# EARLY DYNAMICS OF TABLE MOUNTAIN PINE STANDS FOLLOWING STAND-REPLACEMENT PRESCRIBED FIRES OF VARYING INTENSITY

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**Abstract—**Interest in using stand-replacement prescribed fires to regenerate stands of Table Mountain pine (*Pinus pungens* Lamb.) has increased in the past decade, but the type and intensity of fire needed to achieve success have been undefined. In an earlier paper, we concluded from first-year results that flames must reach into the crowns to kill most overstory trees and provide sunlight to the forest floor. In this paper, we show that lower-intensity flames will eventually achieve the same results. Overstory mortality continued throughout the 6-year measurement period, and pine numbers increased. Stand replacement was successful at all intensities measured.

## INTRODUCTION

Recent fire exclusion policies in the Southern Appalachian Mountains may have reduced plant community diversity (Van Lear and Waldrop 1989). Of concern is Table Mountain pine (*Pinus pungens* Lamb.), whose silvical characteristics, such as serotinous cones and shade intolerance, suggest that fire created stands of this species (Zobel 1969). Today, most stands are entering later seral stages, with oaks (*Quercus* spp.) replacing Table Mountain pines in the overstory and mountain laurel (*Kalmia latifolia* L.) replacing it in the shrub layer. Dendrochronology suggests that large-scale disturbances historically created these stands, and frequent low-intensity fires maintained them (Brose and others 2002, Sutherland and others 1995). As a result of changing species dominance and stand structure, the Southern Appalachian Assessment recognizes Table Mountain pine woodlands as one of 31 rare communities (Southern Appalachian Man and the Biosphere 1996).

Most research addressing the role of fire in Table Mountain pine stands has been limited to postwildfire studies, which suggest that high-intensity prescribed fires are needed to remove the forest canopy and expose mineral soil for successful regeneration (Williams and Johnson 1992, Zobel 1969). Williams (1998) suggested that Table Mountain pine stands are in decline as a result of fire exclusion and inadequate understanding of the species regeneration biology.

High-intensity, stand-replacement prescribed burning may reverse the decline. However, accomplishing these burns is difficult. Such prescriptions provide a narrow window of opportunity and raise questions about worker safety and smoke management. Waldrop and Brose (1999) examined four levels of fire intensity to determine which provided adequate levels of overstory mortality and pine regeneration for successful stand replacement. At the end of the first growing season after burning, they found that pine regeneration was abundant in plots burned at all fire intensities, but that overstory mortality was too low unless flames had reached into the crowns of overstory trees. In this paper, we examine the early dynamics of stands regenerated in that study and evaluate previous conclusions. Specifically, we will report on changes to overstory mortality, pine regeneration, and competing vegetation.

## METHODS

Measurement of study plots followed the methods of our previous study (Waldrop and Brose 1999). The study site is in the War Woman Wildlife Management Area of the Tallulah Ranger District in Rabun County, GA. We established study plots in three separate stands immediately south of Rabun Bald. All three stands were within the same 875-acre burn unit and had similar slope, aspect, and stocking of overstory hardwoods and Table Mountain pine. These areas were the only ones within the burn unit that had significant numbers of Table Mountain pine in the overstory. One stand occupies 44 acres at an elevation of 3,600 feet. The remaining stands are both 30 acres at elevations of 3,000 and 2,900 feet. All study areas cover sharp ridgetops and steep slopes with northeastern or southwestern aspects.

All study stands were burned as one unit on April 4, 1997. The fire covered the entire burn unit including the northeastern and southwestern slopes. Backing fires were set by hand at upper elevations to secure fire lines. At 1030, a helicopter fired the interior portion of the burn unit using a plastic sphere dispenser. Fire intensity was generally high, with crowning in portions of the upper ridges and intermittent torching along the ridge. Other areas of the burn unit burned with high-intensity flames, but crowning was not observed.

Three months after burning, the entire burn unit was surveyed to select study areas exhibiting a range of fire intensity effects. Evidence of fire intensity included bark char height, mortality of overstory trees, portion of the crowns of living trees scorched, presence of scorched needles on the forest floor, soil exposure, insolation on the forest floor, presence of charred cones in the crowns of trees and on the forest floor, and the size of branches on trees and shrubs unconsumed by the fire (see Waldrop and Brose 1999). We placed 60 sample plots, 33 by 66 feet in size, throughout the 3 Table Mountain pine stands in areas burned at a range of intensity levels.

We subjectively described each sample plot by one of four intensity levels (low, medium low, medium high, or high) based on fire effects observed in the plot. Fire-intensity evidence suggested the following description of fire-intensity categories. Low-intensity flames were somewhat uniform in behavior and

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reached heights of 6 to 8 feet. Flames of this intensity would be considered as high intensity in most other studies. Medium-low intensity had slightly higher flames and one or more hot spots where localized flames reached into the lower limbs of the overstory trees. Medium-high intensity flames reached into the crowns of all trees within the plots but were not true crown fires where flames jumped from one tree crown to the next. High-intensity flames were true crown fires where flame height exceeded tree height, and flames carried from one crown to the next.

We measured sample plots at the end of the first (1997), second (1998), third (1999), and sixth (2002) growing seasons after burning. Measurements included overstory diameter at breast height (d.b.h.), species, and mortality; hardwood abundance; and species and size of pine regeneration. The study had an unbalanced completely random design with fire intensity as the independent variable. A more complete description of measurements appears in Waldrop and Brose (1999). Measurements in each sample year followed identical procedures. We compared treatment means for the fire-intensity levels by one-way analysis of variance with mean separation by linear contrast ($\alpha = 0.05$). In analyses of pine seedling density, we used the number of cones on the ground and in the crowns of trees as a covariate to adjust for differences in seed source.

## RESULTS

### Overstory Mortality

During the first year after burning, high and medium-high intensities had killed almost all trees, including pines and hardwoods (fig. 1). Medium-low intensity resulted in the mortality of over half the basal area of the stands. Low-intensity flames reduced basal area by < 20 percent, and most of that mortality was within the smaller d.b.h. classes such as 6 and 8 inches.

Because of these results, our previous conclusion was that only fires of high and medium-high intensity would produce conditions of stand replacement. We assumed that stands with 65 to 100 square feet of basal area would produce too much shade for seedling survival. That conclusion was probably premature, because both pine and hardwood overstory trees continued to die for several years after burning (fig. 1). At the end of the 1998 growing season, basal area remained the same in plots burned at medium-low intensity and above. However, additional mortality occurred in plots burned at low intensity. During that year, the basal areas of plots burned were not significantly different between the low (57.7 square feet per acre) and medium-low intensities (61.3 square feet per acre). By 2002, almost all overstory pines and hardwoods were dead in all study plots. Complete mortality may have occurred before 2002, but measurements were not taken between 1998 and 2002.

Delayed mortality of overstory trees was unexpected, particularly in plots burned at low intensity. Little literature exists on the relationship of fire intensity to hardwood mortality in the Southern Appalachian Mountains. Most studies suggest that low-intensity fires cause scars that eventually lead to disease and death. This study differs from previous ones, however, because fire intensities are higher. We designed the fire to kill hardwoods rather than to protect them. Two unpublished studies associated with the National Fire and Fire Surrogate Study show similar results with moderate fire intensities. Hardwoods in those studies died over a 3- to 4-year period. Causes of delayed mortality may include a combination of xeric site conditions, prolonged drought during the study period, and any root-borne pathogens that may have existed in the study area.

### Pine Regeneration

During the first year after burning, cones opened at all fire intensities, and regeneration was abundant (fig. 2). Even though pine numbers were highest at low and medium-low intensities, we previously concluded that there would be too much shade for seedlings to survive. In 1999, we found that this conclusion was partially true. Table Mountain pine numbers had decreased in all plots but most dramatically in the plots where overstory trees remained alive through that year. However, overstory trees were dying at this time, so not all seedlings were shaded. Pitch pine (*P. rigida* Mill.) seedlings began to appear between 1997 and 1999. We assume that these seedlings were from seed from adjacent stands,

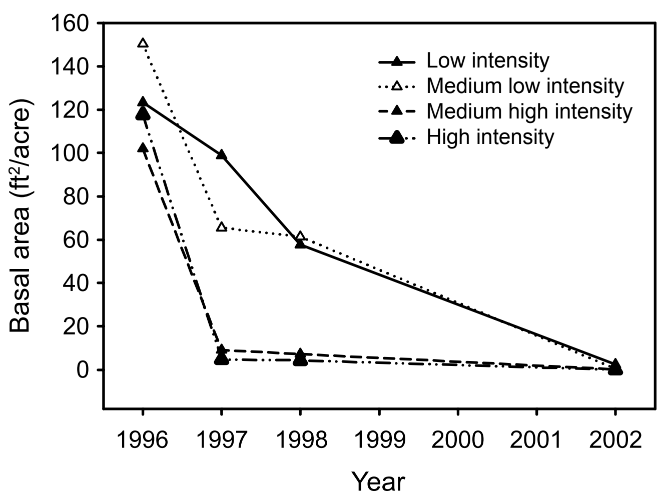


Figure 1—Basal area of surviving trees after prescribed burning by intensity and year.

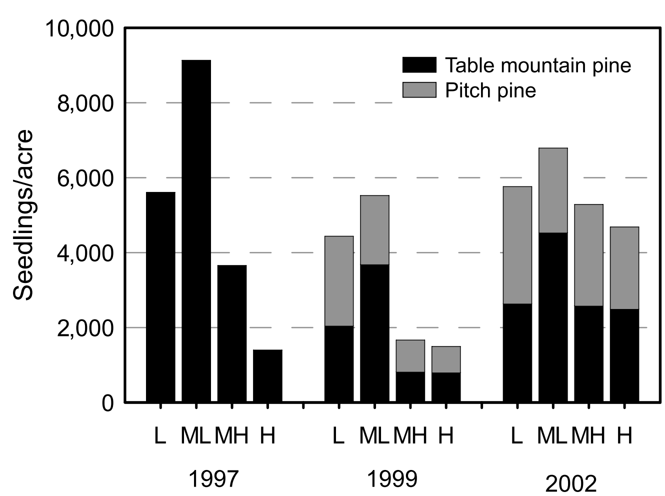


Figure 2—Pine regeneration by intensity and year.

because most overstory trees were dead, and the fire should have consumed the seed in place before burning.

Table Mountain pine seedlings increased in number between 1999 and 2002 in all plots. Pitch pine greatly increased in density between 1999 and 2002 to the point that it outnumbered Table Mountain pine in most plots, thus eliminating the treatment effect for all pines combined. After 6 years, plots burned at all intensities had abundant regeneration of both Table Mountain and pitch pines.

### Sprout Competition

A continuing concern for pine survival is competition from hardwood and shrub spouts. These sprouts overtopped young pines during year one and have continued to be strong competitors (fig. 3). During the year immediately after the fire, there were large numbers of sprouts of all hardwood and shrub species. Common species were blackgum, oaks, and sassafras. Fire intensity had no impact on numbers of sprouts in 1997.

By the third year after burning, density of all species and species groups (oaks and other hardwoods) increased, and the total number of sprouts was significantly higher in plots burned at medium-high and high intensity. This should not be considered a treatment effect, however, because the difference was due to shrubs, particularly mountain laurel. These shrubs had heavy cover in these plots before burning, thus providing the vertical fuels to create the high intensity fires.

By 2002, mountain laurel sprouts were exceptionally dense in plots burned at medium-high and high intensities. Sprouts of all other species were dense but not significantly different in number among fire-intensity levels. Even though shrub and hardwood sprout density was high, competition did not seem to greatly impact pine survival.

Figure 4 compares the height of the various species groups at the most recent measurement. At all intensity levels, hardwood sprouts overtopped pines regardless of fire-intensity level. Hardwoods were approximately 8 feet tall, while Table Mountain pines were 4 to 5 feet tall and pitch pines were 3 to 4 feet tall. Table Mountain pine overtopped shrubs, and pitch pine should outgrow shrubs by the next growing season. Even

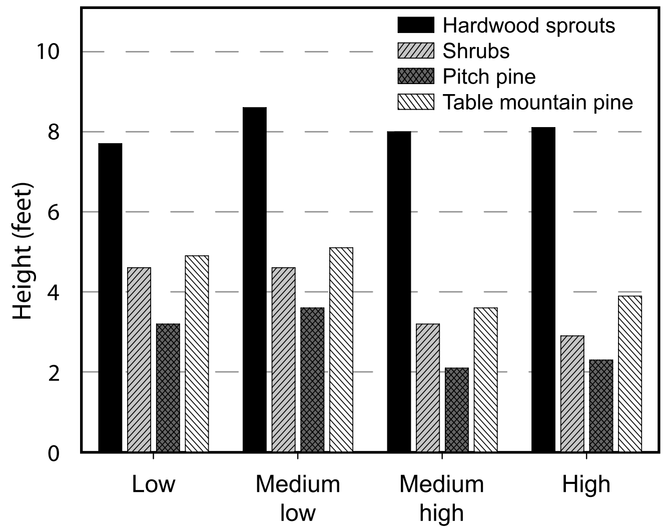


Figure 4—Relative height of pine regeneration and hardwood and shrub sprouts.

though hardwoods overtopped the pines, we do not expect the pines to be eliminated. Pines are numerous and continue to receive overhead sunlight. Previous work with pine-hardwood stands in the Piedmont showed that hardwoods overtopped pines for up to 7 years, but the pines eventually overtopped the hardwoods (Waldrop 1997). We expect a similar pattern here, although the time may be longer.

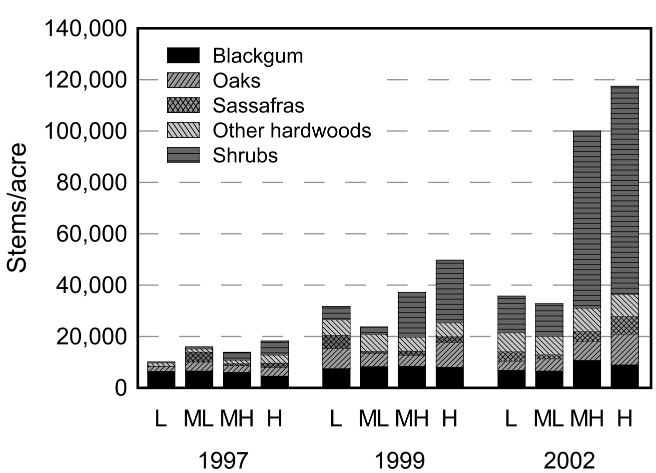


Figure 3—Number of hardwood and shrub sprouts by intensity and year.

## CONCLUSIONS

Because we burned all study plots in a single unit, this project is a case study. Many variables may be confounded in our analyses. However, the study does provide some valuable insight into the types of fires needed to create conditions of stand replacement. Fires of all intensities killed essentially all overstory trees, but mortality was not immediate. Mortality occurred over a 3- to 6-year period. Therefore, our previous interpretation of results after only 1 year (Waldrop and Brose 1999) probably led to incorrect conclusions. Regardless of fire intensity, pine regeneration was abundant in all study plots after 6 years. Table Mountain and pitch pine numbers increased over time, suggesting the presence of an outside seed source. Fires of all intensities created heavy hardwood competition. Shrub density was very high in areas where it was present before burning. Pines remain overtopped by hardwoods but are expected to survive and may eventually outgrow the hardwoods.

The continuation of this study shows that our earlier conclusions were premature. Fires of all intensities tested created successful stand replacement of Table Mountain pine. Eventually, all overstory trees died, and pine regeneration increased in density over time. In our earlier publications, we thought that mortality only occurred when flames reached into the crowns of both hardwoods and pines. Therefore, we recommended medium-high flames as a target for managers. Our new results suggest that lower-intensity fires, such as those with flame heights of 6 to 8 feet, can be just as successful. These fires would be safer and easier to accomplish. This study also suggests that better information is needed to understand the relationship of hardwood mortality to fire intensity.

## ACKNOWLEDGEMENT

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