RESPONSE TO PRESCRIBED BURNING OF 5-YEAR-OLD HARDWOOD REGENERATION ON A MESIC SITE IN THE SOUTHERN APPALACHIAN MOUNTAINS

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Abstract—Five years after a Southern Appalachian cove was regenerated, vegetation was dominated by a dense stand of yellow-poplar (*Liriodendron tulipifera*), which averaged 9,181±13,042 stems per acre, and other mesophytic hardwood seedlings and saplings. The stand was prescribed burned during late spring to improve habitat for turkey by reducing density of saplings to stimulate greater production of grasses and herbs. The prescribed fire completely killed about 69 percent of the saplings; the others were topkilled and produced basal sprouts that reclaimed much of the canopy growing space after one growing season. Regression analysis indicated that over a range of fire intensities the probability of mortality for yellow-poplar saplings was about twice that of other species. Results suggest that additional prescribed burns will be necessary to achieve the desired low density of arborescent vegetation to allow development of herbaceous species beneficial for wildlife.

INTRODUCTION

Recently regenerated stands on mesic sites in the Southern Appalachians are typically dominated by a mixture of mesophytic hardwoods consisting of yellow-poplar (*Liriodendron tulipifera*), black locust (*Robinia pseudoacacia*), sweet birch (*Betula lenta*), and red maple (*Acer rubrum*) (Beck and Hooper 1986). Although the dense sapling stands provide browse for white-tailed deer (*Odocoileus virginianus*), their forage value for other wildlife declines rapidly because canopy shading excludes desirable grasses, herbs, and legumes (Beck and Harlow 1981). Prescribed burning is sometimes used to manipulate vegetation for wildlife habitat with favorable results on dry pine-hardwood sites, (Keetch 1944, Van Lear and Waldrop 1989). Little information is available, however, on the response of arborescent vegetation to prescribed burning for wildlife habitat objectives in young, recently regenerated stands on mesic sites in the Southern Appalachians.

This report documents results of an operational prescribed burn to reduce density of hardwood regeneration for wildlife purposes on a mesic site in the Southern Appalachian Mountains. Our study of the prescribed burn had two objectives: (1) determine the change in density of yellow-poplar regeneration caused by the prescribed burn and (2) determine factors associated with mortality of hardwood saplings. The scope of our case study was limited to results 1 year following the prescribed fire.

METHODS

Study Area and Treatment

The study site was located in a large east-facing cove at 2,750 feet elevation in the Pisgah District of the Pisgah National Forest, adjacent to the Bent Creek Experimental Forest. Within the cove, topography was hilly and aspects ranged from northwest to southeast. Site index (index age of 50 years) was 90 feet for northern red oak (*Quercus rubra* L.) and 110 feet for yellow-poplar. The mature stand averaged 100 years of age and contained about 14,300 board feet per acre of sawtimber that consisted primarily of yellow-poplar (83 percent), with smaller amounts of northern red oak (10 percent), and chestnut oak (*Q. prinus*) (5 percent). Red maple (1 percent) and other low-grade hardwoods accounted for the remainder. The stand was regenerated using a shelterwood with reserves system in June 1995, with basal area of the residual overstory trees averaging about 80 square feet per acre. Merchantable timber was harvested from 16.4 acres of the 21-acre stand using a rubber-tired skidder to remove log-length products. Residual basal area was further reduced to about 40 square feet per acre in December 1996, as a result of salvaging windthrow caused by the remnants of Hurricane Opal (October 1995). Site preparation after harvest consisted of chainsaw-felling residual unmerchantable trees >3 inches diameter at breast height (d.b.h.); stems <3 inches d.b.h. and over 4.5 feet tall were killed with herbicide.

The stand had been regenerated successfully by advance regeneration released by removal of the overstory and newly established seedlings, mostly yellow-poplar. A low (<4 feet height) canopy of xerophytic species was present on about 29 percent of the study area, mainly on upper slopes. Mesophytic species, primarily yellow-poplar, dominated a similar proportion of the stand on moist lower slopes, forming dense "dog-hair" thickets of tall, spindly saplings (fig. 1); the remainder was a mixture of species. Wildlife management objectives specified greater amounts of grasses and herbaceous species suitable for "bugging" by turkey (*Meleagris gallopavo*) poults. Prescribed burning was selected as an appropriate method for reducing density of hardwood saplings to allow increased light to reach the forest floor and stimulate growth of grasses and forbs.

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Figure 1—Five years following the regeneration harvest on the cove study area, much of the vegetation on mesic sites consisted of thickets of yellow-poplar saplings that ranged from 5 to 15 feet in height and up to 2 inches d.b.h.

The stand was burned between 10 a.m. and 4 p.m. on May 3, 2001, using backing and flanking fires. Air temperature ranged from 75 °F to 80 °F, relative humidity was about 55 percent, and winds were variable, averaging 2 to 3 miles per hour from the southeast to the northeast. Fuel loading was estimated as 1 to 2 tons per acre each of humus, leaf litter, and logging debris, for a total loading of 3 to 6 tons per acre. Visual fire intensity ranged from small unburned patches to almost complete consumption of large logging debris. Estimated fuel consumption averaged about 85 percent of the preburn leaf litter, half of the litter layer and most of the logging residues.

Field Samples

Data were collected from sample plots established after the area was burned; the schedule for burning did not allow for their preburn installation. We used two methods of sampling to achieve study objectives: permanent plots and temporary transects. Permanent plots were established in early summer to determine (1) estimated density of live yellow-poplar saplings present before burning and (2) fire-related mortality of yellow-poplar saplings and density and composition of regeneration after burning. A uniform grid of 21 circular 0.01-acre plots (11.8 feet radius) was established at 200- by 200-foot intervals throughout the stand for estimation of vegetative composition and stem density. Saplings were inventoried by species in five height classes (<1 foot, 1 to 2 feet, 2 to 3 feet, 3 to 4 feet, and >4 feet). Dead, e.g., nonsprouting, yellow-poplar saplings were also recorded to provide a conservative estimate of the live population of saplings present before burning. The numbers of dead yellow-poplar saplings, particularly those >1 foot tall, could be inventoried accurately because the succulent green stems were not consumed by the fire and species could be determined with certainty from the distinctive bark and stem characteristics. The numbers of dead yellow-poplar saplings and live saplings of all species were summed by height class to obtain a conservative estimate of saplings present after the prescribed burn.

Transects were established through the burned stand in late summer to investigate the second objective: factors associated with the mortality of hardwood saplings. Sample plots 3.28 feet in radius (0.000776 acre) were systematically established along transects that extended through areas of the stand that exhibited the range of fire intensity. Intensity was quantified by measuring the height aboveground of burned (or charred) bark on the stems of saplings (Waldrop and Brose 1999). Stem char was relatively uniform throughout the small plots, and a single value was recorded for each sample site. Data collected from all saplings on each plot included life status (alive or dead, as indicted by the presence or absence of basal sprouts), total height, and species. Correlation analysis was used to determine the association of sapling size with selected stand variables. Logistic regression was used to determine significant ($P < 0.05$) relationships between sapling mortality and the independent variables.

RESULTS

Density and Species Composition

The preburn density of yellow-poplar saplings was estimated as 9,181 stems per acre (table 1). Sapling height was directly correlated with density ($r = 0.62$, $P < 0.01$); the tallest saplings (>4 feet) occurred in dense thickets. Approximately 6,304 yellow-poplar saplings per acre were killed by the prescribed burn, resulting in an average mortality of about 69 percent. The proportion of saplings killed ranged from 27 to 50 percent for the four shortest height classes, but increased to 87 percent for saplings >4 feet. Approximately half of the postburn population of 5,476 saplings per acre consisted of yellow-poplar.

Sixteen arborescent species were recorded on the 21 sample plots following the prescribed burn (table 2). Three species occurred on more than half of the plots: yellow-poplar, sassafras (*Sassafras albidum*), and black locust, which together accounted for 86 percent of the stem density. Yellow-poplar was present in greatest numbers, but black locust was most widespread, occurring on 90 percent of the plots. Except for black locust, most species tended to occur in patches as indicated by the coefficients of variation, which averaged around 200 percent.

Table 1—Preburn density of yellow-poplar saplings and postburn mortality and density by species and height class following a spring prescribed burn on a mesic site in the Southern Appalachian Mountains (*n* = 21 plots)

		Height class (feet)					
Inventory	Species	<1	1–2	2–3	3–4	>4	Total±SD
		trees per acre					
Preburn	Yellow-poplar	343	628	1238	1505	5467	9181±13,042
Mortality	Yellow-poplar	171	171	514	705	4743	6304±7969
Postburn	Yellow-poplar	172	457	724	800	724	2877±5998
	Miscellaneous	690	852	419	295	343	2599±2470
Total		862	1309	1143	1095	1067	5476±5669

SD = standard deviation.

Table 2—Mean stem density and stocking by species of 5-year-old tree regeneration following a prescribed burn on a mesic site in the Southern Appalachian Mountains (*n* = 21 plots)

Species	Density±SD	Density CV	Stocking
	trees per acre	*percent*	
Yellow-poplar (*Liriodendron tulipifera*)	2876±5998	208	62
Sassafras (*Sassafras albidum*)	1104±2040	185	71
Black locust (*Robinia pseudoacacia*)	714±707	99	90
Sweet birch (*Betula lenta*)	219±676	309	24
Red maple (*Acer rubrum*)	152±225	148	48
Blackgum (*Nyssa sylvatica*)	143±340	238	38
Northern red oak (*Quercus rubra*)	105±166	158	10
White oak (*Q. alba*)	67±203	303	19
Sourwood (*Oxydendrum arboreum*)	38±74	195	29
Flowering dogwood (*Cornus florida*)	19±68	358	10
Cucumber-tree (*Magnolia accuminata*)	10±30	300	10
Chestnut oak (*Q. prinus*)	10±30	300	10
Other[a]	19±22	116	5
All species	5476±5669		

SD = standard deviation; CV = coefficient of variation (SD/mean)*100.

[a] Other = one sapling each of American chestnut (*Castanea dentata*), American holly (*Ilex opaca*), black oak (*Quercus velutina*), and hickory (*Carya* spp.).

Effects of Fire Intensity

A total of 197 saplings were inventoried on 20 sample plots established along transects to investigate causes of mortality. The majority of saplings sampled were yellow-poplar (65 percent), followed by red maple, black locust, and northern red oak (each 7 percent). Sample sizes were sufficient (>30) for analysis by species only for yellow-poplar (n = 128); all others were pooled (n = 69). Sapling d.b.h. averaged 0.30 inch (range from 0.1 to 2.0 inches), and total height averaged 6.3 feet (range from 1.6 to 14 feet). Over 99 percent of the inventoried saplings in this data set were topkilled, but mortality (indicated by absence of basal sprouts) was only 34 percent. Field observations suggested that mortality was associated with fire intensity, stem size, and species.

Logistic regression indicated that sapling life status (LS) (topkilled or dead) was a function of species group and stem char height:

$$\text{LS} = -4.8906 + 2.6662 SpG + 0.3303 SCH \qquad (1)$$

where

SpG = species group (miscellaneous, zero; yellow-poplar, one)
SCH = stem char height (feet)

Both variables were highly significant (P < 0.001). The model was developed with values of char height ranging mainly from 1.6 to 9.8 feet. Standard errors of the model constant, SpG and SCH are 0.925, 0.701, and 0.072, respectively. Figure 2 displays results of solving equation (1) for probability of sapling mortality in exponential form: $P_m = \exp^{(LS)}/(1 + \exp^{(LS)})$ with a range of values of stem char height for the two species groups.

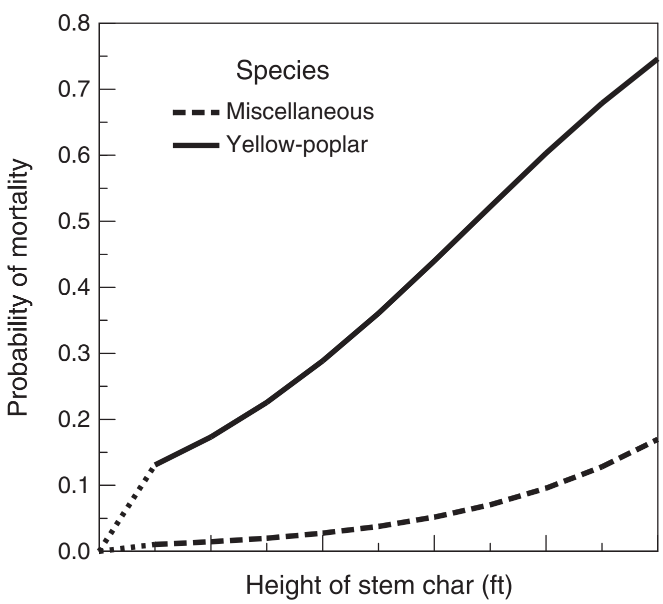

Figure 2—Probability of hardwood sapling mortality in relation to species and height of stem char resulting from a prescribed fire on a mesic site in the Southern Appalachian Mountains.

For example, probability of mortality for a miscellaneous species resulting from stem char height of 3 feet from a prescribed burn on a mesic site 5 years after a regeneration cut is estimated as: $P_m = \exp^{(-3.9)}/(1 + \exp^{(-3.9)}) = 0.02$. Inadequate field data for saplings with char height of zero (unburned) did not allow predictions of the model to pass through the origin.

DISCUSSION

The prescribed burn achieved the desired objective of reducing sapling density, but the level of density remained relatively high—over 5,000 stems per acre. The reduction in stem density is likely to be temporary because we observed newly germinated yellow-poplar seedlings soon after the fire on about half of the permanent plots. The new seedlings likely originated from seeds stored in the litter layer (Shearin and others 1972). Barnes and Van Lear (1998) also reported an increase of yellow-poplar stems following a single spring burn and found that repeated burns were needed to achieve a lasting reduction in density. Keetch (1944) found, however, that neither sprouting capacity nor height growth of sprouts was diminished following three prescribed burns on a dry site. Our results suggest that a series of relatively intense prescribed burns will be required to reduce hardwood stems to a desired density and maintain that density to accomplish the desired wildlife habitat objectives.

Frequent prescribed fires of sufficient intensity to cause additional mortality of yellow-poplar saplings will likely be difficult to achieve on this site. Albrecht and Mattson (1977) found that loading of fuels on mountain cove sites averaged about 4.2 ± 0.5 tons per acre and consisted mostly of leaf litter with little material provided by shrubs. Assuming first that half or less of the average fuel loading reported for coves would be consumed during a typical prescribed burn, and second that total loading on the recently burned study site will be less than occurs on a recently unburned site, then it appears that fire intensity may be marginal to attain adequate sapling mortality. For example, insufficient available fuel was a contributing factor to an unsuccessful second prescribed fire attempted at the study site in early May 2002.

The equation for estimating the probability of sapling mortality provides a quantitative method that managers can use to prescribe a burn of the intensity needed to achieve the desired effects on the sapling stand. The model indicates the probability of mortality of hardwood saplings is directly related to stem char height and species group. Application of the model for planning a prescribed burn to reduce sapling density, for example, indicates that fire intensity resulting in stem char height of about 6.5 feet would be needed to obtain a mortality probability level of 0.5 for a recently regenerated sapling stand on a mesic site. A variable quantifying sapling size was not included in the final regression model because it produced illogical results.

Our results appear to imply that sapling mortality from prescribed burning increases with increasing size, e.g., height (table 1). This relationship is likely an artifact of the dataset that resulted from an interaction between the occurrence of large saplings and fuel loading. In our study area sapling height was correlated with stand density particularly in thickets of yellow-poplar where trees tended to be tall and spindly (fig. 1). We observed that ground fuels in thickets consisted mostly of fallen deciduous foliage with little or no green herbaceous content, and loading appeared to be higher there than elsewhere. Fire intensity, therefore, was likely greater in thickets than elsewhere in the burned area resulting in greater mortality of tall saplings, where d.b.h. ranged up to 2 inches. Even though the larger saplings presumably had slightly thicker bark than the smaller saplings not in thickets (Hengst and Dawson 1994), the increased thickness likely was not sufficient to insulate the cambium from reaching lethal temperature from the pulse of heat produced by rapid combustion of the fine fuels. Generally, tree mortality from prescribed burns is inversely related to their size (Green and Shilling 1987, Hare 1965, McNab 1977).

In summary, results from our study suggest that prescribed burning to reduce density of hardwood regeneration density on mesic sites can be successful, particularly if recent logging residues are present. But, obtaining the desired mortality may be difficult with a single fire. As other studies have shown, a series of prescribed burns will likely be necessary to prevent domination of the site by aggressive yellow-poplar seedlings, saplings, and sprouts. A prediction model provides managers with a means to plan prescribed fires of specified intensity to achieve the desired level of hardwood sapling mortality.

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