Fuels Management Reduces Tree Mortality Following Wildfire

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Abstract

The objective of this study was to test the effectiveness of a regular prescribed burning program for reducing mortality of southern pines when forests are burned by wildfire. This study was conducted on the USDA Forest Service Osceola National Forest, the Florida Division of Forestry Tiger Bay State Forest, and Georgia Pacific Lake Butler Forest. The major portion of the study was installed on the Osceola National Forest where about 10,000 ha of flatwoods forest type was burned by arson-set wildfires under extreme conditions in June 1998. Tree mortality data, summarized by plot, were compared using analyses of variance in an unbalanced design to test for differences in pre-fire fuel treatments, site type, location and fire type. Mean mortality was 41 percent in natural stands and 34 percent in plantations two growing seasons after the wildfire. Burn history significantly affected mortality with those stands prescribed burned 1.5 years before the wildfire having the lowest mortality, while stands prescribed burned 2 years or more before the wildfire had much higher mortality. Site type significantly influenced tree mortality in natural stands. On dry and moist sites, 30% of the pines died whereas the wildfire killed 65% of the trees on normally wet plots. Crown loss, but not bole char was very good at predicting delayed tree mortality. Pines with greater than 70% crown loss were nearly certain to die. There was also a selective removal of the smaller trees from stands. Although significant tree mortality did occur on the Osceola National Forest with all trees killed in some stands, many trees in other burned stands did survive. The overall mortality was much lower in both plantations and natural stands on the Osceola than was found at Tiger Bay where prescribed burning had been much less frequent. The highest mortality rates occurred on the Lake Butler Forest where prescribed burning had not been used since plantation establishment. Thus, we conclude that a regular prescribed burning program will reduce mortality following wildfires in both natural and planted stands of southern pines on flatwoods sites, even under severe drought conditions.

Keywords: prescribed burning, wildfire, longleaf pine, slash pine, mortality

Introduction

In the South, as elsewhere, fuels accumulate with time, until an equilibrium is reached with decomposition. Fuel buildup since the last disturbance has been documented in the palmetto - gallberry fuel complex found on flatwoods sites of the southern coastal plain (Sackett 1975, McNab et al. 1978). For decades frequent, regular prescribed burns have been used to reduce these fuel loads. The judicious use of prescribed fire has been promoted as a practical method to reduce the area burned by wildfire. It has been widely assumed therefore, that wildfires would be kept small and damages limited. Past research tends to support this view. Davis and Cooper (1963) found a strong relationship between the acres burned in wildfires and the time since the last prescribed burn for sites in North Florida and South Georgia. They also found that height of bark char, a measure of fire intensity, was related to the age of the rough, i.e., years of fuel accumulation. Martin (1988) indicated fire intensity during the Florida wildfires of 1985 was lower on areas previously prescribed burned.

As noted by DeBano et al. (1998) there is a general trend of increasing fuel buildup and therefore fire intensity with a lengthening of the fire-return interval. Thus, there exists an implied relationship between overstory tree mortality and time since the last burn. Mortality can result from high-intensity crown-consuming fires or from high-severity ground fires consuming accumulated litter around the base of trees (Ryan and Frandsen 1991). For some species, mortality is closely related to crown scorch (Ryan et al. 1998, Finney and Martin 1993). Mortality in other species seems to be more closely related to bole injury (Peterson et al. 1991). Much recent research in the South has concentrated on injury and growth following prescribed burns (Boyer 1987, Johansen and Wade 1987, Lilieholm and Shih-Chang 1987, Weise and others 1991).

Little information exists, however, on tree mortality following wildfires in areas where fuels are routinely reduced through prescribed burning. The primary objective of this study was to determine the effects of fuel management through prescribed burning on wildfire severity as measured by overstory damage. The null hypothesis was that during severe drought, conditions are so extreme that pre-wildfire fuel treatments have no effect on fire severity or overstory mortality. A secondary objective was to determine if overstory mortality is related to stand origin, i.e., natural versus planted, or site moisture level.

Methods

An attempt was made to locate plots throughout northeast Florida which would cover a range of prior prescribed burning regimes giving fuel buildup times of 3 months to 10 years or greater. Extensive salvage operations prior to the initiation of the study limited the stands available for sampling. The three areas selected for the study were the USDA Forest Service’s Osceola National Forest, Georgia Pacific’s Lake Butler Forest, and Florida Division of Forestry’s Tiger Bay Forest.

The sample stands on the Osceola National Forest were in a 10,000 ha area of flatwoods forest type. This area contained both natural stands and pine plantations. Natural stands were a mixture of slash (*Pinus elliottii*) and longleaf pine (*P. palustris*), while plantations were slash pine. Intermixed throughout the area are wet depression ponds and strands occupied by slash pine, pond cypress (*Taxodium distichum* var. *nutans*), swamp blackgum (*Nyssa sylvatica* var. *biflora*), and loblolly bay (*Gordonia lasianthus*). The understory was typical flatwoods containing a mixture of grasses, saw palmetto (*Serenoa repens*), and gallberry (*Ilex glabra*) on dry and moist sites and loblolly bay and fetterbush (*Lyonia lucida*) on wetter areas. The entire area had been under a regular prescribed burning program for the past 25 years, which included some growing season burning during the last 5 years.

On June 3, 1998 when the drought index was over 700, an arson fire was set at 6 to 8 locations. This wildfire burned 325 ha the first day and by the third day was 600 ha in size (Fig. 1). From June 5th to the 17th the fire was contained but could not be extinguished because it was burning in organic layers in the normally wet depression areas. On the 19th, the wildfire made some new runs and then broke loose the following day. The drought index on June 20th was over 750, the relative humidity was down to 35 % and the temperature was over 32 ^{o}C. During the next 4 days the wildfire burned 7200 ha under these extreme conditions.

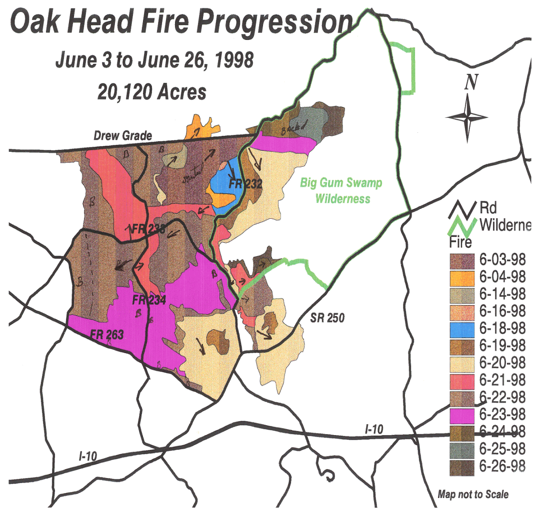

Figure 1—June 1998 wildfire on Osceola National, Forest, Florida.

All pine stands within the burn area on the Osceola National Forest were divided by origin into natural or planted categories. Within each of these two types, 21 stands were randomly selected for sampling. Selected stands were sampled between November 1998 and February 1999. Within each stand, five circular plots were located 30 m apart along a line transect with a randomly selected starting point. Plot size varied with tree density from 0.01 to 0.05 ha so 15 to 20 trees were sampled per plot. When the dominant tree height was greater than 15 m, all pines with a diameter greater than 5 cm were measured. In plantations with dominant trees less than 15 m tall, all pine trees taller than 1.37 m were measured. For each sample tree in a circular plot, the species, diameter, condition (live or dead), crown death (%), and bole char were recorded. Crown death was the portion of the crown with branches killed by the fire and not crown scorch. The first five live trees in each circular plot were labeled to follow longer-term fate.

These trees were resurveyed in October 1999. At each plot the site type (dry, moist or wet) and location relative to the burn (interior or edge) were noted. The fire history (time since last prescribed burn) and fire type (heading or backing) were obtained from Osceola Ranger District records.

Aerial photos of the entire wildfire area on the Osceola National Forest were taken 1 week after the fire. District personnel used these photos to classify damage as light, moderate, or severe. This classification along with stand acreages and prescribed burn history was used to calculate the acres in each damage class by time since the last prescribed burn.

Data was also collected from 10 stands at Tiger Bay State Forest, which had been burned by June wildfires. Half of the stands were slash pine plantations and half were natural mixed stands of slash and longleaf pine. The plantations were in two age classes,10 or 28 years old. The 10-year-old plantations had a grass-dominated understory while the older plantations had an understory dominated by loblolly bay. The area was acquired by the state in 1994 from a forest products company that had practiced limited prescribed burning during the dormant season.

Three stands were sampled on the Lake Butler Forest that had also burned by wildfire in June 1998. All sample stands were 12 to 15 year old slash pine plantations machine planted on heavily site prepared areas. The understory of all plantations had been sprayed with Garlon 9 to 21 months prior to the wildfire. The herbicide had killed most of the gallberry but the dead stems were still standing between the rows of pines. No prescribed burning had been done in the plantations since they were planted. Two of the sample plantations were part of larger 400 to 500 ha wildfires that were ignited by arsonists just after noon on June 15th. The third stand was in a small 10 ha burn ignited by lightning the evening of June 28th.

The same sampling scheme used on the Osceola was used on Tiger Bay State Forest and the Lake Butler Forest, but some salvage cutting had already occurred at these sites. At Tiger Bay some bias was likely introduced because the staff had selected the most severely damaged older plantations for harvest first and they were not available for sampling. On the Lake Butler Forest much of the burn area had been salvaged. The areas we sampled were smaller fingers around the perimeter of the wildfire or small burns of less than 10 ha that were not salvaged.

Data were compared using analyses of variance in an unbalanced design to test for differences in pre-fire fuel treatments, site type, fire type, and stand location. Data tested by this technique included tree mortality and basal area loss. A pooled measure of fire intensity was also assigned based on a damage index calculated by multiplying mean percent crown loss by mean percent bole char on a sample plot. Plots were categorized in four levels with damage index less than 25 at level 1, 25 to 50 level 2, 51 to 75 level 3 and greater than 75 level 4. These levels represent increasing fireline intensity (also called Byrams or frontal intensity). This index was used to compare pre-fire fuel treatments using contingency tables of observed and expected values and the chi square statistic. The percent relative tree size was calculated for each tree by dividing its diameter by the mean tree diameter for the entire plot and then multiplying by 100. This value was then averaged for all live and all dead trees on a plot. Regression was used to test for relationships between tree mortality and plot density, plot basal area, tree bole char, and tree crown loss.

Results

Osceola National Forest

Trees in natural stands on the Osceola National Forest were mostly pole and saw timber size. The average diameter for sample trees in natural stands was 24.4 cm. Mean height for dominants and co-dominates was 26 m. Plantations ranged in age from 8 to 35 years. Average tree diameter in plantations was 14.4 cm and mean height was 16.0 m. Eight of the 21 plantations sampled had mean heights less than 15 m. All natural stands and plantations with trees over 15 m tall had been thinned at least once prior to the wildfire.

Burn Interval.--Fire intensity and therefore tree mortality covered a broad range. In some stands the wildfire totally consumed most crowns, directly killing the trees. In other stands, trees were stressed and many later succumbed to a combination of wildfire injury and insect attacks over the first summer and fall following the fire. Some stands had little apparent damage and only a few dead trees. At the end of the first growing season after the fire, mortality was 32 percent in both plantations and natural stands based on the number of trees. Additional trees died during the

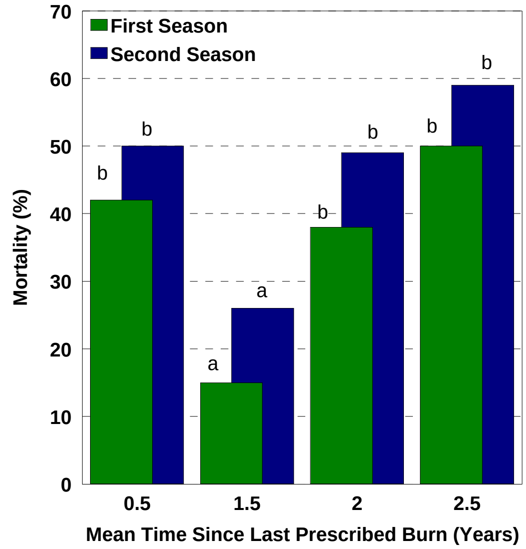

Figure 2.—Tree mortality after first and second growing season following June, 1998 wildfire in natural pine stands on Osceola National Forest, Florida. Letters denote significant differences at 0.05 level.

second growing season, increasing mortality to 34 percent in plantations and 41 percent in natural stands. In natural stands average tree mortality at the end of the first growing season was lowest in areas that had been prescribed burned 1.5 years prior to the wildfire (Fig. 2). Mortality was higher for those areas burned within 6 months of the wildfire and for those burned 2 or more years ago. The additional mortality during the second growing season was evenly distributed across all prescribed burn histories. Mortality remained lowest on the areas burned 1.5 years prior to the wildfire and was significantly higher in stands burned within the last 6 months or 2 or more years ago. Trends in plantations were the same with the lowest mortality on areas prescribed burned 1.5 years before the wildfire and significantly higher mortality on areas burned within 6 months of the wildfire or 2 or more years ago (Fig. 3).

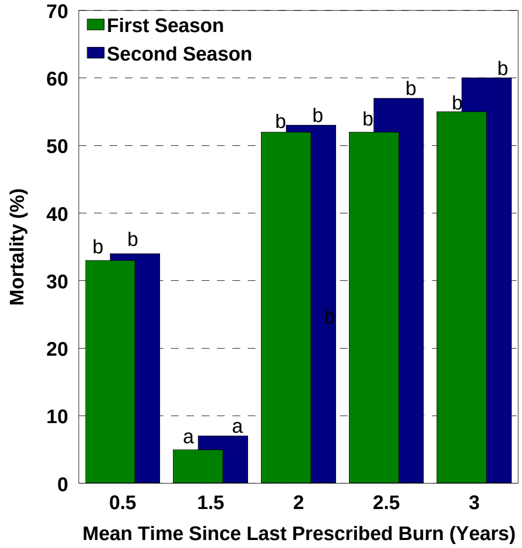

Figure 3.—Tree mortality after first and second growing season following June, 1998 wildfire in pine plantations on Osceola National Forest, Florida. Letters denote significant differences at 0.05 level.

Mean basal area loss was 27 percent in both natural and planted stands at the end of the first growing season following the wildfire. By the end of the second growing season basal area loss had increased to 37 percent in natural stands and 29 percent in plantations. Basal area mortality followed the same patterns as mortality based on the number of trees. The smallest losses occurred in stands prescribed burned 1.5 years prior to the wildfire in both natural (Fig. 4) and planted stands (Fig. 5).

Assessment of the entire wildfire area on aerial photos also showed a pattern of lower intensity in stands prescribed burned 1.5 years prior to the wildfire (Table 1). About half of all the area in

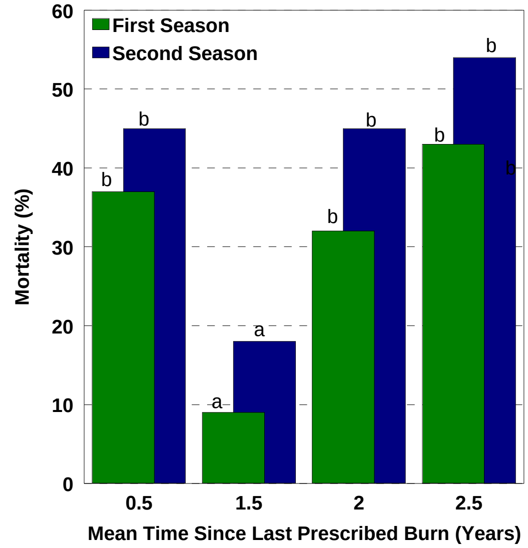

Figure 4.—Basal area loss after first and second growing season following June, 1998 wildfire in natural pine stands on Osceola National Forest, Florida. Letters denote significant difference at 0.05 level.

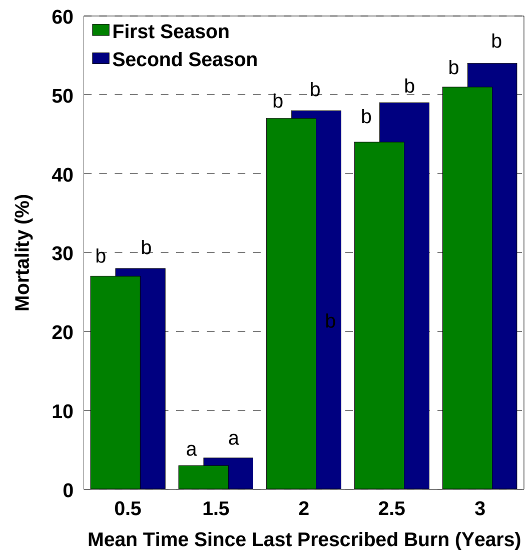

Figure 5.—Basal area loss after first and second growing season following June, 1998 wildfire in pine plantations on Osceola National Forest, Florida. Letters denote significant differences at 0.05 level.

Table 1.—Distribution of stands by damage class, accessed on aerial photos for all pine stands burned by June 1998 wildfire on the Osceola National Forest, Florida.

Damage Level	Time Since Last Prescribed Burn (Years) 0.5	1.5	2	2.5
	----------------Percent----------------------			
Light	26	45	21	26
Moderate	32	30	16	10
Severe	42	25	63	64

Table 2.—Distribution by damage level index, for stands sampled following June 1998 wildfire on the Osceola National Forest, Florida.

Damage Level	Time Since Last Prescribed Burn (Years) 0.5	1.5	2	2.5
	-----------------------Percent-----------------------			
1	40	93	62	53
2	23	7	15	11
3	27	0	8	16
4	10	0	15	20

Table 3.--Average mortality of overstory pines by site moisture level, location, and fire type after second growing season following June 1998 wildfire on Osceola National Forest, Florida.

	Natural Stands	Planted Stands
	---------------Percent-----------	
Relative Moisture Level		
Dry	26a*	28a
Moist	33a	34a
Wet	65b	
Location		
Edge	46a	18a
Interior	36a	43b
Fire Type		
Backfire	36a	21a
Headfire	47a	41a

*Within a column, for each section, means not followed by the same letter are significantly different at the .05 level.

Table 4.--Average basal area loss of overstory pines by site moisture level, location, and fire type after second growing season following June 1998 wildfire on Osceola National Forest, Florida.

	Natural Stands	Planted Stands
	---------------Percent------------	
Relative Moisture Level		
Dry	21a*	22a
Moist	29a	30a
Wet	61b	
Location		
Edge	42a	16a
Interior	32a	37b
Fire Type		
Backfire	32a	16a
Headfire	42a	37a

*Within a column, for each section, means not followed by the same letter are significantly different at the .05 level

these stands had only light damage while over 60 percent of the area burned 2 or more years before the wildfire suffered severe damage. Those areas prescribed burned within months of the wildfire had an intermediate level of damage.

Time since the last prescribed burn had a significant effect on relative wildfire intensity, based on the damage level index. Again, stands prescribed burned 1.5 years before the wildfire had very low intensities with 93 percent in level 1 intensity and none in level 3 or 4 (Table 2). As time since the last prescribed burn increased so did the percent of the sample stands at the highest intensity, level 4.

Site Type, Location, and Fire Type.--Relative moisture level of the area influenced tree mortality within natural stands where losses were significantly higher on the wetter areas (Table 3). There were no plantations on the wettest sites and no difference in tree mortality between dry and moist areas. Natural stands on the edge of the wildfire and those in the interior showed no difference in average tree mortality. In plantations, however, mortality was much lower for those trees near the edge of the burn. There were no significant differences in tree mortality between areas burned by heading fires and those burned by backing fires. Losses in terms of basal area were about 5 percent less but followed the same patterns as mortality based on number of trees (Table 4).

Tree Size.--The relative diameter of dead trees in natural stands was less than mean tree diameter at 86 percent, while the trees that survived the wildfire were larger than average at 106 percent. Relative size of dead trees was lowest in stands prescribed burned 1.5 years before the wildfire (Fig. 6). In plantations relative diameter of dead trees was 90 percent or 10 percent smaller than the overall average tree diameter, while surviving trees were slightly larger than the average at 106 percent. As with natural stands, trees killed by the fire had the lowest relative diameter on sites burned 1.5 years before the wildfire (Fig. 7).

Although tree diameter did effect mortality, there was no relationship between mean plot height and mortality from the fire. Young short trees in plantations had mortality rates similar to those of large trees in natural stands if all other factors, such as time since the last prescribed burn and site type, were equal. In addition, there were no significant regressions between tree mortality and stand density expressed as either stems per hectare or basal area per hectare.

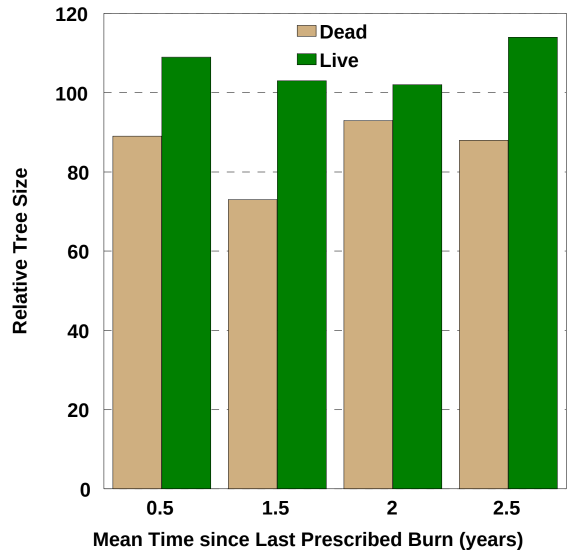

Figure 6.—Mean relative diameter of live and dead trees in natural stands burned by the June, 1998 wildfire on Osceola National Forest, Florida.

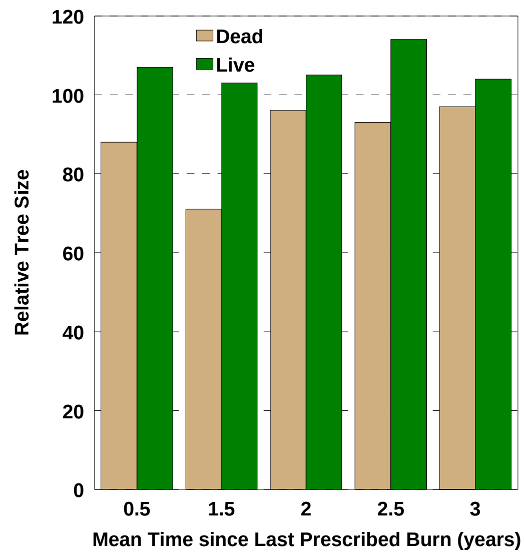

Figure 7.—Mean relative diameter of live and dead trees in planted stands burned by the June, 1998 wildfire on Osceola National Forest, Florida.

Delayed Mortality.--It is often useful to have some way of predicting potential mortality in fire damaged trees to aid in decisions on which to salvage and which to leave. Logistic regression analyses showed no relationship between the likely condition (live or dead) of trees after the second growing season and height of bole char or percent bole char. A significant logistic regression did result for both natural and planted stands between condition after the second season and the percent of crown loss at the end of the first season. These regressions however, had very low r squares and performed very poorly, especially in plantations where all trees were always predicted to live regardless of the level of crown loss. The best system for predicting delayed mortality was based on simple classification into crown loss levels. In planted stands, delayed mortality was very low and most trees alive after one season were also alive after the second, although there does appear to be a slightly increased chance of mortality when crown loss exceeds 75 percent (Table 5). In natural stands the relationship was much stronger. Once crown loss exceeded 70 percent, second season mortality increased substantially and the probability of a tree surviving with greater than 75 percent crown loss was quite low.

Table 5.—Mortality rates for trees the second growing season following June 1998 wildfire on the Osceola National Forest.

Crown Loss	Natural Stands	Planted Stands
(%)	(%)	(%)
1-10	3	3
10-25	12	5
26-50	11	5
51-70	13	3
71-75	56	5
76-95	82	8

Tiger Bay State Forest

At Tiger Bay mean tree diameter was 21.6 cm in natural stands, 14.3 in old plantations (28 years), and 7.9 cm in young plantations (10 years). Natural stands and old plantations had essentially equal basal areas at 21 and 23 m^2/ha, respectively, while young plantations averaged 7 m^2/ha. Tree mortality after 2 growing seasons averaged 61 percent in natural stands and 55 percent in plantations. Although there seemed to be a general trend of increasing tree mortality with increasing time since the last prescribed burn, there were too few stands to statistically test this relationship.

The data from Tiger Bay State Forest did provide an opportunity to test for a general relationship between tree mortality and the time since the last prescribed burn. A regression equation was generated using data collected on dry and moist plots in natural stands on the Osceola National Forest. The regression generated had a rather low r^2 and thus explained only about 15 percent of the variation in the data (Fig. 8). This equation was applied to the data from the natural stands at Tiger Bay to test its usefulness (Table 6).

Table 6.—Predicted and actual mortality rates for natural stands on Tiger Bay State Forest burned by June 1998 wildfire.

Time Since Last Prescribed Burn	Predicted	Actual
(Years)	(%)	(%)
1	23	ND*
2	35	ND
3	47	22
4	59	82
5	70	ND
6	82	80

*No data because no stands that were burned had this history of prescribed burning.

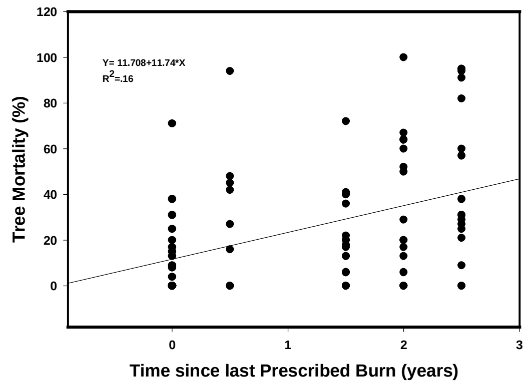

Figure 8.—Relationship between tree mortality and time of last prescribed burn for sample stands burned by June 1998 wildfire on the Osceola National Forest, Florida.

Lake Butler Forest

Plantation grown sample trees had a mean diameter of 13.9 cm and an average height of 15.3 m. Only three stands were sampled but mortality levels were 100 percent after the first growing season in two stands and 67 percent in the third. This gave an average tree mortality following the wildfire of 89 percent.

Discussion

Tree mortality following wildfire on Osceola National Forest was influenced most by the time since the last prescribed burn. Stands prescribed burned 1.5 years prior to wildfire had the lowest intensity wildfire, based on the damage level index. Those stands burned 1.5 years prior to wildfire also had the lowest mortality. The low intensity and lower mean tree mortality in both plantations and natural stands on the Osceola National Forest likely occurred on those areas because they had not yet accumulated much fuel. These stands had only one full growing season since the last burn. Stands prescribed burned 1.5 years prior to the wildfire also had the least damage in the visual assessment on aerial photos of the entire wildfire area.

Although stands burned just before the Osceola wildfire had not accumulated much new fuel, trees also had not had much time to recover from the stress of prescribed burning. Most of these stands had been burned in February, just 3 months before the wildfire. The combined stress of the prescribed burn and the wildfire in a short time likely caused the increase in tree mortality. The accumulation of understory and forest floor fuels in longleaf and slash pine stands is very rapid during the first 10 years following a prescribed burn (McNab et al. 1978). Also prescription burning is done under weather conditions where only part of this fuel is consumed. During severe drought and burning conditions, however, consumption of the understory and forest floor is virtually complete. Thus, it is not surprising that mortality levels increased significantly in those stands that had not been burned for two or more years.

The increased mortality on wet sites was also fuel related. Prescribed burning normally creates a mosaic burn pattern in these flatwoods types, as these fires rarely enter the wetter depressions. Even when these areas do burn, it is a light surface burn that consumes only a portion of the understory, and very little of the forest floor because it is too wet to burn. Under extreme drought conditions such as existed during the wildfire, however, both coverage and consumption of forest floor and understory are nearly complete, resulting in high tree mortality. Fuel differences may be the cause of lower mortality in plantations on the perimeter of the burn as well. Those plantations on the edge of the area burned by the wildfire were mostly quite young and had a grass dominated understory. Many of the interior plantations were older and had understories dominated by saw palmetto and gallberry. This difference in understory did not exist in natural stands, which had equal tree mortality levels at both interior and edge locations.

A headfire should produce greater intensities, but backing fires because of their increased residence time can be expected to cause greater cambial heating near the ground (Wade and Johansen 1986). The stands sampled in this study burned by a headfire had on average greater initial crown damage, while many of those burned with a backing fire had very little crown scorch. Trees in those stands burned with a backing fire had healthy looking green crowns for a number of weeks following the wildfire. However, on areas with a 2-year or greater rough, they experienced substantial bark beetle attack and subsequent mortality during the late summer and fall. Thus, there was no significant difference in mean tree mortality by fire type, even though the nature of the injury differed between the types.

Although natural stands had slightly higher mortality than plantations, this was not significant and was due mostly to higher mortality rates on wet sites. Since there were no plantations on wet areas, this resulted in a somewhat lower overall tree mortality. Mean mortality for natural stands on dry and moist sites only was essentially the same as plantations at 27%. The only real difference between planted and natural stands was a greater amount of delayed mortality in natural stands. In plantations, most of the trees that died were already dead by the end of the first growing season. The greater delayed mortality in natural stands likely resulted from larger trees being able to survive longer, following girdling from severe cambial damage, because of greater carbohydrate reserves in the root system.

When selecting trees for salvage following wildfire it is desirable to select those not likely to survive. Thus, if delayed mortality can be predicted based on tree damage it will help managers determine which trees to keep and which to harvest. Bole char expressed as either percent of the total bole or absolute height has been used successfully to predict mortality in western conifers (Peterson et al. 1991, Regelbrugge and Conard 1993), but this characteristic has not proven to be a reliable indicator of morality in southern pine (Bourgeois 1985 , Mann and Gunter 1960, Villarrubia and Chambers 1978). Crown loss, however, was quite good for predicting delayed mortality in natural stands in this study, where all trees with greater than 70 percent crown loss had a high probability of dying. Crown loss was actual death of the crown and not just crown scorch.

Mortality following the wildfire was greater for the smaller trees in a stand. This was apparent in the difference in relative tree diameter between dead and live trees. It was also the reason tree mortality based on the number of trees was higher than basal area loss. Thus, the wildfire selectively removed a greater proportion of the trees in the smallest size classes. However, mean mortality was no greater in young plantations with smaller trees than it was in older plantations with larger trees. Therefore tree size was important, but only within a particular stand where being smaller than neighboring trees increased the probability of being killed by the wildfire. This likely resulted from greater crown damage to the shorter than average trees in a stand.

Although some stands on the Osceola had 100% tree mortality, many trees in the burned area did survive, even though the wildfire occurred under extreme conditions. No areas in any sample stands were left unburned, so this was not a case of random areas escaping the wildfire. Overall losses averaged less than 40 percent; but was this the result of prescribed burning or just because the trees are able to recover from severe fires? In the New Jersey Pine Barrens Moore et al. (1955) reported tree mortality following a wildfire was 64% in previously unburned areas but only 17% in areas prescribed burned during the preceding 3 years. Prescribed burning provided similar reductions in tree damage following wildfire under extremely dry conditions in the same area of New Jersey (Cumming 1964) and in the ponderosa pine type in Arizona (Wagle and Eakle 1979). Under severe drought conditions, that occur every 10 to 20 years, mortality of southern pines on areas with 5 or more years of fuel accumulation is very high (Eldredge 1935). Those few trees that do survive the immediate effects of these wildfires are usually killed by subsequent bark beetle attacks. Bickford and Bull (1935) reported near total pine mortality for such a wildfire in stands with a 16 year rough. The 34% loss in plantations and 41% in natural stands after the June 1998 Osceola wildfires was quite low by comparison. The increase in mortality with time since the last burn found in our study also indicates that prescribed burning can reduce timber loss.

The wet sites on the Osceola where fuels accumulate because they normally do not burn during prescription burns, can be used as a type of non-burned control. The mortality rate was twice as high on these sites as on the moist sites where prescribed burning had kept fuel loads down. At Tiger Bay State Forest where prescribed burning was less frequent, mortality was 55 percent in plantations that had not been burned for 6 years and 61 percent in natural stands where time since the last burn ranged from 3 to 6 years. On the Lake Butler Forest where prescribed burning had not been used, mortality averaged 89 percent in plantations. Thus, we conclude that a regular prescribed burning program will reduce tree mortality if a wildfire does burn through the area. This reduction in tree mortality occurs in both natural and planted stands of southern pines on flatwoods sites, even with wildfires under extreme drought conditions. Fuels management, i.e. reduction, is the key. A regular prescribed burning program keeps both fuel accumulation on the forest floor and understory stature within tolerable levels. Once fire return interval exceeds 4 years in this community type, wildfires can be expected to cause significant increases in overstory mortality.

Herbicides such as those used at Lake Butler may be able to decrease the fireline intensity of subsequent wildfires, but there is a lag period following application. The stands sampled in this study had received herbicides less than 2 years prior to the wildfire. Although dead, stems of woody ground flora were still standing and contained a substantial amount of needle drape. Until these stems decay sufficiently to fall over and reduce the height of the flammable layer, they are going to increase tree mortality from wildfires. Although herbicide treatment does remove the woody understory fuels a couple of years following treatment, it does not reduce the accumulation of needles in the forest floor. Under severe drought conditions, wildfire is likely to cause high mortality because of root and cambial damage from consumption of this accumulated fuel. Thus, herbicides seem to be a partial replacement for prescribed burning giving good wildfire protection during most years. However, the risk of significant tree mortality is much higher than in prescribed burned stands during severe droughts.

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