myakka River State Park, FL

Block	Date	Temp.	RH	Wind	KBDI	Fires type	Spread rate	Flame length	Fire intensity
		°C	*%*	*kph*			*m/min*	*m*	*kW/m*
1	8/20/2001	32	50	5 – 13	182	Head & flank	18	2 – 3	315
2	7/13/2000	32	65	5 – 8	—	Head & flank	4	1 – 3	70
3	4/6/2001	29	63	5 – 13	399	Head & flank	27	2 – 5	330

RH = relative humidity; Keetch-Byram drought index = a measure of the relative dryness based on precipitation and potential evapotranspiration (Keetch and Byram 1968).
— = no data.

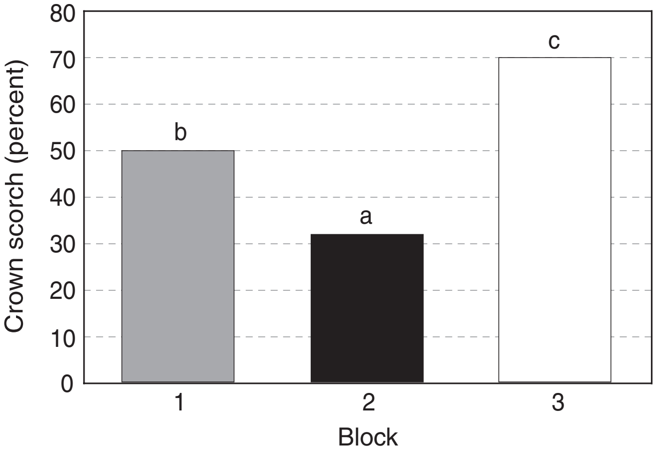

Figure 1—Mean crown scorch from prescribed burns at study sites in Myakka River State Park, FL. Bars with different letters denote significant differences at the 0.05 level.

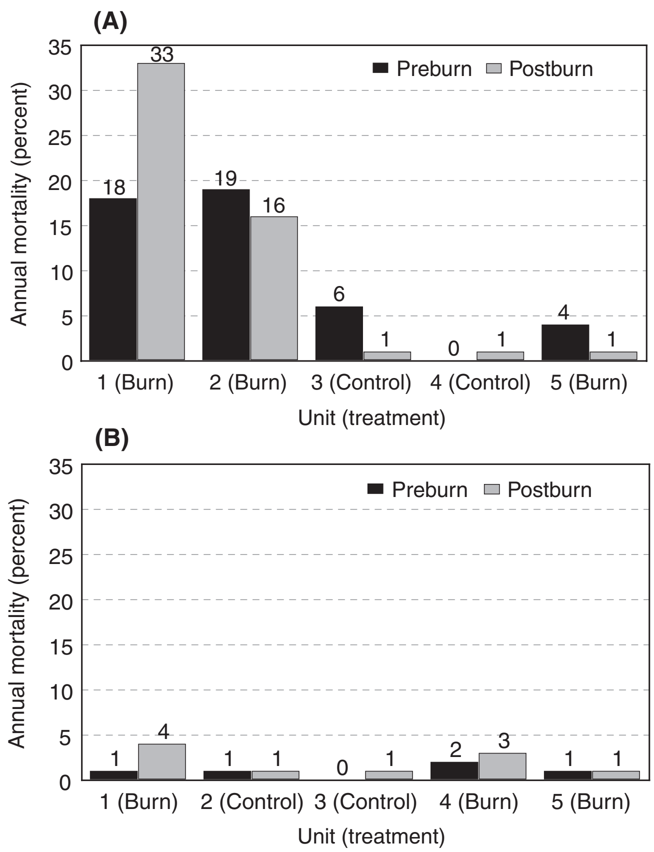

Figure 2—Annual tree mortality by treatment and unit before and after prescribed burns for block 1 (A) and block 3 (B).

treatment units in that block a year after the burns. In block 1, the average annual pretreatment mortality was higher, especially in treatment units 1 and 2 (fig. 2A) than it was in block 3. The year after burning, tree mortality increased in unit 1 but seemed to actually decline slightly in the other two burn units of block 1. For blocks 1 and 3 combined, the year following the burns, there was no significant difference in mean mortality rates between burned and control units.

DISCUSSION

The rates of spread for both blocks 1 and 3 were quite high. Brose and Wade (2002) predicted spread rates of a third to half our rate under drought conditions. This high spread rate resulted from greater windspeeds. Another important factor, however, was likely the location of treatment units relative to initial ignition. Both areas that had a high spread rate were burned by head fires that had considerable distance to develop before they entered the actual burn treatment unit.

Pretreatment fuel loadings for live fuels on all units were very similar to those for north Florida flatwoods systems with a 3-year rough (Brose and Wade 2002). However, 1- and 10-hour fuels in the litter layer were only a third of those for north Florida flatwoods, probably due to a difference in burn efficiency. The growing-season head fires used for recent management burns of the area consume nearly all forest floor material. Because frequent growing-season burning keeps litter from accumulating, there is no duff layer within any of the treatment units. This consumption of the litter layer seems to be the main fuel reduction occurring after our growing-season prescribed burns. Fuel quantities in the living understory were actually higher than those reported by Brose and Wade (2002) 1 year after dormant season burning, but forest floor fuels were about a third of their quantity (129 vs. 336 g/m^2), resulting in essentially the same total fuel load. Some of this difference was likely due to much higher tree density in the north Florida flatwoods, which results in more litterfall but less understory.

Crown scorch was influenced by drought index, location, weather, and firing technique. The highest scorch occurred in a unit of block 3, which was burned during the highest drought index, with a fair wind, and with a well-developed head fire. This combination of conditions produced an intensity of 400 kW/m, the highest intensity of all the burns and the highest crown scorch (83 percent). Although the intensity was quite high, it was less than the 578 kW/m potential intensity for a 4-year rough of this fuel type predicted by Wade and others (2000). The effects of wind and humidity were evident in block 2, where scorch decreased by about half late in the afternoon when wind dropped off and relative humidity increased. Scorch was also reduced because more of the late afternoon units were burned with flanking fires.

Crown scorch is a poor indicator of tree mortality in southern pines (Wade and Johansen 1986). There is generally little mortality until scorch approaches 100 percent. We found no correlation between crown scorch and subsequent mortality. Block 3 had the highest crown scorch but very low mortality, while burned units in block 1 had less scorch but more mortality. Overall, there was not a significant increase in mortality due to burning, but this may change as trees are continuing to die apparently from the combined stress of drought and fire. Inspection the year following burns showed a number of trees that appeared to have died because of the fire in block 1. Just analyzing results following burning, the conclusion would have been a large increase in mortality due to fire. Knowing the pretreatment mortality, however, showed there was high mortality in the burn units before treatment. This resulted from a prolonged drought, which put stress on the trees, especially those on the highest and driest units; i.e., units 1 and 2. Even though this drought ended with substantial rainfall in the 2 months prior to the burn, the trees probably had lowered carbohydrate reserves and therefore were less prepared to reflush. Although fire likely increased mortality in unit 1 of block 1, a number of these trees would probably not have died in the absence of predisposing drought.

The growing-season burns used in this study were at least as effective in reducing fuel loads as dormant-season burns. Over the long term, growing-season treatment could be even more effective due to a reduction in live woody fuels and an increase in herbaceous components that result from repeated burns (Boyer 1993, Haywood and others 2001, Robbins and Myers 1992). The low-mortality rates in block 3 showed that even with moderate drought levels and very aggressive burning techniques, slash and longleaf pines were able to tolerate growing-season burns. It must be remembered, however, that these stands had been burned on a regular basis in the past and thus did not have a large fuel buildup and had crowns only on the upper third of the stem. Potential tree mortality can be reduced by not burning stands that are already stressed and by avoiding the later portion of the growing season (Robbins and Myers 1992, Weise and others 1990). There is also a potential for growth loss with repeated growing-season burns, but it is too early in this study to evaluate growth rates. Growth loss from burning, however, appears to be age-specific, with growth increases in seedling-age stands (Grelen 1983), some growth loss in sapling to pole-sized stands, and little effect in stands beyond age 25 years (Boyer 2000). Because the trees are 40 to 90 years old and needle loss from crown scorch was not complete, we do not expect any measurable growth loss due to burning.

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